THE WIRELESS DATA
HANDBOOK

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FOURTH EDITION

James F. DeRose

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V PUTTING IT TOGETHER

PREFACE

This fourth edition of the *Wireless Data Handbook* will begin to reach readers in 1999, the centennial year of Marconi's first sale of data radio to the British Navy. For the army of fresh, young people now turning their impressive energy and intellect to this growing field, it is fitting to have enough historical perspective to understand the work of their predecessors.

As the title states, this book is devoted to data with only passing reference to voice—and then only as voice and data impact each other. It is also focused on wide area, mostly mobile, applications; it does not cover in-building, wireless LANs. By far the greatest emphasis is on *public* wide area networks, with a conscious effort to make fair business comparisons among the many competing alternatives.

While key technology, which includes airtime protocols, must be discussed, this book is mostly application and business oriented. The necessary technical discussions tend to deal with practical matters, such as the impact of long message lengths on user transmission success. The mathematics require no more than high school algebra. This is not an engineering manual. If you need to calculate path losses, understand turbo coding, or approximate chi-square probability distributions, this is not your book.

The core of this book is a nuts and bolts examination of realistic wireless applications and the networks that can serve them in the short term. Considerable emphasis is placed on deflating unrealistic vendor claims. The time horizon is short, with the most extended market opportunity projection ending in 2005. This book is not visionary. You will find no refrigerators scanning milk carton expiration dates in order to wirelessly place a replenishment order at your local supermarket.

For carriers, the market opportunity estimates tend to be bearish. In my view the estimates are realistic and no apology is made for failing to project a hockey stick upsurge in short term network revenues.

After 42 years of struggling in a market that was always on the brink of exploding. I concluded about ten years ago that the model was wrong. One of the original assumptions was that available spectrum was rare and precious, with limited subscriber capacity. It would be controlled by a very few network operators, who could command premium prices for a limited number of highly profitable applications.

But there has been no practical spectrum shortage. In 1985 CTIA and Telocator successfully lobbied for an additional 12 MHz of spectrum for cellular since the

combined five year forecast for the top 30 markets was projected to be 1.5 million subscribers. The ". . . population will suffer an unacceptable decline in their grade of service or be denied cellular service unless the additional allocation is granted." Now we have perhaps 40 times that many cellular subscribers, with a plethora of noncellular voice alternatives.

There is a local analogy. When I moved to Stamford, CT in 1982 there was a single, presumably profitable, restaurant which featured tablecloths. Today Stamford has 15 yellow pages of restaurant listings, with every ethnic variation. Individual restaurant owners make a living, but most are privately for sale in this fiercely competitive environment.

So it is with wireless networks. There are no realistic capacity restrictions in the near term. A dozen network alternatives are routinely available for prospective customers. Only one or two network offerings are profitable, and casualties are legion. Most networks are (privately) for sale—or at least open to a deal. Prices are dropping with hard fought competitive bidding to gain market share. Inappropriate solutions are being touted by some carriers who ignore actual limitations such as realistic data transmission rates.

Wide area, wireless data is growing very nicely but is not dominated by any one service provider. The long held dream of a new, uniquely profitable, business opportunity is in ashes. End users are the real beneficiaries of this struggle, and I'm now happy to be one of the latter.

James F. DeRose

Stamford, CT 06902
December 1998
jderose@2way.net

ABOUT THE AUTHOR

James F. DeRose has been a data radio consultant since 1987. He is the author of numerous reports in the field; this is the fourth edition of the *Wireless Data Handbook*.

For thirty-two years Mr. DeRose was a designer, manager, and executive for IBM in its first golden age, specializing in telecommunications product development. He began his career on SAGE in 1955; his enthusiasm for his first data radio application (AWACS) was fueled by the devastating collapse into the sea of the "Texas Tower" wireline predecessor.

Mr. DeRose worked on the Gemini/Apollo project, managed the development of the 1966 NYSE Floor Trading System, and was Systems Manager for IBM's initial SNA product line, the 3600 Banking System. For three years he endured the hardship of acting as Planning & Advanced Technology Manager for all communications products developed at IBM's lab on the French Riviera. From 1983 to 1985 he was the Director of IBM's Data Radio Project, a precursor to the present-day ARDIS.

Mr. DeRose was a member of the Computer Science graduate faculty and Director of the Telecommunications program at Iona College. He is a Sloan Fellow and Stanford graduate (MMS).

He lives on Long Island Sound where he and his wife Judy spend summers luring their seven grandchildren onto the sailboat with the excuse that it's good experience for them.

He can be contacted at jderose@2way.net.

I

GETTING STARTED

1

A SHORT HISTORY OF DATA RADIO

1.1 IN THE BEGINNING

In 1899, four years after Marconi's first wireless telegraph, the British Navy converted to data radio.[1] The Czar's Navy quickly followed. By 1905 the Japanese had mastered the key techniques and began to intercept messages from the Russian Vladivostok fleet cruising secretly south of Tokyo Bay. Japan's victorious Battle of Tsushima followed.

Driven by continued military demands, wireless data technology leaped forward. In 1914 the hapless Russians lost the Battle of Tannenburg because of German intercepts of their land-based data radio communications and in 1917 the British successfully employed radio telegraph in tanks at the Battle of Cambrai[2]; by 1918 these same units were adapted for aircraft.

In World War II both the United States and Germany communicated with and controlled their widely scattered submarine fleets via data radio. During this period H. C. A. Van Duuren[3] devised the technique still known as ARQ (Automatic Repeat reQuest), one of those disarmingly simple ideas that seems so trivial in retrospect. The idea was to ensure that a block of characters had been successfully transmitted through the use of error *detection*. A detected error was followed by a signal from the receiver asking the transmitter to repeat the block.

In the late 1950s wireless teletype units such as the CY2977LG were in use in high-profile applications like the media pool aboard Air Force One. The Semi-Automatic Ground Environment (SAGE) air defense system began testing digitized radar information sent by data radio from airborne early warning aircraft. The more complex messages were separated from the continuously repeating X and Y coordinates. A header identifying the radar address was added to the data. These manageable segments were clear forerunners of what would later be called "packets."

These packets traveled from aircraft to ground station over dedicated radio circuits, as in today's data-over-cellular.

In 1957 data radio modems reached speeds of 2000 bits per second (bps), competitive with landlines of the time; by 1967 the General Dynamics ANDEFT/SC-320 modem achieved 4800 bps.[4] In the early 1960s, building on the seminal work of Shannon[5] and Hamming,[6] commercially practical error *correction* techniques were available. The stage was set for commercial exploitation of this knowledge base.

1.2   PRIVATE NETWORKS LEAD THE WAY

In 1969 IBM began to develop a mobile data radio system for police departments. Fueled by block grants from the Law Enforcement Assistance Administration (LEAA), other vendors, including Kustom, Motorola, Sylvania/LTV, and Xerox, offered alternatives. IBM's 2976 Mobile Terminal System was announced on May 12, 1972 (see Appendix B). A polled system, it nonetheless achieved good throughput for its time with a combination of high (~5400 bps) airlink transmission speeds, forward error correction (which consumed half the bits), and ARQ.

The IBM system was a failure and was withdrawn in 1974. Competition fared little better. The failure causes were many:

1. The termination of LEAA funding in 1973
2. The physical inadequacy of the devices: big, heavy, hot, noisy, and unreliable
3. A crushing lack of software support: for example, no dispatch applications
4. Unreadiness of the customers: no data bases or applications in place, inability to cost justify the necessary development activity

But the dreamers persisted. In 1970 the successful University of Hawaii's ALOHA system had established fundamental inbound contention techniques.[7] In 1975 Kleinrock and Tobagi[8] codified carrier sense multiple-access (CSMA) methods, permitting greatly improved inbound performance.

Mobile Data International (MDI), founded in 1978 to provide a data radio system for the Vancouver (B.C.) police, began to work with Federal Express in 1979. The following year the first 12 commercial terminals employing CSMA were delivered to the pioneering package delivery service. Very quickly the Federal Express device count grew to 25,000 units, which attracted Motorola's eye. MDI was purchased, then extinguished.

Meanwhile, IBM's Service Research organization had been privately piloting briefcase-sized "portable" radio terminals, developing a business case for the applications that would yield economic payoff. In November 1981 a contract was signed with Motorola for the Digital Communication System (DCS). Nationwide rollout began in April 1984 and was essentially complete two years later with the installation of more than 1000 base stations.

DCS was a packet switched, pedestrian (low-target-velocity) oriented system that broke much new technical ground. It used a single frequency on adjacent base stations, with deliberately overlapping coverage patterns, to achieve better in-building penetration. The end-user device was hand held, incorporating integrated radio modems and internal dual diversity antennas for improved reception at walk speeds.

1.3   RISE OF PUBLIC PACKET SWITCHED NETWORKS

Of equal business importance, with the signing of the DCS contract, IBM and Motorola agreed to work together on a shared network approach. The initial opportunity estimates were enormous: 5 million subscribers were thought possible by 1987. Within IBM this period later came to be known as the first era of low hanging fruit.

But during the period 1983–1985 there were serious business disagreements between the two equally proud companies. IBM better understood the application development barriers that would hinder rapid roll-out of this technology, having struggled to place experimental customers on DCS via the then-extant IBM Information Network. Motorola had a sounder grasp of the infrastructure changes necessary to provide a high-availability system and had begun development of its own, independent network. The proposal to build a public network resting on the shoulders of DCS was rejected by the decision-making elements of both IBM and Motorola for complex (and often emotional) internal business reasons.

After the collapse of the joint venture negotiations, Motorola unveiled its own public packet switched network, the Digital Radio Network (DRN). This system used DCS-class base stations but with area controllers sharply modified for both performance and high availability. DRN began in Chicago in 1986 (Ericsson began Mobitex in Sweden the same year). As IBM expected, making a market was an extraordinarily difficult task. It was four years before DRN-Chicago had ~135 external users[9]; Los Angeles, rolling out second, took 20 months to achieve about the same number; New York, 18 months behind Los Angeles, reached the 135 milestone after one year. Clearly a positive learning curve existed, but the absolute pace was exceedingly slow.[10]

Five years after the negotiations failed, the plan was refurbished, principally by the incorporation of Motorola's high-availability DRN switching centers. The venture was agreed to by IBM, surprising since the airtime protocol remained proprietary to Motorola. The Advanced Radio Data Information System (ARDIS) was announced in January 1990. The system has been in continuous evolution ever since: new devices, a new higher bit rate protocol, additional frequencies, roaming capability, and extraordinary redundancy added to achieve high availability. The customer base has grown slowly to ~40,000 at the end of 1994, reaching ~80,000 at the close of the third quarter of 1998.[11] Building a market remains a continuous struggle.

On July 6, 1994, protracted disagreements between the two ARDIS partners were resolved when Motorola bought out IBM. There were multiple reasons for this transaction. Paramount was Motorola's desire, and willingness, to make the required

infrastructure investments necessary to drive horizontal markets[12] with their Envoy/Marco devices. Envoy/Marco subsequently failed. At the close of 1997 Motorola, deciding that network management was not its forté and discouraged with the general failure of horizontal market thrusts throughout the industry, sold ARDIS to American Mobile Satellite Corporation (AMSC). AMSC was likely influenced by the fact that ARDIS had won the United Parcel Service (UPS) contract, with devices to be supplied by Motorola. Further, ARDIS had successfully partnered with AMSC on combined terrestrial/satellite devices for trucks. The two companies were not strangers.

In October 1990 RAM announced its public data service based upon Ericsson's newest Mobitex design. Initially plagued by a lack of nearly everything—adequate base stations/coverage, hand-held modems—and a conviction that horizontal applications were the path to success, RAM's failure to achieve an adequate subscriber base was extraordinarily painful.

BellSouth Mobility became an essentially equal RAM partner in 1992 with the investment of $300 million in urgently needed cash. Infrastructure deployment rates jumped. Nationwide coverage was achieved in June 1993, albeit with a less extensive coverage footprint than ARDIS.

By year-end 1994 RAM claimed to have ~27,000 paying subscribers[13] (most in vertical markets) and several intriguing business relationships. As at ARDIS, subscriber growth comes slowly: RAM claimed ~36,000 users at the close of the third quarter of 1995[14] and probably reached ~70,000 at year-end 1997. BellSouth assumed 100% operational control of RAM on March 18, 1998,[15] renaming the company BellSouth Wireless Data (BSWD).

1.4   CIRCUIT SWITCHED SKIMS THE EARLY CREAM

In 1983 the first data users improvised low-speed connections to their host computers using ordinary modems over voice cellular "circuits." Users treated these dial connections much as they used ordinary landlines. They are now greatly helped by far better modem capability, most *cellular ready*, and the formation of carrier *modem pools* in most major metropolitan areas. Facsimile transmission alone, usually from a portable computer to a wireline fax, has created thousands of casual public data radio users.

In early 1992 UPS made a direct connection of its own leased facilities to cellular mobile telephone switching offices (MTSOs), bypassing the public switched network landlines. This resulted in very advantageous pricing, though there were time connection limits. By February 1993 UPS had approximately 50,000[16] operational units with this reduced tariff arrangement, significantly more subscribers than DRN/ARDIS had achieved after seven years of effort. But the struggle to deal with scores of cellular carriers—even though a consortium was created to smooth the path—led UPS to begin the conversion to a nationwide packet switched solution. ARDIS, beginning in late 1998.

Some carriers formed dedicated circuit switched data organizations similar to Sprint's national cellular data team formed during the Spring of 1993.[17] By mid-1994 most carriers had cellular modem pools in operation in at least some cities. The ostensible reason for pool deployment is to avoid forcing users to convert the modem facilities at their host sites. Another important reason is that dialing to a pool gives the carriers the ability to distinguish between voice and data calls. Custom tariffs can follow. An interesting example is that of Cellular One in Buffalo, NY, which charges $0.15 per minute for data calls made during peak hours.[18]

The advent of low-cost (<$300), fast-dial (under 20 seconds), high-speed (~19,200 bps) modems and increasingly robust connections gave packet switched data a hearty competitor for longer messages. This would ultimately be addressed by the carriers with flat-rate packet pricing.

1.5   PACKET SWITCHED GATES CREAK OPEN

In 1991 many cellular carriers, both wireline and nonwireline, began to seriously evaluate packet switched data with the expectation of securing a large new market. In general, they tended to dismiss the hard ARDIS/BSWD experience as aberrant. Several carriers issued request for proposals (RFPs). Motorola prepared responsible proposals based on its high-speed radio data link access procedure (RD-LAP) protocol. Ericsson held back, presumably because of business constraints evolving from Mobitex and BellSouth.

The key issue for the carriers was whether Motorola would make RD-LAP an open protocol. Motorola, awash in hubris, refused, thus snatching defeat from the jaws of victory. The result was Cellular Digital Packet Data (CDPD) implementations by multiple carriers and vendors.

CDPD was late to the market. By the third quarter of 1995 only 26 markets had coverage equivalent to their voice cellular footprint[19] and AirTouch had already closed its San Diego system[20] "due to a lack of potential customers." By the close of 1998 fifteen states had no CDPD presence, and key cities such as Atlanta and Los Angeles remain uncovered. The carriers are Balkanized, with erratic roaming agreements. Subscriber acceptance is low, probably ~15,000 total at year-end 1997.

There is a real possibility that the original nationwide vision may not unfold. Bell Atlantic Mobile—first to market with CDPD—has said[21] that "one of the biggest surprises it has encountered is the demand for more local and regional use versus the demand for nationwide service." Sprint is blunter[21]: "there's money to be made in local and regional markets; customers can go elsewhere, such as (BSWD) or ARDIS. for nationwide solutions." Ameritech announced that it will act as a nationwide reseller for ARDIS and BSWD "at the same time it continues to build out CDPD."[22] The practical result of this excess capacity is to drive airtime prices down. Perhaps, at last, the long awaited, widespread adoption of wireless packet switched data is about to be triggered.

1.6   NEW WIRELESS DATA ALTERNATIVES

In the satellite arena Qualcomm's slow-bit-rate, data-only OmniTRACS system rapidly began to show an increase in trucking company subscribers in mid-1993. By the first quarter of 1998 OmniTRACS had shipped 230,000 units worldwide and was a clear success. This accomplishment attracted competitors, most of whom also offered voice. AMSC and a terrestrial alternative, HighwayMaster, picked off a great many potential OmniTRACS subscribers during the period 1997–1998.

None of these solutions could attack the trailer opportunity. Qualcomm is poised to attack that problem with the use of Aeris Microburst, a terrestrial cellular control channel approach. The first proponent of the use of the cellular control channel for telemetry purposes was BellSouth, with its Cellemetry system. These control channel systems are ideally suited to infrequent, very small information content messages.

Other data-only alternatives began to appear in 1994. The first operational was Metricom's very low priced, high-bit-rate, regional system Ricochet. While confined to a limited number of cities and airports, Ricochet offers high bit rates, which will grow even higher in 1999, suitable for Internet access.

Testing also commenced on Mobile Telecommunications Technologies (MTel's) narrow-band personal communication services (PCS) system, then called Destineer. In September 1995 MTel's subsidiary, SkyTel, began its initial two-way pager service with narrow-band devices built by Motorola. This was a prelude to a series of similar offerings. BSWD, followed by ARDIS, began to introduce competitive two-way paging with devices built by Research-In-Motion (RIM). To prepare for this undertaking, BSWD has invested an enormous amount of capital in extensive network upgrades. At the close of 1998, major success has eluded all three participants. There was also activity in the primarily voice-oriented special data services. NexTel, focused on eliminating problems with its new digital voice dispatch service, was able to introduce a limited-message-length, circuit switched data service at the close of 1994. More than 60,000 data capable voice instruments were in operation by the third quarter of 1995.[23] Nextel does not give data much emphasis, seemingly poised for a new packet alternative in 1999 or beyond. GeoTek, with a different digital technology, introduced its voice/data system in 1996 but was bankrupt by October 1998.

In the private market Federal Express began moving to a new generation of devices in 1998, with 40,000 devices to be deployed by 1999. The radio modems and infrastructure are supplied by subsidiaries of AMP. The design is such that the devices could be used on a public packet switched system if that mode of operation makes more business sense in the future.

1.7   SUMMARY

Over the nine decades commencing in 1899 wireless data evolved from low-bit-rate military systems into high-cost private systems developed for quasi-military organizations such as police departments. In just the past decade a remarkable

convergence of technologies permitted reasonably priced, physically small, near-wireline-speed, public wireless systems to become a reality.

Key technology drivers include the nearly simultaneous occurrence of the voice cellular systems, with their now unthinkably low priced hand-held phones, and the fast growing laptop computer. The 1985 perception of ruinous spectrum constraints has yielded to a variety of mostly digital technical solutions, including inexpensive, tiny, reasonably fast modems. Continued application development, along with a once unimaginable growth in complex data bases, has begun to create a desire for work to be accomplished *anytime/anywhere*.

Adoption results to date have been disappointing to all pioneers, but the struggle continues. Ever more competitors enter the potential marketplace, with the inevitable lowering of network usage costs. Many pioneers suffer, even perish, but the user is likely to have a rich choice of alternatives in the future.

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2

DATA NETWORK TYPES

2.1   A ROUGH SORT OF TWO-WAY SYSTEMS

In North America terrestrial, two-way wireless data networks can initially be sorted into private versus public systems. Private system examples include a few very large users, such as Federal Express, and many smaller systems for public safety (police and fire departments), taxi/limo dispatch, and utilities. In private systems the infrastructure is owned, and the spectrum is licensed, by the user. Public systems are "for hire." The end user does not own the infrastructure and has no special rights to the spectrum that carries the traffic.

2.2   PRIVATE SYSTEMS

2.2.1   Overview

Private systems are often marked by geographic constraints: a metropolitan area or, smaller still, a railroad yard. Even Federal Express is organized on a city basis; package delivery vehicles do not drive from New York to Boston (though some 18 wheelers do). Often, private systems have protected frequencies allocated by the Federal Communications Commission (FCC) for particular industry areas. Coverage requirements are frequently "street level": relatively few base stations aimed at vehicular targets. Thus, private systems tend to be the provenance of public safety, utility, and taxi/limo dispatch applications.

   No new, very large private systems are being started. The constrained availability of spectrum in major metropolitan areas virtually precludes the creation of the new

1000 user-per-city systems like those IBM initiated in 1981. Indeed, IBM's private system has now been absorbed into ARDIS.

In 1989, after 18 months testing, GE Consumer Services selected Kustom Electronics to build its nationwide mobile data network.[1] A year later Kustom began the layoffs[2] that presaged its precipitous decline. In May 1991, with 60 zones operating, GE announced that it would integrate "its existing dispatching operations with RAM Mobile Data (now BSWD) . . . to expand its coverage areas and relieve spectrum congestion in some of its cities."[3] GE would "also allow other corporations to use the GE network." That did not happen. Instead, by mid-1995 GE Appliance had approximately 1600 service personnel on BSWD[4] using quite normal devices.

In 1982 Federal Express began installing a nationwide, mostly data, system using airtime protocols and devices developed by Mobile Data International (MDI). In 1992 the FedEx waiver request for exclusive use of a single nationwide channel[5] engendered fierce resistance from the Industrial Telecommunications Association. In 1993 Federal Express began to explore public alternatives with a pilot test of 15 vehicles on CDPD.

AT&T Wireless (then McCaw) prematurely announced that Federal Express "plans to begin using McCaw's (AirData CDPD system) to augment its existing private 800 MHz . . . network by early fall (1994) in Las Vegas."[6] This was not totally surprising given that James Barksdale, once a strong advocate of data radio at Federal Express, had joined McCaw in 1993. But CDPD schedules slipped alarmingly, there was no voice backup capability, and Mr. Barksdale went on to more interesting activities at Netscape. At the close of 1998 Federal Express is roughly one-quarter of the way through the rollout of their new private system, built by M/A-COM. In 1999 it is entirely possible that FedEx will have more devices installed than all CDPD carriers combined.

One early vendor motivation for erecting public data systems was that customers would "grow up" and graduate to the vendor's private infrastructure. There is no known example of such an event. Indeed, as early as 1992 private networks such as PSE&G of New Jersey began testing BSWD[7] and later switched to CDPD.[8] Several other utility companies, including Boston Edison, Florida Power and Light, Illinois Power, Jacksonville Electric, Pacific Gas & Electric, Southwest Gas, and Washington Natural Gas are known BSWD users. Motorola sold more than 400 of its private DataTAC systems in the United States. Now, rather than upgrade to the new high-bit-rate technology, some are converting to ARDIS, which uses Motorola infrastructure.

Spectrum considerations aside, the economics favoring public systems are compelling. Consider a metropolitan area requiring 16 base stations to provide the desired coverage. Assume that the one-time cost for a private network is $1.75 million, based on the data in Table 2-1. For simplicity, assume that all one-time costs can be capitalized and written off over a 10-year period at an interest rate of 10%. Then the prorated monthly costs of the private system, ignoring inflation, can be estimated as indicated in Table 2-2.

Table 2-1 One-time cost: Private network

		Cost ($)	
	Quantity	Unit	Total
Hardware			
Concentrator/switch	2	40,000	80,000
Software licenses	2	40,000	80,000
A/B switch	1	10,000	10,000
Modem rack and 16 modems	1	20,000	20,000
Base stations including modems	16	60,000	960,000
Subtotal			1,150,000
All installation and staging			600,000
Total, with installation			1,750,000

It is reasonable to add contingency to this calculation. The private versus public break-even curve shown in Figure 2-1 has both the base curve and a 20% uplifted version graphed as a function of the number of subscribers. A representative price curve is also plotted (dashed line) to show public network competitiveness. Average subscriber revenues from most public carriers have been driven into the range of $50–$55 per month. While there may be traffic dependencies, that price level is certainly reached in volume bids. In this example the public price declines with volume to the $550-per-month level.

For a private system of this size to compete on price grounds the customer must have on the order of 1000 subscribers in a somewhat constrained geographic area. This

Table 2-2 Prorated monthly cost: Private system

		Cost ($)			Prorated Monthly Cost ($)
Item	Quantity	Monthly	Annual	10-Year Total	
One-time costs				1,750,000	
120 months at 10%					23,126
Recurring costs					
Hardware maintenance[a]			13,000	130,000	1,083
Leased lines	16	500	96,000	960,000	8,000
Rooftop rentals	16	400	76,800	768,000	6,400
Operations[b]			255,000	2,550,000	21,250
					59,859

[a]10% of purchase price.
[b]Three additional monitoring staff at $75,000 per year on 6 × 6 schedule.
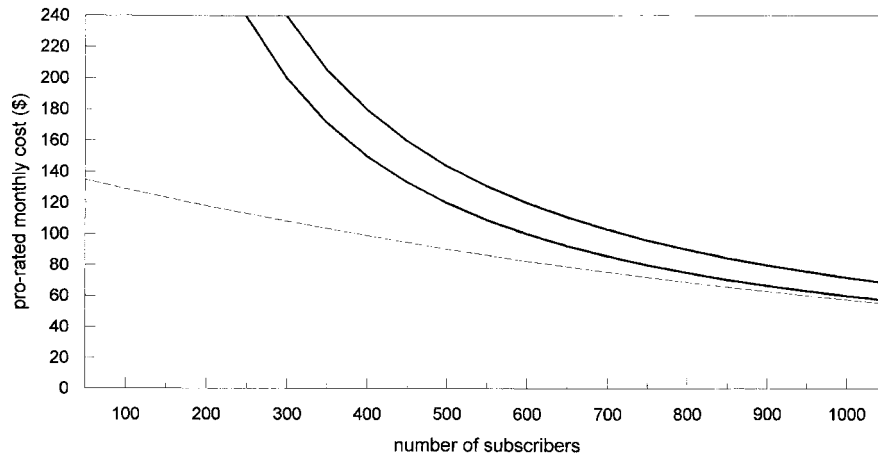
Figure 2-1   Private vs. public break-even point: 16 base stations.

is very rare. IBM's Field Service force was about 900 in Chicago in 1984, an exceptional case. If today's customer has only, say, 250 subscribers, the private system would cost twice as much as going public.

Naturally there are other reasons for choosing a private system, tight control being the most obvious. Iowa Electric did a major pilot test on ARDIS but, in the end, chose to go private with a 60-base-station DataTAC system. And more than one utility company harbors visions of having it both ways. The Southern Company has installed a Motorola integrated dispatch enhanced network (iDEN) system. This mostly voice network permits data speeds up to 4800 bps. Southern intends to sell excess capacity on their network through a subsidiary called Southern Communication Services, with functions much like Nextel (covered in Chapter 5).

However, as public networks become ubiquitous, there will be a tendency for users to convert away from their private systems. Even in the public service bastion the trend toward public systems has begun: the New York City's Sheriff's Department switched to ARDIS for parking enforcement,[9] as has Philadelphia.[10] Four of BSWD's earliest test customers were the Hoboken Fire Department, the Orange County (FL) Sheriff's Department,[11] the Washington, DC, Police, and the Overland Park, Kansas, fire departments.[12]

While these customers may not be earth shaking—some not even successful—it is an indication that public safety installations can be breached by public systems. CDPD specifically targeted Public Safety for its service. AT&T Wireless is known to have 6 police/sheriff's departments, with Jacksonville, Florida, having 150 units installed.[13] Bell Atlantic Mobile (BAM) has 10 police installations, including a 14-unit pilot in Washington, DC, that was first tried with BSWD. BAM's largest police installation is in Philadelphia, with 600 units.[14] GTE Mobilecomm is known to have at least four police departments, the largest in Lakeland, Florida, with 140

units.[15] Even little Southern New England Telephone (SNET) has 39 small Connecticut police departments on-line, with an aggregate total of 600 units.[16]

2.2.2   Estimating Private Users

In the 1980s there were many suppliers of private systems: for example, Coded Communications, Electrocom Automation, Gandalf, Kustom, MDI, and Motorola. Prospects were bright. Federal Express and IBM were thought to be the first in a long string of major companies to install custom radio data terminals. But eventually Federal Express was fully deployed, IBM switched to a public system, and the taxi market, for example, proved to be low margin and exceedingly difficult to penetrate. In the latter case, New York City Medallion cabs are prohibited by law from being radio dispatched. By 1989 many of the early contenders had failed.

Motorola bought MDI and consolidated its position in fertile areas such as the utilities industry. The Canadian vendor Dataradio branched out of fixed equipment sales in 1987. By 1997 it claimed "a 60 percent market share (of devices) . . . for private networks sold since 1988."[17] In May 1998 it claimed to have "over 120,000 (fixed and mobile) units in service in more than 30 countries."[18] Clearly, device shipments had turned sharply upward again in 1991. To the delight of the few surviving hardware providers, a significant number of new units shipped were replacement devices for systems first built 10 years before.

Figure 2-2 portrays this phenomenon. There are two important characteristics of this chart. First, IBM has been completely removed from all counts. The 1990 switch from private to public thus does not appear as a sudden decline in private users. Second, the installed base represents operational units; all spare stocking has been eliminated.

From the hardware vendors viewpoint, it is quite clear that private systems are preferable, although their contribution to absolute subscriber growth is not eye-popping. There were about 125,000 operational users on all terrestrial, two-way
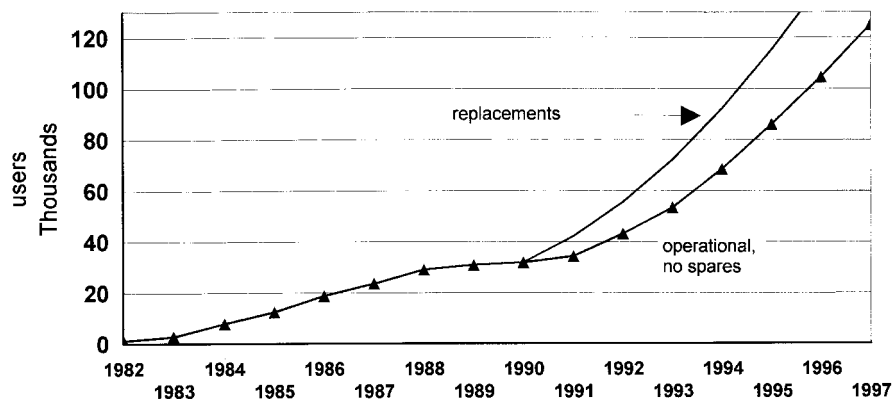
Figure 2-2   U.S. private systems installed base: two-way data.

data systems in 1997. Progress in 1998 is expected to be good for Motorola, in particular, which has carefully protected its *private* DataTAC engineering base. There are also significant, ongoing shipments to Federal Express by M/A-COM that are mostly new technology replacement units. The net new users of private systems will not be greatly enhanced by this upgrade.

2.3   PUBLIC SYSTEMS

If one concentrates on public systems, important differences exist between satellite and terrestrial offerings. Within public terrestrial, the distinction between circuit switched and packet switched solutions must be understood.

2.3.1   Satellite Systems

Commercial, two-way data transmission between mobile terminals and satellites began in 1988. While there have been costly failures in the intervening decade, at the close of 1998 there was one outstanding success, Qualcomm's OmniTRACS. There were also several contenders, including AMSC and Norcom. The coming of low earth-orbiting satellites (LEOS), covered in Chapter 6, is certain to raise the level of activity in this area.

Current satellite systems are distinguished by their unique coverage capability, which embraces all of the nonmetropolitan areas of the United States. In large metropolitan areas, building "shadows" cloak the radio energy. This is exactly where terrestrial systems perform best and hybrid satellite/terrestrial systems exist that can provide nearly continuous coverage.

Mobile devices used with satellite systems are typically physically large; their antenna requirements compel it. This unpleasant characteristic should change with LEOS. Satellite devices are usually more expensive than the legion of terrestrial alternatives.

Communication characteristics are often mediocre. These traits range from very slow bit rates (OmniTRACS) to long latency caused by polling (AMSC). OmniTRACS time shares a relatively slow speed link among many terminals. Depending upon received signal strength, each device sees a bit rate of only 55–165 bps. Not unexpectedly with such low bit rates, message lengths are limited to a maximum of 1900 characters, which can take nearly 5 minutes to send.

AMSC's bit rates are far higher, suitable for both voice and facsimile transmission. However, in data mode latency problems occur because the satellite polls each mobile terminal one after the other. When a poll reaches a ready terminal, it transmits all messages it has accumulated. If there are many ready terminals, the poll cycle, the time required to check every device and return to the top of the list, can easily become 5 minutes.

Satellite airtime costs are typically very much higher than terrestrial counterparts. In hybrid systems this becomes one more motivating factor to escape the satellite link as soon as a terrestrial system can be "heard."

2.3.1.1   One-Way Paging A special form of satellite data transmission is ubiquitous in the United States: one-way paging. Free of the need to respond, the paging device shrinks to its customary small size. Pager prices are somewhat higher but still inexpensive—typically ~$200. Permissible message lengths are short, rarely exceeding 240 characters. Monthly charges vary according to the areas of coverage (which can be international) sought by the user.

In these networks the person initiating the page usually does so by sending the message from a phone or modem-equipped computer. The message travels to a *paging terminal*, actually a ground station with an attached satellite dish. The ground station sends the message, along with the identification number of the receiving pager, to a satellite. The satellite can broadcast the message and pager ID to one or all of the terrestrial paging transmitters in the country. Each of these sites rebroadcasts the message in their particular service area. Every pager in the area hears all messages but only responds to one with its identification number.

2.3.2   Terrestrial Systems

Terrestrial public systems can be further subdivided into circuit switched [e.g., data over Advanced Mobile Phone System (AMPS) cellular, Groupe Speciale Mobile (GSM)] and packet switched (e.g., ARDIS, BSWD, CDPD, and Ricochet). They differ principally in how they allocate transmission bandwidth. Circuit switched systems use preallocation of bandwidth; packet switched systems are dynamic.

Telephone networks are circuit switched systems in which a fixed bandwidth is preallocated for the duration of the call, whether it is voice, data, or image facsimile. Today's voice cellular systems fall into this category. When the user dials a number, the virtual path from, say, device to host computer is dedicated to that call (never mind that the underlying channels may be switching around because of load or user motion). There is no sharing of that path with any other user.

In dynamic, or packet switched, systems, multiple users may share at least parts of the same path to get at their own devices/hosts. Historically, the telegraph dynamically allocated bandwidth one link at a time, never attempting to schedule the whole source-to-destination path. Obviously this service was limited to non-real-time systems. The advent of the computer permitted dynamic allocation techniques to be reexamined for new communication alternatives. Packet switching was the result.

Packet switching was not really an invention, but rather a highly intelligent reapplication of basic dynamic allocation techniques to data transmission. A packet switched network only allocates bandwidth when a block of data is ready to be sent; sophisticated networks only assign enough bandwidth for one block to travel over one network link at a time.

Depending upon message length, packet switching can be many times more efficient than circuit switching in reducing bandwidth wastage. But packet switching carries relatively high unit overhead; it certainly requires both processing power and buffer storage resources at every node in the network, including the subscriber unit.

The economic trade-off is easy to state but hard to calculate:

1. If "lines" (including cellular) are cheap, use circuit switching.
2. If "computing" (includes devices) is cheap, use packet switching.

It is not surprising that Europe led the way in packet switching because of its historically punitive communication tariffs. The continuous decline in the cost of computing clearly reinforced the drive toward packet switching. The comparison is less clear in the United States. Useful measurement of these competing costs is the subject of Chapter 4.

2.3.2.1 *Packet Confusion* One fact that often confuses new users is that packets—segments of messages—are not constrained to packet switching systems. Forty years ago the messages carried by the SAGE system were segmented to provide better system control. In the six-year-period 1958–1964 IBM developed the SABRE system for American Airlines, drawing on SAGE knowledge. The message segmentation functions began to be more cleanly defined. The first system/360 teleprocessing system embraced many of these conventions with its basic telecommunications access method (BTAM), but the simple challenge of reconfiguring a line or terminal demonstrated how much work remained.

Gradually structure emerged. Each message segment had a header containing basic information that marked at least:

1. The beginning of the message segment.
2. Address (often both source and destination).
3. Sequence number.

In addition, a trailer held an error detection code and marked the end of the message segment. By the time the United Kingdom's Donald Davies coined the term *packet* in 1965, a recognizable header, data, trailer structure had been moving across leased, then circuit switched, facilities for roughly 10 years. Packets still flow on circuit switched connections. Their structure often has vendor-proprietary wrinkles to distinguish them from public domain alternatives. But even the flag and the error detection process used in Microcom's networking protocol (MNP) series is identical to that of the common packet switched networks. A formal message structure designed for packet switching can be quite at home on circuit switched alternatives. This is what dial back-up is all about.

2.4 SUMMARY

The initial classification of systems is into private versus public categories. Until the 1986 advent of Motorola's DRN, all systems were private. If better than street-level coverage were required, private systems could be built by only the largest customers. Even without that financial barrier, the scarcity of spectrum created a finite cap on the number of strictly private systems that could be built.

   Public systems are slowly supplanting private ones, even in traditional applications such as public safety. The user entry-level quantity can be very low, coverage is generally superior, and professional management of the wireless network leads to highly satisfactory availability. Public systems may be either satellite or terrestrial. Satellite is clearly superior when wide coverage is required, but it is burdened by large, vehicular devices, low communication performance, and high airtime costs. Terrestrial systems are growing at a far faster rate than satellite. Devices are small, including two-way pagers that are unfeasible with satellite. Communication performance is good, and monthly airtime costs are plummeting.

   Terrestrial systems can take two basic forms: circuit switched or packet switched. They are surprisingly competitive and it is not yet clear if one form will dominate future business activity.

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3

KEY PUBLIC NETWORK CHARACTERISTICS

The variety of public network choices cited in the preceding chapter lead some potential users to despair at what seems a plethora of alternatives. Actually, specific user requirements can quickly eliminate many network candidates. This permits a more straightforward assessment of realistic alternatives. A few of those salient user characteristics are discussed here.

3.1 COVERAGE

While the scale is continuous, ranging from international down to a single truck depot, the user coverage requirements discussed in this book fall into three broad categories:

1. *Nationwide*.

2. *Regional*: Examples of this might include the field sales company that works a territory from Philadelphia to Boston but has no interest whatsoever in St. Louis or San Diego.

3. *Metropolitan*: Taxi companies fall into this category, as do many blue collar dispatching jobs (e.g., plumbers, electricians). But many highly professional occupations such as lawyers and physicians may well be interested in only local coverage.

As user coverage requirements broaden, the number of qualified service providers diminishes rapidly. Metropolitan vehicle location networks such as Teletrac are useless for statewide applications. Multistate packet networks established by regional Bell operating companies (RBOCs) and their counterparts are often early casualties

when the application spans the nation. The old circuit switched cellular networks usually provide wide connection capability at the cost of a roaming fee. But the RBOCs are going digital, and no two carriers, it seems, can agree on a common standard. Digital AT&T Wireless devices will not operate on BAM networks (and vice versa); neither can work with the new PCS. Service provider candidates are classified by their network coverage capability in subsequent chapters.

ARDIS and BSWD are examples of nationwide networks. But that classification does not prove required coverage. Insidious problems remain. These terrestrial systems truly cover, and seamlessly link, population centers of the United States. They do not cover vast stretches of mostly open geography in between the metropolitan areas. The executive or salesman or professional using a car to traverse Pennsylvania will be mostly out of coverage on Interstate 80, even though all the cities and most of the towns of the Keystone state are covered. Satellite carriers will cover these beautiful mountain areas but may be useless in Philadelphia.

The user must first define the required coverage area, then test the candidate's capability in those areas. Techniques for limiting test costs, along with many field test results, are discussed in Chapter 12.

3.2 PENETRATION

Street-level, metropolitan area coverage does not ensure that contact can be held or established inside a building. Failure does not manifest itself as a knife switch; the problem becomes progressively worse the further one retreats to the interior, away from windows. Few systems are designed to specifically address this problem. One that does, ARDIS, provides a contractual performance guarantee since this is a major selling point. But excellent penetration can often be encountered in a system that has rich infrastructure in particular areas. BSWD clearly falls in this category in the Greater New York metropolitan area.

Some customers have unrealistic penetration targets: Utility companies may want meter readers to transmit in deep basements, for example. This type of requirement is a recipe for failure; radio does not yet transmit through dirt.

Building penetration capability can sometimes be inferred. If a cellular voice phone call can be sustained from deep within a building, then the packet data counterpart is likely to succeed, given that CDPD has been built out. If voice fails, so too will data. Some data-only carriers provide prediction tools that estimate the percentage of in-building coverage by ZIP code. These tools are usually directionally correct and can reduce much manual, tiresome labor to verify penetration.

3.3 MESSAGE LENGTH

This user requirement spans the gamut from the shortest of status messages to multipage facsimiles. Very short messages, especially, may also be infrequent: a monthly odometer reading or a random door open/closed indicator. In between these

extremes are a range of message lengths that can absolutely force one network design to be chosen over another.

Paging messages tend to be short; millions of users have long since been trained to live with only 40 characters of information. Dispatch messages are somewhat longer, accompanied as they are by location addresses, problem symptoms, or warranty identification numbers. There are a myriad solutions, including the new PCSs, which are well suited to traffic with a length less than ~150 characters.

Messaging traffic is longer still and can become impressively large if there are a series of message-forwarding actions that concatenate prior notes. Further, peer-to-peer messaging traffic is balanced. The outbound traffic equals the inbound, and some systems have problems with inbound activity. Conventional E-mail traffic often has long message lengths if for no other reason than the user tends to sign on intermittently, gathering several notes at a time. Both packet and circuit switched solutions abound in the messaging/E-mail area. They are very price competitive, so that the user decision is rarely based on cost alone, but on secondary factors such as coverage or the need for facsimile as well.

Worldwide Web access via the Internet can produce enormous traffic, especially from the Web to the user device. There are techniques for suppressing graphic information, of course, but that is often exactly what is desired. In that case, a circuit switched solution is called for. The purest form of nontextual, graphic information is the facsimile. Data-only systems cannot handle a facsimile in the form of a pictorial representation of a piece of paper. However, it is possible to send a text message from a device to a facsimile machine.

In general, with current technology, the longer the message length, the more that traffic is suited for circuit switched solutions.

3.4　MESSAGE RATES

A key application characteristic is message frequency—the rate at which traffic is generated. It is sometimes crucial to make provision for the rate factor with a carrier. As an extreme example, the user interested in just a monthly odometer reading must make provision in the device to suppress registration until the moment comes to transmit. Otherwise the device may roam the nation, constantly registering on new base stations and generating considerable unwanted overhead for the carrier. Locking the device down to a specific time interval can result in greatly reduced monthly airtime charges.

At the other extreme is the high-traffic generator, with 30–60 messages per hour. This is usually seen in "campus" situations where, say, the MacDonald's order taker works the line of waiting automobiles to generate take-out hamburger requests. If the message traffic has any appreciable message length, as in MacDonald's, it may be best to abandon any hope of using a public system and install a private system instead.

Every variation in between exists, and each case is different. Generally, however, high rate applications are best suited to packet switched solutions, but will be vulnerable to response time delays.

3.5 DEVICE SPEED

In general, sustainable bit rates fall as the user device goes into motion (the particulars are covered in Chapter 13). In circuit switched systems the modems literally slow down. In packet switched systems, retry rates rise, as the network has increasing difficulty delivering a clean message.

Each network solution is designed to perform best at a specific speed. Some, like Metricom's Ricochet, can tolerate very little motion at all. It is really a desktop solution. Others, like the high-speed protocols used in ARDIS or CDPD, perform best at vehicular speeds encountered in metropolitan areas: 20–40 mph. Some low-speed protocols, such as the alternative used in ARDIS, are particularly well suited to slow-speed pedestrian movement. It is rare to find a protocol that performs consistently well at speeds over 70 mph.

If the application requires relatively high target speeds, it is best to clearly understand the carrier's pricing plan. Some packet carriers charge only for user messages successfully transmitted; any necessary retries are absorbed by the carrier. Others charge every retry against the customer's bill. Indirectly, the most obvious example of charging the user for network retries is circuit switched cellular. The user is charged for time on the system. If the messages are faltering, and modem speeds are dropping, the extended time necessary to complete the transaction shows up in the monthly phone bill.

3.6 CONNECTIVITY

Most users contemplating wireless data communications approach the new networks with an installed base of application programs. To preserve precious spectrum, many packet carriers have unique protocols the new user must master before exploiting the network. Existing application programs must be converted—a slow, costly task. Worse, once converted, the modifications tend to tie the user to a specific network. A flood of "middleware" has evolved that enables the user to convert once and gain network independence. Chapter 17 discusses these alternatives in more detail.

Some network solutions require very little in the way of application conversion. Consider the laptop PC user who dials an application host over a conventional wireline modem. This user can generally connect via circuit switched cellular, and exploit wireless data, with no application change. This includes sending and receipt of true facsimiles.

The packet switched solution CDPD uses the ubiquitous transmission control protocol/Internet protocol (TCP/IP). This makes application conversion a vastly simpler task but often leads to miserable performance. Once again, middleware providers have stepped in to ease the connectivity problems, essentially by eliminating TCP/IP at a gateway ahead of the wireless network.

Table 3-1 Application requirements versus service providers

Requirement	Best Match
Wide-area geographic coverage	Circuit switched cellular; Geostationary satellites (GEOS): AMSC, Qualcomm OmniTRACS.
Nationwide metropolitan coverage	ARDIS, BSWD, SkyTel2
In-building penetration	ARDIS, most paging systems
Short, infrequent status messages	Aeris, Cellemetry
Two-way paging	ARDIS, BSWD, SkyTel2
Regional, metropolitan messaging traffic	ARDIS, BSWD, CDPD
Long file transfers	Circuit switched cellular
True image facsimile	Circuit switched cellular
Full Internet access; nonmobile situation	Circuit switched cellular (price premium); Metricom Ricochet (where available)
Intense message rate activity	Private system
Low-impact application development	Circuit switched cellular; middleware for TCP/IP (most packet networks); CDPD especially for user datagram protocol (UDP) transition
Voice, with modest supplementary data	Nextel, PCS: Aerial, BSM, Omnipoint, PacBell

3.7 SUMMARY

Users of today's technology can make an initial sort of network services as a function of their own application requirements. Table 3-1 lists representative application characteristic and matches them to the carriers that are best suited to match that need.

   The chapters that follow will expand on these themes so that well informed initial judgments become the norm.

4

PUBLIC TERRESTRIAL PACKET SWITCHED NETWORKS

4.1 MESSAGING/DISPATCH ORIENTATION

Amateur packet radio has been active in the 2- and 20-meter bands since the early 1980s. But recognizable pay-for-service packet switched offerings began in Chicago in 1986 with Motorola's DRN. With coverage in only three cities and weak marketing, DRN struggled for three years. In 1990 it was folded into a joint venture that also embraced IBM's Field Service System. The result was ARDIS, a truly nationwide public packet data network.

The formation of ARDIS was quickly followed by an alternative carrier: RAM Mobile Data. With extremely limited geographic coverage, RAM's early struggles were every bit as severe as that of Motorola's DRN. It was saved by a partnership with BellSouth Mobility, which, in 1998, became the sole owner. RAM was subsequently renamed BellSouth Wireless Data. BSWD has continued to expand its infrastructure, and create supporting network alternatives, in order to obtain nationwide coverage.

In April 1993 a consortium of wireless carriers announced a series of regional systems called CDPD. Differing in only a few technical respects from ARDIS and RAM, and very late to market, CDPD's combined blood loss easily surpassed that of the earlier pioneers. CDPD's subscriber growth has been exceedingly slow. There have been vertical application successes, initially in street-level public safety, but the marketing emphasis is clearly shifting to horizontal applications.

Since CDPD's announcement in 1993 many new packet data alternatives—mostly regional or metropolitan—have been placed in production or are being aggressively tested. Several services have already failed.

4.2 ALPHANUNERIC PAGING ORIENTATION

In 1983, during the first unsuccessful IBM/Motorola attempt to create a data radio joint venture, IBM defined "ack-back" paging as a major market opportunity. The IBM "brick," the KDT800, would be stripped of its QWERTY keyboard, the application memory/processors discarded, and the battery size reduced in order to obtain a lower cost/smaller sized device. The resulting ack-back pager would operate on the IBM Field Service network. Motorola resisted fiercely since it would then be competing with the service providers to whom it sold paging hardware. The IBM proposal died, but the technical capability remained.

One-way alphanumeric pagers already existed, of course, and became widely visible at the 1984 Los Angeles Summer Olympics. Enormous growth for this class of function was predicted. But acceptance was painfully slow. In 1987 alphanumeric pagers were described as a "product in search of a market."[1] One of the few mass users was Tandem Computers, which had 450 units deployed for their field service personnel. Uncertainty of message delivery was considered to be the most troublesome weak point.

Three years later things seemed to be looking up: "1990 is likely to be the year of alphanumeric paging"[2] was the marketing mantra. Motorola announced the wristwatch pager: "a pager whose time has come."[3] It also bought Contemporary Communications, a 900-MHz nationwide paging carrier and formed EMBARC. It would both build devices and operate a "nonthreatening" paging network. Even Borland, then riding high, modified Sidekick 2.0 to dispatch pages from a PC. If not 1990, then certainly 1991, would be THE year.

But the "much anticipated boom in alphanumeric paging did not happen in 1991, as the category grew meagerly to less than 5% of all pagers in service."[4] During that disappointing year Dial Page petitioned the FCC for rulemaking on a notion called "acknowledgment paging."[5]

Technology was moving in the right direction. By 1993 both Skytel and Mobilecomm had nationwide one-way paging in place. Both used Personal Computer Memory Card International Association (PCMCIA) format paging cards in a variety of mobile devices. In 1994 Motorola formed its Advanced Messaging Systems Division. It announced the ReFLEX transport protocol for two-way messaging, Motorola was not unmindful of the fact that 10 licenses had been awarded to six carriers; this was an unmistakable hardware opportunity. AT&T countered with its own personal Air Communications Technology (pACT) protocol. After a bitter fight a firmly entrenched Motorola won this battle.

EMBARC failed in April 1996. Motorola's competitive constraints and its inability to simultaneously build devices and operate a network were simply too much to overcome. Motorola would henceforth concentrate on manufacturing hardware. A true two-way pager, the PageWriter, was announced for SkyTel2 the same year. Deployment on this narrow-band system had been initiated in 1995 with high hopes.

In January 1997, BSWD formally announced[6] its RAMfirst interactive pager, which was intended to be a head-to-head competitor with SkyTel2. After a last

internal struggle with Motorola, ARDIS soon followed. The fight for this competitive market segment was on.

4.3   REPRESENTATIVE NATIONWIDE NETWORKS

Table 4-1 presents a business comparison of three major competing data-only public packet switched services organized to highlight their key characteristics. While each offering is distinct, and may optimize for a particular application, ARDIS and BSWD have closely comparable business characteristics. Over the air both are balanced pseudodigital systems, which require modems for the devices. Each has a unique data infrastructure. Neither has its own voice or image fax capability, and both depend only upon data for business success. Both have ample near-term subscriber capacity.

SkyTel2 has functions similar to ARDIS and BSWD, but it employs a sharply different technology that impacts the optimal application. SkyTel2 employs Motorola's ReFLEX50 unbalanced protocol.[7] That is, the forward or outbound (to the device) channel operates at about four times the data rate of the inbound. There are from 5 to 15 receivers per transmitter, primarily to improve in-building coverage. This infrastructure investment and the resulting message length constraints permit ARDIS and BSWD to compete very sharply with SkyTel2 for the true two-way paging market. In turn, SkyTel2 has begun to compete for fixed-position telemetry applications against both ARDIS and BSWD.

4.3.1   Advanced Radio Data Information System

ARDIS's chief marketing distinction has been superior in-building penetration. This advantage has narrowed in selected metropolitan areas as alternative carriers saturate the location with infrastructure. ARDIS still reaches many more small cities and towns, has a good stable of field service applications, has a measurable presence in personal communications, and is particularly strong in hand-held, low-user-velocity applications.

ARDIS has struggled to build a significant paying subscriber base. Its growth was clearly blunted throughout 1993 because of prospective customers' uncertainty over the implications of CDPD. During this period work on alternative applications was initiated. The first successful variant bore fruit in 1994: fixed, not mobile, telemetry applications such as burglar alarms. In late 1994 ARDIS formed an alliance with Rockwell for multimode devices for wide-area trucking. These units could transmit via AMSC's L-band satellite when on the highway, out of ARDIS coverage. The experiment was successful and AMSC eventually purchased ARDIS from Motorola in 1998. As a result of many initiatives of this type, growth resumed during the period 1994–1996.

In 1997 a marked slowdown in growth occurred. IBM continued to reduce its field service employees, the last of the Envoy/Marco horizontal market units were retired, and one key customer went bankrupt. ARDIS had to endure significant churn. In addition, marketing emphasis was concentrated on two key priorities:

Table 4-1   Business characteristics: Nationwide networks

Service name	ARDIS	BSWD	SkyTel2
Parent company	AMSC	BellSouth Mobility	Mtel
Key parent owners	AT&T Wireless, Hughes Communications, Singapore Telecom	—	Mtel (80%); Microsoft (Bill Gates); Paul Allen
Infrastructure	Motorola	Ericsson	Motorola
Protocol(s)	MDC4800; RD-LAP	Mobitex	ReFLEX
First operational	January 1990	October 1990	September 1995
Principal emphasis	Hand-held devices • In-building penetration • Short (≤240 byte) messages ideal • New two-way paging effort	Hand-held devices • Street-level coverage moving to in-building • Medium (≤500 character) messages ideal • Intense effort directed toward two-way paging	Hand-held devices • Acknowledgment back and two-way pager • Very short (≤10 character) messages ideal
	Vehicular devices • Package delivery • Over-the-road trucking	Horizontal application • Two-way paging	Fixed wireless • Telemetry • Meter reading
	Vertical applications • Field service dominates • Courier overtaking Fixed-position applications	Vertical dominates today • Field service: 50% • Transportation: 25%	
Limitations	No voice, no image fax, no intrinsic automatic vehicle location (AVL)	No voice, no image fax zone AVL only	No voice, no fax, no AVL
Third quarter 1998 coverage	1750 base stations, 427 metropolitan areas, 10,700 towns, 50 states, Puerto Rico, USVI, nonmetropolitan satellite offering; links to Australia, Canada, Germany, Japan, Hong Kong, Korea, Indonesia, Kuwait, Malaysia, Singapore, Taiwan, Thailand	1900 base stations, 266 metropolitan areas, 7500 towns, 45 states, CS-cellular rig, nonmetropolitan satellite offering; links to 13 countries, including U.K., Canada, Germany, Belgium, Netherlands, Sweden, Norway, Finland, Australia, Indonesia, Singapore	3000 base stations, 280 metropolitan areas
Planned coverage	RD-LAP deployment for additional capacity; only modest footprint expansions	2500 base stations by year-end 2000; coverage comparable to one-way paging nationwide	

(continued)

Table 4-1   (*Continued*)

Service name	ARDIS		BSWD		SkyTel2	
U.S. subscribers	YE'90:	~22,000			SkyTel 2-way (direct + wholesale)	
	YE'91:	~27,000	YE'91:	<200		
	YE'92:	~31,000	YE'92:	<1,000		
	YE'93:	~32,000	YE'93:	<5,000		
	YE'94:	~40,000	YE'94:	~27,000		
	YE'95:	~50,000	YE'95:	~40,000	YE'95:	~12,100
	YE'96:	~60,000	YE'96:	~55,000	YE'96:	~21,600
	YE'97:	~65,000	YE'97:	~70,000	YE'97:	~60,700
Single user monthly list price, two-way paging	20 kbytes	$19.95	200 × 500 bytes $39.95		6 kbytes	$24.95
	150 kbytes	$49.95	240 × 500 byte $49.95		10 kbytes	$29.95
	350 kbytes	$99.95	$.25/500 byte overallowance		15 kbytes	$39.95
	750 kbytes	$189.95			20 kbytes	$49.95

1. Winning the UPS bid
2. Initiating a second foray into the horizontal marketplace with the introduction of the RIM interactive pager

Both goals were successfully met. However, the concentration on these two goals, while simultaneously holding down marketing expenses and infrastructure expansion in order to drive the company to break-even cash flow, limited the net new 1997 subscriber growth to about 10%. In 1998, the painful ground work began to pay off with a surge of new subscribers. ARDIS's parent company, AMSC, announced that more than 100,000 paying subscribers were on both networks as of the third quarter of 1998; the core-ARDIS share was believed to be ~85,000.

Meanwhile, the initial ARDIS airtime protocol, MDC4800, nears end-of-life. First developed in 1980 for public safety applications, it became codified for IBM's Field Service System (DCS) in 1983. While the bit rates and protocol efficiency of MDC4800 are no longer in the van, the adjacent cell frequency reuse approach remains unique and powerful. It can withstand very long fades, and its short acknowledgment (ACK) sequence is particularly powerful.

ARDIS's second-generation infrastructure, using the improved RD-LAP protocol, was operational in Washington, D.C., in October 1992. With a far higher bit rate and

greatly reduced overhead, it yields about a six times capacity improvement over the same channel as its predecessor. Single-frequency reuse is an option in RD-LAP and is deployed in that manner by ARDIS to improve in-building penetration.

Eight metropolitan areas were reported in production on the new protocol at year-end 1994.[8] In fact, dismal Motorola Envoy/Marco device rollouts and the lack of dual-protocol modems probably held RD-LAP to less than 1000 users across six CSMAs until the end of the third quarter of 1995. The new base station buildup was further slowed by investment disagreements between the then joint owners: IBM and Motorola. This disagreement contributed to the buyout of IBM's half share of ARDIS by Motorola.

By year-end 1996 there were 17 CSMAs with RD-LAP infrastructure installed, but only 11 CSMAs were in production. Regrettably, low subscriber demand simply did not warrant turning on all of the newly installed base stations. However, the 220 base stations in those 11 CSMAs covered more than 35% of the U.S. business population. In late 1997, responding to the projected need for increased capacity demanded by its major new customer UPS, ARDIS began bringing RD-LAP on-line at a feverish pace. By the third quarter of 1998 there were 26 operational CSMAs, with 410 base stations covering 53% of the business population; 11 CSMAs were being installed.

4.3.2   BellSouth Wireless Data

BSWD, then RAM Mobile Data, began its operational life nine months after ARDIS, but spent most of the next three years installing infrastructure in major cities. By its own admission[9] and independent tests,[10] its early coverage and in-building penetration did not match ARDIS. But continuous annual testing[11] in major metropolitan areas indicates that the two offerings are now essentially equivalent in specific target areas. Coverage and penetration comparisons are covered in detail in Chapter 12.

BSWD concentrates on the top 265 or so major metropolitan areas where its coverage footprint is comparable to ARDIS. It has made a series of arresting business partnerships. Its prices, especially custom bids, are extremely competitive. Attractive modem alternatives now exist. Since mid-1993 BSWD subscriber growth has been consistently good, overtaking ARDIS in paying subscribers at year-end 1997, a lead that is since thought to have been relinquished.

BSWD faces even more pronounced wide-area coverage problems than ARDIS. Indeed, it has no physical presence whatsoever in five states. In 1995 BSWD announced its strategic network, at its core a separate radio that permits the user device to communicate with its host application via the cellular network. Lured by a legitimate ARDIS coverage weaknesses in Florida, BSWD also created a satellite alternative using Norcom devices. Ironically, the satellite airtime is purchased from AMSC, ARDIS's parent company. However, this solution permitted BSWD to capture 40% of the Sears subscriber units.[12]

In 1992 BellSouth became an essentially equal partner in RAM Mobile Data and immediately began to infuse cash for infrastructure build-out. In 1995, with the

introduction of a very much lower cost, single-channel "suitcase" base station, the pace of the build-out began to pick up. While there is some reporting confusion in earlier RAM press releases, it seems reasonable that the year-end base station counts were approximately as follows:

Year	Number of Base Stations	Reference
1993	850	13
1994	900	14
1995	1000	15
1996	1100	16
1997	1350	17

This accelerating build-out, driven by the perceived two-way paging horizontal market opportunity, is projected to reach 2500 base stations by year-end 2000 "with coverage comparable to one way paging nationwide."[18]

BSWD employs Ericsson's cellular-like Mobitex protocol, which was upgraded to 8000 bps when introduced in the United States. The capacity of individual Mobitex channels is superior to MDC4800 used by ARDIS. However, it is inferior to the higher capacity Motorola RD-LAP approach. No known improvements to Mobitex transmission speeds appear to be contemplated.

BSWD spends far more heavily than ARDIS on both a large sales force and continued, extensive network expansion. In early 1997 BSWD (as RAM) stated its intent to have break-even cash flow by 1999.[19] However, with major new investments projected for the 1998–2000 time frame, it is not clear when break-even cash, let alone a period profit, can be contemplated.

4.3.3   SkyTel2

In 1991 Mobile Telecommunications Technologies (Mtel), parent of SkyTel signaled its intent "to establish a nationwide wireless network for two-way data services"[20] with a petition for rulemaking to the FCC. The original design[21] anticipated very long outbound messages, averaging 3000 characters—"newspaper delivery." Mtel was awarded an unlicensed frequency in the 900-MHz band in 1993, about the time its one-way paging subscribers on SkyTel exceeded a quarter million.[22] Mtel projections for total network cost were $100 million.[23] Mtel acquired other frequencies during the 1995 FCC auctions.[24]

During the planning stages the anticipated message length contracted to less than 300 characters,[25] then down to acknowledgment paging with a maximum outbound message length of less than 100 characters. In fact, pricing was fixed to encourage very short (at most 10-character) messages. Infrastructure investment costs soared, reaching $400 million, 44% of Mtel's assets, by 1996.[26]

The new service was known first as Nationwide Wireless Network, then as Destineer. In midsummer 1995 Mtel decided to market the service under the SkyTel

brand name.[27] In September 1995 SkyTel2 became operational with expectations of 200,000 subscribers by year-end 1995.[28] About 12,000 users actually materialized.

Most analysts called the launch premature, and key network functions such as a dial-up package were not in place. My own very early testing indicated that the terrestrial receiver leg was not particularly satisfactory. At least one-fourth of the pages were not received and an even higher percentage did not receive an ACK-back. But these problems are quite normal in the early stages of a network roll-out. Not so easily dismissed were lack of function and technical problems with the Motorola Tango pager. Replacement units, the Motorola PageWriter 250/2000, were brought to market in early 1997. The very low subscriber acceptance rates immediately ticked upward. During these struggles, which took a toll of executive management, Mtel announced[29] that Enron Energy Services would use SkyTel2 "to support wireless meter reading and provide advanced services for residential power customers nationwide." This represents a marked shift away from total dependency upon paging applications.

Mtel is making a totally new business with SkyTel2. The heavy startup costs and unexpectedly low subscriber acceptance rate forced Mtel into the red. However, the loss in 1997 ($89 million) was less drastic than that in 1996 ($172 million, including a $39 million one-time asset write-down). By the summer of 1998 management predicted[30] that "the strong demand we anticipate . . . should accelerate our growth and drive SkyTel to positive consolidated net income by the fourth quarter."

4.4 REPRESENTATIVE REGIONAL NETWORKS

4.4.1 Cellular Digital Packet Data

Representative regional carriers can be conveniently lumped together as members of the CDPD Consortium. CDPD itself has a twisted history almost worthy of a business novel. In 1985 the protracted joint venture discussions between IBM and Motorola for a nationwide wireless network collapsed. While IBM was not fault free, the failure was largely due to Motorola's refusal to make its protocol public. In 1989 the talks were on again, but IBM quietly began work on its own protocol just in case Motorola continued its intransigence. It did, but the joint venture was consummated (only to break up later), and ARDIS was formed.

IBM was wary of its partner and had learned a great deal about spectrum sharing through pioneering work done by MDI (later acquired by Motorola). It stepped up its protocol efforts and began to tailor them for AMPS cellular with a "channel-hopping" twist. A receptive carrier was found in McCaw Cellular, whose top management appeared to detest Motorola.

PacTel Cellular, picking up hints of wireless data design work at its competitor McCaw, issued an RFP for network infrastructure. Motorola responded with a good design based on RD-LAP. McCaw was furious and in November 1991 forced a three-way meeting (with PacTel) at Motorola's Mobile Data Division (formerly MDI) headquarters in Richmond, BC. There was no question that RD-LAP was, at that time,

a superior design. Indeed, it is probable that the CDPD design then on the table would not have worked. McCaw's single question was coarse and blunt: Would Motorola agree to make RD-LAP a public protocol? Motorola, awash in hubris and certainly aware that the CDPD proposal was flawed, bluntly refused. The meeting collapsed. The green light flashed for all carriers to pursue non-Motorola initiatives.

Out of this debacle odd alliances were formed: PacTel teamed with McCaw and began to drive hard on the CDPD design. The protocol was given first to Pacific Communications Sciences (PCSI), which fumbled it, then to an MPR Teltech group composed of ex-MDI people forced, or preferring, out after Motorola took over. MPR Teltech people had participated in the design of RD-LAP and knew its weaknesses. The CDPD protocol rapidly became a contender. Too late Motorola agreed to go public with both its protocols. After a stable CDPD design was in hand, the MPR Teltech people broke free and formed Sierra Wireless. Ironically, Sierra now pays license fees to Motorola for patented elements of the modem design.

Coming full circle, PacTel Cellular formed AirTouch and began to invest heavily in CDPD. After a series of failures, including the full roll-out of San Diego without ever achieving a single customer, AirTouch pulled back. It dissolved its Wireless Data Division, scattering rare talent to Nextel (among others), and threw in its lot with U.S.West. That is, they became de facto CDPD opponents along with BellSouth Mobility.

CDPD Consortium infrastructure investments were rich throughout 1994 and 1995, visibly slowing in 1996 because of the lack of market success. It also became clear that the quarterly report cards issued by the Consortium were far from truthful. The mere presence of a single CDPD base station in a locale, perhaps alongside an Interstate, caused the entire city to be classified as fully available to CDPD. Complaints forced revisions in the availability classifications. What was considered full availability now meant over 50% coverage.

The Consortium also fudged the number of metropolitan statistical areas (MSAs) with CDPD coverage. As usual, the devil is in the details. Some of the covered MSAs are trivial areas such as CA12 (Kings), CT2 (Windham), FL3 (Hardee), and KY7 (Trimble), with total populations ranging from 25,000 to 150,000. Very little mention is made of the major cities in which there is *no* coverage—and none contemplated: Atlanta, New Orleans, and Los Angeles. In fact, there are entire states—even entire regions such as the old Confederate South—without *any* CDPD presence. Examples are as follows:

Alabama	Iowa	Nebraska
Alaska	Kansas	North Dakota
Arkansas	Louisiana	South Dakota
Georgia	Mississippi	Vermont
Idaho	Montana	Wyoming

CDPD's current MSA presence can be summarized as in Table 4-2.

In late 1997 the CDPD Forum was terminated. A new organization, the Wireless Data Forum, replaced it. It is an autonomous organization with its own board of

Table 4-2   CDPD CSMA/MSA coverage

Period	Coverage		
	Initial	Core	Full
First quarter 1996	12	29	44
Second quarter 1996	20	39	54
Third quarter 1996	17	36	62
Period	Trial	< 50% Cover	> 50% Cover
Fourth quarter 1996	9	9	85
Third quarter 1997	24	28	111

directors, members, and dues structure, but it is closely aligned with the Cellular Telecommunications Industry Association (CTIA). No longer dedicated solely to CDPD, the Wireless Data Forum pledged to "remain technologically neutral among the various data formats, (and) . . . be evangelical in its promotion of wireless data applications both inside and outside the industry."[31]

4.4.1.1   Ameritech In August 1994 Ameritech was the second cellular carrier to introduce CDPD.[32] Its first market area was Greater Chicago. The initial deployment was massive: 125 cell sites, almost all of them trisectored, outfitted by Hughes. Even though it had been working with at least 12 beta customers for six months, there was no single major commitment to the service. As of the fourth quarter 1998 the largest publicly identified user was Detroit's Clawson Concrete with (perhaps) 100 trucks.

A year after CDPD's introduction Ameritech began to function as a reseller of airtime for ARDIS and RAM.[33] Nine months later it began a major emphasis on circuit switched data via modem pools[34] and Compaq laptops. In May 1998 a merger between SBC (not a CDPD advocate) and Ameritech was proposed. Subject to Department of Justice (DOJ) and FCC approval, the merger is scheduled for completion in mid-1999. There is no discussion of CDPD in the press releases, which focus on "jump-starting competition through the deployment of 2,900 miles of fiber and 140 switches."[35] However, Ameritech signed an agreement with IBM in the third quarter of 1998 in which IBM will act as system integrator for the CDPD installation at the Missouri State Highway Patrol.[36]

4.4.1.2   AT&T Wireless On April 17, 1995, more than 18 months behind schedule, McCaw announced commercial service was available for its AirData System. Since it had two carriers' pricing schemes as models, AirData was priced quite aggressively—for a short time. There was even a hand-wringing trade press article entitled "Has McCaw crippled CDPD?"[37] referring to the low prices.

The notion, of course, was to jump start the market. However, the first commercial use reported[38] did not occur until the following November when American Airlines equipped eight agents in the Las Vegas airport with IBM ThinkPads. This was a high-value application with "each device us(ing) about $500 worth of wireless services a month."[39]

As the months dragged by with few CDPD takers, prices were dropped an additional 60%, largely in response to other carrier moves. By the summer of 1996 AT&T Wireless, which had purchased McCaw, began to experiment with alternatives to CDPD. The first push[40] was Circuit Data Service, with modem pools in 37 cities and bundled cellular modem offerings. There were still some conventional announcements: Robison Heating Oil Supply[41] is one thriller. But more and more, CDPD was seen as an augmentation to voice services. The current emphasis is twofold: Wireless IP data for laptop and hand-held devices using a CDPD modem,nd PocketNet a voice cellular phone with a built-in modem that permits short CDPD messages to be seen on its small screen. One can also reply with a complex, rather clumsy use of the telephone keypad.

On the positive side, AT&T Wireless personnel claim that in their coverage areas CDPD uses only dedicated channels and is fitted out in every voice base station. If this assertion is true, CDPD coverage should be very good throughout its regional areas. On the negative side, the roaming agreements with other carriers are sometimes contentious,[42] restricting economical areas of coverage.

4.4.1.3   Bell Atlantic Mobile   Prior to its takeover of NYNEX, Bell Atlantic was the first to announce, on April 28, 1994, commercial service on CDPD: AirBridge. Hopes were high, with CDPD expected to be generating $50 million per year by 1996.[43] The useful time horizon was surprisingly short: "CDPD will be viable until at least 2000."[44]

In what is now a familiar story, nothing happened as planned. It was December before the first paying customer was signed: the Groton, CT, Police Department.[45] The first real success did not come for 19 months when PSE&G of New Jersey entered into a five-year contract to deploy CDPD.[46] Some observers were uneasy since PSE&G had announced similar plans with MDI (a private system) and later RAM. Both came to nothing. However, by the first quarter of 1997, BAM said[47] that there were 1000 units in the field for meter reading.

In 1996 BAM continued to plow the public safety field and did sign the Bethlehem, PA, Police Department,[48] the Clinton, NJ, Township Police,[49] and, more important, the Philadelphia Police (with a potential of 600 squad cars).[50] However, by autumn BAM began to switch to the *voice-first, CDPD augmentation* strategy by closing a deal to provide 150 smart phones to Walsh Messenger in New York City.[51]

There were several other strategic moves signaled in October 1996. Dennis Strigl, BAM's President & CEO, speaking at CTIA, made three key points:

1. "(Circuit switched) cellular currently attracts some data business because of its coverage advantage, but could lose that advantage as competitors mature."

2. "Yes, there is a (cellular data) business, but I'm not sure my company can make a lot of money in (it)."

3. "We're used to the quick sell. That is not true in the data world where there is often an 18–24 month sales cycle."

Unlike AT&T Wireless, BAM does not always dedicate channels to CDPD (this is especially troublesome to this Connecticut resident). It is quite common to find CDPD essentially unavailable for use, preempted by voice, during rush hours.

4.4.1.4   GTE MobileCom The general trajectory of GTE Mobile's CDPD business is similar to all other carriers: few pure CDPD customers. GTE, however, has been aggressive in its remedial actions. In January 1996 it took price action[52] to prime the market, with little result. In fact, one of the few customer success stories GTE Mobile carried on its Web pages was New Hanover Township, North Carolina (since vanished from the Web).

GTE Mobile long perceived the fatal problem to be lack of coverage. In February 1995[53] a plan was advanced for circuit switched CDPD (CS-CDPD). This is a formal protocol modification to permit transmission over CDPD when it is present, or via circuit switched cellular when CDPD is unavailable. Modifications are required in both device and infrastructure. A year later PCSI (no longer in business) had a device implementation in the personal access link (PAL) phone and Hughes began to modify its base stations. However, no other carrier would join GTE Mobile. In January 1997[54] CS-CDPD was announced only for GTE Mobile, and only for an intrinsically voice device.

The technical approach is complex: Circuitry within the PALphone, and its successors, senses when the field strength of CDPD is fading and determines when the transition to circuit switch is necessary. The circuit switched signals are routed through a modem pool (more on this later) to a CDPD access point. If the user is merely on the fringe of a CDPD service area, the modem pool contact is via a local line. If the user is beyond the range of a local line, the phone automatically dials GTE's national modem pool via a toll-free number. A new circuit switched uplink makes a 2–3 second transition between CDPD and circuit switched achievable. Critics claim the response time delay is all too noticeable, and too much traffic has to pass via circuit switched with its attendant higher costs.

4.4.1.5   CDPD Summary Table 4-3 is a comparison of three large carriers' CDPD offerings. In addition to Ameritech, which has been dropped from the table for organizational convenience, there are other CDPD participants: Comcast, SNET Mobility, Southwestco, and more. However, this table captures most of the interesting variations. Note that GTE Mobile is often trapped by its licenses into relatively uninteresting locales.

The regional problem can only be solved by a network of alliances. Figure 4-1 portrays the third quarter 1997 CDPD visiting agreements. The four major players all have agreements with each other, and all have at least one agreement with a smaller

Table 4-3 Business characteristics: Regional networks

Service name	AirBridge	AirData	
Parent company	Bell Atlantic Mobile	AT&T Wireless	GTE Mobilcom
Infrastructure	Principally Hughes Network Systems; some AT&T Network Systems	AT&T Network Systems: BS, PCSI/Steinbrecher; IS, Retix	AT&T Network Systems: e.g., Houston Hughes Network Systems: e.g, San Francisco
First operational	April 1994	April 1995	October 1994
Principal emphasis	Short messages: telemetry to retail credit card processing Unlimited Internet connect Cellscape: cellular voice and CDPD adjunct	Pure CDPD: public safety Wireless IP Internet connection PocketNet: cellular voice with CDPD adjunct	Pure CDPD: public safety to retail credit cards CS-CDPD for coverage SuperPhone: cellular voice with CDPD adjunct
Limitations	Voice, image fax by circuit switched cellular Need roaming agreements for nationwide coverage	Voice, image fax by circuit switched cellular Need roaming agreements for nationwide coverage	Voice, image fax by circuit switched cellular Need roaming agreements for nationwide coverage
Second quarter 1998 major metropolitan (top 50 CSMA) direct coverage	Boston, Charlotte, Hartford, New York City metropolitan area, New Haven, Philadelphia, Pittsburgh, Washington/ Baltimore	Dallas/Ft. Worth, Miami/Ft. Lauderdale, Minneapolis/St. Paul, New York metropolitan area, Oklahoma City, Pittsburgh, Portland, Sacramento, Salt Lake City, San Antonio, San Francisco, San Jose, Seattle, Tampa	Cleveland, Greensboro, Honolulu, Houston, Indianapolis, Louisville, Memphis, Norfolk, San Diego, San Francisco, Tampa
Typical single-user monthly list prices in home area (first quarter 1998)	150 kbytes: $15 400 kbytes: $30 1100 kbytes: $50 4000 kbytes: $90	200 kbytes: $19 1100 kbytes: $49 2000 kbytes: $69 4000 kbytes: $115	125 kbytes: $15 1000 kbytes: $50 3000 kbytes: $100
Unlimited usage plans (second quarter 1998)	$54.95/month in BAM area; $0.08/kbytes in other areas	$54.99 in AT&T areas; $64.99 nationwide	
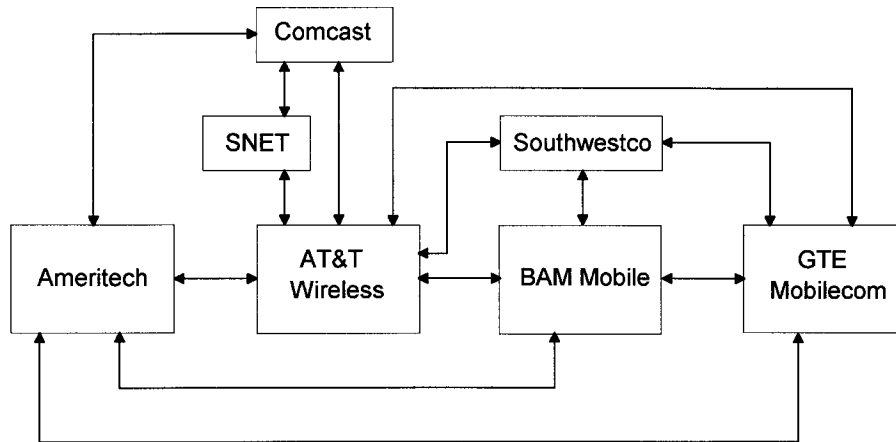
Figure 4-1   CDPD visiting agreements, third quarter 1997.

player. AT&T Wireless is the most aggressive, with a total of six agreements in place. These agreements are far from comprehensive. For example, the AT&T Wireless/BAM agreement does not extend to Connecticut, which forces allegiance to BAM if the user is a New York City commuter. Connecticut users of SNET Mobility can roam freely to Long Island but pay punitive fees if they travel to, say, Cleveland or Chicago. This cost of roaming never appears in Web site price promotions.

4.4.2 Cellular Control Channel

4.4.2.1   Cellemetry In 1994 BellSouth Mobility was not an enthusiastic CDPD adherent. Nevertheless, it did experiments with CDPD hardware in a variety of forums, including campus use at Atlanta's Emory University. In August 1994 it began testing a small CDPD system for Indiana Gas.[55] The principal motivation was the fact that Indiana Gas operated in 35 counties and BellSouth's then-joint-venture partner, RAM, was only present in 8 of the 35.

BellSouth learned a great deal about this application, including the fact that an expensive rollout of CDPD was unnecessary. In July 1995, BellSouth announced it had been testing a new short packet message transmission scheme employing the control channels of the Indianapolis voice cellular system.[56] The test user was CINergy and the application was meter reading. But BellSouth believed that the short messages, constrained to only 32 bits, could be used for a great variety of low-usage, small-data-telemetry applications. Thus the name Cellemetry.

The technical approach is simple, functionally limited, but inexpensive. It was long known that the control channels in most AMPS installations were lightly utilized. BellSouth had a special data radio designed by Standard Communications that had some attributes of a roaming cellular telephone. If this new device showed up on the

control channels, it was perceived to be a roaming phone. Under normal conditions the mobile identification number (MIN) and electronic serial number (ESN) of roaming phones are sent to the home system of the roamer. In the Cellemetry design the MIN is specially coded and causes the message to be sent to a Cellemetry service gateway connected to the same intracellular network. The ESN now contains the data payload—thus the 32-bit limit. The information flow is depicted in Figure 4-2.

In May 1996 BellSouth signed a three-year agreement with CommNet Cellular and Skywire to begin the first commercial deployment of Cellemetry.[57] The application was vending machine monitoring, which Motorola used to call "vendet" when it went after this market in the 1980s. CommNet has a cellular presence in nine states. Skywire was to provide its flagship product, VendView, a combination of vending machine hardware and supporting software. No installation was ever observed, and Skywire went out of business in February 1998.

In February 1997 BellSouth licensed its Cellemetry technology to Ericsson. The result was a full 3-watt transceiver in a very small physical package.[58] In October of that year the Fisher Pierce Division of Pacific Scientific, together with Florida Power, begin beta testing Cellemetry for remote monitoring of electric power delivery systems.[59]

In February 1998 Global Research Systems, together with the Paul Bunyan (this is no joke) division of Rural Cellular, announced that the global positioning system (GPS) based BusCall service would be used to track school buses for the Memidji school district during the 1998 school year.[60]

The struggle to make a market continues. Perhaps Wireless Data Concepts ORION system, which is planned to remotely monitor Time-Warner standby power units,[61] will be the one! But BellSouth will no longer search for the market alone. It formed a joint venture with NumereX, retaining only a 40% minority stake in a new company, Cellemetry, L.L.C.[62]

The Cellemetry technology has been cross licensed to HighwayMaster[63] (see Chapter 5). Service pricing is highly variable since "Cellemetry uses value-based
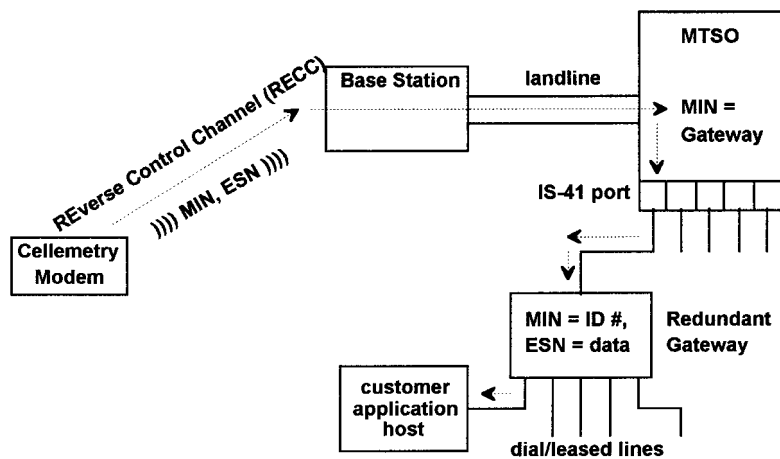
Figure 4-2   Cellemetry inbound information flow.

pricing, where the price(s) . . . are negotiated with each application provider and vary from market to market."[64] This leaves the user in much the same position as anyone who buys oriental rugs.

By the fourth quarter of 1998 coverage existed for about half the geography of the United States. In addition to BellSouth itself, 22 U.S. carriers, mostly very small systems, were lined up to use Cellemetry.[65] An important large carrier addition during this quarter was Bell Atlantic Mobile (BAM).[66] Following is a list of U.S. carriers who have agreed to provide the transmission medium:

AirTouch Cellular	Frontier Cellular
Aliant Cellular	Glacial Lakes Cellular 2000
Bell Atlantic Mobile	Illinois Valley Cellular
BellSouth Cellular	Kansas Cellular
Blue Mountain Cellular	Lake Huron Cellular
Carolina West Wireless	Midwest Wireless Communications
Cellular Mobile Systems of St. Cloud	Pioneer Cellular
Cellular South	Plateau Cellular
CommNet Cellular	Rural Cellular Corporation
Dobson Cellular	Sygnet Communications
Douglas Telecommunications	Vanguard Cellular
First Cellular of Southern Illinois	

4.4.2.2 Aeris Communications Aeris Communications, originally Axion Logistics, has also developed a proprietary, two-way short packet messaging capability it calls MicroBurst. This approach transmits over cellular network signaling system (SS7) control channels using standard EIA-553 signaling procedures. It then backhauls the packets to the customer through the Internet. Testing began in the fourth quarter of 1996. Western Wireless announced[67] it would deploy MicroBurst in its cellular territory in July 1997. AlarmNet announced[68] it would use MicroBurst for its SafetyNet Cellular service during the September International Security Conference. Ameritech announced[69] it would employ MicroBurst in November 1997, followed by Century Cellnet in December.[70] Cellnet expected to have customers operating in the second quarter of 1998, about one year behind the initial Aeris goals. At least some units actually became operational in the third quarter of 1998.[71]

MicroBurst requires no network modifications. It packages very short user packets to resemble roaming client originating phone calls. The packets pass through the control network like all other signaling traffic. The packets, in an Aeris-proprietary format, are routed to the Aeris central hub facility in San Jose, CA.

MicroBurst exploits the requirement that a cellular network must perform account verification before it services a call. A carrier switch routes the incoming data to what it thinks is going to be an authentication event. It is actually sending the data to the Aeris hub, which acts as a home location register. The hub responds to the carrier switch with instructions to drop the transaction. The data are then processed at the hub and sent to the customer through a hot-socket Internet connection. The maximum packet size is 50 bits. McroBurst software is required in the cellular radio portion of every remote device.

Aeris acts as a wholesaler of wireless connectivity, operating between the carrier and remote-access equipment vendors. The company is working with cooperating carriers to negotiate per-packet pricing agreements.

MicroBurst is being positioned as a low-cost, nationally available alternative to existing technologies: "We provide a signaling overlay on the whole country."[72] At the beginning of 1997 Aeris had hoped to have nationwide agreements in place by year-end. In actual fact it was present in only three regions of the country. But nationwide roll-out is clearly planned. Qualcomm announced in April 1998 that it planned to deploy MicroBurst "for a new terrestrial-based service for tracking untethered trailers."[73]

Aeris competes directly against Cellemetry. The two offerings are not mutually exclusive; a carrier could have both. MicroBurst does not require gateway hardware at every cellular switch location. It does need a contract with each participating cellular carrier, as well as roamer port access and modifications to the MSC switch translation tables to recognize the destination point code of the Aeris hub.

A summary of these two offerings is provided in Table 4-4.

Table 4-4   Cellular control channel offerings

Service name	Cellemetry	MicroBurst
Parent compan(ies)	NumereX (60%), BellSouth Mobility (40%)	Aeris Communications
Technical approach	AMPS control channel; distributed gateways	AMPS control channel; hub-central approach
Protocol(s)	MIN/ESN variants	SS#7 variants
First operational	1995	1997
Principal emphasis	Very short (32-bit), telemetry status type messages	Very short (50-bit), telemetry status type messages
Limitations	No fax, no voice, low traffic rates, no interactive capability, very short message lengths	No fax, no voice, low traffic rates, no interactive capability, very short message lengths
Fourth quarter 1998 coverage	Twenty-three cellular companies licensed for ~50% of U.S. geography	
Planned coverage	Nationwide	Nationwide
Claimed advantages	Better geographic coverage; Two low-cost (~$100) modem suppliers; payload can be expanded to 122 bits by using antifraud fields	Potentially more mobile; greater basic payload; better security
Monthly user prices	Established on a carrier-by-carrier basis	Established on a carrier-by-carrier basis

4.5   REPRESENTATIVE METROPOLITAN NETWORKS

4.5.1   Introduction

A few networks make no claim for either nationwide or regional service. Rather, they concentrate on individual metropolitan areas as their targets. Table 4-5 is a summary of three such systems. Two are data only. The third, Geotek, was a digital voice/data system that failed in October 1998. Ricochet, a data-only system, concentrates on static wireless Internet access. Teletrac, and Geotek before it failed, focused on vehicle location applications.

These systems are not as closely comparable in function as the prior two categories. Only their business characteristics are related. There are no profits here, and the survivors are watching their financial status with exceptional care. Yet all three seized specific market niches. The subscribers they handle erode the total opportunity for the nationwide or regional players.

4.5.2   Metricom Ricochet

A new data alternative, Ricochet, was launched in 1994. This system grew out of Metricom's private data networks for utility companies. The 19 existing utility networks are characterized by wireless transmission from utility meters in stationary locations.

Ricochet operates in the unlicensed 902–928 MHz industrial, scientific and medical (ISM) band, something of a cross between a wide-area network (WAN) and a local-area network (LAN). Its raw bit rate is a theoretical 100 kbps[74]; the effective user rate is far lower: Hewlett Packard experiences throughputs of 19.2–28.8 kbps on three campuses[75]; *New York Times* journalists experienced[76] 14.4 kbps "or slightly worse"; Sun Microsystems "has experienced throughputs of anywhere from 4.8 to 28.8 kbps."[77] There are special conditions in which throughput can reach ~40,000 bps between PC/radio modem combinations that are communicating directly with each other without employing the network.

Metricom continues to experiment with a new technique, using two different spectrum bands, to raise user bit rates. In September 1998 Metricom announced that 80 new technology radios were operational in the San Jose area. The plan is to bring existing modems up to 56 kbps by mid-1999; brand new modems will be able to approach 128 kbps.[78]

When the network is used, the PC/radio modem communicates with the nearest low-power radio "node," typically mounted on a utility pole less than 400 meters away. The receiving node must pass the data to other nodes until it finds one with either a public switched network interconnection facility or a network router to a packet switched system (Ricochet modems support both kinds of connection). Best case data transfer rates in this mode are 28,800 bps. Because of cell hand-off overhead in its very small diameter cells, "the service is best suited to users who remain within

Table 4-5   Business characteristics: Metropolitan networks

Service name	Geonet	Teletrac	Ricochet
Parent company	Geotek	Teletrac	Metricom
Key parent owners	CIBC, Toronto Dominion, Palladin Group, Soros, Promethean Investment Group, Vanguard Cellular	—	Microsoft, 10%; Vulcan Ventures (Paul Allen), 50%
Infrastructure	Israeli Joint Venture	Teletrac	Alps Electric
Protocol(s)	Proprietary	Proprietary	Hayes-AT; TCP/IP; PPP; "StarMode" (proprietary)
First operational	March 1996	1988	June 1994
Principal emphasis	Turnkey mobile fleets • digital voice, • dispatch data, • GPS-based AVL	Vehicular solutions • proprietary AVL, • street-level coverage, • short messages, • small (20–50 vehicles) in-city fleets	Horizontal • notebook PC connections Vertical • physician support
Limitations	No fax	No voice, no image fax	No voice, no fax, no AVL
First quarter 1998 coverage	Baltimore/Washington, Boston, Dallas/Ft. Worth, Houston, Miami, New York City metropolitan area, Orlando/Daytona, Phoenix, Philadelphia, San Antonio, Tampa/St. Pete	Baltimore/Washington, Chicago, Dallas/Ft. Worth, Detroit, Houston, Los Angeles, Miami, Orlando, Sacramento, San Diego, San Francisco	San Francisco Bay Area, Seattle, Washington, DC, 11 airports, rural Nebraska
Planned coverage	—	Boston, New York Metro, Philadelphia	Southern and central California
U.S. subscribers,			
year end 1992	—	~9,500	
year end 1993	—	~27,300	
year end 1994	—	Unknown	<50
year end 1995	—	Unknown	~300
year end 1996	~1,550	~57,000	~9,000
year end 1997	~12,600	~75,300	~19,000
Typical single-user monthly list prices	125 minutes, $39 200 minutes, $59 AVL feature, $20	Average, < $30	Unlimited internet access, $29.95/month

a single cell while sending data"[79] and keep their speed under 10 mph. Essentially this data service is for the static user, not one in motion.

Ricochet's basic price has been stable at $29.95 per month ($19.95 for schools[80]) since mid-1996. The very low prices were initially expected[81] to blowtorch the market: "we hope to have a million users by the end of '95."[82] There were actually 19,000 users at the close of 1997.

Rollout plans at announcement time envisioned four or five operational areas by year-end 1994.[83] Two were up: Silicon Valley and Dearborn, MI. Five more areas were planned for 1995. By the first quarter of 1998 Ricochet was available in three major metropolitan areas, 11 airports, and portions of rural Nebraska covered by KN Energy.[84]

Ricochet is a limited metropolitan (even campus) system, basically for Internet access. Med-E-Systems[85] is writing gateway software that will permit medical information to be transmitted across multiple networks. Its familiar protocols (Hayes-AT, TCP/IP with point-to-point protocol (PPP)) are reasonably compatible with many key applications but, typically, "it wasn't easy . . . to wireless-enable Lotus Notes."[86] The point-to-point protocol[87] meshes well with the IS-99 CDMA data standard.

In May 1995 Metricom and Potomac Electric Power (Pepco) announced[88] a joint venture to make Washington, DC, the first East Coast city on Ricochet. Pepco has invested $7 million for a 20%, exclusive-rights share of the Washington area wireless data market. It was operational in November 1996.[89] In April 1997 Brooklyn Union Gas and Metricom announced a joint venture, KeySpan-Metricom, with an initial investment of $25 million dollars from each company. The plan is to begin infrastructure build-out in five major metropolitan areas, including New York and Chicago,[90] a task that may require $300 million. Thus, Ricochet is clearly on the road to a focused wide area capability. Its deployment will be impeded by "battles . . . with governments, federal and local. It takes about seven minutes to install a Ricochet cell but it's no secret that a lot of politics goes before the seven minutes."[91]

Like every other airtime provider, Ricochet has struggled to build a significant subscriber base. From a position of about 300 subscribers at year-end 1995, the company reached 25,000 users in November 1998.[92] Device deployment has slowed considerably during the year, averaging a net new subscriber growth of ~550 per month. In defense, this user base has been achieved in a relatively tiny geographic area. Revenue growth from the first quarter of 1996 to the third quarter of 1998 has been at a 38% compound growth rate (CGR). But financial losses have been draining and have risen steadily at a negative CGR of nearly 46%, as shown in Figure 4-3. Attempts to take on additional debt appear to have been attempted but were rejected by the financial markets. However, limited line-of-credit borrowing capability has been worked out with Vulcan Ventures.

4.5.3   Teletrac

Founded in 1988 as a vehicle location subsidiary of AirTouch Communications (née PacTel Cellular), Teletrac bought its independence in January 1996. Much to its
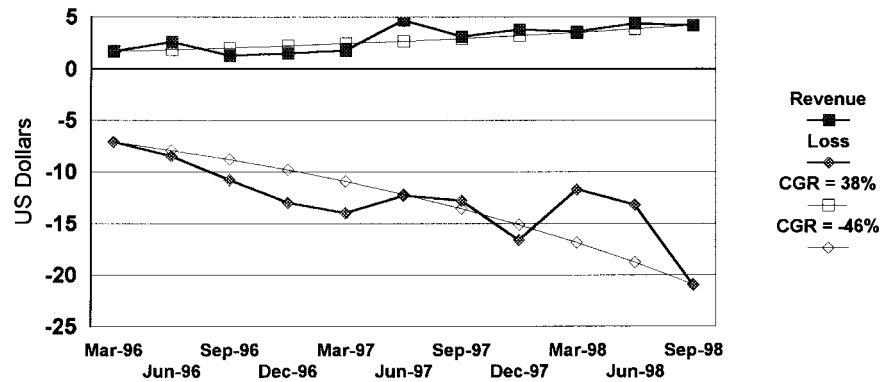
Figure 4-3   Metricom Ricochet financial snapshot.

former parent surprise, the company had significant subscriber and revenue (though not profit) growth during the year, reaching 57,000 subscribers, across 1700 customers, in only six cities. In 1997 the number of cities covered reached nine; the *net* number of subscribers (there was considerable churn) grew to 75,344,[93] including consumer devices, more than either ARDIS or BSWD, nationwide. But losses were high: $9.7 million for the fourth quarter alone.

In September 1997 Teletrac announced[94] that it had completed a $105 million dollar debt offering, intended to finance network expansion. In January 1998 Teletrac's tenth metropolitan area, Washington/Baltimore, became operational. In addition, the 1998 expansion plans for the New York metropolitan area, Philadelphia, and Boston were revealed.[95]

The financial report for the first quarter of 1998 was posted on May 13—the last update to the Web site as of November 16. With a slightly declining consumer base, total subscribers crept over the 80,000 mark. Revenues were up, but painful losses were still present. On August 7, Standard & Poor's lowered the speculative grade ratings to CCC+, placing its debt on CreditWatch and pointing out that Teletrac's cash balances were only $13 million on June 30, not enough to "provide adequate funding of capital and operating requirements beyond the next few months."[96] The company's future will probably be determined during the New York City rollout if it has the capital to finish the task.

Teletrac does not use GPS for vehicle location but rather uses a proprietary technique called multilateration. Operating in the 900-MHz band, the device calculates position status accurate to within 150 feet, even within buildings and parking garages. Teletrac's marketing arguments make much of the fact that GPS tends to lose its target inside a metropolitan area. This assertion can be disputed, and many competitors are willing to do just that. The very small devices are supported by extensive fleet management software. Teletrac also supports two-way messaging and offers personal vehicle (consumer) services aimed at trapping car thieves.

4.6 NOTABLE CLOSINGS

For those loyal to the Zagat Guide, this category needs little explanation. It is sufficient to say that many of the early entrepreneurs, both network and device providers, have failed. What follows is a representative sample of some of these casualties. It was too depressing to create a comprehensive listing.

4.6.1 AirTouch CDPD

One of the first out of the starting gate for CDPD, AirTouch (then PacTel Cellular) formed a dedicated Wireless Data Division to attack the perceived opportunity. Hands-on customer demonstrations were underway in the San Francisco Bay Area during June 1993.[97] By 1994 AirTouch had an impressive program in place to assist hardware and software developers working on CDPD applications. These aids included technical documentation, development tools, electronic bulletin boards, discount programs, and marketing assistance.

In May 1995, after the full build-out of CDPD in San Diego, AirTouch called it quits: "There simply aren't enough businesses in San Diego that fit the profile for CDPD to justify a commercial rollout."[98] AirTouch tried mightily to soften the blow, assuring its customers that it would appear in San Francisco in 1996. It did not.

4.6.2 Cellular Data Incorporated

The attempt to pack data into unused cellular spectrum is continuous, even chronic. In 1988 Cellular Data Incorporated (CDI) began to develop transceivers intended to fit low-powered, narrow data transmission channels into the guardbands between cellular voice channels. The intent was to have no interference with voice transmissions. The transceivers would then communicate with CDI base station equipment located at the cellular phone sites. The market was estimated to be \$4 billion (yes, billion).[99] The technology was compatible with time division multiple access (TDMA), which is where CDI saw the cellular voice market moving.

This proposal was greeted with considerable enthusiasm by some carriers. In January 1991 GTE Mobilnet announced that it would begin field tests in Houston.[100] BAM announced Philadelphia tests in March[101] and took a \$1 million stake in CDI at the end of that month.[102] Venture capital flowed; trade press—even *Business Week*—articles were in abundance. BAM saw an immediate market of 220,000 customers.[103] Truly fantastic annual revenues were forecast.

But the tests dragged on. In March 1992 GTE Mobilnet released a statement that there was no voice/data interference in the test but that they were having problems justifying the market size, acceptance, and deployment costs. BAM held on longer. In September 1992 it announced it would test in Baltimore with Westinghouse, which would resell the data service as part of its fleet management operation.

But CDPD was on the horizon. Its premature announcement hurt carriers such as ARDIS and BSWD. It killed CDI, which, in 1993, went under the waves.

4.6.3   Cincinnati Microwave

In October 1993 the radar detector company Cincinnati Microwave announced its first CDPD modem, the MC-DART 100. This restricted-function unit was aimed initially at the vending machine market. The company was optimistic about capturing "a significant share of the . . . 200,000 to 500,000 CDPD modems"[104] that will ship in 1994. This outlandish market estimate was created by BIS Strategic Decisions. Priced at $495, it is not clear that any measurable quantity of the unit, or its successor, ever sold. Cincinnati Microwave went bankrupt in 1996.[105] Its products were acquired by Sierra Wireless in 1997.[106]

4.6.4   CoveragePLUS

First operational in the fourth quarter of 1989, Motorola's CoveragePLUS used similar base stations as deployed for its own DRN public packet system. However, CoveragePLUS was a linked SMR system with voice dispatch standard (and higher priority for airtime access). Elementary AVL was standard, initially with LORAN-C. The switch was quickly made to GPS. CoveragePLUS could be usefully operational with no user application development, although there was provision for extra cost data features. Motorola tried to avoid this roll-out impediment, offering "no-brainer" capabilities such as mobile fax. By the first quarter of 1993 all 750 Motorola-controlled SMRs were connected and terrestrial coverage was surprisingly good.

Device prices ranged from $3500 to $5000 depending upon function, competitive with satellite alternatives. Entry airtime pricing began at $35 per month, lower than OmniTRACS. The national average monthly bill was $40–$45, sharply lower than OmniTRACS. But this attractive airtime pricing was death to profitability. In late 1993 Motorola threw in the towel. CoveragePLUS was terminated and the ~8000 users were "made whole" financially on OmniTRACS.

4.6.5   Electrocom Automation

During the 1980s Electrocom was an important supplier of mobile data device and infrastructure for private systems. Typical of the state of the art at that time, its radio modems could achieve nearly 4800 bps. The actual throughput was, arguably, even higher. Electrocom did not use error correction techniques that consume much user capacity. If the message failed, it simply retransmitted it. Electrocom controlled the placement of base stations and therefore had surprisingly low retransmission rates. It never won a truly major customer, and the mobile data staff were out of place in a company that built postal sorters. The wireless division was sold to Siemens. Only the MDC2000 in-vehicle computer survives, which uses someone else's radio modems and infrastructure.

4.6.6 Geotek

In the Spring of 1993 Geotek purchased two-thirds of Gandalf Mobile Systems and announced its "future will be . . . turnkey digital voice and data services. . . . The first digital system will be launched in the middle of (1994) in Philadelphia."[107]

Geotek was a hybrid voice/data system, with its principal emphasis on voice. Data functions were related to the dispatch application and clearly designed for street-level vehicles. The infrastructure was proprietary and unique. It had relatively few[108] but quite high powered[109] outbound base stations. Like the ReFLEX protocol used in SkyTel2, Geotek operated "unbalanced" with a much higher outbound transmission speed. For each transmitter there were five to six inbound base stations that replied at less than half the outbound rate. To distinguish itself from other new digital voice/data developments (notably Nextel), GeoTek pointed out that its fleet systems will offer vehicle location.[110]

Aggressive roll-out plans were announced: "During the first half of (1995) GeoTek intends to provide service from Boston to Norfolk. The remainder . . . in 36 of 40 top U.S. markets will begin digital service during 1996."[111] With little fanfare schedules began slipping:

1. September 1994: GeoTek announced it will offer data transmission[112] during 1995: "By 1997, the company expects to have . . . systems operational in 35 major markets."[113]

2. April 1995: "Full deployment of GeoTek's 36 market system will take (until 1998)."[114]

3. November 1996: Geotek has "scaled back its plans to expand."[115] The new goal was 25–27 markets by year-end 1997.

4. May 1997: "The number of target markets by year-end 1997 has been reduced to 13–22."[116]

The actual number of operational markets at year-end 1997 was 11.[117]

In July 1995 small users were permitted to play on the Philadelphia test bed[118] by paying $30 for 500 minutes of connect time. Multifunction devices built by both Hughes and Mitsubishi began to appear, priced at about $900 each. Geotek was very bullish on data: By mid-1997 "40% of (our) customers will be using data. . . . Data applications include . . . vehicle location."[119]

By March 1996 commercial service in Philadelphia was ready, but it was clear that "only voice services will be available at the outset. Data is not only more difficult to sell, but it's also more difficult to implement."[120] Prices were raised. The entry airtime package was 125 minutes for $39 ($.312 per minute) with a 75-minute limitation on interconnect time; the midrange package bought 200 minutes for $59 ($.295 per minute); device prices climbed to $1250 ± $50.

In May 1996 GeoTek announced its first data offering: AVL. The plan "is to sell a GPS PC Card from Trimble for $225 to $250 . . . (which) fits into the GeoTek terminal. We think AVL will be very hot."[121]

In a decline explored more fully in Chapter 9, Geotek staggered above the 10,000 user mark in 1997 and part of 1998, hemorrhaging cash all the way. It turned off its network in October 1998, stranding all customers.

4.6.7   Global Vehicle Tracking System

In January 1992 Facilitech (Bingham Farms, MI) announced both its Global Vehicle Tracking System (GVTS) and a wholly owned subsidiary bearing the same name. Under development throughout 1991, GVTS was held back because of a lack of GPS satellites in orbit. At the start of 1992 the GPS constellation included 24 satellites, enough to reasonably ensure that three would be visible at all times.

GVTS included an AVL device that was initially mounted in hazardous waste trucks. Position information could be transferred over SMRS/PLMR to a display on the dispatching workstation (Sunsparc) which held Etak's computerized maps. The device was also capable of transmitting onboard sensor data and could support data messaging between driver and dispatcher.

GVTS also announced its intention of transmitting data over both cellular and satellite systems, but it would wait for LEOSs since "the high cost of satellite communications makes the technology unattractive to most customers" (somebody should have told OmniTRACS about that drawback). A test-bed installation began in May 1992 for an unnamed company with 600 trucks. GVTS was never heard from again.

4.6.8   Kustom Electronics

Founded in Lenaxa, Kansas, in 1965 as an electric guitar maker, Kustom began building wireless data terminals in 1988. Their finest hour occurred a year later. Kustom won a 335 DXT terminal contract for the Philadelphia Gas Works[122] and was profitable. Glenayre was attracted and purchased 74% of the company, providing enough cash for Kustom to purchase the software dispatch house digital dispatch service (DDS) and engage in a long competitive field test to win the GE Consumer Services service technician business. They won the GE contract in January 1990,[123] beating out Electrocom and Motorola/MDI.

In July 1990 Kustom won a pilot test with Airborne with giveaway prices, selling its traffic services division to concentrate on the mobile data opportunity. By the close of 1990 it was taking losses for the first time. Sharp layoffs occurred in January 1991, but Kustom remained optimistic: "Unless things go really sad, . . . looking at the potential business, it's extremely strong."[124]

In June 1991 Airborne decided not to go with Kustom, citing the poor dispatch software from DDS.[125] The next month Glenayre sold two-thirds of Kustom to Simmonds Communications, which had been foiled in its attempt to purchase MDI. In August sales were down 60%. By November Kustom had to sell the rights to the DXT to Coded Communications. In January 1992 Gandalf bought out and

extinguished Kustom. Gandalf itself was consumed by Geotek in 1993 and is no longer in the wireless data business.

4.6.9 Magnavox (Nav-Com) Automatic Vehicle Location

On September 12, 1989, at the Vehicle Navigation and Information Systems Conference, Magnavox presented its paper on its operational field testing phase pilot with the Toronto Department of Ambulance Services. There is no question that the system functioned, even falling back on dead-reckoning devices when the then-incomplete GPS constellation presented insufficient satellites. However, the device price was staggering; the project was terminated.

4.6.10 Mobile Data International

MDI was incorporated in April 1978 and had its first real success with the capture of the Federal Express data dispatch business in 1982. Progress was steady through 1986, with over 13,000 devices installed.[126] Many of the technical solutions were highly innovative for their time; the channel-hopping techniques and Reed-Solomon forward error correction code were later adopted by CDPD (the latter with the help of ex-MDI folks), for example.

   MDI's success was tolerated, perhaps even appreciated, by Motorola as long as the mobile devices used Motorola radios. MDI then began to integrate other radios, principally from Uniden, in its devices. Motorola then purchased MDI, which became a division, then slipped into the history books.

4.6.11 Motorola Tracknet/Diversified Computer Systems (DCP)

On October 8, 1990, *Mobile Data Report* ran a report on this elevating exchange: "Motorola's Tracknet automated vehicle location (AVL) system is a dead monkey [note: it was], says Bob Johnson, VP at Diversified Computer Systems. Johnson said his firm is trying to interest . . . MDI in DCP's own AVL software. MDI is interested in AVL and is investigating a number of firms, but it does not wish to discuss particulars or offer a prognosis on the health of the monkey, says MDI's John Mitchell." (MDI was later purchased by Motorola and effectively put out of business.)

4.6.12 Navtech

During November 1993 Navigation Technologies demonstrated its capability on two packet networks: (now) AT&T Wireless CDPD and ARDIS. "The combination of wireless networks and NavTech's database will change the economics of dispatch . . . opening up both vertical and horizontal markets,"[127] said Chris Hrut, NavTech's Director of Business Development.

While NavTech is still very much alive, writing software for applications as unusual as Psion Series 3 palmtop with aircraft pilot GPS, the wireless dispatch thrust failed. The CDPD Web site was discontinued on March 21, 1994.

4.6.13   Pacific Communication Sciences

In 1991 PCSI got an early start on CDPD by making the first draft definition of the airtime protocol (this task was later assumed with greater success by MPR Teltech). Very quickly PCSI found a partner in IBM, which, in late 1992, awarded PCSI a development contract for integrated CDPD modems for IBM's line of ThinkPad laptops.[128] One key reason was PCSI's long lead on other potential suppliers of CDPD chipsets/modules.

On April 13, 1994, PCSI received the first FCC certification for any CDPD product when both its base station and the Ubiquity 2000 modem were approved.[129] The Ubiquity line and its identical IBM counterpart were marketed intensely for the next year. In May 1995 PCSI formed a strategic partnership with ComputerLand to provide CDPD products to customers nationwide.[130] In March 1996 PCSI released a family of base stations in support of AT&T Wireless' personal Air Communications Technology (pACT).[131] They were later damaged when AT&T Wireless threw in the towel and ceded the protocol war to Motorola and its FLEX design.

As pure-data CDPD languished, PCSI switched to a voice/data solution. It introduced the first "smartphone" in September 1996. AT&T Wireless marketed it as PocketNet. Hype ran high: "By 2000, half of the mobile phones shipped in the U.S. will have . . . integrated data capability."[132] The magic box had been discovered: "I truly believe that (smartphones) will be one of the major factors that finally drives wireless data adoption—1996 and 1997 will be the years when the curve did start to turn up."[133]

Pressed for cash, PCSI's parent, Cirrus Logic, began to sell off parts of the company.[134] It was of no avail. On May 15, 1997, PCSI announced it was closing its doors.[135]

4.6.14   PinPoint Communications

In 1989 PinPoint Communications began to develop a packet switched system targeted for AVL and other in-vehicle applications. It called its system Array, after the repeating triangular pattern of base station layout. The patented modulation technique could achieve very high bit rates—400,000 bps in the slower speed version—but required the allocation of considerable bandwidth to achieve these speeds.

Field tests of the technical approach were conducted in four cities during the summer of 1991,[136] leading to the establishment of optimum packet sizes (20 bytes) and trial prices ($0.001–$0.005 per packet). By the close of 1993 PinPoint was poised to begin beta tests in Dallas during the second half of 1994 but, lacking money, closed its doors instead.

4.6.15 RAMTrack

In 1993 RAM System Development announced RAMTrack, an "integrated" vehicle location and management system. Actually, the GPS device was independent of the "computing mobile," the two-way messaging device, which in turn was independent of the Mobitex radio modem. The tracking/maps/dispatch software ran on Sun workstations. There were no known sales.

4.6.16 RadioMail

Founded in 1988 as Anterior Technology, a decisive move to wireless E-mail gateway services was underway by 1991. The following year the company's name was changed to RadioMail to reflect its principal thrust. In 1993 it received a critical cash infusion of $3 million as 2M Invest and Motorola purchased a minority stake.[1] After a series of uncommonly public battles, Motorola executives "lost patience with . . . the firm's top management" and took control to "restore calm."[2] Motorola became the majority owner and a number of initiatives were attempted, including Web access via RadioWeb in 1996. Always struggling to survive, RadioMail bet on CDPD as its salvation. Executives came and went, its founder retiring to the Czech Republic. In 1997, after a complete management restructuring, 2M Invest provided a final round of capital.[3] By June 1998 RadioMail was no longer operational.

4.6.17 Skywire

In August 1995, "the first major roll out of a remote wireless monitoring system for the United States vending industry"[137] was announced by Coca-Cola Bottling of Nashville. This was VendView, a private network that passed data via Ademco's AlarmNet system. In late 1996, a major strategic blunder occurred. Skywire would "integrate Uniden's . . . CDPD technology into . . . VendView to provide an effective and affordable (public) communication system for the wireless monitoring of vending machines."[137] By 1998 Skywire had vanished, along with its Web site.

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5

PUBLIC TERRESTRIAL CIRCUIT SWITCHED NETWORKS

5.1 REPRESENTATIVE NATIONWIDE NETWORKS

Nationwide circuit switched networks exist in vehicular, mobile applications; the successful ones use the existing voice cellular network as a "last mile" solution. One well-known system is that of United Parcel Service (UPS), which has no voice capability in its devices. During 1998 UPS began its move to a packet switched approach via a public network: ARDIS. Other circuit switched systems are also beginning to experiment with packet alternatives, from hybrid CS-CDPD through Cellemetry.

The prominent cellular alternative, Nextel's digital network, is nationwide by pricing and advertising but has huge coverage gaps. Nextel's major emphasis is voice, and it has attractive hand-held as well as vehicular devices. While Nextel's iDEN architecture permits short-message activity, the only data function currently stressed is paging. The company has decided to skip the circuit switched stage for true data and develop a packet system instead: "wireless data . . . will come down our product delivery pipeline in the next couple of years."[1]

A summary of representative offerings is contained in Table 5-1.

5.1.1 HighwayMaster: A Stubborn Fighter

From its network switching center in Dallas, HighwayMaster manages information from the nationwide circuit switched cellular resources of 73 different carriers. Concentrating on the over-the-road trucking application, it has a uniform pricing scheme that accounts for, screens, and consolidates the roaming costs. HighwayMaster was established in April 1992 and began offering combined voice,

Table 5-1 Business characteristics: Nationwide circuit switched networks

Service name	HighwayMaster	InTouch	Nextel
Parent company	HighwayMaster Communications	PeopleNet	Nextel
Key parent owners	SBC Communications (20%), Erin Mills Group (20%), Carlyle/Clipper (10%)	—	McCaw Family
Infrastructure	AMPS Cellular	AMPS Cellular	Motorola
Protocol(s)	Hayes	—	Motorola Integrated Radio System (MIRS)
First operational	September 1993	January 1998	September 1995
Principal emphasis	Voice/data messaging, sensitive load GPS, Rolling ETA (12/minute), in-cab facsimile	Tractors, voice/data; messaging (voice optional) Trailers: location, status	Voice hand-held devices • ACK back and two-way pager • very short ($\leq$10 characters) messages ideal
Limitations	—	No fax	No fax
First quarter 1998 coverage	More than 99% of the available cellular coverage areas in the U.S.	Approximately 90% of the U.S. geographic area	~75% of the U.S. population; 79 of the top 100 MSAs
Planned coverage	—	—	85% of U.S. population, 1998
U.S. subscribers, year end 1993	~2000		
1994	~6000		
1995	~12,000		
1996	~20,300		
1997	~33,100		
First quarter 1998	~40,000	0	
Typical single-user monthly list prices (Nextel = text message additional fee)	$41 month plus • $.53/minute voice; • $.48/minute data Average cost ~$80/month	Positioning only: $1 per day	100 messages, $3.00 300 messages, $7.00 Additional messages, $0.10 Third quarter 1998 monthly subscriber, average $70

data, and vehicle location services in September 1993. By the close of the third quarter of 1998 it had a revenue-producing installed base of 39,673 vehicular units.[2]

Reflecting the high average air time costs of a nationwide cellular system, usage tends to be light. Reported air time consumed during the first quarter of 1995 averaged 140 minutes per truck. This calculates to only 1.5 minutes per day per truck. Some of this air time is business voice, not data; personal calls made via AT&T Calling Card do not appear in the tally. This low business use profile matches driver comments[3]: "They only track you if they've got a problem with you. If you're new, or if you've got a sensitive load, then they might track you." HighwayMaster's promotional brochure emphasizes that "the unit . . . automatically provides a proximity location report every time a truck moves into a new cellular coverage area. If the need arises, the unit will also provide an actual positioning report using . . . GPS."[*]

HighwayMaster's selling approach is wide-area coverage: "100% of the major metropolitan areas, and over 95% of available coverage throughout the US and Canada."[12]

While HighwayMaster began with tractors, the *trailer* opportunity was understood at least as early as the second half of 1995: "If you're buying mobile communications just to track trucks, you're wasting your money."[4] To achieve the low costs required by this market, HighwayMaster began planning a new, data-only service. They concentrated "on a way to send a short burst of data more economically. Cellular is . . . not cost effective. . . . The new technology would take advantage of the signaling protocol that different cellular switches use to communicate with each other. We've developed and patented a way to encode some information in that signaling channel that . . . is more cost effective."[5]

During February 1998 BellSouth and HighwayMaster announced that they had cross-licensed each other's technology[6] and then that HighwayMaster had been granted "exclusive rights to provide a tracking solution for detachable trailers utilizing BellSouth Cellemetry Data Services technology."[7]

HighwayMaster's prospectus for its public offering warned that a potential problem existed with AT&T Wireless, which had "developed a specific facility for enhanced call processing, data management and long distance network transport for HighwayMaster."[†] For the preceding three quarters HighwayMaster "had not met certain air time usage thresholds spelled out in the contract with AT&T." Further, "HighwayMaster doesn't expect to meet those thresholds in the foreseeable future." AT&T Wireless could (and did) terminate the contract with 180 days notice.

HighwayMaster laid some of the responsibility at AT&T's door: "The AT&T complex has had downtimes that lasted from several minutes to several hours. These service impairments were a factor contributing to the slower than anticipated growth of the company's subscriber base and revenues."

After a bitter legal struggle with AT&T, with trade secret court injunctions and charges[8] that AT&T broke "an exclusive provision in the contract restraining AT&T

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[*]HighwayMaster specifications, 8-93, p. 1
[†]*Mobile Data Report*, 22 June 1995 initial public offering, 7-3-95.

from servicing any of HighwayMaster's competitors," the two companies severed ties in March 1996. GTE Mobilnet stepped into the breach to "provide cellular coverage for 20% of HighwayMaster's network and technical and administrative support for the remaining cellular carriers."[9] HighwayMaster immediately activated its own network management facility in Dallas, initially intended only to back up AT&T, and by year-end 1997 completed a remarkably smooth transition of all its subscribers to its own care.[10]

In July 1995 HighwayMaster released a new hardware unit, the model 5000, and a software enhancement called Rolling ETA. Much of the work fell to the new unit's microprocessor, which continually calculates the estimated time of arrival based upon average truck speed. Satellite positions are still checked every 5 seconds, versus competing satellite systems that poll only once per hour.[11] There is strong anecdotal evidence that Rolling ETA was unsuccessful.

In September 1996 HighwayMaster made a strategic alliance with Southwest Bell (SBC). It received a $20 million cash infusion that provided "both significant working capital and a clean balance sheet."[12] It also gave SBC 6% of the company, with warrants that can yield a 20% stake.[13] Sales and installation progress continues—but slowed mightily during 1998. Quarterly revenue has been essentially flat since the second quarter of 1997, but losses have mounted, some of them because of one-time events. These gross trends are portrayed in Figure 5-1.

In the face of these business problems HighwayMaster stock fell from a high of $8 to less than a dollar. Management was changed; some product lines were killed. The trade press headlines summed it up: "HighwayMaster results dismal, company to study operations."[14]

5.1.2   Nextel: Good Field, No Hit

In 1991 FleetCall, then a startup company, purchased many fleet dispatch frequencies across the nation in order to make a complete digital voice and data wireless communications network. Its eventual name was Nextel. With Motorola infrastructure and multifunction handsets (and crucial financial/licensing assistance), the key, highly voice oriented functions include:
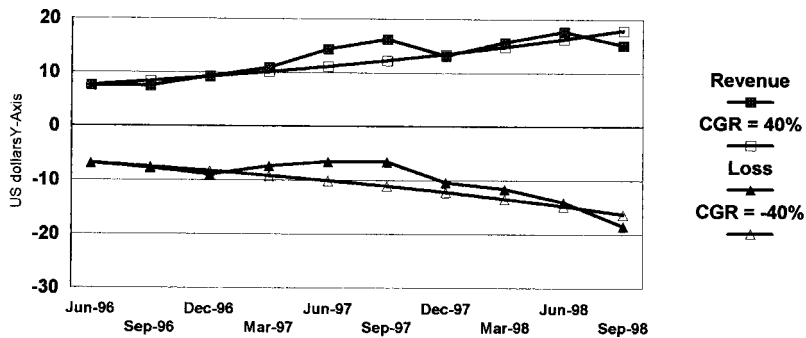
Figure 5-1   HighwayMaster financial snapshot.

1. Cellularlike, public switched telephone capability
2. Dispatching via two-way voice radio
3. Alphanumeric paging, with message lengths up to 140 characters

These capabilities were available initially in the hand-held Motorola Lingo phone and have been upgraded into the new Motorola i600 and i1000 handsets.

Both circuit and packet switched data had considerable emphasis in Nextel's early plans. There was even a yearlong negotiation with AMSC for complementary satellite data service. However, the fourth quarter of 1994 circuit switched data connection of a laptop computer to the RS-232 port of the Lingo phones[15] was delayed, primarily because of problems with the basic voice system. Packet switched data was canceled when the McCaw family invested $300 million[16] and Craig McCaw took over the company. In defense of this decision, Nextel's director of data had already noted[17] that "most . . . customers don't necessarily want data communications now." Packet switched data is still in the planning stages with a widespread availability unlikely before 1999.

The current focus is voice with simple billing plans, always cheaper than cellular, there are no roaming charges, there is no prime time premium, billing is at 1-second intervals, and there are embedded functions (e.g., voice mail, call waiting) and direct connect—a low-cost conferencing scheme. The voice subscriber base is most impressive: 2,417,400 digital users at the close of the third quarter of 1998,[18] up from 96,000 at year-end 1995.[19] However, Nextel is not at all profitable and "expects to continue to generate operating losses over the next several years."[19] Half of the third-quarter revenue was offset simply by selling, general, and administrative operating costs.

Nextel merged with OneComm and Dial Page in July 1995; the combined company has good, though far from complete, nationwide reach. U.S. coverage now includes 91 of the top 100 U.S. markets[20] with a plan to cover 85% of the U.S. population by year-end 1998.

Nextel's 1-second billing provides the potential for low-cost data transmission. It has text paging capability as long as the message size does not exceed its SMS- (short-message service) like maximum: 140 characters. All Lingo phones have RS-232 ports that can accommodate, say, a separate vehicular GPS unit for AVL applications. But any circuit switched data potential, except paging and MessageMail adjuncts, has not been vigorously pursued.

5.1.3 PeopleNet: A New Kid on the Block

On March 18, 1996, PeopleNet Communications, a privately held company in Chaska, Minnesota, announced a low-cost locating and mobile communications system called InTouch at the Interstate Truckload Carriers (ITC) Conference in Las Vegas. The business plan is for PeopleNet to "focus its efforts on product development, manufacturing, installation, new applications and providing the locating and communication service."[21] Another company, T-Chek Systems of Eden

Prairie, Minnesota, is to act as the exclusive sales agent. The manufacturing task was subsequently given to Winland Electronics of Mankato, Minnesota.

On October 7, 1996, PeopleNet announced it had won a contract to provide 12,500 InTouch units to the Rolling Advertising Network (mobile billboards) of Dallas. Initial units were to be installed early in 1997.[22] The first production units became available at year-end 1997.[23]

In March 1997 PeopleNet formed an alliance with a carrier to provide national cellular services.[24] The carrier is GTE Mobile,[25] which "will act as a single source in delivering nationwide cellular service to PeopleNet's customers. PeopleNet will integrate other carrier's charges into a single monthly customer statement." GTE Mobile may not have secured as many carrier agreements as HighwayMaster, or perhaps PeopleNet is simply more accurate in its coverage claims: "approximately 90% of the U.S. geographic area."[26] The basic package will carry an air time burden of ~$1/day.[27]

PeopleNet sees their chief problem as distinguishing their offering from other circuit switched cellular alternatives. Their answer: *flexibility*. Put the onboard unit in the cab or on the trailer. If on the trailer, operate it either tethered or untethered. If untethered, offer multiple battery options: rechargeable batteries (30-day life), refrigeration unit batteries (if applicable), or solar panels. The hardware comes in at least three configurations:

1. Basic positioning (GPS): the LD (locating device)
2. Positioning *plus* in-cab text messaging
3. Positioning, messaging *plus* onboard fax/voice

Since message lengths for the trucking application tend to be short, PeopleNet also has plans to become somewhat less dependent on high cellular air time costs. The long-range plan appears to be a move to GTE Mobile's CS-CDPD offering.

5.2   REPRESENTATIVE REGIONAL NETWORKS

5.2.1   Data over Analog Cellular Voice Channels

The first cellular system became operational in October 1983. Nearly simultaneously Tandy introduced its first notebook computer, the TRS-80 model 100. Users quickly realized that Tandy's cellular phone portable adapter kit permitted an awkward, but workable, physical connection of the notebook to the cellular network. Using the TRS-80's slow (300-bps) internal modem and a great deal of manual intervention, journalists began to send publication copy from the story site itself, though not while in motion. A market opportunity was detected.

In March 1985 Spectrum Cellular introduced its first 300-bps cellular modem with forward error correction; the speed was increased to 1200 bps in April 1986[28] and reached 2400 bps in 1989.[29] The Spectrum approach featured a modestly proprietary protocol that was installed in a specific modem pair: the Bridge and the Span.
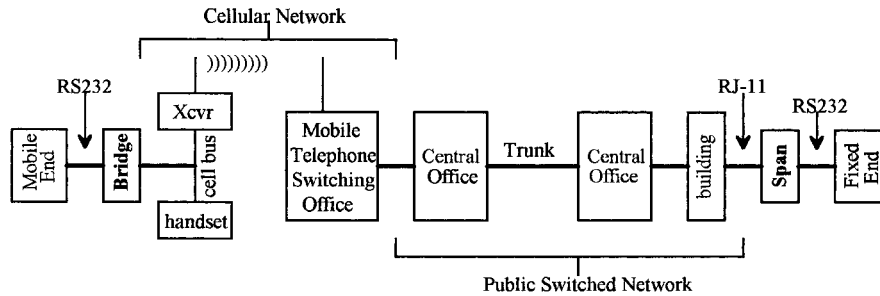
Figure 5-2 Cellular device connection: initial spectrum approach.

Virtually identical in external appearance, the video-cassette-sized Span was intended for *fixed-base* equipment such as the communications front end of mainframes. Its physical connection was to conventional wire line services. The Bridge was attached to the mobile unit. Since it had no radio of its own, it was required to attach to a reasonably rich mix of cellular phones to obtain the radio function. A representative configuration is shown in Figure 5-2.

5.2.1.1 Modem Pools

5.2.1.1.1 Mobile to VAN/MTSO A practical business problem of the Bridge/Span combination for private systems was the need to enlist the cooperation of the data processing manager to install Span modems at the fixed site. Value-added networks (VANs) such as CompuServe, interested in solving this problem, responded by moving the Span forward and providing conversion facilities; five cities were operational by February 1986.[30]

A noteworthy variation quickly evolved. Interested cellular carriers located the Span at the MTSO, where it was connected to a normal landline modem, as shown in Figure 5-3.
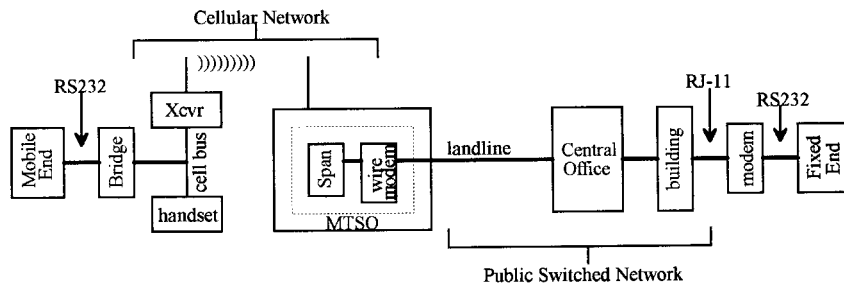
Figure 5-3 Precursor modem pool: spectrum approach.

The mobile user was thus free of the need to have a Span purchased and installed at the fixed end. The cellular service provider was able to offer a data-only service via designated numbers. By 1989, 43 SPCL data service markets were operational in the United States,[31] with 54 service providers. But the use of 311 prefixes to identify and place a premium on data calls, as Cantel did in Canada,[32] was not successful. By mid-1990 only about 12,000 Spectrum modems of all types had been sold in North America.[33]

5.2.1.1.2 Bypassing the Public Landline Network The notion of direct connection to the MTSO was revived when UPS connected its UPSnet to the MTSOs of four cooperating cellular carriers in order to bypass the public landline network (Figure 5-4).[34] With this technique, and a guarantee of short connect time on the network, UPS secured for itself exceptionally low cellular tariffs. The result: 50,000 data-only delivery information and acquisition devices (DIADs) were installed in 1992, the largest single customer mobile data installation in the world.

For six years the relatively primitive, slow speed, multiple "standards" general modem pool implementations made little impact. In 1991 the Consultative Committee International Telegraph & Telephone (CCITT) ratified V.42 as the standard landline error control protocol. High (14,400-bps) speed modem development activity surged. These devices were successfully adapted for cellular use, though generally at slower bit rates, by special interfaces. San Diego–based Primary Access developed a modem pool offering that dealt with these new modems as well as a number of protocol enhancements intended to improve call hold times. In August 1993 Ameritech adopted the Primary Access approach for use in Chicago[35] and went territorywide in December.[36] The Ameritech pools were quickly followed by the other carriers. Bell Atlantic Mobile had Primary Access pools territory wide by March 1994,[37] and most carriers followed suit throughout 1994 and 1995. Even MCI had an 800 number variant: Xstream Air.[38] In its simplest form the Primary Access offering can be represented as in Figure 5-5.

Access to a pool requires a short dialing sequence: *data (3282). Most carriers charge an extra $2.95 per month for data usage, with air time billed at normal voice rates (which may be lower than "normal" for volume users). There is at least one exception. Buffalo Telephone, a Cellular One franchise, charges an extra $4.95 per month for data service, but then provides a low air time rate: $0.15 per minute during peak hours and $0.03 per minute off peak,[39] even for a single user.
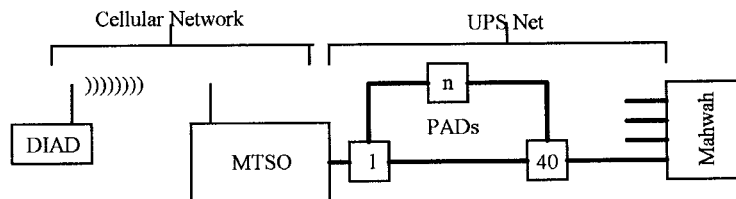
Figure 5-4 UPS MTSO connection.
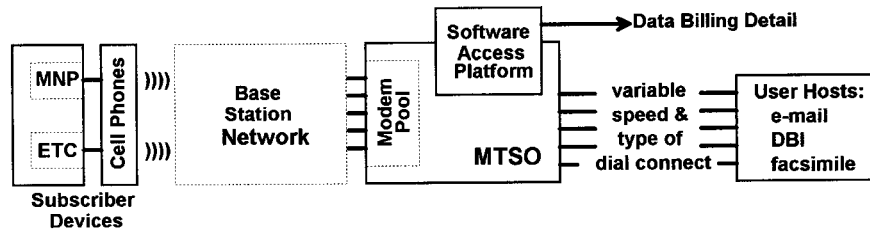
Figure 5-5   Representative modem pool configuration.

5.2.2   Broadband PCS: GSM

5.2.2.1   Introduction   The complex history of broadband PCS development in the United States is filled with competing technologies leading to incompatible deployments. Indeed, most observers are easily confused as to what PCS really is. By mid-1998 the current approaches of interest in the United States could be simplified to three digital air interface standards (you will need another book if you wish to examine a half-dozen alternatives!). Note that there are degrees of difference within the three.

The first two are simply replacements to the existing analog cellular technique to obtain more user capacity. These deployments use the same frequency band, spacing, and device power levels as in today's analog cellular systems. The voice instruments are dual mode, capable of working on either the analog (AMPS) or digital standards. Nevertheless, these digital, cellular system extensions sometimes carry the PCS moniker (e.g., wideband CDMA offered by Sprint PCS), which sometimes confuses at least this author.

The third approach, GSM, is a competitive alternative to existing cellular systems. In many cases, the networks have been constructed by nontraditional carriers. Not only does GSM operate in a very different frequency band there are typically many more cells covering a given area since the coverage radius is about 40% of the size of cellular. This can lead to lower power requirements in the device, often improving battery life, or talk time, or both. Building penetration is also generally better.

The three leading wide area standards are summarized in Table 5-2.

5.2.2.2   Representative GSM Carriers

5.2.2.2.1   Aerial Communications   Aerial, formerly American Portable Telecom, provides GSM-based PCS service in six major metropolitan areas and is a partner in a joint venture for coverage in the upper Midwest. The metropolitan areas served are Columbus, Houston, Kansas City, Minneapolis-St. Paul, Pittsburgh, and Tampa-St. Petersburg. While voice is the absolute priority, Aerial does provide limited data functions including 160-character (maximum) two-way text messaging. Unlike Sprint PCS or Omnipoint, the E-mail cannot be sent directly to the phone, which has no

Table 5-2   Representative PCS alternatives

Designation	Technology	Band (MHz)	Originator	Example Users
IS 95	CDMA	800	Qualcomm	Ameritech, BAM, U.S. West
IS 54/IS 136	TDMA	800	L.M. Ericsson	AT&T Wireless, SBC
GSM 1900	TDMA	1850–1990	European GSM	Aerial, BellSouth, Omnipoint

Internet E-mail address.[40] Aerial also sells a Mobile Office Service package, with licensed software, to permit a laptop to access the network, via the handset, to send faxes or E-mail.

In its first year of service, ending June 1, 1998, Aerial placed 200,000 voice subscribers on its more than 1000 base stations in just six metropolitan areas. Aggressively priced, the cities in which Aerial offers service have seen their competing analog cellular rates drop by as much as 40%.[41]

5.2.2.2.2   BellSouth Mobility DCS BellSouth Mobility offers its GSM-based service in the mostly rural parts of five southern states: the Carolinas, eastern Georgia, and east Tennessee/south West Virginia.

In the earliest battles over PCS spectrum, BellSouth "sees 12 million PCS subscribers" (by 1994).[42] This was a most aggressive view of both schedule roll-out and business future. When 1994 rolled around, still with no PCS deployment, "BellSouth . . . expect[s] data to become an important part of . . . PCS offerings from the outset of service."[43] BellSouth DCS actually began with an exceedingly low data profile: only numeric paging. Perhaps this was a reflection of the business balance required to coexist with BSWD.

BellSouth now has a limited array of GSM-based text messaging offerings[44]:

1. *Mobile Originate Text*. Permits the owner of some (not all) DCS phones to send text messages to another eligible phone by typing the message in on the handset's keypad. If you have not tried it, it's no fun. If you get carried away and try this more than 50 times per month, BellSouth charges $0.20 per message.

2. *Computer-Based Text*. Using a wireline connected modem, messages originating from a Windows-based PC can be sent to multiple DCS phones. It can be irritating to read them on the handset screen. Each recipient pays $8.95 per month, plus $0.20 per message after 75 messages are received.

3. *E-mail Service*. A handset subscriber can receive messages up to 160 characters long. If the handset permits it, a reply can also be generated à la

Mobile Originate Text. An Internet address is provided to permit cross-network communication. There is a $4.95 per month charge to receive messages, $1.95 to send them, with the ubiquitous $0.20 per message charge above 40 messages per month.

5.2.2.2.3   Omnipoint Omnipoint had an early start, coming into existence in 1987, with a trial network operational in 1992.[45] It is the fourth largest PCS license holder in the United States; by some calculations its licenses cover nearly 100 million people. It has operational PCS systems in much of the northeast: Connecticut, Delaware, Massachusetts, New Jersey, New York, eastern Pennsylvania, and Rhode Island. It also has operational systems in south Florida and Kansas and is still building out.

In its early days Omnipoint management was cautious: "data PCS will remain a significantly smaller total market in terms of service revenue than voice PCS."[46] However, it has many clever data-based broadcast services, including the *New York Times* headlines, stock quotes, sports scores, lottery results, and horoscopes, for approximately $10 per month above the basic voice plan; one also can be paged, as well as receive one short E-mail message per day, for the extra $10.

Every Omnipoint phone is delivered with an Internet address, ready for short E-mail messages. In addition, Omnipoint offers Dedicated Data Service,[47] which assigns a full 9600-bps channel for transmission of documents or files from laptops plugged into a handset. Now the billing is by minute, and Omnipoint does not round to the second, as most GSM carriers do. In the Greater New York area this amounts to $0.49 per minute as long as the call is local.

Omnipoint ended the first quarter of 1998 with about 190,000 net subscribers. Its revenues are rising smartly, but the company is still incurring heavy quarterly losses.

5.2.2.3   The GSM Alliance Seven GSM-based PCS carriers have banded together to form the GSM Alliance. This action created a good roaming network covering 600 cities and towns in the United States. Premium prices are charged for roaming, and not all carriers provide the same levels of data service. Nevertheless, it's a start! The participating U.S. carriers are:

1. Aerial Communications
2. BellSouth Mobility DCS
3. Omnipoint
4. Pacific Bell Mobile Services (SBC)
5. Powertel PCS
6. Western Wireless

These six carriers served nearly 800,000 people in the United States during the second quarter of 1998.

5.3 NOTABLE CLOSINGS

5.3.1 AirTouch Cellular and CTA

In October 1990 the California Trucking Association (CTA) announced that cellular would be the wireless conduit for its mobile 2500-vehicle tracking system. CTA signed a four-year agreement with PacTel Cellular (now AirTouch) for this service. Cellular was a lure because many of the trucks already had mobile telephones, and there was a strong need for other information that could come by fax: bills of lading, maps, permit documentation. The unsuccessful effort was abandoned in 1992.

5.3.2 Rockwell/GTE Mobile

In December 1992 Rockwell announced its intention to place a GPS receiver in a mobile cellular phone. "It's an application we think will take off. We have active customers,"[48] said Ray Mathis, Rockwell's GPS Business Products Director. "The application fits cellular well. . . . People who pay for fleet management products have a need to know where their vehicles are on basis,"[48] said Charles Napier, GTE Mobile's New Business development manager. The idea seems to have foundered on cost grounds.

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6

PUBLIC SATELLITE NETWORKS

6.1 INTRODUCTION

Satellites have been carrying communications since the early 1960s, serving as relays for voice, video, or data. They have long been dominated by the military and, in their direct broadcast form, by large television communications companies. In 1989 the Gartner Group believed that "the mobile satellite industry will be one of the great growth markets of the next decade—surpassing cellular telephones and digital paging, and in the same league as personal computers."[1] Gartner believed that there would be 800,000 satellite data terminals installed by 1993, growing to 2 million by 1995. A flood of vendors rushed toward this magnificent opportunity, many of which were never seen again.

After this debacle, intense activity began for new classes of satellites, mostly for voice communications. The successful September 1993 deployment of NASA's Advanced Communications Technology Satellite (ACTS) showed the potential value of the new designs: on-board processors, spot beams, and Ka band operation to penetrate rain clouds. Hundreds of competitive launches are scheduled for the next few years. By some tallies, at least 1300 satellites are scheduled to be launched into the Ka band alone.[2]

Iridium was scheduled to be operational in September 1998. Broadband capability will not be operational until 2002 and includes Craig McCaw's and Bill Gates's Teledesic. The enormous broadband capacity is certain to revolutionize some forms of communications. Some market research firms now estimate that just the near-term satellite business could triple to $29 billion per year by 2000. But we have heard predictions like that before.

6.2 GEOSTATIONARY SATELLITE SYSTEMS

6.2.1 GEOS Overview

Geostationary satellites (GEOS) operate at roughly 22,300 miles altitude, above the equator, where the satellite is always over the same spot on Earth. Because of the huge physical separation between device and satellite, long ($\frac{1}{2}$-second) round-trip transmission delays are inescapable. Originally intended for voice, this latency has always been a user problem, requiring speaker discipline. More and more, GEOS are being used for data applications where small message delays are not critical. However, the latency remains a problem for current implementations of some data protocols, particularly TCP/IP.

The GEOS ground footprint is huge, capable of communicating with stations in most of a hemisphere. Transmissions generally get through anywhere there is a clear view of the sky in the general direction of the equator but can be blocked in metropolitan areas by buildings. Power requirements are high, leading to physically large and fairly costly ground devices.

Geostationary is an expensive and difficult orbit to achieve, but successful systems can function with only a single satellite. Only a half dozen sites in the world are capable of launching these large vehicles. About 60% of GEOS launches are controlled by Europe's Ariane consortium, which is under continuous criticism for high prices and limited capacity. Another 30% of the work falls to McDonnell Douglas and Lockheed Martin, which launch Delta and Atlas rockets from Cape Canaveral and Vandenburg Air Force Base. The balance of the launches are currently performed by the Russian, Ukranian, and Chinese programs. Struggling to compete are new ventures in Brazil, India, Israel, Italy, and Japan, where Hughes recently signed a $1 billion deal with a Mitsubishi-led consortium for 10 launches.

6.2.2 OmniTRACS

In January 1988 a small company named Omninet demonstrated a truck-tracking system that leased time on underutilized GEOS. Because of the size and cost of the device, the solution was only useful for the tractor portion, not trailers. Attracted by this system, Qualcomm absorbed Omninet in August and renamed the offering OmniTRACS. It operated on GSTAR-1's Ku-band GEOS.

With OmniTRACS, Qualcomm began to execute a successful business strategy that had eluded other contenders for 15 years. OmniTRACS slowly rose to the very forefront of the market for AVL-based trucking systems. The device transmission scheme is CDMA, a technology that Qualcomm has since ridden hard and well in the AMPS replacement market. Bit rates are quite low, and facsimile is completely impractical.

Studies done in 1989[3] clearly depict the OmniTRACS goals: scheduling equipment and drivers more profitably, improving driver turnover, and providing better information to customers. In spite of a quick start from Schneider (5000 units ordered in 1988 and completely installed by August 1989[4]), sales progress was initially slower than expected. At announcement 30,000 installs were anticipated by year-end 1989. This goal was actually achieved three years later. Beginning mid-1993 the pace of installations began to climb rapidly. By the first quarter of 1998 OmniTRACS had *shipped* (not installed) 230,000 units *worldwide*, which likely translates to ~145,000 operational U.S. subscribers.

As is foreordained with GEOS, the device is relatively large and expensive (~$4500). OmniTRACS defends the device with a "Proven Hardware That Retains Its Value"[5] and "The First Mobile Communications Technology Is Still the Best Solution"[6] marketing strategy. This seems to be a successful ploy, as worldwide shipments continue their linear growth path.

Incremental improvements to the system are being made via software changes. The area currently receiving the greatest emphasis is the TrailerTRACS trailer monitoring system.[7] This approach provides a unique ID for every trailer. The ID is reported to the OmniTRACS tractor unit on every connect/disconnect. This positive trailer ID is a means of tracking trailer assets and provides the ability to monitor trailer pools. Critical events are monitored and exception reports prepared: for example, lost trailer, excessive trailers at one location, too few trailers, unscheduled movement, wrong trailer connected to tractor, unauthorized cargo, and trailer late for intermodal origin. GPS and time verification of scheduled "drops" and "hooks" are combined with the Dispatch software to track the trailers very closely.

But these improvements remain tractor based. In April 1998 Qualcomm signed an agreement[8] to deploy Aeris Microburst technology, a terrestrial approach, for the essentially untapped trailer market.

6.2.3   AMSC Skycell

Formed in 1988 from a pool of eight applicants, AMSC began test operations in late 1990 by leasing time on the Galaxy InMarSat-C system. True operational service was long delayed; AMSC finally got its own SkyCell satellites operational in the summer of 1995. With careful deployment of its spot beams, AMSC blankets all the United States, including Alaska, Hawaii, Puerto Rico, and the Virgin Islands, as well as a great deal of U.S. coastal waters. It is fully interoperable with the Canadian MSAT system.

AMSC's earliest homegrown service, Mobile Messaging, was available in 1993, still via leased satellite time. It offered two-way mobile data and GPS for transportation fleets.[9] Customers such as Southeastern Freight Lines (LTL)[10] require both voice and facsimile capability. AMSC provides these, as well as circuit switched data, but separate devices (including antennas) are required for each. There were few early takers of either approach; West Motor Freight[11] is an example.

The AMSC emphasis has been voice, and it is quite proud of its OmniQuest (how's that for name confusion) notebook-sized satellite telephone. Indeed, the quarterly financial reports stress how much voice revenue is generated per subscriber. Until recently, data was not mentioned. Most revenues are still being generated by equipment sales. Service revenues from the satellite-only business make up only about 40% of the total.

At year-end 1996 Rockwell "sold" (a cash-free transaction) its multimode fleet management system to AMSC. In this compact AMSC acquired 43 new customers and doubled its data subscriber base with the 8400 units Rockwell shared with ARDIS. This pleasant jolt can clearly be seen in the year-end 1997 total subscriber figures.

On March 31, 1998, AMSC completed its purchase of ARDIS from Motorola, stating that it "is positioned to leverage an integrated terrestrial/satellite network."[12] The financial markets evidently believe this is true. AMSC's debt offering was sharply oversubscribed and yielded $335 million for the new company.

6.2.4   GEOS Summary

Table 6-1 is a summary of the key business characteristics of the two representative GEOS offerings. Note that each is moving to cut its absolute dependency on this form of satellite communication. Qualcomm is moving the trailer application to either LEOS (Globalstar) or terrestrial (Aeris Microburst). AMSC has a successful terrestrial hybrid system, which is discussed in Chapter 7.

6.3   LOW EARTH-ORBITING SATELLITES

6.3.1   LEOS Overview

Low Earth-orbiting satellites operate at 420–1200 nautical miles altitude in polar orbits. They are not geostationary, and they do not constantly overlook the same point on Earth. Multiple "birds" must be arranged in an orbital pattern that produces continuous coverage. LEOS are required to have a way of handing off calls from a setting satellite to a rising one. Digital techniques are employed that are well suited to data transmission, although the initial focus of most LEOS is decidedly voice. The ground footprint is small to very small, depending upon the system chosen. Spot coverage on the order of 440 (Teledesic) to 2800 (Iridium) miles in diameter is typical. The lower the orbit, the more the satellite must be almost directly overhead for signals to get through reliably.

The satellites themselves are much smaller and lighter than their GEOS counterparts and can be launched in a number of innovative ways. Orbcomm, for example, saves fuel and avoids the wait for ground launch openings by firing its Pegasus rockets from under the wings of a jumbo jet flying at 40,000 feet. The small satellite size makes possible multiple, simultaneous launchings. Globalstar, for example, plans to launch 12 satellites at a time.

Table 6-1 Business characteristics: GEOS networks

Service name	OmniTRACS	SkyCell
Parent company	Qualcomm	AMSC
Key parent owners	—	AT&T Wireless
Protocol(s)	CDMA Packet	Polled
First operational	1988	1993
Principal emphasis	Trucking/transportation companies: AVL: QASPAR/GPS; nonmetropolitan coverage; long (2000-byte) messages	Trucking/transportation companies: voice, facsimile, two-way messaging, AVL
Limitations	No voice, no facsimile, low (~150 bps) bit rates	Polled technique can lead to 4–5 minute latency
First quarter 1998 coverage	Australia, Brazil, Canada, Europe, Japan, Korea, Malaysia, Mexico, USA	Fifty States, Caribbean territories, and U.S. maritime waters
U.S. subscribers (AMSC has overlap with ARDIS), year-end		
1989	~5,500	
1990	~8,600	
1991	~19,500	
1992	~31,000	
1993	~54,000	
1994	~82,700	
1995	~110,000	~4,000
1996	~133,000	~20,300
1997	~145,000	~32,400
Typical single-user monthly list prices	Monthly access (includes 800 messages), $35; additional messages, $0.15 + $.002/byte	

6.3.2 Orbcomm

At least as early as 1989 Orbital Sciences subsidiary Orbital Communications began the design of a LEOS. On August 23, 1993, the 87-pound MicroStar was unveiled.[13] The launch date was planned for the first quarter of 1994 with service to begin a few months later. The rest of the constellation was to be deployed in four launches of eight satellites each: "By 1995 . . . Orbcomm . . . will be fully operational." Airtime pricing "will be similar to cellular . . . at wholesale . . . $15 per month."[13] Subscriber devices were expected to "range from $50 to $400, depending on options." A data system, the primary early adopter was expected to be cargo tracking. The system was optimized for the vehicle location application, with a bright future envisioned for units in cars.

No launches occurred in 1994. The first attempt in 1995 was ruined when pieces of the thermal protection system peeled off the Pegasus launcher while the host aircraft was in flight. On April 3, 1995, the first two LEOSs were successfully launched.[14] With only two birds aloft, no real-time application could be contemplated. The devices had to wait for short windows when the satellite came over them.

During this time Orbcomm began discussing its ability to act as a gap-filler service for packet radio networks such as ARDIS and RAM. Follow-on devices would have PCMCIA card slots to interface with laptop computers. Equally important from a vehicle location point of view is that on April 28, 1995, an agreement was announced for Qualcomm to resell Orbcomm airtime as part of OmniTRACS.[15] The market was seen as trailers, with the offering dubbed TrailerTRACS.

By July 1995 the device developer, Israel's Elisra Electronic Systems (a subsidiary of Tadiran), was successfully transferring messages from the Dead Sea to Dulles, VA.[16] The bit rate was slow, only 2400 bps, but it worked. In February 1996 the first commercial traffic—300,000 messages the first day—began to pass via these two satellites.[17] Considering that they were only in view 1–2 hours per day, this was an interesting milestone.

What is key now is deployment of more satellites. The 1996 plan was for a total of 26 in orbit by year-end 1997, enough to put the company in the near-real-time business.[18] That did not happen. In December 1997 eight satellites were launched and were transferred to the network in operational status in April 1998.[19] New launches occurred in August and September. As of September 23, there were 28 satellites in orbit, though only 13 were operational.[20] An additional 8 were scheduled to be launched in 1999 to fill out "the space segment."[21] Orbcomm has FCC permission to increase its constellation to 48 satellites.[22]

Thus, the lure of small, hand-held, relatively low cost devices may permit the market to develop, although perhaps not for "boating, hunting and backpacking adventures."[23] Orbcomm sees a market of over 31 million U.S. messaging services customers,[24] just one segment of their market opportunity.

Qualcomm's OmniTRACS Division previously announced it would act as a reseller of Orbcomm's services.[25] For this OmniTRACS had funded the development of a new device called Untethered TrailerTRACS,[26] which had a target price of $800. In 1997 inquiries to Qualcomm by this author indicated that the device development effort (in Israel) had been placed on the back burner. It now appears that Qualcomm will go after the trailer market via terrestrial means, with Aeris Communications Microburst.

6.3.3   GlobalStar

In the 1980s Qualcomm and Space Systems/Loral (then a division of Ford Motor) were independently investigating the feasibility of worldwide, satellite-based communications for voice, position location, and messaging. In June 1991 the two companies formed Loral Qualcomm Satellite Services and filed an application for

construction with the FCC. In 1994 eight new investors, PacTel Cellular among them, joined the founders with a major new cash infusion. The newcomers added $275 million with a pledge to "include an additional $300 million of equity at a propitious time."[27]

Globalstar's $1.8 billion plan featured the launch of 48 LEOSs at an altitude of 750 miles. The voice/data communications link will use Qualcomm's CDMA technology. Qualcomm would also provide the ground communications segment and have the right to provide worldwide position determination similar to OmniTRACS: "Most of this will be done within 48 months."[28]

In 1995, as the plan matured, Globalstar announced it would begin launching satellites in the second half of 1997 and would begin commercial operations via a 24-satellite constellation in 1998. Full coverage would occur in 1999.[29] The anticipated air time costs were $0.35–$0.53 per minute with usage incentive targets for even lower prices.

Reality began to intrude in 1996. The required investment crept up to $2.2, then to $2.5 billion.[30] These cash demands led to financial arrangements with over 100 partners and the sale of Loral's defense business to raise more money. The required number of satellites also rose, to 56, to allow for spares. A fully operational system is still expected by 1999. This is feasible. In the second quarter of 1998 Globalstar had eight satellites up, four operational, providing Web Cast service for $2\frac{1}{2}$ hours every evening on the U.S. East Coast. Heavy launch activity is scheduled from Baikonur, Kazakhstan, during the fourth quarter of 1998.

6.3.4 LEOS Summary

Table 6-2 summarizes the business characteristics of two representative LEOS offerings. Orbcomm has begun to have an operational presence with its GlobalGram

Table 6-2   Business characteristics: LEOS networks

Service name	Orbcomm	GlobalStar
Parent company	Orbital Communications	Loral, Qualcomm
Key parent owners	Orbital Sciences	102 partners
Protocol(s)	—	CDMA
Limited testing	February 1996	Second quarter 1998
Partially operational	Second quarter 1998	—
Fully operational	1999	1999
Principal emphasis	Data only: cargo tracking/vehicle location, messaging services	Voice and Data: high-quality telephony, data transmission, paging, facsimile, position location
Limitations	No voice, no facsimile	Not operational
Second quarter 1998 coverage	Worldwide, 1–2 hours/day	U.S. East Coast: $2\frac{1}{2}$ hours/day
Planned coverage	Worldwide	Worldwide

messaging service. The Magellan GSC 100 devices were visibly in evidence in the environs of Tegucigalpa in the aftermath of Hurricane Mitch. The Government of Honduras issued a 2-month executive decree permitting their use by the staff of the International Hospital for Children in relief efforts.

6.4 NOTABLE CLOSINGS

6.4.1 Geostar

On February 21, 1990, Geostar hosted a reception in Washington to celebrate the FCC grant of new spectrum for its service. Device prices were announced that, in light of history, seem reasonably prescient: $3000 in 1992 "dropping to $1,000 in the late 1990s." But in 1990 the device price was instead ~$4500 and Geostar distinguished itself from rival OmniTRACS chiefly by airtime pricing: $35 versus $45 per month for basic service.

Geostar's greatest moment occurred on October 8, 1990. Trans-Western Express (TWX) and United Van Lines (UVL) announced ambitious plans for their tracking applications (TWX had been tracking its refrigerated *trailers* since 1988; UVL was operating even earlier with Sony devices). But trouble was already apparent: The applications had not been rousing successes and expansion of capability was urgently needed. TWX was expanding to 200 trucks, UVL to 175.

Five months later the roof fell in. Geostar went bankrupt on March 11, 1991, stranding 4200 subscribers, 1750 of them on Burlington Motor Carriers' vehicles. Sony elected to leave the mobile device business. OmniTRACS was the winner.

6.4.2 MARCOR Humminbird

On January 28, 1991, MARCOR announced the first GPS receiver designed for AVL. The Humminbird was "also the first satellite radio receiver of any sort to sell for under $1,000. The palm-sized radio is expected to herald a new age of . . . mobile communications via satellite." At announcement time one of the best competitors, the Magnavox MX100, cost $3950. The RS232 interface permitted connection to a variety of packet radio modems, and tests were made with RAM. Volume shipment was scheduled to begin September 1991. By March 1992 the price had been dropped to $700 in volume. No operational Humminbird was ever seen by this author.

6.4.3 Meteorburst Approaches

6.4.3.1 Introduction Meteorburst, or "natural satellite," technology bounces radio signals off the ionized air trails of the millions of small meteors entering Earth's atmosphere every day. There is a delay while waiting for these random events. The typical wait is about 10 minutes; it is possible to make devices that scan larger areas

of the sky and find a trail in roughly 30 seconds. Because of the unpredictable angle at which the bounce occurs, terrestrial ranges much over 1200 miles are rare. Meteorburst companies must install ground relay stations, typically every 1000 miles, to get the message cross-country.

A survivor is Meteor Communications Corp. (MCC). MCC has been in business since 1975 and began serious work on vehicle tracking with Freightliner Corp. in 1991. Encouraged by the results (the company was even able to transmit faxes between trucks), MCC began rolling out a complex of 64 ground stations for message relay. The scheduled completion date was September 1992. The device was $10 \times 9 \times 2$ inches (180 in.^{3}), very small for that time. The system evolved into an extended-line-of-sight mode using groundwave technology. The principal focus is on 50–100-mile range coverage, with meteorburst providing occasional long-range (1000-mile) transmission.

6.4.3.2 Broadcomm In the summer of 1992 Broadcomm unveiled its first system for "a vehicle location and messaging system at about half the cost of . . . satellite based services."[31] The system was a commercial failure.

6.4.3.3 Pegasus Messaging Operating under an FCC experimental license, Pegasus began sending AVL data in late 1988. It had ground stations operational in Washington, DC, Kentucky, and Tennessee, by February 1989. Norand built the $2500 device for Pegasus, which emphasized messaging. The average airtime for participating companies ran $30–$45 per month per vehicle. In July 1990 Yong Lee and Carlos Roberts, respectively Pegasus' President and EVP, quit after Pegasus began to sink in financial woes. The company itself quit not long after.

6.4.3.4 Transtrack Founded in 1986, Transtrack focused its energies on the trucking industry. The primary applications were long-distance vehicle location and data transmission services. Its device and airtime charges were equivalent to Pegasus. North American Van Lines and Midwest Coast Transport both tested the system but did not go commercial: "We based our business plans on overly optimistic sales projections."[32] Transtrack was bought out by MCC in July, 1990.

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7

HYBRID NETWORKS

7.1 TERRESTRIAL PACKET/SATELLITE

Trucking company Boyle Transport makes it crystal clear: "you should be able to pick a radio or cellular based system for regional service and satellite for long haul, but be able to use the same provider."[1] This is the goal of most hybrid offerings, though satellite may well be avoided in favor of an alternative technique such as circuit switched cellular.

7.1.1 AMSC/ARDIS Multimode System

In March 1990 Rockwell announced that it was developing a satellite-based vehicle location and two-way data system.[2] Rockwell's plan was to lease L-band capacity from AMSC, which was leasing time from InMarSat. Rockwell concentrated on the vehicular terminals and communications hardware. It began to develop a new control center for switching data between customer's headquarters and their vehicles. Rockwell saw its competition as OmniTRACS (then only ~7500 units) and Geostar (now defunct).

Rockwell's perceived edge were its customers, who had already installed 80,000 TripMasters. Since Rockwell's product was not yet ready (indeed, it was still debating whether or not Loran-C was the best way to go), it purchased the first two year's devices from Canadian Aeronautics (CAL). The plan was to resell each unit for $3500; its own device was estimated to be ~$2500. This was markedly cheaper than the $4000–$5000 charged by Geostar and OmniTRACS. However, the Rockwell airtime costs were estimated to be $50–$60 per month, quite a bit more than the $35–$45 charged by Geostar and OmniTRACS.[3]

As with many acts of bravado, the world did not accommodate itself to Rockwell's goals. After long delays, Rockwell finally had the Pro2000 product in April 1993—for $4000. The airtime price was $60 for 15,000 bytes ($4 per kilobyte).[4]

Rockwell's device sold slowly: 3000 units over six months. Meanwhile, OmniTRACS' acceptances began to accelerate, climbing a steep hill. In October 1994 after OmniTRACS had reached 90,000 subscribers, Rockwell announced the first multimode device: the Pro2000SL. This unit contained a Motorola radio modem for communication over ARDIS. The price was $4495. There were also airtime pricing adjustments: $40 per 20,000 bytes per month. Each additional kilobyte was $1.65 during peak times (7:00 AM to 7:00 PM Central Time)[5]; the nonpeak kilobyte charge was $0.75.

Prior to the multimode system announcement, Rockwell had tested in a 100 mile radius of its Cedar Rapids plant using an ARDIS hand-held device. The conclusion was that about half the traffic would flow via satellite. This guess permitted new customers such as Umthun Trucking (400 units) to calculate an 18-month payback.

But when using an external antenna mounted high in a truck, the device began picking up ARDIS well outside the expected range of coverage. Instead of half the traffic to ARDIS, 70 ± 5% of the messages flowed via the terrestrial source, which must have made Umthun happy! However, it did not please Rockwell; the business was "sold" to AMSC at year-end 1996. AMSC, in turn, purchased ARDIS on March 31, 1998, and announced its intent to "leverage an integrated terrestrial/satellite network to advance its leadership in wireless data services."[6]

7.1.2   BSWD/Norcom

On November 10, 1992, ARDIS and Sears began a field test with 150 service technicians. After years of the most grueling network-independent application development work, the number of technicians had expanded to 7000 by December 1997.

Sears, like most major corporations, is loath to be dependent upon a single vendor. In September 1996 BSWD approached Sears with a proposal to provide service in areas thinly covered by ARDIS. Unfortunately, BSWD's terrestrial coverage was not that hot in those sectors either. Its "strategic network" approach, which uses circuit switched cellular when the packet coverage is unavailable, was rejected by Sears as "too expensive, insufficiently reliable, and lacking adequate nationwide coverage."[7]

BSWD, taking a leaf from ARDIS' book, then began work on terrestrial/satellite hybrid device. The "network" chosen was Norcom, a subsidiary of Telenor, which leases Ku/L-band time on AMSC's satellites. The key advantage is that the Norcom design uses an X.25 call setup protocol, resulting in a short response time, typically 3–5 seconds. ARDIS bid the Rockwell multimode solution, of course, but in its 1996 incarnation it was a polled device. This produced a design that could have a 5–10 minutes latency, unacceptable to Sears. BSWD/Norcom are installing the last 5000 Sears devices using their hybrid approach.

Note that the technician does not walk around interchanging data with a GEOS. When the hybrid device is out of the cradle, there is no wireless connectivity. Only when it is returned to the cradle can communication with the satellite begin.

7.2 TERRESTRIAL PACKET/CIRCUIT SWITCHED CELLULAR

This combination depends upon having a modem capable of operating on either packet or circuit switched networks, which is not so unusual. However, the modem must also be capable of automatically detecting when one of the services is unavailable. Typically the modems are designed to listen for packet first. The modem will then select the alternative service, sometimes in the middle of a transaction. The key advantages for the customer are increased coverage (often at higher airtime cost), without manual intervention or changes to the user application. Application transparency requires network enhancement to hide the message source from the user host. The notion is wonderfully attractive; customer acceptance has been disappointing.

7.2.1 CS-CDPD

The CS-CDPD design was pioneered by GTE Mobile, Hughes Electronics, and the now-departed PCSI in early 1995. In this implementation a device operating on CDPD continually tests the field strength of the CDPD signals. If they begin to fade, a special circuit switched uplink protocol is dialed that can make a connection in about 3 seconds—a delay often not noticed by the user. The dialing plan can be complex, including the use of 800 numbers when out of range of GTE Mobile coverage.

In the spring of 1996, in cooperation with GTE Mobile, TranSettlements Network Services announced a wireless communications system for less-than-truckload (LTL) carriers.[8] The "Tracker" was intended to serve the pickup and delivery application; all emphasis is on telephone handset functions. TranSettlements began testing the PCSI PalPhone in the fourth quarter of 1996 with Silver Eagle (30 units) of Portland and Cal Pak of Hayward.[9] Beta testing was essentially complete on January 31[10] and the price list was placed on the Web.[11]

However, the production roll-out failed. The many problems, not the least of which was the demise of PCSI, were best summarized in May 1998 by TranSettlements: "our initial customers (in a decision made concurrently with TranSettlements) have had to discontinue use of the Tracker P&D system, as problems with CDPD reliability, interoperability, and lack of warranty for the hardware have greatly increased the overhead necessary to support the service."[12]

7.2.2 BSWD Strategic Network

On October 31, 1995, BSWD (then RAM) announced[13] the first segment of its "strategic network": connection to the circuit switched cellular and public switched telephone (PSTN) network.
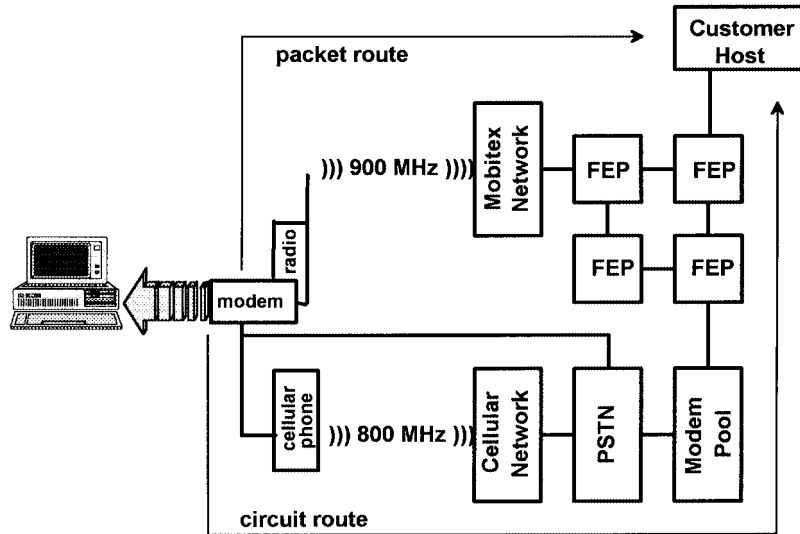
Figure 7-1 BSWD strategic network.

CS-CDPD operates on the same 800-MHz cellular channels whether in packet or circuit mode. BSWD's Mobitex network operates in the 900-MHz band. Not only is the band allocation different, so is the channel width. CS-CDPD operates in 30-kHz wide channels; BSWD operates in 12.5-kHz wide channels. A single, inexpensive radio simply will not bridge this gap.

Thus, the BSWD implementation requires two radios that operate on two completely independent networks. A single, special-purpose modem—initially, the NovaLink GoAnywhere—was the bridging unit. Conceptually, the system looked as shown in Figure 7-1. Note that the modem was capable of dialing in over conventional landline networks, bypassing radio altogether. A small problem: The GoAnywhere modem never shipped.

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II

BUSINESS 101:
PRICE AND QUANTITY
FIXATIONS

8

FITTING APPLICATIONS TO PUBLIC OFFERINGS

8.1   NETWORK PRICE POSITIONING

We are always interested in simple ways to classify complex choices. An initial "application fit" technique for terrestrial, two-way wireless data networks is shown in Figure 8-1. If traffic activity is brisk but message lengths are short, public packet switched networks are a reasonable business choice. If traffic activity is modest but message lengths are long, data over cellular channels are a better fit. This category includes "pure" (image) facsimile. If the application requires both high activity and long messages, a private network is appropriate. Public packet switched and cellular systems can be extremely price competitive with each other for application profiles featuring both medium activity and message lengths.

8.2   REPRESENTATIVE PUBLIC PACKET SWITCHED NETWORKS

The steep line of Figure 8-1 is only representational. What is the real shape of today's public packet switched curve? *List* prices for many carriers are easily revealed with a Web search. Unfortunately, useful comparative evaluation of list prices is deeply flawed for at least five reasons:

1. Some carriers count only *user* traffic that is successfully delivered. Others count *all* traffic in the air, including protocol overhead and retransmissions.
2. Some carriers make no distinction between peak and nonpeak hours. For carriers who do make this distinction, the peak hours are rarely in perfect alignment.

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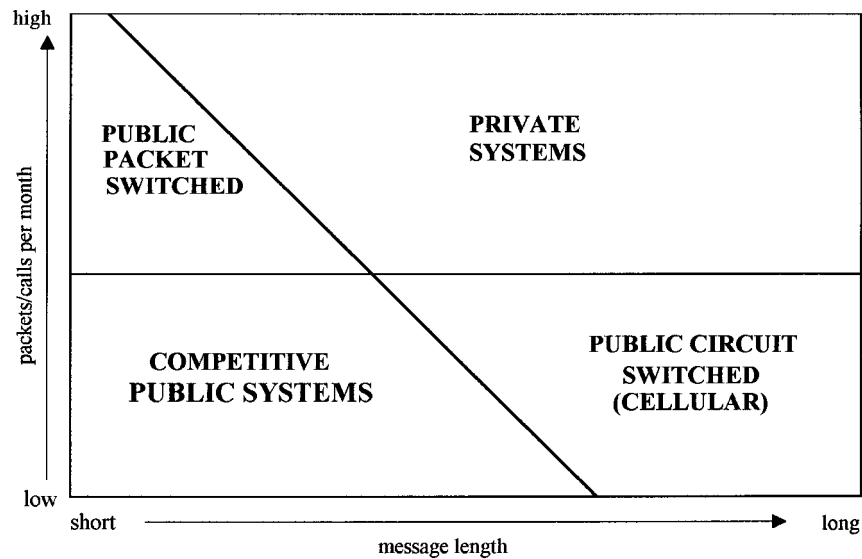
Figure 8-1 Network types by message characteristic.

3. Some carriers are truly nationwide with pricing insensitive to distance. Others have pricing regions or other "long-distance" charges.

4. Some carriers have discounted bulk rate pricing,[1] bundled offerings,[2] and special tariffs.[3]

5. Some carriers offer special, "all-you-can-eat" pricing for specific application types they are trying to encourage. These are rarely the same applications, making comparisons difficult.

Even more frustrating, many carriers change at least some of their parameters from plan to plan. Three very different pricing alternatives will be examined to set the stage for useful comparisons.

8.2.1 ARDIS Examples

The ARDIS philosophy is to charge only for *user* information that is successfully transmitted. All necessary registration messages, retransmissions, and protocol overhead associated with its airtime protocols are absorbed, not billed. ARDIS has numerous nationwide pricing plans, which cover a reasonable range of applications, but all are skewed to favor short message lengths.

8.2.1.1 Short-Message Service ARDIS exploits a characteristic of its airtime protocol to offer low-cost pricing for telemetry messages. The charge for message lengths up to 64 bits is $0.03, regardless of time of day.[4] This low cost is especially

useful in fixed-position security alarm or vending machine applications as well as mobile applications such as vehicle positioning, perhaps accompanied by key status information on the vehicle itself.

The list price for short-message service has a monthly minimum airtime charge of $20. This charge is levied for a truck cruising down the highway, free to transmit at any instant, generating no billable user traffic, but registering on one base station after another on its way across the country. If the truck device has a time-of-day clock, or if the device is actually a fixed-position vending machine or burglar alarm, a special price is negotiated. In the truck example, the device must "sleep" without registering on the network. It can "awaken" once or twice a day to report its position and, say, whether it is attached to a trailer. This type of contract permits the minimum monthly charge to fall below $4, reflecting (mostly) the administrative costs of billing a user.

8.2.1.2   Basic Message Unit Pricing   ARDIS' standard, low-volume pricing plan is shaped by the actual cost of transmitting a user packet through the air. Even if there are only 10 user bytes present, there are tangible costs associated with getting them airborne. The costs grow only gradually after that, until the packet achieves its maximum length and requests an acknowledgment. The pricing length of the packet is set at 240 bytes—an artifact of the MDC4800 protocol. The Basic Message Unit[5] plan is also time-of-day sensitive, seeing its peak costs between 7 AM and 6 PM local time.

During the peak hour the list price "empty message" cost is $0.06. The cost per byte, and they are counted one by one, is $0.0003. Obviously, the cost of a user message will vary according to how much user information it contains, from $0.06 when empty to $0.13 when full. For the individual user, without any volume pricing, the peak-hour monthly cost at a variety of average message lengths and traffic volume is shown in Figure 8-2.

Assume a light usage profile with an average message length of 180 bytes and a combined total of 210 messages sent and received each month. This solitary peak-hour user would pay nearly $28 per month.
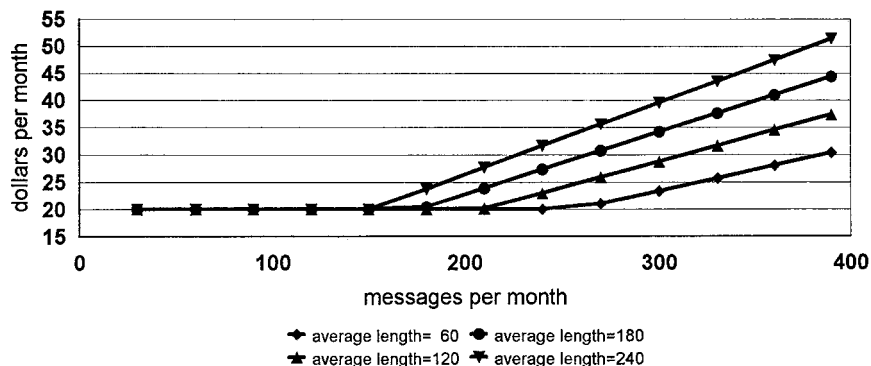
Figure 8-2   ARDIS basic message unit charges: peak-hour list prices.
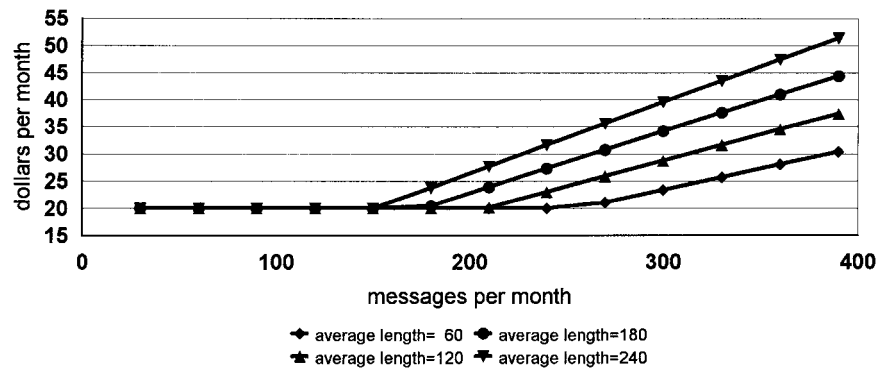
Figure 8-3 ARDIS basic message unit charges: peak-hour discounted prices.

ARDIS markets to high-volume vertical markets. These subscribers simply do not live with list prices. Minimum monthly charges drop, as do both message unit and byte prices. During the peak hour the volume user with the same profile would typically pay ~$19 per month, as shown in Figure 8-3.

8.2.1.3 DataPak Pricing There are three distinct DataPak plans[6]:

1. AirMobile Mobile Office covering cc:Mail, Lotus Notes, and Mail on the Run!
2. RadioMail (this service was terminated in July 1998)
3. IKON's MobileCHOICE for Windows CE

All three DataPak plans break free of the 240-byte packet and peak-hour considerations. Instead they are tailored to four monthly character usage levels: 20, 150, 350, and 750 kbytes. Between the price steps, which have a flatter slope than the Basic Message Unit plan, the incremental price per kilobyte is $0.54, very close to the price of a perfectly packed, 240-byte basic message unit. On the surface this kilobyte pricing appears to be 5–10 times higher than some competitive airtime prices. In reality it is not nearly that bad, but clearly the user is being charged for application function, not just airtime. A summary of the three DataPak plans is provided in Table 8-1. A visual comparison is shown in Figure 8-4.

8.2.1.4 Two-Way Messaging Services ARDIS' price plan for its Inter@ctive Pager is reminiscent of the Basic Message Unit offering. Once again the number of messages is the key accounting unit, and each message may be up to 240 characters in length. However, there is no attempt to count bytes within a message. If you send or receive two characters, say, "OK," the message charge is the same as 240 characters. A 241-character message counts as two messages. The notion of peak/off hours is discarded. The plan assumes nationwide coverage is required; no break is given for metropolitan or regional use. Two activity levels are fixed, along with

Table 8-1   ARDIS DataPak pricing

Kilobytes per month	20	150	350	750
DataPak Plans				
AirMobile (cc:Mail, Lotus Notes)	$19.95	$49.95	$99.95	$189.95
RadioMail	$33.95	$63.95	$113.95	$203.95
MobileCHOICE (Windows CE)	$29.95	$69.95	$127.95	$227.95
Additional kbyte	$0.54	$0.54	$0.54	$0.54

several options, including Internet access for other E-mail offerings and transmission of text to a facsimile machine. The Two-Way Messaging Service plan is summarized in Table 8-2.

8.2.1.5   *"All-You-Can-Eat" Pricing* Virtually every carrier has a particularly enticing price plan for selected services it wishes to promote. The most attractive ARDIS offerings are identical: $49.95 per month for unlimited usage for one full year. After that promotional entry, prices return to the normal list level. During the second quarter of 1998 the services covered included:

1. Two-Way Interactive Messaging
2. Mail on the Run!
3. RadioMail
4. Ikon MobileChoice

Within each plan there are often other enticements: lower device costs, free Internet access, or reduced-price operator-assisted paging; see Table 8-2.
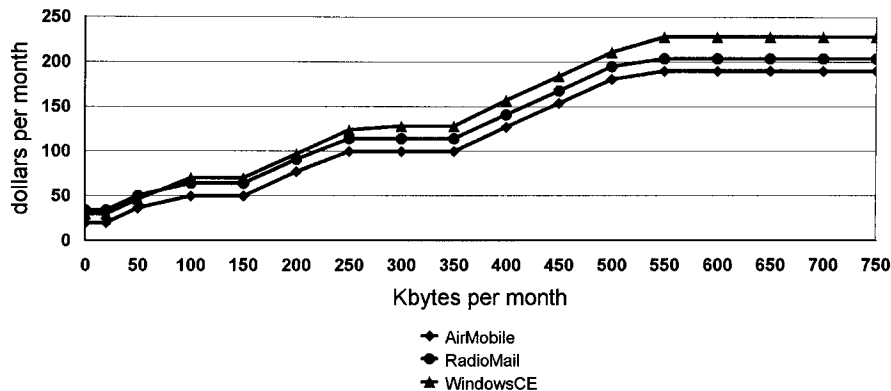
Figure 8-4   ARDIS DataPak pricing.

Table 8-2 ARDIS two-way messaging services

	Plan 100	Plan 250
Number of messages (240 bytes)	100	250
Monthly fee	$34.95	$49.95
Incremental charge/message	$0.35	$0.35
Options		

Operator-assisted messaging	$10/month +
	   $0.40/message
		$10/month +
		   $0.40/message

Internet services	$6.00 per month	Included
Facsimile, per page	$1.00	$1.00

8.2.2 BSWD Examples

BSWD has multiple price plans. The Standard Plan is usage based, with both peak and off-peak rates. At its optimum point it delivers characters for about $0.24 per kbyte, roughly half that of the ARDIS Basic Message Unit or DataPak plans. The Standard Plan is often the strawman tariff quoted to corporate customers and is accompanied by steep discounts tied to subscriber quantities and contract length.

In October 1993 BSWD (then RAM Mobile) announced a simplified "packets-carried" plan[7] for its E-mail users. This plan was insensitive to time of day and had the very first all-you-can-eat provision for those "power users" willing to pay $135 per month. This price point became economical when usage exceeded 700,000 bytes per month. The first CDPD pricing plan, that of BAM in April 1994, was structured to lie literally on top of this BSWD plan.

BSWD prices have mutated since 1993, and most customers are given special bids instead. The most common list price plans in the second quarter 1998 were those that competed with ARDIS DataPak and Two-Way Messaging plans.

8.2.2.1 *Wireless Lotus Notes* BSWD announced Motorola AirMobile support for Lotus Notes in January 1996.[8] Every effort was made to simplify the pricing plan; there was no peak-hour distinction, and no need to be aware of an arbitrary packet length. Four usage levels were established, based solely on actual data sent. These tiers, with BSWD descriptors, are shown in Table 8-3.

The Lotus Notes service represents a price increase from the earlier "packets carried" plan in that the $135 mark is reached at 500, not 700, kbytes. Further the unlimited usage has been dropped and the optimum price per kilobyte raised. However, there is specific user function provided in this plan, which always brings a price premium.

8.2.2.2 *WyndMail Pricing* BSWD has several E-mail offerings. Examples include the now defunct RadioMail, as well as DTS Zap-It (purchased by GoAmerica

Table 8-3   BSWD Lotus Notes plan

	Tier 1, Occasional	Tier 2, Frequent	Tier 3, Typical	Tier 4, High traffic
Kilobytes per month	100	200	275	500
Monthly fee	$25.00	$66.00	$85.00	$135.00
Additional kbyte	$0.35	$0.33	$0.31	$0.27

on July 14, 1998) and WyndMail, available only on BSWD. WyndMail is feature rich and has many two-way paging, text facsimile capability and text–speech–text functions. It is usage based and ignores peak hours. WyndMail is very much in tune with BSWD coverage limitations and offers an optional "high gain antenna to boost signal strength."[9] A very simplified summary of the pricing plan is shown in Table 8-4.

8.2.2.3   *Two-Way Paging*   BSWD has created a rapid sequence of pricing plans for its interactive paging service. The earliest emphasis was regional in nature, with sharp price breaks if one did not employ the nationwide capability. The May 1998 promotional plan[10] ignored the regionalized structure in favor of reduced message fees and higher message counts.

Like ARDIS, BSWD uses a message-based plan, but the maximum size of the message is doubled: 500 bytes. Discounts are published depending upon user quantity, and pager rental options are also offered. One restriction that existed throughout 1998 was that BSWD's Gateway would not permit entry to all E-mail services employing the Internet. Access to ARDIS 2way.net was specifically blocked by BSWD, for example. A simplified summary of the "customer-owned" promotional plan is shown in Table 8-5.

8.2.3   CDPD Examples

8.2.3.1   *Low-Volume Usage*   The general CDPD philosophy is to charge for all traffic that flows through the air, including TCP/IP overhead, headers, forward error

Table 8-4   WyndMail price summary

	Plan 1	Plan 2	Plan 3	Plan 4
Kilobytes per month	50	400	800	1,200
Monthly fee	$19.95	$59.95	$89.95	$119.95
Additional kbyte	$0.49	$0.39	$0.35	$0.25
Facsimile, per page	$0.25	$0.25	$0.25	$0.25

Table 8-5   BSWD interactive paging service pricing:

	Customer-Owned Equipment	
Number of messages (500 bytes)	200	400
Monthly fee		
1–50 subscribers	$24.95	$34.95
51–100 subscribers	$24.25	$34.25
101–150 subscribers	$23.50	$33.50
151+ subscribers	$23.00	$30.00
Incremental charge per message	$0.25	$0.25
Options		
Operator-assisted messaging	$0.50	$0.50
Internet services	Unclear	Unclear
Facsimile, one page	$1.00	$1.00

correction overhead, and even retransmissions. In practice, this philosophy only holds together for volumes less than ~1.5 Mbytes per month. In these cases care must be taken in competitive evaluations; a CDPD byte is simply not the same as, say, an ARDIS byte.

ARDIS DataPak prices become quite uninteresting after ~750 kbytes per month. Most CDPD offerings are just coming into their own at that point. As 1996 began, GTE Mobilnet became the price leader when it "slashed prices of CDPD service."[11] The key GTE focus was at 1000 kbytes per month, a price point where it is still competitive. But GTE has not refreshed its prices; lowering them did not "definitely stimulate interest in wireless data"[12] as hoped.

In 1997 BAM became the clear price leader[13] and remained so until May 1998. Then AT&T Wireless announced new Wireless IP (CDPD) rates that generally undercut BAM.[14] The usage-based AT&T list prices are $0.05 per kbyte when volumes are greater than 200 kbytes per month. After usage levels rise above ~1120 bytes per month, the user becomes a candidate for one of two unlimited usage plans. Figure 8-5 is a comparison of the three carrier's offerings at volumes less than 1.5 Mbytes per month. AT&T's local offering is emphasized so that it is easier to thread through the maze of dots.

It is interesting to read the words accompanying these price offerings. GTE Mobile's Bronze plan[15] is "designed for low-volume applications such as remote meter reading, vehicle location tracking, and automated dispatch." This description encompasses an unusually broad range of applications and makes comparisons difficult. Meter reading usually demands a very low byte count, say 4–6, with very low frequency of use, perhaps once per month. The automated dispatch profile usually has outbound message lengths of ~120 bytes, with an inbound return averaging ~60 bytes. Moreover, dispatch activity is usually brisk, with some kind of traffic occurring many times a day (even several times an hour).

Both BAM and GTE Mobile's *list* minimum monthly charge is ~$15, which surely must be lowered for, say, a volume meter reading application. While AT&T Wireless
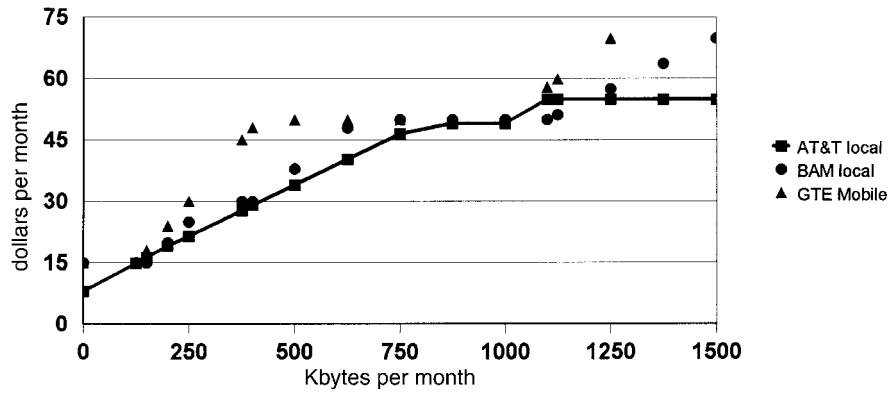
Figure 8-5   Representative CDPD list prices: low-volume usage.

undercuts both, starting at $8 per month, no meter reading application is currently known to exist on CDPD.

8.2.3.2   *High-Volume Usage*   This is the area of most dramatic change. AT&T Wireless now undercuts BAM by nearly 40%. The difference grows even greater should the usage grow beyond 4 Mbytes per month, the best BAM price point. GTE Mobile clearly does not choose to compete in the very high volume game. It begins to give up at 3 Mbytes per month; at 4 Mbytes per month its list prices are roughly double that of BAM and 2.5 times that of AT&T Wireless.

A simplified summary of the prices in this high-volume area is shown in Figure 8-6.

8.2.3.3   *"All You Can Eat" Plans*

8.2.3.3.1   Bell Atlantic Mobile   BAM was exceptionally aggressive in establishing a $55 flat monthly fee plan for unlimited access to the Internet, or company intranets,
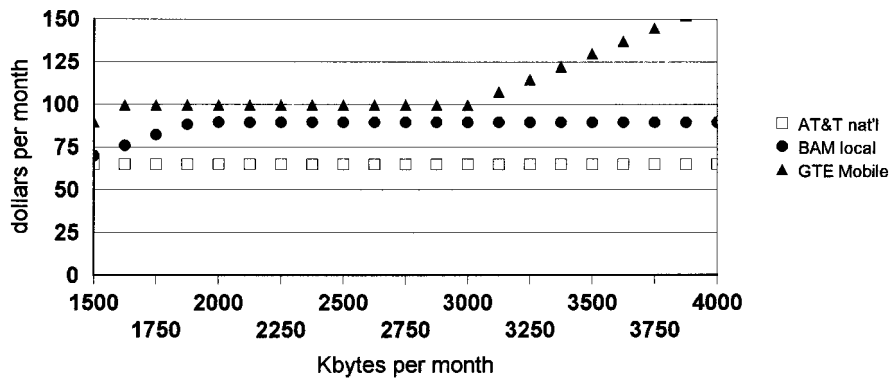
Figure 8-6   Representative CDPD list prices: high-volume usage.

while the subscriber is in BAM's home territory.[16] This attractive price can be driven still lower for relatively small (more than 30) user volumes. BAM also helps offset the price of the CDPD modems, offering a national price of $699 for a Sierra Wireless AirCard and subsidizing the Minstrel (more on devices in Chapter 16).

In truth, Internet-only restrictions tend to cap any damage that might be caused by a wayward fanatic. Some of you may still brew a cup of coffee while waiting for a 14.4-kbps landline modem, operating over a dedicated dial link, to retrieve Web screens. But by January 1998, 85% of PC users were already operating at 28.8 kbps or faster, 53% at 33.6 kbps or faster, in order to reduce the insufferable wait times.[17] Thus, it is an enormous shock to access the Web via CDPD. If no one else is on the base station (alas, too often the case), an effective bit rate of ~9600 bps feels insupportable. If you have the misfortune to be sharing the channel with another user the wait times seem intolerable.

If you want to conduct a simple test, a pair of side-by-side users can access BAM's Web site simultaneously. Make it easy on yourself; for example, retrieve the Cellscape price list. Do not wait for images to appear on the screen. Click on Wireless Data, then Airbridge, then Cellscape, then Price Plans just as fast as you can read the words. This will put 39 objects in your temporary Internet file—and about 104 kbytes. That is quite enough to demonstrate the response time problem of sharing this resource at low bit rates.

Cellscape was chosen as a segue to a variation of the all-you-can-eat plan: Cellscape Service, a voice telephone with CDPD capability but greatly constrained human factors. The viewing area is a tiny 4×16-character telephone screen. Data entry beyond simple yes/no indications is annoying and slow. But the plan has a low $20 entry point for the additional data functions, doubling if one has both E-mail and personal organizer functions in the phone. As long as one stays in the BAM home areas, there is no additional charge for data sent or received.

8.2.3.3.2 AT&T Wireless A variant of AT&T's May 1998 plan is called Unlimited Service. In a nutshell, if you know that you will always be in an AT&T CDPD area, you can send and receive all the data you want for $55 per month. If you roam, you pay an extra $0.05 per kbyte when in the domain of a CDPD carrier with whom AT&T has an interconnection agreement.

You can escape the uncertainty of the extra $0.05 per kbyte by paying AT&T $65 per month; AT&T will manage the roaming charges for you. This "roaming cap" astounded individuals at other carriers who were tempted to sign up for the AT&T Wireless plan; the revenue brought to their own company by high cross-carrier interconnection fees exceeded $10. AT&T Wireless blunts that ploy by specifying that "the address of the person using the service must be in . . . areas where AT&T Wireless operates."[27]

How can this uncapped pricing be explained? AT&T will not cap my long-distance phone bill, no matter how much I use it. The answer probably lies in the fact that AT&T Wireless has dedicated one voice channel per sector in each CDPD base station. In busy metropolitan areas such as New York the voice revenue is already lost. It is better to get *some* money back on this idle channel.

But suppose the plan works, and users really do begin to show up. Will AT&T sacrifice *another* voice channel in New York City? That channel, on one cell site sector, is capable of returning $1100–$1400 per working day, more than $24,000 per month, from voice. At $55 per CDPD user (AT&T's take), every dedicated sector on a base station must have ~25 CDPD users to break even with voice. If it cannot be done, the CDPD unlimited service plan is unlikely to be extended.

8.3   COMPARATIVE PRICING: NATIONWIDE CARRIERS

Given the wide differences in carrier pricing philosophies, one has to be fairly selective about what constitutes a fair comparison. It is unfair to match a nationwide price against a regional offering or a peak-hour plan against an "anytime" alternative, for example. These problems alone make it harder to incorporate CDPD in side-by-side comparisons. The added difficulty of what constitutes a billable byte can ruin the analysis. An attempt to deal with the special CDPD problems will be treated in the next section.

8.3.1   Mobile Office

Both ARDIS and BSWD have multiple mobile office solutions. One point of reasonable overlap is the Lotus Notes support derived from Motorola's AirMobile software. Both carriers provide it, both count only bytes transmitted, neither has a peak-time sensitivity, and both have four price "steps" (albeit, not at the same point) so that a look at the cost of the airtime offerings becomes meaningful.

Figure 8-7 is calculated from the prices shown in Tables 8-1 and 8-3. Clearly the two carriers offer closely comparable price solutions. In the area equivalent to BSWD's description of "typical" usage, there is essentially no difference at all. Note that the ARDIS promotional plan has *not* been employed. If a high-usage subscriber expects to spend more than $50 per month, the first-year unlimited-usage plan would normally be employed, undercutting BSWD.

8.3.2   Electronic Mail

RadioMail (RM) was available a very long time (this author was a subscriber from 1993 through 1998). It was never particularly successful, and has now gone away, perhaps to be replaced by a product called MobileAccess. When it was still available on both ARDIS and BSWD, it made for an instructive comparison.

In June 1998 RM's Business Plan on BSWD was priced at the ubiquitous $49.95 per 100 kbytes. Subsequent traffic was priced at $0.34 per kbyte. There was a $149.95 unlimited-usage Power Plan.[18] The results are portrayed in Figure 8-8. When usage was below ~450 kbytes per month—quite a lot of traffic for "post-it notes" messaging—ARDIS and BSWD had price parity. At high-usage figures—600 kbytes
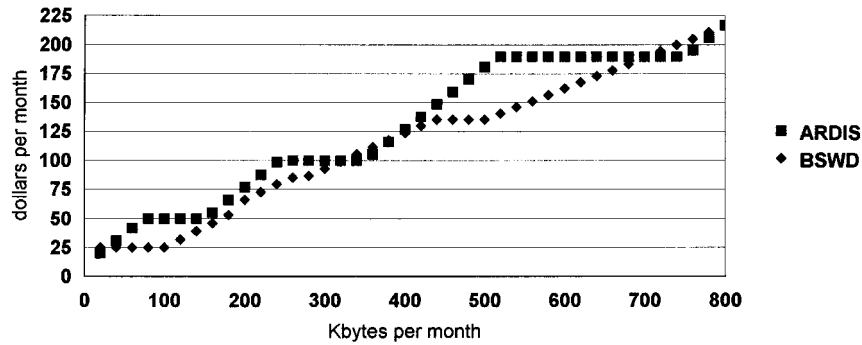
Figure 8-7   ARDIS vs. BSWD wireless Lotus Notes pricing.

can be thought of as 30 messages of 1000 characters each, every working day—BSWD was the better airtime choice.

Two other uncalculated factors favor ARDIS at these high-usage levels:

1. The modems required for ARDIS are typically lower priced than those necessary for BSWD. Motorola's PM100D lists at $400 and is often seen in catalogs as low as $250. The Megahertz AllPoints modem required for BSWD carries a promotional price of $499.
2. ARDIS can invoke the $49.95, one-year, unlimited-usage plan to blunt startup costs.

If these factors are used to calculate the four-year cost at the current prime rate of 8.5%, the net present value (NPV) cost of ARDIS for 750 kbytes per month is $6760; the equivalent figure for BSWD is $6534. The $226 difference is only ~3%.
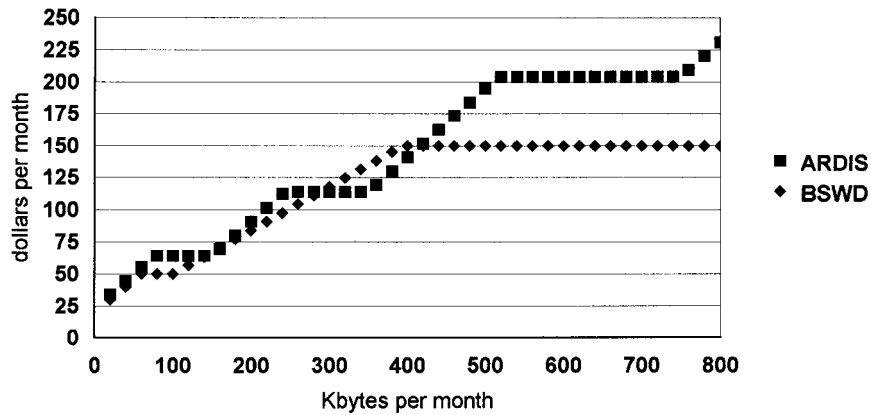
Figure 8-8   ARDIS vs. BSWD RadioMail pricing.
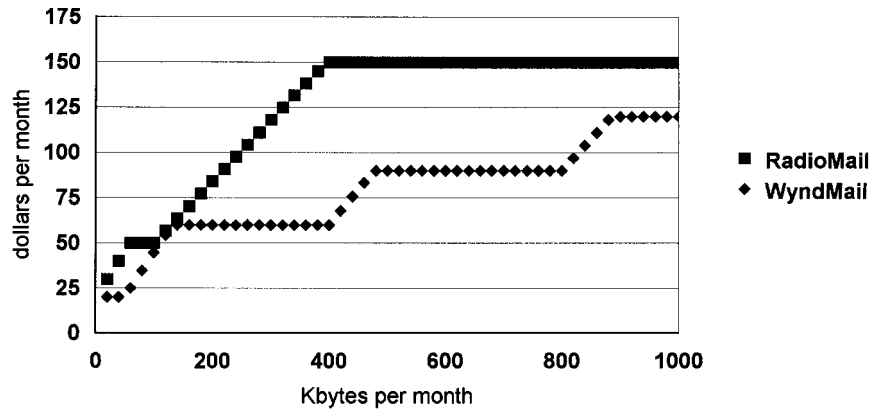
Figure 8-9   BSWD E-mail pricing: RM vs. WyndMail.

Conclusion: essentially a dead heat between the two carriers. But RM had competition. WyndMail is a feature-rich example. WyndMail only operates on BSWD, not ARDIS, so carrier comparisons are meaningless. Look at Figure 8-9. Except for the low-volume user (~180 kbytes per month), RM is simply not a contender. Perhaps this was one reason for its problems.

8.3.3   Nationwide Two-Way Paging

Three carriers provide nationwide, interactive two-way paging: ARDIS, BSWD, and SkyTel's 2-Way service. The three approaches have real-life differences:

1. Coverage is not identical, with ARDIS and SkyTel having a presence over more geography than BSWD (see Table 4-1).
2. ARDIS and BSWD did share a virtually identical paging unit, the RIM I@P, which carries a different price depending upon the carrier. ARDIS lists the unit at $575 and "promotes" it at $499. BSWD lists the unit at $650 but sells it for $430. But BSWD is currently introducing the I@P950, which has a list price of $359 and an introductory price of $249.[19]
3. The most closely comparable SkyTel unit is Motorola's PageWriter 2000, which SkyTel sells for $330.
4. No unusual product cost differences appear to exist between I@Ps and PageWriter. Obviously these wide-ranging device prices give one the same uncomfortable feeling engendered at an oriental rug sale.

All three plans are based on messages, not kilobytes, per month. SkyTel's pricing is highly granular and skewed toward very short messages, even though PageWriter can display 243 characters. BSWD's pricing plan is the other extreme, favoring long
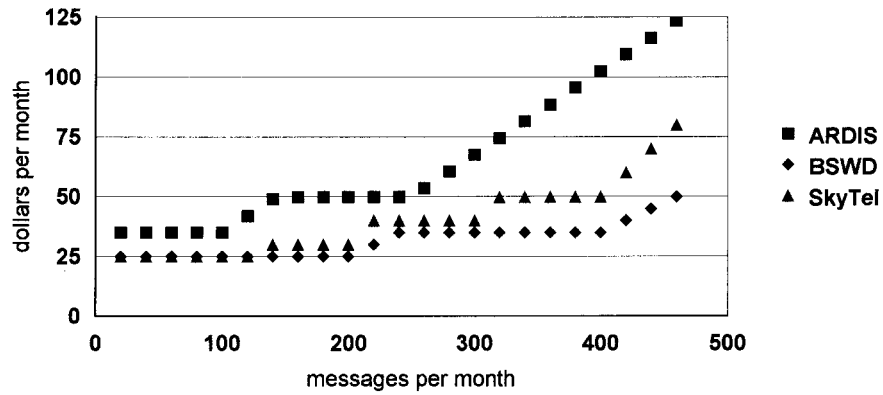
Figure 8-10   Interactive paging prices: 50 bytes per message.

(500-character) messages that cannot be conveniently displayed on the 90-character screen I@P.

The effect of message length on user costs is dramatic. At 50 characters per message BSWD and SkyTel are neck and neck out to 300 messages per month, about 15 messages per working day. ARDIS is premium priced, and no promotional plan can help at these low price levels. This is portrayed in Figure 8-10.

If the average message size grows to 100 characters, SkyTel begins to falter, rising to track ARDIS out to the 200-message-per-month frequency, then exploding. See Figure 8-11. With an average message length of 300 characters, ARDIS is twice the price of BSWD out to 125 messages per month; then it also bursts. See Figure 8-12.

For this application BSWD is the hands-down winner.
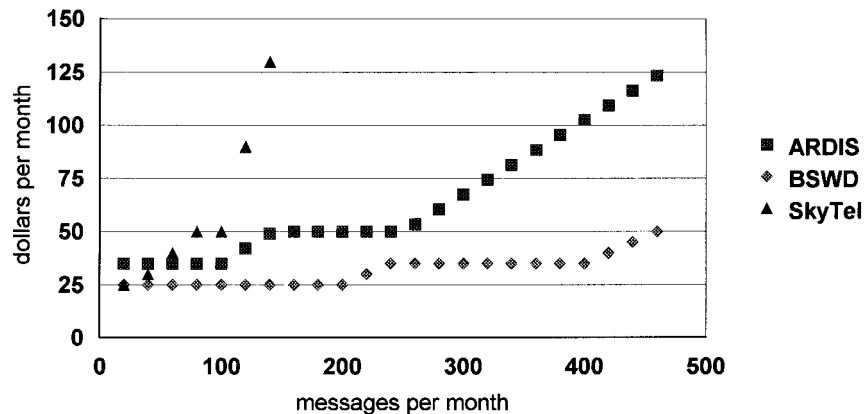
Figure 8-11   Interactive paging prices: 100 bytes per message.
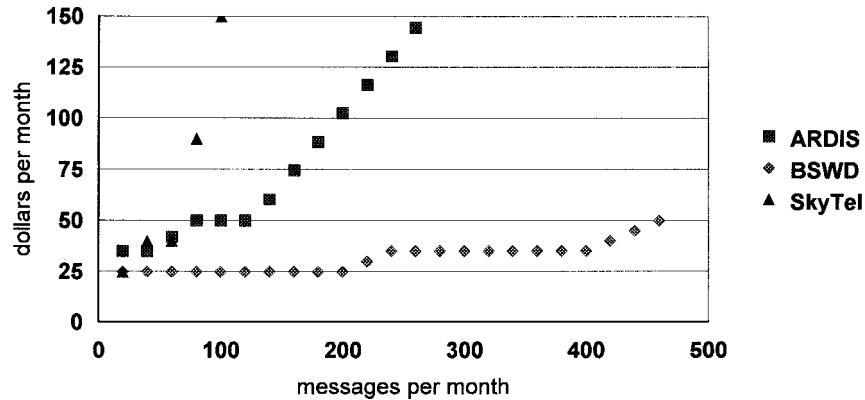
Figure 8-12   Interactive paging prices: 300 bytes per message.

8.4   ESTABLISHING A REPRESENTATIVE PACKET SWITCHED PRICE CURVE

It is very desirable to have an image of the best packet switched price curve—monthly costs versus kilobytes transmitted—at selected price levels. Given the difference in carrier pricing philosophies, especially how they bill or ignore airlink overhead at low usage levels, it is useful to establish an adjusted price curve for the various competitors.

   A test was performed between ARDIS and BAM CDPD to get at this necessary adjustment. The test was utterly simple: 250 canned E-mail messages sent to myself, generating 500 messages in all. The first 50 messages had a user size of 100 bytes; every 50 thereafter were increased by 100 bytes until the last 50 messages were each 500 bytes. The average message length was thus 300 bytes, with exactly as many inbound as outbound. Both carriers agreed to provide the actual *billable* byte count for this user traffic.

8.4.1   ARDIS

8.4.1.1   Internal Traffic: RadioMail   The ARDIS philosophy is to charge users only for the information they create. But sometimes there may be additional risks of message loss if, say, the packets transit the Internet on the way to E-mail systems. In this case the application, not the user's fingers, may create billable bytes. As an example, with RM there was a small cost component called the Application ACK.

   Assume the user initiates a message. The successful receipt of that message at ARDIS is ACK'd back to the device at no charge. When the message was successfully received at RM, a short Application ACK was generated that also flowed back to the device. This ACK conveyed to the user that the message is now on file and would be delivered by RM as soon as the addressee—who may be on virtually any

Internet-connected E-mail system—signs on. It also changes the status displayed on the device screen. For example:

   Outbound: 1 messages

changes to

   Outbound: 0 messages

This is a useful clue to let the user know that RM had message responsibility; the device could now be powered down. ARDIS also generated a no-charge radio ACK as a result of RM's Application ACK. The message flow is shown in Figure 8-13.

   The labeling in this figure is not meant to imply that RM was constrained to lengths of <1920 bytes when operating with ARDIS. RM could, and did, chain 1920 character blocks together to create large logical messages. It simply took a breather at 1920 to check that everything was OK. The same RM break point on BSWD was 512 bytes. While the Application ACK messages are very short, and virtually insignificant for long user messages, they are a steady drip, drip that can have a 5–10% impact on a very short-message, post-it-notes profile.

8.4.1.2 *External From/To/Date Traffic: RadioMail* A much larger impact on user message lengths comes from information that is simply taken for granted but is nonetheless very real. In the test I initiated each message to myself by entering jderose

Inbound

Outbound
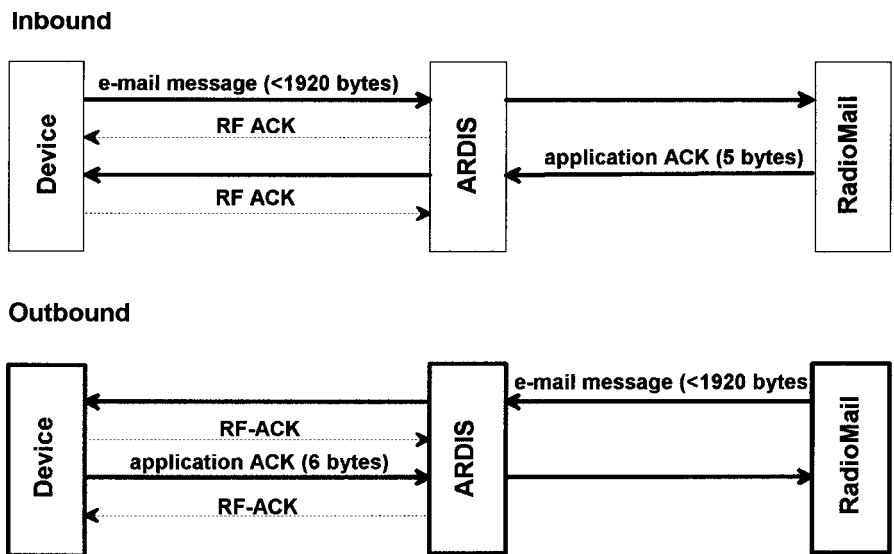
Figure 8-13   ARDIS/RadioMail message flow.

in the TO field. Since the RM gateway does not see an @ sign, it assumes I am going to another RM user (true: myself). I omitted any entry in the SUBJECT, CC, or BCC fields. FROM is derived from the modem ID, which is provided as part of 3 bytes of routing information sent to the RM gateway. In this particular case the routing information, the keyed TO address, and field delimiters add 16 bytes. My 100-byte test message is now 116 billable bytes long. This same 16 bytes is added to my message when it was 500 bytes long. Thus, the inbound impact is not particularly harsh.

The outbound response is another story. The TO/FROM information returns, this time as fully specified addresses. Nickname information also accompanies the FROM address. New additions include the date, time, and control number, along with title information: DATE, FROM, SUBJECT, and TO. The resulting billable character expansion is impressive. In my trivial example 102 bytes are added to the text body, doubling the 100-byte test message to 202 bytes. This expansion is variable, depending a great deal on address configuration, but you get the idea.

8.4.1.3   *ARDIS Test Results*   On May 2, 1998, the test was conducted via ARDIS and RM. As luck would have it, all traffic flowed via RD-LAP base stations located on Long Island (my office is in coastal Connecticut). The received signal strength indicator (RSSI) observed on an adjacent I@P was –91 dBm. There were no negative acknowledgements (NAKs). The test duration was 109 minutes, absolutely constrained by my keystroke time, plus one battery change. Response time was essentially immediate; the first message was usually back before I could begin keying the address for the second.

After the test ARDIS provided a transaction-by-transaction log of billable characters. Including 500 Application ACK'S, the actual count of billable bytes expanded as in Table 8-6. Assume this profile represented a month's traffic: a total of 500 messages in and out, varying in length but averaging 300 characters. The 150,000 bytes I may have naively thought constituted my entire billable character count—holding me at $64 per month—expands to 182,250 bytes and $81 per month.

Table 8-6   RadioMail message expansion example

Number of Messages	Message Length	"User" Count	Inbound Actual	Inbound Count	Message Length	Outbound Actual	Outbound Actual
50	100	5,000	116	5,800	100	202	10,100
50	200	10,000	216	10,800	200	302	15,100
50	300	15,000	316	15,800	300	402	20,100
50	400	20,000	416	20,800	400	502	25,100
50	500	25,000	516	25,800	500	602	30,100
		75,000		79,000			100,500
250			5	1,250		6	1,500
Total		150,000		80,250			102,000

There is a 22% expansion overall. Naturally, the impact of the adders becomes negligible for long messages. The message expansion is <13% when the average user text length is 500 bytes.

8.4.2 BAM CDPD

8.4.2.1 Test Conditions The simple round-trip test was repeated on Bell Atlantic Mobile's CDPD system on Sunday, May 3, 1998. Weekend days were chosen in a conscious effort to avoid voice interference in this channel-hopping area. Nevertheless, humans still speak on Sunday, and hopping overhead did occur. To reduce the possibility of retransmission errors exploding the billable byte count, an external mag mount antenna was used. This provided a fine RSSI of −78 dBm. Further, the modem was set to exclude AT&T Wireless since interference from that carrier can be quite strong in my office.

8.4.2.2 BAM Test Results The test required 185 minutes to complete. Set up on an IBM ThinkPad plugged into a wall socket, there was no battery replacement or keying required. The extra time required was dominantly a function of the very slow CDPD response time. While there were many swift responses, there were just as many that required 2–3 minutes. The overall average response time was 44 seconds per message. My belief is that I encountered voice interference. BAM personnel were unsure of this conclusion and pointed out that the Sierra Wireless AirCard cannot take the internal heat of an IBM ThinkPad. They believe the modem may have been intermittently shutting down.

BAM did not provide a detailed transaction log, but rather a summary at 15-minute intervals. Multiple requests for finer granularity were not answered. It was impossible to tell what was data traffic and what was control overhead. But the results were clear: Exactly the same canned user messages generated approximately six times as much billable traffic via CDPD than via ARDIS: 1,054,334 bytes versus 182,250 bytes. The CDPD outbound channel was particularly hungry, consuming, on average, twice the number of bytes as the inbound channel.

A clue that this sharp difference would exist arrived a few days before the BAM results. InStep Communications personnel called[20] to tell me that their taxi application, which generates about 500 kbytes of data per month, was actually causing 3–4 Mbytes to be transmitted when using the SmartPhone and Unwired Planet's HDML. This is an expansion of six to eight times.

TCP/IP chattiness is the cause of this character explosion. BAM personnel ultimately agreed to send a single 24-character message—"message sent with $$$$$$"—inbound. This transaction was captured on a logger and the hexadecimal printout was given to me. A total of 32 packets were transmitted for this simple exchange: 15 in, 17 out. A total of 2344 bytes traveled back and forth to deliver this message—a gigantic percentage expansion on a trivial message length. The partially deciphered printout is contained in Appendix C.

8.4.3   Creating a Representative Packet Curve

To create a "strawman" price curve based on these test results we must create an application profile. Assume that:

1. The ratio of inbound to outbound messages is identical.

2. User message lengths are adjusted for the billable overhead encountered in the May tests. The average user-created length of the 500 test messages was 300 bytes. With the addition of, for example, date, time, control number, and nicknames, the ARDIS billable message length expanded by 20%. But the CDPD expansion was sevenfold. We have a pretty good fix on that single point. To estimate the slope of the CDPD curve at other message lengths, the ARDIS *percentages* were used as a surrogate.

3. The number of expanded messages that can be sent for $49.95 is then calculated. There is no magic about this figure; every carrier offers at least one plan pegged around that price level.

Sample results are shown in Table 8-7. ARDIS is the least competitive, BAM is the best—barely. The reason for this position exchange with AT&T Wireless is the selection of $49.95 as the target price. BAM offers 1100 kbytes at that point. AT&T Wireless offers 1000 kbytes for $49 and delivers only 19 kbytes more for the additional $0.95. BAM can transmit nearly 30% more messages than ARDIS for $49.95, but the difference is not nearly so great as the 10:1 disparity the list price per kilobyte suggests. It is also quite clear that, given CDPD inefficiency,[21] AT&T's Mobile Professional is not going to be able to transmit/receive 500 E-mails, each 1000 characters long, at this price.

For our purposes the BAM CDPD curve, at its $49.95 price point, will be used to represent the low-volume usage packet switched price levels. This "packet curve" is depicted in Figure 8-14, with logarithmic scales. Log scales have the effect of

Table 8-7   Adjusted messages per month: $49.95

User Bytes Created	ARDIS		AT&T Wireless		BAM	
	Average Bytes Transmitted	Maximum Messages, $49.95	Average Bytes Transmitted	Maximum Messages, $49.95	Average Bytes Transmitted	Maximum Messages, $49.95
100	165	912	964	1,057	964	1,141
300	365	**411**	**2,109**	**483**	**2,109**	522
500	565	266	3,307	308	3,307	333
1,000	1,065	141	6,235	163	6,235	176
1,500	1,565	96	9,164	111	9,164	120
2,000	2,065	73	12,093	84	12,093	91

Figure 8-14   Representative packet switched curve.

straightening out the curve so that it begins to resemble the one first postulated in Figure 8-1.

8.5   ESTABLISHING A REPRESENTATIVE CIRCUIT SWITCHED CELLULAR CURVE

8.5.1   Data Using Voice Tariffs

8.5.1.1   Selecting a Representative Cellular Tariff   In 1998, after years of smoky claims that cellular tariffs were falling, they actually did start down. On March 9, BAM made the first sharp break with its Digitalchoice plan, which also embraced CDMA.[22] Voice airtime prices within BAM's geographic coverage were streamlined, as shown in Table 8-8.

Two months later AT&T Wireless announced its 50-state Digital One rate.[23] This plan is for high-usage subscribers. Its entry point is 600 minutes per month, where it undercuts BAM by $10. But Digital One has many conditions that make it unusable for conventional data-over-cellular comparisons. It is geared toward TDMA voice and requires a multinetwork phone, currently without a data port. The user must also subscribe to AT&T Wireless long-distance service.[24] Thus, the BAM prices will be used as a surrogate for circuit switched cellular.

8.5.1.2   Establishing the Connect Time   Today, V.32*bis* modems (covered in Chapter 15) are generally used for data-over-cellular purposes. These are fine devices but have a slow connect time, usually 14 seconds or more. This connect interval is billed on circuit switched cellular and thus has a serious impact on user cost. V.32*bis*

Table 8-8   BAM Digitalchoice prices

Minutes Included	Monthly Charge
60	$ 29.99
150	$ 49.99
600	$ 99.99
1,200	$159.99

modems are also a bit slow when transmitting via cellular, rarely exceeding 9600 bps for any prolonged time.

In 1996 AT&T Paradyne announced the ETC2 Quick Connect modem.[25] The new design can sharply reduce the connection interval and is able to sustain higher bit rates over normal cellular channels. It requires paired ETC2 modems; there is no benefit without an identical modem at both ends. In addition, the central-site modem must be "digitally connected" using T1 or integrated service digital network (ISDN), but that is virtually the norm these days. When these conditions are met, the results are impressive.

The relatively long startup procedure of V.32*bis* modems is streamlined, and the modem simultaneously and independently works the separate transmit and receive audio paths. If one channel is impaired, the other proceeds at full speed. If the central-site modem is actually at the MTSO, as in a modem pool, the network switching time (IN-USE till the modem "hears" RING) is 1 second; the modem startup time (RING till CONNECT, including training and error control negotiation) is another second. If the central-site modem is beyond the PSTN, switching time expands to 4 seconds and the startup time to 2 seconds, as required by the FCC.

Data transmission begins at 9600 bps. Assuming good cellular channels, the modem can reach 19,200 bps within 10 seconds.[26] In tests with "zipped" files, the modem averages >13 kbps over 2-minute intervals.

8.5.1.3   *Estimating the Customer Data/Message Rate*   Short connect time is a most important cellular modem parameter. With ETC2, even on an end-to-end connection, a 1-minute billable interval permits 54 seconds of transmit/receive time—perhaps 65–90 kbytes worth of data. One can easily imagine a scenario where the user composes a few E-mails or prepares a parts order, turns on, then transmits/receives multiple E-mails or order information. It is important to get off the connection within 1 minute or the carrier will cheerfully bill a second minute when the 61st second is reached. This may seem harsh, but the current UPS application places the call, dumps 15–20 minutes of accumulated data, and is clear in less than 45 seconds. It can be done.

With this scenario in mind, the number of 1-minute calls that can be placed for $50 can be overlaid on the prior packet curve. The result is shown in Figure 8-15. In a

nutshell, if the transaction rate exceeds 150 per month, you must consider packet as a solution to meet the price constraint. Naturally, the higher the transaction rate, the shorter the permissible message length. If the transaction rate is less than 150 per month, packet and circuit solutions are price competitive up to an average message length of ~1200 bytes. As the average message length climbs above 1200 bytes, increasingly only circuit switched cellular can meet the required price target.

8.5.1.4   Application Variables Figure 8-15 tries to portray, in a simplistic way, the message characteristics that best suit packet or circuit switched cellular price structures. Some applications do not require heavy thought. The standard ARDIS Over-the-Road Transport profile is:

Peak hour
   Outbound   One message, average length 105 bytes

   Inbound   Two messages, average length 25 bytes

$$\text{Peak hour percent of total day} = 14 \pm 3\%$$

Thus, the average transport subscriber transmits and receives:

$$1/0.14 \; = \; 7.14 \text{ messages/day} \times 20 \text{ working days/month} \; = \; 143$$

$$2/0.14 \; = \; 14.3 \text{ messages/day} \times 20 \text{ working days/month} \; = \; 286$$

$$429 \text{ messages per month}$$
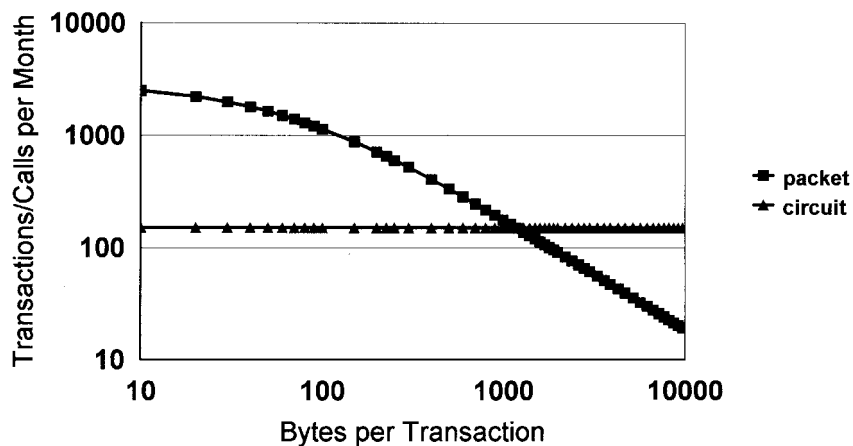
Figure 8-15   Packet vs. circuit switch crossover point.

with an average message length of 42 bytes. It would be hard to find an application more squarely inside the "packet" zone of Figure 8-15. But this profile is an exception; reality is far more complex.

8.5.1.4.1   E-mail Suppose the application is purely E-mail. Then 150 cellular connections per month permit transfers nearly once per hour every working day since 150 calls divided by 20 working days/month equals 7.5 calls per day. But during a single cellular call it is possible to receive and transmit several messages. Suppose that, on average, one message is received and one is sent on each call. This is equivalent to a packet frequency of 300 messages per month. If that really is the scenario, the average message length cannot exceed ~575 bytes for packet or the price target will be missed.

8.5.1.4.2   Mixed E-Mail/Data Base Interactive Now suppose the application is a mix of E-mail and data base interactive (DBI). The user's average E-mail rate drops to once every two hours. DBI work is performed on average once per day. Assume the user makes an inquiry/response once every 30–45 seconds, pondering the results between each transaction. On cellular this requires a 3-minute call because of the wasteful, but billed, "think time" between successive DBI transactions. Four such inquiries can occur in 3 minutes, equivalent to eight packet transactions. If the responses are short, packet is the right choice. But if the responses are long, full-screen 3270 display type, packet cannot endure the message lengths and still meet the price target; cellular is the right selection.

8.5.1.4.3   Internet Access Both AT&T Wireless and BAM offer unlimited CDPD access to the Internet for \$55–\$65 per month. If the data-over-cellular price target is eased up to this level, one can expect to have more minutes per month available. These extra minutes, call it 180 total, are unlikely to provide any meaningful competition to packet. Part of the problem is that the Internet service providers have really not recognized the existence of nonlandline connections. When I connect to CompuServe to access the Internet, after the dial connection is made, I lose 47 ± 11 seconds stepping through:

1. Verifying account information
2. Account verified; connecting to CompuServe
3. Logging on to CompuServe
4. Connected to CompuServe
5. First target screen appears

At sign-off time, I must click Yes to confirm that I wish to exit, then confirm that I want to shut down smartcenter.exe and get out of active dial networking. During this time the cellular clock continues to run.

With only 9 minutes per day available to compete with packet, one can hardly afford to throw away 2 minutes just to get in position. Stepping through screens is faster via cellular (though still *much* slower than I am accustomed to in the office) than packet, but the minutes fly by. It is nothing to burn up 10 minutes ordering a single book via amazon.com. Packet is slow, but cellular cannot beat "unlimited."

8.6   SUMMARY

Price comparisons between carriers is an inexact science. Philosophical variations are simply too great, right down to what constitutes a billable byte. Nevertheless useful positioning is possible. For these purposes list prices were used, with the caveat that custom bidding is the norm.

The inspection clearly reveals that ARDIS is oriented toward low-volume users and simply does not compete in the Internet access market sought by CDPD. The price competition at the high-volume end is so intense that two of the carriers have adopted unlimited-usage plans.

Comparisons of equivalent, relatively low volume functions, such as E-mail and mobile office, on equivalent carriers reveals that they are comparably priced. It is also clear that drastic change is taking place in the E-mail arena as new arrivals sharply undercut established offerings.

Comparisons of equivalent nationwide two-way paging offerings reveals that BSWD has the most attractive pricing but, paradoxically, is having little market success. SkyTel has premium prices on a nationwide basis but is developing an attractive user base. This suggests that local service and availability of coverage in a given area are more important to users than price.

To establish a general packet switched price curve, tests were done between carriers with very different pricing philosophies: ARDIS and BAM. BAM clearly has the better prices, but the differences are not nearly so dramatic as the list prices indicate.

The Paradyne ETC2 modem was used to define the short-connection-time, high-speed data transfer that can be obtained with data-over-cellular.

The optimum packet and data-over-cellular low-volume price curves were superimposed to understand the trade-offs between message length and transaction frequency. With a $50-per-month price target, cellular cannot go above 150 calls per month, although each call may contain multiple transactions. Packet can withstand far higher transaction rates but rapidly loses ground to data-over-cellular if the average message lengths exceed 1200 bytes.

An area of greatest application "fit" can be depicted for both packet and data-over-cellular. However, the infinite variety found in most applications still requires a careful plotting of message profiles—length, frequency, interval between transactions—to make an accurate final selection. Looming over all evaluations is the impact of unlimited usage on packet systems. Will it be extended, displacing voice users, or simply used as an interim lure to attract traffic to currently idle channels?

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9

SUBSCRIBER GROWTH: HISTORY AND BARRIERS

9.1 APPROACH

Each public service provider has a different philosophy on reporting subscribers. Not unexpectedly the most successful, OmniTRACS, is also the most forthright about both customer names and device shipments, though one must take care to discriminate between U.S. and worldwide totals.

ARDIS is good at overall subscriber counts, a bit more guarded on customer names and their specific active devices. For years RAM was very guarded in both respects, but in 1996 it began to reveal gross subscriber count summaries. User names, and especially quantities for those users, were more difficult to obtain. With the acquisition of RAM, BSWD reverted to the prior policy of blocking subscriber counts.[1] CDPD users are also fairly difficult to determine, especially with the closing of the original CDPD Forum Web site. SMRS data users and their circuit switched counterparts, data-over-cellular, broadband PCS, and Enhanced SMR (ESMR) are the most difficult of all.

Through 1992 a valuable source of information for packet systems was the FCC loading records. While this was only a register of *licenses*, not subscribers, it provided a useful sanity check. After that date the FCC requirement to record the license of all new users was dropped; a valuable piece of market research information dropped with it. For the next five years the information gap could be partially filled by NewsNet. However, the growth of the Web put NewsNet out of business. The information must now be obtained by tedious Web searches, examination of annual reports, interviews with and presentations from service providers, and other traditional labor-intensive techniques.

9.2   PUBLIC PACKET SWITCHED NETWORKS

9.2.1   Cross-Network Applications: E-mail

In the 1992 words of the pundits: "E-mail will provide a key application in making wireless data networks attractive to corporate users."[2] Or how about this one: "Like the spreadsheet was to the PC, e-mail is to wireless communications."[3] And it was not simply "market observers" who had romantic notions. So, too, did the application providers such as WyndMail: "There's a huge market in front of us."[4] By 1996, as the real world drove home its bitter truths, new WyndMail executives were relieved to be able to say, "We've survived the dead pioneers stage."[5]

9.2.1.1   RadioMail   RadioMail was the first external E-mail package available on BSWD, then ARDIS. Estimates of its success varied widely, but one of the more conservative views[6] was 3000 subscribers at the close of summer 1994. That assessment was too optimistic.

   A very different kind of pundit, the late Isaac Asimov, reports in *The Book of Facts* that the surnames listed in Table 9-1 accounted for at least 8.5 million people (~3.5%) in the United States. At the end of June 1995, and again in June 1998, I searched for these five surnames, using RM's directory service, with the results given in Table 9-2. These numbers suggest that RM's total subscriber base in the second quarter of 1995, allowing for a lower U.S. population at the time of Asimov's demise, was ~2400; the total in the second quarter of 1998, the time of RM's demise, was probably ~1260. Numerous other spot tests were performed on common surnames. All pointed in the same direction: a tiny, shrinking customer base. Checks of other known ARDIS and BSWD users gave an estimate of the subscriber distribution. It is not a stretch to estimate that 30% of the RM users were on ARDIS, 70% on BSWD. Most RM users on ARDIS converted to the IKON service (2way.net). Presumably most RM users on BSWD moved to WyndMail. Zap-it was a possible alternative before it was taken over by GoAmerica.

Table 9-1   "Top five" surnames

Surname	Millions of People
Smith	2.4
Johnson	1.8
Williams(on)	1.6
Brown	1.4
Jones	1.3
	8.5

Table 9-2   RadioMail count: "Top 5" surnames

Surname	Total Listed	
	June 1995	June 1998
Smith	25	15
Johnson	20	11
Williams(on)	11	3
Brown	21	10
Jones	8	5
	85	44

9.2.1.2   WyndMail Founded in 1994, and exclusive to BSWD, WyndMail is feature rich and competitively priced. It has survived, barely. Its executives[7] claimed 1000 subscribers during fourth quarter of 1997. During 1998 it will undoubtedly pick up some of the refugees from RM's subscribers that used BSWD.

9.2.1.3   Zap-it Founded in 1992, Zap-it was the E-mail offering of DTS Wireless, a subsidiary of L. M. Ericsson and the original owners of RAM Mobile. Zap-it was also only available via BSWD. Close-mouthed on the subject of subscribers, Zap-it is not believed to have had any more success in this market than RadioMail or WyndMail.

9.2.2   ARDIS

The first task was to estimate the IBM/ROLM U.S. subscriber base through the third quarter of 1998. When the original private field service system was created, IBM purchased 25,000 KDT800 terminals from Motorola. Only 21,000 of these units were actually put into service. Spare stocking, at the 5% level, put ~20,000 subscribers on the private system in the peak year, 1985. That historical figure still appears in some trade journal articles.

Beginning in 1986, IBM U.S. employment began to decline. By 1990, when ARDIS was formed, there were only 15,000 actual IBM/ROLM users on the network. This total continued to decline to about 11,000 in the second quarter of 1998. Some of the decline is due to device modernization. The original KDT800's were single-frequency units and some field service personnel were forced to carry two devices. With the complete changeover of IBM field service to the RIM Inter@active Pager,[8] such anomalies were eliminated.

The second task was to record subscriber unit quantities from pre-1993 FCC loading records and from those counts reported by ARDIS, their customers, or other reasonable and reliable sources. This tally, which is detailed in Appendix D, captures

a surprisingly high percentage of ARDIS users, about 72% of the subscriber counts reported by ARDIS for year-end 1997.

Discontinuances are rarely reported by ARDIS. G.O.D. (Guaranteed Overnight Delivery), Wilson Sporting Goods, and Xerox are the only clearly identified examples. Many of the very small customers listed in Appendix D have undoubtedly gone away, but several have likely grown. The secretive Motorola is quite likely to have gone beyond the confines of the first three DRN cities, for example. Thus, the overall correlation is considered reliable.

The shift in ARDIS users between 1990 and 1997 is illustrated in Table 9-3. IBM no longer dominates the business and will become the third ranking customer as Enron and UPS roll out in 1999. This sea change is not yet understood in the CDPD world, whose denizens persist in believing that "IBM field service technicians . . . still comprise almost one-half of the ARDIS subscriber base."[9] Also especially interesting is the very long time it sometimes takes for a trial user to move into red hot production. Otis Elevator began trials in Chicago and Los Angeles in May 1989; it was three years before full rollout. Sears remained at a 600-unit plateau for six years before expanding in 1996 (and then giving 40% of the business to BSWD). United Parcel Service began limited application work in Los Angeles and New York City in August 1990; the explosive growth began eight years later. You gotta be patient!

A representative graph of subscriber history is shown in Figure 9-1. Every annual nuance is smoothed in order to highlight the major events:

1. The decline of IBM users from its private system high of 20,000 to the current stable level of ~11,000 users.
2. The 1990/1991 growth spurt that led ARDIS to predict[10] that 40,000 subscribers would be on-line by year-end 1992.
3. The impact of the CDPD announcement, with its wildly optimistic system availability dates, which essentially froze the market for a year.
4. The final achievement of 40,000 subscribers[11] in March 1995—$2\frac{1}{4}$ years later than originally planned.

Table 9-3   Estimated ARDIS users

	1990 Subscribers		1997 Subscribers	
	Number	% of Total	Number	% of Total
IBM Field Service	15,000	68	11,000	17
Other: external sources	2,087	10	35,748	55
Unidentified	4,913	22	18,252	28
Total	22,000		65,000	
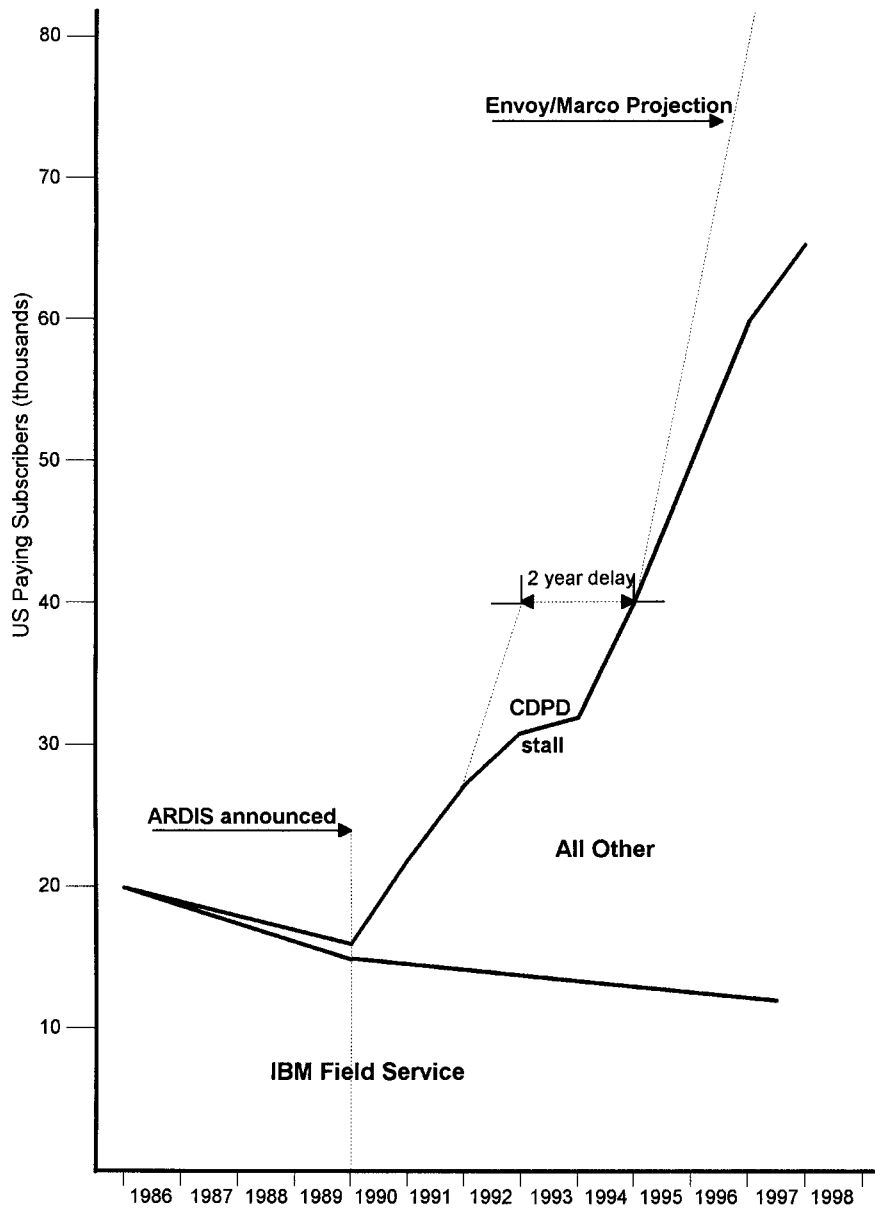
Figure 9-1 ARDIS U.S. subscribers.

5. The 1995 projection for 100,000 subscribers by year-end 1996—led by 40,000 Motorola Envoy/Marco devices—which was not achieved. ARDIS may approach 100,000 users at year-end 1998—a two-year delay.

9.2.3   BSWD

In October 1990 BSWD, then RAM, became marginally operational with 10 channels in each of 10 MSAs across a total of 28 base stations.[12] No subscribers existed. For the next three years BSWD was plagued by poor customer acceptance. City rollout was initially slow. Reports of poor coverage were common[13] and persisted for years. Competitive modems were unavailable.[14] The application focus was on horizontal markets that simply did not materialize.

BSWD building penetration (covered fully in Chapter 12) was not as good as ARDIS in the early years. This was no surprise. BellSouth Mobility had predicted[15] that "RAM will have good in-building penetration in (only) 20 of its 100 markets by the middle of 1993." But there are clear indications, supported by independent testing, that BSWD is closing the penetration gap, especially in areas where infrastructure upgrade for two-way paging has been achieved. In Manhattan, BSWD building penetration is quite competitive to ARDIS.

Another early inhibitor to BSWD customer acceptance was lack of a competitive modem. The now defunct PCSI announced in early 1990 that it would have a product ready in 1991 in time for MSA expansion.[16] This did not happen. Further, Ericsson's Mobidem[17] was not yet commercially available; British Airways Speedwing airport test was conducted on three prerelease units.[18] When the Mobidem was available, it was a lackluster performer. Motorola's InfoTAC unit was finally certified on BSWD in the Spring of 1994.[19] Ericsson's follow-on modem (also labeled for IBM) was in the Type III PC card format, which made it unusable for most personal digital assistant (PDA) class devices. The early Type II cards such as the GoAnyWhere modem were announced with great fanfare[20] but were never delivered.

Throughout 1994 BSWD, with RadioMail and later Wireless Telecomm, initiated a series of extreme marketing approaches to improve its horizontal subscriber base.[21] One blunt technique was to eliminate the Mobidem price as a barrier. But it is clear that the "Wild Wireless Frenzy" promotion[22] (for example) was unsuccessful.

In 1994 BSWD temporarily altered its close-mouthed policies and began to reveal subscriber counts[23] (the door closed again at year-end 1997). These figures were surprisingly robust with a 1994 year-end total of more than 27,000 subscribers. The subscriber base has since grown to a reported 70,000 at year-end 1997 based upon BSWD customer presentations.[24] However, that number is neither confirmed nor denied by BellSouth Mobility or BSWD's public relations firm, Barkley & Evergreen.

Actually identifying the users is very difficult. The usual attempt was made to count early licenses in the top three metropolitan areas from FCC loading records. The results were unsatisfactory, complicated by the presence of SMR voice units on the BSWD channels and fractional unit license balancing across multiple call signs and

bases. About one-third of the early licenses originated with Ericsson/GE or BSWD itself, a phenomenon not unlike ARDIS with IBM & Motorola.

GE Consumer Services did not appear in New York or the other two major cities. A three-year rollout had been projected,[25] but the schedule was damaged by the financial collapse of Kustom and the subsequent purchase of Kustom by Coded Communications,[26] which later fell into bankruptcy. It is also possible that early Mobidem shortages retarded rollout.

Appendix E lists known BSWD subscribers where a user count was reported in the trade press, a BSWD media advisory, or *Signals*. After considerable data base searching, less than 20% of BSWD's claimed subscriber base could be identified by year-end 1997, a number low enough to make one uneasy. It is particularly surprising that data base searches yield so little reward given BSWD's claim[27] to have "over 1700 direct and indirect *customers* (not subscriber units)."

Of course, there are known customers whose subscriber counts remain hidden, particularly in the public utilities where BSWD, GoAmerica, and Melard have teamed to provide an industry-specific solution.[28] But utilities are tough. BSWD won, then lost, Public Service Electric and Gas to BAM CDPD. BAM also took the field service business at Boston Edison after BSWD had won the E-mail application.

RAM executives long retained high confidence about their subscriber base: "Wireless messaging will grow slowly and surely in 1994 and explosively in 1995."[29] Didn't happen. "There is no doubt in my mind as we move forward through 1995, we will exceed ARDIS."[30] Didn't happen. In October 1995 a more realistic assessment was made: "We're two years behind our subscriber projections and expect 12–18 months more slowness."[31]

By 1997 the focus had changed to two-way paging, endorsed by the parent company: "Our strategy is to provide coverage that is comparable to one-way local paging coverage nationwide."[32] This announcement had been preceded by an order for $90 million to RIM for its interactive pagers, $20 million of which were to be delivered during the first quarter of 1999.[33] At ~$200 apiece, that is 100,000 units to be placed in just that quarter. This should be interesting!

A simplified representation of the very nearly vertical BSWD claimed subscriber counts is depicted in Figure 9-2. Superimposed on the BSWD chart is the ARDIS progress *without IBM*. That is, customers began loading in 1987 on the three-city DRN network—a situation not unlike BSWD's early days—and reached 54,000 paying users in 11 years. By comparison, BSWD claims to have installed 30% more users in just 7 years. It is possible, of course, but unlikely!

9.2.4   CDPD

Few network offerings have ever expected as much short-term business as CDPD. Even after its rocky, long delayed start, in 1995 the mere existence of a carrier-backed alternative caused market observers to pile on ARDIS and BSWD. Following are some examples:
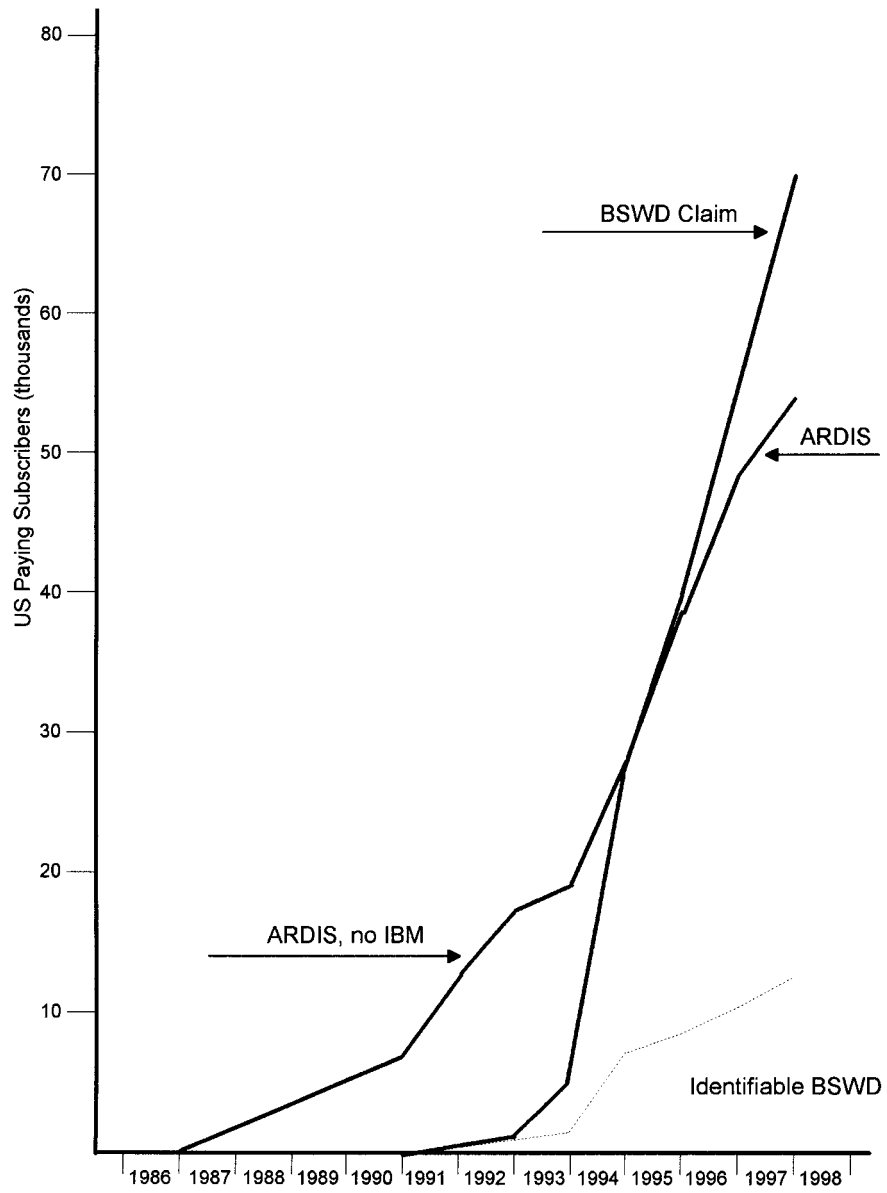
Figure 9-2   BSWD subscriber growth

1. Seybold[34]: ARDIS and BSWD "are not dead yet . . ., but they have to make some moves if they want to keep from being stepped over."
2. Brodsky[35]: "I don't see ARDIS succeeding. . . . Unless they reinvent themselves, [ARDIS] will disappear."
3. Brodsky[36]: "ARDIS and RAM [BSWD] . . . will reach their peaks in total subscribership in 1996 . . . [These] networks then will suffer rapid declines in the following years, and they will go dark around 2000."

Not only were the pundits gloomy, the CDPD enthusiasts were bubbling. In 1996 RadioMail staked its future on CDPD as the best network alternative: "1997 will be the year of CDPD. I predict 100,000 subscribers."[37]

As shown in the prior sections, ARDIS and BSWD did not go away (although RadioMail did). Shown here is evidence that CDPD acceptance has been poor. Appendix F tallies known CDPD users through the third quarter of 1998. If the BSWD 20% identifiable rule is also applied here, CDPD is unlikely to have had more than ~15,500 subscribers at year-end 1997.

It is possible to do a little spin, which you will hear in carrier presentations, and make a case that CDPD actually added early year customers at a higher rate than ARDIS did. This trick is done by stripping away all the IBM content from ARDIS and starting the clock in 1989 when the DRN (ARDIS' predecessor) had three cities fully operational. With this methodology it can be claimed that ARDIS had about 12,750 paying subscribers, net of IBM, at the close of 1991, its "third" year. CDPD, using the five-times identifiable subscribers technique, thus might have grown somewhat faster in its second and third years, ending in 1997. Neither match the BSWD claim, of course. These highly fictionalized accounts are illustrated in Figure 9-3. There is no evaluation of the treasure, both physical and human, expended by CDPD carriers to get these meager results.

9.2.5 Geotek

While GeoTek has expired, it had begun to build a base of data subscribers before the end came. Presumably at least a portion of these users will move to an alternative carrier, possibly Nextel. It is worth taking a count on where Geotek stood at the end of the third quarter of 1998.

In May 1996 GeoTek announced its first data offering: AVL. The plan was "to sell a GPS PC Card from Trimble for $225 to $250 . . . (which) fits into the GeoTek terminal. We think AVL will be very hot."[38]

By August six markets were operational, but the company only had 500 paying customers.[39] By October this had reportedly risen to 2000[40] in seven markets (including Dallas/Ft. Worth). The year-end 1996 goal was 10,000 subscribers. At the same time a fleet management service was announced with heavy emphasis on AVL, priced at $19.95 per month.

But trouble occurred during the fourth quarter of 1996. Loading essentially stopped, and there were clearly accounting problems with the earlier reported
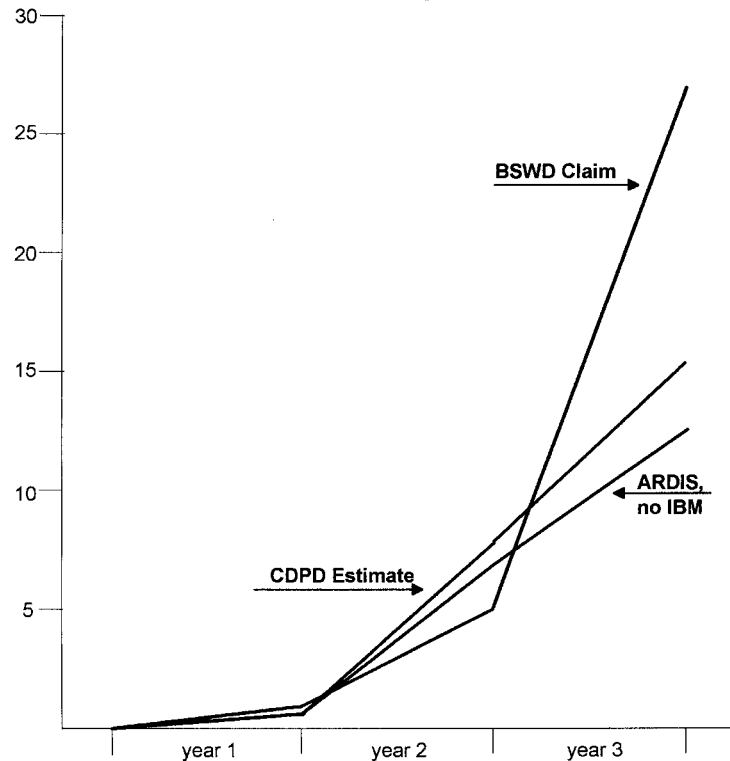
Figure 9-3   Initial three-year performance.

subscriber count. At year-end 1996 there were only 1500–1600 subscribers,[41] a sharp decline from the earlier third quarter 1996 reported position.

After that low point, Geotek seemed to recover. Subscriber counts began to rise. But disaster loomed in May 1998, when Geotek announced: "Cash resources at May 15 are insufficient to fund both . . . current operations and the full implementation of [the] business plan in the short and long term."[42] On June 29 Geotek entered Chapter 11 bankruptcy court proceedings but kept its subscribers on the air[43] until October.

It is, of course, impossible to know the true voice/data usage mix of these subscribers. However, Geotek reported in early 1997 that "85% of its potential customers were not willing to sign on for voice alone; they also wanted the ability to send wireless data and to locate vehicles."[44] Thus, the total subscribers are reduced by 15% to approximate those devices using data. See Table 9-4.

9.2.6   Metricom Ricochet

From a position of about 300 subscribers at year-end 1995, Ricochet reached 19,000 users at year-end 1997[50] and 24,000 by second quarter 1998.[51] Growth subsequently

Table 9-4   Estimated Geotek data users

Period	Number of Subscribers	Number of Data Users
1997		
First quarter	2,000[45]	1,700
Second quarter	5,400[46]	4,590
Third quarter	10,000[47]	10,000
Fourth quarter	12,595[48]	10,706
First quarter 1998	17,053[49]	14,495

slowed, with the subscriber count only reaching 25,000 by mid-November.[52] This is still a very rapid expansion, especially as it was accomplished in a relatively tiny geographic area. Unlike Geotek, there is no uncertainty here; all users are data, and only data. The documented subscriber counts are given in Table 9-5 for the dates specified.

9.2.7   SkyTel2

SkyTel has a variety of product and service offerings. For this analysis only the SkyTel two-way devices were examined. The device counts came from SkyTel quarterly reports, especially the "Domestic Units in Service Detail" sections. Counts were taken from both SkyTel direct and the Destineer wholesale reports. A summary is given in Table 9-6.

After a sluggish 1996 waiting for Pagewriter to replace Tango, SkyTel two-way devices surged through the second quarter of 1998. This growth is depicted in Figure 9-4.

Table 9-5   Metricom Ricochet subscribers

Date	Number of Subscribers
12-31-95	300
9-30-96	6,100
12-31-96	9,000
3-31-97	12,000
6-30-97	15,000
12-31-97	19,000
6-30-98	24,000
11-11-98	25,000

Table 9-6   SkyTel 2-way pager growth

	Fourth Quarter 1995	1996				1997				1998	
		First Quarter	Second Quarter	Third Quarter	Fourth Quarter	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	First Quarter	Second Quarter
Direct	—	13,600	15,900	18,200	20,200	24,000	28,600	42,100	50,900		
Wholesale	—	2,500	2,500	1,600	1,400	2,100	7,100	8,600	9,800		
Total	12,100	16,100	18,400	19,800	21,600	26,100	35,700	50,700	60,700	65,500	80,000
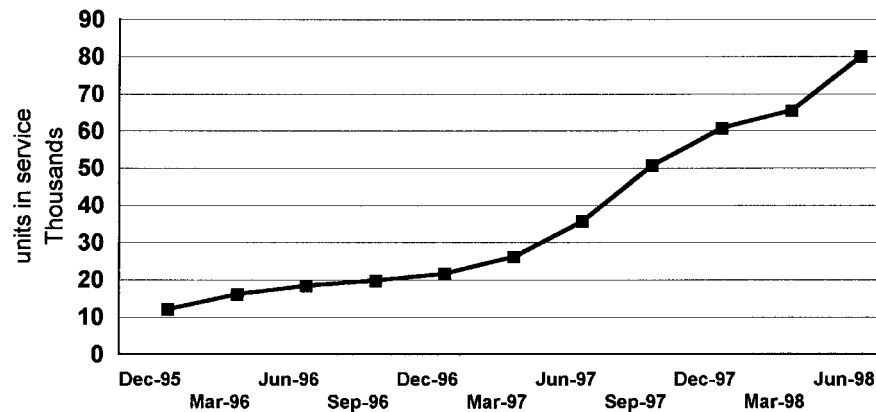
Figure 9-4   SkyTel 2-Way pager growth.

9.2.8   Teletrac

Founded in 1988, Teletrac subscribers grew slowly for four years, then shot skyward to more than 75,000 subscribers by year-end 1997, more than 80,000 by the first quarter of 1998.[53] This later trajectory is much like that of BSWD. The prior year-by-year figures were previously given in Table 4-8.

9.2.9   Analog SMRS

In 1986, after endorsements[54] from leading manufacturers such as General Electric, E. F. Johnson, and Motorola, the FCC allowed SMRS data transmission on a secondary basis. The goal was to encourage new application development while conserving spectrum via data technology. The applications envisioned were not particularly complex, chiefly telemetry and automatic vehicle monitoring. Results were expected to be near instantaneous[55]: "Data communications over SMR networks is just across the border . . . MDI soon will be offering a 'digital clipboard.'"

But little happened[56]: "despite rosy reports from data equipment manufacturers, including some projections of 50% data users by 1992, most of the operators at ASNA's meeting were lukewarm about . . . data on their trunked systems." In fairness to the equipment vendors, there were also some operators[57] who were "bullish on data," believing as many as 20% of their customers were ready.

The years dragged by. Many promising device manufacturers failed. Every unexpected incident of data usage via SMR—Dixie Marine's facsimiles,[58] the Memphis Police[59] test of portable computers, Arizona Public Service,[60] Express-It Courier[61] with GPS, Coast Plumbing,[62] Minute Man Delivery,[63] or Messenger Express[64]—was seen as proof that[65] "the year of planting seeds . . . is getting ready to harvest its first fruit." (I really did not make that up.)

At the close of 1993 Economic and Management Consultants International (EMCI) and American Mobile Telecommunications Association (AMTA) released the results of a survey of the SMR industry[66]: "about half (of the SMR operators) offer some type of mobile data services compared to 45% at (YE'92). Only about 7% of . . . subscribers, however, used these services." At last! A number of reasonable magnitude! Since 1993 was certain to close at ~1.5 million SMRS subscribers, the number of data users was presumably ~100,000—not too bad considering that earlier unrelated work indicated[67] that "only about 15% of today's radios offer data connectors."

But the subscriber counts remained elusive. Vendor-by-vendor tallies revealed low shipments, with the equipment manufacturers often surviving only on their Canadian and private network business (and, alas, many did not make it). Dataradio is an example of a survivor. Note carefully the wording of its market share claim[68]: "Dataradio enjoys a 60 percent market share based on sales of radio modems for *private* [italics added] networks sold since 1988." Do not rush to perform a Dun & Bradstreet (D&B) analysis of this important manufacturer. It is not kept up to date. Nor can it be found on the Securities and Exchange Commission's (SEC) EDGAR archives.

But the probing did reveal a sense that data devices employed on SMRS were of the simplest type: unidirectional number identification and status reports, as well as GPS positions. In early 1995 EMCI and AMTA released the results of a new SMRS survey[69]: "about 5% of SMR subscribers—some 96,000 users—currently transmit data." That is, while SMRS subscribers rose by ~300,000 during 1994 to 1.8 million users, data users were stagnant at best and probably fell. The most common form of data was AVL (35% of users).

Interest in data continued to decline. along with the analog base. In 1996 the SMR industry added 210,000 digital subscribers, driven by Nextel, but only 80,000 analog users.[70] In 1997, digital made spectacular gains; Nextel alone added 1.27 million digital subscribers.[71] But Nextel also turned off more than 200,000 analog subscribers of more than a million units; overall analog actually declined by 160,000 subscribers,[72] bringing it below 1994 levels. As the SMR industry struggled with new opportunities in other frequency bands, the common cry went up: "Let other services handle combined paging, . . . and data . . . 220 MHz will serve the oldest of land mobile needs, . . . voice dispatch."[73] The judgment is that all analog SMRS had fewer than 100,000 data users at year-end 1997.

9.2.10   Public Packet Switched Summary

While no individual public packet switched carrier has met its own internal goals, the cumulative growth rate of the eight "leaders" (counting the defunct Geotek) has produced an impressive compound growth rate of 31% per year since 1989. What is more, that growth rate is accelerating in spite of flat performance from analog SMRS. There were more than 415,000 public packet data users at the close of 1997. The summaries are given in Table 9-7 and displayed in Figure 9-5.

Table 9-7   Public packet switched subscriber growth

Year End	SMRS (1)	Teletrac (2)	ARDIS (3)	BSWD (4)	SkyTel2 (5)	Ricochet (6)	CDPD (7)	Geonet (8)
1989	30,000	0	16,771	0	0	0	0	0
1990	40,000	2,000	22,000	0	0	0	0	0
1991	50,000	5,000	27,000	50	0	0	0	0
1992	60,000	9,500	31,000	1,000	0	0	0	0
1993	75,000	27,300	32,000	5,000	0	0	0	0
1994	96,000	37,200	40,000	27,000	0	50	50	0
1995	98,000	47,100	50,000	40,000	12,100	300	770	0
1996	99,000	57,000	60,000	55,000	21,600	9,000	7,920	1,300
1997	100,000	75,300	65,000	70,000	60,700	19,000	15,510	10,710
Cumulative	1	1+2	1+2+3	1+2+3+4	1+2+3+4+5	1+2+3+4+5+6	1+2+3+4+5+6+7	All
1989	30,000	30,000	46,771	46,771	46,771	46,771	46,771	46,771
1990	40,000	42,000	64,000	64,000	64,000	64,000	64,000	64,000
1991	50,000	55,000	82,000	82,050	82,050	82,050	82,050	82,050
1992	60,000	69,500	100,500	101,500	101,500	101,500	101,500	101,500
1993	75,000	102,300	134,300	139,300	139,300	139,300	139,300	139,300
1994	96,000	133,200	173,200	200,200	200,200	200,250	200,300	200,300
1995	98,000	145,100	195,100	235,100	247,200	247,500	248,270	248,270
1996	99,000	156,000	216,000	271,000	292,600	301,600	309,520	310,820
1997	100,000	175,300	240,300	310,300	371,000	390,000	405,510	416,220
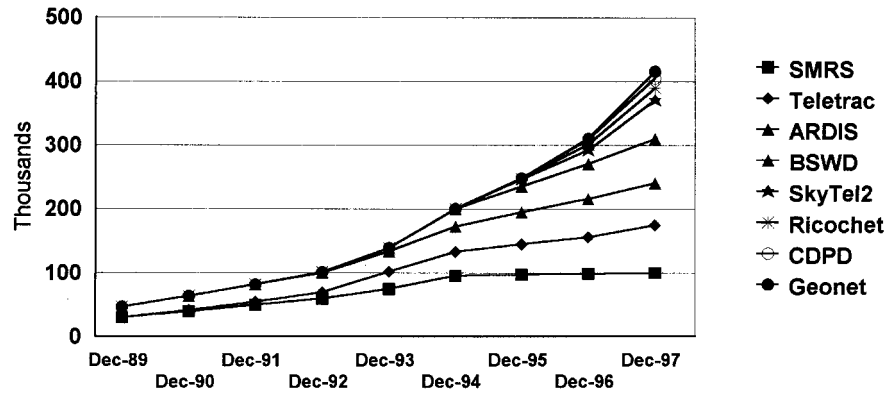
Figure 9-5 Public packet switched subscribers: cumulative.

9.3 PUBLIC CIRCUIT SWITCHED SUBSCRIBERS

9.3.1 Data over Cellular

Users began to transmit data over cellular as soon as Chicago AMPS was available in October 1983. Sensing a potential opportunity, in the Spring of 1985 Bell Atlantic began piloting with 20 organizations using three different laptop models and the CTS1620 modem.[74] CompuServe had five operational "cellular cities" by February 1986.[75] In March 1987 Ameritech offered the first "311" U.S. data service.[76] In 1991 Information Systems introduced its Computer Automated Transmission system, based squarely on Tandy products: PCs, integrated modem, and cellular phone; these were tied together with Tandy's data adapter, which also could handle a Ricoh fax.[77]

Carrier hopes ran high. In 1988 Ameritech's president stated: "Transmission of data . . . is going to become a major portion of the cellular industry's growth in the next few years—probably up to 20% of future cellular service."[78] The same year BellSouth Mobility stated: "the 90's will definitely be the decade of data. . . . More than 15% of our customers have indicated a strong interest in data communications service."[79] In 1992 Bell-Mobility (Canada) predicted that "within 5 years as much as 20 percent of [our] . . . *traffic* could be data."[80]

But customer resistance quickly stiffened, and some carriers were disillusioned:

1. In April 1986, after a year of intense effort, Spectrum Cellular had only been able to sell 1000 Bridge/Span cellular modems[81]; by June 1990, more than five years after first customer ship, the Spectrum cumulative total had reached only 12,000 units.[82]

2. In 1989 the Los Angeles Police Department announced plans to test ~25 laptops via cellular, commencing the first quarter of 1990. The market potential was estimated to be 3500 ± 500 units in an application already using ~850

Electrocom Automation devices.[83] Nearly simultaneously the California Trucking Association announced a plan for 2500 members to use data over cellular.[84] Both projects stalled out.

3. In February 1990 Cellular Solutions' carefully targeted Multiple Listing Service system for real estate agents failed in spite of the choice of the agent-familiar T.I.707 terminal and the fact that one-third of the agents already had cellular phones.[85] The reasons given were agent resistance and high turnover.

4. In 1991 GTE abandoned testing of Spectrum's Bridge and Span because it "wasn't sufficiently impressed . . . to include (them) at the MTSO. If a customer wants to transmit data over cellular we won't stand in their way, but it's not cost effective."[86]

5. In 1992 Shell Oil ceased work on its Houston cellular data network since data "was getting splattered by noise."[87]

6. In March 1992 AT&T Safari said that "marketing of (wireless) options is going slow, very slow . . . and it doesn't look like it will pick up any time soon."[88]

7. In 1993 Eastman Kodak, after a four-city "technical success" using MNP10 modems to save a half hour per day of a service technician's time, did not proceed with the project because they could not offset the $250/month cost by time saved.[89]

8. In 1995 MCI announced that it "has put off introducing [cellular] wireless connectivity to its 5,000 member sales staff until later [in 1996] at the earliest. In addition to the headaches of training and support, the lack of an affordable, ubiquitous network has relegated wireless connectivity to the back burner."[90]

It became clear that in spite of success with UPS, data over cellular was not going to be easy. But it was hard to know whether there was trouble in River City. Prior to the advent of modem pools, the carriers did not really know how many data users were on the air. A better grasp of who is using data via circuit switched cellular is now available to modem pool providers, but it is not truly complete. The casual users of data/fax via cellular, those who choose not to pay for modem pool data service, are still unidentified. Estimates must be made the hard way—via public reports from users proud of their success and through sampling.

9.3.1.1   Practical Counting Problems   A data/fax call can be handled as if it were just an oddball voice. The range of modem types known to be using cellular is as wide as anything encountered on wireline systems. Parsons Bromfield-Redniss & Mead, a surveying firm in Fairfield County, Connecticut, has long used very low speed acoustic couplers attached to a cellular phone to transmit data to and from laptops in the field. I very occasionally use an ordinary 1200-bps integrated wireline modem (a true artifact!) via a Spectrum AXCELL interface. It works fine. The Miami Fire Department has cellular EKG units in its emergency rescue vehicles.[91] Ubiquitous wireline grade MNP modems also work well with cellular. AirTrue

published results of "dialing hundreds of BBS numbers randomly scattered throughout the U.S."[92] with results nearly equivalent to that achieved on the wireline network. None of this activity is detectable by the carriers.

The same generalities hold true for facsimile transmission via cellular. If the speed is held down to, say, 4800 bps, "any old" facsimile works well with fax modems and cellular phones with data attachment capability. During 1994 my Ricoh PF-2 portable fax actually outperformed my wireline machine (I have lousy, underground, wet-when-it-rains wireline service). Naturally, the cellular carrier could not distinguish the fax from voice.

9.3.1.2   *Search for the Right Ballpark* Estimates of the number of cellular data users are extremely wide ranging. In 1993 carriers began to report estimates of cellular data or facsimile usage on their own systems. Sprint thought that 3–10% of its subscriber[93] could be users—a relatively imprecise guess. Bell Atlantic Mobile was not particularly helpful either. They felt that 3% of their cellular *traffic* was data,[94] but this could easily have been generated by 1 or 20% of users. Bell Mobility (Canada) projected that "2 to 3 percent . . . of (their) customers may be using the system for data transmission by the end of (1993)."[95]

Into this information void stepped a number of consultants with their own guesses. Samples of these estimates are provided in Table 9-8.

Since the first EMCI estimate was flawed, and later withdrawn, it can be discarded. The estimates of BIS Strategic Decisions and its successor Giga Information are so erratic as to be unusable. Both 1993 estimates, while very close to each other, may have been tainted by the "big news" of UPS adopting data over cellular for the brown trucks. This leaves four data points, one each from four separate sources, that lie along a believable regression line. The results are shown in Figure 9-6 and indicate that there were ~800,000 data users at the close of 1997.

9.3.1.3   *Sanity Checks*

9.3.1.3.1   Business Cellular A straight regression line for cellular seems counterintuitive. Everyone knows cellular usage is exploding. Why doesn't the data curve take on a hockey stick shape? After all, in the words of Thomas E. Wheeler, CTIA President & CEO, "the (cellular) wireless revolution continues unabated."[96]

CTIA also notes that "the average monthly phone bill continues to fall." But, pre-1998, was the reason for the decline in average monthly bills an airtime price reduction? Probably not. It is more likely that "the average monthly bill was declining mainly because of a change in the mix of customers."[97] This is a clue that the undeniable, eye-popping growth in total cellular customers does not map precisely to data users. Cellular *business* customers—the source of data traffic—are not truly exploding (though growing very, very nicely).

Consider the example of my airtime service bill. In 1993, when portable instrument prices first routinely dropped below $100, I got one to pass between glove compartments. Sometimes I take it on my boat. I rarely use it for anything. But this

Table 9-8 Historical data-over-cellular user estimates

Carrier	User Estimates				
	1992	1993	1994	1995	1996
Herschel Shosteck Assoc.	220,650[a]	480,000[b]			
EMCI	500,000[c]				
U.S. Commerce Dept.		500,000[d]			
EDS			480,000[e]		
BIS Strategic Decisions			300,000[f]		
Giga Information Group[g]	88,500	—	—	1,052,000	
Dataquest				510,000[h]	
MTA-EMCI					700,000[i]

[a]"~2% of [11,032,753] of the cellular subscribers . . . are transmitting data *including facsimile* [italics mine]"; *Mobile Data Report*, 12-21-92.

[b]"~3% of [16,009,461] cellular subscribers use the services to transmit data"; *Communications Week*, 1-3-94.

[c]"Portable facsimile and laptop computing . . . already are being used by approximately 500,000 subscribers"; *Land Mobile Radio News*, 3-19-93. The study was later recanted.

[d]"Approximately 500,000 U.S. cellular subscribers currently use portable faxes and modems"; *U.S. Industrial Outlook*, 1994.

[e]Barry Goodstadt, EDS Director of Wireless Industry Consulting, "Right now, only ~2% of all [24,134,421] cellular voice customers use the network for data"; *Data Communications*, 3-21-95.

[f]"The (total two way) wireless data installed base (was) 500,000 last year"; *Wireless Messaging Report*, 7-4-95. Since ARDIS, BSWD, SMRS, Omnitracs, and Teletrac accounted for ~200,000 units, the balance has been assigned to cellular.

[g]Formerly BIS Strategic Decisions, "the number of wireless data users . . . grew from 190,000 in 1992 to 1.3 million in 1995"; *Information Week*, 1-29-96. Rated to allow for same-year packet totals of 101,500 and 248,270.

[h]www.3com.com/carrier/nsd/technology/30201.html.

[i]www.3com.com/carrier/nsd/technology/30201.html.

phone counts in the exploding subscriber base and in the declining average monthly airtime bill. It will never be used as a data conveyance. Suppose we generalize on the business versus consumer mix. While the carriers tend to guard this distinction, CTIA tells us much that we need to know to make reasonable guesses. Using CTIA document No. 3100, the first analysis item is the average call duration. It has held at $2.36 \pm .21$ minutes for more than nine years. This indicates little change in the average call profile, permitting us to deal with one less estimating variable.

An infinite number of price values can be assigned to call types. For illustration purposes let us assume that the cellular subscriber consistently seeing an average monthly bill of $20 is almost certainly nonbusiness. Note that the bill can wobble around: $15 this month, $25 the next. Our interest is only in a low long-term average. Assume further that the cellular subscriber consistently racking up an average monthly bill of $120 per month is almost certainly using the phone for business purposes.
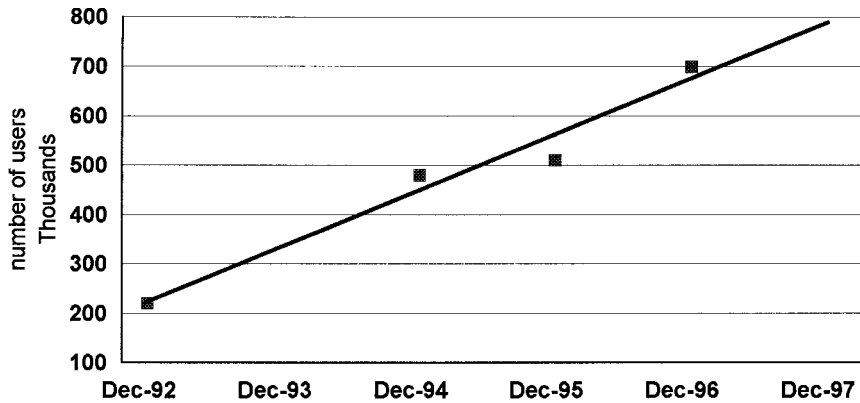
Figure 9-6   Data-over-cellular user growth.

With these simple assumptions and using the CTIA report of total subscribers and their average monthly bill, one can crudely assign how many subscribers of each type, consumer versus business, exist:

$$\frac{(\$20 \times \text{number of consumers} + [\$120 \times (\text{subscribers} - \text{consumers})]}{\text{Total number of subscribers}}$$

$$= \text{average monthly bill}$$

This calculation permits Table 9-9 to be constructed.

The first two columns, date and total subscribers, are direct lifts from CTIA document No. 3100. Columns 3 and 4 reflect the \$20/\$120 algebra, which produces the CTIA average monthly bill. Thus, the true explosion in cellular subscribers comes from consumers: a 68.9% CGR over nine years. The business growth has "only" a 32.8% CGR. These calculations appear inherently reasonable; no weird anomaly jumps off the pages. The graphic view of this split is shown in Figure 9-7.

The estimated data users created from our little regression analysis are present in column 6. Note that while 2% of all cellular subscribers were estimated to be data users in 1992, 4.1% of the business users were. As our data estimates move, so the percent penetration of business data users increases. The business data growth rate is *not* linear; it is actually accelerating, though masked by the consumer voice acceptance.

9.3.1.3.2   UPS   In the first quarter of 1993 ~50,000 UPS trucks were equipped with dedicated data devices,[98] more than each of the ARDIS, Teletrac, or OmniTRACS total installed base. This bump was likely the cause of enhanced data rate change between 1992 and 1993 in Table 9-8. Later, UPS increased the units to 55,000,[99] finally reaching 70,000 drivers in 1997.[100] It will begin to decline in the second half of 1998 as UPS switches from cellular to packet switched using ARDIS.

Table 9-9   CTIA cellular statistics and derivatives

Date	Number of subscribers			CTIA Average ($) Bill	Estimated Data Users	Percent Business Data
	Total	Consumers	Business			
Jan. 1985	91,600					
Jun. 1985	203,600					
Dec. 1985	340,213					
Jun. 1986	500,000					
Dec. 1986	681,825					
Jun. 1987	883,778					
Dec. 1987	1,230,855	285,190	945,665	96.83		
Jun. 1988	1,608,697	402,170	1,206,527	95.00		
Dec. 1988	2,069,441	454,870	1,614,571	98.02		
Jun. 1989	2,691,793	928,100	1,763,693	85.52		
Dec. 1989	3,508,944	1,265,500	2,243,444	83.94		
Jun. 1990	4,368,686	1,575,300	2,793,386	83.94		
Dec. 1990	5,283,055	2,065,700	3,217,355	80.90	112,000	3.5
Jun. 1991	6,380,053	2,899,000	3,481,053	74.56		
Dec. 1991	7,557,148	3,571,500	3,985,648	72.74	150,000	3.8
Jun. 1992	8,892,535	4,578,400	4,314,135	68.51		
Dec. 1992	11,032,753	5,662,000	5,370,753	68.68	220,000	4.1
Jun. 1993	13,067,318	6,885,000	6,182,318	67.31		
Dec. 1993	16,009,461	9,368,000	6,641,461	61.48	320,000	4.8
Jun. 1994	19,283,306	11,830,000	7,453,306	58.65		
Dec. 1994	24,134,421	15,395,000	8,739,421	56.21	450,000	5.1
Jun. 1995	28,154,415	19,019,000	9,135,415	52.45		
Dec. 1995	33,785,661	23,311,000	10,474,661	51.00	570,000	5.4
Jun. 1996	38,195,466	27,180,000	11,015,466	48.84		
Dec. 1996	44,042,992	31,841,000	12,201,992	47.70	700,000	5.7

9.3.1.3.3 HighwayMaster As reported in Chapter 5, HighwayMaster ended in the third quarter of 1998 with nearly 40,000 users. This is a better early year net subscriber acceptance rate than, say, BSWD. Some historical data assembled primarily from quarterly financial reports is shown in Table 9-10. Some of the major names contributing to this growth are contained in Appendix G.

9.3.1.3.4 Miscellaneous A few other blocks of cellular data users exist: Anheuser-Busch's 5000 field sales representatives[101] use AT&T Cellular and U.S. West; F. D. Titus and Sons was scheduled to have 900 field sales representatives using multiple cellular networks by the end of 1996[102]; Univax Biologics put 135 field sales staff on multiple networks the same year.[103]
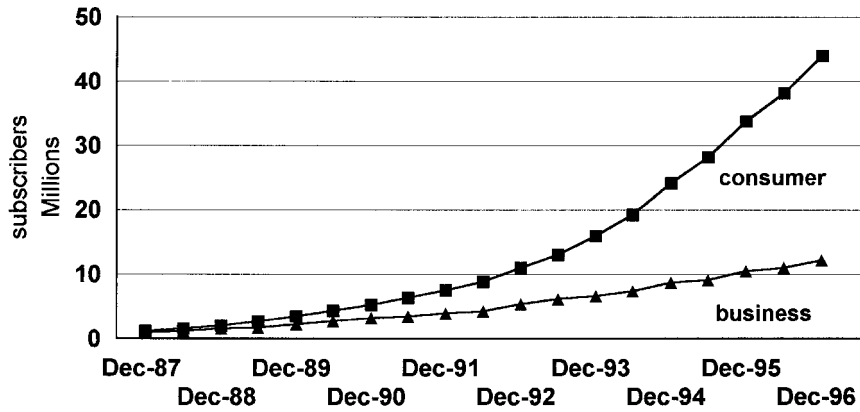
Figure 9-7   Consumer vs. business subscriber mix. Consumer = $20; business = $120 per month.

Cellular One's Bay Area AirWorks provides service to smaller quantities of Hitachi, McKesson, and Octel[104] in the Bay Area. Queries to Cellular One have gone unanswered, but the total number of subscribers is thought to be small.

9.3.1.3.5   Facsimile   A possible wild card is facsimile. A staggering statistic from the Los Angeles market is that "one in four telephone calls today are facsimile to facsimile."[105] It would seem that this phenomenon must have backed up into the Los

Table 9-10   HighwayMaster subscriber growth

Date	Quarterly				Cumulative Subscribers
	Shipped	Installed	Removed	Net Installed	
Sep. 1993					0
Mar. 1995					8,400
Mar. 1996					16,044
Sep. 1996					18,916
Dec. 1996	2,316	1,775	337	1,438	20,354
Mar. 1997	2,932	—	—	2,410	22,764
Jun. 1997	4,758	3,783	1,314	2,469	25,233
Sep. 1997	4,370	4,881	181	4,700	29,933
Dec. 1997	4,251	3,704	515	3,189	33,122
Mar. 1998	2,497	3,211	879	2,332	35,454
Jun. 1998	2,714	2,388	760	1,628	37,082
Sep. 1998	—	—	—	2,591	39,673

Angeles wireless market, driving fax-via-cellular subscriber counts. However, portable fax machines have simply failed to take off since their 1988 introduction, nearly vanishing from sight. As an example, both Nissei and Medbar Enterprises, early pioneers, "either closed or moved to other product categories."[106]

9.3.1.4 *Realistic Expectations* The residual problem is no longer transmission reliability, bit rates, device costs, or "too many boxes." However, stable, enduring connections can be problematic and, until 1998, there was considerable airtime "price stickiness." Meanwhile, the enhanced transmission capability (ETC), MNP, or V.42*bis* laptop modem that works well with a cellular phone usually works even better on landlines—and landlines are everywhere. The mobile need is quite often well served by the ubiquitous RJ-11C phone jack.

   In spite of the inability to identify more than a few large blocks of users—less than 100,000 subscribers—today's cellular data/fax subscribers probably outnumber their packet switched equivalents by a 2-to-1 margin. But these subscribers do not have equivalent business value. The once-per-week facsimile user is simply not a major revenue producer. Cellular data is shaping up to be a case of many low-intensity subscribers—making business value comparisons to packet switched more difficult.

9.3.2 Broadband PCS: GSM

9.3.2.1 *Voice Subscriber Growth* With the exception of BellSouth Mobility, the U.S. members of the GSM Alliance report their PCS voice subscriber counts quite openly. A search of the SEC's EDGAR database yields the required BellSouth counts, filed in various 10K/Q reports. BellSouth Mobility may be shy about publicizing their progress since they have the poorest track record to date, as shown in Table 9-11.

Table 9-11   GSM alliance PCS subscriber growth

	1997				First Quarter 1998
Carrier	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	
Aerial Communications		28,000	65,000	125,000	200,000
BellSouth Mobility	49,000	65,000	77,000	88,000	105,000
Omnipoint		42,000	80,000	141,000	190,000
Pacific Bell Mobile	26,500	123,000	266,000	340,000	420,000
Powertel PCS	34,886	45,271	66,066	118,757	157,000
Western Wireless	49,000	74,400	101,000	127,000	164,600
Totals		377,671	655,066	939,757	1,236,600

9.3.2.2 Data Estimates The natural next question to ask about this most impressive subscriber growth is: How many of these consumers use data? Written requests for carrier information on SMS traffic, or the more intense dedicated data services (not offered by all service providers), or even a single customer data success story, were sent to all six service providers. Only Powertel responded, saying such information was not made public and deflecting the questions to the GSM North American Alliance staff. Subsequent discussions with Alliance personnel[107] revealed that they had no figures on data usage, however much they might wish to blend them into a composite figure. There were anecdotal reports of people liking the data functions; there were no known customer referrals.

GSM data traffic can originate from two very different sources:

1. *Short-Message Service (SMS).* GSM has the ability to transmit short data messages, each up to 160 alphanumeric characters long, over its signaling channels. In the point-to-point mode, this function operates much like a two-way pager. Confirmation is also provided that the message has been received. SMS traffic is typically billed on a per-message basis. Cell broadcast mode is one way and can be used to transmit, for example, traffic conditions, sports news, and stock quotes. That mode is ignored here.

2. *Data Instead of Voice.* Since GSM has a digital TDMA structure, it is possible to assign a time slot to data rather than digitized voice. Multiple data transmission speeds are possible, but the 1998 implementations yield a usable rate of 9600 bps. This capability is typically billed like all circuit switch data, on a time basis.

Because of coverage restrictions, most carriers do not overly emphasize SMS as a paging function. Instead, it is usually promoted first as short E-mail service. The restricted message lengths, and additional message fees, tend to blunt usage. One only has to look at the hard history of RadioMail, WyndMail, or Zap-it to understand how hard it is to be successful with wireless E-mail, especially with severe length restrictions. Dedicated data is not uniformly available. Where it does exist, it contains extra monthly fees (e.g., BellSouth Mobility) or 1-minute, rather than 1-second, airtime billing (e.g., Omnipoint). There is no hard evidence that data usage has been widely embraced by PCS-GSM users. According to the Mobile Data Initiative,[108] "only 2% of GSM subscribers currently use mobile data." That percentage is believed to be somewhat high for a technology in its first full year of roll-out but reasonable. Thus, at year-end 1997 PCS-GSM likely had ~19,000 data users—more than CDPD.

9.3.3 ESMR: Nextel Digital Subscribers

After its initial rocky start, Nextel's entire 1996 subscriber growth came from the addition of digital devices. In 1997, traditional analog SMR devices began to be driven from the playing field, as shown in Figure 9-8.
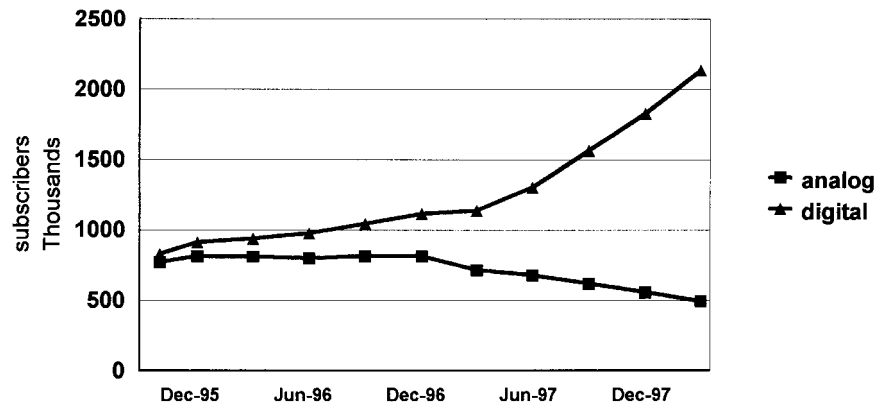
Figure 9-8   Nextel subscriber growth.

While the Nextel digital subscriber base is truly impressive, more than $1\frac{1}{4}$ million at year-end 1997, data emphasis has been virtually nonexistent. In its third quarter 1996 quarterly report Nextel noted that "the Company is focused on providing . . . future data transmission capabilities in . . . a handset." In 1997 the i600 handset was delivered with only "text/numeric paging" capability. This SMS-like function is only capable of 140-character messages.

Nextel's subscriber base has a rich mix of nonbusiness users. The 1997 business subscribers had so little data function available to them that their data usage is believed to be too small to influence the user counts of this chapter.

9.4   PUBLIC SATELLITE NETWORKS

9.4.1   AMSC

After a slow, discouraging start, AMSC finally got its own satellites operational in mid-1995. Starting the subscriber clock from that point, AMSC achieved a year-end 1997 subscriber count of 32,400, some of which are shared with ARDIS in hybrid configurations.[109] Note that ~8400 of these shared units came over with AMSC's "purchase" of Rockwell/ARDIS hybrids, a situation somewhat akin to OmniTRAC's acquisition of CoveragePLUS customers. That hit occurred during the second half of 1996, quite obvious in the subscriber counts. The AMSC subscriber growth, obtained from the company's quarterly reports, is recorded in Table 9-12.

The new AMSC subscribers include many companies previously devoted solely to OmniTRACS, such as J. B. Hunt.

It is interesting to compare AMSC with HighwayMaster, already covered in Section 9.3.1.3.3. Both go after the same market, both have voice capability, and their real production rollouts occurred on very much the same time schedule. They have

Table 9-12   AMSC subscriber growth

Date	Number of Subscribers	Change from Previous Quarter
Mar. 31, 1996	6,300	
Jun. 30, 1996	9,200	2,900
Sept. 30, 1996	13,400	4,200
Dec. 31, 1996	20,300	6,900
Mar. 31, 1997	23,000	2,700
Jun. 30, 1997	25,700	2,700
Sept. 30, 1997	29,300	3,600
Dec. 31, 1997	32,400	3,100

accumulated a bit more than 65,000 units between them, shared neatly, half for each, as shown in Figure 9-9.

9.4.2   OmniTRACS

Qualcomm is quite open about reporting its U.S. customer names and its worldwide terminal shipments. A representative list of U.S. users can be found in Appendix H. This is not meant to be exhaustive; it is simply a record of OmniTRACS orders/installs captured while searching for other information. This list is believed to account for more than half of the U.S. operational units.

At the close of 1994 Qualcomm switched from U.S. to worldwide shipment reports. Estimates of U.S.-only devices, which uniquely generate billable message traffic, are now obscured. It is clear that the growth rate has slowed. In the quarterly report reflecting 1996 U.S. activity the warning was issued[110] that "domestic *and*
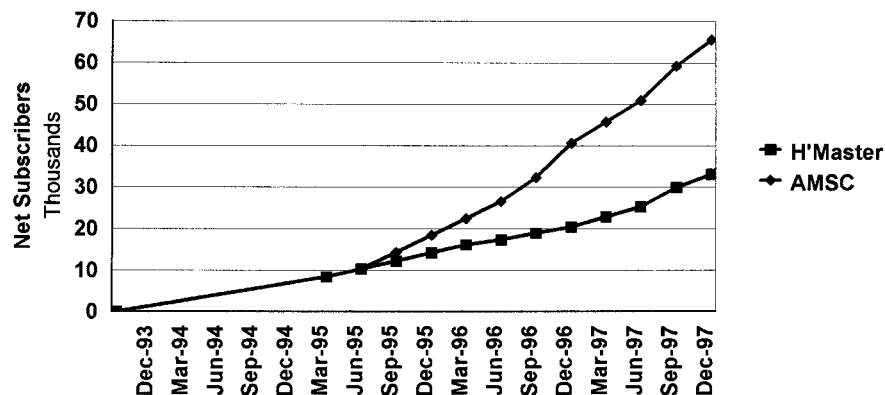
Figure 9-9   AMSC and HighwayMaster subscriber growth.

international [italics mine] . . . shipments continued strong in the face of a soft trucking market in the U.S." Eight months later Qualcomm warned[111] in its 10Q that "competition has resulted in a reduction of the margins on unit sales and service in fiscal 1996 and through the first nine months of fiscal 1997." Some of this competition clearly came from both AMSC and HighwayMaster. Together they likely counted for 30,000–35,000 U.S. units that might have gone to OmniTRACS in its salad days. Even TranSettlements, operating via CS-CDPD, appears to have picked off an OmniTRACS customer: Silver Eagle.[112]

A gross summary of worldwide OmniTRACS device "shipments" is included in Table 9-13. Be careful. There is some imprecision in Qualcomm's reporting. The words *shipment*, *install*, and *sales* are sometimes used interchangeably.

Table 9-13   OmniTRACS worldwide shipments

Shipping Date	U.S. Shipments	Worldwide Shipments	Source
Oct. 1989	5,500		*Industrial Communications*, 11-10-89.
Dec. 1989	5,515		*Communications Daily*, 7-12-96.
May 1990	7,500		*Mobile Data Report*, 6-18-90.
Sep. 1990	8,600		*Mobile Satellite News*, Sept. 1990.
Dec. 1990	10,000		*Edge On & About AT&T*, 1-23-95.
Jan. 1991	12,000		*Inside IVHS*, 2-4-91.
Mar. 1991	13,500		*Mobile Data Report*, 3-11-91.
Jan. 1992	22,000		*En Route Technology*, 2-5-92.
Jul. 1992	29,000		*En Route Technology*, 8-5-92.
Dec. 1992	30,000		*Edge On & About AT&T*, 1-23-95.
Mar. 1993	35,000		*Communications Daily*, 4-7-93.
Jun. 1993	45,000		*Mobile Satellite Reports*, 7-5-93.
Dec. 1993	60,000		*Edge On & About AT&T*, 1-23-95.
Mar. 1994	65,000		*Mobile Satellite Reports*, 4-25-94.
Nov. 1994	95,000		*Mobile Satellite News*, 11-17-94.
Jan. 1995	—	106,000	*Edge On & About AT&T*, 1-23-95.
Apr. 1995	—	111,000	*Mobile Satellite News*, 4-6-95.
Apr. 1995	100,000	116,000	M2 presswire, 4-21-95.
Nov. 1995		137,000	*Wireless Business & Finance*, 11-8-95.
Jan. 1996		147,000	*Mobile Satellite News*, 1-25-96.
May 1996		155,000	*Knight Ridder/Tribune*, 5-30-96.
Jul. 1996		165,000	*Communications Daily*, 7-12-96.
Dec. 1996		175,000	Qualcomm press release, 1-2-97.
Dec. 1996		185,000	Qualcomm Fiscal 1Q97 Report, 1-20-97.
Mar. 1997		194,000	Qualcomm Fiscal 2Q97 Report, 4-21-97.
Jun. 1997		195,000	Qualcomm press release, 7-1-97.
Aug. 1997		201,000	Qualcomm press release, 8-12-97.
Sep. 1997		210,000	Qualcomm Fiscal 4Q97 Report, 11-11-97.
Dec. 1997		216,000	Qualcomm press release, 1-7-98.
Jan. 1998		224,000	Qualcomm press release, 1-26-98.
Mar. 1998		230,000	Qualcomm press release, 3-31-98.

One must further discount some of these U.S. devices as spares, not airtime message generators. Further, there is no mention of attrition, replacements, or churn of any kind. Some of this must have occurred with the coming of SensorTRACS. The U.S. estimate, therefore, is considered unrealistically high if it is taken as a count of current, paying U.S. subscribers. The actual number, less spares and modest replacement activity, is likely to be closer to 135,000 than to 150,000 units. A chart of worldwide shipments, with an estimate of the U.S. component, is shown in Figure 9-10.

9.5 SUMMARY

While there are varying degrees of openness, precise information on subscriber counts tends to be guarded by the packet switched and satellite carriers. The circuit switched cellular carriers face a more basic problem. Often they are unable to discriminate between a voice and data call and thus could not give an accurate count even if they wanted to. Except for SMS traffic, which is not reported, the members of the GSM Alliance face a similar problem, though the need for device software gives them an excellent "marker."

Traditional market research techniques have been used to estimate operational subscribers. Some counts, such as SMRS users, are exceedingly hard to estimate accurately, and the data numbers that do exist are almost certainly riddled with simple, unidirectional applications. Some counts are believed to be overstated by the carriers but, accepted at face value, they must produce very little revenue for the investment made to date. All carriers are years behind their original data deployment schedules, but real growth is evident. The cumulative impact of all these competitors, growing at rates that are uniquely disappointing to them, yields a very good overall growth rate for the industry. This is illustrated in Figure 9-11, a summary of the activity in the three
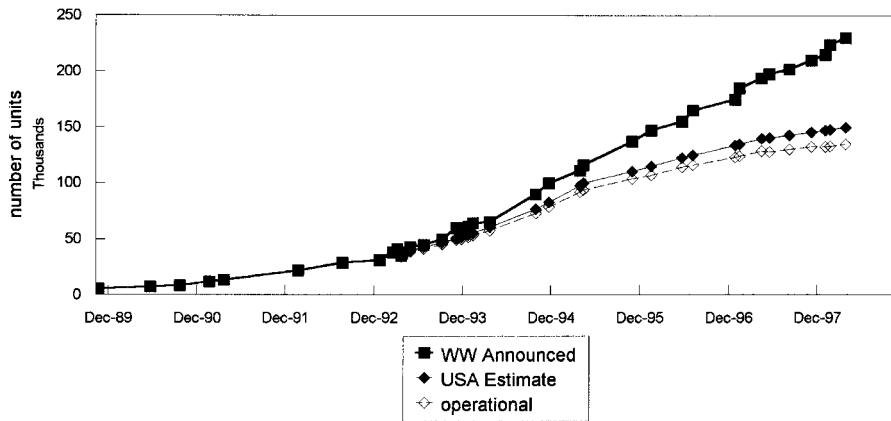
Figure 9-10 OmniTRACS shipments.
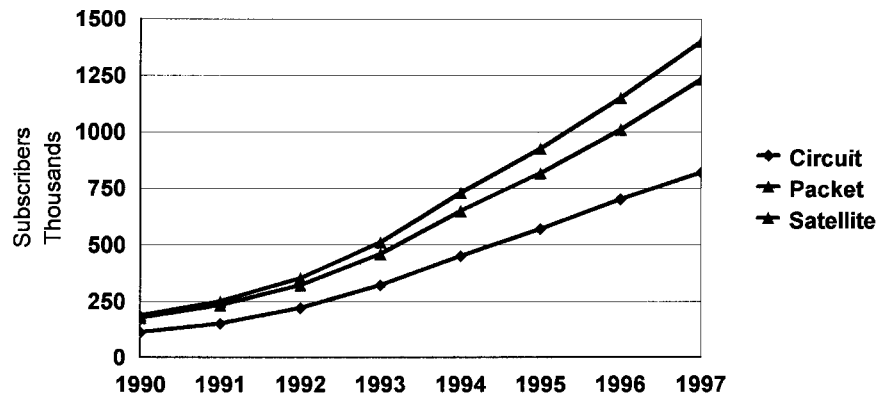
Figure 9-11 Combined two-way wireless data subscribers: public networks.

major categories. From year-end 1990 to year-end 1997 the subscriber compound growth rate exceeds 33%. The packet/satellite combination is growing at a faster rate than data over cellular. This difference is expected to become more pronounced by the close of 1998.

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10

MARKET OPPORTUNITY

10.1   SECOND ERA OF LOW HANGING FRUIT

Most carrier business planning personnel and hardware providers have long been captivated by the perceived market opportunity for data. In 1993 AT&T Wireless projected that "1 billion people will use wireless modems for electronic data communications by the year 2000."[1] Since that was one-quarter of the population of the earth, only seven years in the future, the number was bound to draw attention. While that particular projection was patently absurd, for the next few years AT&T Wireless continued to espouse greatly reduced but still aggressive forecasts. A 1995 example is: "Paging and data . . . could grow to 62 million by 2000 and 90 million by 2005."[2]

Consultants, pundits, and the desperately needy have had a field day with projections of how large, and how quickly, the wireless data market would develop. The peak fantasy year may well have been 1992. With ARDIS, BSWD, and OmniTRACS all operational and CDPD announced, the future never looked rosier.

Table 10-1 is a representative sample of very large subscriber forecasts made during this period. More than half are "unanchored" projections: views of the future in which the present was unknown, unstated, or unreported. Lotus had the steepest slope; its forecast had 10 million in place within three years. Jack Blumenstein's 60 million for the year 2000 was later sustained by AT&T's Kendra VanderMeulen. The next four projections were richly similar to each other. In 1994, when counterevidence was clearly available, BIS Strategic Decisions, after a prior, conservative 1993 forecast, joined the high flyer group in 1994, just as they began to waver in their convictions.

Table 10-1 does not contain information that really helps one plan a business. Given the vintage, the large quantities were almost certainly emotionally driven. Key

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Table 10-1   Representative early subscriber projections (high)

Source	Year of Estimate	Estimated User Base	Projection	
			Year	Quantity
Lotus Portable Computing Group[a]	1992	350,000	1995	10,000,000
Jack Blumstein: ARDIS CEO[b]	1992	Unknown	2000	60,000,000
K. VanderMeulen: AT&T Wireless[c]	1995	Unknown	2000	62,000,000
EMCI[d]	1992	Unknown	2000	16,000,000
Arthur D. Little (Cliff Bean)[e]	1992	<500,000	2000	13,500,000
PacTel Cellular[f]	1992	Unknown	2000	13,000,000
Yankee Group (Roberta Wiggins)[a]	1992	500,000	2000	13,000,000
BIS Strategic Decisions[h]	1994	Unknown	2000	15,000,000

[a]Woody Benson, *Reseller Management*, Jun. 1992.
[b]*Industrial Communications*, 4-24-92.
[c]*Communications Daily*, 10-31-95.
[d]*Communications Daily*, 12-30-92.
[e]*Communications Week*, 12-14-92 (includes EMBARC).
[f]*Mobile Phone News*, 10-8-92.
[g]*Communications Week*, 10-26-92.
[h]*Wireless Data News*, 11-30-94; *Land Mobile Radio News*, 9-2-94.

phrases flag such sentiments: "This is going to be an explosive market"[3] or "mobile data . . . will undergo explosive growth in the next decade" (do I detect a cliché?)[4] or "it has amazing growth potential."[5] There was also serious self-delusion: "Suddenly, the wireless market is taking off" (really?).[6]

By comparison, Table 10-2 is a model of prudence, even though no two forecasts agree. But hidden in this seemingly random blur of numbers are useful insights into how the market has developed over time.

With a few simplifying selections, an interesting view of the changing opportunity projections is shown in Figure 10-1. The IBM/Motorola enthusiasm of 1982—the first era of low hanging fruit—had barely dimmed seven years later with the ARDIS Red Book forecast. But with each successive annual disappointment, the then-current install position was recalculated; the slope of the curves became less intense. The "realistic slope" line, suggested from this continuous adjustment of the installed base, turns out to be lower than the seemingly too-conservative Forrester Research projection of 1992.

When will the ramp become a curve? In early 1998 Yankee Group believed a marked upward turn would begin in 1999. It had earlier predicted a truly "mass market" by 2002.[7] Through the years Yankee Group has had problems with its forecasts. Initially, there was the usual tendency to overestimate the current installed base. But as late as 1996 Roberta Wiggins, Yankee Group's Director, Wireless & Mobile Communications, stated, "I believe there are as many as 500,000 CDPD devices operating in pilot today." This claim was later retracted.[8]
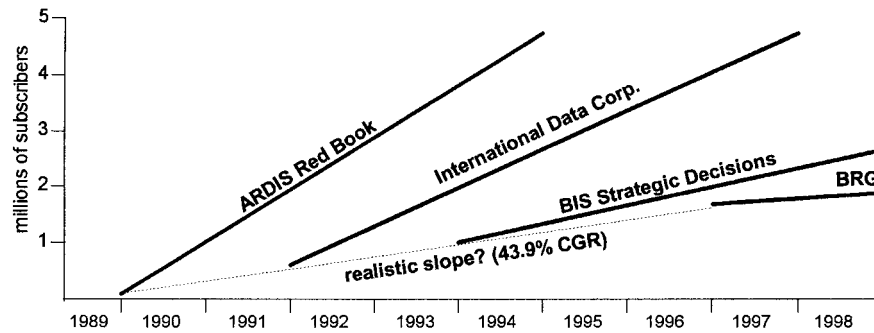
Figure 10-1 Shifting subscriber projections (medium)

Table 10-2 Representative subscriber projections (moderate)

Source	Year of Estimate	Estimated User Base	Projection Year	Projection Quantity
IBM/Motorola ARDIS Red Book	1989	125,000	1994	5,000,000
International Data Corp[a]	1991	600,000	1997	5,000,000
Forrester Research[b]	1992	<140,000	1993	147,210
			1994	640,640
			1995	1,188,480
			1996	1,841,120
			1997	2,625,000
Decision Resources[c]	1993	600,000	1997	5,000,000
Link Resources[d]	1993	Unknown	1998	4,208,000
Ovum, Ltd.[e]	1993	Unknown	1998	2,670,000
BIS Strategic Decisions[f]	1993	1,000,000	2000	3,900,000
PCIA[g]	1994	Unknown	1998	3,360,000
			2003	5,600,000
Business Research Group (#1)	1994	1,500,000	1998	6,800,000
Business Research Group (#2)[h]	1997	1,600,000	1998	1,900,000
			1999	3,000,000
			2000	6,000,000
			2001	8,600,000

[a]*Data Communications*, Feb. 1993.
[b]*Mobile Data Report*, 6-1-92.
[c]*Mobile Satellite News*, 9-15-93.
[d]ARDIS Lexington Conference, 7-27-93.
[e]ARDIS Lexington Conference, 7-27-93.
[f]*Land Mobile Radio News*, 10-1-93.
[g]*Telecommunications Reports*, 1-31-94.
[h]*Wireless Week*, 3-9-98.

In 1992 Yankee Group projected approximately 13 million users by the year 2000. A year later the projections dropped to less than 10 million. In 1995 their view altered still further[9]: "Why aren't more businesses willing to transmit data over wireless networks? They have little business need. . . . Widespread demand for wireless data communications will take time to develop." By 1998 the forecast for the year 2000 was down to 6,400,000.[10] A sample of these forecast revisions is shown in Table 10-3.

But Yankee Group is not simply creating forecasts that support a time-delayed ramp. They believe that while the startup has been disappointingly slow, a huge opportunity is still there. Subscriber growth rates are about to "hook" to realize that opportunity. This is shown in Figure 10-2 with three representative Yankee Group forecasts.

Table 10-3   Sample Yankee group projections

Source	Year of Estimate	Estimated User Base	Projection Year	Projection Quantity
Communications Week, 10-26-62	1992	500,000	1995	5,000,000
			2000	13,000,000
ARDIS Lexington Conference, 7-27-93	1993	1,000,000	1994	1,800,000
			1995	3,200,000
			1996	4,600,000
			1997	5,900,000
			1998	7,300,000
			1999	8,600,000
			2000	9,900,000
Information Week, 2-3-97[a]	1996	1,900,000	1997	2,750,000
			1998	4,000,000
			1999	5,800,000
			2000	8,400,000
			2001	12,180,000
			2002	17,660,000
Global Wireless, Mar.–Apr. 1998	1996	1,600,000	1997	2,200,000
			1998	3,100,000
			1999	4,600,000
			2000	6,400,000
			2001	9,000,000

[a]"The US Market for mobile data networking, which has 1.9 million users today, is expected to grow 45% a year over the next 5 years, reaching 10 million by 2002." Note: a CGR of 45% does not produce the Yankee Group value.
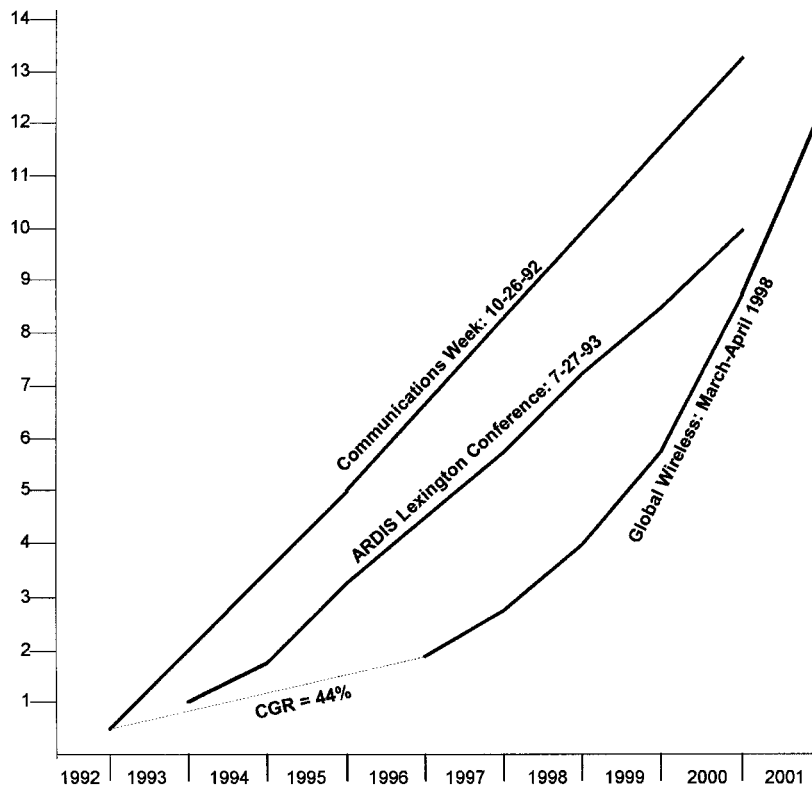
Figure 10-2   Representative Yankee Group projections.

10.2   SOME UNPLEASANT HISTORY

10.2.1   Job-Based Market Opportunity Approach

In 1987 a unique study of the U.S. data radio opportunity was completed.[11] This report had wide circulation, but its conclusion that the data radio market opportunity was quite finite was not lovingly received.

The approach was to build a detailed database of occupations, with principal source information obtained from the BLS Occupation Industry matrix. This information was supplemented by census data to make self-employment estimates. The 579 detailed occupation codes were initially compressed to 408 categories; three sensitive occupation codes were expanded to 26 from other data sources. The result was 434 detailed occupation codes organized for bottoms-up analysis. Two levels of summary information were provided for ease of use. Projections to 1991 and 1996 were made from the 1986 base.

This work was aimed at public data service providers, not hardware vendors. The object was to estimate the wide-area mobile (WAM) opportunity for business data

users on public networks, that is, data radio users who ranged over a wide area, as opposed to in-building or campus, and who would use public services, as opposed to private networks. The focus was entirely on business jobs since, except for the deaf, few nonbusiness data radio users were anticipated.

There was no examination of fixed-position opportunity: no burglar alarms, credit card terminals, telemetry, or vending machines. Truck *drivers* were counted, but the trailer portion of a tractor/trailer rig was not evaluated. Nor was there much consideration of exotica such as wireless breath analysis systems.[12]

The approach used in a subsequent JFD Associates update of the 1987 work was as follows:

1. All 434 occupations were first evaluated to determine the *mobile* content. Thus, barbers, podiatrists, and dental hygienists, for example, were rejected as mobile candidates.

2. Mobile jobs were then examined for classification as *campus/in-building* or *wide area*. Thus, stock clerks, waiters, and lobby attendants, for example, are mobile but not in a wide area. An obvious contrast is the long-haul tractor trailer driver who is clearly not campus confined. These detailed judgments were not binary but probabilistic. High school principals, for example, were judged to be 95% campus, but there are exceptional cases where the principal moves from school to school. There were no double counts. A worker mobile in both categories, campus and wide area, was classified as WAM.

3. Judgments were then made as to which jobs use *two-way radio*, either voice or data. Fishing vessel captains, police and fire fighters, and taxi drivers are all naturals.

4. The two-way radio users were then classified for *public* versus private. Health services managers were judged very likely to choose public systems, if available. But subway motormen or fire inspectors will tend to be on private systems.

5. Finally, the WAM, two-way, public radio users were examined to determine who fit *data* as opposed to voice (one can have both). Electronic repair personnel were high data; motorcycle mechanics have low data utility.

The result was a 125-page report with six statistical appendices that quantified the opportunity in both 1991 and 1996.

10.2.2 1996 Projections: 1987 Work

So how did the 1996 projection pan out? First, consider the dramatic impact of the filtering process on the predicted 1996 jobs. A simplified summary is shown in Figure 10-3.

Remember, these were worker counts. The consumer, as in personal cellular phones, did not appear. Nor did these counts correlate directly to devices. It is quite

all jobs	124,295,473
all mobile jobs	51,720,630
wide area mobile jobs	24,983,772
2 way radio wide area mobile jobs	9,561,192
public 2 way radio wide area mobile jobs	7,022,814
public data 2 way radio wide area mobile jobs	1,437,732
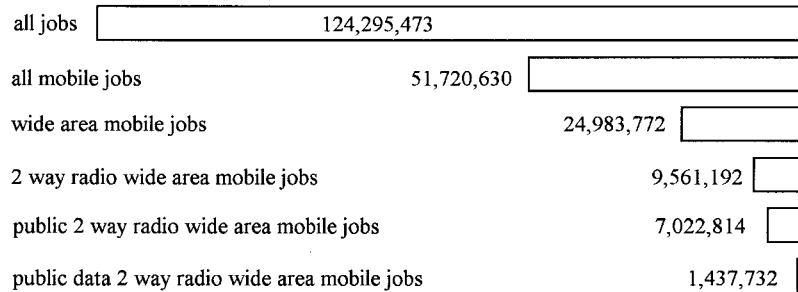
Figure 10-3 JFD Associates market opportunity: 1996.

possible for the public mobile data user to have multiple radios—even multiple data radios. Railroad workers may have several wireless data terminals spotted throughout a yard (I once used ARDIS, BSWD, *and* data over cellular, but the resulting payload aggravated my tendonitis). This is an airtime service view. The worker may be as loaded with devices as a mule—that makes device manufacturers happy—but that same worker will only operate one device at a time.

A breakout of the then-seen 1996 potential is shown in Figure 10-4. Note that the final bar groups several small-volume categories as "other."

In general, both the 1991 and 1996 projections were rejected by carriers as totally understating the market. Actually, the 1991 forecast was greatly overstated. We now "know" that less than 20% of the market potential was met from all public providers in 1991. The 1996 forecast was much closer: ~1.1 million actual subscribers began to pay for service versus the 1.4 predicted.

This seemingly close fit occurred only because the true market potential was understated. There were two main problems with the 1996 forecast:

1. The national economy performed wonderfully well in the period 1990–1996. Total civilian jobs at the end of November 1996 were 127.6 million,[13] not the 124.3 million projected. That is less than a 3% difference, but those extra 3.3 million jobs would have permitted another 380,000 public WAM data users, more than the total of all packet users combined at the close of 1996.

2. The growth of business cellular users was woefully underestimated. When the work was originally done, only selected year-end 1986 cellular statistics existed: <700,000 voice subscribers served by ~1500 base stations. At the close of 1996 there were 44 million voice cellular subscribers served by more than 30,000 base stations.[14] The 10-year-old estimate of less than 8 million *business* cellular users was undervalued by at least 50%.

The gross effect of these two errors is that it would have been possible for ~2 million WAM public data users to have existed by year-end 1996, not the ~1.1 million actually reached. Thus, the industry clearly underachieved.
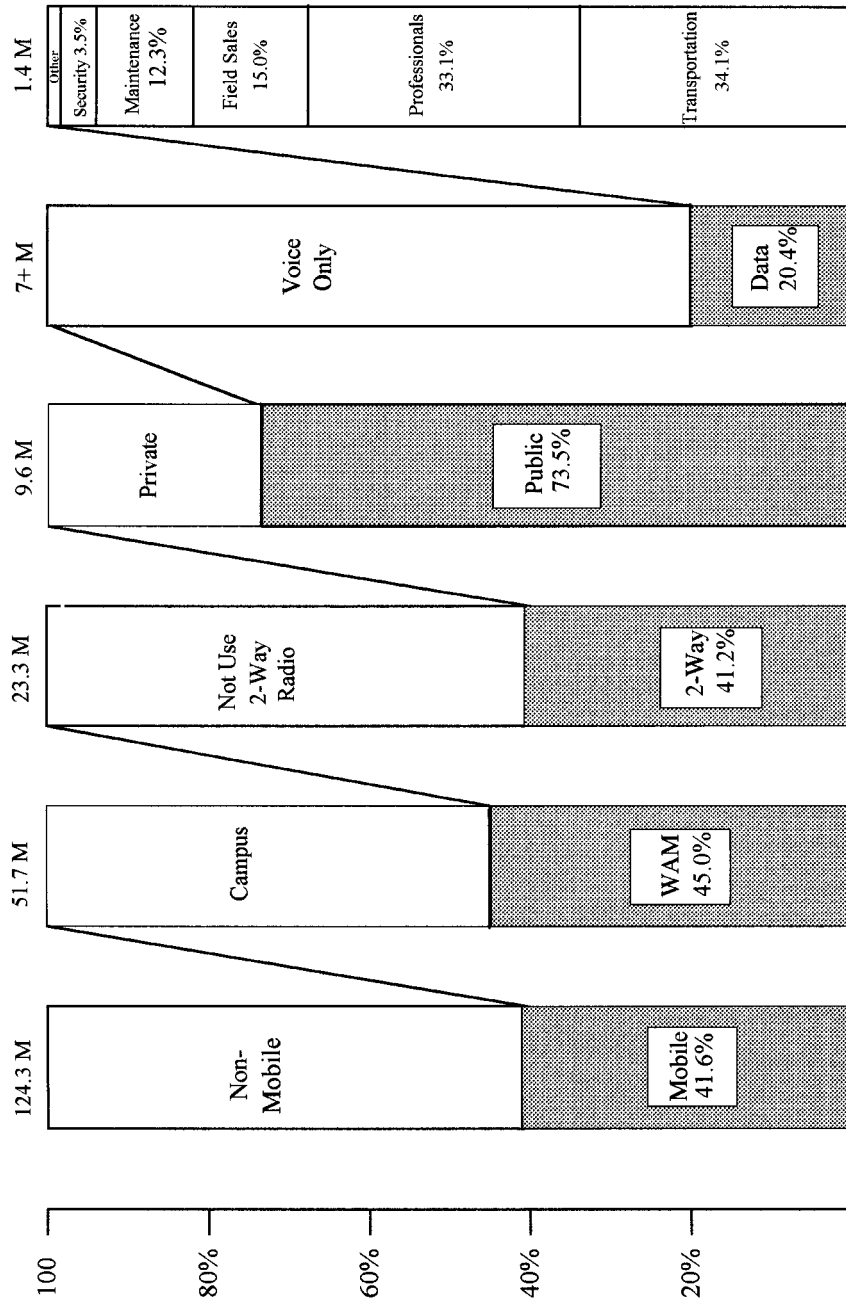
Figure 10-4 1996 market opportunity as seen in 1987.

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Table 10-4   WAM public data candidates: 1991 >10,000

Occupation	Number of Jobs
Total all jobs	1,317,046
Data sorted: total	**1,087,847**
Percent	82.6
Management	
Managers, food service and lodging	11,185
All other managers and administrators	34,597
General managers and top executives	86,334
Total	**132,116**
Professionals	
Surveyors	14,345
Accountants and auditors	32,307
Physicians and surgeons	53,631
Registered nurses	15,144
Licensed practical nurses	17,938
Reporters, writers, editors	23,215
Lawyers	15,217
Special agents, insurance	20,611
Brokers, real estate	48,055
Total	**240,463**
Field sales	
Nontechnical sales representatives, excludes scientific and related products/services and retail	48,675
Sales agents, selected business services	11,534
Technical sales representatives, scientific and related products/services, except retail	34,084
Total	**94,293**
Maintenance	
Data processing equipment repairers	31,243
Electronics repairers, commercial and industrial equipment	10,995
Station installers and repairers, telephone	15,390
Office machine and cash register servicers	21,546
Television and cable TV line installers and repairers	20,632
Industrial machinery mechanics	20,761
Automotive, bus, truck mechanics	16,297
Total	**136,864**
Transportation	
Messengers	10,477
Bus drivers	24,566
Driver/sales workers	25,551
Truck drivers, light (includes delivery and route workers)	49,639
Truck drivers, heavy or tractor trailer	332,185
Total	**442,419**
Security	
Police, patrol officers	27,216
Fire fighters, supervisors	14,478
Total	**41,694**

10.2.3   Analyzing the Data

Assuming one gets it right, the power of this job base organization can be demonstrated with the following example: After the publication of a report one buyer asked the question: "In what occupations, and how large, is the 1991 Public Data Radio Opportunity when the market is segmented so that only classifications having a job count greater than 10,000 are evaluated?" After combining fine grain job breakdowns that, individually, would have been missed, the Public Data file was sorted at the 10,000-job level. This yielded the surprisingly compressed results tabulated in Table 10-4.

Much to this client's delight, 82.6% of the Public Data opportunity was covered in spite of the "nothing less than 10,000" constraint. This boded well for a Top 500 marketing strategy. Other general, high-level conclusions, which had relevance to 1991 business planning, could be quickly drawn:

1. The category "maintenance" is not particularly big. Given ARDIS' success in this target segment at year-end 1991, it suggested that ARDIS would branch into other application areas to continue its growth. This clearly happened: for example, AVIS, Coca Cola, G.O.D. (later a cropper), UPS, as well as nonmobile tasks such as the alarm systems of National Guardian.

2. The size of the category "truck drivers, heavy or tractor trailer" opportunity was obvious. Qualcomm could have installed OmniTRACS at its then current rate for years and not run dry. Clearly competition would appear. It did: for example, AMSC and HighwayMaster.

3. Nearly half the opportunity—still virtually untouched—came from three super categories: "management," "professionals," and "field sales." No single profile adequately describes these applications, but the users have by far the strongest need for laptops as opposed to special, often hardened, devices. Their information needs are greater, and E-mail is a routine requirement. These categories retain a marked need for voice communications and a residual need for facsimile. Thus, multiprotocol modems, with provision for voice cellular access, will probably be a significant asset for these segments. The origins of Smartphones lie in this type of analysis.

10.3   A NEW(ER) LOOK AT JOBS

In 1995 the 1987 work was totally redone. This was not exclusively a need for "fresher numbers." Job growth (or decline) moves slowly enough so that directions change at a relatively glacial pace. Simple extension to a more distant time horizon, factored for any unexpected gains in the gross total, can produce workable results.

The best new reason for a totally fresh update was to attack the job estimates by region so that, ideally, an individual city breakdown can be achieved. There are few oil riggers in the extractive trades in Manhattan, but quite a few in Texas. Customized

versions of the new study have been successfully prepared for specific carrier coverage areas.

A high-level summary of the new general opportunity report[15] is worth reviewing. The first goal was to estimate the opportunity by regions in which the resident and the job are coincident. A secondary goal was to pick up the very large "shadow economy"—those jobs that go unreported in labor statistics reported in the newspaper. This was achieved the following way:

1. Data diskettes were obtained from the Department of Commerce (BEA). This raw summary data contained current statistics and projections on all coincident residents and jobs, including military, self-employed, and the shadow economy, broken down by 183 U.S. regions.

2. Separately, the industry/occupation matrix (IOM) was obtained from the BLS. This 15-year projection has 507 occupation classes but does not include self-employed.

3. The BLS statistics were compressed from 507 to 236 occupation classes to provide a more tractable format.

4. Self-employed estimates were added to the BLS statistics based on census estimates. There were also a series of normalcy checks (e.g., farmers have high self-employed ratios; state/local/federal government employees are zero) to ensure that the addition was valid.

5. The IOM and the BEA statistics were then forced onto the same industry base. During this process all BEA military jobs were excluded.

6. This merger revealed two problems: public hospitals and education are placed under state/local government by the BEA; the IOM tallies them under service industries.

7. The problem areas were handled by creating two unique industry classes:

    a. *Hospital workers*: Federal bulletins assisted in the manual distribution, with high confidence.

    b. *Education*: Distribution was more difficult, with cross checks on both state capitols and "university cities." While there is somewhat less confidence in the precision of this allocation, it is clearly directionally correct (mismatch <10%).

8. The base year, 1993, was created by calculation from the 1991 and 1995 estimates.

The result was the ability to tailor a detailed statistical analysis by *region* (from New York City to, say, Aberdeen, South Dakota) in four years of interest (1993, 1995, 2000, 2005) by 14 industry classes and 236 individual occupations.

Table 10-5 lists the summary job counts for the analysis period and the CGR from 1993 through 2005.

If one has a neat vertical application strategy tailored to linemen (the sexist labeling is a government artifact), the projected job slump in that area would be worth thinking

Table 10-5   Summary job counts and CGRs for all U.S. occupations

		Number of Jobs				
Segment	Summary Description	1993	1995	2000	2005	CGR (%)
11	Management professionals	10,567	10,840	11,547	12,033	1.09
12	Technical professionals	5,822	6,042	6,633	7,148	1.73
13	Accounting professionals	1,289	1,336	1,460	1,558	1.59
14	Health professionals	9,145	9,502	10,451	11,172	1.68
15	News professionals	444	457	491	516	1.26
19	Other professionals	11,082	11,399	12,229	12,862	1.25
20	Traveling sales	6,519	6,738	7,316	7,786	1.49
29	Other sales	9,167	9,377	9,918	10,234	0.92
31	Information auditors	5,434	5,545	5,829	5,998	0.83
35	Inventory and stockers	1,631	1,645	1,679	1,684	0.27
41	Office equipment maintenance	1,390	1,404	1,448	1,472	0.48
42	Linemen	251	245	232	216	−1.24
43	Other equipment repair	1,890	1,930	2,030	2,093	0.85
49	Other repairers	1,535	1,574	1,675	1,739	1.05
52	Messengers	154	156	159	158	0.20
53	Bus drivers	91	93	101	106	1.33
54	School bus drivers	452	467	505	537	1.43
55	Taxi drivers	69	71	75	78	1.03
56	Driver/sales	345	350	361	366	0.48
57	Truck drivers	2,457	2,538	2,749	2,914	1.43
58	Refuse collectors	69	70	74	76	0.77
59	Other transport.	982	1,004	1,062	1,104	0.98
61	Police	726	743	787	816	0.98
62	Fire	303	310	328	341	0.99
63	Ambulance	118	121	130	136	1.24
69	Other security	1,587	1,638	1,769	1,857	1.32
70	Construction	5,718	5,814	6,057	6,198	0.67
81	Farm workers	4,572	4,615	4,725	4,758	0.33
82	Forest workers	153	155	159	162	0.49
89	Other farm, forest	525	542	585	619	1.38
90	Miscellaneous	53,936	54,536	56,131	56,644	0.41
	Total	138,424	141,257	148,695	153,380	0.86
1X	Professionals	38,349	39,576	42,811	45,288	1.40
2X	Sales	15,685	16,115	17,234	18,020	1.16
3X	Information collectors	7,064	7,190	7,508	7,682	0.70
4X	Maintenance	5,066	5,153	5,384	5,520	0.72
5X	Transportation	4,619	4,750	5,086	5,338	1.21
6X	Security	2,734	2,812	3,014	3,150	1.19
7X	Construction	5,718	5,814	6,057	6,198	0.67
8X	Farm and forest	5,250	5,311	5,469	5,539	0.45
9X	Miscellaneous	53,936	54,536	56,131	56,644	0.41

about. In contrast, if technical professionals are the target, you may be on to something.

Troubled by the large "miscellaneous" area? Don't be. This slow-growing segment is stuffed with musicians, telephone operators, billing clerks, administrative support workers, precision assemblers, and others who are not particularly good candidates for mobile data.

The gross job estimates yield some insights but are far removed from the slogging bottoms-up estimates needed to get at the WAM public data user. An intermediate step is the size of the summary WAM job counts at the millennium, as shown in Figure 10-5.

The "miscellaneous" category has started its precipitous decline. But even the joint "sales" and "professionals" categories have lost 75% of their gross potential. "Transportation," on the other hand, retained 97% of its job counts and is a big time contender. Now one begins to understand the AMSC/HighwayMaster/ Orbcomm/OmniTRACS . . . thrust. "Construction" has an even larger gross potential, many of which will be winnowed out as satisfaction through voice dispatch, or even just paging, does away with the requirement for two-way data.

Find it odd that the category "farm and forest" is robust? A farmer plowing a field is absolutely both wide area and mobile. But there are not too many farmers plowing the Loop, Century City, or Battery Park. Filtering will continue and the process must include geographic coverage. Most farmers are not going to make the final cut.

Without struggling through all the detail in the published report, a summary of the filtering process is portrayed in Figure 10-6.
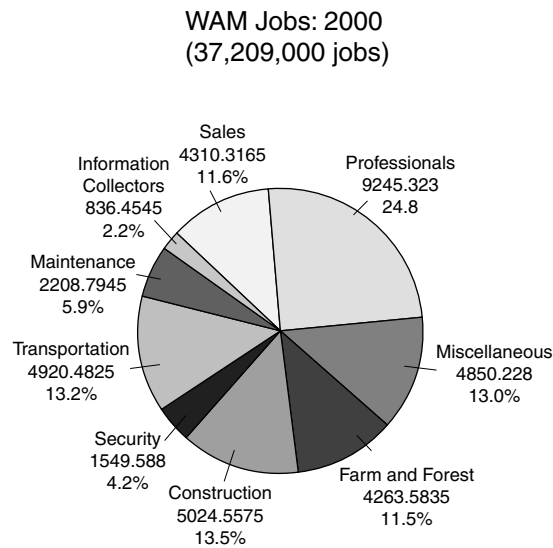
WAM Jobs: 2000
(37,209,000 jobs)

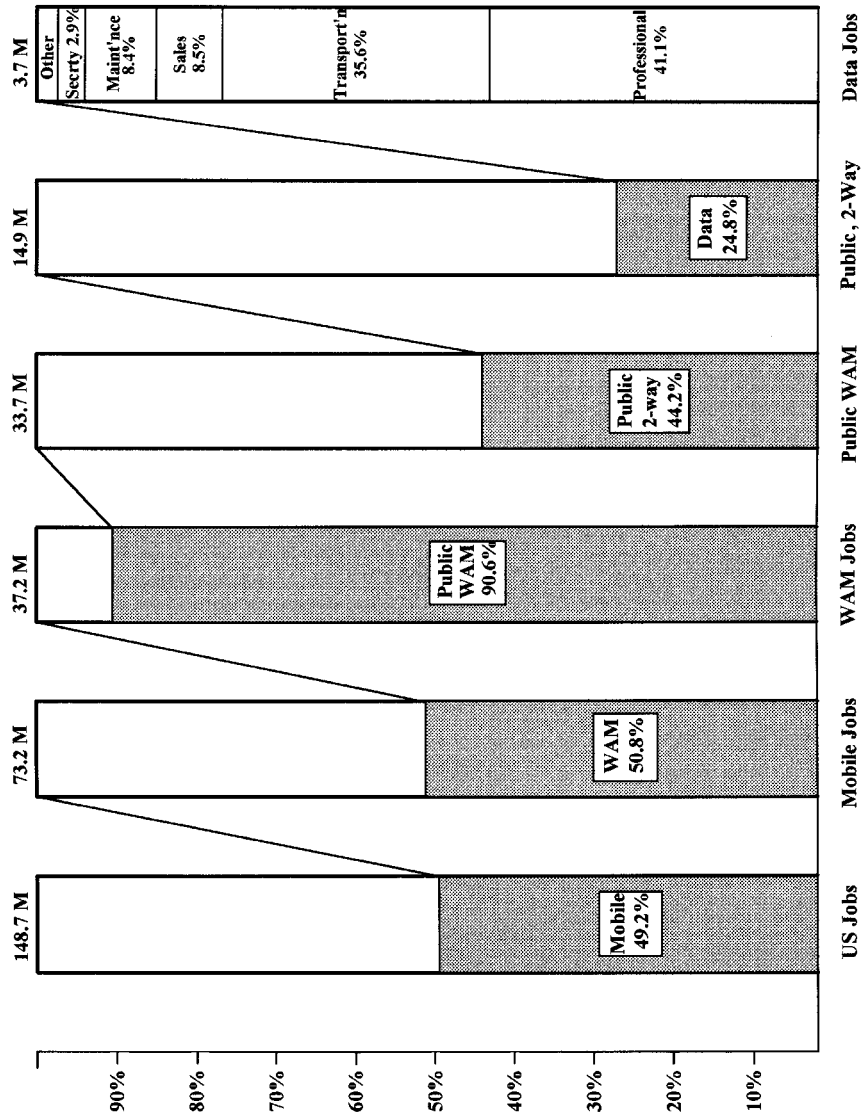**Figure 10-5**   WAM segmentation: 2000.

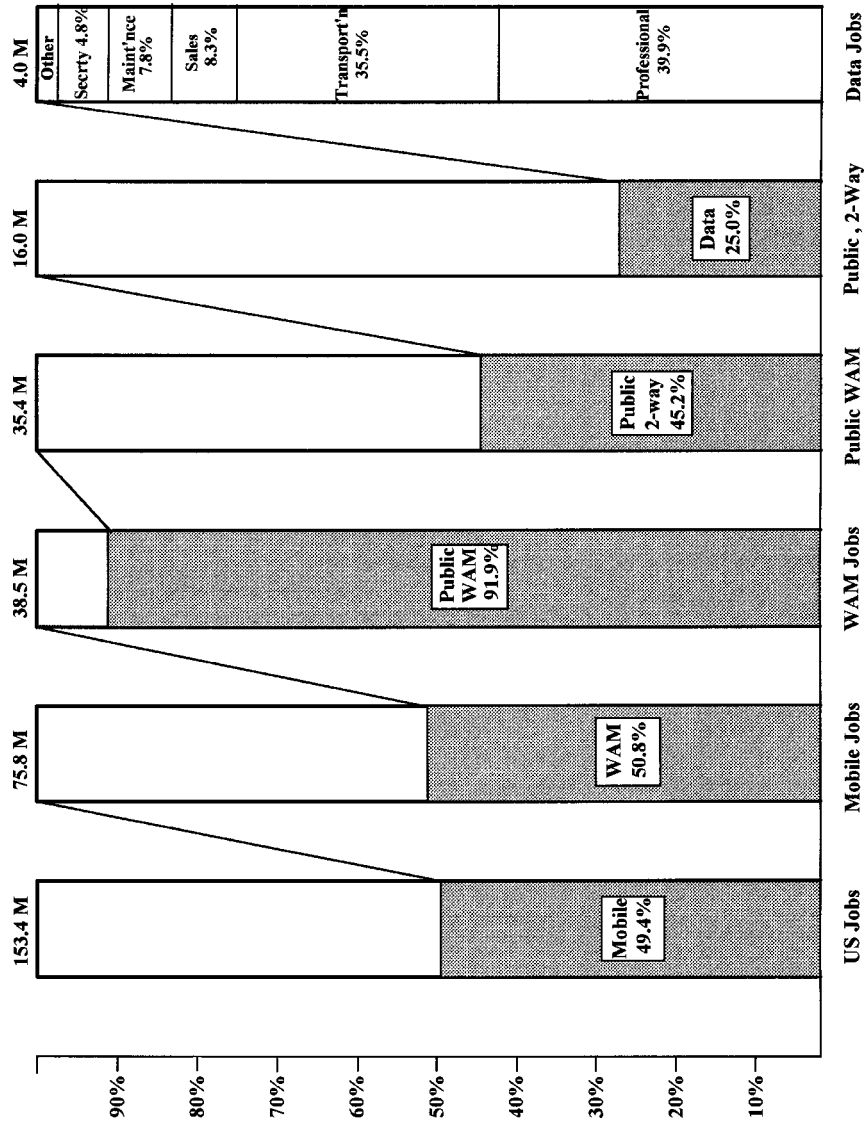**Figure 10-6** Mobile worker job opportunity: 2000.

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Figure 10-7 Mobile worker job opportunity: 2005.

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The total two-way, public, WAM worker opportunity in the year 2000 is ~3.7 million users. Each of these users may, in fact, subscribe to multiple services, which will produce upward pressure on *subscriber* counts. However, the message *traffic* will be determined by this relatively finite user potential.

And what about 2005? Might as well go all the way out on a limb to see how that looked. As shown in Figure 10-7, WAM data radio jobs exceed 4 million, with an interesting (and somewhat depressing) increase in the share allocated to "security": police, guards, even traffic enforcement officers.

These pessimistic (I believe realistic) sizings are not welcomed by those carriers looking for "the next cellular." Even if the estimates are doubled, they are not high enough for proponents of "10–15 million users, pretty soon." Their resistance stiffens at the suggestion that the market may not be as big as they hoped. In their defense, the carrier's view of the opportunity is *not* simply mobile job driven. They see fixed-position opportunities everywhere: vending machines, elevators, alarm systems. Indeed, ARDIS is installing more than 50,000 Enron devices in 1998/1999, which will certainly help their "subscriber" count. But periodic status messages are not a source of high volume (read: high revenue) airtime traffic. One can achieve high subscriber counts in return for very little money.

There are also those who trust in Internet access as a source of millions of users. Never mind that current technology is painfully inadequate to provide useful screen responses. Focus just on the number of wireline users of the Internet. In April 1996 Vanderbilt University published the results of a critical study that indicated that the number of people in the United States 16 and older who accessed the Internet at least once within the past three months was 16.4 million.[16] Not as large as you expected? That was the reaction of nearly everyone. But Nielsen subsequently reduced its "significantly inflated" demographic numbers. Wireless is simply not going to capture a huge number of Internet subscribers, and the pool of *daily* users is not as vast as it seems.

Another carrier riposte is that the opportunity lies in the consumer, not business, market. I was once the recipient of two serious proposals by independent CDPD builders on how prime airtime will be consumed by interactive game playing. PDAs notwithstanding, can one really imagine subscribing to data services "so that kids can compete playing Marioworld? . . . Are we going to order pizzas interactively? Few people are focusing on business applications. . . . But that's the real market. Business, not consumers. The office, not the home."[17]

10.4 SUMMARY

The world does not want for wireless data opportunity estimates. They pour forth continually, some with highly aggressive viewpoints. However, successive annual projections from the same sources indicate that all estimators are having second thoughts about both the size of the market and when it will be realized.

A 1987 job-based analysis, a unique approach at the time, was originally perceived as bearish in its final year forecast: 1996. The reality is that these projections were not

achieved in the early years. If success is measured solely by the number of subscribers, not traffic intensity, then circuit switched cellular is clearly in the van. However, caution is in order. Explosive cellular subscriber counts do not translate directly into business users. They are growing far more slowly than the overall cellular pace, and the data segment remains very small.

A new job-based analysis has been completed projecting to 2005. The number of two-way, public wireless data users in a more quickly measurable year, 2000, is ~3.7 million. This number is well below many current market estimates. Since some users will subscribe to more than one service, the mandatory double counts will increase the number of subscribers, but the traffic—which generates revenue—will be spread across these complementary offerings.

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11

AIRTIME PRICE PROJECTIONS

11.1 GREAT EXPECTATIONS

"When Bell Atlantic Mobile Systems (BAMS) launches its first . . . CDPD . . . system in Washington . . . it will initiate a new business that will impact the . . . bottom line by 1995. . . . The average monthly bill for cellular is dropping, and . . . new services such as data will boost those bills."[1]

This BAMS management expectation was common to all nascent data carriers of the period. But were their expectations realistic? With multiple carriers bringing increasingly untapped capacity to market, is it reasonable to believe that data prices will permit high-revenue goals?

11.2 SUBSCRIBER CAPACITY POTENTIAL

ARDIS reported[2] a year-end 1991 capacity for 800,000 field service class subscribers on a system rarely having more than two channels per city and using the inefficient MDC4800 protocol.

By April 1993 ARDIS had secured 70 channel pairs in the top 20 cities[3] (6 each in New York and Los Angeles) and begun conversion to the faster, more efficient RD-LAP protocol in order to build capacity for the expected Mobile Office/PDA boom. That application did not happen. Many base stations were "mothballed" until the 1997 win of the UPS contract when buildout resumed.

Application profiles also changed. Often, traffic intensified. Some users who began at two messages per hour moved to one every 10 minutes. The early morning/end-of-day message spikes associated with field service were smoothed by

the addition of applications with different message profiles. While there are *always* individual "hot spots," ARDIS subscriber capacity with the new, more message intensive profiles, now exceeds 1 million users, less than 10% of current network utilization.

BSWD has up to 30 channel pairs per major metropolitan area. These channels are only half the width of ARDIS channels. and the maximum bit rate in a channel is only 8 kbps. BSWD's cellularlike reuse plan reduces the number of channels at a single, complex base station location to about four. However, BSWD is installing an extremely large number of single-channel base stations. Nevertheless, it certainly has an untapped capacity potential as large as ARDIS.

Ricochet, with high bit rates and unusual load dispersion, has very good capacity potential for static users. Both GSM and MIRS technologies give PCS and SMRS users latent data capacity of unusual magnitude with dynamic capacity allocation between voice and data.

CDPD, if rolled out to all cellular base stations on a dedicated-channel, sectored basis, has enormous potential. Much of this will be consumed by TCP/IP overhead; much more will be devoted to new application classes featuring image transmission. It remains to be seen whether the necessary rollout will actually occur but, if so, the subscriber capacity potential can be high.

What does all this unused capacity coming to market mean for airtime prices in general and, as an interesting surrogate, CDPD in particular?

11.3 LIST PRICE HISTORY: CDPD

BAM was first with a priced CDPD offering, structured to land squarely atop BSWD's (then RAM Mobile) packet offering. When CDPD acceptance lagged, each successive carrier price plan flattened the curve in an attempt to make data more attractive. Figure 11-1 illustrates this phenomenon without dwelling on the sometimes important
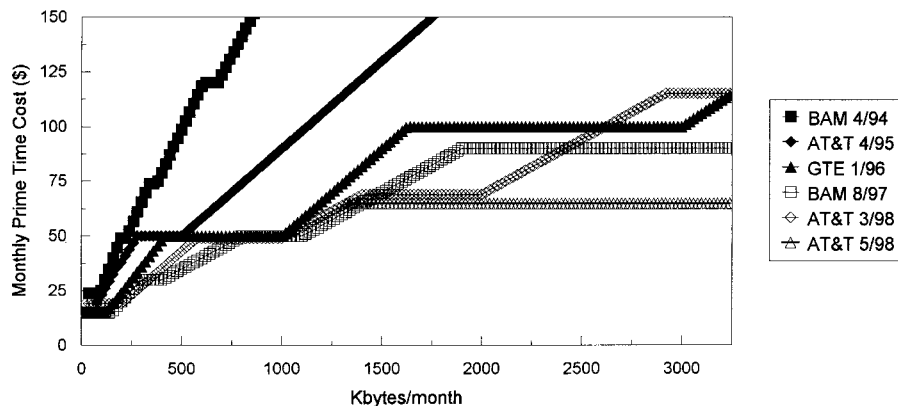
Figure 11-1 CDPD price change history.

distinctions such as perfect packet size requirements, national versus local rates, and prime time versus time-insensitive plans. The May 1998 culmination was the AT&T Wireless Unlimited Service plan, which puts CDPD in internal competition for voice channel resources.

11.4 VOICE/DATA CHANNEL RESOURCE COMPETITION: CDPD

11.4.1 Choosing a Representative Carrier

Channel availability is not a constraint to carriers providing voice service in relatively low density metropolitan areas such as Racine, Raleigh, Richmond, and Roanoke. But it is a major problem in thickly populated urban locales such as New York City.

The two cellular carriers in Greater New York City have long begun their migration to digital technologies to increase voice subscriber capacity. AT&T Wireless has chosen TDMA; BAM has opted for CDMA. Both carriers are also encountering significant New York area competition from the GSM PCS carrier Omnipoint as well as the ESMR carrier Nextel. This competition has led to the first true voice cellular airtime price reductions.

AT&T Wireless in Greater New York City was chosen as the surrogate for the value of a voice channel. Its choice of TDMA permits a granular substitute of digital for analog channels. With seven pricing plans, its user charges are very competitive to both Nextel and Omnipoint when minutes per month approach 100. Beyond that usage point—where business users are likely to be—AT&T Wireless trounces its competitors. Its 1998 Digital One Rate plan is untouched by the cellular alternatives. Figure 11-2 is an example of the competitive New York City offerings. The first AT&T plan shown is the $49.99, "$.50/minute beyond 180" level; the Digital One Rate plan is also plotted.
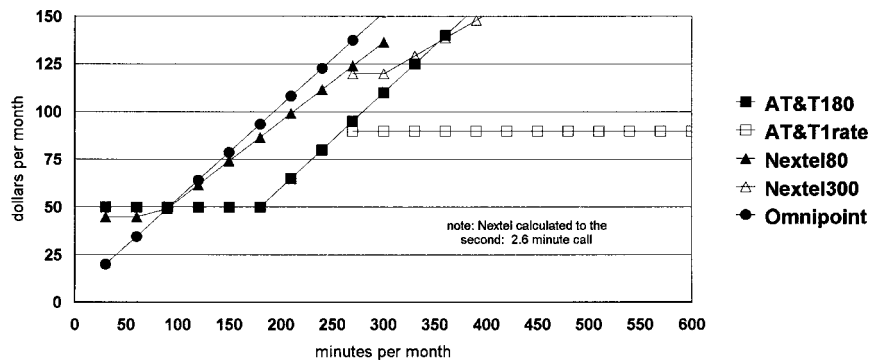
Figure 11-2 Representation voice price plans: New York City.

11.4.2   Establishing a Representative Voice Profile

The granularity of the AT&T Wireless plans forces a "strawman" choice. For this analysis the business user is assumed to consume 290 ± 110 voice minutes per month. This is a range of 9–20 minutes per working day. Within this wide range the monthly service charge is fixed at $69.99. This selection is shown in Figure 11-3.

For capacity purposes, call duration is assumed to be the national cellular average, 2.32 minutes, which is likely a bit light for business users. However, AT&T rounds up to the next full minute in its pricing; that fact tends to compensate for some of this lightness. Thus, the business user is assumed to average ~4.8 calls per working day, each averaging less than 3 minutes in duration. The wide variations inherent in the $69.99 plan apply.

11.4.3   Estimating Voice Capacity per Cell

Without dwelling on the technical intricacies of Erlang tables, the number of analog AMPS calls was estimated with the following assumptions:

1. Erlang "B" blocked-calls-cleared tables.
2. Grade of service is 2% blocking probability for busy-hour call initiation.
3. Number of user analog channels per sector: 18 (54 per omni site).
4. Average call duration: 2.32 minutes.

From the Erlang tables the offered load present at the intersection of 18 (channels) and 0.02 (blocking probability) is 11.5. Since we have assumed an average call duration, the maximum number of AMPS calls that can occur during the peak hour can be calculated by
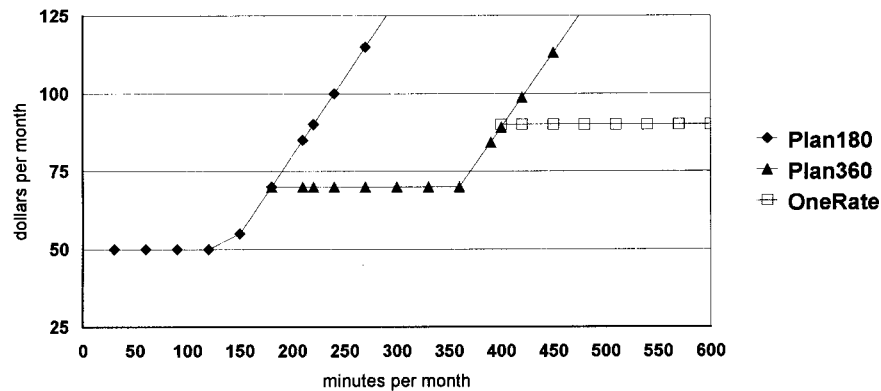
Figure 11-3   AT&T wireless voice price plan comparisons: New York City.

$$\text{Calls during peak hour} = \frac{\text{offered load} \times \text{minutes/hour}}{\text{average call duration}} = \frac{11.5 \times 60}{2.32} = 297.41$$

To simplify matters, assume that we are dealing only with business users. Assume further that one of the average 4.8 business calls per day is generated during the peak hour. Thus, each sector can support ~297 active subscribers with our business profile; each trisectored cell can support ~892 such users, as shown in Figure 11-4.

Because cellular subscriber growth has been so relentless, AT&T began the conversion of existing AMPS channels to TDMA some years ago. This conversion had to be started before the number of users saturated the analog channel capacity since, using our call profile, the conversion of the first three channels to TDMA actually reduces maximum call capacity slightly. With four channels converted, the break-even point on call capacity is reached. As more and more channels are converted, total call capacity rises steadily, as shown in Figure 11-5.

11.4.4   Estimating Voice Revenue per Sector

Assume that six channels on each sector have already been converted to TDMA. This is a convenient number that marks the point where overall call capacity has risen ~17% (to 348 per busy hour), and both the analog and TDMA channels are each carrying about half the voice traffic. Assume further that every user fits our business profile and makes one call during the busy hour. Thus, an average of 348 subscribers (1044 per
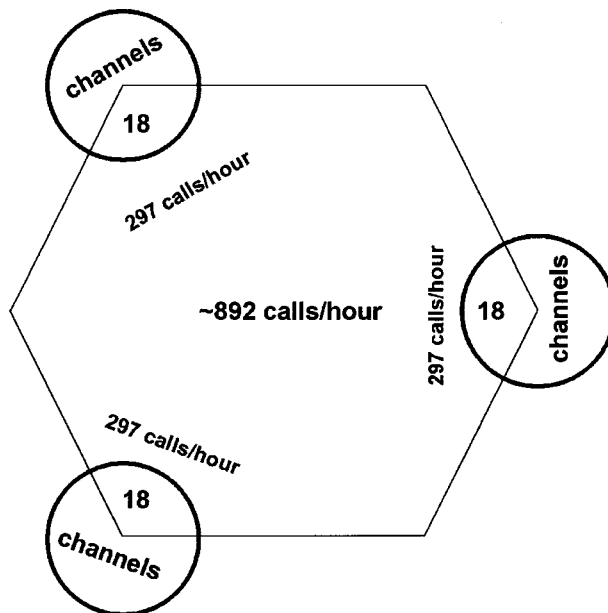
Figure 11-4   Trisectored cell capacity representation.
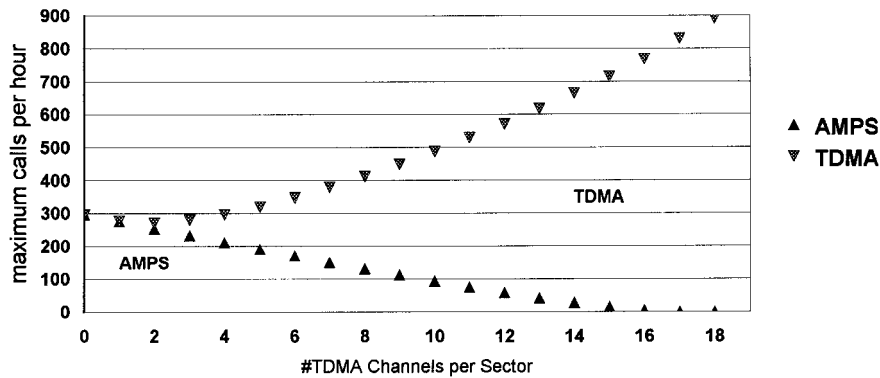
Figure 11-5   AMPS/TDMA sector trade-off: average cell duration, 2.32 minutes; 2% blocking.

cell) use that sector. This conversion point yields an average per sector revenue of
$69.99 × 348 = $24,356 per month. As voice traffic grows, and TDMA conversions
continue, sector revenue would theoretically head toward the $60,000 per month
mark.

11.4.5   Calculating the Required Data Revenue

AT&T Wireless has made the business decision to dedicate one channel per sector to
CDPD data. Occurring at the same time as TDMA conversion, this must have been a
difficult choice. With one channel unavailable to the voice pool, the number of peak-
hour calls—and thus subscribers per sector—are down to ~328 at our six-channel
conversion point. The monthly revenue contribution required from data to reach the
break-even point can now be estimated (see Table 11-1). That is, for data to be an
interesting business contributor, this sector must have enough subscribers to yield
$1394 per month. If data can not deliver—and assuming the demand for voice is still
growing—AT&T Wireless would be better off sticking with voice.

Table 11-1   Required data revenue per sector

Source	Voice Only			Voice and Data		
	Subscribers	Rate	Revenue	Subscribers	Rate	Revenue
Analog	170.9	69.99	11,961	151	69.99	10,568
TDMA	176.9	69.99	12,381	176.9	69.99	12,381
Data	—	—	0	—	—	**1,394**
Total	347.8		24,343	327.9		24,343

11.5   ESTIMATING FUTURE DATA PRICE LEVELS

Assume that all CDPD data activity is Internet oriented. Yes, there will be the Otis Elevator telemetry applications, but per-unit revenue is small. It is not particularly valuable to divine the future through narrow differentiation between $5.00 and $5.50 offerings. Let us concentrate on the "big money" instead, and guess at how low monthly prices can go.

If all the Internet business users are "local unlimited," they pay $54.99 per month for Wireless IP (CDPD) service. The break-even point is thus $1394 ÷ $54.99 = 25.4 average data users per sector. Said another way, ~8% of the business voice users must also subscribe to data.

While worst case scenarios can always be constructed, the required user count should not present a technical load problem even if all 25 data users are engaged in *realistic* Internet access. One valuable characteristic of the Internet profile is that it presents little load to the inbound side, which is the first choke point on CDPD. With a dedicated channel there is no hopping overhead. Thus, the principal constraint on the number of users is the capacity of the outbound channel to deliver information to, say, the mobile professional's laptop.

Internet access will create data usage far beyond AT&T's estimates for the mobile professional.[4] Assume that once during the busy hour each of our 25 users makes a single inquiry to the Web for something like price information, as described in Chapter 8. The outbound channel must deliver ~100 kbytes to give the user what is desired. Naturally this much information must be parceled out by the gateway so that a single user does not monopolize the channel for inordinate periods of time.

AT&T studies indicate that achievable CDPD user bit rates range from 4400 to 6400 bps during long file transfers[5]; I have personally tuned file transfers over CDPD to achieve ~7150 bps when the device is not in motion. Assume that the compression techniques like those employed in Nettech's Smart IP middleware[6] can squeeze 35% of the bits out of my efforts and achieve an effective rate of 9600 bps. This beautifully tuned CDPD channel, with address compression in place, no retries, no hopping, . . . is now capable of delivering ~1200 user bytes a second. Thus, each user will require 84 seconds of pure transmit time, possibly broken up after, say, 2-second intervals, to give someone else a shot. During the busy-hour all 25 users combined will require 2100 seconds. There will be conflicts and delays, but a combined channel utilization of less than 60% (2100/3600) is a reasonable place to be at this juncture.

In time, and with historical measurements to aid the calculations, AT&T may be able to load the channel toward the 90% point, ~38 users per channel (ARDIS currently has ~50 per channel per base station, with a much less intense message profile than Internet access). After this point a new channel is required, and a dedicated/hopping hybrid is certainly feasible. But if voice demand is being comfortably accommodated by the TDMA conversion, another dedicated data channel may be deployed.

Conversely, if the data subscribers do not appear, AT&T Wireless can ease its prices down again to attract users. Since the channel may be able to handle ~38

Internet users per hour, each requiring a 100K message, the "local unlimited" price could theoretically fall all the way to ~$36 per month. This is close to Metricom's current $30 Ricochet price, while offering vastly broader coverage and flexibility.

In fact, a precipitous plunge to ~$36 per month is unlikely. Rather, incremental steps to $49, then $44, then $39—as the business circumstances dictated—would be a more reasonable expectation. But if PCS and ESMR impact forces lower voice prices, the value of the voice channel declines and so will data prices.

Will these price levels "boost those monthly bills" as the carrier executives originally hoped? Not likely.

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6. Nettech press release, 6-22-98.

III

BUSINESS 102: OTHER THINGS ARE IMPORTANT TOO

12

COVERAGE VERSUS CAPACITY

12.1 INTRODUCTION

Paraphrasing the late Tip O'Neill: "All coverage is local." With 12–14-in. full wavelengths it is quite possible to encounter an ARDIS, BSWD, CDPD, or circuit switched cellular dead spot simply by walking to another position in a room.

This annoying fact does not mean that all carriers operating near the same frequency band offer essentially the same coverage choices. Design trade-offs are made between area coverage and its close cousin, building penetration, versus subscriber capacity. These trade-offs flow from fundamental decisions on channels allocated for data versus control, channel reuse philosophy, base station quantity and location, transmit power levels, FM capture exploitation, bit rates, and message redundancy—to name just a few.

Each of these decisions can cloud the certainty of coverage comparisons. ARDIS configures minimal infrastructure for maximum in-building penetration at the cost of subscriber capacity. For roughly equivalent geography, BSWD's technical choices predispose it toward maximum subscriber potential at the cost of some penetration. CDPD is not closely comparable to either ARDIS or BSWD because, in a full-blown implementation, it would deploy *many* more base stations, each with a dedicated channel, thereby achieving both high capacity and good penetration. But carriers are hesitant about the cost of a CDPD deployment of that scope. Bell Atlantic Mobile has stated[1]: "CDPD will be offered in markets where it is expected to be commercially viable, although equipment will not be installed at all cell sites in those markets."

This uncertainty does not mean that coverage is simply unknowable without comprehensive field tests. A great deal can be accomplished, without the special

knowledge of a radio engineer, by analysis of site location licenses, judicious use of vendor coverage maps, and ZIP code predictors. Not all carriers make these tools available, and there are often quality variations in those that do exist. The base station license and vendor coverage map techniques are most effective when judging relatively wide geography such as an entire county. At their weakest these simple methods permit the user to confine field testing to likely trouble spots. At their best they are often powerful enough to be excellent predictors of coverage, eliminating much tiresome, labor-intensive work.

Ultimately, some field tests are required to prove "contract coverage" in specific areas. For a prospective user these tests need not be laden with instrumentation. Far simpler techniques can give the thoughtful reviewer valuable insight into coverage and retransmission performance that tends to vary with message length.

Since 1994 JFD Associates has conducted coverage and building penetration tests at roughly six-month intervals on ARDIS, BSWD, and, later, CDPD. There are also public domain summary reports from users such as Pitney-Bowes and Schindler/Millar elevator, as well as carrier reports from BSWD. Illustrative extracts from these sources are used in this chapter.

12.2   KEY COVERAGE PHILOSOPHIES

12.2.1   ARDIS

ARDIS employs each channel in a given area in single-frequency reuse (SFR) mode. As the user moves from one single channel cell to another, the device remains tuned to the same frequency. Higher level logic determines which base station will work with the device. Its 90% coverage areas are deliberately designed *not* to overlap, as illustrated in Figure 12-1.

Since ARDIS employs SFR, the area of reduced coverage probability between two adjacent cells can be exploited. Extending beyond the solid 90% line are areas of ever-decreasing coverage. The 70% curve is portrayed as a dotted line.

Where two of these 70% zones overlap, the effective coverage is 90% since the user can be handled by either of two base stations. The explanation is straightforward: When in an overlap zone there is a 30% probability that the user cannot be heard by cell A; the same 30% probability extends to cell B. But the probability that the user will not be heard by *either* cell A or B is $0.30^2 = 9\%$. The probability that the user *will* be heard by at least one base station is thus 91%.

Note that there are scattered areas in which the probability of success is very high (shown here as triple-coverage zones). The proper siting of base stations can cause these areas to become quite rich, thus improving building penetration. As an illustration, the "typical user transmission in Chicago is heard by 8 to 10 base stations."[2] Clearly not all these base stations hear with anything like a 70% probability, but there is always some finite chance that a message that would be missed by BSWD or CDPD will be picked up by ARDIS.
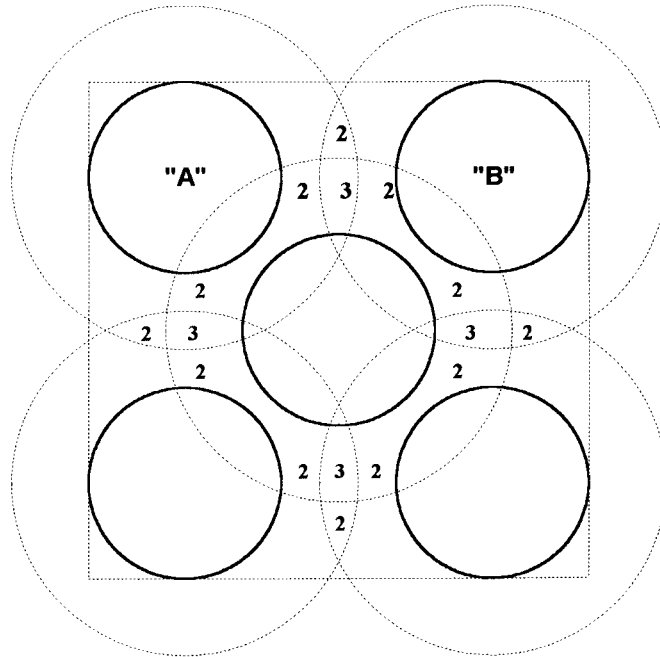
Figure 12-1   ARDIS base station siting (representative).

When ARDIS adds a new channel, a new base station is typically installed at the same physical site. Stamford, Connecticut, has such an overlay. When the device modem is powered on, it "listens" first for an RD-LAP channel. If found, it begins operation there. Lacking RD-LAP, it will switch to MDC4800. As the device moves around, or as channel loads/conditions vary, it is quite possible to receive sequential packets from the same message on different channels, some RD-LAP, some MDC. These layers of channels are currently highest in metropolitan New York with a total of eight 25-kHz-wide channels.

12.2.2   BSWD

BSWD has a cellularlike base station siting plan, though on a smaller scale. Omnidirectional cells are grouped in clusters; no two cells in the same cluster employ the same frequencies. The initial goal was to provide a 90% or greater probability of street-level coverage. With the drive toward two-way paging, the goal has evolved to "coverage comparable to one-way paging, nationwide."[3]

BSWD's base station density does not approach that of cellular. As an example, in March 1998 BSWD had only 26 base stations in the entire state of Connecticut. There are other "helper" sites along the Massachusetts, New York, and Rhode Island borders. Since Connecticut is very small, about 5000 square miles, the *average* cell radius for just the 26 Connecticut base stations is ~7.8 miles. This is not the same

design criteria as, say, metropolitan voice cellular, which sometimes operates with 1/2-mile-radius cells and microcells.

Naturally the sites are not uniformly distributed. BSWD has 12 of the 26 located just in Fairfield County to improve Interactive Pager (I@P) coverage for the Greater New York metropolitan area. Fairfield County is ~435 square miles, so the average cell radius drops to ~3.4 miles in this densely populated sector.

BSWD has stated that it is "able to reuse (each channel) easily four times."[4] This requires a broad geographic spread employing perhaps 30 base stations. While the reuse figure has been disputed, in this analysis BSWD's claim is accepted as correct. Thus, say, Los Angeles County has ~4 channels per cell and 7 cells per cluster. The 90% coverage lines of each cell in the cluster overlap to ensure smooth hand-off. An overly simplified representation of BSWD's base station siting is shown in Figure 12-2; the principal hand-off areas from the central base station are designated H.

12.2.3   ARDIS Versus BSWD: Representative 90% Coverage Contours

The resulting 90% area contours are depicted in Figure 12-3. The key point is that for approximately the same geographic area coverage contours are always somewhat different. There will be locations in which BSWD will operate and ARDIS will not, and vice-versa. Note that in this example BSWD requires more cells to achieve roughly the same 90% area coverage.
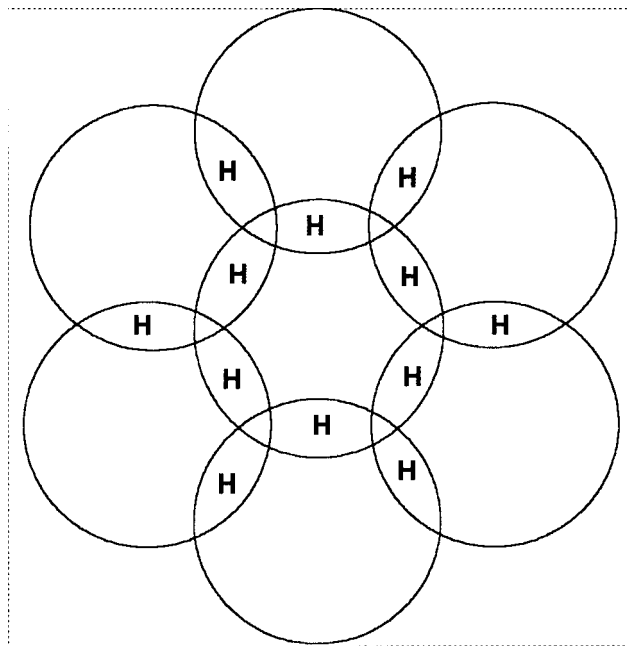
Figure 12-2   BSWD base station siting (representative).

BSWD : 90% Coverage

ARDIS: 90% Coverage
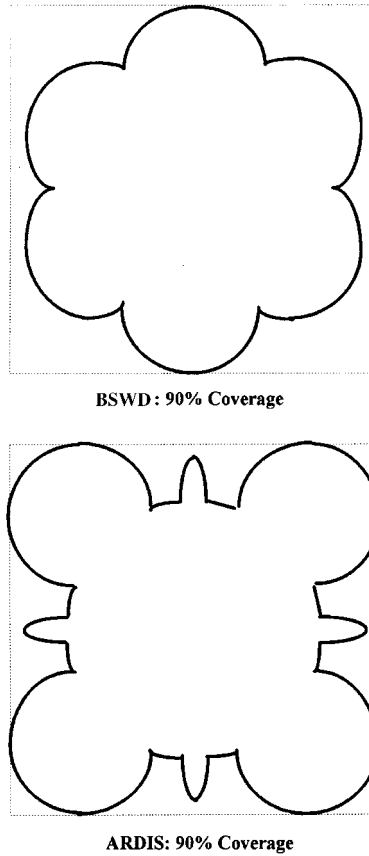
Figure 12-3   Comparative areas of 90% coverage.

12.2.4 Improving Building Penetration with More Base Stations

BSWD is clearly on a path to enrich its infrastructure for two-way paging building penetration. One must be wary about carrier base station counts; they seldom correspond to geographic locations. ARDIS counts each new frequency deployed at the same physical location as an additional base station. BSWD counts two transceivers at the same location as two base stations. Nevertheless, BSWD's August 1998 claim of 1900 installed base stations[5] probably brings it to a parity position with ARDIS in unique site locations—and BSWD is growing its infrastructure more rapidly than ARDIS. Further, BSWD is focused on ~160 fewer cities, each of which costs ARDIS a base station. In selected areas, BSWD likely has more actual base stations than ARDIS.

   An interesting example is Fairfield County, Connecticut. BSWD has 12 physical locations; ARDIS has only 9. As noted in Section 12.2.3, BSWD probably requires

more base stations to achieve parity in an equivalent area. Field tests at 48 street-level locations in Fairfield County during January 1998 show that ARDIS and BSWD have equivalent, and very good, street-level coverage.

Additional tests revealed that ARDIS had ~6% coverage edge in totally enclosed buildings. Continued enhancements in BSWD infrastructure would tend to offset any building penetration shortfall. Very large additions might permit it to outperform ARDIS and gain more capacity as well. But one must be mindful of the rules of plane geometry. If BSWD drove its infrastructure to 18 locations, doubling the number of ARDIS sites, the average cell diameter would only fall from 3.4 to 2.8 miles. This is a significant reduction—and would surely be pleasantly noted by BSWD users—but this major investment would not result in microcells.

12.2.5 CDPD

CDPD, using the same physical locations (and, e.g., antennas, T1 lines) as voice cellular, follows the voice cochannel reuse rules. In metropolitan areas where CDPD build-out is most complete, this means a trisectored layout. Hand-offs occur in the zones marked H, as shown in Figure 12-4.

The hand-off threshold varies somewhat by carrier; the right user device is key. In early BAM dedicated channel implementations, using the PCSI PAL phone, it was possible to be in the central hand-off area and be unable to transmit or receive. Putting the phone in "diag" mode, one could watch the hunt: channel 721, 555, 729, 721, 555, . . .—unable to decide which channel was the best! Now BAM has time and dBm selection

Figure 12-4 CDPD trisectored base station siting (representative).

thresholds. Every 90 seconds the device "listens" for alternatives. If the other channels that can be heard are not 8 dBm better than the current channel, no switching occurs.
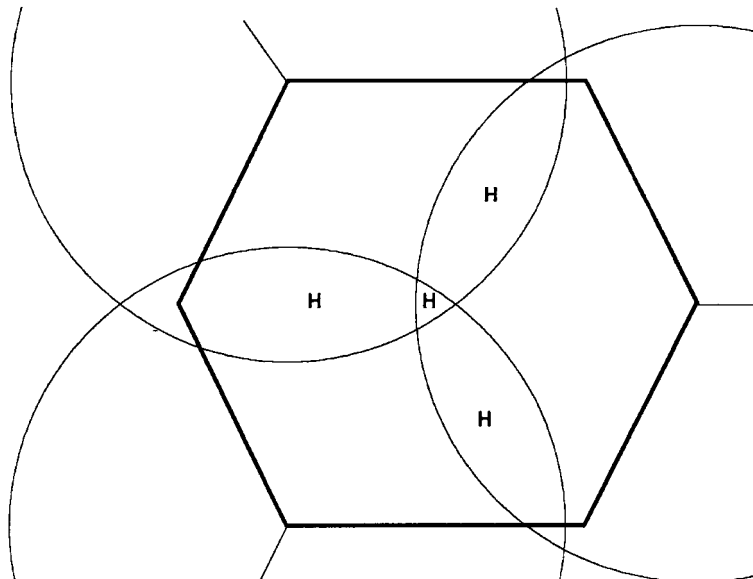
12.2.6   Other Coverage Considerations

12.2.6.1   *Transmit Power Levels*

12.2.6.1.1   ARDIS Pre-ARDIS, the KDT-800 device used in IBM's Field Service system had a transmit power of 4 watts. Much of this energy was wasted because the hand-held "brick" had internal antennas (this was a dual-diversity receive unit). As the infrastructure was enriched, succeeding internal antenna devices such as the KDT-840 had their output power reduced to 3 watts. This level remains the upper limit for vehicular devices employing, say, Motorola's mobile radio modem (MRM) line of modems.

With the coming of frequency-agile, hand-held devices a design trade-off was made. The power-hungry synthesizers, which replaced simple crystal cut oscillators, drew so much current at the 3-watt transmission level as to make battery life unacceptably short. Regrettably for some users who treated their devices carelessly, the antenna would have to be external. The trade-off was a reduction in output power to 1.5 watts and longer battery life. This is the usual output power level for ARDIS hand held devices.

The Interactive Pager (I@P) returned to an internal antenna located inside its flip-top lid. The transmit power level was also eased down to 1 watt. Performance is good with the lid open. It has been reported that IBM Field Service people who normally work with the lid closed encounter reduced coverage as compared to the old KDT-800.

12.2.6.1.2   BSWD The Ericsson infrastructure employed in the original RAM deployment had poor receive sensitivity, which limited the optimum radius of the base station to ~5 miles (–115 dBm laboratory capability).[6] In 1997, to prepare for the coming of the I@P, BSWD began to retrofit all existing base stations to improve the receive sensitivity to –121 dBm. This pushed their effective radius to ~7 miles. Because of these early restrictions, the original external modems for portable users had a transmit power of 2 watts AND an external antenna. The version of the I@P built for BSWD also has 2 watts transmit power.

The higher transmit power requirement forced Ericsson, then subsequent vendors, into excellent battery-saving techniques. They are among the best available today. During one 14-day test I transmitted 157 messages each on both an ARDIS and a BSWD I@P. The ARDIS unit was an early version, and there was actually a bit of extra traffic on it, but that does not justify the very different results. I was forced to replace ARDIS I@P batteries three times during the 14 days; I never changed the BSWD I@P batteries. (*Note*: In some heavy usage CDPD tests external modem batteries must be changed every 2–3 *hours*).

All BSWD I@P tests were performed with lids open. A "lids-closed" test might have revealed shortcomings, but it is a moot point since, in August 1998, BSWD announced the availability of the "no-lid" RIM I@P950.

12.2.6.1.3 CDPD After early consideration of 256 discrete power levels, CDPD settled on the same range as its voice cellular counterpart. Except for expensive, multipurpose vehicular units, CDPD modems generally operate with a maximum transmission power of .6 watts, identical to hand-held voice phones. This is generally satisfactory in richly endowed urban areas with small-diameter cells. In the period 1995–1996, before some urban areas were optimized for portable phones, CDPD performance was very poor. The lack of power is still evident along many interstates that are really designed for 3-watt vehicular devices. Very large, very troublesome coverage holes often appear in this situation.
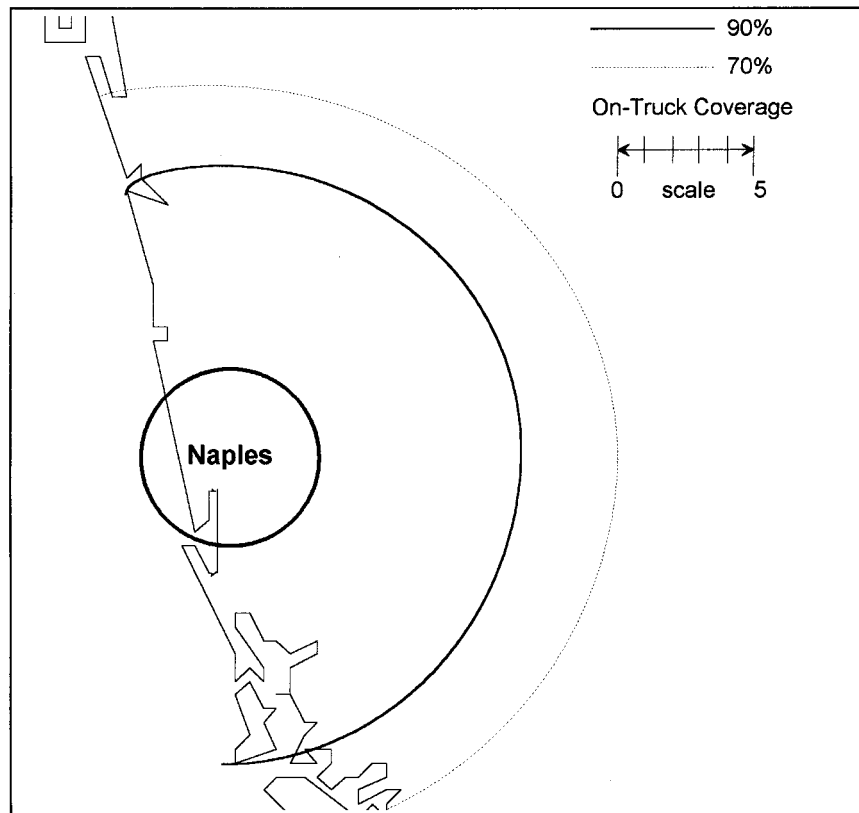
Figure 12-5 ARDIS RF coverage contours: Naples, Florida.

12.2.6.2   External Antennas Another technique to extend the coverage area of packet modems is to use external antennas without an increase in transmit power. The use of an external mag mount antenna in my office improves CDPD signal strength by about 20 dBm. Naturally, these improvements are terrain dependent. In the flat geography of Florida the effects can be quite pronounced. Figure 12-5 shows the improvement in the 90% ARDIS coverage area when a mag mount antenna is employed with a PM100D class modem. The 90% coverage line extends an additional 5 miles from the base station center. Note, also, that coverage does not suddenly vanish after the 90% contour curve is reached. Some success will be had at even greater distances.

   This technique is often employed with over-the-road trucks having multiprotocol modems that feature satellite connections. Extending the terrestrial coverage markedly lowers the higher cost satellite bills.

12.2.6.3   Repeaters In   some   countries   bidirectional   amplifiers—or repeaters—are used to extend coverage into areas without base stations. This technique is used in Germany's DataTAC system, for example. The use of repeaters in the United States tends to be limited to frequencies below 450 MHz. If selected carriers did gain FCC approval for repeaters in the 800/900-MHz bands, coverage might well be extended into rural areas.

12.3   ESTIMATING COVERAGE WITHOUT FIELD TESTS

12.3.1   License Examinations

For years most carriers filed a radio station license with the FCC. Reference copies are available to all U.S. citizens for a nominal fee. The copious information on these licenses includes a number of facts that can help a coverage analysis, including the base station:

   1. Address (street, city, county, state)
   2. Latitude/longitude
   3. Output power (watts)
   4. Effective radiated power (watts)
   5. Antenna height (meters)

Recently, BSWD license facts have become more difficult to check. BSWD administratively canceled its licenses as a part of the 900-MHz auction process by a letter to the FCC on September 26, 1996.[7] However, even purged records are still public information. Much of the data can still be recovered. A listing of base station sites for ARDIS and BSWD in Connecticut is contained in Appendix I. With position

information in hand, it is quite easy to plot base stations in a particular area of interest to see how the "paper coverage" compares.

Figure 12-6 is a plot of ARDIS coverage in part of New Haven County using a 7-mile radius for the 90% coverage "reach" of the base station. This is probably an overstatement of the radius since each ARDIS base station simply does not have to

Figure 12-6 Representative ARDIS base station locations: New Haven county, CT.

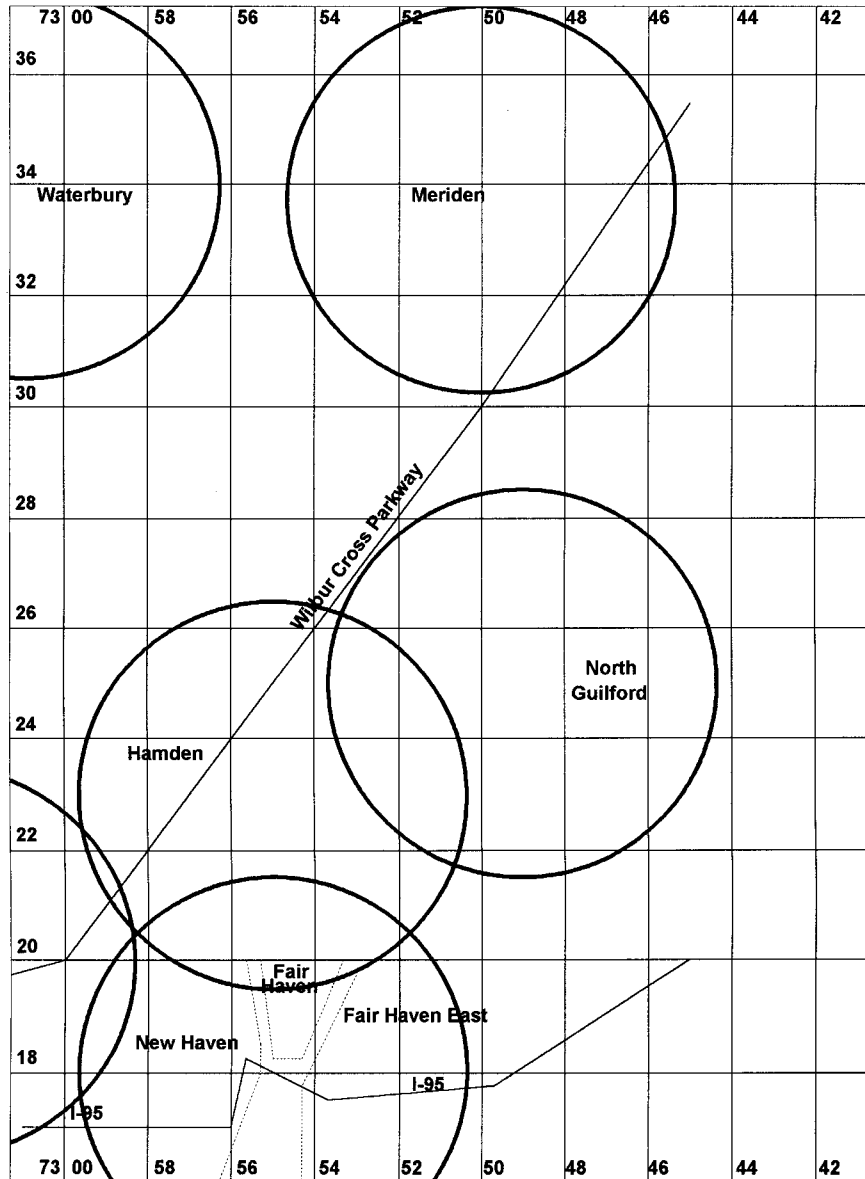cover that much territory with 90% power. However, it is easier to represent than plotting 70 and 90% curves.

Figure 12-7 is the identical layout for BSWD, also using a 7-mile radius—the stated capability of a retrofitted base station.
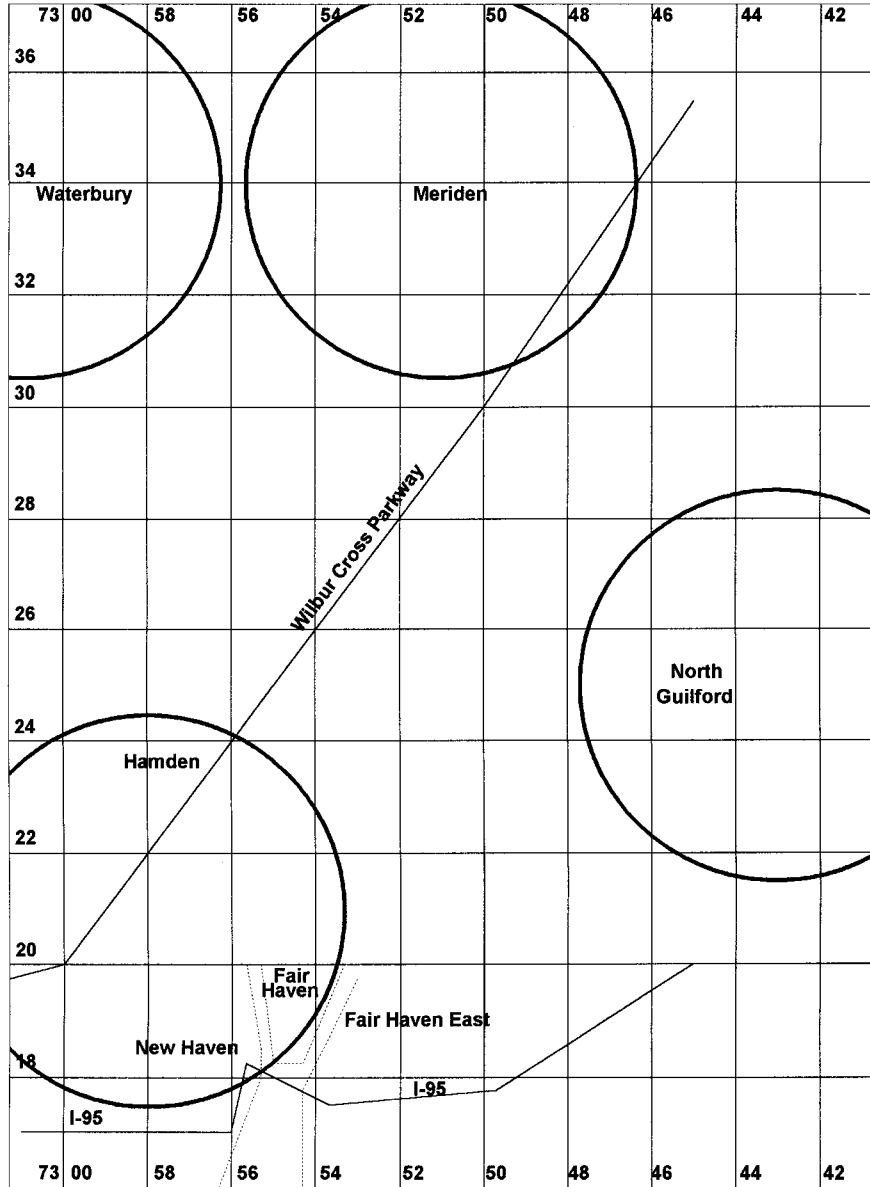
Figure 12-7   Representative BSWD base station locations: New Haven county, CT.

A cursory look at these plots indicates that ARDIS will likely have better in-building coverage in Hamden/New Haven. Indeed, this seems to be true. In side-by-side testing during January 1998, BSWD hit 6 for 6 on street and 3 for 3 in buildings with large windows. But when severe conditions were attempted—inside a closed stairwell, an elevator, the ancient stone City Hall, a Yale University building, or the back room of a restaurant—BSWD failed all five while ARDIS was completely successful.

12.3.2 Coverage Maps

Most carriers provide coverage maps that are easily accessible on the Web. The quality of these maps ranges widely: some useless, some misleading, a few that are useful. There is still value in examining them, even when the greatest payoff is in understanding what is *not* mentioned. A representative sampling of each class of coverage map follows as a guide for more determined study.

12.3.2.1   Obfuscation, Not Illumination   The first class of maps are those that seem to reveal something but, upon closer study, provide very little real insight into realistic coverage expectations. The maps are generally blobs or clouds of a rather large geographic area. No ability is given to the user to zoom in on specific cities. No map scale is present for orientation, and geographic landmarks are generally limited to interstate highways. The coverage blobs are not identified as either contours for higher powered mobile devices or the more limited range portable or hand-held units. Examples of this breed include:

1. *Ameritech* (Figure 12-8): There are only four maps in the entire repertoire. The southwestern Ohio area, spilling over into Indiana and Kentucky, embraces ~20,000 square miles. One can guess at the main coverage by tracing the Interstates on a road atlas. But there also odd splatter patterns around Washington Court House south to Greenfield and near the Hocking State Forest (I think; no towns or natural landmarks are on the map).

2. *GTE Mobile* (Figure 12-9): These maps have a scale and cover more limited areas, typically ~6500 square miles, which is about 30% more land area than the entire state of Connecticut. But since there is little detail, one is unsure about, say, the San Mateo county edges in the San Francisco/San Jose map. Are Saratoga and Los Gatos in or out? The map does not say.

3. *Bell Atlantic Mobile* (Figure 12-10): BAM's maps are especially disappointing since they initially began with considerable detail. Individual base stations were identifiable by the separated circles or arcs. Areas without any coverage were clear. In a retrograde action BAM threw out all the detail and replaced it with crude area maps like those shown for the New York City metropolitan area, an area of 7600 square miles.
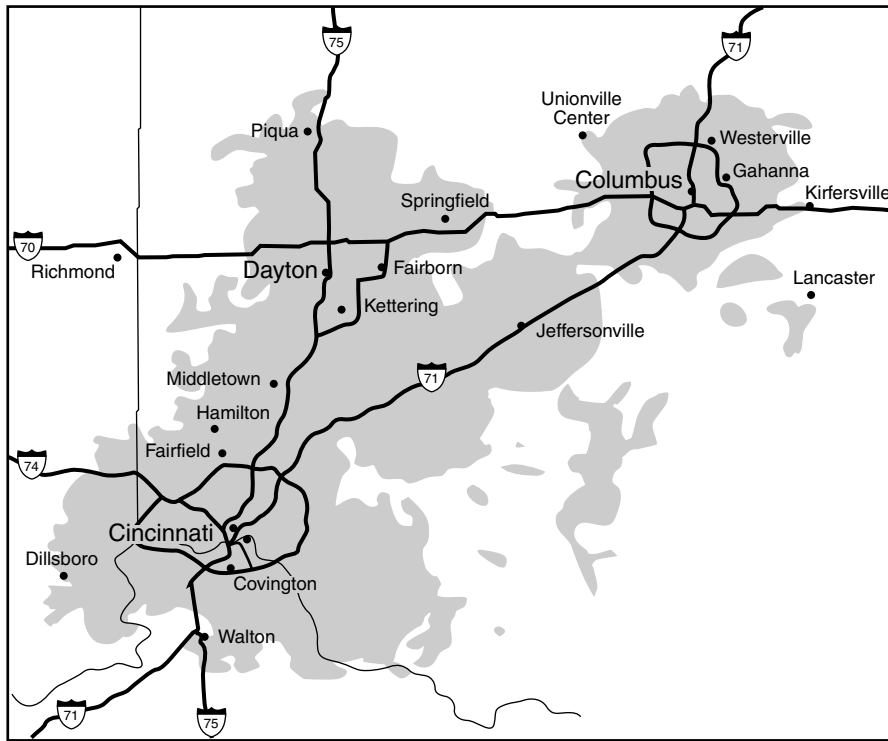
Figure 12-8   Ameritech: Southwestern Ohio CDPD coverage (8-26-98).

12.3.2.2   Useful But with Careless Errors   The second class contains scaled, sequential maps of ever-increasing detail, often to less than 50 square miles. Not only interstate highways but also secondary state and county roads often appear. The primary example of this category is ARDIS. One can progress from the 50 United States and its territories down to towns of less than 5000 people. An example is shown in Figure 12-11.

This particular base station is a low-elevation "gap filler." During September 1998 field tests the signal strength was −74 dBm inside the windowless barroom of the 225-year-old Griswold Inn in downtown Essex. Two miles away, at the intersection of Route 9 and I-95, it was −104 dBm. Three miles away, west along I-95, the RSSI was −111 dBm. Contact was lost at the 4-mile mark.

There are problems with the ARDIS coverage maps. First, they do not state what to them is obvious: ARDIS contractually guarantees 90% probability of success for hand-held devices operating within its coverage contours. That is what the maps depict, but the legend says nothing about this crucial piece of information.

Second, the map maker (American Digital Cartography) sometimes makes ridiculous errors. The expansion view for New London shows the path of the

San Francisco/San Jose   GTE CDPD Service
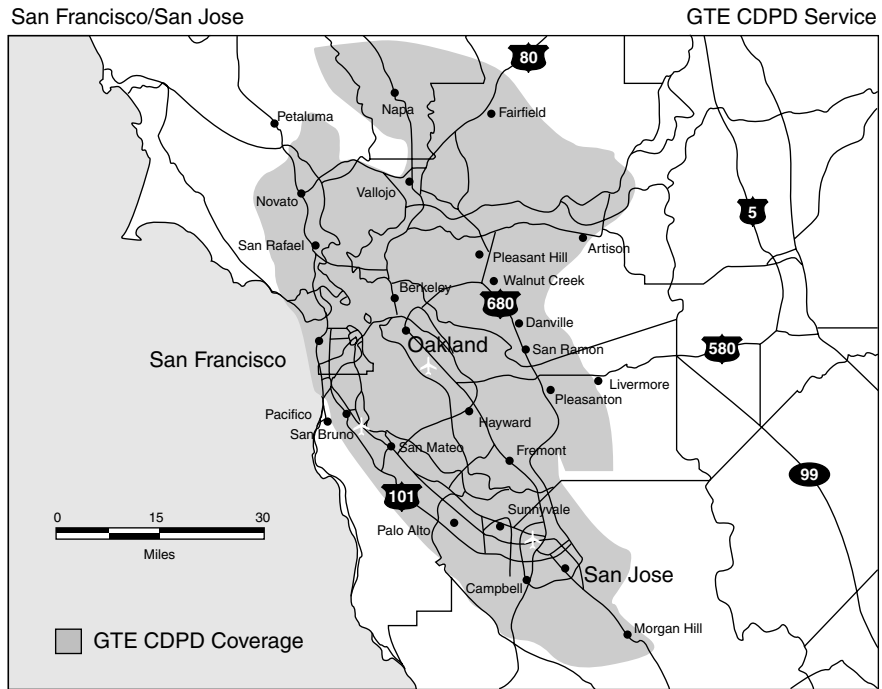
Figure 12-9   GTE Mobile: San Francisco Bay Area CDPD coverage (8-26-98).
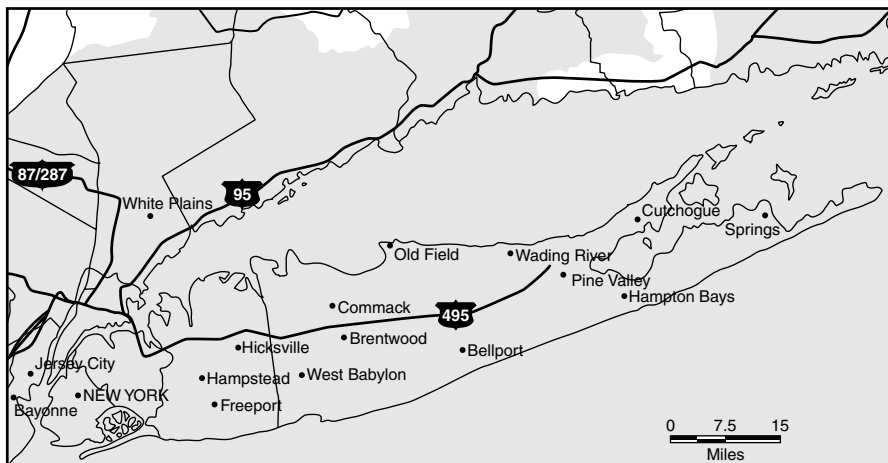
Figure 12-10   BAM: Greater New York City metropolitan area coverage.
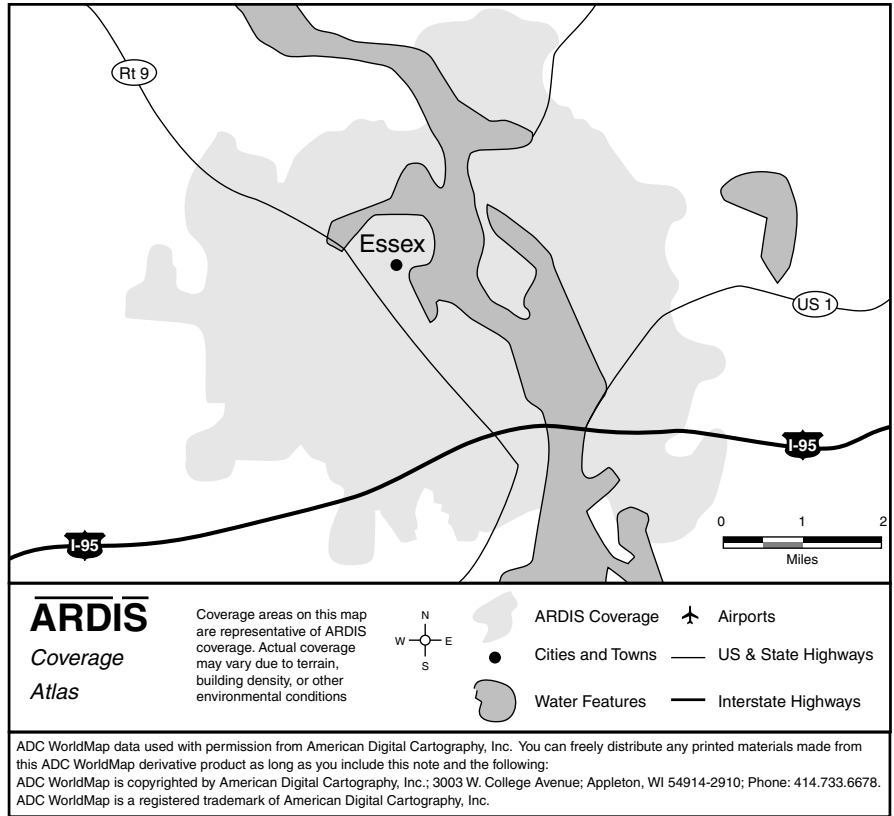
Figure 12-11   ARDIS: Essex, CT, coverage.

Orient Point ferry—right over dry land (see Figure 12-12). The Thames, a wide, deep river that is home for the Atlantic submarine fleet, is completely missing. The river should bisect the map from north to south and provide important orientation. Errors of this type harm the utility of what otherwise could be an excellent customer tool.

12.3.2.3   Misleading   In the final class are those maps that seem to deliberately lead the viewer to the wrong conclusion. Examples include:

1. AT&T Wireless: In Connecticut, CDPD coverage is provided by BAM or SNET. Yet one can call up AT&T coverage maps for Connecticut cities whose contours are identical to BAM's. That is because it actually *is* BAM's coverage, not their own (which does not exist). The AT&T map is shown in Figure 12-13.

Preconsolidation, the service providers for New York City and Long Island were AT&T Wireless (A side) and NYNEX (B side). When NYNEX was absorbed by
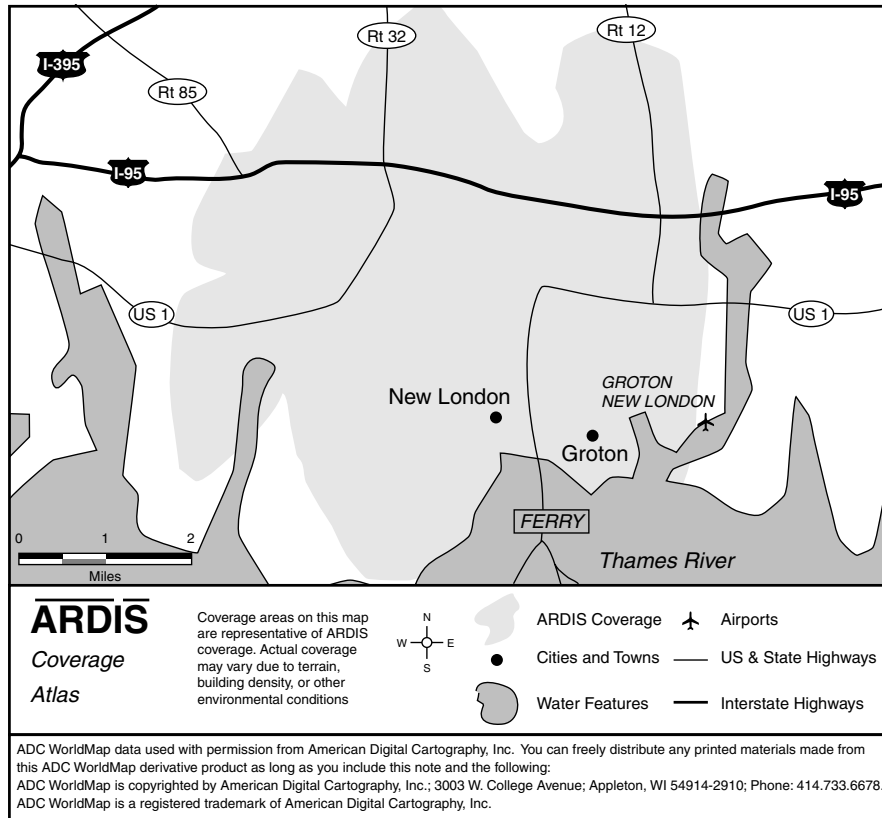
Figure 12-12 ARDIS: New London, CT, map errors.

BAM, its A side Connecticut users commuting to New York City had to be programmed to switch from A to B or AT&T Wireless got the business. This should be taken literally; one can be stung by unexpected roaming charges. When an AT&T CDPD user roams from Long Island (New York metropolitan area) to Connecticut, BAM provides the service. The user pays a roaming fee. There is no intercarrier agreement between AT&T and BAM for Connecticut.[8] BAM's explanation is straightforward: "we want our customers to use our own system." The extra charges are not mentioned in the AT&T coverage map.

2. BSWD: Does some things exactly right. Its maps uniquely depict both portable and mobile coverage. Further, one can search by state and specific cities within the state. However, the resulting maps are disappointingly coarse, rarely depicting anything less than ~2000 square miles. This coarseness disguises dissembling. If Macallen, Texas, is called up, one is rewarded with a correctly titled, circular coverage map. Unfortunately, those who had trouble with grade school geography will tend to think Macallen is in the center of the blob. In fact, Macallen is 35 miles west of Harlingen and has no BSWD coverage. See Figure 12-14.

Figure 12-13   AT&T Wireless "Connecticut" coverage.

If Alexandria, Louisiana, is sought, it is very hard to tell that it is completely off the map, 80 miles northwest of Lafayette on I-49 (see Figure 12-15).

In short, BSWD maps are perfect example of the reason for Ronald Reagan's old maxim: "trust, but verify."

12.3.3   ZIP Code Predictors

It is virtually certain that all carriers have internal tools that yield the probability of coverage by ZIP code. ARDIS and BSWD predict both in-building and on-street coverage by ZIP code and provide this information as part of their customer bids. AT&T Wireless apparently only has on-street coverage predictions; at least that is all that will be externally shared.[9]

Some carriers, ARDIS is one, provide ZIP code prediction tools to all relevant parties—even consultants! As would be expected, one is immediately wary of a carrier-provided tool. In my own case, I called up ARDISZIP, entered my own ZIP code, 06902, and received the prediction shown in Figure 12-16. The in-building probability prediction: 95.48%.

I immediately did 17 in-building tests within this ZIP code, from train station tunnels to doctor's waiting rooms, to the insides of supermarkets. Sixteen of the
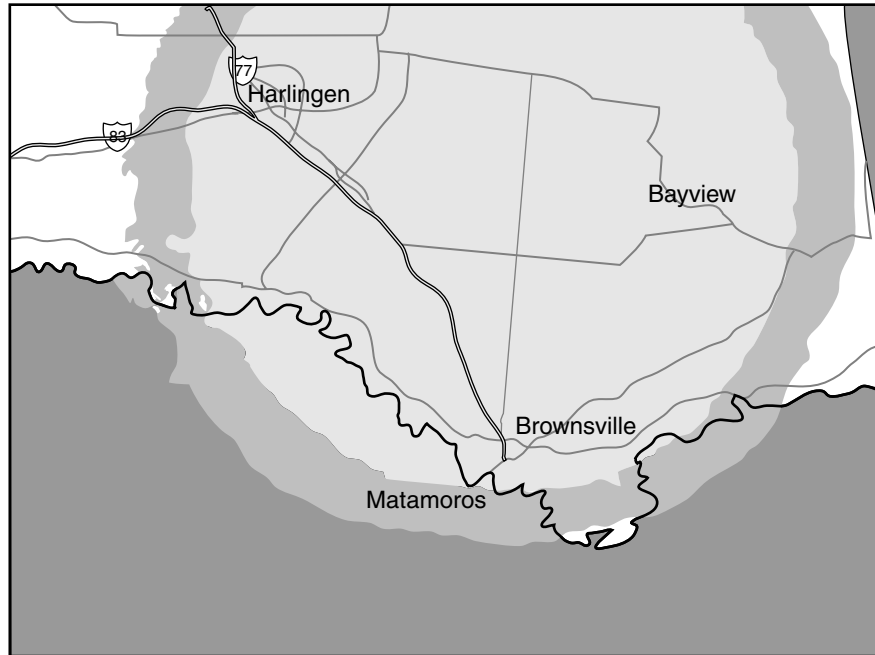
Figure 12-14 BSWD: "Macallen," TX, coverage.
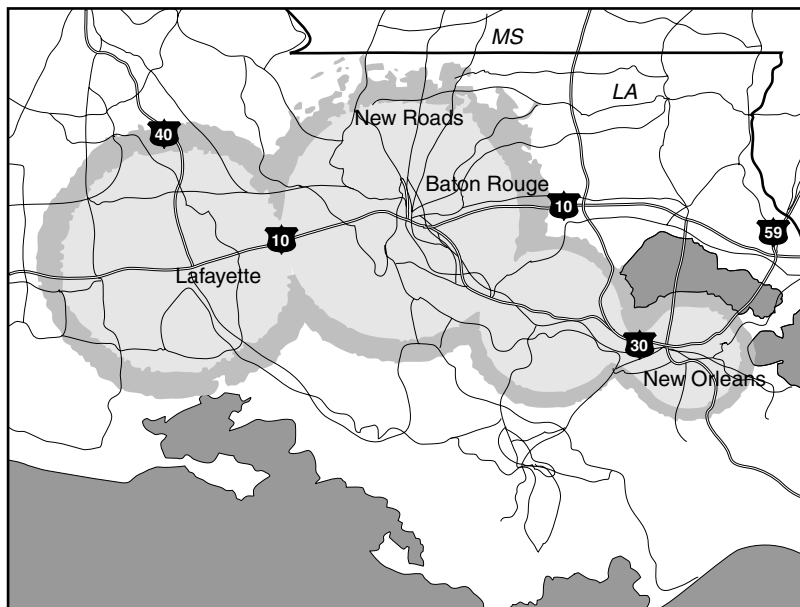
Figure 12-15 BSWD: "Alexandria," LA, coverage.
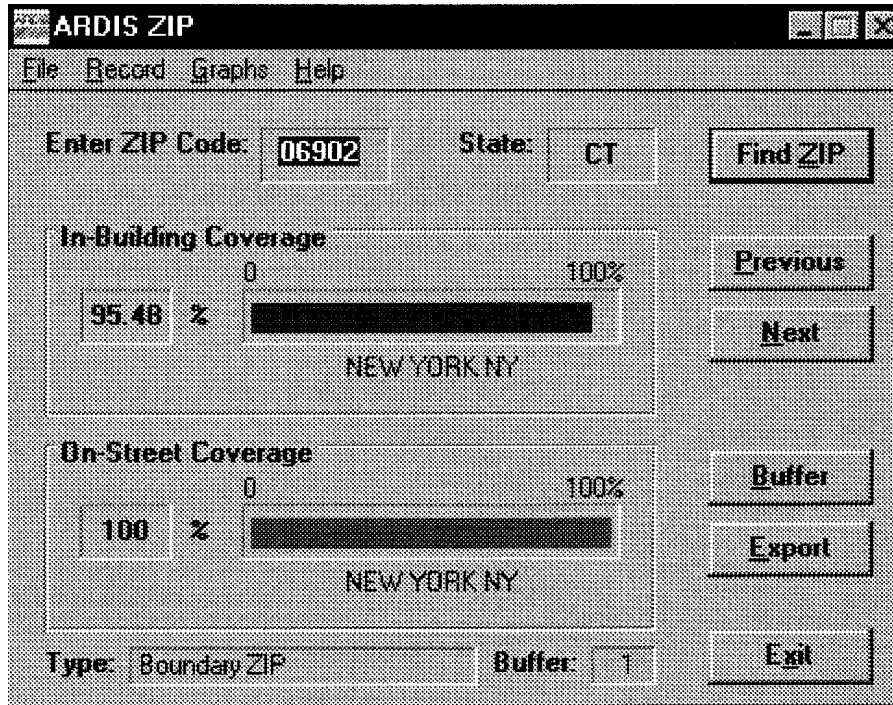
Figure 12-16   ARDISZIP prediction: zip code 06902.

17 were successful: 94.1% versus 95.5% predicted. Maybe I had something here! In fact, the ZIP tool has proven to be an extraordinarily good indicator of coverage.

If the ZIP code prediction is off the mark, it does not necessarily mean a poor sample size. When I consistently received much lower than expected results in the Groton/New London area, I reported this fact to ARDIS. The Motorola maintenance force reported the base station on spec. The coverage results remained dismal. ARDIS network management people were dispatched and found that a new building had been erected beside the base station. It was on spec all right, but blasting much of its energy into a brick wall. An exculpatory comment: Groton/New London has fallen on terrible economic times with the cancellation of virtually all submarine contracts. Message traffic has declined precipitously as users moved away. The practical existence of the problem had thus been somewhat masked.

Since that time results of other user field tests have been reported. An extract from the Schindler/Millar Elevator report is summarized in Table 12-1, which indicates that every prospective user should begin the coverage analysis problem with a ZIP code prediction tool.

Table 12-1 Schindler/Millar elevator in-building predicted versus actual results

	ARDIS		BSWD	
	Predicted	Actual	Predicted	Actual
Percent coverage (weighted)	88	86	76	72
Number of locations	71	71	47	47
Number of test points	231	231	155	155

12.4   FIELD TESTS

12.4.1   Simplified Approaches

Analysis is great, but do field tests support the analytic conclusions? The general answer is yes. The JFD Associates field tests[10] conducted through the years employ no engineering tools. Instead, carrier-supplied devices are used to transmit fixed-length, canned messages via E-mail. If response time is not a consideration, the traffic can be sent to a large-scale system, such as a CompuServe account, for later data reduction. Internet transfers also permit messages to flow between devices, a convenient way to generate incoming traffic.

If the carrier is cooperating fully and will provide a post test transaction log, a swifter approach is to send the same canned traffic to yourself. Response time goes from minutes to seconds, speeding up the entire process, and each message transmitted results in a paired receipt, doubling the traffic in the already shortened test time.

To simplify decisions, arbitrary ground rules are fixed. For example, the device is turned off at the end of each test. After moving to the new location, the device is powered on. Failure is declared if the device fails to register within 5 minutes or, having registered, is unable to successfully complete message transmission within 5 minutes.

Since the tests have been ongoing, the device mix has steadily changed. ARDIS has gone from the external InfoTAC to the PC-Card PM100D to the I@P. BSWD has gone from the external Mobidem to the InfoTAC to the I@P. CDPD has moved from internal Ubiquity modems to PALphones to both external and internal Sierra modems. Device choices impact test results. It seems clear that BSWD performed better with the Motorola InfoTAC than it did with the Ericcson Mobidem. But BSWD was steadily enriching its infrastructure during these intervals; the impression could be erroneous. It is best to test device for device, as in comparative I@P trials.

Gradually one learns what not to test. Without a speedometer readout, high-speed vehicular tests are futile. One should note totally enclosed, versus windowed in-building, tests, but not make too fine a point on how far away the windows are. Longer (1000-byte) messages tend to fail a bit more often than 250-byte messages, but

the tiny percentage difference is not worth the extra time invested. The tester seeks directional accuracy, not flyspeck precision.

12.4.2   External Approaches

Side-by-side testing of ARDIS versus RAM was first performed by Pitney Bowes in 1993. Testing at 647 statistically chosen customer locations was performed in the following priority sequence:

1. At the machine to be serviced (preferred)

If unsuccessful:

2. Somewhere in the same room with the machine

If unsuccessful:

3. At the nearest window

If unsuccessful:

4. Outside the building

The summary tabulation of successful tests *by height in the building* (0 = ground, 1 = first floor) is given in Table 12-2.

On October 31, 1995, BSWD (then RAM Mobile) made a presentation claiming "equal in-building coverage" with ARDIS.[11] The words were most emphatic. They were also laced with frequent references to the objectivity of their own "independent study" as well as inaccurate references to the Pitney Bowes tests. Interested, I read the White Paper on the subject.[12] There one learns that:

1. The modem used for both carriers was the InfoTAC, an excellent normalizing decision.
2. While RD-LAP was available in Boston, the test location, BSWD chose not to use it. Instead, it employed only MDC4800 for ARDIS. Better response time

Table 12-2   Pitney Bowes field test summary

Floor Number	Percentage of Successful Tests		Number of Successful Tests
	ARDIS	RAM	
−1	68.0	20.0	25
0	73.3	38.9	90
1	75.0	46.1	395
2	90.9	67.7	65
3, 4	91.2	78.1	32
>4	92.5	95.0	40
All (weighted)	78.1	50.9	647

was then claimed for BSWD, which is not surprising, but unfairly portrayed during the presentation.

3. The "in-building" test may have had no deep penetration component at all: "At each selected location a test was run for each service outside and inside a building." There went half the in-building count. Further, in-building tests were "close to a window as well as away from the window." Were any totally enclosed?

Thus, the BSWD test was reported with great distortion. Once again, potential users must be wary about accepting sales pitches at face value.

12.4.3   Summary Field Test Results

Table 12-3 summarizes five years of test results, divided into two main categories: street-level and in-building coverage. It is possible to subdivide many of the in-building tests still further (e.g., window present, completely enclosed). However, these gross summaries give a high-level view that is a reasonable characterization of the coverage capability of the three main packet providers.

12.4.3.1   Street-Level Tests   These results are dominated by JFD Associates tests. ARDIS and BSWD have similar results, with ARDIS holding a useful advantage. The cumulative results are less than the 90% goal. This is primarily a result of the severity of testing in the first half of 1994. The "marginal suburbs" tests worked the very edges of the coverage contour lines; many of the Stamford tests were equally difficult. These tests were not random and dragged down both ARDIS and BSWD. If the results are plotted, as in Figure 12-17, one gets a better comparative feel for street-level coverage.
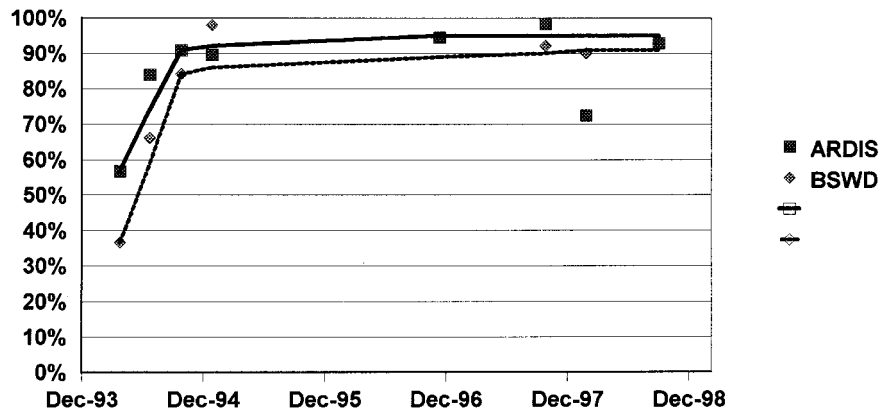
Figure 12-17   ARDIS vs. BSWD street-level coverage.

Table 12-3 Field test summary report

Date	Tester	Description	ARDIS		BSWD		CDPD	
			Number of Tests	Good	Number of Tests	Good	Number of Tests	Good
		Street Level						
2Q94	JFD Assoc.	Marginal suburbs	30	17	30	11	—	—
	JFD Assoc.	Stamford, CT	56	47	56	37	—	—
4Q94	JFD Assoc.	Philadelphia metropolitan area	44	40	44	37	—	—
	JFD Assoc.	Brooklyn street level	48	43	48	47	Abandoned	
4Q96	JFD Assoc.	CT metropolitan area: on-street	36	34	—	—	43	12
3Q97	Schindler	Workday on-street	60	59	38	35	Abandoned	
1Q98	JFD Assoc.	I@P street/highway	94	68	100	90	—	—
3Q98	JFD Assoc.	I@P partial failure retest	14	13	—	—	43	12
			382	321	316	257	43	12
Percentage of success				84.0		81.3		27.9

Table 12-3 (*Continued*)

Date	Tester	Description	ARDIS		BSWD		CDPD	
			Number of Tests	Good	Number of Tests	Good	Number of Tests	Good
		In-Building						
1993	PitneyBowes	Workday locations	747	660	647	444	—	—
1Q95	JFD Assoc.	Brooklyn	23	16	23	15	23	7
1Q95	JFD Assoc.	Manhattan	20	13	17	6	—	—
2Q95	BSWD	Boston: ~25% in-build'g	422	335	422	334	—	—
1Q96	JFD Assoc.	InfoTAC	70	56	—	—	—	—
1Q96	JFD Assoc.	PM100D	70	60	—	—	—	—
4Q96	JFD Assoc.	CT metropolitan area	25	21	—	—	25	13
1Q97	Schindler	Workday in-building	176	153	117	67	Abandoned	
	JFD Assoc.	Fairfield, CT	46	40	—	—	45	34
	JFD Assoc.	NYC	62	60	—	—	63	54
	JFD Assoc.	Westchester	25	16	—	—	24	12
	JFD Assoc.	Nassau/Hudson	17	16	—	—	17	15
1Q98	JFD Assoc.	I@P NYC/CT metropolitan area	53	40	54	45	—	—
			1756	1486	1280	911	197	135
Percentage of success				84.6		71.2		68.5

Both ARDIS and BSWD are now generally above 90% coverage and are tending to converge. Indeed, BSWD was actually much better than ARDIS in the January 1998 I@P tests. There are three reasons for this result. First, many of the tests were conducted in the Greater New York City metropolitan area whose base stations BSWD has specifically enriched for two-way paging. This is a good indicator that BSWD coverage can be expected to improve even further as infrastructure enhancements continue.

Second, a problem with a revised version of ARDIS MDC4800 base station microcode was exposed during testing. ARDIS subsequently corrected the error on all Connecticut base stations; a spot check of just the failing locations was conducted in September 1998 with good results.

Third, a significant number of tests took place in the New London/Groton area, where ARDIS performance was abysmal because of the base station siting problem mentioned earlier.

Note that six fewer tests were recorded for ARDIS than BSWD in January 1998. This is because ARDISZIP predicted no coverage in that ~30-mile stretch of I-95 from Branford to Essex (I tried anyway; ARDISZIP was correct). However, BSWD was generally present—clearly an advantage for, say, a traveling sales person.

CDPD (AT&T Wireless & BAM) was essentially not in the race. Schindler "stopped testing CDPD early into the field test due to limited success and coverage."[13]

12.4.3.2   *In-Building Tests*

The most noticeable number present in Table 12-3 is the large ARDIS test sample. This resulted from an eagerness on the part of ARDIS to be tested against anyone. Often BSWD refused to cooperate, and test devices were obtained from its customers instead. BAM is open and interested in comparative testing, but in the early years CDPD was simply not ready.

These tests should not be considered statistically valid. They have a strong East Coast bias, with most of the testing occurring between Boston (one-third of the BSWD tests) and Washington, D.C. Some testing occurred in Chicago, Los Angeles, Seattle, and Tucson, but the East Coast was dominant.

Second, the devices were not always held constant throughout each test. BSWD tests were conducted with the InfoTAC for both carriers, Schindler tests used the Itronix XC-6000, and the latest JFD Associates test used the I@P. These "device constant" tests accounted for about 46% of BSWD results. But the balance was a mixture of Mobidem's versus InfoTAC's. On the CDPD side there were such problems with devices that it was rare to have the same device for more than a week. Internal modems, external modems, PALphones, even a PALM unit were tried (the PALM unit failed). As time went by, the ARDIS unit progressed from InfoTAC to PM100D to I@P.

Given those caveats, the general results are at least indicative of the truth. ARDIS holds an edge on in-building penetration, though BSWD I@P test results in Greater New York City are especially good. It is worth noting that CDPD is closing its in-building coverage gap throughout the tristate area. If one concentrates only on the 149 tests performed during the third quarter of 1997, CDPD was successful 77% of

the time. Not yet a winner, but light years removed from its abysmal performance in Brooklyn 2½ years earlier.

As an aside, diligent efforts were made to test AT&T Wireless as well as BAM CDPD. There was an initial, enthusiastic reception from the Pacific Northwest staff. But when it became clear that I intended to test independently, and that Manhattan would be high on the list, AT&T Wireless backed away. In September 1998 they had "lots of issues in the concrete canyons" and "were going through their second market re-tune." They had "different coverage designs" in an attempt to make the situation better. I was requested to confine my testing to Westchester County, where "you'll find coverage that is more representative of what the final network will be like."[14] I stuck with the BAM results.

12.5   CAPACITY COST OF BETTER IN-BUILDING PENETRATION

12.5.1   Agreeing on a Baseline

The technical solutions offered by equipment manufacturers have such wide variations that agreeing on valid capacity comparisons is difficult. ARDIS, for example, uses two Motorola designs, both of which depend on full-width (25-kHz) channels. BSWD uses an Ericsson design that sends information down half-width (12.5-kHz) channels. The airtime protocols, all half-duplex (HDX), have a wide range in the amount of information allocated to error correction. The bit rates differ, and even the spectrum allocated varies sharply between ARDIS and BSWD. How can one comfortably compare the information-carrying capacity of each?

Begin with a single ARDIS channel at a physical base site—a common configuration—and compare it to *two* RAM channels at the same site: 25 versus 25 kHz. Next, evaluate only the more modern ARDIS RD-LAP protocol: 19,200 bps versus RAM's 8000 bps on *each* of its channels. The Motorola approach delivers more raw bits per second over the same allocated spectrum than Ericsson: 19,200 bps versus ($2 \times 8000 = 16,000$ bps. Third, the Motorola protocol is years newer in design and allocates 25% of its bits to error correction. The older RAM protocol yields one-third of its raw capacity to error correction.

Thus, if only 25 kHz of spectrum at a single physical site were to be evaluated, the Motorola approach delivers, very grossly, about 1.35 times as many user bits (which will incur further losses for headers and control) as Ericsson:

$$\text{Motorola:} \quad 19,200 \text{ bps} \times 0.75 = 14,400 \text{ bps}$$

$$\text{Ericsson:} \quad 16,000 \text{ bps} \times 0.67 = 10,667 \text{ bps}$$

12.5.2   Single-Base-Station Cities

ARDIS equates a base station to a single-channel pair; some BSWD base stations operate with multiple-channel pairs. In the real world ARDIS will have only one channel available at a small remote city such as Battle Creek, Michigan, or Lawrence, Kansas (both of which have coverage from each carrier). BSWD could theoretically have 10 (they will not, but could). The comparative spectrum: 25 versus 125 kHz. Thus the crude capacity potential shifts. It is now more like 14,400 bps versus 10,667 $\times$ 5 = 53,335 bps. This gives BSWD the theoretical ability to handle 3.7 times the number of users having identical message profiles. Unfortunately, this capacity would be available in a location that really does not need it.

12.5.3   Putting Multiple Base Stations to Work

In Section 12.2 a comparison of BSWD with seven overlapping base stations versus ARDIS with five separated sites was used to illustrate the different coverage/penetration philosophies. For large metropolitan areas that example can be extended in not-so-extreme ways to dramatically illustrate capacity impacts.

Assume that 30 half-wide channels are available for the seven BSWD sites. After allowing for control channel overhead, assume that each site has four user data half-wide channels, all quite capable of transmitting simultaneously. So far these assumptions are routine. Now bend reality a bit and assume that there is such a fierce outbound load that every channel across all stations has a message queue. Then BSWD can unload $2 \times 7 = 14 \times 10,667$ bps = 149,338 bps.

For ARDIS assume that there is only a single full-width channel available and that it is present on all five base stations. Assume further that when the center base station transmits all surrounding base stations must be quieted to avoid interference. However, the diagonally opposed stations may transmit simultaneously since there is enough physical separation between them to permit FM capture to lock up the receiving device. If every base station has a message queue, the firing sequence might be as shown in Figure 12-18.

With this sequencing problem to solve, ARDIS, on average, can only have 1.67 base stations in operation simultaneously. Since there is only one full-width channel available, ARDIS can unload only $1.67 \times 14,400$ = 24,048 bps.

Thus, in this fictitious example BSWD has 6.2 times the potential subscriber capacity of ARDIS (149,338 ÷ 24,048).

But large metropolitan areas are exactly where ARDIS acquires additional channel capacity. Many major cities have six channels; New York City has eight. Not all are RD-LAP; MDC4800 is certain to be a historical presence for years to come. Some of the new RD-LAP channels/base stations may be restricted to just the core area of intense traffic, possibly just for high-powered vehicular devices. The ARDIS coverage therefore tends to resemble a wedding cake, with the device switching between protocols. This is depicted in Figure 12-19.
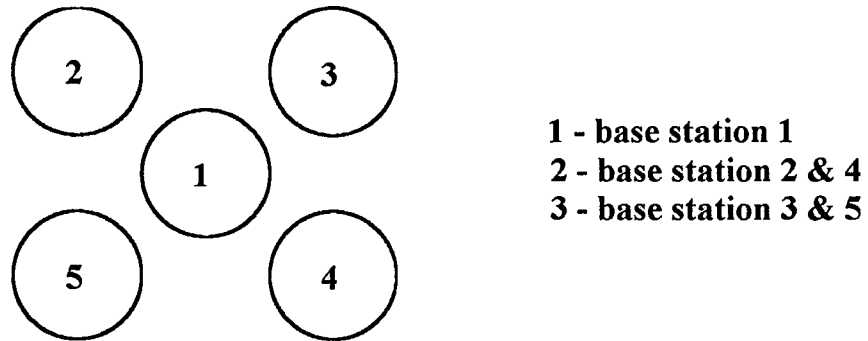
Figure 12-18   ARDIS sequential transmission (illustrative).

A Stamford commuter may begin E-mail activity on the outer MDC4800 layers. By the time Grand Central Station is reached, the device will switch to an RD-LAP level, if it is free. In the core high-traffic area, the device has multiple opportunities to connect. This capability reduces—possibly eliminates—the BSWD capacity edge.
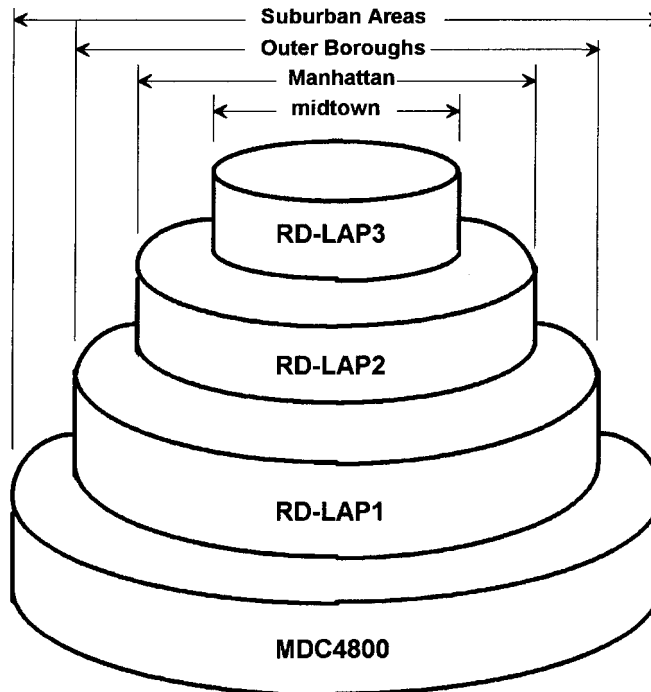
Figure 12-19   ARDIS channel/base station layers (representative).

12.5.4   Future Outlook: Coverage Versus Capacity

ARDIS in-building capability does come at a price: subscriber capacity. To build capacity, ARDIS must add additional infrastructure. Each new channel layer added forces a new round of base stations. Single-channel ARDIS base stations are less complex, and less costly, than the multichannel BSWD Mobitex units. But each new ARDIS base station has a new leased-line requirement, one reason why they are so often co-located with a prior base. There may also be additional rooftop rental costs, and certainly there is additional maintenance.

BSWD has better subscriber capacity potential at a cost of in-building performance. Ironically, the two-way paging drive forced BSWD to a new objective: "Coverage comparable to one way paging, nationwide."[15] In 1997 it began a $3\frac{1}{2}$-year plan to improve all existing base stations and add 1300 more minibases. In the New York City metropolitan area (Danbury, CT, to Ocean County, NJ) BSWD added 60 additional base stations during 1997. The total cost of the nationwide infrastructure improvements for in-building coverage is $120 million to deploy and $30 million in operating costs.[16] The insertion of so much infrastructure is certain to raise BSWD's capacity potential.

It is reasonable to assume that, over time, both ARDIS and BSWD will provide comparable in-building coverage. It is essentially already at that point in Manhattan. Further, CDPD is coming on strong in Gotham. This is good news for future users who may not wish to be tied to one vendor choice.

12.6   SUMMARY

The most important *coverage* conclusions based upon both position analysis and field tests are:

1. No carrier has anything remotely approaching "anytime, anywhere" service.
2. ARDIS' geographic coverage, its nationwide area "footprint," is considerably better than BSWD's. CDPD is a distant third.
3. In street-level locations where both provide coverage, ARDIS has an edge over BSWD.

The most important *in-building penetration* conclusions are:

1. ARDIS' in-building penetration capability is better than BSWD's; both are far better than CDPD.
2. Channel for channel, better in-building penetration extracts a capacity cost from ARDIS.
3. When infrastructure and channel counts are reasonably normalized, as in New York City, ARDIS and BSWD coverage converges.

4. CDPD has good in-building coverage in selected, finite areas but tails away drastically when one leaves those areas.

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IV

SOME PRIMITIVE TECHNICAL CONSIDERATIONS

13

UNDERSTANDING AIRTIME PROTOCOLS

13.1 THE PACKET REVISITED

A "packet" is the information unit formed when a message is partitioned into more manageable sections for transmission and recovery. Most landline packets have three logical subsections created when control information is added to user data (Figure 13-1). Packets are not required to travel only on packet switched networks. They function quite nicely on circuit switched systems as well—often a source of confusion for persons first encountering *adaptive packet assembly* in Microcom's protocols sent over circuit switched facilities. Since February 1997 GTE Wireless has offered CS-CDPD[1] (circuit switched CDPD), "which enables CDPD users to transmit packet data over existing circuit switched networks."[2]

To grasp the principle of the packet, the most common form of landline implementation will be discussed first. It is possible to transmit landline packets over radio links, as is routinely done in data over cellular. As bit rates rise, however, error-*checking* codes become less satisfactory and are usually augmented with error *correction* codes. These differences will be explored second.

13.1.1 Message Segmentation: The Flag

When the user message is partitioned into packets, a reserved separation character called the flag marks both the beginning and the end of the packet (Figure 13-2). The most common flag implementation, found in such diverse protocols as SDLC/HDLC, MNP, and CDPD, is the 8-bit sequence 01111110.

In these protocols the flag is one of three reserved patterns. The flag can also be manipulated in hardware by a technique known as "bit stuffing," which permits data transparency. These special variations will be discussed shortly.

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HEADER	USER DATA	TRAILER

Beginning of Message
Source Address
Destination Address
Sequence Number(s)
Routing Information
Billing Information

Error Checking Code
End-of-Message
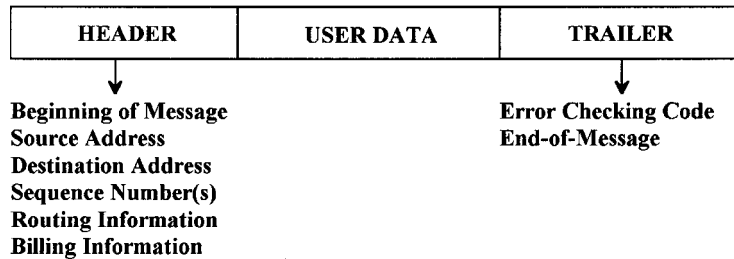
Figure 13-1   The packet.

13.1.2 Address Field

The field following the flag is the address. Its minimum size is 8 bits, which yields only 256 unique addresses. In practice, address fields are *very* much larger, leading to the use of complex surrogate techniques to reduce the associated transmission overhead. One trivial technique is to uniquely identify the source or destination address depending upon the function being performed. Using balanced address rules (unbalanced rules also exist), the field specifies the destination for commands; the same field specifies the source for responses (Figure 13-3).

13.1.3 Control Field

Following the address is a tightly packed field that defines the functions to be performed (Figure 13-4). The information format controls the transmission and

User Message

Segment 1	Segment 2	Segment 3

packet1   packet2   packet3

■ = separator, frame character or FLAG

Figure 13-2   The flag.

Flag	Address	

Balanced Addressing Rules
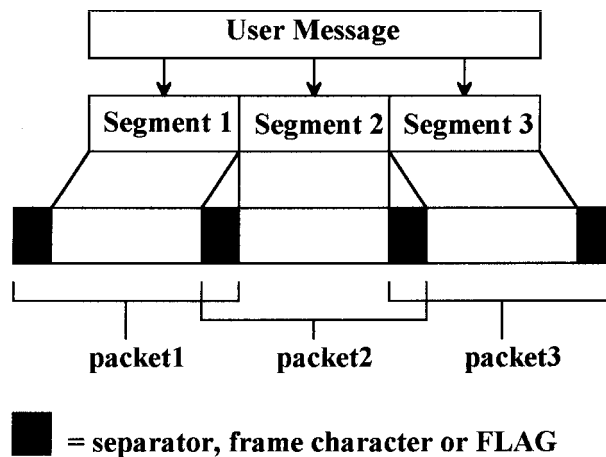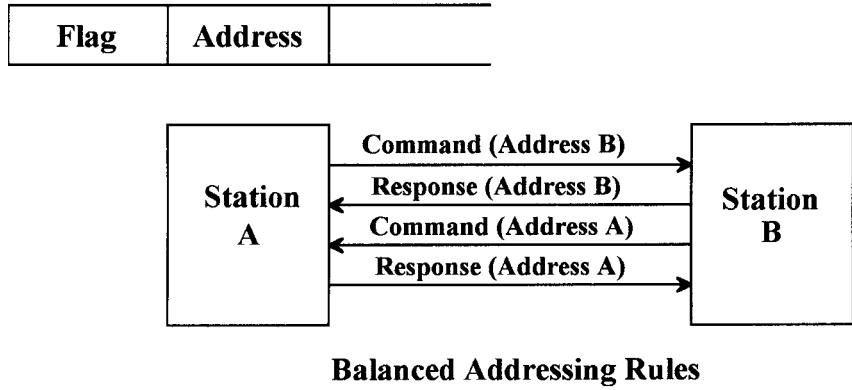
Figure 13-3 The address field.

Flag	Address	Control	
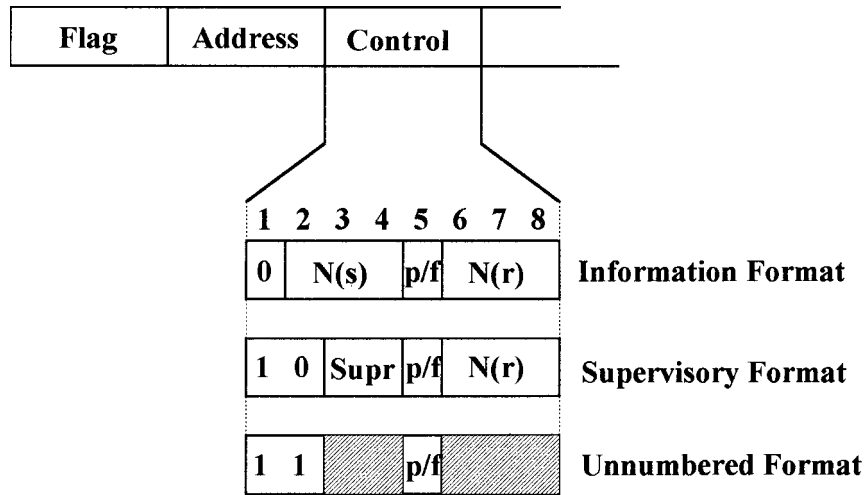
N(s) = send sequence number of this packet

N(r) = next sequence number expected to be received

p/f = poll/final bit

Figure 13-4 The control field.

acknowledgment of end-user data, along with a poll to solicit a status response. The supervisory format controls requests for retransmission; the unnumbered format controls initialization and disconnection.

In the single-octet implementation there is room enough for the information format to track the sequence numbers of seven separate packets on both the send and receive sides. When the inbound response is unpredictable, as in CDPD, this field is expanded so that 128 packets may be outstanding in each direction.[3]

13.1.4 Information Field

User data is optional and is only associated with the information format. The information field follows the control field and can be variable in length up to a defined system limit. The greater the length of the information field, the more vulnerable the packet is to error and subsequent retransmission. CDPD defaults vary by carrier. ARDIS (RD-LAP) and BSWD have 512-octet maximums. This does not imply that the message length is limited to 512 bytes. It simply defines the maximum size of each segment of a multisegment message.

Flag	Address	Control	User Data	

Flag-Like Sequences Broken By Bit Stuffing:

Transmitter Inserts "0" After Encountering Five "1"s

Receiver "Unstuffs":
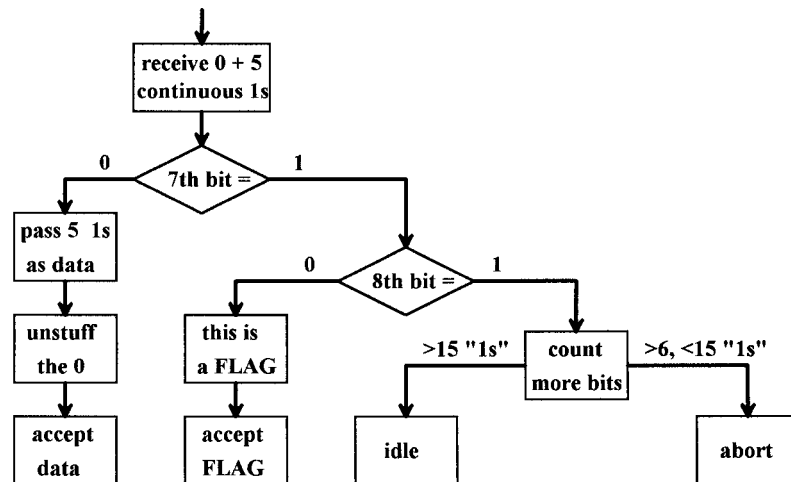
Figure 13-5   Bit stuffing.

Usually the information format is "transparent": Any format is legal, which puts user data into potential conflict with the flag and the other two reserved patterns. This problem is solved by bit stuffing, as shown in Figure 13-5.

13.1.5   Frame Check Sequence Field

The final field, occurring just before the ending flag, is the frame check sequence. Usually called the CRC, or cyclic redundancy check, this field is used for error *detection*. In its most common form the CRC is two octets long, quite useful for lower speed (~2400-bps) transmission. As transmission speeds rise, this simple code begins to let a small number of undetected errors slip past. With the Mobitex protocol employed by BSWD, noise bursts greater than 16 bits (2 milliseconds at 8000 bps) will very occasionally permit undetected errors to occur.

Modern implementations for the RD-LAP protocol employed by ARDIS use four-octet CRCs. Naturally there is an overhead penalty, but the undetected error rate in the presence of noise is infinitesimal. These trade-offs, as well as the use of error *correction* will be discussed next.

13.2   ERROR-HANDLING APPROACHES

13.2.1   Philosophy

A key distinguishing characteristic between airtime protocols is their particular philosophy of error handling. Nearly all vendors claim to have error correction protocols. In the very strictest sense many do not. Instead, their protocols actually feature error *detection* and retransmission to (finally) produce a clean copy. Well-known examples of vendors that claim this form of error correction are Microcom, with its MNP defacto standard, or any vendor using the V.42 standard that is present in virtually all circuit switched cellular modems. There will be more about V.42 in Chapter 15.

A true error *correction* protocol is one that transmits enough redundant data, in a particular mathematical way, to permit faulty information to be corrected upon receipt without retransmission. All Motorola protocols, Ericsson's Mobitex, as well as CDPD fall into this category.

Some protocols mix techniques; the combinations are endless. It is possible to use error detect mode until the retransmissions become onerous, switch to forward error correct mode, and back that up with yet another level of detect/retransmit. All protocols, detection or correction, have breaking points. The power of the error correction technique is usually expressed as the UBER, the undetected bit error rate. This is the frequency with which a bit in error escapes unnoticed into the data

processing system. The less often this happens, the better, but good UBERs have a practical cost that may not be justified in some applications.

13.2.2 Error Detection Versus Correction Basics

Assume an artificial world in which no more than one bit in 100 would ever be in error (there are such environments, though not in data radio). The protocol designer might then enforce a maximum block size of 10 octets. Since the single-bit error is not frequently encountered, the designer might settle on a detect/retransmit scheme. Each octet could be assigned, say, a single odd parity bit. The detection of the single-bit error in the transmitted letter "d" could be represented as in Figure 13-6.

Since the error is detectable, the message will be retransmitted and likely will be fine on the second attempt. Thus, one bit in nine is redundant, yielding a "pure" protocol efficiency of ~89%. Now assume the single-bit-in-100 rule holds but that the occurrence is expected to be unpleasantly frequent at times. In the worst case every retransmitted block would be contaminated. Retransmission could occur endlessly, but no useful information would ever reach the destination. The designer could now elect to add forward error correction to the block by adding an LRC, or vertical parity, code.

The transmitted block would then look like Figure 13-7. Now 18 bits in every 99 is redundant for a "pure" protocol efficiency of ~81%. But retransmissions have been stopped since the location of the error is known—caught in the crossfire of the two parities—and can be corrected. The designer trade-off is thus reasonably straightforward. If only a few blocks in 10 will have an error, use error detect/retransmit. If many blocks, including all 10, will contain a single error, expend the overhead and use forward error correction. For a 100-octet message with exactly one bit error every 10 blocks, this can be demonstrated as follows (TRIB means transfer rate of information bits):

	User Octets	Bits/Block	Number Blocks	Bits Sent	Bits Resent	TRIB Efficiency
Detect	100	90	10	900	90	800/990 = 80.8%
Correct	100	99	10	990	—	800/990 = 80.8%

Although real-world scenarios are fiercely more complex than this trivial drill, it is exactly this kind of trade-off, on a far grander scale, that eternally faces the protocol designer.

13.2.3 Error Detection Versus Correction: Vendor Examples

In data radio environments bit errors rarely occur in isolation, a phenomenon usually associated with miscellaneous transmission impairments such as Gaussian noise.

letter	EBCDIC	parity		bits sent	bits rec'ved	
u	10100100	+ 0	=	101001000	101001000	
n	10010101	+ 0	=	100101010	100101010	
d	10000100	+ 1	=	100001001	101001001	<= even parity
e	10000101	+ 0	=	100001010	100001010	
r	10011001	+ 1	=	100110011	100110011	
w	10100110	+ 1	=	101001101	101001101	
a	10000001	+ 1	=	100000011	100000011	
t	10100011	+ 1	=	101000111	101000111	
e	10000101	+ 0	=	100001010	100001010	
r	10011001	+ 1	=	100110011	100110011	

Figure 13-6 Error detection: simple parity

letter	EBCDIC	parity		bits sent	bits rec'ved	
u	10100100	+ 0	=	101001000	101001000	
n	10010101	+ 0	=	100101010	100101010	
d	10000100	+ 1	=	100001001	101001001	<= even parity
e	10000101	+ 0	=	100001010	100001010	
r	10011001	+ 1	=	100110011	100110011	
w	10100110	+ 1	=	101001101	101001101	
a	10000001	+ 1	=	100000011	100000011	
t	10100011	+ 1	=	101000111	101000111	
e	10000101	+ 0	=	100001010	100001010	
r	10011001	+ 1	=	100110011	100110011	
(lrc)	11001110	+ 1	=	110011101	110011101	

Figure 13-7 Error correction example: parity with LRC

Scattered errors are ever present, of course, but are accompanied by troublesome bursts associated with Rayleigh fading (and other problems). This error profile makes simple parity techniques quite impractical.

There are four general methods of attacking real-world problems, all of which are combined with ARQ (retransmission) techniques in different ways by different vendors:

1. *Error Detection via CRC.* The most common CRC is 16 bits, specified by CCITT, and used in the V.42 approach. It detects all possible single-error bursts not exceeding 16 bits and 99.9984% of all possible longer bursts.[4]

When bit rates are low, say 2400 bps as once used on Millicom's cellular CDLC devices,[5] burst errors of 16/2400 = 6.7 milliseconds could always be detected. For reference, note that the AMPS design assumes that deep fades [−15 dB carrier-to-noise ration (C/N)] of an average duration of 2.5 milliseconds occurs about 6 times per second at 20 mph.[6] As bit rates rise, the message becomes vulnerable to

these long burst errors. There are now many cellular modems rated at 14,400 bps. The guaranteed fade duration protection at this bit rate is only about 1 millisecond. Errors this long will occur 10 times per second at 20 mph.

How can this be endured? There are two crude methods:

(a) The modem slows down. Field tests[7] have revealed that 14,400-bps cellular modems operate at 7200 bps (2.2-millisecond fade protection) 70% of the time and 4800 bps (3.3-millisecond protection) another 10% of the time.

(b) The user sits still. One is usually unable to read, type, and drive at the same time (although we have all seen examples of people trying to do exactly that). However, there are users who take commuter trains. But if the key application is, say, E-mail, does it hurt if 16 out of every 10,000 packets has a spelling error? But suppose this is a financial transaction? One answer: The 32-bit CRC discussed in category 3 has begun to appear in some protocols.

2. *Weak Error Correction; Interleaving; CRC.* A simple, low-cost, fast-response but weak and inefficient error correction technique is employed. For a fixed data block, 1- or 2-bit errors are *always* correctable. The block's bits are interleaved prior to transmission; if a burst error causes damage, the errors are scattered upon reassembly; they are then attacked by the weak forward error correction (FEC).

This approach is employed in Ericsson's Mobitex protocol employed by BSWD. Data is organized in a series of 160-bit blocks. Each block includes a 16-bit CRC. The user's 144 bits (18 octets) *and* the CRC are expanded to 240 bits (60% efficiency) with the addition of a weak (can correct single errors) Hamming code. The protected data and CRC is then interleaved to scatter the bits so as to be able to withstand a 20-bit (2.5-millisecond) burst error.

Motorola's MDC4800 protocol employed by ARDIS also uses this technique. The Motorola example is representative: a rate $\frac{1}{2}$ (50% of bits transmitted are "parity"), $k = 7$ convolutional encoding algorithm is used in a 112-bit block. The block code has a minimum distance of five; there are patterns of three or more errors within the block for which the decoder output will be incorrect.[8] A 16-bit CRC guards against an undetected *packet* (which may be many blocks) error.

Interleaving is used to reduce the susceptibility to burst errors. All 112 bits of every block are placed in a 7×16 matrix in column order and read out in row order, as shown in Figure 13-8.

Detailed simulations[9] show that the decoder is sometimes overwhelmed by short burst errors whose placement is simply not optimum; other error placement sometimes permits even longer bursts (~20 bits) to be corrected. Typically the interleaving approach permits correction of ~16-bit (3.3-millisecond) burst errors about 90% of the time; the CRC detects nearly all the balance.

3. *Good Error Correction; Interleaving; Strong CRC Backup.* This philosophy is employed in Motorola's RD-LAP protocol. Obviously there are major technical improvements over MDC4800. FEC is achieved via a rate $\frac{3}{4}$ trellis-coded modulation (TCM) technique, which is discussed in Chapter 15. Interleaving is organized to permit correction of ~32 bit errors; there are cascaded CRCs with a final CRC-32 to detect uncorrectable packet errors. A burst error as long as $32/19200 = \sim 1.7$

```
          <--------------------------------- column ----------------------------------->
              1     2     3     4     5     6              13    14    15    16

row       --------------------------------------------------------------------------------

  1       D0    P3    D7    P10   D14   P17   D21   .......  .......  .......  .......  P52

  2       P0    D4    P7    D11   P14   D18   .......  .......  .......  .......  P49   S5

  3       D1    P4    D8    P11   D15   .......  .......  .......  .......  P46   S2    P53

  4       P1    D5    P8    D12   .......  .......  .......  .......  P43   D47   P50   S6

  5       D2    P5    D9    ......   .......  .......  .......  P40   D44   P47   S3    P54

  6       P2    D6    .......  .......  .......  .......  P37   D41   P44   D48   P51   S7

  7       D3    ......   ......   ......   P34   D38   P41   D45   P48   S4    P55
```

Figure 13-8   MDC4800 interleaving technique.

milliseconds can always be safely handled, and very few longer bursts escape detection.

The CRC-32 detects all bursts of 32 bits or less, 99.99999995% of bursts of length 33, and 99.99999998% of bursts longer than 33 bits.[10] There is still a miniscule error possibility but one most people don't worry about. RD-LAP's published undetected bit error rate is 1.4×10^{-11}, an astonishingly low 1.4 errors in 100 billion bits.

4. *Strong FEC; No Interleave; No CRC.* The objective is to exploit the processing power of new "engines" so that virtually all errors can be corrected without retransmission. The most common technique used is Reed-Solomon coding, developed in 1960 and initially used in large file controllers capable of bearing the processing expense associated with this technique.

By 1982 microprocessors permitted Reed-Solomon codes to be used in MDI's (now absorbed by Motorola) MMP-based vehicular terminals. The practical results were outstanding, with a published UBER of 1 in 10 billion characters.[11]

Reed-Solomon codes are also used for CDPD. The implementation is very similar to the MDI approach, including the absence of a backup CRC (see Table 13-1).

CDPD fade duration protection reads well in comparison to RD-LAP. With a fade duration of, say, 2.4 milliseconds—typically encountered at very low velocities such as human walk speed—RD-LAP may be forced to retransmit while CDPD's message makes it on the first try. But if the errors are scattered, perhaps a few small fades combined with random bit errors, CDPD's eight-symbol error correction capability can be overwhelmed. This is a more serious problem. Under these conditions CDPD has a weak undetected *block* error rate of only 1.2×10^{-5} (1.2 in 100,000),[12] significantly weaker than RD-LAP. CDPD has an implementation-dependent way out (your carrier may or may not use it). The fade duration protection is reduced to seven symbols (2.2 milliseconds) but yielding an undetected block error rate of 2.75×10^{-8} (100 million).[12]

Table 13-1   MMP versus recommended CDPD Reed-Solomon code

Parameter	CDPD	MMP
m, bits/symbol	6	6
Symbol alphabet size (2^m)	2^6 (64)	2^6 (64)
k		
Encoder input symbols	47	45
Encoder input bits	282	270
n		
$2^m - 1$ symbols	63	63
$m(2^m - 1)$ bits	378	378
Code rate (k/n)	0.746	0.71
$n - k$		
$2t$ symbols	16	18
$2mt$ bits	96	108
t		
Symbol error-correcting ability	8	9
Bit error-correcting ability	48	54
Transmission speed, bps	19,200	4800
Fade duration protection, ms	2.50	11.25

13.2.4 ARQ Alternatives

13.2.4.1 ARQ Variations There are three principal automatic repeat request (ARQ) variations:

1. *Stop and Wait.* The sender transmits one variable-length packet and waits for an acknowledgment before the next packet is sent. If an ACK is received, the packet contents, which have been temporarily held in a buffer, are discarded and the next packet transmitted. If a NAK, or time-out, is received, the saved packet is retransmitted. This is the technique used by Motorola in MDC4800 and RD-LAP and is the simplest, lowest cost device implementation.

2. *Go Back N.* Multiple packets are sent continuously without waiting for acknowledgments. A ceiling is placed on the permissible number of blocks that can be outstanding without an ACK. If an error is detected, the sender must retransmit the error packet as well as all succeeding packets. This ensures that the blocks at the receiver end are in the correct sequence with a minimum of processing but with necessary storage expansion. It results in modest device cost increases but offers greater transmission efficiency for long messages. This technique is used by Ericsson in Mobitex.

3. *Selective.* Only the packet(s) in error are retransmitted. The device message buffer space is large, as it is in go-back-N, but the device processing complexity is also increased as the packet sequence must be maintained. It offers superior

transmission efficiency for long messages. This approach is often seen with CDPD.

13.2.4.2   Practical Results   While the stop-and-wait approach intrinsically "feels" inferior, this may not prove to be the case in real-world situations. For short single-packet messages of 75–125-user octets, a common message size for both ARDIS and BSWD, there is no practical difference between ARQ techniques. All must await the successful ACK indicator.

Only as message lengths rise do practical differences manifest themselves. Assume a 450–500-octet message. Using RD-LAP, Motorola's stop-and-wait approach will transmit the message as a single large packet. Depending upon carrier default values, CDPD could transmit this message as four individual packets. Long messages are more vulnerable to the occurrence of error some time during their transmission. Thus, with a single burst error RD-LAP will repeatedly try to resend the full message, exposing it to a new error each time; CDPD (the other extreme) might only retransmit the ~128-octet packet containing the error; the probability of successful receipt of this specific segment is improved.

An extreme representation of the value of selective ARQ can be seen in Figure 13-9. The CDPD V1.0 block success rate was modeled[13] with a block error rate of 5%—a harsh but permissible[14] level. To successfully deliver better than 99.7% of messages with a length of 450–500 octets, the stop-and-wait approach is forced to go to three retries. Only ~50% of the packets sent over the air are successful. The rest are wasted in retry activity. The selective approach could achieve identical results with 62–70% successful packets. Overall capacity potential would thus be increased by 30–40%, depending upon the new overhead required by each packet.

Practically speaking, the CDPD advantage rarely exists. Granular packets are often not employed; CDPD might also attempt to send 450 bytes as a single packet, nullifying any possible advantage. Further, the extra TCP/IP traffic to convey a single
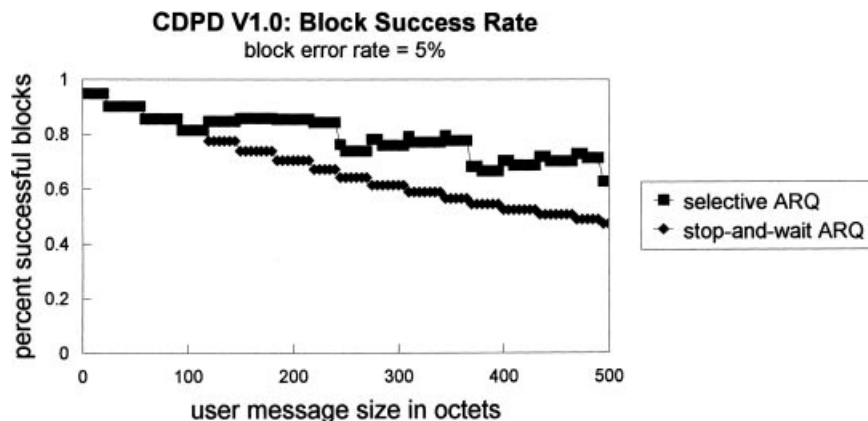

Figure 13-9   Selective vs. stop-and-wait ARQ.

Base A Sends	B, I S=6, R=4	B, I S=7, R=4 (error)	B, I S=0, R=4	B, I S=7, R=4	B, I, P S=1, R=4	
Unit B Sends			B, SREJ, F R = 7			B, RR, F R=2

Figure 13-10 Data flow example.

packet exposes the entire message to far higher odds of encountering some damaging noise as device and server "chat" over the air.

13.2.5   Data Flow Example

To illustrate the packet principles just covered, an outbound, multipacket message with a single transmission error controlled by selective ARQ is shown in Figure 13-10. Using the address/control notation described in Section 13.1, base A first sends an information *command* to B identifying this outbound packet as number 6; it also notifies B that the next packet expected from B is number 4. In the second step of the sequence A sends an information block numbered 7, which is damaged en route. In sequence 3, A sends another packet to B (note the 7-bit counter has wrapped from 7 to 0), unaware of the prior problem.

Meanwhile, B *responds* with its address and tells A that it is selectively rejecting packet number 7, which contained an error. The poll/final bit says that is all B has to say. Then A sends B the corrected copy of packet 7, out of sequence, and finishes the message by sending packet number 1. Perhaps a little nervous, A *polls* B for its status.

Sequence B *responds* with its address, says that everything is OK (it is in the receive ready state), the next packet it expects to receive from A is number 2, and that is all it has to say—Simple, precise, unambiguous, and highly efficient.

13.3   FADE RATE VERSUS FADE DURATION

13.3.1   Characteristics of a Fading Channel

A protocol's fade resistance varies with the speed of the target—vehicle or human. Before this can be explored, some background is required.

There are very major differences in the bit error rate characteristics of static and fading channels. Figure 13-11 is a representative bit error rate curve having both static and fading traces. The demodulated bit error rate is plotted against the radio input carrier level. At low input signal levels the radio input thermal noise is predominant, resulting in a completely random demodulated waveform. Ones and zeros come and go, with a resulting BER of 0.5. As the carrier level increases, it becomes larger than the noise. The proper demodulated data begins to emerge.
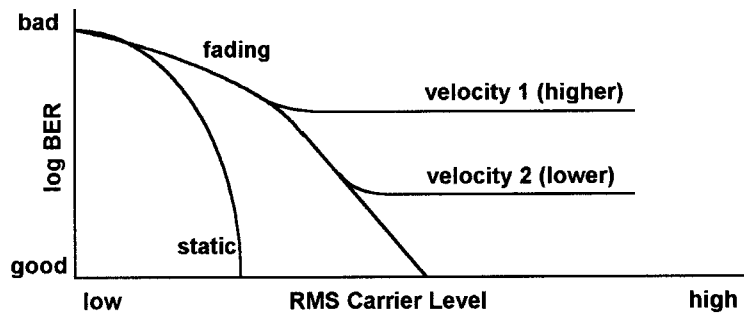
Figure 13-11 Representative bit error rate curves.

In the static case the signal level increases until the bit error rate falls off, effectively to zero. No short-term variations in the signal level occur. The carrier level is constant with respect to the noise and results in some constant demodulated bit error rate. This curve is easy to calculate and relatively easy to generate in a laboratory. It is therefore often used to compare different modulation schemes.

In the fading case one is dealing with a severely distorted mobile channel environment. Signal reflections from ground, buildings, and vehicles give rise to multiple signal paths between transmitter and receiver. At the receiving antenna these multiple signal paths result in many received versions of the original signal, each arriving at the antenna at a slightly different time and phase delay.

Typical signal levels due to fading cover attenuations ranging from a small increase in signal strength to decreases of −30 dB and beyond. The distribution of fade depths is statistical. At a given frequency, fade rate and duration depend upon both the fade depth and the velocity of the mobile radio. As velocity increases, so does the fade rate. But the fade duration shortens as the radio moves in and out of the fading zone more quickly. The number of times per second that the signal crosses a specific decibel level (the fade *rate*) and the duration of time it spends below that level (the fade *duration*) are variable. A fading signal crosses the −20-dB level and spends less time below −20 dB than it does at −10 dB.

It is possible to estimate target-in-motion error profiles concentrating on second-order statistics: time- or velocity-related functions such as the fade rate, average duration of the fades, and block/packet/word error rates. A midrange velocity can be used as a performance surrogate.

13.3.2   Fade Rate

Figure 13-12 is a plot, with mobile unit velocity a parameter, of the *fade rate* at a variety of instantaneous signal power levels relative to the mean value. Figure 13-12 is derived from Reudink's[15] formula:
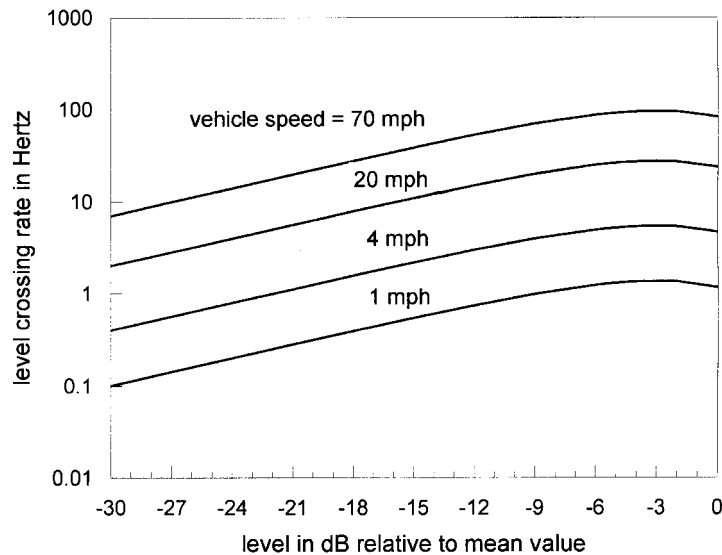
$$Nr = (2\Pi)^{1/2} \, FAe(-A^2)$$

Figure 13-12 Fade rate vs. velocity.

where *F* is vehicle velocity radio wavelength and *A* is the signal amplitude in the fade/ RMS signal level. Imagine a target moving at a constant *speed* and encountering a destructive fade. If the fade rate is more frequent than the packet rate, the protocol can never be free of the error. Each message *length* also has a critical fade rate, the point at which a destructive failure can never be shaken.

The critical fade rates in hertz can be calculated for all protocols. There are the usual problems. For example: Is the outbound channel continuously keyed (dedicated channel CDPD) or not (ARDIS)? How long is the message (longer messages are more vulnerable to damaging error)? How does one account for the idle-time variations on the inbound channel; what is the velocity of the target/transmitter?

For CDPD the critical fade rate is one packet that, in a simplified default mode, is one to four blocks (~30–128 user octets). Any ruined block within that packet forces the entire packet to be retried.

As an example, for single-block packets the critical fade rate on the inbound channel is ~36 times per second. Referring to Figure 13-12, this rapid fade rate will be encountered in a potentially harmful way—some retries required—when the transmitter is moving at 70 mph. However, it is not critical when the transmitter is moving at metro speeds: ~30 mph (or lower). A single CDPD block requires about 20 milliseconds of pure transmission time (ignoring all the inbound synchronization bits). Even at 70 mph critical fades are, on average, occurring only once every 28 milliseconds. Many blocks will shoot through unscathed.

When the packet lengthens to four blocks (~128 user octets) the critical fade rate drops to ~11 times per second on both inbound and outbound channels. High-velocity

(70-mph) targets/transmitters begin to see many fade rate problems. There may even be an occasional damaging hit at 20 mph. Velocity counts.

Two quite different examples for ARDIS are instructive. Imagine a packet containing 108 user octets, a realistic size for most of today's dispatch-oriented applications. The critical fade rate (Nr) for the two Motorola protocols is:

For MDC4800[16]:

$$Nr = \frac{1.0}{\text{sync times} + \text{GIB}/\text{GRB}/\text{UCB times} + (n \times \text{block time})}$$

$$= \frac{1.0}{18.33 + 70.0 + (18 \times 23.33)} = \frac{1.0}{88.33 + 419.94} = \frac{1.0}{508.27} = \textbf{1.97 Hz}$$

where *n* is the number of encoded blocks.

For RD-LAP[17]:

$$Nr = \frac{1.0}{\text{preamble time} + (n \times \text{block time}) + \text{CRC time}}$$

$$= \frac{1.0}{12.19 + (9 \times 6.875) + 1.67}$$

$$= \frac{1.0}{12.19 + 61.875 + 1.67} = \frac{1.0}{75.73} = \textbf{13.2 Hz}$$

Clearly the low-speed (4800-bps), inefficient MDC4800 protocol, which needs $\frac{1}{2}$ second to transmit 108 octets, will be exposed to fade rate problems. The much higher speed (19,200 bps) and more efficient RD-LAP protocol is much less sensitive to rate problems. A protocol with rate sensitivity is one in which the target velocity should be slow. MDC4800 (not surprisingly) has good rate characteristics for pedestrians using hand-held devices.

13.3.3   Fade Duration

In like manner a plot of *fade duration*, the average time the fading signal spends below a given level, is shown in Figure 13-13.

Fade duration is inversely proportional to target speed: 70 mph is now the bottom curve. Like Figure 10-12, these curves are also derived from another Reudink formula:

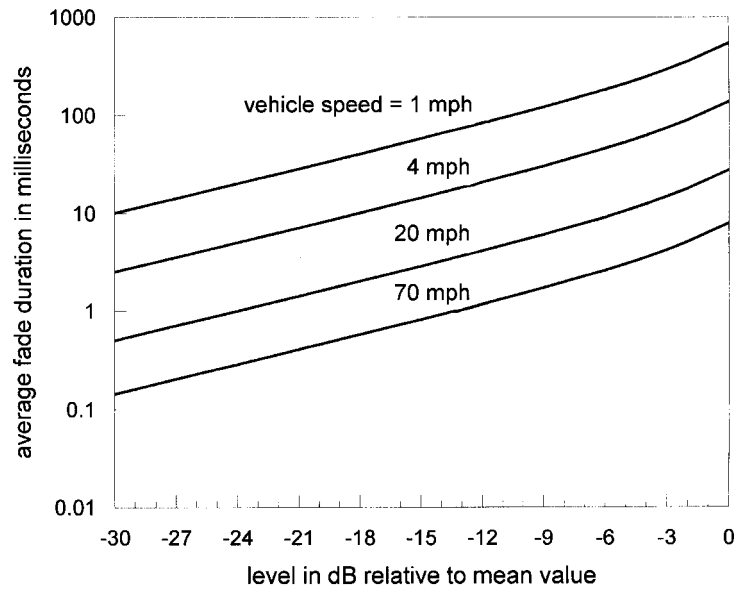$$t = \frac{e(A^2) - 1}{(2\Pi)^{1/2} FA}$$

Figure 13-13   Fade duration vs. velocity.

Again, imagine a target moving at a constant speed and encountering a destructive fade. If that fade duration is longer than the correction mechanism can accommodate, the protocol can never be error free. It is of little help to always detect the failure; if it cannot be corrected, the packet can never be successfully received. Length sensitivity is real. A long, multipacket message is more likely to see an unpleasant fade than a brief ACK.

Even short messages will be damaged at times. CDPD's best correction power is seven 6-bit symbols per block. Ignoring the effect of static bit errors (which are very damaging to Reed-Solomon correction techniques), a block can theoretically withstand a fade of 42 bits (2.2 milliseconds). Walk speed targets will sometimes encounter fades of far greater duration than the error correction code can possibly handle.

13.3.4   Optimum Target Velocity

Reudink's formulas can be graphically portrayed in an alternative manner to create four zones (Figure 13-14). The zones are:

1. *Failure*: No blocks get through because both fade duration and fade rate exceed the critical thresholds.
2. *Success*: All blocks always get through since both fade duration and fade rate are always less than the critical values.
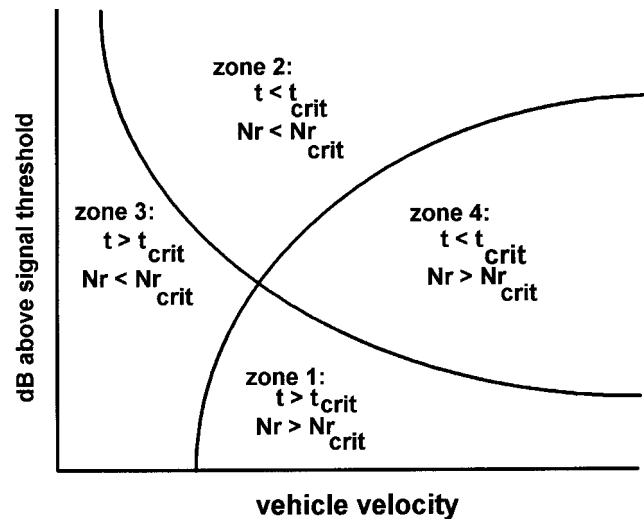
Figure 13-14   Theoretical retransmission zones.

3. *Retry*: The fade duration is always greater than the critical value, but the fade rate is always less. The noncritical fade rate permits blocks to pass between fades. Retries will be necessary due to fade duration hits somewhere in the block, but retransmission will eventually pass a successful block.

4. *Retry*: The fade duration is always less than the critical value, but the fade rate is greater. The frequent short fade bursts appear as random errors and cause retransmission when the cumulative effect is an uncorrectable block.

There is actually a class of curves that must be generated for each protocol, determined by:

1. The smallest size of the block that can be protected by the error correction/detection approach

2. The maximum fade duration that the FEC technique can correct

Even then, no hard, fast boundaries between the four zones exist. The fade rate/fade duration equations are time-averaged values and do not account for retransmission time-out effects. In practice, smooth transitions from one zone to another occur. Relative probabilities of successful transmission can be calculated that will produce 5, 50, and 95% curves that will resemble those shown in Figure 13-15.

But note that these curves can never be precise. They do not account for static bit errors that overlay the fade, nor do they account for compensatory techniques such as antenna diversity that will exist in some devices.
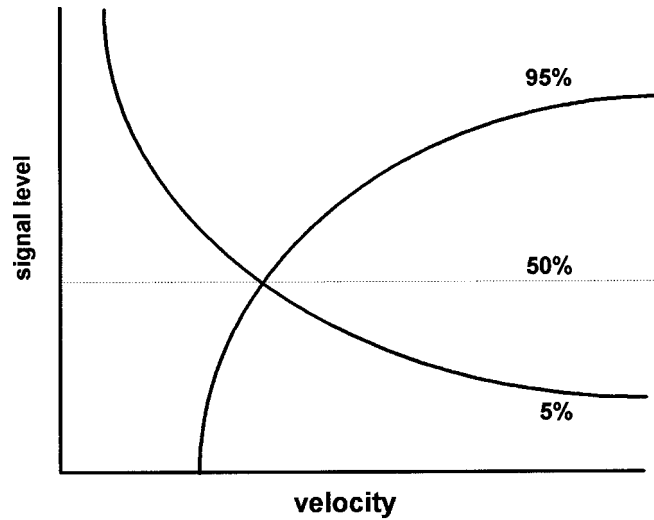
Figure 13-15   Signal vs. velocity probabilities.

However, calculating the curves for each protocol gives a good indication of its optimum design speed, the signal strength required, and the message length sensitivity.

As an example, when the curves are displayed for the two 108-octet Motorola examples (Figure 13-16), an application design fit is suggested. MDC4800 will perform best at very slow target speeds, ideal for the field service person walking with device hanging from belt or shoulder. RD-LAP will be optimum on metro speed vehicles. ARDIS, with dual-protocol modems, exploits this characteristic.
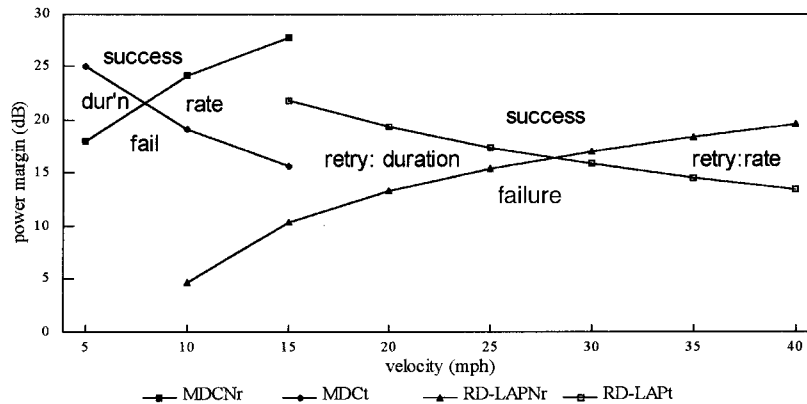
Figure 13-16   Fade rate vs. fade duration: Motorola protocols (108 user octet packet).

Figure 13-17 Fade rate vs. fade duration: CDPD (830 MHz, no diversity, no static errors).

This does not mean that a single protocol will not operate at a suboptimum velocity. It does indicate that retransmission rates will likely rise—a possible capacity problem for the service provider, a possible response time problem for the user.

Retries can be reduced by providing space diversity antennas in correctly engineered subscriber units. Motorola's old KDT8x0 family, and associated external modems,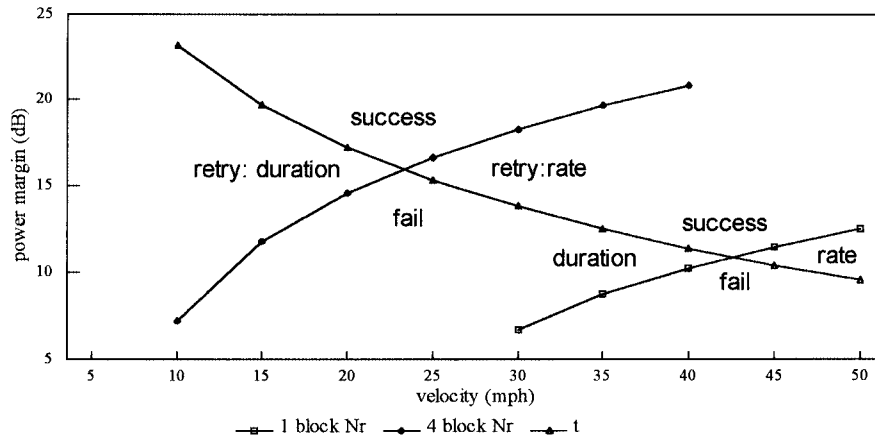 used dual-receive, switched diversity antennas. So did IBM's first ThinkPad implementations for CDPD. But the pressure to reduce physical size—the drive to the PC Card—tends to be mutually exclusive with space diversity.

The impact of message length can be illustrated by a CDPD example[18] (Figure 13-17). The curves for both single- and four-block messages indicate that very short CDPD messages can be successfully transmitted at relatively high target speeds with very low power margins. As the message lengthens, the optimum speed falls below 25 mph. The power margin requirement also rises but is still within the cellular edge of coverage. These theoretical constraints, first calculated in 1992, have been observed in a limited number of field measurements.[19]

13.4 SYNCHRONIZATION ERRORS

Another contributor to message retry is the failure to achieve synchronization. With continuous outbound transmissions the main problem tends to be frame synchronization failures; keyed transmission (usually inbound, but also outbound in ARDIS implementations) also sees impact from bit synchronization problems.

The frame synchronization approach varies widely by vendor. Motorola's MDC4800 protocol uses a single frame synchronization in the preamble of a packet. It is a pseudorandom pattern, 40 bits in length, with a correlation peak-to-side-lobe ratio of ~7 to 1. Many bit errors are tolerated in the pattern. The incoming bits are slid

past the synchronization pattern, multiplied bit by bit, and summed. A perfect answer is, of course, 40. But results below that number may still permit frame synchronization to be declared.

Simulation results[20] on MDC4800 show that if no bit errors are tolerated, failure to achieve frame synchronization will occur ~3% of the time. If 12-bit errors are permitted, false frame synchronization will be declared ~3% of the time. Each system can be tuned individually between those limits to eliminate most frame synchronization errors, missed or false.

Since the ARDIS implementation is keyed transmission, the optimum bit synchronization length can also be simulated. At length 48, with a realistic error profile,[21] less than 1% of packets are retried because of bit synchronization errors.

Note that Mobitex has a 16-bit pattern for both bit and frame synchronization. Only a single-bit error is tolerated in the frame synchronization pattern. Synchronization error message retries could be high for Mobitex.

CDPD[22] has a distributed 35-bit forward synchronization pattern, which does double duty as a busy/idle indicator, for each block. A decode pattern also can be viewed as part of the forward channel synchronization process. The error tolerances for these multiple synchronizations vary but are generous; simulation after simulation[23] indicate that they are quite robust. Less than 1% fail with a representative error profile.

13.5 INBOUND ACCESS: CONTENTION MODE

13.5.1 ALOHA

The simplest contention mechanism is ALOHA.[24] The throughput formula for ALOHA is

$$S = Ge^{-2G}$$

where S (throughput) is the average number of *successful* transmissions per packet transmission time P and G (offered traffic) is the average number of *attempted* packet transmissions per P.

This formula is a Poisson distribution in disguise, developed the following way:

$$P\{k \text{ arrivals in } t \text{ seconds}\} = \frac{(At)^k}{k!} e^{-At}$$

where A is the arrival rate in packets per second. If the average packet transmission time is length P, and colliding packets can begin any time, the vulnerable period is length $2P$. A packet in process can have its very last bit ruined by an interloper (one bad P time), and the villain transmits through a second P even though its first bit has been destroyed.

It is also possible to define the relationship between *S* and *G* very simplistically:

$$S = GP\{\text{good transmission}\}$$

That is, throughput equals offered traffic times the probability that the transmission is good.

Define $P\{\text{good transmission}\}$ as no additional transmissions during the vulnerable period $2P$. Then in the Poisson distribution k becomes zero, as in $P\{0 \text{ arrivals in } 2P \text{ seconds}\}$. When $k = 0$ the fraction in the Poisson distribution vanishes. Further, t can be defined as $2P$, and A (arrival rate) can be defined as G/P. This leaves

$$P\{0 \text{ arrivals in } 2P\} = e^{-(G/P)2P} = e^{-2G}$$

Now one can substitute this new value of P into the prior equation to obtain

$$S = Ge^{-2G}$$

ALOHA contention schemes have passed into history as a primary design; most designers reject the low maximum throughput (18.4%) and instability of this technique. The maximum throughput can be achieved in an ideal world when the offered traffic reaches 50%. Drive the channel harder and the throughput actually drops, leading to chaos. Two more common contention alternatives follow.

13.5.2   Slotted ALOHA

This simple refinement of ALOHA, developed initially for satellite channels, forces packets to begin only on defined boundaries. Using the ALOHA example, these slots are exactly one *P*. This halving of the vulnerable period converts the ALOHA formula to

$$S = Ge^{-G}$$

and doubles the throughput potential. Now the inbound channel can theoretically reach a useful throughput of 36.8% when the channel is 100% loaded. There is more overhead to consider, and the channel can still be unstable (but manageable); still, the throughput draws vendors.

13.5.3   Slotted CSMA

Of the myriad varieties of carrier sense protocols, the most common candidate is slotted CSMA. This technique is used in CDPD, Mobitex, and RD-LAP. Each vendor has its own variation, but the principle is the same: Sense the outbound channel for information about the status of the inbound channel; if the channel appears free,

transmit as slotted ALOHA; if the channel is busy, back off a random time interval; in either case when the receiver detects inbound traffic, place channel busy information in the outbound channel for the next round of sensing.

The equation for slotted nonpersistent CSMA is

$$S = \frac{aGe^{-aG}}{1 - e^{-aG} + a}$$

with a the ratio of time without knowledge of the channel state to the average transmission time. This is a new variable often called the collision window. The goal is to keep it as short as possible. If the average transmission time is 100 milliseconds, and the collision window is also 100 milliseconds, CSMA is worse than useless. Two devices could be ready; each sense the channel free, destructively collide upon transmission, and complete their transmissions; and then the channel is signaled busy for no good purpose. Fortunately, well-designed systems pay careful attention to a, which, after all, determines the throughput of slotted CSMA.

Half-duplex systems such as Ericsson's or Motorola's have an inherent disadvantage when designing collision windows. When a packet is ready, the device "listens" for an outbound signal indicating channel status. Sensing the channel is free, it switches off the receiver to reprogram the frequency synthesizer. At this instant the inbound channel is busy since the decision to transmit is irrevocable. When the synthesizer locks on to the desired frequency, the transmitter is keyed. It rises to full power, simultaneously transmitting synchronization patterns, until message transmission begins. This interval is driven by transceiver characteristics. In a good system the time period will be on the order of 5 milliseconds.

Only now can the base station act on this signal, even though damage may already have occurred to a simultaneous device's transmission. The busy channel status is set 3–4 milliseconds later, if appropriate (the count field may indicate otherwise), and the idle devices must sense repetitive busy indicators to avoid falsing. It is not uncommon to find collision window intervals of 10–15 milliseconds in half-duplex systems.

The collision window and the average packet length constrain the achievable CSMA throughput. For RD-LAP an error-free S of ~40% is probably achievable on realistic message lengths with a G of 80%.[25] But note that this means that each message, on average, tries twice before succeeding—and this is before retransmission due to errors.

The CDPD base design is full duplex since the data devices must always listen for voice in order to scramble out of the way if necessary. CDPD exploits this reality by shortening its collision window dramatically. Further, extraordinary efforts are made to shorten the busy hang time—the interval in which the channel is actually free but the devices are not yet aware of it. CDPD can signal busy within one slot time (60 bits): 3.13 milliseconds. The busy hang time varies with message length, and even the nature of vendor devices, but has the potential to be very short indeed under certain circumstances. CDPD appears capable of achieving an error-free S of 40% when the channel is loaded only to 70%.

13.6   **RETRANSMISSION RATES**

It is clear that under busy conditions the actual number of successful transmissions, especially inbound, is a fraction of those attempted. Contention constraints halve the attempts, and those packets that escape this trial are beset by new torments. Depending upon message length, target speed, and the ambient noise/fade conditions, the successful messages are slashed still further and must be repeated.

An examination of the old MDC4800 protocol used in ARDIS can be instructive.[26] Figure 13-18 portrays the message success rate when frequent burst errors occur, on average, at 2560-bit intervals (once every 533 milliseconds) with fixed lengths of 16, 18, and 20 bits. Background Gaussian noise is also present; a bit is marked to fail, on average, every 430 bit times.[27] Under these conditions, with 18-bit burst errors, ~95% of 20-byte messages would succeed on the first attempt but only ~60% of the 240 byte messages would do so. Message length sensitivity is obvious.

IBM has reported[28] that DCS (now ARDIS) experienced 15% retry rates with message sizes ranging from 62 to 108 octets. ARDIS itself has reported[29] a 90% success rate on the initial transmission of ~110-octet messages, 6.2% on the first retry, 2.8% on the second retry, with only 1% going to a third retry.

This suggests that a real-world fade duration of 17 bits (3.5 milliseconds), though harsh, is not unrealistic in slow target speed environments. For somber illustration, that number was used in the following estimates. Note the implication of this fade duration interval on higher speed protocols as RD-LAP and CDPD, which are designed to handle fade durations of only ~2 ± 0.2 milliseconds.

Table 13-2 illustrates that with short messages (up to ~60 octets) no more than two retransmissions are required to achieve message success. If the message exceeds 200 octets, not only is a fourth retry occasionally required, a very small number of messages, 1 in a 1000, are not successful.
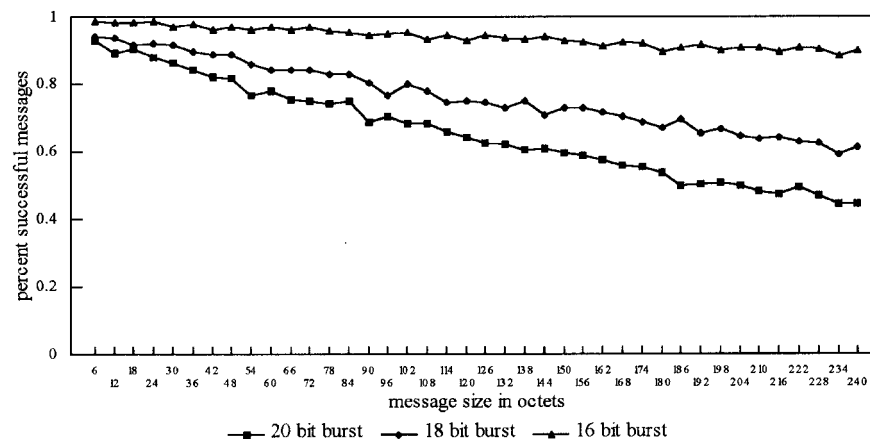

Figure 13-18   MDC4800 message success rate (burst error interval 2560; random 430).

Table 13-2   Successful message transmission rate

	Percentage of Messages Successful On					Percent Success
	First Transmission	First Retry	Second Retry	Third Retry	Fourth Retry	
6	0.980	0.020	0.000	0.000	0.000	1.000
12	0.974	0.026	0.001	0.000	0.000	1.000
18	0.968	0.031	0.001	0.000	0.000	1.000
24	0.961	0.037	0.001	0.000	0.000	1.000
30	0.955	0.043	0.002	0.000	0.000	1.000
36	0.949	0.048	0.002	0.000	0.000	1.000
42	0.943	0.054	0.003	0.000	0.000	1.000
48	0.937	0.059	0.004	0.000	0.000	1.000
54	0.930	0.065	0.005	0.000	0.000	1.000
60	0.924	0.070	0.005	0.000	0.000	1.000
66	0.918	0.075	0.006	0.001	0.000	1.000
72	0.912	0.080	0.007	0.001	0.000	1.000
78	0.906	0.085	0.008	0.001	0.000	1.000
84	0.899	0.090	0.009	0.001	0.000	1.000
90	0.893	0.095	0.010	0.001	0.000	1.000
96	0.887	0.100	0.011	0.001	0.000	1.000
102	0.881	0.105	0.013	0.001	0.000	1.000
108	0.875	0.110	0.014	0.002	0.000	1.000
114	0.868	0.114	0.015	0.002	0.000	1.000
120	0.862	0.119	0.016	0.002	0.000	1.000
126	0.856	0.123	0.018	0.003	0.000	1.000
132	0.850	0.128	0.019	0.003	0.000	1.000
138	0.844	0.132	0.021	0.003	0.001	1.000
144	0.837	0.136	0.022	0.004	0.001	1.000
150	0.831	0.140	0.024	0.004	0.001	1.000
156	0.825	0.144	0.025	0.004	0.001	1.000
162	0.819	0.148	0.027	0.005	0.001	1.000
168	0.813	0.152	0.029	0.005	0.001	1.000
174	0.806	0.156	0.030	0.006	0.001	1.000
180	0.800	0.160	0.032	0.006	0.001	1.000
186	0.794	0.164	0.034	0.007	0.001	1.000
192	0.788	0.167	0.035	0.008	0.002	1.000
198	0.782	0.171	0.037	0.008	0.002	1.000
204	0.775	0.174	0.039	0.009	0.002	0.999
210	0.769	0.178	0.041	0.009	0.002	0.999
216	0.763	0.181	0.043	0.010	0.002	0.999
222	0.757	0.184	0.045	0.011	0.003	0.999
228	0.751	0.187	0.047	0.012	0.003	0.999
234	0.744	0.190	0.049	0.012	0.003	0.999
240	0.738	0.193	0.051	0.013	0.003	0.999

Table 13-3   Retries required for successful transmission

	Retry Rate	Initial Attempt	Successive Attempts (%)				Total Transmission
			First Retry	Second Retry	Third Retry	Fourth Retry	
6	0.980	1	0.020	0.000	0.000	0.000	1.020
12	0.974	1	0.026	0.001	0.000	0.000	1.027
18	0.968	1	0.032	0.001	0.000	0.000	1.033
24	0.961	1	0.039	0.001	0.000	0.000	1.040
30	0.955	1	0.045	0.002	0.000	0.000	1.047
36	0.949	1	0.051	0.003	0.000	0.000	1.054
42	0.943	1	0.057	0.003	0.000	0.000	1.061
48	0.937	1	0.063	0.004	0.000	0.000	1.068
54	0.930	1	0.070	0.005	0.000	0.000	1.075
60	0.924	1	0.076	0.006	0.000	0.000	1.082
66	0.918	1	0.082	0.007	0.001	0.000	1.089
72	0.912	1	0.088	0.008	0.001	0.000	1.097
78	0.906	1	0.094	0.009	0.001	0.000	1.104
84	0.899	1	0.101	0.010	0.001	0.000	1.112
90	0.893	1	0.107	0.011	0.001	0.000	1.120
96	0.887	1	0.113	0.013	0.001	0.000	1.127
102	0.881	1	0.119	0.014	0.002	0.000	1.135
108	0.875	1	0.125	0.016	0.002	0.000	1.143
114	0.868	1	0.132	0.017	0.002	0.000	1.151
120	0.862	1	0.138	0.019	0.003	0.000	1.160
126	0.856	1	0.144	0.021	0.003	0.000	1.168
132	0.850	1	0.150	0.023	0.003	0.001	1.177
138	0.844	1	0.156	0.024	0.004	0.001	1.185
144	0.837	1	0.163	0.026	0.004	0.001	1.194
150	0.831	1	0.169	0.028	0.005	0.001	1.203
156	0.825	1	0.175	0.031	0.005	0.001	1.212
162	0.819	1	0.181	0.033	0.006	0.001	1.221
168	0.813	1	0.187	0.035	0.007	0.001	1.230
174	0.806	1	0.194	0.037	0.007	0.001	1.240
180	0.800	1	0.200	0.040	0.008	0.002	1.249
186	0.794	1	0.206	0.042	0.009	0.002	1.259
192	0.788	1	0.212	0.045	0.010	0.002	1.269
198	0.782	1	0.218	0.048	0.010	0.002	1.279
204	0.775	1	0.225	0.050	0.011	0.003	1.289
210	0.769	1	0.231	0.053	0.012	0.003	1.299
216	0.763	1	0.237	0.056	0.013	0.003	1.310
222	0.757	1	0.243	0.059	0.014	0.003	1.320
228	0.751	1	0.249	0.062	0.016	0.004	1.331
234	0.744	1	0.256	0.065	0.017	0.004	1.342
240	0.738	1	0.262	0.069	0.018	0.005	1.353

Table 13-3 demonstrates this phenomenon another way. If 100 six-octet packets are to be sent under these conditions, the system will have to make 102 transmissions to successfully transmit them. But it will have to make more than 135 transmissions to successfully send the same number of 240-octet packets.

Note that these losses occur *after* contention impact on the inbound side. But do not think the task impossible; ARDIS guarantees response times (a crude indicator of retry activity) in its contracts, a strong indicator that in the general case the problem is not this severe.

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14

ESTIMATING AIRLINK CAPACITY: PACKET SYSTEMS

14.1   INTRODUCTION

The number of variables in a packet switched data radio system are virtually endless. This does not mean that the task of estimating user capacity is hopeless. Directionally accurate but labor-intensive results can be derived if one knows the basic conditions under which the data transfers occur. This most assuredly includes assumptions about the communications software being employed.

Examples of the necessary effort are shown here by comparing ARDIS RD-LAP to CDPD. The all-important application example will be the 30-character inbound message whose CDPD component was captured in Appendix C. It does not take much imagination to know that the TCP/IP impact will have a very detrimental effect on CDPD; thus a demonstration of what can be done to minimize that impact is also included.

14.2   ILLUSTRATIVE SINGLE-BASE-STATION COMPARISON

Assume that a small town exists with only a single base station. This is a fairly infrequent case, especially for CDPD, but this fictitious town permits the establishment of a performance baseline relatively free from practical arguments. In this special situation the ARDIS infrastructure will employ a continuously keyed forward channel, greatly improving its outbound capacity. Since the voice cellular demand is also small town, CDPD will install a dedicated-channel, unsectored base station.

The ARDIS devices will be evaluated as half duplex (HDX). While the protocol does not require that restriction, all of today's RD-LAP devices are HDX in order to

minimize device product cost. CDPD will be evaluated as full duplex (FDX) since that is by far its dominant modem type.

14.2.1   ARDIS

If there are no other users on the inbound channel, RD-LAP will dispose of our strawman message quickly. There is no "handshaking." If a message is ready, it goes! The initial sequence is portrayed in Figure 14-1.

The device, which is listening to the outbound channel, believes the inbound path to be idle. It then commits, irrevocably, to an inbound transmission. The device switches off its receiver and can no longer hear channel status information. The frequency synthesizer is reprogrammed, and the device locks on to the channel of choice. Within 5 milliseconds of the decision to switch, the device transmitter is keyed and begins sending symbol synchronization characters.

When the base station senses symbol synchronization at full power, just after microslot 3 is completed, it could theoretically set busy at the end of microslot 4. In fact, ARDIS RD-LAP only sets busy every five microslots. The frame synchronization, and then the control information, begins transmitting inbound. At the next slot boundary, the first new opportunity for competition from another device, the channel status indicator is solidly busy.

Following the frame synchronization is the SID, a very compact 30-bit station ID field that has its own 6-bit CRC. Next in sequence is the RD-LAP header, also quite terse: 12 bytes, including its own protective 2-byte CRC. The SID/header bytes identify the format and content of the information to follow (e.g., data, response, idle) as well as the source or destination address (a link layer address, not a TCP/IP format), the packet length, and sequencing information. The user data follows immediately, also in 12-byte blocks. Since our strawman message has additional RadioMail overhead, it is 46 bytes long. This happens to be a very poor fit. Two bytes of the 4-byte CRC "spill," forcing an entire 12-byte block to be added.

The complete message is then expanded with error correction information. For its own design convenience, Motorola chose to have the format of the inbound message be exactly that of the outbound. Thus, space for meaningless busy/idle information is retained in the input stream, wasting 4–5% of the capacity. The 46-byte message has now grown to 924 bits, including frame synchronization, control overhead, padding, and error correction/detection information.

After transmitting these bits, RD-LAP breaks off the transmission and the device ramps down its power in less than a millisecond. Because of slot boundaries, there is a delay in which the channel is really free, but no one knows it. This particular message causes an 80-bit, 4.2-millisecond "busy hang time."

Under light-load conditions, that would be the end of it. If RD-LAP were compelled to handle a string of such 46-byte user messages, it could theoretically push through 16.7 per second on the inbound channel *if there were no contention.*

Alas, the real world is rife with channel clashes. Using the digital sense multiple access (DSMA) formula given in Chapter 13, realistic inbound throughput at this short
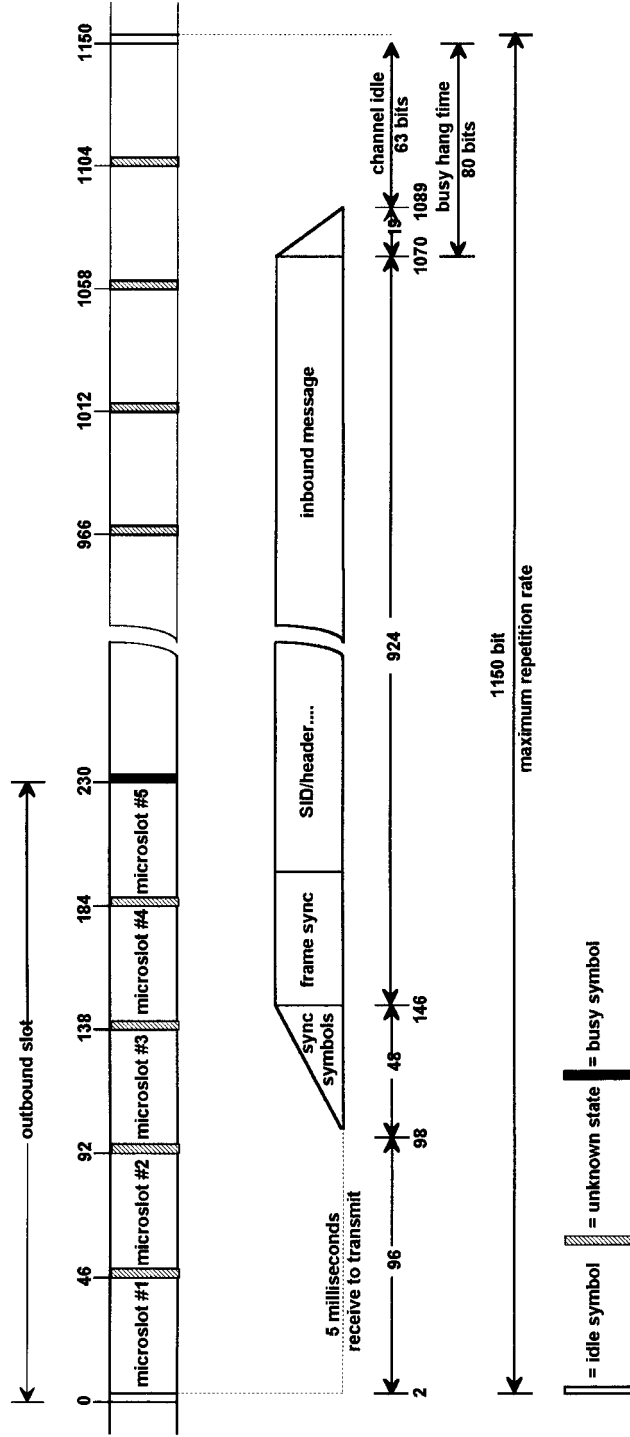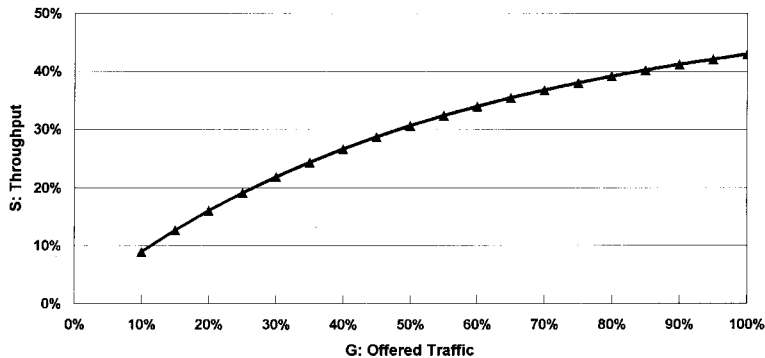
Figure 14-1 RD-LAP inbound message: 45–56 user bytes.

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Figure 14-2   RD–LAP inbound efficiency: 45–56 user bytes.

message length is about 25–40% of the channel capacity, as shown in Figure 14-2. Note that if 40% throughput is achieved, each message will, on average, make two attempts to get in.

Our strawman scenario includes an "application ACK" returning from RadioMail. This message must, in turn, be acknowledged by the device on the inbound channel. Fortunately, RD-LAP is a reasonably good "ACKer." It is up and down in two slot times, as shown in Figure 14-3.

The relationship between the inbound user message and an ACK are shown in Figure 14-4. If one selects the peak-hour design maximum to be, say, 60% offered traffic, then more than 12 ACKs per second can be handled if that were the only message mix. In contrast, less than 6 messages per second of the 46-byte user message can be handled. If the two must be combined in equal measure—one ACK for every user message as they are in this scenario—then the combined message rate drops to four per second. Note that all of these calculations assume no errors are present that will force retransmissions.

It is possible to estimate the RD-LAP message rate for a range of message lengths as long as one settles on the offered traffic percentage. Figure 14-5 is the message rate with a *G* of 80%—two attempts for every success. With a fully loaded packet of 512 bytes, RD-LAP can sustain a rate of 1.3 messages per second.

14.2.2   CDPD

The TCP/IP profile experienced with the BAM transaction uses 15 inbound messages to participate in the handshaking that ultimately delivers the 30 user bytes. Twelve of those 15 are short two-block sequences carrying 37–56 bytes of address and control information. This is an oddly fortuitous match to the RD-LAP user byte message. Figure 14-6 depicts this most common handshake message.

Unlike ARDIS, most CDPD devices are full duplex and the airlink protocol exploits this fact. Busy/idle indicators come with 60-bit spacing. The devices do not
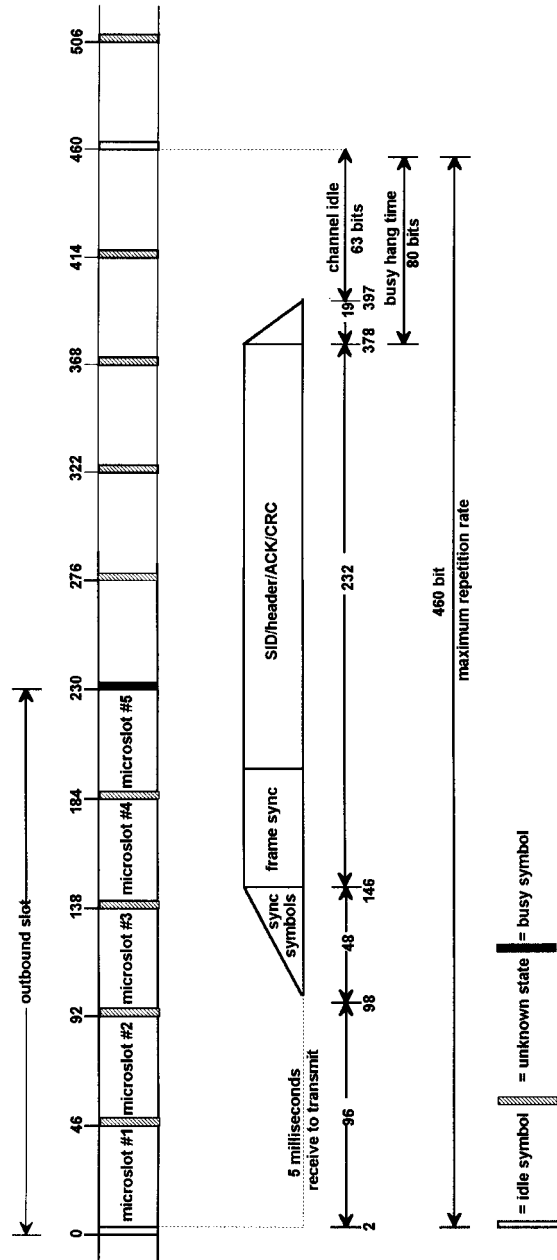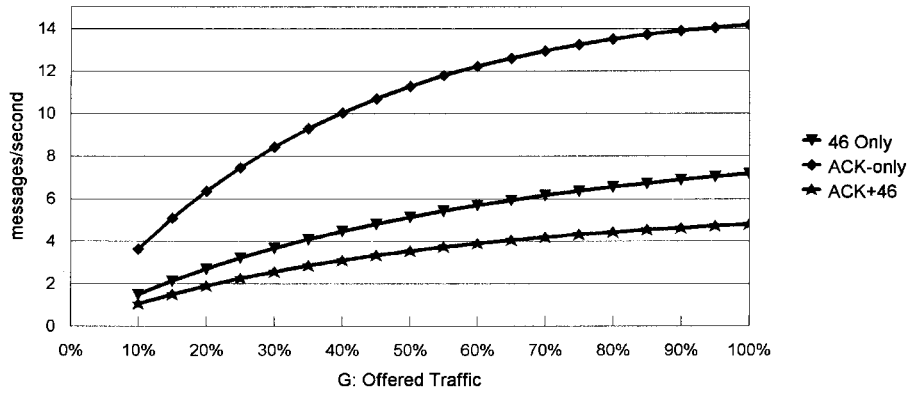
Figure 14-3 RD-LAP inbound ACK.

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Figure 14-4 RD-LAP inbound message rates: 46 user bytes + ACK.

enter a dark interval while they switch from receive to transmit. They respond within 8-bit times to the idle indicator and ramp up more quickly than RD-LAP units. The frame synchronization interval is much shorter, and no capacity is thrown away by reserving space for meaningless channel status information.

However, one of the limitations of Reed-Solomon coding now makes itself felt. Because of this choice of error protection schemes, CDPD cannot be very granular. The smallest block must be 385 bits long; RD-LAP can get an entire encoded message, with SID and header, into 184 bits. The most granular CDPD block can carry ~32 bytes. Since the TCP/IP addressing demands are greater than that, a second 385-bit block is forced. Thus, the maximum repetition rate that CDPD can handle is 900 bits. This is better than RD-LAP, of course, but vaguely disappointing when one considers the elegance of the contention design.
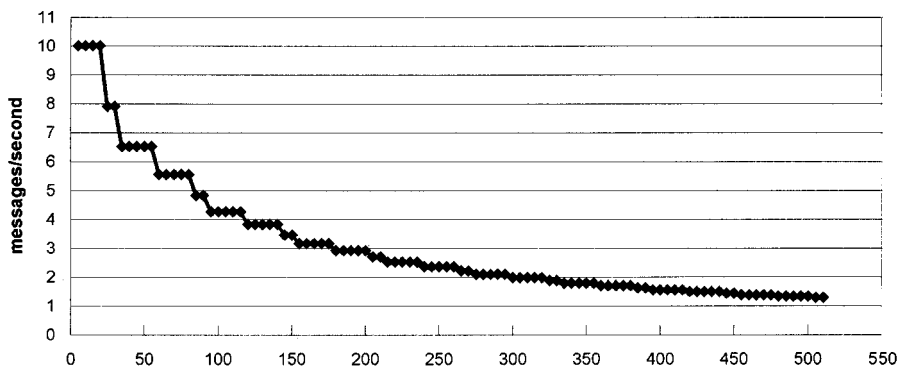

Figure 14-5 RD-LAP inbound message rate: offered traffic G = 80%.
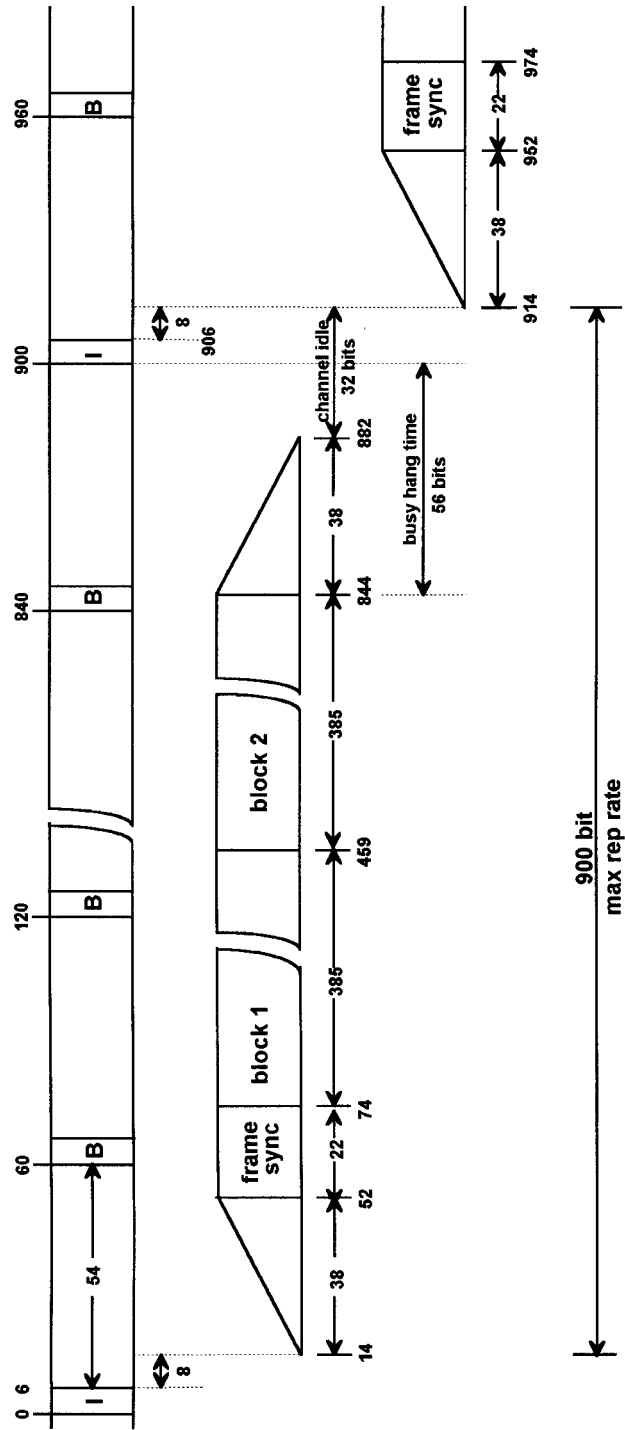
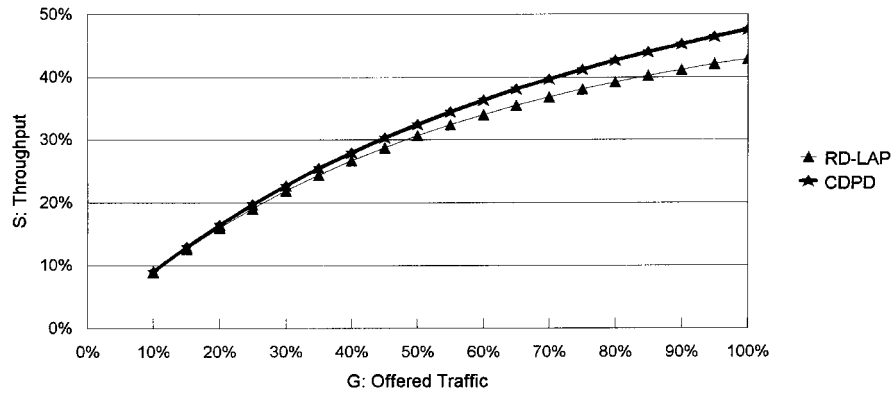Figure 14-6   CDPD inbound: two-block handshake message.

Figure 14-7   Inbound efficiency: CDPD vs. RD-LAP (RD-LAP: 46 user bytes; CDPD = 2 blocks).

As shown in Figure 14-7, CDPD's very short collision window pays off in better throughput if the offered traffic rises above ~40%. The minimal effect at lower offered loads should be no surprise. If there is little contention, skillful design techniques to avoid it are of little avail. But at the 80% offered load used in the RD-LAP example, CDPD achieves ~10% greater throughput at the two-block length.

This enhanced throughput leads to a better message-per-second rate, shown in Figure 14-8. With $G = 80\%$, CDPD can move more than 9 two-block messages per second; RD-LAP can only manage 6.5. However, because of TCP/IP, CDPD has to transmit 12 two-block messages, 2 more three-block messages, and the final 471-byte magilla, which contains the 30 user bytes.

At $G = 80\%$, the number of transactions of this length that CDPD can move is 0.44 per second. RD-LAP can transmit 4.43 transactions per second, including the response
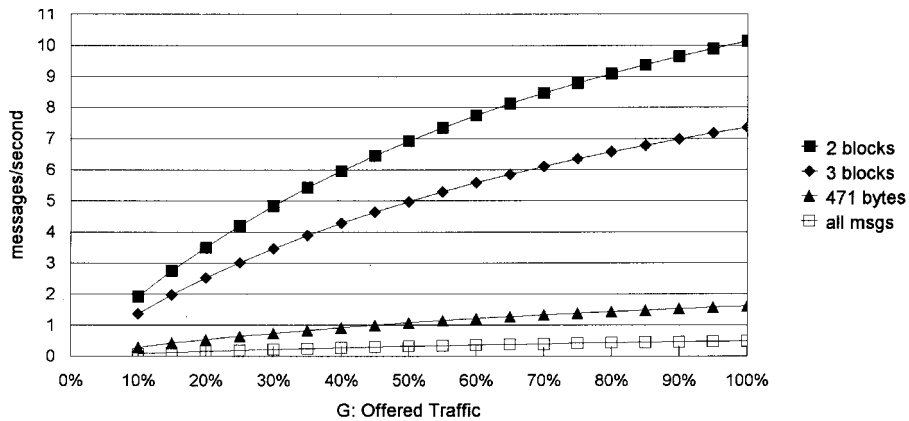

Figure 14-8   CDPD inbound message rates.

to the RadioMail application ACK. It thus has 10 times the transaction processing capability, essentially for two reasons:

1. The ghastly inefficiency of TCP/IP in short-message environments
2. The assumption that RD-LAP is operating in a continuously keyed environment that permits its inbound channel to always operates in DSMA mode

14.3   MULTICELL CAPACITY

14.3.1   Base Station Quantity Mismatch

The capacity calculations for a single base station are of little value in large metropolitan areas with many supporting channel locations.

In early 1994 Ameritech brought up 200 CDPD stations in "Chicago," a geographic area[1] extending well into northwestern Indiana.[2] In mid-1994 ARDIS had a total of 68 stations on two different frequencies covering its smaller definition of the Chicago CSMA.[3] Thus, Ameritech had already deployed ~2.9 times more data infrastructure than ARDIS, albeit over a somewhat larger physical area.

By June 1995 the total number of voice cellular base stations installed in the United States reached nearly 20,000,[4] but only a fraction were equipped for data. At year-end 1996 there were 30,000 voice base stations installed, and an interesting percentage were CDPD capable. But many of the national voice sites are owned by carriers who simply do not participate in CDPD. Others are in rural/suburban areas where, even if the carrier has enthusiastically embraced CDPD, it is unlikely to be deployed.

The Greater New York City metropolitan area is one in which CDPD is richly employed and competes directly with ARDIS. CDPD deployed relatively late in the New York/New Jersey area. NYNEX, before its absorption by BAM, had 30 trisectored CDPD base stations in place by the second quarter of 1994, growing to 95 by the end of the year, and advancing to 176 during the first half of 1995. By contrast, a decade earlier ARDIS had deployed 70 MDC4800 base stations in the New York/New Jersey area, which grew to more than 80 locations in mid-1995.

Both ARDIS and BAM have continued their enhancement programs, but with a different focus. BAM spreads its footprint. All of Long Island—potato farms, vineyards, fishing villages—is covered, for example. ARDIS provides only partial coverage in Suffolk County. There is no North Shore presence east of Northport and the central part of the island is only covered as far as SUNY Brookhaven. In north Jersey, BAM pushes westward beyond Sussex County to the Pocono Foothills; ARDIS tends to cover only the main highways in that region.

The ARDIS enhancement effort, by contrast, has been focused on modernization to RD-LAP and vertical capacity improvements. The 80+ *locations* have had more and more base stations and channels added, but there has been little geographic expansion.

In areas where head-to-head competition is encountered, a CDPD discrete base station *location* edge of 3.5 to 1 over ARDIS probably represents an upper limit.

It has already been established that, in an error-free environment and ignoring TCP/IP impact, CDPD and RD-LAP are nearly equivalent technical alternatives from a capacity viewpoint. Simplistically (and inaccurately), if each CDPD carrier employed one dedicated channel in each trisectored cell, their overall capacity potential would be more than 10 (3.5 × 3) times greater than a single-frequency ARDIS layer at 19.2 kbps. The TCP/IP short-message inefficiencies would be offset at one stroke!

But in a multicell, single-frequency case the ARDIS capacity potential is actually greatly reduced. Recalling Section 12.5.3, if ARDIS deploys five single-frequency base stations, with perfect user distribution, their effective outbound capacity yield is equivalent to 1.67 stations—one-third rated capacity.

The inbound side suffers as well. When a base station is not keyed for transmission, the inbound devices cannot hear busy/idle information and resort to pure ALOHA input.[5] ALOHA is an unstable technique. Using the formula derived in Section 13.5.1, it is possible to show that offered traffic G should be held below 50% or the resulting contention will actually reduce throughput. A best case practical inbound throughput is probably ~15% when the output channel is off, restabilizing as the outbound channel is keyed and presents busy/idle information again.

In a multicell environment, if CDPD deploys 18 independently operating base stations for every five that ARDIS places on the same frequency, the crude capacity difference is

$$\frac{3 \times 18}{1.67} = 32 \text{ to } 1$$

This is a very noticeable capacity potential in favor of CDPD. It is no wonder that ARDIS has installed several channel layers to provide comparable capacity, gaining a building penetration edge at the same time.

14.3.2   CDPD Sector Impact

Voice cellular sites are commonly outfitted with three sectors (or "faces"). If CDPD is deployed in every voice site, it will follow the voice "footprint," crudely tripling base station data capacity. But smaller base station diameters, with the coverage area broken into sectors, greatly increases the handoff rate.

In the past there were severe inefficiencies in CDPD sector/cell hand-off. Assume a metropolitan area with contiguous cells each having a 1/2-mile radius. Then an arbitrary vehicle moving at a 30-mph metropolitan speed through the midst of these cells will encounter a hand-off about every 36 seconds. Half of these will be sector hand-offs; half will be cell hand-offs. The principle is illustrated in Figure 14-9.

CDPD hand-off times can be captured by the end user. Appendix Q is a partial edited log of cell hand-offs. It was created by using an IBM ThinkPad to execute the following program, the core repeating every 2 seconds:
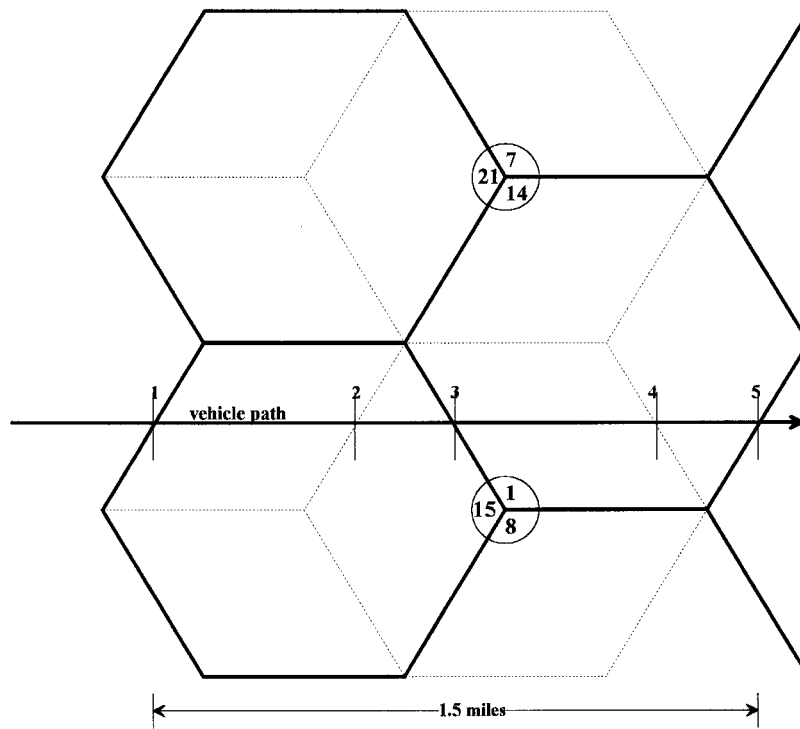
Figure 14-9   Handoff time impact on vehicular targets.

```
"at!cdpd$0d"
CAPTURE (1)
:K
"at!chaninfo$0d"
type ("@cTIME @cSECOND")
twait(2, "sec")
:END
CAPTURE (0)
```

The initial acquisition time on this particular system was at least 12 seconds; a cell transfer was at least 16 seconds; some cell transfers were even messier. In the trivial example of Figure 14-9, with a vehicle at 30 mph, at least 48 seconds out of every 180 (27%) are lost to cell hand-offs. Of course there is no hand-off impact on a fixed-position device or a slow-moving pedestrian.

Clearly, the hand-off problem should be fixed—and the carriers have been working on it. If we assume a cell transfer can be made in 1 second, and a sector hand-off completed in 300 milliseconds, the hand-off inefficiency in our little example drops to 3.6 seconds: 2% lost capacity. But you might like to test *your* CDPD carrier with that little program.

14.3.3   CDPD Channel Hopping

A problem akin to sector/cell hand-off is the time lost to CDPD channel hopping. Hopping has been a fiercely debated subject in technical circles with talented, capable people having seemingly different views. Examples include:

1. "Although the hopping scheme creates additional capacity, it degrades system performance due to additional interference contributed by data transmission. . . . Using a dedicated channel for data transmission could be a better option."[6]

2. "Dedicated protocol was found to have higher throughput and lower average delay than the frequency hopping protocol. In addition, dedicated protocol had less impact on . . . voice traffic loss."[7]

3. "Congested cellular systems should employ channel hopping. . . . A dedicated channel will increase (voice) call blocking and reduce airtime revenue. . . . A typical CDPD channel stream will hop almost 300 times per hour and efficient protocols are needed to ensure that "dead" time between hops is minimized. . . . CDPD must hop completely off the system whenever all . . . voice channels are busy . . . making 100% availability for CDPD impossible."[8]

In fact, the views are not really very different. Most think hopping is a lousy solution for data but is sometimes necessary to protect the voice business. For this comparison it is assumed that channel hopping will *not* be employed. No practical hopping system can be constructed if the data has critical time value.

14.3.4   Busy-Cell-Factor Impact

All systems are plagued by the *busy-cell factor*[9]: the ratio of the percent of traffic carried by the busy cell to the percent of traffic carried by a "normalized" cell. Normalized cell traffic assumes that every cell in the system carries equal traffic. Clearly this is not so.

In low (~9-cell) count configurations, average busy cell factors of 2.7 have been reported by the carriers[10]; in moderate (~28-cell) count configurations, average busy cell factors of 3.8 have been measured. That is, the busiest cell is carrying 2.7 or 3.8 times the traffic of an average cell. A linear regression on four known test points, illustrated in Figure 14-10, suggests that an ARDIS cluster of five base stations, the example used in Chapter 12, will have a busy-cell factor of ~2.5; a CDPD configuration of 18 cells will have a busy-cell factor of 3.3.

The idealized ARDIS "firing sequence" is further disrupted by the busy-cell factor. Assume a work topology in which users flow from the outer suburbs each morning to the center of the city. Then the beleaguered central base station, using a 2.5 busy-cell factor, will carry half the user load. This abnormal distribution is illustrated in Figure 14-11.

To handle the load, the central base station will fire approximately two-thirds of the time, to the exclusion of all other base stations. Figure 14-12 illustrates this time line.
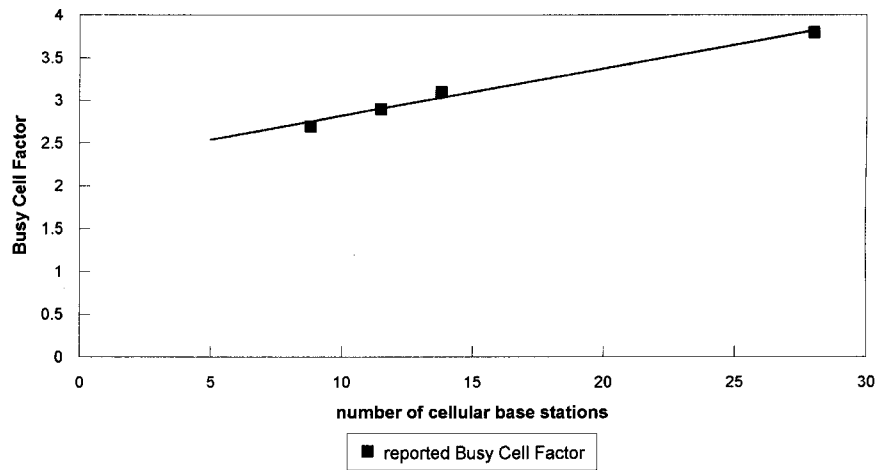
Figure 14-10 Busy-cell factor regression.

Thus the average number of ARDIS stations in operation drops still further to 1.33. Impossible? In one known field test conducted on 34 base stations, only ~3.5 were consistently firing simultaneously. Naturally, it was not possible to force a maximum load condition; the stations simply may not have had that much activity.

ARDIS is not a cobra transfixed by a mongoose. It adds base stations and frequencies to peak-load pressure points. In September 1998 ARDIS' parent company, AMSC, announced the activation of its 32nd RD-LAP metropolitan area and stated,[11] "American Mobile plans to continue to expand the ARDIS network. In the next few months, the rollout continues with an additional four cities expected to be in production by year-end and 40 new cities over the next two years. With these additional cities, the ARDIS network will have added over 600 base stations to the network to provide the 19.2 Kbps services."

CDPD will also encounter idle base stations at peak service times, but the calculated degradation is not so profound. Assume 18 CDPD base stations cover the
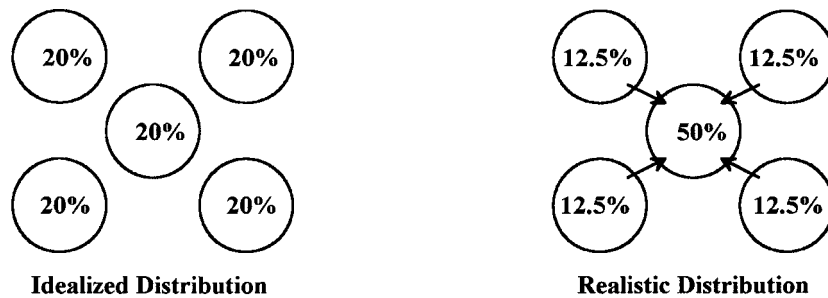

Figure 14-11 Busy-cell factor: 5 base ARDIS.

time sequence	1	2	3	4	5	6	
central base	1 - 12.5%	1 - 12.5%		1 - 12.5%	1 - 12.5%		50%
diagonal bases			2 - 12.5%			3 - 12.5%	25%
			4 - 12.5%			5 - 12.5%	25%

Figure 14-12 Busy-cell factor impact on firing sequence.

same area as the "ARDIS 5." With a busy-cell factor of 3.3, one of the base stations will be carrying $5.6\% \times 3.3 = 18.5\%$ of the peak load. The remaining 81.5% will be distributed in a declining pattern across 17 stations. The resulting math, including hand-off inefficiencies, indicates that the equivalent of ~3 base stations worth of capacity (~17%) will be lost.

The CDPD loss could be worse. The same 34-base-station ARDIS test was also performed on 34 BSWD stations. BSWD, which also uses a cellular approach, was only able to keep 8–10 stations busy—a loss of at least 60% capacity.

The difference in ARDIS and CDPD potential capacity in a small geographic area is summarized in Table 14-1. Remember that no ARDIS layering is present, and CDPD is a dedicated-channel system without consideration of TCP/IP impact.

Thus, CDPD has to invest 3.6 times as much in infrastructure as ARDIS but might achieve from 10 to 30 times as much raw capacity potential. That's leverage! The question: Is that much capacity necessary for the market demand?

14.3.5 Message Rate Activity

Consider some fragmentary live traffic reports. In early 1995, Omnitracs reported[12] that its 100,000 users were generating 2 million messages per day. By September 1996, 175,000 users were generating or receiving 4 million messages per day.[13] Truckers tend to operate round the clock. Even if we hold them to 10 hours per day, each truck is handling a bit more than 2 messages per hour—not a particularly intense rate.

Table 14-1 ARDIS versus CDPD capacity potential summary

	ARDIS	CDPD
Base stations installed	5	18
Unbalanced load impact		
Busy-cell factor	2.5	3.3
Peak traffic, busiest cell, %	50	18.5
Peak equivalent base stations	1.33	15
Peak equivalent sectors	1.33	45

ARDIS is a very different case. In 1992, based on 40 million messages per month from 30,000 active users,[14] the IBM Field Service dominated traffic generated ~8 messages per user during the peak hour. By mid-1993, with the addition of alternative applications, 77,000 messages were sent in the peak 20 minutes by 32,000 users[15]—~7 messages per hour per user. At the close of 1994 there were 2500 messages being sent every 45 seconds,[16] which yields ~5 messages per user during the peak hour. Throughout 1997 and 1998 with the addition of first Enron, then ABB Information Systems,[17] low-volume, short-message applications such as Automatic Meter Reading have become important, tending to spread the message load, not build peak-hour rates.

There were ~40,000 users at the close of 1994 being served by ~1400 base stations. With a uniform distribution of users, and assuming every message is a full 240-octet packet delivered only by MDC4800 (~1 second of airtime), the average base station was only 4% utilized for user traffic. Clearly there is no average base station. But if we guess that the traffic in a hot zone is 10 times more intense than the average, the base station still has plenty of capacity for retries and control overhead.

Meanwhile, the ARDIS base station count was rising: 400 new stations were installed during 1995,[18] almost all RD-LAP, which is roughly 5–6 times as efficient as MDC4800. The ARDIS base station capacity utilization may be inefficient but there is no evidence that it is inadequate.

14.4   DEALING WITH TCP/IP IMPACT

The short-message example used in this chapter made TCP/IP a performance villain. Others would go further. Nettech, in its literature,[19] states: "running these (TCP/IP) applications in a wireless environment . . . makes communication unreliable and inefficient. . . . TCP/IP generates excessive overhead and is intolerant to the relatively harsh wireless conditions. . . . Coverage conditions fluctuate, making TCP/IP transmissions unreliable. Other problems . . . include poor throughput, high communication costs and reduced device battery life."

Well! This chapter does not deal with poor battery life, though we all have experienced it. Chapter 12 indirectly dealt with unreliable transmission. The essential message was that the longer the transmission, the more vulnerable it is to error.

This chapter is focused on throughput and capacity. While the carriers' new all-you-can-eat pricing plans have hidden the dollar cost of TCP/IP inefficiency from the end user, the problem does show up indirectly in longer transaction intervals. And no amount of salesmanship can hide the internal cost of this inefficiency from the carriers themselves. They have three choices:

1. Live with it, and focus primarily on long-message-length applications. Thus, CDPD will gradually become king of FTPs and Web access, and ARDIS/BSWD will dominate short-message applications from burglar alarms to dispatch to paging.

2. Persuade their users to develop more efficient UDP applications. That will take a load off the network, all right, but slow down customer rollout as the user struggles with the application development necessary to retrieve missing packets or handle packets delivered out of sequence.

3. Convince users to embrace extra software licensing costs in order to gain optimization techniques that reduce the number of packets and bytes transmitted. That is, abandon TCP/IP.

Approach 1 could become reality. Approach 2 is vulnerable to competition, which has offerings that are at least as good. In the ARDIS short-message example, the inbound channel had to answer an application ACK from RadioMail. If users are content with UDP, they will surely be content with ARDIS 2way.net, which does away with the response to an application ACK. Approach 3 is clearly of interest in this chapter. One practical problem is that the carriers must convince the user to pay more in one time costs in order to help the carrier's network. There is likely to be some cost underwriting performed by the carriers in order to achieve this goal.

How effective are these TCP/IP avoidance techniques? The answer: very. Table 14-2 is an extension of Nettech test claims reported for its "Smart IP" product.[20] Ironically, the approach is to "replace TCP/IP with Nettech's optimized wireless transport protocol."[21] You did not think they were knocking TCP/IP for nothing, did you? But the general trend seems clear. CDPD will present a TCP/IP interface to its users so they have to make minimal software changes to their applications. Underneath TCP/IP will be stripped away in order to make a product more suitable for a wireless environment. Then, and only then, will CDPD's vast capacity potential be fulfilled.

Table 14-2   Smart IP TCP/IP overhead reduction

	Packets	Bytes
FTP: get 10,000 bytes		
Native FTP	53	12,879
Smart IP	10	6,485
Percent change	81	50
HTTP: 1 page, 8 images		
Without Images		
Native FTP	39	9,634
Smart IP	6	2,947
Percent change	85	69
With Images		
Native FTP	314	67,688
Smart IP	80	47,421
Percent change	75	30

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15

ENABLING "SOFT" TECHNOLOGIES

15.1   ALPHABET SOUP

Thirty seconds into a review of communication product specifications one encounters a babble of "vee-dot" (V.) versus MNP variations, and mysterious acronyms such as EC^2, ETC, and TX-CEL. It is unwise to dismiss this sometimes unintelligible gibberish as an unimportant attempt to break/protect vendor proprietary interests. These alphabetic designators are often surrogates for key communication developments required for the success of wireless data.

   This chapter is a simplified look at some nonhardware technologies, protocols, and communication standards that drive both network and device development. The focus is on modulation techniques, error detection/correction, and data compression.

15.2   MODULATION

15.2.1   Circuit Switched

The modems initially used to transmit data via analog cellular channels were conventional, dial-up wireline devices with CCITT-standardized "V" series modulation techniques. The most common are listed in Table 15-1. The user either could plug these modems into a cellular phone (with adapter) or use landlines via the usual wall phone jacks. A useful characteristic for cellular was, under adverse conditions, the V.26/27 implementations dropped to half speed. They actually worked well but connected slowly and transmitted data oh-so-slowly.

Table 15-1   Early wireline modulation techniques

CCITT No.	User bps	HDX/FDX	Modulation Technique
V.21	300	Both	Frequency shift
V.22	1,200	FDX	Phase shift key (PSK)
V.22*bis*	2,400	FDX	Quadrature amplitude
V.26*bis*	2,400	HDX	Differential quadrature
V.27*ter*	4,800	HDX	Differential 8-PSK

Between 1976 and 1982 IBM's Gottfried Ungerboeck developed the theory, and received the patent,[1] on what is now known as trellis-coded modulation (TCM).

Briefly, TCM introduces redundancy in the information bits to be transmitted. These extra bits are used for detecting, and usually correcting, transmission errors. Of naming interest is the fact that the redundancy is added in such a way that sequential data symbols cannot succeed each other. The possible states can be represented by a transition diagram that (imaginatively) resembles a trellis. The state sequences can be explored recursively using the Viterbi algorithm to predict the most likely sequence. An error that disrupts this sequence can often be corrected by substitution.

The TCM goal was to permit 9600-bps transmission over dial lines. Initially ignored, even within IBM, continued development, as well as the evolution of affordable signal processors, proved that TCM was eminently practical. In 1986 the technique was standardized by CCITT as V.32 over the resistance of the U.S. delegates, who stated, "the V.32 recommendation is not workable . . . and is needlessly sophisticated for most PC communications."[2]

Three years before the formal V.32 standardization, IBM Research saw that the TCM techniques could be pushed to higher user speeds.[3] Thus was born the development efforts that ultimately became V.32*bis*. In this implementation, 7-bit symbols are transmitted at 2400 baud to produce a raw transmission speed of 16,800 bps. The user bit rate is specified as 14,400 bps (14% redundancy). This TCM technique was embraced quickly by manufacturers. IBM was beaten to market by the 14,400-bps Codex 2360/2660 in 1984, two years before CCITT endorsed the 9600-bps standard! V.32*bis* was standardized by CCITT in early 1991.

With relentless reduction in both size and cost, V.32/V.32*bis* modems became the favored modulation technique for circuit switched wireline modems by 1992. Since the standard permits fallback to half speed under adverse line conditions (e.g., 9600 bps drops to 4800 bps), this slower speed operation proved useful on cellular.

In 1993 multidimensional trellis coding became the core of the V.Fast proposals. In June 1994 they were standardized as V.34 by the International Telecommunications Union (ITU), a United Nations agency that had replaced CCITT. This backward-compatible, variable-speed approach permitted raw data transmission capability of 28.8 kbps and, optionally, 33.6 kbps.

Work was already underway on faster "56-kbps" modems. Two competing, incompatible technologies were on the table, with all the usual claims for technical superiority (and attendant saber rattling over patent positions):

1. K56 (or K56flex)—supported by 3Com, Lucent, Motorola, Rockwell, and others
2. x2—supported by Texas Instruments and USRobotics

In March 1997, ITU-T began work on harmonizing the two competing proposals. The effort was probably aided by the acquisition of USRobotics by 3Com. On February 6, 1998, agreement was reached on the V.90 56K modem standard, which was expected to be formally ratified in September 1998.

These sharp bit rate improvements in wireline modems did not directly transfer to the more hostile wireless environment. Until recently, the best cellular modems were all based on V.32*bis*, offering the potential for speeds up to 14,400 bps (Rockwell permits its cellular modems to operate in V.34 mode, but with poor results). Typically wireless cellular modem speeds lag their wireline counterparts by a very great deal, as shown in Figure 15-1.
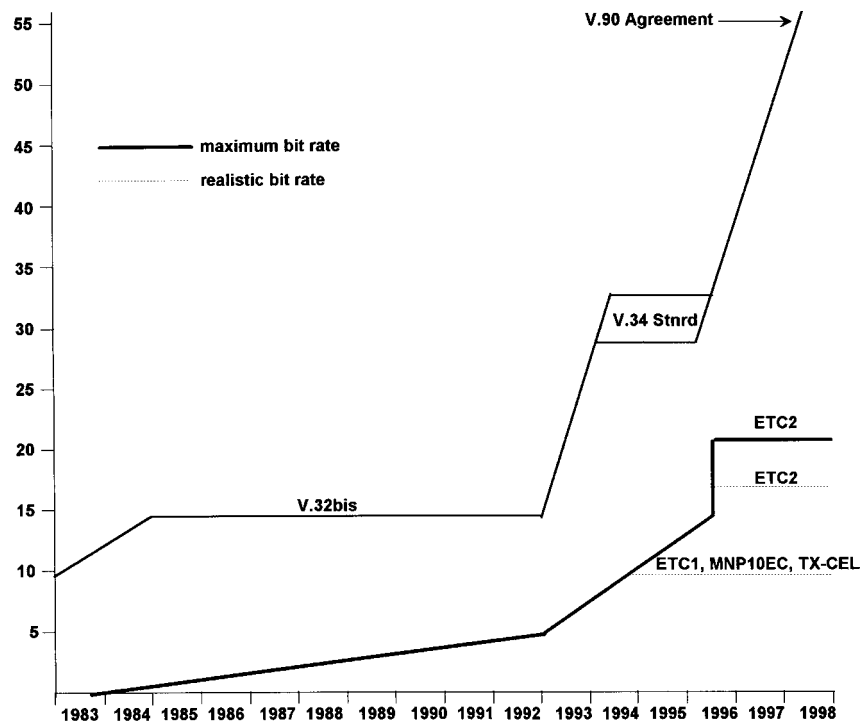

Figure 15-1 Circuit switched wireline vs. wiereless modem rates.

15.2.2   Packet Switched

15.2.2.1   Narrow-Band Low-Speed Devices   Most packet switched data radio devices have a history of digital modulation techniques with arcane names such as *modified duo-binary* (MDI's MMP), *noncoherent baseband FSK* (Motorola's MDC4800), or *binary digital baseband filtered FM—modified GMSK* (Ericsson's Mobitex).

The *frequency shift keying* (FSK) variant was in widespread use in wireless devices at the start of the 1980s. It was easy to generate and detect and permitted much lower cost devices. The problem with FSK is that it is extravagant in its use of bandwidth. It was quite clear that Motorola would be unable to get much beyond 4800 bps using this modulation technique.

At the close of the 1980s Motorola, keying off wireline progress, developed an enriched TCM technique to improve both the speed and correction power of RD-LAP. Here 8 bits per baud, not 7, are sent at a raw transmission rate of 19,200 bps. Two of the 8 bits are redundant, producing a user yield of 14,400 bps, comparable to V.32*bis*. One of the psychological differences is that Motorola began to claim the raw bit rate, not the effective user rate, for RD-LAP. All competitors would be forced to follow this imprecise convention or thought to be bit rate laggards.

CDPD chose not to use TCM, using *Gaussian minimum shift keying* (GMSK) instead. The initial IBM CelluPlan design goal was 16,800 bps. With Motorola's announcement of RD-LAP in late 1991, that rate would no longer suffice. A variety of modulation techniques were considered that, in future implementations, might yield far higher bit rates in the 30-kHz-wide cellular channel. With the participation of PCSI as the modem/base station designer, the alternatives were narrowed to three with the grossly simplified selection criteria of Table 15-2.

GMSK has the weakest spectral efficiency, and there were early concerns about transmission power control. But GMSK variations were employed in both Mobitex and the European GSM system; it had good product cost numbers and could be driven to match RD-LAP's speed. Reed-Solomon coding permitted Motorola equivalency in correction efficiency: 19,200 bps, which yields 14,400 user bps.

Table 15-2   CDPD modulation alternatives

	GMSK	4-FSK	DQPSK
Radio complexity	Good: standard FM		Costlier
Baseband sophistication	Good	Costlier	Good
Spectral efficiency	Worst	Very good	Best
Eb/no performance			
Static	Good	Worst	Best
Rayleigh	Good	Worst	Good
Process power/memory	Good	Harder	Harder

15.2.2.2   Narrow-Band Medium-Speed Devices   In   September   1991[4]
Motorola announced a new digital wireless technology, then called MIRS. This
combination of techniques, employed by Nextel among others, employs M16QAM[5]
modulation and achieves a raw bit rate of 64 kbps in a 25-kHz-wide channel. Nextel
states that "no other modulation technology transmits as much information in a narrow
band channel."[6]

Quadrature amplitude modulation (QAM) is a solution to the phase jitter problem
seen in PSK. PSK, in itself, was designed to squeeze more bits into a given bandwidth.
The first commercial QAM modulation appeared in V.29 leased-line modems and was
limited to 9600 bps. QAM, as employed in iDEN for Nextel, uses this high bit rate and
time division to carry digitized voice. If Nextel chooses to offer a packet data solution,
it should be possible to send information across multiple time slots, trading off voice
for data. This could provide attractive narrow-band channel rates. As of the fourth
quarter of 1998, this narrow-band bit rate has not been exploited for any data solutions.

15.2.2.3   Wide-Band High-Speed Devices   An   alternative   to   narrow-band
schemes is the use of spread spectrum, a term often used interchangeably with CDMA.
Spread   spectrum   was   originally   developed   to   foil   jamming   of   military
communications. In this approach the data stream is imprinted onto a spreading signal
that has a bandwidth much greater than the data rate.

It seems counterintuitive that in a limited spectrum world such a design
requirement could lead to a viable, spectrally efficient solution. But it is possible for
a spread spectrum receiver to operate when its input signal is literally buried in noise.
As long as the received power can be equalized, hundreds of "interfering" signals can
operate in the same spectrum. If all transmitters in a mobile system used fixed transmit
power, as they do in ARDIS, BSWD, and CDPD, the power equalization requirement
could not be met. Devices close to a base station would swamp the signals from more
distant units, a problem known as the near–far effect. This transmit power control
problem has gradually become tractable, as is evident in the (now) successful
Qualcomm CDMA techniques employed by many carriers for digital voice.

Qualcomm is not the only user of CDMA. Metricom's Ricochet system was a user
from the outset. The positioning of many low-power nodes helps to provide a solution
to the near–far problem. In the initial design, device modems separated by distances
less than ~600 meters can transfer data to each other without passing through a
receiver/relay node. In this special case, rates up to 40,000 bps are achievable. Typical
speeds through the nodes ranged from 9600 to 28,800 bps.

In March 1997 Metricom announced a new technology to sharply increase data
speeds.[7] The new approach, code named Autobahn, utilizes two unlicensed spectrum
bands: 900 MHz and 2.4 GHz. The top speed was to be 85 kbps, available in 1998. In
addition, broadening the bands still further (Starlite) offered a potential speed of 256
kbps—which would be really moving! In September 1998 Metricom announced the
demonstration of what is now called Ricochet II, at speeds "which will be comparable
to a wired 56K modem."[8] Clearly, there has been some trouble along the way. It is also
a bit late: The new service will begin deployment in mid-1999.

15.3   ERROR DETECTION: V.42/V.42 FAST AND MNP4/10

In 1988, after bruising political battles, CCITT recommended V.42 as its error control standard. The competitive approaches were a protocol called LAP-M and Microcom's MNP4. LAP-M is a variant of the HDLC protocol devised for ISDN: LAP-D. It is a full-duplex protocol and was backed by U.S. modem manufacturer Hayes as well as AT&T and British Telecom.[9] MNP4 is a half-duplex technique developed by U.S. modem manufacturer Microcom and backed by the Belgian, French, and Italian postal, telephone, and telegraph (PTTs) providers.[10]

Both approaches are speed independent. One does not have to have V.32/V.32*bis*/V.34 for V.42. In fact, virtually all initial implementations were on the older, slower V.22 modulation standard. Both competing error detection techniques use CRC with ARQ retransmission. Technical differences are minor; both protocols provide virtually identical performance. The camel compromise: V.42 requires modems to use LAP-M and support a secondary mode of operation that uses MNP4. The theory was that enhancements would flow to LAP-M, gradually retiring MNP4. Microcom did not permit that to happen.

In 1991 Microcom used V.42 as a base to extend error detection with a series of MNP levels, some of which were useful for cellular data. The core of the approach is to depend upon the 16-bit CRC for the detection of an error in a packet that does not exceed 256 octets. With MNP4 the size of this packet varies with transmission quality: the better the "line" (reflecting the original design), the larger the packet. Continuous ARQ can be used to retransmit faulty packets.

Collectively, the MNP Cellular features are called MNP10. This is a proprietary, two-sided protocol. That is, both the remote user and the host (or cellular modem pool) must have MNP10 to gain any benefit. When used with cellular, which is detectable by the modem, the key differences with the MNP4 versions are:

1. MNP4 operating on wireline uses large packets at the beginning of a session; if there are too many errors, the packet size is reduced until the error rate reaches an acceptable level. MNP10 does the opposite: It begins with small packets and continues to increase packet size in the absence of errors.

2. The initial MNP10 connection is made at 1200 bps.[11] Bit rates are reduced in the presence of noise; when the noise eases, the bit rates are advanced (a function not specified in V.42). These speed shifts can be dramatic: 300 bps under adverse conditions to 4000 bps in a "clean" environment.[12]

3. The modem begins transmission at low modulation amplitudes. If channel background noise is detected, the receiver can ask the sender to increase signal power. In the presence of distortion the receiver can ask the sender to decrease signal power.

This philosophy tends to make the protocol perform less well if the target is moving since it often detects problems and slows the bit rate just as the target leaves the trouble area. In 1991 Microcom tests on low-bit-rate modems, executed along Boston's Route

128 in high-signal-strength areas, revealed that bit rates for comparable messages on stationary targets was 1.4–1.9 times higher than for "moving" targets.

Further, MNP10 sees cellular "events" as damaging noise. The modems lose synchronization and must retrain after each event. This can have punishing impact on throughput since retrain cycles can vary between 6 and 25 seconds.

Meanwhile, the original V.42 LAP-M proponent was not idle. AT&T Paradyne continued its work on modem improvements for cellular. In 1993 it introduced its own proprietary, two-sided modem called ETC: Enhanced Throughput Cellular.

Confusing everyone, AT&T Paradyne advertisements sometimes make claims[13] for ETC error-correcting algorithms. These claims are advertising puffery. ETC is an error detection protocol that employs[14] V.42cell: essentially V.42, Appendix III modifications to improve reliability with potentially high bit rates under adverse transmission conditions. However, ETC is modulation dependent and uses only V.32, V.32*bis*, and V.34.

In 1997 Paradyne introduced extensions called ETC2 Quick Connect.[15] Paradyne claims that ETC2 is more reliable, causing V.42 error detection to be invoked less often: "the lowest rate of ETC2 . . . (4800 bps) operates 4 dB better than the lowest rate of other cellular protocols."[16]

15.4   DATA COMPRESSION: V.42*BIS* AND MNP5/7

In a reprise of the V.42 battles, CCITT was faced with two competing proposals for modem data compression in 1988. The first was the extant MNP5 developed by Microcom. This Microcom approach used a real-time adaptive algorithm to achieve a nominal doubling of throughput. That is, under the right conditions a 2400-bps modem would be able to make an effective data transfer rate of 4800 bps. Fully aware of its modest compression achievement, Microcom delivered MNP7 in the second half of 1988. This technique used Huffman coding (few bits for frequent English language letters such as E, T, A; more bits for infrequently appearing letters such as Q and Z) with a predictive algorithm. The result: ~3-to-1 improvement under good conditions.

ACT's CommPressor alternative based on Lempel Ziv techniques, which could yield 4-to-1 improvements, was selected as the V.42*bis* standard in September 1989. Microcom continues to license and build its MNP alternatives but admits that V.42*bis* "will increasingly become the preferred method of data compression."[17]

The actual compression achieved in practice varies widely with the application. The algorithm works by recognizing repeated patterns in data and substituting shorter symbols for them. The more repetition a file has, the greater the compression. But purely random data contains no patterns at all and cannot be compressed. Precompressed information, such as ZIP files, do not benefit from V.42*bis* either. Further, data files that have been encrypted through a randomization process will also show little reduction in size because the data has had identifiable patterns removed. This suggests that CDPD, for example, might not benefit from data compression. A data compression summary[18] is shown in Figure 15-2. These are average ratios. A
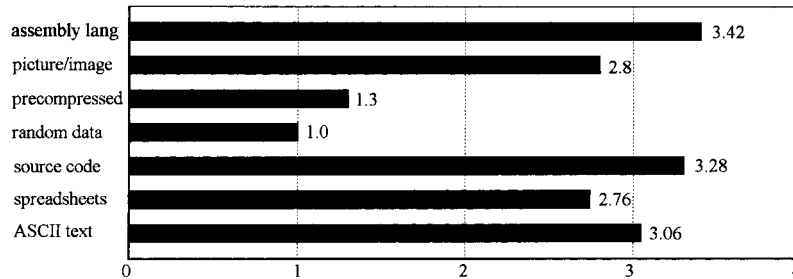
assembly lang   3.42
picture/image   2.8
precompressed   1.3
random data   1.0
source code   3.28
spreadsheets   2.76
ASCII text   3.06

0   1   2   3   4

Figure 15-2   Data compression summary.

compression ratio of 2.0 indicates that the data can be compressed by a factor of 2 and transmitted in half the time needed to transmit it uncompressed.

15.5   ON-GOING ENHANCEMENTS TO ALPHABET SOUP MODEMS

ETC addressed some MNP10 weaknesses, including the ability to operate (with degradation) if only the mobile user has an ETC modem. It still treats cellular events as noise. It was quickly tested at Bell Atlantic Mobile, Ameritech, and Southwestern Bell[19] and is now available through most modem pools.

As might be expected, AT&T Paradyne claimed markedly superior performance to MNP10: "ETC blows MNP10 out of the water"[20] and "V.42cell outperforms . . . MNP10 by a significant margin."[21] Microcom disputed all the test results.

However, disquieting murmurs about the effectiveness of MNP10 had long been extant. In 1991 low-bit-rate field tests were performed in Los Angeles with Microcom's Microporte 1042 modem. The customer's summary was[22]: "The performance of MNP10 . . . may be only marginally better than the performance of other protocols . . . (and) appears to be the same as other protocols in practical applications."

In 1994 the results of Network World's tests of high-bit-rate modems were bluntly summarized[23]: "The results of this trial cast little doubt that ETC modems outperform MNP10 modems. The ETC supporting modems generally connected faster and at higher initial rates than MNP10 modems. When it comes to transmitting over the cellular network, the ETC modems are far superior to the MNP10 devices aggregate throughput."

Celeritas Technologies developed, and patented, spectral shaping firmware called TX-CEL (throughput accelerator). The technology is essentially protocol independent and will work with either MNP10 or ETC variants. The licensing has been quite successful, including the gateway products of Primary Access.[24]

To improve MNP10 performance, in November 1994 Rockwell announced a chipset called MNP 10EC. The new functions include signal conditioning technology and specific algorithms to deal with cellular "impairments" such as hand-offs, dropouts, interference, fading, echoes, and audio distortion. By April 1995 more than

Table 15-3   Cellular modem connectivity comparisons

Category	Connectivity (%)
Modems with interfaces	20–50
EC^2 solutions	38–45
ETC direct connect solutions	40–49
AirTrue	90–96

100 modem companies had pledged to deploy cellular modems with the MNP10EC technology.[25]

The competition between these two approaches has forced continuing improvements in data performance over circuit switched cellular—clearly with more emphasis on cellular problems. Motorola, with its CELLect line of modems, used V.32/v.32*bis* modulation, V.42 LAP-M error control, and V.42*bis* data compression. (Motorola also had problems with ad writers who extolled the virtues of "V.42*bis* error correction."[26]) From this base Motorola developed Enhanced Cellular Control (EC^2) to "optimize cellular data communications by managing the hand-off between one cell and another, noise distortion, and other cellular functions."[27] But Motorola could not compete: "With slumping sales, questionable profitability and increasing price competition, Motorola's (October 1997) decision to sell off its consumer modem business"[28] was not unexpected.

Another casualty was AirTrue from Air Communications. Introduced in late 1994, AirTrue was a cellular-side-only protocol optimized to work with any V.42 modem at the host end. AirTrue was confined to V.32*bis*. At this speed AirTrue attacked transceiver noise/distortion and attempted to interpret cellular events as something other than just noise.

AirTrue performed extensive testing on both connectivity and interoperability. Connectivity was defined[29] as "the ratio of successful first try connects to total numbers called (discounting modem busy and ring-no-answers)." Summary results are shown in Table 15-3. But in spite of the boldest assertions that "AirTrue offers a level of functionality that its competitors cannot match,"[30] the Air Communicator was not a success. Today Air Communications concentrates on GSM products.

The new battle is being fought by Paradyne ETC2[31]: "No other cellular protocol supports the high rates . . . Rockwell . . . MNP10EC . . . reliability is poor. No other cellular protocol has a 'quick connect' mode. No other cellular protocol is widely licensed, etc." The fights are ugly, but the products are improving and the prices are dropping. What more can we ask?

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V

PUTTING IT TOGETHER

16

DEVICE ALTERNATIVES

16.1   INTRODUCTION: COMBINATIONS AND PERMUTATIONS

A bewildering array of subscriber unit options are available for wireless data ranging from fully integrated terminal/modem/radio units to multibox combinations of PCs, external modems, cellular transceivers, and portable faxes. A (too) simple representation of some of the terrestrial variations is illustrated in Figure 16-1.

This convoluted collection of hardware alternatives is extraordinarily volatile. It is not uncommon for a monthly trade magazine to publish reviews of a product only to have some details revealed as outdated by the vendor's new ad in the same issue. An up-to-the-minute review of the wide range of product possibilities makes little sense for a book with an even slower publishing schedule.

There is also the question of personal choice in devices. For some users "carrying an extra bag isn't as comfortable as putting a palmtop in their pocket."[1] Users with a similar profile require at least a notebook because they cannot tolerate the small keyboard, hard-to-read display, or Windows incompatibility[2] of some palmtops. Still others will carry the latest "desktop replacement" notebook PC even if it weighs 9 pounds.

The key trends for pivotal segments that permit the devices to communicate wirelessly is clear:

1. Universal adoption of the PC Card, Type II format radio modems, with multiprotocol capability. These are most often seen in notebook/laptop PCs.

2. Integration of radio modems within devices, especially for custom designed, "rugged" terminals. However, full integration also extends to pagers as well as voice handsets.
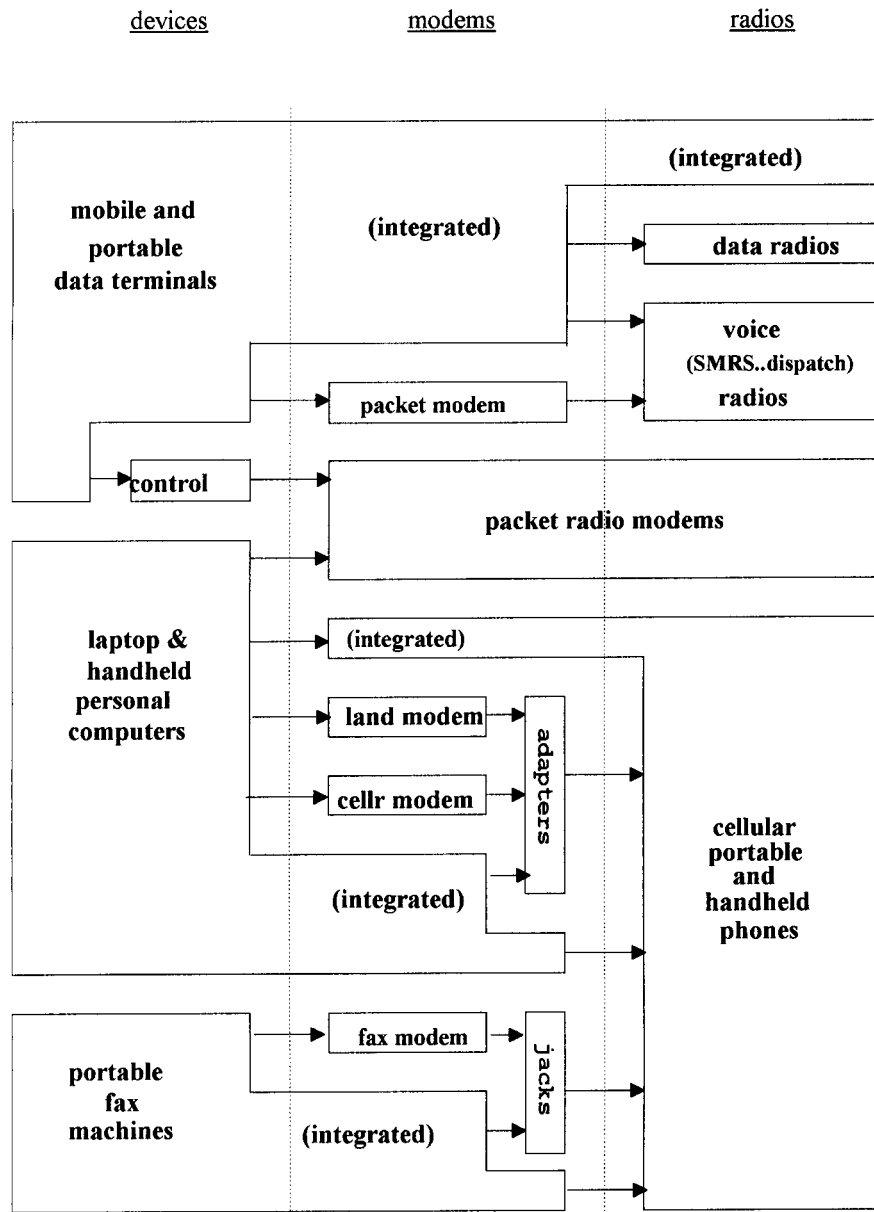
Figure 16-1 Device combinations and permutations.

3. Relentless attempts to introduce useful, well-packaged radio modems for palm PCs.

16.2   MODEM COMPLEXITY

Wireless modems have four levels of hardware sophistication:

1. No *hardware* consideration for errors. With data over cellular this class of modem is usually limited to very low speed (300–1200 bps) where error tolerance is high. Error control rests with simple communications protocols such as Xmodem[3] (and its variants), Kermit,[4] and Zmodem.[5] These modems are virtually an extinct breed, but the overlay protocol Zmodem is still recommended by BCTEL[6] because of its ability to resume the transfer at the point of disconnect.

2. Error *detection* mechanisms, combined with ARQ techniques, and often accompanied by packet resizing to optimize performance. These units tend to be moderate speed (2400 bps) since longer burst errors can now be tolerated. The foremost examples are Microcom units and their many MNP cousins. These moderate-bit-rate protocols are being relegated to history, appearing only as artifacts in multiprotocol modems.

3. Trellis-coded modulation to provide initial error *correction* capability at higher bit rates (5–20 kbps). This more reliable data transmission technique is usually combined with error detection, usually V.42, and ARQ to improve the chances of successful message delivery. On cellular these modems are increasingly equipped with signal shaping and hand-off detection technology to reduce the occurrence of cellular "incidents." On packet systems such as Motorola's RD-LAP, the bit stream is interleaved to spread burst errors.

4. The use of more powerful error correction coding techniques, deliberately sacrificing airlink capacity, in an attempt to deliver a clean message *without* retransmission. The most well known example of this class of modems are CDPD units.

Wireless modems can be packaged as stand-alone units or, increasingly, integrated into paging devices, laptops, or cellular phones. Years of ground-laying packaging development for PC Cards has made fully integrated units a very powerful option.

When modems are used on circuit switched cellular. vendor variations on the cellular instruments often force the need for an adaptive device, now a "smart" cable, between modem and cellular radio. These adapters mimic wireline dial operations for communications software. Increasingly, adapters are being integrated into either modem or cellular phone.

Some modems contain the radio transceiver. Packet switched radio modems integrated into custom devices have been available from Motorola for more than a

decade. Both Motorola and Ericsson began to deliver external radio modems at manageable price levels in 1992–1993.

16.3   CELLULAR SPEARHEADS MODEM DEVELOPMENT

Multiple slow-speed modems capable of operating via circuit switched cellular were announced within a year of the initial cellular rollout in October 1983. Most were failures, but all contributed to the relentless trend toward lower weight and smaller physical volume. These physical improvements ultimately made device integration possible.

For nearly six years the cellular modem physical trends were pleasant: a 300-bps modem in 1984 weighed 20 ounces; in 1990 a 1200-bps unit weighed the same 20 ounces; 300-bps units weighed 5 ounces. This compound annual weight reduction of ~20% and a compound bit rate increase of ~25% per year seemed a new law of physics and often appeared on forecast charts.

The 1991 introduction of the Telebit QBlazer was the first break in the trend lines. This modem departed from the old modulation techniques, which were topping off at 4800 bps on wireline systems. Telebit employed V.32 (9600-bps) TCM as well as recovery strategies originally developed for wireline units. With the transmission speed reduced, typically to 4800 bps, these techniques made a good fit for cellular. Raw bit rates thus rose by a factor of 8; weights/volumes fell to one-third of the prior best: the V.32 Digicom 9624LE. The unit had V.42 error detection, with ARQ, and V.42*bis* data compression, which had the *potential* for quadrupling throughput (see Section 15.4).

This sharp break signaled the end of the medium-speed stand-alone modem. Excellent new units such as Microcom's MP1042, in normal times a breakthrough unit, were doomed by the V.32 development. Dozens of vendors[7] began to produce V.32 and the even faster V.32*bis* pocket modems. Nearly all included fax capability as well. This tight packaging was made possible by the advent of inexpensive chip sets from AT&T, Exar, Rockwell, and Sierra.

Three years later the nails were hammered ever faster into the stand-alone modem coffin. V.32*bis* (14,400-bps) PC Card modems now weighed less than 35 grams—a little over an ounce. During much of this period list prices fell very slowly until the impact of wireline V.32/V.32*bis* cellular-capable modems was felt. In the first quarter of 1985 Spectrum Cellular's Bridge/Span units delivered 300 bps for $595: 1 bit per second for ~$2. The coming of devices such as Megahertz's PC Card cellular modem permitted theoretical speeds up to 14,400 bps for a list price of $459: 1 bit per second for $0.03. Further, the new modems included many extras, including fax capability and communications software for both data and fax. In the first quarter of 1995 it was routine to find direct order retailers selling brand name cellular modems for $289: 1 bit per second for ~$0.02. By the fourth quarter of 1997 V.34 modems with cellular support could be purchased for $50–$90[8]: 1 bit per second for about a half cent. This 400-fold price-per-bps decline in just 12 years ranks with the best technology shifts of the decade.

16.4   VOICE/DATA PUSH–PULL

16.4.1   Positioning Tussles

During the transition from stand-alone modem to PC Card, vendors were able to produce small OEM modems capable of being integrated into either data devices or cellular phones. Hybrid solutions were developed for each alternative. This competition over function placement, voice versus data centric, continues.

16.4.2   Voice Devices Swallow Modems

In 1992 Mitsubishi integrated the Microcom 1042, a 2400-bps MNP10 modem, under the covers of its 1500MOB series phones. The resulting CDL300 was a 3-watt portable cellular phone with attractive physical characteristics for its time. With battery, it weighed 4.3 pounds—not bad for such a high-transmit-power machine.

In 1993 PowerTek announced its CMI-3000 cellular data link. Rich with connection options, the CMI-3000 contained a 3-watt transmitter and a V.32*bis* (14,400) bps data/fax modem using MNP10 correction and V.42bis compression. The identical unit was also offered by Audiovox as the CDI-1000. To add interest to the MNP10-versus-ETC dispute, both PowerTek and Audiovox claimed a 96% first-time connect rate[9] with MNP10. This may have reflected the high transmit power available in these rather large units. The PowerTek/Audiovox units made advertising claims for full integration but, like Mitsubishi's CDL300, the handset was distinctly separate.

In 1994 Air Communications announced a product that truly was fully integrated. Weighing in at 1 pound, the modem section was multiprotocol, including V.32*bis* and fax. The device used the proprietary AirTrue enhancements to improve the probability of call connection as well as duration. The battery permitted 2 hours of data transmission. When disconnected from a PC it operated as a conventional cellular phone, with features such as voice mail. In this mode it served as an answering machine for incoming calls (16 minutes maximum time). Its storage capability also permitted it to hold up to 37 fax pages for later transmission to a fax machine. The Air Communicator was marketed by both Ameritech and Sprint Cellular, but in spite of diligent efforts, it failed.

The philosophy of these "voice-centric" products is shown in Figure 16-2. The voice handset is the key communications device. The data user requires no modem within the laptop. A regular RS-232 cable connects the laptop to the phone modem. This modem can sometimes connect to wireline networks via normal RJ11 cables. Principally, it uses the voice radio to make a circuit cellular, facsimile, and, now, CDPD connection.

16.4.2.1   *Voice Devices Try to Do It All*   In 1994 BellSouth announced IBM's Simon, a cellular telephone with limited PDA functions such as appointment scheduler and calendar, personal electronic directory, and calculator. Simon used a
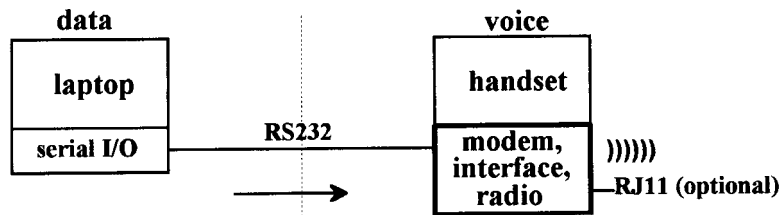
Figure 16-2   Voice devices swallow modems.

backlit liquid crystal display (LCD) screen as telephone keypad, pen annotation area, and computer display. Its communication functions were limited:

1. *E-mail.* Twenty messages could be received, but the data modem only operated at 2400 bps. There was no way to connect Simon to a PC and no wireline mode.

2. *Paging.* The coverage and costs were cellular based. Nine phone numbers (no text) could be received and stored.

3. *Facsimile.* Three facsimiles could be viewed on the small screen and hand annotated for retransmission.

The BellSouth theme was "Simon Says Have It All." Simon was occasionally spotted in the movies, rarely in real life.

Ignoring ill-fated detours such as the AT&T EO440/880 class devices, the newest do-it-all unit is Qualcomm's pdQ.[10] Sometime in 1999 we will see this voice cellular phone wrapped around a 3Com Palm Pilot. Two models were under test in the fourth quarter of 1998, an 800-MHz analog/digital voice version as well as a single-mode 1900-MHz digital-only unit. Three Qualcomm applications will exist to permit short-messaging service (SMS), E-mail (likely Eudora), and Web browsing.

The resulting device is odd looking and fairly large, though smaller than a palm Pilot stuffed on top of a Minstrel modem. I felt faintly embarrassed putting a demonstration unit up to my face to talk. I also have trouble with the Palm Pilot as a pen-based data entry device. The pdQ price is unknown at this writing, so we must simply wait and see if the product(s) are successful.

16.4.2.2   A Compromise: SmartPhones PCSI's Unwired Planet Browser/HDML-based PALphone was the first example of what was immediately tagged a "smartphone." PDA functions are not integral to the phone instrument, as in Simon or the pdQ, but are obtained from the network from a built-in "micro web browser." The address book and calendar (for example) can be located on your own personal Web page, which the smartphone accesses.

The notion behind the smartphone was that many users (perhaps most) were voice junkies with a secondary need for data from the web or their own corporate network, especially one using Lotus Notes. There is only a tertiary need for any data input other

than checklist yes/no responses. Entering any real message of substance from a telephone keypad is time consuming and unusually annoying.

The PAL phone was, first and foremost, a cellular voice handset. But it had a good multiprotocol modem under the covers for CDPD, circuit switched cellular. and facsimile. It was all wireless, all the way; the RJ11 connection to wireline networks did not exist. Introduced in 1996, it was gone in May 1997,[11] an obvious casualty of the death of PCSI.

Before its end, there was a feeling that the PALphone did not quite measure up to the smartphones that quickly followed, especially Samsung's Duette[12] and the Mitsubishi MobileAccess 110.[13] Initially priced at $500, they dropped to $300 by first quarter of 1998.[14] These units are now subsidized by the carriers. In the fourth quarter of 1998 AT&T Wireless offered units for $99 for those users subscribing to its WorldNet E-mail service.[15]

AT&T Wireless bet heavily on these new devices with its PocketNet Service. The introduction[16] was all upbeat: "I truly believe (smartphones) will be one of the major factors that finally drives (wireless data) adoption—1996 and 1997 will be the years when the curve did start to turn up." But that hardly happened. Within months some customers in pilot "opted to discontinue the service."[17] when they realized that "the technology requires an IS department or an application from one of the (software developers) we're working with."[18] AT&T Wireless was reasonably cautious about its equipment orders, awarding Samsung an $18 million dollar contract in June 1997[19]—20% of what BellSouth committed to RIM for two-way pagers.

In 1988 Mitsubishi began to ship its *Mobile*Access 100 series cellular phones, a greatly improved technology advance over 1992's 1500MOB phones. The multiprotocol *Mobile*Access phones have an extra cost PC/PalmPilot connection kit.[20] It provides a 34-in. cable and supporting software for Windows-based PCs, Palm III, PalmPilot Professional, and IBM WorkPads. The phone thus can act as a radio modem for connecting the data device to a variety of wireless (no wireline) options.

16.4.2.3   *Annoying Residual Problems*   The current smartphone offerings are exclusively loved by zealots. Their voice clarity is only fair.[21] The display screen, at 4×12 (really only 3×12 for received messages) characters, is incredibly limited. Entering data makes one want to throw the instrument on the ground. Example: to enter the name DeRose (Nokia/Tegic T9 software is unlikely to find that name in a linguistic database) requires 18 key depressions and 6 pauses:

Number of Keystrokes	Sequence
1	D (pause)
3	Softkey, D, E (pause)
4	Softkey, P, Q, R (pause)
4	Softkey, M, N, O (pause)
4	P, Q, R, S (pause)
2	D, E (pause)

Do not bother to attempt numbers. If you want to respond to the simple query "what time shall we meet?" with the four-character reply 2:30, one practical keypad sequence is

> 2, 2, 2, 2, pause, softkey, softkey, 0, 0, 0, 0, 0, 0, 0, 0, pause, softkey, 3, 0, softkey
> for another 18 depressions and 2 pauses.

Tethered data devices, especially PCs, eliminate this human data entry problem, but it is particularly difficult to juggle two boxes, linked by a yard of cable, on a city street.

Battery life is also found wanting. With the standard battery (when brand new), one can only get an hour's "talk" time; standby time is 9 hours. As shown in Figure 16-3, if the phone is on standby for, say, 3 hours, the usable time drops to 40 minutes. The message: Always carry a spare battery and keep those chargers working every night.

There are also qualitative problems with smartphones when using CDPD (at least BAM's version, Cellscape). Successful message transmission often takes 2–3 *minutes* of fussing: much sending)))), network not responding, retry, sending)))))), gateway not responding, and so on.

Once or twice I decided to torment a BAM Cellscape phone by sending a "long" (500-octet!) message to it from another device. With BAM's network settings only about half the CDPD message is delivered initially. To see the balance, one must hit "MORE," which results in the hateful sending))))) sequences. If a really long message (say 1500 bytes) is attempted in a difficult area (Grand Central Station's main
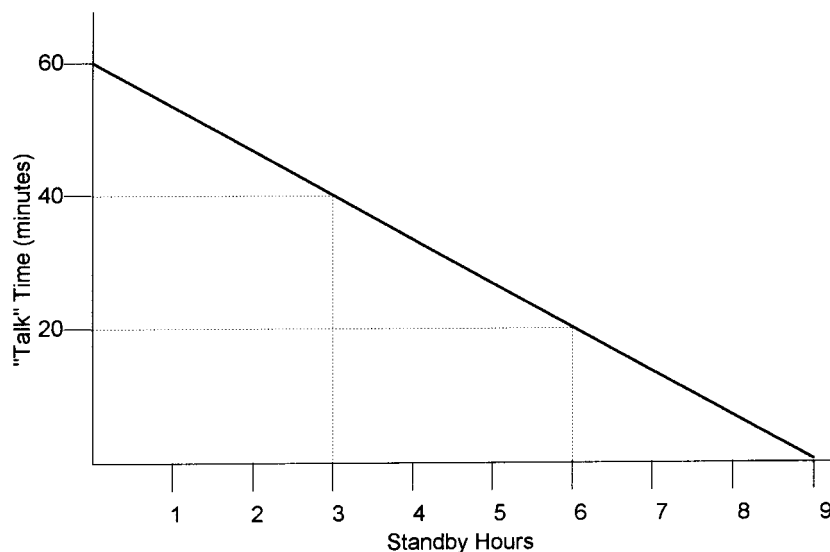
Figure 16-3   "Talk" vs. standby time trade-off: PocketNet phones.

concourse is such a spot), you might as well buy a sandwich while you wait to read your mail.

It is also extremely tedious to delete a received message: READ, ACT, sending))))), DELETE, sending))))), OK, sending))))), message deleted, OK, sending))))). Any one of the sending))))) sequences are vulnerable to "network/gateway not responding" responses, forcing a retry. After a while I simply gave up deleting messages and then gave up the phone.

16.4.3   Data Devices Swallow the Radio

Data-centric devices containing the radio transceiver fall into three categories:

1. External radio modems for connection to the serial input–output (I/O) port of the terminal or PC.
2. PC Card radio modems for laptops, PDAs, and custom devices. Except in high-transmit-power applications, the PC Card radio modems have largely driven out their external predecessors.
3. Integrated units hidden under the covers of laptops or custom products. These are becoming increasingly popular in high-production-run, application-specific devices.

An advantage often claimed for CDPD over competing alternatives is that there are many multivendor radio modems to choose from.[22] In truth, with the demise of Cincinnati Microwave and PCSI, the steady withdrawal of Coded Communications, Ericsson, IBM, and Motorola (for CDPD, for now), and the increasing marginalization of suppliers such as Uniden, the total number of radio modem suppliers for all carriers is remarkably small. It is likely that six to eight manufacturers account for 95% of all shipments to date. Of these, just seven vendors, four of them Canadian, dominate all current, in production, alternatives:

1. *Dataradio*: Has augmented its private radio offerings with its purchase of the Motorola R-net line in February 1998.[23]
2. *Megahertz*: Provides PC Card radio modems for BSWD.
3. *Metricom*: Manufactures a line of external modems for cable connection to hand-held and notebook PC devices. The modems are designed in Richmond, British Columbia, by ax-Motorola (MDI) engineers.
4. *Motorola*: The only U.S. vendor, it offers a full line of radio modems—external, PC Card, other equipment manufacturer (OEM) modules—for RD-LAP/MDC4800 (ARDIS) and Mobitex (BSWD).
5. *NovAtel*: Concentrates on small external devices and OEM modules for CDPD.
6. *RIM*: Specializes in integrated solutions, from OEM modules to custom products, for ARDIS and BSWD.

7. *Sierra Wireless*: Offers a line at least as rich as Motorola's, but for CDPD and its circuit switched cellular variants.

Motorola has been slowly withdrawing from the modem market. Consumer modems were first to go,[24] in the fourth quarter of 1997. CDPD PC Card radio modems followed in the first quarter of 1998. No enhancements to the current DataTAC offerings appear to be in the works. A logical candidate to fill this product gap would be Sierra Wireless, whose employees are largely ex-Motorola (via MDI) and understand Motorola protocols very well. Thus, the number of qualified North American radio modem vendors for most public packet networks could easily shrink to three or four.

Representative examples of the solutions available during the fourth quarter of 1998 follow.

16.4.3.1   *External Radio Modems* From 1990 to 1994 the mainstream packet switched thrust was external data modems with their own internally packaged radio. For hand-held devices/PCs, this category was dominated by Ericsson's Mobidem and Motorola's InfoTAC. Radio characteristics aside, there were sharp functional differences between these two units. The InfoTAC was a sort of pseudoterminal, with functions such as message memory, display, and keys that permitted it to run without a driving device.

Competition slowly drove the hand-held 1990 $2500 price levels downward, reaching end-of-life fire sale levels of ~$350 in 1994. At the beginning of that year small quantities of external CDPD radio modems began to ship. A successful unit, the Sierra Wireless PocketPlus was initially priced at ~$1200. This sharp price differential between CDPD and ARDIS/BSWD alternatives persists, even in new technology descendants.

The PocketPlus was phased out in 1996 with the coming of the AirCard, seemingly the last one would hear of external modems for PCs. But in September 1998 NovAtel shipped[25] a PocketPlus look-alike, the Sage, for $400. This apparent technological throwback has some advantages: It is well priced, it has its own battery to relieve some of the parasitic drain on the host PC, and it is relatively heat insensitive. PC Cards, inside the confines of relatively warm high-speed PCs, often do not perform well in high-duty-cycle environments such as CDPD.

In early 1994 the first CDPD modem expressly designed for short-message telemetry such as vending machines was shipped by Cincinnati Microwave. This half-duplex unit was priced at $500 and prospects seemed bright since BIS Strategic Decisions forecasted that "the industry will ship . . . 200,000 to 500,000 CDPD modems in 1994."[26] In May 1997 Sierra Wireless acquired the now bankrupt Cincinnati Microwave modem product line[27] and has kept the Dart 200 alive.

In the harsh duty vehicular category Motorola initially offered the MRM420 during 1990; it was later replaced by the MRM660. This modem is essentially for BSWD,

since it does not offer both ARDIS protocols, only RD-LAP. Neither modem has been a major factor in U.S. device sales. During these years Gandalf also fielded a useful competitor for the private taxi market. In late 1995 Sierra Wireless introduced its MP200 unit for CDPD systems. This rugged unit was incrementally extended in 1997 to house an integral GPS. In April 1996 the initial version was installed in 38 patrol cars in West Jordan, Utah.[28] In June 1998 the CS-CDPD version began pilot testing with the Indiana State Police on GTE's network.[29]

A representative list of operational external modems still found using the three leading packet networks is provided in Table 16-1. Note that many of these devices are no longer in production.

16.4.3.2   PC Card Radio Modems   Motorola was the first vendor to deliver a radio modem within the physical constraints of PCMCIA Release 2.0 format. It did this by combining digital signal processor (DSP) and random-access memory/read-only memory (RAM/ROM) on a single chip, replacing filters, clippers, and detectors with ZIF logic and relaxing some functions; notably:

1. Transmit power (from 3 watts to ~1.5 watts)
2. Going to commercial temperature specs (0–50° C) from industrial

Table 16-1   External modems in use on leading packet networks

ARDIS	BSWD	CDPD
Handheld/Notebook Devices		
E. Com Pdxpress	Ericsson Mobidem 1090;	NovAtel Minstrel
Motorola InfoTAC	Motorola InfoTAC	NovAtel Sage
SCS DataPac		Sierra Wireless PocketPlus
Telemetry		
ABB Alpha electric meter		AirLink Communications Raven
Detection Systems PMM-1		Sierra Wireless Dart 200
Transdata Mark V electric meter		Uniden Data 1000
Vehicular		
Motorola MRM 420	Motrola MRM 660	AirLink Communications PinPoint
Rockwell Pro 2000-SL		Sierra Wireless MP200 family

3. Simplifying the data terminal equipment (DTE) interface

4. Lowering the selectivity (from 60 to 50 dB)

5. Lowering the intermodulation (from 60 to 55 dB)

Motorola had read all the PCMCIA projections and believed that ~10 million PCMCIA enabled laptops would exist by 1996. Thus, PCMCIA was the target form factor.

The engineering task was formidable. Since the transmit power was to be reduced, the antenna had to be external to gain enough effective radiated power (ERP) for ARDIS. But the antenna had to be protected from radiation emanating from the host PC, and the modem's radiation must not harm the host. Shielding agreements with laptop manufacturers had to be worked out. Some laptops with PCMCIA slots in front cannot use the radio modem (besides, who wants to think about what that little guy is doing radiating into your face?).

Electrical current demands were attacked. The likely current drains equated to a tough battery budget for laptops; the unit would have to have its own external battery and rudimentary indicators. Thus was born the notion of the "tootsie roll" extension to the PCMCIA card.

In usual Motorola fashion, hardware "piece-parts" were deployed ahead of the PCMCIA schedule in environments that Motorola controlled. The MicroTAC RSVP cellular phone/pager was announced in September 1993 for first quarter 1994 availability. Envoy also used a custom design: digital circuitry, custom integrated circuits (ICs), and a different main processing unit (MPU) architecture instead of a general-purpose DSP.

On June 15, 1993, Motorola announced[30] its major new thrust for packet switched radio modems: a series of PCMCIA type II cards, each having an embedded radio. The key strategic elements were:

1. One-way WAN: EMBARC, MobilComm, SkyTel

2. Two-way WAN: ARDIS, RAM, CDPD

3. LAN extensions: 1-Mbps, 2.4-GHz spread spectrum

Function blurring exists in the packet switched units, as in InfoTAC, in that the cards contain 128 kbytes of time-stamped message memory that can operate independently from the host laptop. The first of the packet switched units was to ship "middle to late 1994 for . . . ARDIS and RAM."[31] More confidence: "(Motorola's PCMCIA) CDPD radio modem is on track for introduction in 4Q94."[32] But Motorola radio modem developments had a history of not meeting their schedules. Initial InfoTACs were plagued by roaming bugs, some flushed by RadioMail. The dual-protocol version was 2 1/2 *years* late.

The Motorola PC Card radio modem was also late. Ericsson beat Motorola to market,[33] with a type 3 card in November 1994. Ericsson's technical achievement was less than Motorola's, in form factor and protocol simplicity, and it drew its power

parasitically from the host PC, but BSWD had a "workable" unit (actually, the M2190 had several bugs[34]).

In April 1995 IBM's radio-on-a-rope (Wrigley) dual-protocol PC Card modems for ARDIS also arrived[35] before Motorola; the circuit switched/CDPD multiprotocol followed in June. Motorola beta testers began using Eagle in July; I began using one of the first commercially available Motorola dual-protocol (ARDIS) PC Card modems in December 1995.

In spite of the bitter lessons of the InfoTAC, the Motorola PC Card modems did not initially have a battery-saving protocol. The anticipated battery life[36] using rechargeable NiCad was 1 1/2 hours. This was later greatly improved, requiring a factory microcode load, but until the day I gave up the PM100D in June 1998 I remained ever mindful of battery life constraints.

Other PC Card alternatives have been announced, and some have shipped, including Megahertz's type 2 unit for BSWD (actually built by RIM with its own custom chip set and radio.[37] NovaLINK's multiprotocol unit (chip set by Rockwell) and radio (designed by Northrop Grumman) was announced with great fanfare and technical promises. It never shipped.

The first CDPD type II PC Card was Motorola's PM100C, since withdrawn because of poor sales. In 1997 Sierra Wireless released its AirCard, which it somewhat ingenuously claimed "can fit into any laptop computer with Type II PC Card slots."[38] The pluralization of "slots" is an important distinction. The original AirCard required two of them. It was also relatively expensive, with a street price of ~$900. Even with carrier subsidies, as in BAM's AirBridge Internet Access plan,[39] the price was $700. In October 1998 Sierra announced its AirCard CE, "a true type 2 PC Card package."[40]

Uniden has long promised a PC Card radio modem for CDPD. At this writing (October 1998) it had not yet shipped, and little is known about its technical characteristics or price.

A representative sample of current PC Card offerings is contained in Table 16-2.

16.4.3.3   Under-the-Cover Solutions

Surprisingly, integrated radio modems appeared early in packet switched devices. One was at the core of Motorola's KDT800 (1983). This smaller-than-a-cigarette pack unit contained tightly packaged discretes, not very large scale integrated (VLSI) circuits, and had a crystal cut oscillator (single-channel operation) but no synthesizer. Still, it fit beneath the covers of a very small hand-held unit, transmitted at 4 watts, and had a useful battery life. Most of the device integration problems were first tackled there, including under-the-covers dual-diversity receive antennas.

16.4.3.3.1   OEM Radio Modems

Well before the InfoTAC was announced Motorola was at work on miniaturizing both modem and radio. The general approach was to move from discrete components (KDT) to VLSI (840C) to DSP (400i/405i), and ultimately to ASIC. The units were designed specifically for OEM integration in Motorola and other vendor devices.

Table 16-2   Representative PC Card Modems/Devices

ARDIS	BSWD	CDPD
PC Card Radio Modems		
Motorola PM100D	3Com Megahertz AllPoints	Sierra Wireless AirCards
		Uniden Data 2000 (4Q98)
Representative Devices Using PC Card Radio Modems		
e.com Pdxpress		3Com PalmPilot
Enbloc R/F PalmStation		Fujitsu Stylistic 1000
Hewlett Packard:		Hewlett Packard WinCE
100/200LX		IBM Thinkpad
300/320LX		
Palmtop PC		
IBM Thinkpad		
NEC MobilePro H/PC		
Panasonic CF27 Toughbook		
Psion HC R800		
Sharp Zaurus ZR-5800/FX		

The 400i (July 1991) was first. Its logic section alone consumed 93.5 cubic centimeters, just small enough for vendors to embrace in such ill-fated products as the IBM PCRadio,[41] Lectogram,[42] and Telxon PTC860.[43]

The much smaller, but two-part, RPM405i (December 1991) was next. Announcement of this 3-watt unit occurred after PCMCIA (PC Card) "standardization." The 405i was OEM priced for vendor integration at $500–1000, depending upon quantities.[44] At 10,000 units the price was $800.[45] It was quickly adopted by Psion PLC's HC4[46] and Toshiba's 486-based laptops[47] and was initially released on ARDIS in the PT220.[48] It became the core of the InfoTAC, the only real volume success, and the MRM420 19,200-bps modems. The 900-MHz version, the 435i, is used on BSWD and found in such units as the Itronix T5000 PC, EX-C 6000, and Telxon PTC-1144.[49]

The 405i made three important contributions:

1. It was broadly adaptable to multiple protocols (MMP, MDC, RD-LAP, Mobitex), transmission speeds (4800, 8000, 9600, 19200 bps), frequencies (403–946 MHz), channel spacings (12.5–25 kHz), and modulation types (FSK, bipolar FSK, 4-level FSK, GMSK).

2. The 256K flash PROM permitted the modem to be upgraded to incorporate new features and protocols without removing the modem or changing the software.

3. The digital signal processor (56156) eliminated much analog circuitry and reduced current drain by about one-third.

In 1995 Ericsson released the M2190 module, the first to fit PC Card type III physical constraints. It was adopted for use by Melard in the Scout, Norand in its 6x00 series devices, and Symbol in its PPT unit.

Nearly simultaneously RIM developed two OEM radio modems for ARDIS and BSWD protocols. The first effort to gain significant press attention was the Megahertz AllPoints modem for BSWD, priced at less than $500. The RIM OEM units are very competitive to the Motorola 4x5 series and have found their way into a number of devices operating on both ARDIS and BSWD.

Another OEM device was developed in 1996 by Sierra Wireless for CDPD use. The SB220 is noticeably larger than the RIM unit. It is also a heavy current user, which Sierra masks in its puff brochures. They do not cite current requirements by voltage level for transmit, receive, standby, and sleep modes. Instead, they cite an average power consumption of 0.24 watt with a footnote saying "24,000 bytes and 255 seconds."

Here is what I make of the footnote. The 24,000 bytes is presumed to be transmit time. At an idealized CDPD user bit rate of 12,800 bps it would take exactly 15 seconds to transmit this information. The 255 seconds is presumed to be receive/standby time. Combined, this equals 270 seconds, exactly 4.5 minutes. This combined $\frac{3}{10}$ of 1% duty cycle is unusually, unrealistically low. It certainly makes no sense in a "wireless IP" environment. Depending upon how one allocates sleep time, the RIM unit may consume only one-third the wattage of the SB220.

Later the same year Motorola announced its 500 series, which could be its last. At 48 cubic centimeters it fits the PC Card type III dimensions. The 500 series draws far less power than its predecessor and has a clearly defined sleep mode. However, its transmit power is down to 1 watt, and its receiver sensitivity is –108 dB—openings for a competitor like RIM to exploit.

In 1997 NovAtel released its OEM radio modem, the NRM6812. There is little technical excitement in this unit. It is large, although published discrepancies in its metric/U.S. dimensions make it difficult to say exactly how big the unit is. It is also a heavy power user and limited solely to the CDPD protocol. But it is cheap, reportedly priced at ~$100 in quantity for the Otis Elevator penthouse modem, where size and power consumption are not material.

Table 16-3 is a comparison of key characteristics of the OEM radio modems extant in 1998, listed in availability sequence.

16.4.3.3.2   Devices with Integrated Radio Modems   In 1992 Motorola began to deliver cellular radio modems to UPS. They were integrated into special-purpose data-only devices called DIADs (delivery information and acquisition devices) that accompanied the brown-truck drivers on their rounds. At periodic intervals, typically every 20 minutes, the DIAD would make a dial call from its power cradle in the truck, dumping the contents of its buffers, which contained everything from delivery time to captured "signatures." In time 70,000 units were shipped.

Two years later IBM, and its then-partner PCSI. integrated a radio modem inside the IBM ThinkPAD series 750 laptop. The space normally reserved for a diskette drive

Table 16-3   Representative OEM radio modems

Modem	Protocols Supported	Output Power (W)	Dimension (mm)	Voltages	Current Draw × Voltage (W)				Receive Sensitivity (dBm)
					Transmit	Receive	Standby	Sleep	
Motorola 4x5i	MDC4800 RD-LAP Mobitex	3	81.8 × 64.4 × 6.5 + 84 × 67 × 12	7.2, 5	1.8A × 7.2 90 ma × 5	45 ma × 7.2 80 ma × 5	11 ma × 5	Not given	–114
Ericsson 2190	Mobitex	2	85.6 × 54 × 10.5	5	800 ma × 5	80 ma × 5	80 ma × 5	Off	–113
RIM x00 Series	MDC4800 RD-LAP Mobitex	2	87.5 × 65 × 9.5	7.2	900 ma × 7.2	70 ma × 7.2	70 ma × 7.2	12 ma × 7.2	–113
Sierra Wireless SB220	CDPD V.32bis ETC facsimile	0.6	158.75 × 61 × 11	7, 5	0.24 W for 24,000 bytes/day and 255 seconds				Not given
Motorola 500 Series	MDC4800 RD-LAP	1	86.6 × 54 × 10.5	7.2, 5, 3.3	645 ma avg.	60 ma avg.	Not given	9.6 ma avg	–108
NovAtel NRM-6812	CDPD	0.6	120 × 50 × 12 (estimated)	5	850 ma × 5	350 ma × 5	200 ma × 5	20 ma × 5	Not given

was sacrificed to make room for a multiprotocol—which specifically included CDPD—radio modem. There were two antennas (antennae are for bugs), one hidden beneath a modified cover for the display.

The radio worked the 800-MHz band and could be used for voice calls with the insertion of an optional handset. Later versions used a "gummy bear" headset that doubled as a microphone picking up voice signals from the user's skull. The major emphasis, however. remained data/fax. This radio modem, and its PCSI Ubiquity 1000 counterpart, was not successful. The sacrifice of the only diskette drive often could not be tolerated; the radio modem added to the battery drain of the already short-legged ThinkPAD (especially the color versions); the microcode load times at each power-on were long; the price was very high—and PC Card radio modems were coming. Integration simply did not make sense here.

Starting in 1995, the demands of the two-way paging market created many interesting integrated devices. For SkyTel there was the Motorola Tango (unsuccessful), then the PageWriter (doing well). In 1997 RIM released versions of its I@P for use on both ARDIS and BSWD. In August 1998 BSWD announced the I@P950.[50] One month later ARDIS revealed that it would follow suit.[51]

During the second half of 1998 Motorola began to deliver the new DIAD-III to UPS for use on ARDIS. There were the usual schedule glitches; about 5000 units are expected to be installed by the first quarter of 1999. A sharp roll-out is projected during the balance of that year as the new packet units displace the circuit cellular predecessors.

Very quietly a new modem provider has arrived on the scene. In 1993 Federal Express began testing CDPD on 15 vans in Las Vegas. There were enough problems to cause FedEx to search for a replacement private radio system. In 1995 FedEx contracted with MPR Teltech, which was now staffed by the ex-MDI personnel who had designed their first system. A sort-of-CDPD system resulted: The upper layers of the protocol were preserved so that conventional base stations were usable. The lower layers were modified for private land mobile, for example, HDX and 25-khz wide channels.

In a complex series of business moves, MPR Teltech was broken into business units. The one handling the FedEx design was sold to MA/COM. Retix, a supplier of CDPD infrastructure, was renamed Vertel and also sold to MA/COM. MA/COM then purchased Cray's unused gallium arsenide (GaAs) chip facilities. MA/COM itself was purchased by AMP.

Using these carefully assembled resources, a "software radio" was built in GaAs for FedEx. By changing microcode, one can change protocols and modulation techniques. By November 1998 AMP had shipped 10,000 of these integrated devices, with the intent to surpass total CDPD shipments by 1999 with 40,000 devices. Naturally, these devices will work with 150–200 Vertel MD-IS units. When the FedEx contract is complete, one can reasonably expect AMP to come looking for other uses for its software radio.

Integrated units hidden under the covers of custom products are becoming increasingly popular in high-production-run, application-specific devices. Table 16-4

Table 16-4   Representative devices with integrated radio modems

Service Name	ARDIS	BSWD	CDPD	SkyTel2
Hand-held devices with internal radio modems	E.Com Discovery Group Technologies: Badger GT486N, P2 Hypercom POS terminal Intellect POS terminal Itronix: T3500, T5000/EFP, X-C 6000 Melard: Ranger, Scout Motorola DIAD-III (UPS) Norand 6100/6300 Panasonic CF-25 Symbol Technologies portable Teklogix TKX-3000 Telxon: PTC-1140/1144, PTC-1124/34/94 XL Computing PCMobile Novatel C-O-N-T-A-C-T	Granite VP4i Itronix: T5000EFP, X-C 6000 Melard Scout Microslate Datellite 400L Norand PEN*KEY Panasonic RIM MPT Symbol PPT 4600 Telxon PTC-1144 WLI Acknowledger		Motorola PageWriter 2000 Wireless Access AccessLink
Integrated pagers	RIM Inter@ctive Pager 800	RIM Inter@ctive Pager 900 RIM I@P950	—	
Vehicular devices with integrated radio modem	GeoFocus TrainTrac Group Tech. CSX Badger Mobile Integ. Tech. MT500 OnBoard Computing Mobil Rockwell Pro2000-SL Symbol Mobile Gateway Telxon 870-IM (Avis)	Mobile Tracker MT500	Nikean X-1	
Miscellaneous		Lipman Nurit 2070 (POS)		

lists representative examples of devices in use on public networks during the fourth quarter of 1998.

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17

CONNECTIVITY

17.1   INTRODUCTION

Cut the cord. *Right now*. Unfortunately, simply buying wireless data devices is the least of the problems, especially on packet networks. Actually getting applications to execute over wireless communications links leads to dozens of developmental barriers. Hardware, software—even airtime service providers—deliver some application assistance with their products, but the range of offerings, while clearly related, is far from uniform and is never enough. Further, the terminology is often blurred. One company's toolkit is another's middleware or operating environment or platform.

Packet systems are the least uniform and most complex. Examples of the enormous range of products follow, in increasing degrees of complexity, beginning with the client modem and working through servers and gateways to the host application.

17.2   DEFINING THE PROBLEM

17.2.1   Origins

In 1982 IBM began to convert its existing field service application programs to operate over its private DCS system. The software changes were deep and insidious. At the host, system programmers were forced to stay one level behind the current virtual telecommunications access method (VTAM) release. The addressing structure for 32,000 mobile devices (the initial design) was unlike anything that had yet been

seen; a variation of IBM's System Network Architecture's (SNA's), LU-0, was used. This was nonstandard and very primitive.

New error/alert conditions had to be accommodated. Notification codes for base station problems had to be developed and inserted in the network management software. When repair personnel were dispatched to a base station site, sometimes on a mountain top, the system had to respond to the cabinet doors being opened, a sign that the repair person had likely arrived.

Application development in both client (device) and server (S/370 host) was intimately interlocked and very radio aware. For example, the application approach was first to "page" for a field service representative. The modem had been designed *not* to acknowledge this page. The fear was that an uncontrolled ACK would transmit 4 watts of energy into the field engineer's (FE's) surroundings, which might be the interior of an innocent customer's mainframe. Instead, upon receiving the page, the FE was expected to put an appropriate distance between device and customer equipment and respond with an "I am here" message. The application code in the device then began a "time slice"—a period of 30–45 seconds in which all further traffic could be automatically acknowledged. Only then would the contents of the dispatch message be sent to the FE.

The client code was so intimately intertwined with the Motorola radio modem supervisor—and often locked in ROM, not dynamic memory—that a simpler IBM read/write interface was developed for the application programmers. This was the first stirring of independent thought. If the application code were written to the IBM interface, theoretically that interface could be changed underneath to run on a different type of infrastructure.

Further, the nature of how the information itself was processed had to be changed. IBM service personnel could actually connect to the internal VNET PROFS systems. This full-screen system was uncommonly hard to read on very small devices but harder still to accommodate on the network. In a slow-speed system that worried about every character transmitted, the tendency of 3270-class applications to blast back with 2000 character responses was devastating. Could a gateway be constructed to permit application operation in a wireless world and dampen this unwanted traffic?

17.2.2   Connectivity Goals

Most wireless data application developers, from SMR to satellite, have two secondary objectives:

1. To protect their application development from the vagaries of the underlying wireless transport technologies.
2. To achieve network independence. Many customers are actually willing to throw out existing applications, or make major changes to them, if it is the last time they have to endure such trials.

There is sometimes a third, derivative goal. The user might be happy with its wide-area wireless carrier but wants the same application code to work when the

mobile user is out of that carrier's reach or has returned to the office—perhaps to operate on a LAN.

While many techniques have been tried to achieve these goals, there are two principal thrusts. The programmer can use one of the following approaches:

1. Write a new wireless application to an application interface (API) that supports multiple networks. Then, in theory, the task of moving from one network to another boils down to picking the correct modem and device drivers.

2. Use an (often existing) application that is compatible with TCP/IP. Gateways are then installed to translate the TCP/IP data into another network format. These are usually referred to as *wireless-enabled* applications.

Both approaches have adherents, and both are becoming ever more interesting. But each approach also has drawbacks. The new application/multinetwork approach was often offered up by vendors who kept the API proprietary (e.g., Racotek, Oracle Mobile Agents), charged dearly for it and sometimes were financially unstable. The IP approach brings with it all the overhead baggage and inefficiency of TCP/IP, which means the application really may not be suitable for wireless networks.

The developer must honestly answer a few basic questions before settling on the TCP/IP approach. Common questions include:

1. *Is it cost effective*? In spite of some all-you-can-eat carrier pricing plans, be wary if the application consists of large-file or image transfers, often innocently generated by Web searches. If the carrier of choice is not present everywhere, large data transfers can be punitive. What is perfectly acceptable on BAM CDPD in New York City may well be economically intolerable on ARDIS Atlanta.

2. *Will the response time be acceptable*? It easy to forget that a narrow-band channel being shared by many users will sometimes not be fast enough for an application, especially one that streams copious data. Further, data compression techniques may not be in place or will yield no real improvement for some classes of information.

3. *Is the application robust enough for the wireless environment*? How does it deal with abnormal terminations, which are sure to arise in a wireless environment? What happens when the user wanders out of coverage? CS-CDPD is an example of a partial fix to this problem, but it is hardly bulletproof.

4. *Do you really have the necessary security*? Using the Internet to connect client and server may well be a weak link.

Given that the correct decision has been made—an all new wireless application versus exploitation of an existing wireless-enabled application—the job is not over. In the words of META Group's Bruce Robertson[1]: "Don't assume that connectivity equates to successful application implementation. Middleware can't fix applications,

it can only help them. Applications have to work efficiently, too. They must become network aware."

17.3   SUPPORTING SOFTWARE

17.3.1   Radio Modems

No wireless radio modem ships without supporting software. This code can be elemental: hooks for the application programmer to determine the radio coverage the modem is encountering. It can also be reasonably rich: E-mail packages are quite common.

17.3.1.1   Single-Network Implementations   An example of a widely used OEM modem type is the RIM x00. Separate models exist for ARDIS and BSWD. The RIM 800 is useless for Mobitex; the RIM 900 cannot be used with MDC or RD-LAP protocols. But the simple connectivity software accompanying them at least presents a common interface for the application programmer, even if the device is quite rudimentary.

The RIM 900 ships with one airtime protocol and two APIs in place. The first API, MASC, pulls the levers on the Mobitex protocol, which is little known to most client application developers. It is memory hungry, requiring 10–50 kbytes in the device for proper implementation. If the application is tailored to MASC, then it must be changed if it is to be used with a RIM 800 unit.

The developer can instead choose to use RIM's radio access protocol (RAP) application interface, the over-the-air protocol remains Mobitex. RAP is light on memory consumption, demanding only 1–3 kbytes, a significant advantage in very low cost devices. RIM claims[2] that "using RAP, companies with no previous Mobitex experience normally require just 3–10 days to complete a fully operational wireless interface." An application written to the RAP interface will work on the counterpart in the RIM 800, offering some freedom for the device to operate on two separate networks: ARDIS and BSWD.

Figure 17-1 is a representation of the relationship between the two modems, which are very different animals. The RAP connection is emphasized; if one wants to preserve most application code for network flexibility, the programmer writing for ARDIS would avoid the native control language (NCL) interface in the RIM 800.

The RIM modems also offer software "hooks" that permit the application programmer to extract supplementary data: modem serial number, device ID (ARDIS), MAN (BSWD), RSSI level, battery strength, diagnostic information, and key network parameters. If one picks up the I@P—hardly a Windows-based PC—the value of this type of information is very clear. Depress setup on the keyboard, then F3 (radio). A display of the form shown below is offered:
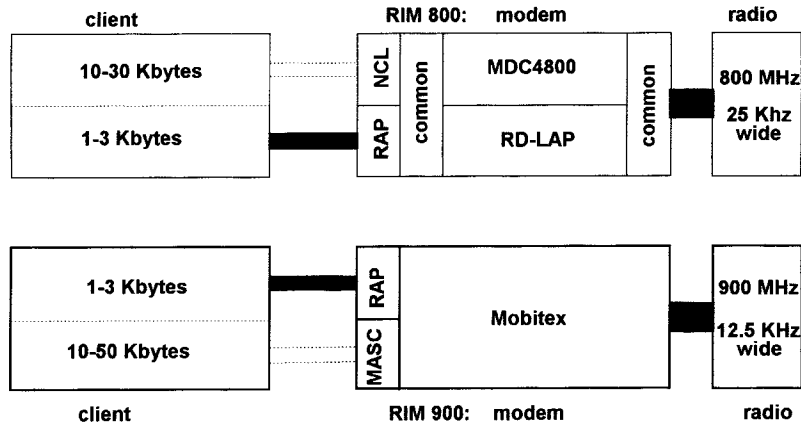
Figure 17-1   RAP interface in RIM X00 radio modems.

Radio mode	On
Transmitter	Enabled
LLI	880009e5
ESN	128/04/001587

Some of these parameters may be changed by the user. The radio can be turned off, for example, when one is in an airplane composing messages without any hope (or desire) to transmit. If one now enters the word "debug" on the keyboard, supplemental information appears:

Transmitter	Enabled
RSSI	−92 dBm
Area: 2D	Base: 15

this is often of great value to the user in areas of spotty coverage. An application programmer simply cannot get at this information without help.

17.3.1.2   Multiple-Network Implementations The software supporting modems that span multiple networks is considerably more complex. In general, it means the client is Windows based and requires access to the full capability of a PC: graphical color display, good processing power, file storage, and file retrieval.

To illustrate this point, consider the extensive software delivered with a Sierra Wireless AirCard. This unit is designed to work on wireline systems. The V.34 modem section can send and receive both data (33.6 kbps) and facsimile (14.4 kbps). With normal tweaking, it also operates over circuit switched cellular. There is some support of voice telephony options in both modes. The principal target, however, is data via CDPD.

Sierra Wireless ships multiple diskettes along with its AirCard. The user must use Windows 95/98 or NT 4.0 since the Sierra Watcher/Wireless Expert programs are 32-bit implementations. The intent of this utility software is to be "plug and play." This is a fair description as long as certain preconditions are met. For example, the AirCard cannot be enabled for cellular unless specific PC Card controller software is present. The native Windows NT 4.0 driver will not do the job. If you do not have the right controller software, you must obtain it from Award Software or Softex (to name two).

When all conditions are go, Windows does indeed recognize the presence of the AirCard and installation can begin. Since wireline must be supported, all the usual AT/DT stuff, as well as advanced modem configuration features, must take place during this phase. Drivers are loaded, stacks set up, hooks established for Watcher to report on the status of the connection. An attractive but faintly intimidating graphic screen shows the connection status. The screen has expanded well beyond the modem mode, registration, battery level, signal strength, and radio channel number of the original PocketPlus modem. Now one is awash in channel event logs and modem object (MOB) tables. Sierra "provides all of the tools necessary to start developing applications."[3] Whew!

Both the circuit switched cellular and CDPD installations introduce the application programmer to the whole world of special UDP and TCP/IP stacks. The TCP/IP stack of choice is one developed by Walker, Richer, and Quinn (WRQ). WRQ's Reflection SmartStack began to tackle TCP/IP problems that first appeared on dropped cellular connections. Scripts were written, and decision logic was employed to choose the right reconnection script for the incident. Along the way, WRQ streamlined the stack operation to cut down overhead and improve performance. The comparative approach is shown in Figure 17-2.[4]

That is, in WRQ's approach the application and the stack are isolated from dialing/sending. If a datagram is ready, the script dials or registers. The stack checks to see if the link is OK. Datagrams are sent continuously. If the connection is broken, the script is invoked and the connection is remade, permitting the data transfer to continue. In conventional stacks, the loss of a link causes the application to abort. The stack is then shut down and the entire process must begin anew. There is no credit for datagrams that passed before the trouble was encountered.

WRQ also reduces the frequency of ACKS, not sending one for each datagram if wireless conditions are good. With progressive acknowledgments and synchronized retransmissions, WRQ claims to chop 20% of the overhead from a typical TCP/IP transaction.

The TCP/IP overhead problem plagues everyone. One solution to minimize communications overhead is by using UDP. UDP is not as reliable as TCP, lacking the ability to ensure datagram arrival and to correct for sequencing errors. But some application programmers are willing to obtain reduced overhead by direct management of the task. When vendors like WRQ balked at a UDP stack, Sierra Wireless created its own and shipped it with its modems.

The Sierra UDP operates in CDPD mode and is controlled through AT commands. The stack performs packet assembly/disassembly (PAD) of data to and from CDPD
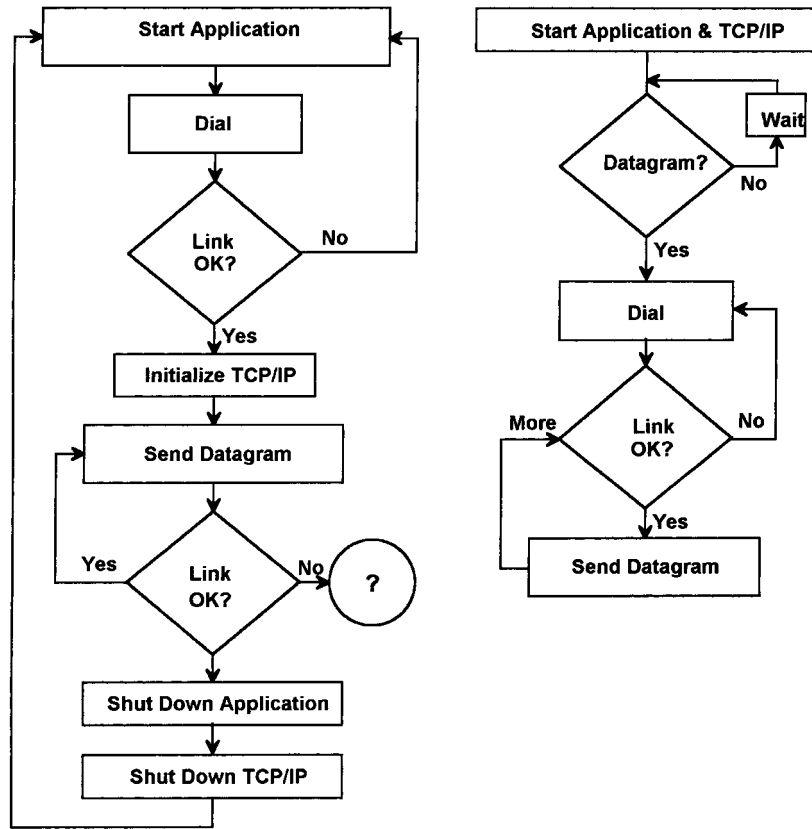
Figure 17-2   Traditional TCP/IP vs. SmartStack implementation.

packets. Sierra aims its UDP stack at specific unbalanced applications having light inbound traffic compared to outbound. Examples include point-of-sale, telemetry, positioning, and inquiry/response database actions. The maximum inbound packet length is 128 octets; the outbound maximum is 2000 octets.

The market for UDP is one in which one packet is the entire message, preferably one in which the risk of loss is small. The usual escape clause applies: "If the developer is concerned about packet loss, then the application can be designed to ensure delivery."[5]

17.3.2   Exploiting Gateways

In the late 1980s IBM Europe's Field Service operation confronted a double challenge. They wanted to:

1. Exploit the capability of the oncoming laptops to give their technicians a common, rich set of applications beyond dispatch and parts order entry, and do it with full-screen displays.

2. Utilize multiple networks in many countries, but manage the host application from a single central site.

A sense of the network variety can be gleaned from this sample:

1. IBM Deutschland: DataTAC/Modacom (Motorola Infrastructure)

2. IBM UK: Mobitex (Ericsson Infrastructure)

3. IBM France: GSM

4. Mediterranean Basin: InMarSat

All service technicians use the same application package, which operates with a variety of modems optimized for the specific network.

A mainstream philosophy of the time was expressed by middleware provider Aironet, who counted on redesign to suppress wireless traffic: "an application . . . needs to be designed . . . (to) eliminate all unnecessary packets. . . . Wireless applications need to rethink what is being sent over the airwaves."[6]

IBM Europe, and its then-named ARTour, took exactly the opposite philosophy. IBM had an application base already designed for TCP/IP operation. The investment in these applications was preserved and gateways (OS/2 or AIX based) installed between the application hosts and the different wireless networks, as shown in Figure 17-3.

It is clear from the figure that ARTour was not a trivial undertaking. Not only were existing applications protected, but also the amount of data transmitted on the radio networks was greatly reduced. ARTour first attacked the header problem with a Van-Jacobsen algorithm that "reduces the 40 byte header to a minimum of 7 bytes."[7] It then applied one of three data compression algorithms, depending upon the length of the message (V.42*bis* gives best results for packet sizes less than 300 bytes), Finally, for 3270/5250 class applications it used a terminal emulator to "keep the static portions of the screens in memory and exchange only screen updates. . . . A host screen of approximately 2000 bytes can often be reduced to less than 100 bytes (including . . . compression)."[8]

ARTour was renamed IBM eNetwork Web Express (how is that for tripping lightly off the tongue). It had some modest successes in 1997, including Bossier City, LA Police.[9] License prices were relatively high at $345 per user in quantities of 100[10] (deeper discounts at higher quantities were available). It also has some limitations: "ARTour does not help application transition from wireless to dial-up or LAN connections."[11]

The newest attempt at solving this TCP/IP conundrum is Nettech's Smart IP. This is a noteworthy extension to Nettech's successful InstantRF package, for which they claimed a mid-1998 install base of 35,000 mobile users.
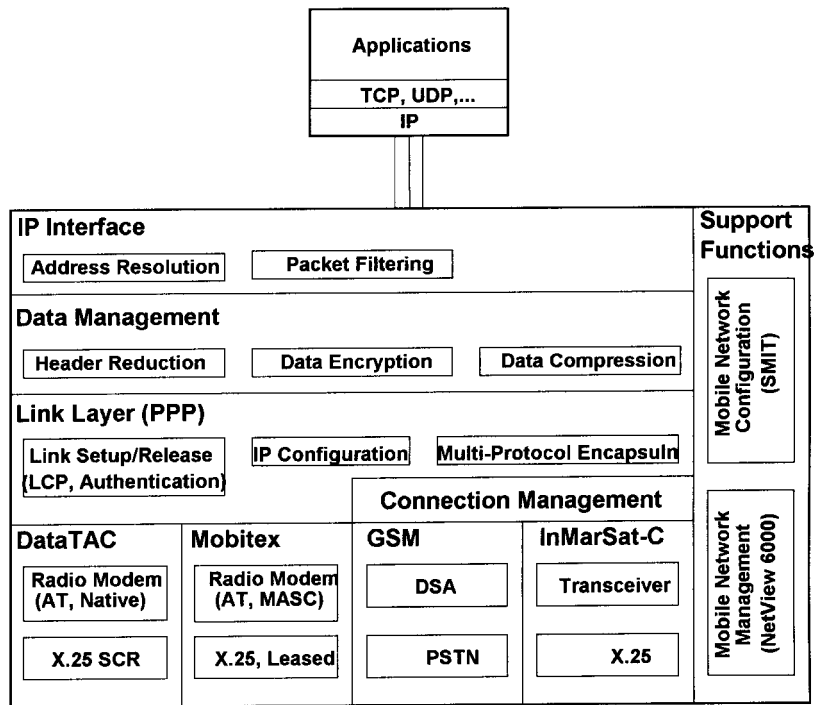
Figure 17-3   IBM ArTour Protocol/Service layering.

A key difference from ARTour is a major emphasis on client software as well as gateways. Yes, ARTour does have an optional 3270/5250 terminal emulator package (basically screen buffers), but Smart IP works with "any" PC-based client application written to the Winsock API. Thus, browsers (Internet Explorer, Netscape Navigator), E-mail (Eudora, POP3, IMAP4) packages, FTP, HTTP, and SMTP can reside in the client PC. Nettech ships one intelligent agent (IPA) for FTPs[12] and provides a software development kit "to add application-level optimization through IPAs"[13] for the others.

Smart IP allows standard TCP/IP applications to run over many wireless networks, including:

1. Public packet: ARDIS, BSWD, CDPD

2. Packet satellite: Norcom

3. Private packet: Ericsson EDACS, Motorola DataTAC

4. Circuit switched cellular: AMPS, CDMA, GSM

5. Wireless LANs
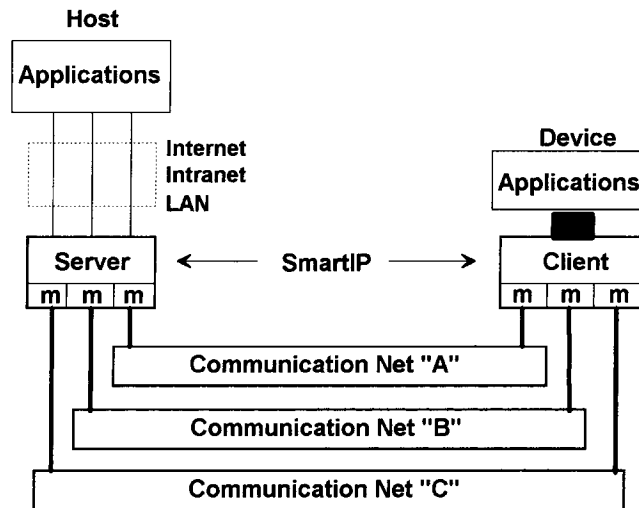
Figure 17-4   SmartIP representative configuration.

The operation can be portrayed as shown in Figure 17-4. Host and devices can use the same applications, changing only the modems to work across a different wireless network.

SmartIP is well priced at $140 per user, quantity one.[14] But Anthony Frey's warning about using "wireless-enabled" TCP/IP applications is worth a thought: "designing an application for wireless environments results in a better application."[15]

One practical example of the custom application approach is Sears. About 60% of its installed base is on ARDIS. The original devices, since upgraded, were IBM's ill-fated PCRadios, which used an API derived from IBM's field service units. When Sears awarded the second segment of its business, it went to a combination of BSWD and Norcom. BSWD paid Nettech to convert the applications to a standard API, and Sears employees now communicate via ARDIS or BSWD (terrestrial) or Norcom (satellite), depending upon location.

17.4   NONGATEWAY HOST CONNECTIVITY OPTIONS

17.4.1   All Wireless

In 1984 IBM's first efforts to commercialize the existing private DCS network ran into practical problems so severe that pilot efforts were suffocated. Access to the wireless network could only be obtained by running a leased line from the customer's host to the commercial facility then operating at Gaithersburg, Maryland. For the customer interested in a trivial, six-device pilot the leased-line costs were unbearable. Alternative connection was provided through the then extant IBM Information

Network (IN), but the costs were still high, the installation was always cumbersome, and the IN shut down twice a week for routine maintenance.

The solution lay in using an IBM PC as a "host" and connecting it to the radio network via a KDT800 device. Actually, only the modem portion of the device was of interest, but at that time no separate radio-modem existed. The airlink traffic doubled since all communication to and from field devices had to pass through the single modem, as shown in Figure 17-5.

A pilot host message (1) was sent over the airlink to the first base station to capture it. The message then flowed over landlines to the switching center in Gaithersburg and was logged. The destination address was examined, and the message sent to the base station closest to the target (this could have been across country). The base transmitted the message (2) to the field device. The mobile ACK (3) was sent over the air, again finding its way to Gaithersburg via landline. After logging the ACK, the message was sent to the base station closest to the pilot host and once again transmitted (4) over the airwaves.

There were a few practical problems with this approach but, functionally it worked. Motorola's DRN, then ARDIS, later used this approach for small-scale piloting, especially when the Motorola 840C11 external modem came into existence. BSWD still uses this technique "to accommodate a small group of mobile users (up to 10 depending on levels and patterns of usage)."[16]

17.4.2   Dial-Up

When the first KDT800 devices began operation on DCS (1983), all were equipped with a slow speed dial back-up capability, an artifact of the assumption that not all the United States would have radio coverage. This became academic as the radio footprint was expanded from Alaska to the Virgin Islands. Installing a base station was simply cheaper than managing multiple dial-up calls—proven on those occasions when a city concentrator was out of service and everyone had to use dial-up.
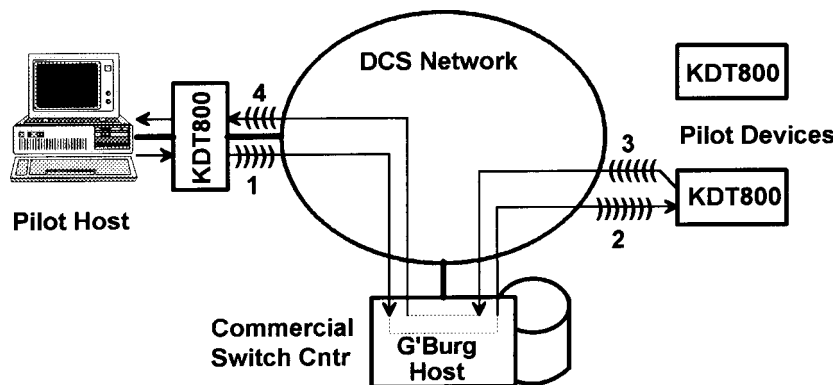
Figure 17-5   Precursor all-wireless connection.

After ARDIS was founded, many die-hards continued to encourage the use of the built-in AT command set in the modems. Development tools were given to customers. Some pilots were run in dial-up. Generally, however, this mode of operation was a failure.

BSWD still offers a dial-up option to "connect . . . up to 30 mobile users depending upon levels and patterns of usage."[17] The approach is illustrated in Figure 17-6.

Within the BSWD network there are five dial-up gateways scattered across the nation. The mobile user must have software capable of accepting the phone number of the gateway of choice and their own host. The BSWD dial-up gateway accepts the call, converts the message in its PAD, then dials the customer's host with the second number. The initial connect time is typically at least 30 seconds, but it can get a relatively large pilot in operation without waiting for new landline facilities.

17.4.3 Public Data Networks

Some companies employ public data networks (PDNS) rather than construct their own leased-line system. Customers who choose PDNs generally do so in order to avoid high initial installation costs and ongoing monthly charges associated with leased lines.

Those companies who also use a wireless service need a link between the networks. This is typically X.25. ARDIS has very few PDN connected user hosts, but BSWD appears to have several. Its X.25 gateways are supported by internal network monitoring, backup, and problem resolution facilities. The flow of traffic is across the BSWD network to an X.25 gateway, then through a high-speed (56-kbps) link to the PDN, then across the PDN to the host computer/server.
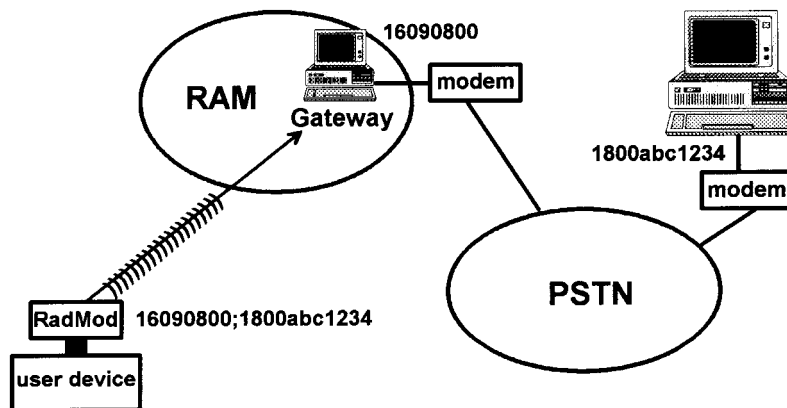
Figure 17-6   Wireless to PSTN to LAN.

17.4.4 Leased-Line Connections

The flip side of the PDN configuration is the high-performance leased-line connection from a customer host directly to the packet switched radio network. Enriched carrier offerings permit connections for as low as $495 per month. One can also obtain frame relay connections for about this price level. If one is daring (reckless?), fixed and dynamic addressing Internet connections are also possible. Large customers typically pay ARDIS $1500–$2000 per month to get a well-managed, reliable link. The fee includes network management for the leased line, which ARDIS arranges. This level of expenditure is clearly the mark of a major company, not, for example, a small taxi dispatch operation.

ARDIS supports several types of leased-line connections including asynchronous, a few varieties of BSC (especially for 3270), some SNA/SDLC connections, and X.25. BSWD tends to confine its leased links to X.25.

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18

SYSTEMS AND SUBSYSTEMS

18.1   CONTROL APPROACHES

The airlink subsystem is defined as the span between the user host's connection point and the subscriber unit. It includes the service provider's message switch/area controller, base stations, and the radio modem. There are (at least!) four current philosophical control approaches:

1. *Decentralized*: Nearby units are able to communicate with each other with no intervening infrastructure. As the distance increases, disrupting the information flow, nearby nodes pick up the transmitting signal. They hand off the data from node to node until a base capable of connecting to the wireline network is found. The message is then forwarded for action. An example of this approach is Metricom's Ricochet.

2. *Partially Decentralized*: The subscriber unit, assisted by a high-function base station, makes many channel assignment decisions. A base station knowing the location of the target subscriber unit can make the data transfer without going to higher levels. An example of this approach is the Ericsson system (Mobitex) used by BSWD.

3. *Partially Centralized*: High-function base stations are responsible for detailed control of the radio interface, including channel allocation and access control. The subscriber units listen to commands broadcast by the base stations and follow those directions. A higher authority controls routing and relay functions for the base stations. The primary example of this approach is CDPD.

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4. *Centralized*: High-level processors control all elements of channel assignment and message sequencing for a given geographical area, which can range from citywide to multistate. Data transfers between subscriber units always rise to the highest level before descending again to the target. The primary example of this approach is the Motorola system used for ARDIS.

Each of these approaches will be examined in order, from highly decentralized to highly centralized.

18.2   DECENTRALIZED: METRICOM RICOCHET

The Ricochet system consists of four major elements:

1. Spread spectrum, intelligent radio modems that respond to the AT command set.
2. Many low-power base station repeaters, or microcell radios, sometimes called nodes. Because of transmit power limitations, nodes cover a very small area, typically about one-fifth of a square mile with a working radius that rarely exceeds 800 meters.
3. A special node class, called a WAP. This wired access point collects the RF data that has been relayed to it by the repeaters and sends it out via a T1 frame-relay connection.
4. An NIF, or network interconnection facility, which is connected to the WAP (don't you just love these acronyms?). This collection of equipment includes a name server, router, and gateway to the Internet, intranets, and LANs.

Under certain conditions, typically at ranges ~400 meters, two radio modem equipped PCs can communicate directly with each other (assuming they want to). In this peer-to-peer mode bit rates of 10–45 kbps have been measured by Metricom.

Under more typical conditions, the subscriber radio modem is looking for a remote device or, more likely, a network connection. It locates the nearest node it can hear well and transmits the data to it in pieces not exceeding 400 milliseconds in duration. Under most conditions the receiving node will be a repeater, which simply passes the message segment along. While the transfer path can change from segment to segment, the flow of information is toward another node that can get to the desired device or, more likely, the WAP. The WAP hands the traffic to the NIF, which can deliver the message via public packet networks (including AOL and CompuServe) or the public switched network.

In this network mode, effective data rates range from 9600 to 28,800 bps but may double by mid-1999. Typical maximum packet lengths are 500 bytes, with each message segment moving over a different pseudorandom channel. A representation of the Ricochet network information flow, with different message segments flowing in different paths, is shown in Figure 18-1.
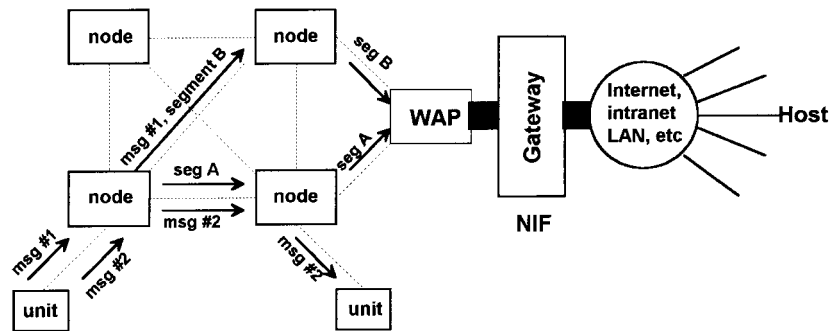
Figure 18-1   Ricochet information flow.

18.3   PARTIALLY DECENTRALIZED: BSWD

A simplified view of the Mobitex network hierarchy is shown in Figure 18-2. The subscriber units communicate with high-function base stations; the base stations are capable of controlling the connection to other subscriber units registered to the same base without higher level reference—impossible with either CDPD or ARDIS.

If the target is a fixed unit in the same area or a subscriber unit not registered to this base, the message flows to the local switch or area exchange (the MOX).

If the traffic is out-of-area, the message flows still higher to a regional switch or main exchange (the MHX). Regional switches can be cascaded as the destination area expands.

The network control center (NCC) does not take part in traffic handling; it includes operation and maintenance functions as well as the subscription handler.

Control of this hierarchical system depends upon the allocation of national system channels; their existence ensures that the mobile need not scan far for control instructions. Message traffic normally flows over one of four types of traffic channels.

The degree to which functions are decentralized is demonstrated with the following example:

1. The subscriber unit is switched on and its synthesizer begins to scan the frequency pool.

2. Roaming signals from surrounding base stations are gathered by the subscriber unit and their field strengths are measured.

3. The subscriber unit chooses a base station based on this evaluation.

4. If the selected base station is the same one last used, the network is ready; if not, a roam packet is generated by the subscriber unit and:

   a. The roam packet is transmitted on the National System Channel.

   b. If the base has no subscriber data, a connection request is transferred to the superior node, the MOX.
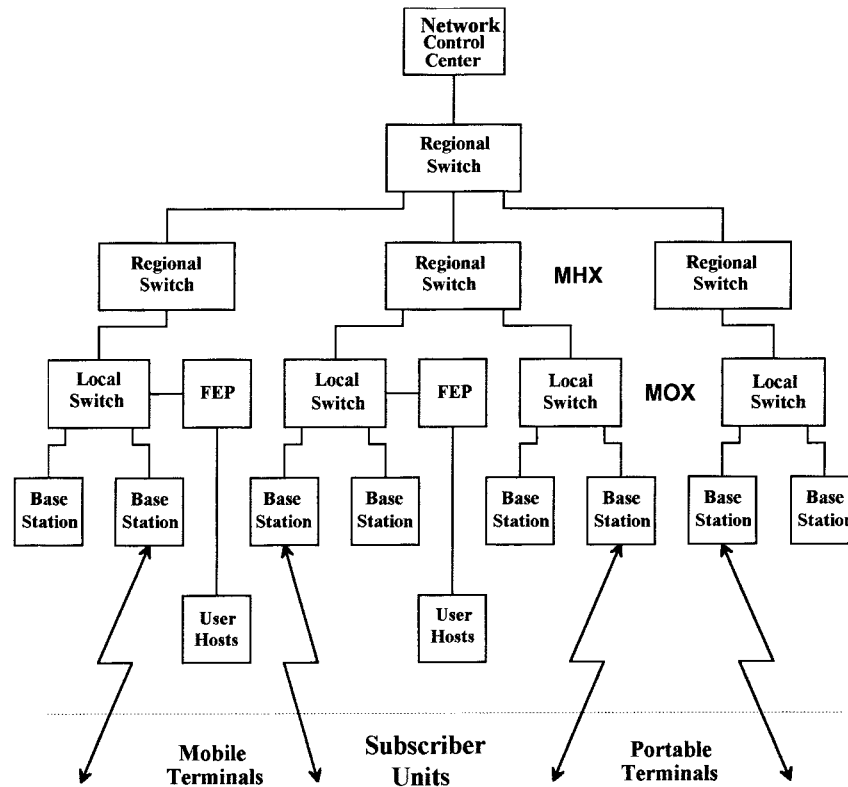
Figure 18-2 BSWD network hierarchy.

c. Assume the MOX is able to obtain subscriber information; the new base is updated with the necessary information (this process can be extended to the MHX as well).

d. The network is now ready; everybody knows the whereabouts of the subscriber unit.

Availability numbers for BSWD are now routinely available. In the summer of 1995 "the reliability of RAM's networks has reached an impressive 99.97%."[1] By October 1995 the quoted reliability had inched up to 99.98%,[2] then to 99.99% in February 1997.[3] After BellSouth took over ownership from RAM Mobile, these numbers were eased down to 99.95%,[4] still a noteworthy accomplishment. These figures exclude occasional scheduled maintenance periods and are probably solely a measure of switch availability.

BSWD works hard to achieve high availability for its base stations, including battery back-up, but plain, ordinary single base station failures are ever present when the network becomes very large. With a single base station out of service, BSWD's

cellularlike configuration can cause a "hole" in local coverage. This hole will persist for the hours necessary for customers to begin calling in with complaints and for the repair crew to be dispatched and complete the service call. It is unlikely that individual cell failures, though locally disruptive, are counted in the network availability statistics.

It is important to note that BSWD vehicular users tend not to see an occassional base station hole. Rolling along a city street, even at 20 mph, they quickly pass to another base station domain and their message will go out with only the evanescent trace of a long response time. The hand-held user cannot run that fast, however, and occasionally gets sore. As the number of two-way pagers increases, so will the sensitivity to scattered network failures, which usually manifest themselves to subscribers as coverage problems.

18.4 PARTIALLY CENTRALIZED: CDPD

Designed from the ground up as an open system, multiple vendors provide some, or all, of the building blocks for different CDPD systems. These building blocks are often based on relatively general purpose computers; thus there are vendor variations on precisely which functions are performed where. A representative configuration that uses multiple-vendor units tends to resemble the block diagram of Figure 18-3.

In this configuration the Mobile Data intermediate system (MD-IS) complex is a network of general-purpose computers with T1 connectivity over frame relay to the cell sites containing the CDPD Mobile Data base stations (MD-BSs).

A T1 you say? How can CDPD afford it? The answer: it's free. The CDPD MD-IS is co-located at the voice MTSO. The T1 line runs from the MTSO to the voice cellular
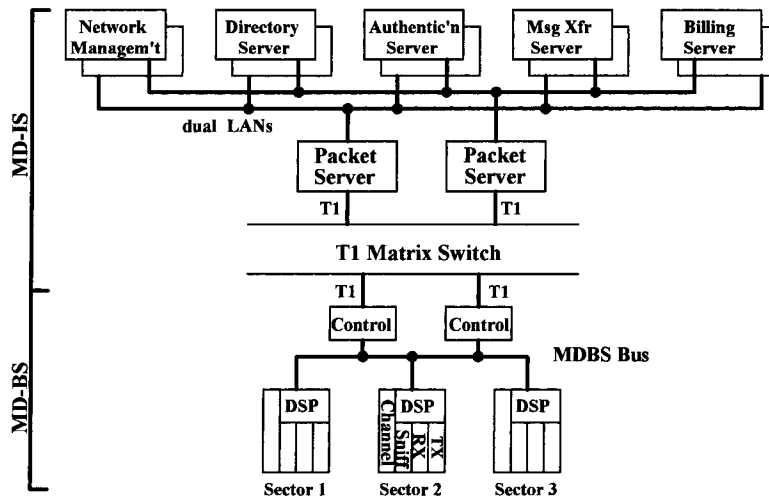
Figure 18-3 Representative CDPD system diagram.

site where the MD-BS also sits. Each T1 line serves a cellular sector. It is time sliced into 24 slots, 19 of which are used by the voice channels. One of the five spare time slots can be allocated to a CDPD channel, as shown in Figure 18-4. The MD-BS also shares the voice antenna, as well as the power and floor space of the voice site.

LAN connectivity exists at the MD-IS for all external services connections. There is a clean functional split between packet movement and administration. The packet server(s) handle routing; the administrative server complex handles all fixed-end services for network management, accounting, and subscriber management.

The MD-BS primary control and status is via network DS0 facilities, with secondary control via a utility port. System parameters and software downloads can occur over either the network or the utility port. All software is held in nonvolatile memory in the control computer. Redundancy is optional but, where present, is capable of automatic switchover upon detection of a failure. Spare parts can be both removed and inserted while the units are powered up ("hot").

Normal connectivity is via TCP/IP or OSI connections. Options exist for direct leased-line connections to other routers, the Internet, or value-added networks.

With a heritage as public telephone providers, the CDPD service suppliers understand the high-availability problem very well and have the physical facilities in place to confine problems. As the MD-BSs are located at voice cell sites, so the MD-ISs are located at the MTSO or central office sites. These facilities are generally "hardened," with tightly controlled physical access. Backup power is routinely available.

The CDPD high-availability goals are intended to be achieved by minimizing, or eliminating, all single points of failure. There are tight controls over all engineering/programming changes. Software upgrades are now infrequent, and those upgrades are made without shutting down any part of the system. Like BSWD, individual base station outages are not counted in system availability percentages. I have tested in areas with no CDPD coverage when coverage was expected. When my
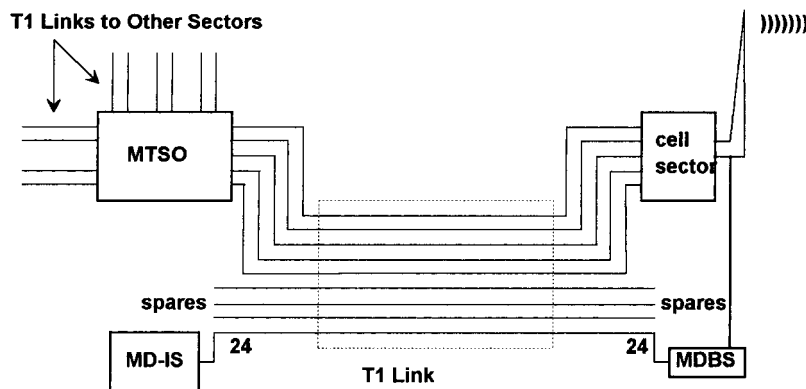
Figure 18-4   CDPD T1 voice link sharing.

individual report finally was examined (one week later), it was discovered that a base station radio had been out of service during the entire test.

18.5 CENTRALIZED: ARDIS

18.5.1 System Approach

ARDIS base stations are very low function, essentially responsible only for forward error correction code addition/removal. The device radio modem has only moderate function: the same FEC responsibility as base stations and a proactive responsibility to move to RD-LAP as the preferred channel. All message transfers, even to a device on the same base station, must rise to a message switch center. A simplified view of the ARDIS network hierarchy is shown in Figure 18-5.

Subscriber units communicate with low-function base stations that act as relay points to the network communications processor (NCP). Here all decisions are made as to which transmitter to key (and when), to set busy or not, and so on. While NCPs are regionalized for control and back-up, some service a single city. Until a few years ago the subscriber unit working in Chicago was not really expected to show up in New York City. ARDIS's "blue collar" subscriber base were not big roamers. Executive class users, particularly those using E-mail, forced useful changes.

There is no concept of a control channel. All control rests in the NCP. The single allocated channel is used only for data transmission.

The degree to which functions are centralized can be demonstrated with the following example:

1. The subscriber unit is switched on. It tries to register on the last channel/protocol it used; failing that, it listens for RD-LAP; failing that, it locks onto an MDC channel.
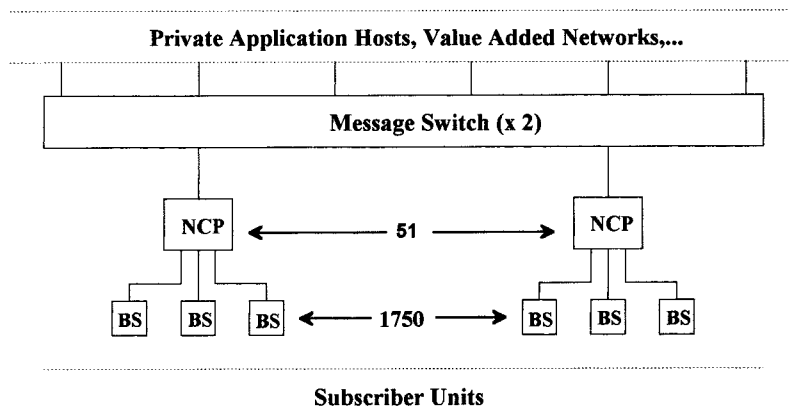
Figure 18-5 ARDIS network hierarchy.

2. An inbound message is broadcast by the device without regard to base station location.

3. A copy of the inbound message may be received by multiple base stations; the FEC code is stripped away; the resulting wireline message is sent to the NCP for action.

4. The NCP evaluates the multiple copies, discarding all but best and second best. A signal strength indicator (SSI) is the primary decision criteria.

5. The NCP, not the base station, determines whether to set busy. The message may be too short to make this worthwhile, especially if a transmitter must be keyed. If the decision is yes, the NCP determines how many base stations (there may be several) must be set busy to avoid interference to the incoming signal.

6. The NCP determines the best path to reach the subscriber unit:

    a. If a long outbound queue exists on the primary path, the alternate can be tried.

    b. If the SSI indicates that the subscriber unit is in a fringe area, the NCP may queue the message temporarily until it completes transmissions on adjacent base stations using the same channel. Those stations are then quiesced so the distant device can receive a clean transmission.

    c. In locations having many base stations, "maximum reuse" interference tables permit simultaneous outbound messages on adjacent base stations using the same frequency. FM capture effects help ensure coincident delivery.

18.5.2   System Details

By ARDIS count, their 1750 ARDIS base stations provide coverage in 417 geographic areas[5] (CSMA/MSAs). NCR, a nationwide user, sees it as 427 metropolitan areas,[6] a reminder of the confusion that can creep in with these urban designations. Either way, ARDIS coverage is broader than BSWD's 270 metropolitan areas.

Ignoring redundancy, 45 operational NCPs service these 1750 base stations. The wireline connection between base station and NCP is T1/T3 digital service arranged as shown in Figure 18-6.

With redundant units, the 51 NCPS, formerly scattered across the nation, are now grouped in six licensed space arrangement (LSA), AT&T hardened facilities, with high-security limited access, uninterruptible power, and back-up generators: (1) Atlanta, (2) Chicago, (3) Dallas, (4) Los Angeles, (5) Washington, D.C., and (6) White Plains, New York. NCP redundancy at each LSA is achieved as shown in Figure 18-7.

Unlike cellular configurations, a single base station out of service in a large metropolitan area is often unnoticed by even the hand-held user. If, say, triple coverage exists, the user may not even have to turn toward a window upon base station failure for the message to get through.

The LSAs are interconnected to two network switching centers: (1) Lincolnshire, Illinois, and (2) Lexington, Kentucky. El Segundo, in operation through 1993, was mothballed. Lincolnshire provides primary operational control, carrying ~75% of the traffic. Lexington absorbs a share of the load and is the site where both development
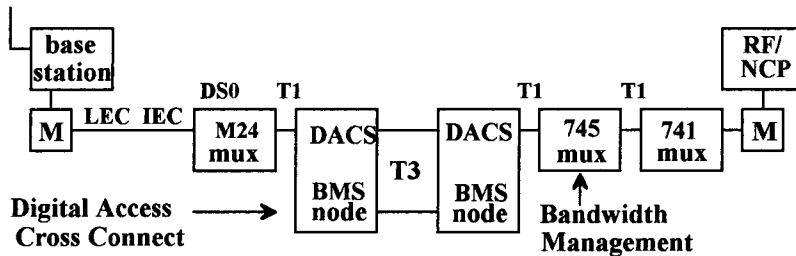
Figure 18-6   ARDIS base station to RF/NCP wireline configuration.

work and billing/accounting are performed. Both centers are connected via dual, diversely routed 56-kbps tandem "Expand" links, as shown in Figure 18-8.

18.5.3   Network Availability

When private wireless packet systems began, moderate attention was paid to up time. IBM's DCS system, for example, had its area controllers (early versions of the NCP) in IBM branch offices where they could be restarted manually when the branch was open. A failing controller, which took out at least an entire city, could be patched around with a 30–40-step dial back-up sequence. The basis for high availability was the assumption that the controller would not go down often, which, indeed, it did not (each controller failed roughly annually). But DCS had ~30 controllers so that a long outage occurred somewhere in the nation about every two weeks.

These techniques were not adequate to the demands of a public network. Thus, ARDIS radically upgraded the system to achieve 24-hour/day, 7-day/week coverage. Network availability goals were set at 6 sigma—for all events, scheduled and unscheduled. This is equivalent to 9 *seconds* of downtime in a month, or 1.8 minutes total outage in a year. It was the 1996 target.[7]
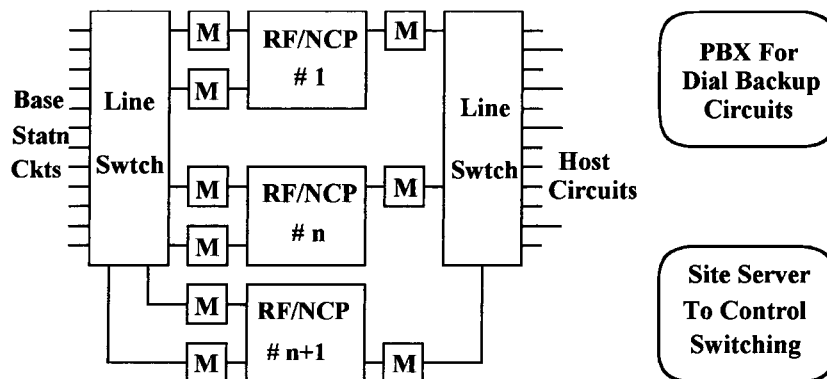
Figure 18-7   ARDIS licensed space arrangements (LSAs).

Lincolnshire
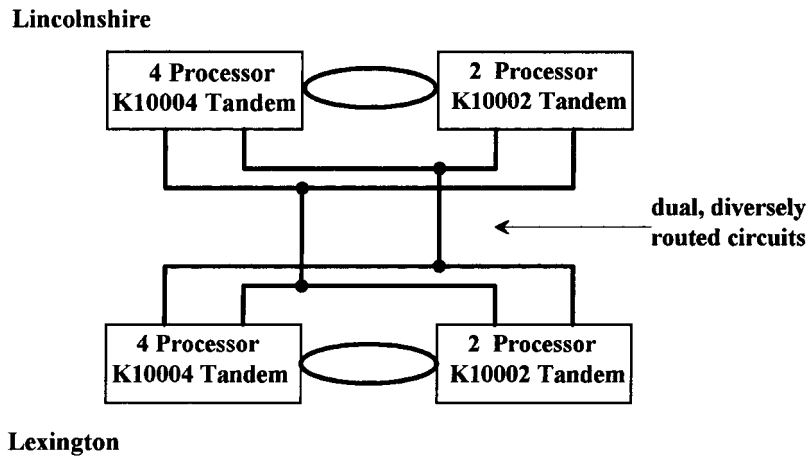
Figure 18-8   ARDIS switch linkage.

For the first half of 1992 ARDIS network availability was ~99.985% (~6.5 minutes outage) per month. After that change teams upgraded every base station in the system to accommodate automatic roaming, with another expansion pass for RD-LAP. Overall system availability declined to 99.978%[8] (~9.6 minutes per month) in March 1994. The system stabilized in 1996, and availability improved to 99.9975%[9] (~1 minute per month). Note that ARDIS contractually guarantees availability to its users.

However, the warning issued earlier with BSWD is valid here. These are switch outages. Individual base stations are up and down all the time and do not really factor into the system availability percentages. Still, there is no question that the mature networks have very high reliability.

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19

USER APPLICATIONS

19.1   VERTICAL VERSUS HORIZONTAL

The trade press is rife with conventional wisdom reports on vertical versus horizontal markets. ARDIS is "known" to focus only on the verticals because of its "heritage and infrastructure limitations"[1] or its "genetic" differences.[2] BSWD is thought to focus only on horizontals. In reality, during 1996 roughly 90% of BSWD's revenues came from vertical applications.[3] CDPD carriers work for the horizontal market with credit card processing[4] or Smartphone plans, but sell in the verticals, especially public safety. It is fair to say their focus is highly variable, with some exceptions: "GTE is concentrating on vertical markets."[5]

   Ironically, in 1995 ARDIS departed from its relatively successful vertical marketing strategy in a failed attempt to push Marco and Envoy for its then parent company, Motorola. BSWD, having seen the light in 1994 with a series of E-mail failures, switched to a vertical approach with considerably more success. It targeted five vertical markets[6] (field service, field sales, transportation, utilities, and finance), relegating horizontals such as messaging and point-of-sale to secondary applications. In late 1997 BSWD swung back to the horizontal market with a vengeance, staking the future of the business on two-way paging.

   What do these vertical/horizontal buzzwords mean? To most people a "vertical" is application specific: perhaps parts order entry from a mobile device transmitted upward to the same company's host computer for processing. The applications are highly tailored since field service firms, for example, often see the intricacies of their particular part-stocking response as a competitive edge. The applications are not generic and do not transfer well from, say, high-technology medical/computer service to truck repair service—or to public safety or field sales for that matter. A "horizontal"

cuts across market segmentation boundaries with generic tasks: broadcast information such as financial or sports reports, credit card authorization, E-mail, or paging/messaging, for example.

ARDIS began life with a good hand-held device, strong field service experience, and a bias to take those two assets into a vertical market: field service. The only radio modem alternative for the ARDIS laptop user was both external and expensive. There were no extant wireless applications for the laptop. It is true that messaging, a horizontal task, was well understood. About a third of IBM traffic, which accounted for >90% of all ARDIS devices in 1990, was messaging (nonmailbox, intracompany). But IBM could not calculate displaceable costs based on messaging and neither could ARDIS. The horizontal alternative was stifled. So, too, was the attempt to provide "fax servers." Customers clearly wanted true image fax, not cost justifiable on packet switched networks, and used cellular instead. ARDIS began to focus more and more on the vertical markets, where it could make money.

BSWD became operational without a captive application. Its initial orientation was horizontal, a notion that was continually reinforced by (then) executive management of Ericsson GE, which carried enormous weight with BSWD: "E-mail applications will be a vital component of the Mobitex strategy. . . . there's likely to be faster and potentially greater payoff from concentrating on horizontal applications . . . (because) the sales cycle is significantly shorter."[7]

BSWD created a rich array of business alliances, especially in E-mail, clear testimony to a horizontal drive. But it was unable to make a successful business in those markets. Gradually, BSWD stopped trying to make money on just E-mail/messaging alone and began having success in verticals:

1. *Field Service*: GE Appliances, Hobart, Kodak, Olivetti, Unisys, Xerox

2. *Field Sales*: Data Solutions, Pepsi-Allied/Pennsauken, Physicians Sales & Service, Ryckoff Sexton, Sysco

3. *Finance*: Bank of America, CitiCorp, Home Savings, Morgan Stanley

4. *Transport*: American Freightways, G.O.D., Merchants Home Delivery, Transmodal Trucking, Yellow Freight

5. *Utilities*: Boston Edison, Florida Power, Illinois Power, Jacksonville Electric, Pacific Gas & Electric, Southwest Gas, Washington Natural Gas

But the focus changed constantly. ARDIS application profiles revealed that two-way messaging was "critical to the functionality or economics" of 20 out of 22 application profiles.[8] E-mail (mailbox, intercompany) was not critical to the bread-and-butter field service application but began to appear more often as a critical requirement for field and insurance sales, financial services, lawyers, accountants, consultants, and executives/managers (many of these applications also require voice, a powerful lure for CDPD marketing personnel).

The need was not lost on Motorola, who initially invested $2 million for a minority share in RadioMail,[9] then converted its bridge loans to equity and gained a majority interest.[10] ARDIS tried the horizontal track with RadioMail[11] in September 1993, and

the Motorola PM100D ARDIS modems came packaged with RadioMail as standard. ARDIS also announced its own PersonalMessaging[12] service in March 1994 and made its prices more competitive the following October.[13] But RadioMail failed in mid-1998, and the majority of new ARDIS success stories came from vertical applications such as United Parcel Service.

19.2 VERTICAL APPLICATION EXAMPLES: FIELD SERVICE

19.2.1 IBM's DCS

IBM's field service dispatch history stretches back decades to pager-based systems (until ca. 1984 IBM had the largest private paging system in the United States). Split into two service divisions in the 1970s, each division pursued alternatives to pure paging.

The first change came with voice pagers. The field engineering (FE) division, after measuring thousands of dispatch calls, developed the dependable time profile shown in Figure 19-1.

The sequence of actions was as follows:

1. The customer called an IBM 800 number to connect to an agent at a dispatching center.

2. Using a custom application that identified customer, maintenance contract status, equipment location, and primary/secondary field service personnel—and listening to the customer's problem—the agent made a voice page to the right service person (the primary service person could be on vacation, already on a call, or otherwise unavailable).

3. When the service person got the beep, an average of 72 seconds was required to listen to the voice page.

4. The service person then required, on average, 120 seconds to find a phone (often a customer phone, not always appreciated). Dial time required an additional 10 seconds.

5. The ring/hold/talk time required, on average, another 136 seconds. If the talking was to the dispatch agent in order to "sell the call" (reassign it because the
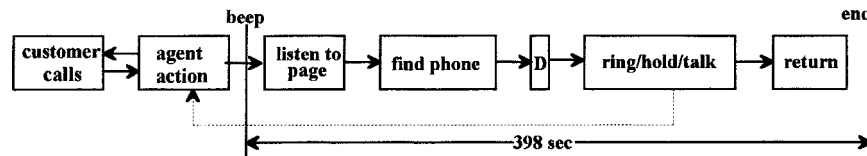
Figure 19-1 Beep-to-complete field service dispatch via alpha paging.

service person was already busy), there was inevitable time lost asking how the Cubs did last night.

6. On average, the service person was back at work in 60 additional seconds.

Total "beep-to-complete" time was thus $72 + 120 + 10 + 136 + 60 = 398$ seconds. Meanwhile the customer service (CS) division had been experimenting with portable terminals. It had developed a small unit that altered the dispatch flow, as shown in Figure 19-2.

The sequence of actions was now as follows:

1. The voice pager was replaced with a simple tone pager (IBM tended to be antivoice).
2. When the customer called, the agent filled in the trouble report on-line, then beeped the service person.
3. The service person took 120 seconds to find a phone.
4. Picking up the unit (3 seconds), plugging it into an RJ-11 jack (15 seconds), dialing the number (same 10 seconds), and handshaking with the dispatch host (2 seconds) came next for a total of 30 seconds.
5. The dispatch host then responded with the trouble report previously entered by the agent. The read/response time was 25 seconds.
6. Next the terminal was unplugged (10 seconds) and put down (3 seconds).
7. The service person was back at work in the same 60 seconds.

Total "beep-to-complete" time was thus $120 + 30 + 25 + 13 + 60 = 248$ seconds: It took no rocket scientist to deduce that most of the 136 seconds spent in agent ring/hold/talk time vanished with approach 2. Call it 2 minutes. It was clear that taking the dispatch via a data message would radically reduce the number of dispatch agents, their tubes, desks, even offices (some regional centers were closed in the subsequent consolidation).

The next step was to go after the service representative time consumed by telephone search and dial. The only answer was wireless; several in-house prototype units were built and tested. They led to interesting business case discoveries:
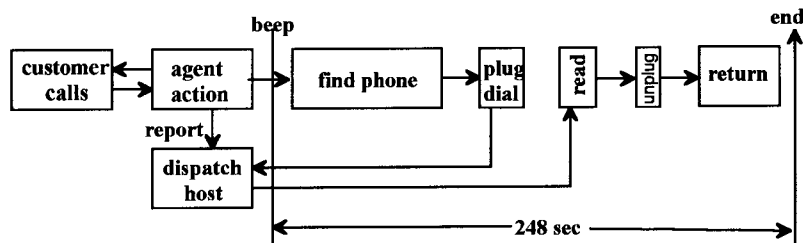
Figure 19-2   Beep-to-complete field service dispatch: page plus terminal.

1. When the device beep occurred, the dispatch message was already present. With a small unit the service representative could pick up the device in 3 seconds.

2. Reading the message and keying the response to accept or sell the call took 14 seconds.

3. Putting the device down took 3 additional seconds.

Now the beep-to-complete cycle had contracted to 20 seconds. Automated dispatch was getting interesting. Further, the system absolutely knew that the message had been delivered and could begin seeking alternative service personnel quickly if it had not been (there was always a time uncertainty with paging).

Further, it was clear that two other pay-off areas existed:

1. *Parts Order Entry*: Embraced not just ordering but also checking on the delivery status and changing priorities. It was later expanded so that the field service representative could be told that the part sought was in, say, the city warehouse five blocks away.

2. *Incident Reporting*: Caused the failure source, its part number, and symptoms to be sent to a central file. Summary reports were then sent to the responsible engineering group for early warning use.

Other areas could not be justified:

1. Pure messaging, as noted in Section 19.1

2. The use of the portable wireless terminal as a plug-in diagnostic aid

Building on years of steady application development, knowing which applications paid off, which did not, how rapidly the new system must come up, and counting on resale of the paging system (which happened), the DCS contract was signed in November 1981. A classic vertical system, it took on the form shown in Figure 19-3.

The customer called in the trouble report to a regional dispatching center. The dispatch agent posted the problem to the regional hosts. The regional host "paged" the field service person of choice. That is, it sent out the briefest "are you there?" inquiry to the last known location of the service representative. The page was highly likely to get through because of its short length. It also required no ACK, an application requirement that modified how the radio system functions. The field representative receiving the inquiry responded with an "I am here" message. This brief, manual ACK did two key things:

1. It let the *application* system know that the selected service representative was available.

2. It let the *data radio* system know the received signal strength from the device. Note that it would have been theoretically possible for the device to also report
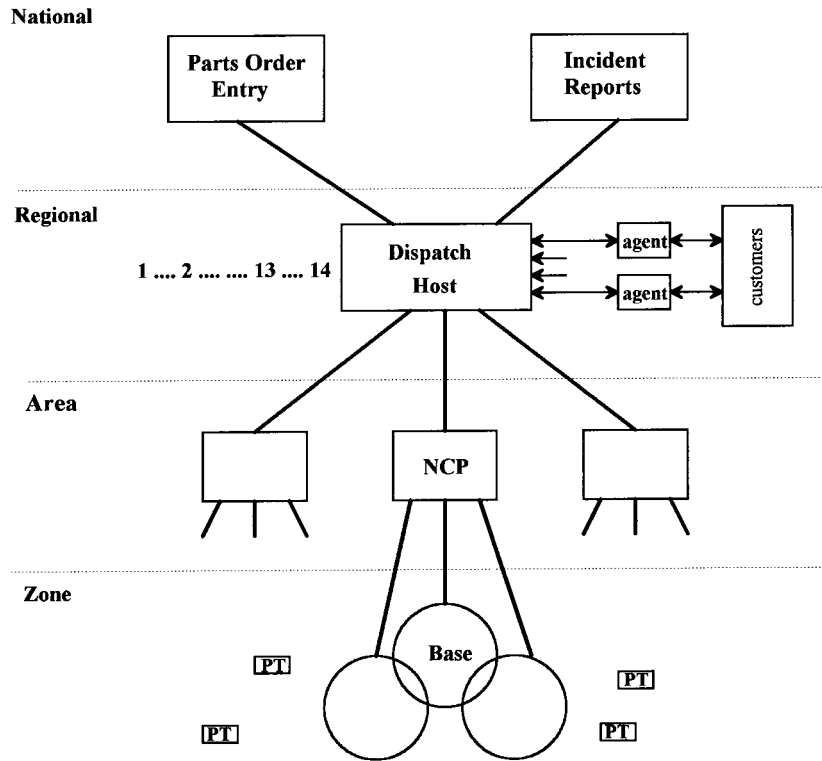
Figure 19-3   Vertical application example: IBM field service.

the signal strength it had received from the base station. This was not implemented.

The application system now responded with the full dispatch text to the radio system. The radio system selected the best route, aided by signal strength indications from multiple base stations that had received the "I am here" message. It thus delivered the full text with high (>90%) probability of success on the first attempt (error retries are the responsibility of the radio system; the application is unaware of any underlying messiness).

A variety of things could happen next. The most common was that the service representative took the call. The time was posted back to the application and the customer's trouble call updated on-line. If the problem was complex or unfamiliar, there was often peer-to-peer messaging as the representative asked buddies if they had ever seen this problem. If it was *really* bad, or the customer was livid, the representative might contact the field service manager for assistance.

When the trouble was corrected, the representative closed out the incident and possibly back ordered parts. These messages arrived at the regional dispatch center

first; it realized they were intended for another system and forwarded them over the interconnected SNA links to the proper destination. Built into the application, not the radio system, were contact scenarios. If representative A had primary responsibility for the customer, and the radio system was unable to get a response in four tries, that fact was reported to the application. A broader search pattern could be requested by the application (very rare) and the radio system would range outside home areas.

Typically the application logic decided that:

1. This is not a burning problem (e.g., an annoying flicker on a PC screen) and will initiate a request for representative A every 15–30 minutes. People often like to eat in peace; the representative may have turned off the terminal. After an hour the application program may revise its strategy to step 2.

2. This problem cannot wait. The radio system is instructed to find representative B.

Note that an underlying assumption of the system design is that the service representative is not wide ranging. If someone does jump in the subway at Grand Central Station, cutting off communication, the reregistration message signals that they are once again reachable when they surface at Battery Park. Ironically, the initial infrastructure design seemed to indicate that the system was intended to let the field service representative roam the nation. IBM secured a common nationwide channel from the FCC, with some exceptions in areas abutting the Mexican and Canadian borders. But the goal was far more pedestrian. The hand-held device's weight/size/battery life targets were so stringent that Motorola was unable to include a synthesizer. The KDT terminals had crystal cut oscillators. Since IBM was concerned with spare stocking, matching devices to numerous possible city frequencies would have been a logistical nightmare; ergo, a common frequency.

Coverage requirements were plotted with great precision. The nation was broken up into 2-kilometer zones and service representative populations were projected for each zone. There are enormous population differences between Manhattan, New York, and Manhattan, Kansas. It was thought that a significant number of service representatives would never receive radio coverage. Thus, the KDT also had a 300-bps integrated modem standard, since it might be useful in a base-station-down situation. The KDT was priced with and without radio transceiver.

As the roll-out proceeded, and as the base station reliability was measured, the decision was made to ship all KDTs with radio transceiver in place if only to minimize spare-parts-stocking problems. In fact, radio coverage became ubiquitous, extending to the business areas of Alaska, Hawaii, and the Caribbean.

Field trials were held with the marketing divisions in an attempt to establish a business case for them. Sales personnel loved to be notified when a customer's mainframe had been down for 2 hours with the problem not yet diagnosed. They were able to speed over and reassure the customer that they were on top of the situation. But a price value could not be placed on such information and the field trials were abandoned.

New, cost justifiable applications could be envisioned. However, they usually did not fit in the memory-constrained KDT800, and they were always extremely hard to develop. There was also the usual risk of committing them to ROM when still unstable. As the devices aged, IBM began to move away from the KDT. It experimented with its own ThinkPAD laptops with integrated radio modems but settled on the I@P as a suitable substitute. The day of the special-purpose, rugged hand-held radio unit is probably coming to a close, though, for example, Husky, Itronix, Melard, and Telxon would certainly dispute that conclusion.

19.2.2 Pitney Bowes' AIM

Roughly five years after IBM's pioneering field service work, Pitney Bowes began to plow similar ground. Like IBM, it had developed (1985) a mainframe-based field service system called ACESS: Automated Customer Support System. This system was essentially telephone-based. Service representatives called in at the end of the day to obtain the first call for the following day. When they called in to report the job complete, they received their next dispatch. Only special field service representatives were given pagers; thus the managers could not initiate calls to most of the staff. Pitney Bowes knew that its customers disliked field service representatives using their phones.

In January 1990 ARDIS was announced; the two companies were working together by February. The agonizing application specification, cost justification, and coverage tests consumed a year, without a contract in place.

Large-scale implementation took nearly another year. Some mistakes were made, especially in terms of message volume and length. This problem was compensated for by doubling the size of the front-end processors and a great deal of system optimization work at the hand-held device (the KDT840, a memory-enriched successor to the KDT800), including data compression and transmission of only changed data.

There were also registration problems, which were satisfactorily patched for Pitney Bowes but forced ARDIS to deal with its lack of automatic roaming.

By the beginning of 1993 more than 2800 users were on the system. The payoff was clear[14]:

1. Eighteen dispatch centers consolidate to six.

2. Dispatch agents were reduced by 60%.

3. There was a 5% increase in representative productivity (there were reductions in the number of representatives).

And during this time, Pitney-Bowes machine inventory grew 4%.

There were also problems. In spite of the fact that the KDT840 has considerably more memory than its predecessor, it was not enough. Further, the lack of a synthesizer hurt Pitney Bowes, which had to stock spares with 10 different frequency allocations.

Radio coverage patterns differed from IBM's so that dead spots existed. Further, Pitney Bowes wanted multiple public airtime service providers to drive down airtime costs. In spite of repeated coverage tests, no suitable replacement was found.

19.2.3 Sears

In 1985, Chicago-based Sears could see IBM technicians arriving at their locations after having been dispatched by DCS. Plans were put in place for a Sears-specific effort, but the Motorola KDT terminal was ruled out as a device; a full-screen unit capable of 3270 emulation was sought. In late 1990, after the announcement of ARDIS, IBM approached Sears with a partial answer: the PCRadio. A disastrous emulation project was actually attempted but failed miserably. In mid-1991 the decision was made to develop a wireless application from the ground up, which consumed nearly 18 months before the first pilot could be attempted at the close of 1992. A California test area was selected for the new pilot, not the least because the ARDIS coverage was good and would not plague the test with unwanted problems. Another full year was spent redesigning work flow and writing the necessary application package. As with IBM, justifiable applications were discovered and exploited. This included up-to-the-minute information on parts and their prices. By 1994 about 500 service technicians were gainfully using the applications.

But the IBM PCRadio was not adequate to the task. Sears sent out RFPs for a new device. Some were tested but found wanting. Itronix developed the winning unit, the XC 6000: rugged, print capable, a better radio modem than on the IBM device. By now it was late 1995 and the project was treading water. A new, accelerated rollout plan was put in place with important delegation of responsibility, much of it to Itronix. The first five months of 1996 were filled with intense activity as 5000 technicians went on the air via ARDIS in its areas of best coverage.

As the rollout picked up steam, Sears began running into geographic areas with inadequate coverage. BSWD did not have the coverage either, but it had a fresh, inventive idea. BSWD proposed a multiprotocol solution that had a key satellite dependency. The satellite vendor was Norcom; AMSC (now ARDIS' parent company) has a polled system and the 5–10-minute latency was completely unworkable for Sears. Nettech replaced all the obsolete middleware with its own design; the new applications could operate with ARDIS or BSWD terrestrial and Norcom satellite.

By mid-1998 (13 years after inception) Sears had 12,000 technicians on this hybrid system: 7000 on ARDIS, 5000 on BSWD/Norcom. In many areas of the country the Sears technician connects solely by satellite, there is simply no terrestrial coverage. Note that satellite coverage is street-level only. The device must be connected to a satellite antenna in the service vehicle.

19.2.4 A Generic Approach

The overriding message of the DCS, Pitney Bowes, and Sears examples is that vertical applications demand enormous planning, long development cycles, an understanding

of cost benefits, and a tailoring of the radio system and devices to meet the application needs.

It is no surprise that ARDIS chose to concentrate on field service as an initial application. They understood the problems, many of the IBM/Motorola heritage staff having bled through DCS, and had a unique device with the integrated radio modem (KDT840). But the fastest sales cycle (this is EDS) required more than two years (see Table 19-1).[15]

This enormous up-front investment in each customer, accurately foreseen by the IBM participants in the first IBM/Motorola exploration of the airtime service business, is akin to having a business like selling clarinets. Not a bad business, but not a big one either, because clarinets are too hard to learn to play (apologies to Paul Carroll).[16] ARDIS resources were strained by the requirement to provide the end-to-end implementation services shown in Figure 19-4.

It seemed clear that there would be no way to make the necessary investment to reach the small (<100 users) vertical application. Inability to reach the low-volume user has long been seen as a crippling obstacle to market expansion. In March 1987 a detailed examination of voice SMR user distribution in Manhattan was made by JFD Associates.[17] A summary of size categories is given in Table 19-2.

In that long ago time there were 15,934 voice special mobile radios (SMRs) licensed in Manhattan, many of them logical candidates for conversion to data. These radios were owned by 2166 businesses (e.g., courier and messenger, plumbing, electrical contractors, towing services), a discouragingly low average of 7.4 voice radios per user.

A ray of hope was that just three users (0.1% of total) accounted for 468 radios (2.9% of total). The sales and marketing focus could be on just those three, two of which (Yellow Freight and DHL) happened to be nationwide. But calling on enough users to account for ~20% of the cumulative device potential meant 64 sales efforts;

Table 19-1   Fast track sales cycle: Vertical application

Jul. 1991	Decision maker call
Aug. 1991	ARDIS application study
Sept. 1991	Proposal made; Starter kit contract signed
Oct.–Dec. 1991	Pilot
Jan. 1992	Evaluate pilot results
Feb.–Apr. 1992	Application Requirements redefined; customer reference visits; Lexington/Lincolnshire executive briefings; devices selected
May 1992	Requirements complete; application work started
Jul. 1992	Services contract signed
Aug.–Nov. 1992	System development and test; 11/15/92: 25-unit test
Dec. 1992	Application/hardware delay production rollout
Jan.–Feb. 1993	Rollout begins
Mar. 1993	Hardware reevaluation; suspend rollout
Apr.–Aug. 1993	Rollout resumes and concludes (700 users)
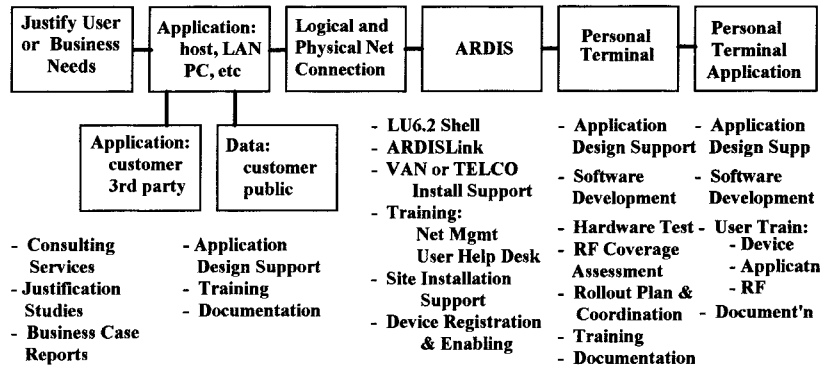
Figure 19-4 ARDIS end-to-end implementation services.

51 of those calls were on prospects averaging only 42.5 devices each. It was all downhill after that.

This problem led ARDIS to the development of ServiceXpress, a bundled flat monthly fee offering created by a four-way alliance:

1. ARDIS
2. SonicAir (courier and warehousing logistics provider)
3. SSI: Service Systems International (field service applications software)
4. Business Partners Solutions (connectivity solutions)

Table 19-2   User size distributions: Manhattan

User Size	Number of Users	Percent of Total Users	Cumulative from Largest (%)	Number of Radios	Percent of Total Radios	Cumulative from Largest (%)	Number of Radios/ User
1	498	23.0	100.0	481	3.0	100.0	1
2–3	416	19.2	77.0	1,055	6.6	97.0	2.5
4–7	648	29.9	57.8	3,484	21.9	90.4	5.4
8–15	374	17.3	27.9	3,904	24.5	68.5	10.4
16–31	166	7.7	10.6	3,582	22.5	44.0	21.6
32–63	51	2.4	3.0	2,166	13.6	21.6	42.5
64–127	10	0.5	0.6	803	5.0	8.0	80.3
≥128	3	0.1	0.1	468	2.9	2.9	156
	2,166			15,934			7.4

As expected, the emphasis was on field service applications. Parts information was held on SonicAir's inventory management system and delivered by its couriers. There was no up-front capital expense since the system was "pay as you go" ($250/month for 31 months) for airtime, subscriber units, dispatch terminals, maintenance and repair, and key applications: call handling (dispatch, messaging, status/inquiry, incident report) and parts logistics (inquiry, requisition, receipt, transfer).

ARDIS was delighted, and falsely encouraged, to have a six-technician company sign up by telephone. A more typical response was the field service operation of Great Western Bank:

Nov. 1992	ServiceXpress Announced; Great Western Signs
Dec. 1992	Contracts with BPS, DCS, SonicAir, SSI
Jan. 1993	Training: ARDIS, BPS, SSI
Feb. 1993	Training: DCS, SonicAir
Mar. 1993	GW field test installation (2 days)
	GW connection to existing application (15 days)
	Production

which, at least, shortened the "fast" two-year EDS cycle to five months. The success at Great Western led to reference sales at Colonial Business Equipment, Siemens Medical, and CompuComm in April, and to the qualification of nine more prospects thereafter.

The fixed-fee arrangement not only had the benefit of predictability; it also permitted easier cost justification. Customer payback demands are quite stringent. A summary of a typical ARDIS field service cost–benefit analysis is shown in Appendix J. Savings must be defensible from a dozen displaceable costs; the payback certainly has to occur within two years (in the Appendix J example the break-even point is reached in 1.38 years).

With a lease form of payout the first year of the business case does not have to absorb the full capital cost of devices. This distribution of costs effectively broadens the justification time horizon, something vertical customers concentrate on with great intensity.

After all this enormous effort, how did it pan out? "When ServiceXpress was launched, ARDIS emphasized not just its one-stop-shopping aspect, but also its relatively low cost. . . . In hindsight, it might have been a mistake to place so much emphasis on low cost. Developing these applications is time consuming and requires a significant amount of support."[18] ServiceXpress died, and some of the customers died with it. All but one of the remainder had converted to a custom application by 1998.

SSI immediately began working with BSWD and Wireless Telecom to provide ServPac, a second pass at the same target. SSI girded its loins for a tough sell: "It might take a reseller a year of education and five wireless installations before he becomes comfortable with his level of expertise."[19] ServPac failed.

But BSWD kept on truckin', lining up multiple partners in several industry segments. None have been roaring successes, but all have contributed to BSWD's success in vertical markets. A representative listing of these partners is contained in Table 19-3.

Table 19-3   BSWD vertical market application partners

Provider	Product Name	Emphasis
Field Service		
Astea International	Dispatch-1/Remote-1	Thirty modules: call center management
BellSouth	RAM Interactive Dispatch	Entry-level dispatch
Cheetah Software	Cheetah Service	Schedule, route, manage inventory
ETE	MobileTRAK III AVL	Internet enabled vehicle tracking
Mobile Data Solutions	Tech-Net	Dispatch management, scheduling
	S2000 Service Management	Modules: dispatch, inventory
Pacific Decision Sciences	Super Service	Modules: dispatch, billing, scheduling
	Nucleus	Small service organizations
Wenn/Soft LLC	MobileTEC	Host/technician/peer communication
Transport: Less Than Load		
Carrier Logistics	Routronic 2000	Routing and dispatch
Industrial Computer Systems	Dynamic Dispatch III	Fleet dispatch, pickup/delivery scheduling
Mobile Information Systems	globalEXPRESS	Informix LTL package
Roadshow International	Roadshow P&D	Routing and dispatch
Synergistic Systems	Synergy Dispatch	Local pickup and delivery
Transport: Courier		
ASCAR Business Systems	Dispatcher Mobile Data Module	Message exchange: dispatcher/courier
Cheetah Software	Cheetah Courier	Large organizations: 1000 P&D/day
Datatrac	Courier Order Processing	Order entry, dispatch, rating/pricing
LADS Network Solutions	LADS CELS	Message exchange: dispatcher/courier
Mobile Information Systems	microEXPRESS	Courier order entry, dispatch, billing
QuickComm	D.O.T.S.	Courier pickup and delivery
Wireless Links	CourierLink	Fleet management

Table 19-3   (*Continued*)

Provider	Product Name	Emphasis
	Transport: Private	
Cheetah Software	Cheetah Delivery 3.0	Route, schedule, dispatch, track
	Transport: Waste Management	
Mobile Computing	Waste Disposal System	Weights, distance traveled
	Utilities	
Datamatic	Caravan	Inventory, service orders, billing
Future Horizons	FieldPAC	Windows: schematics, service records
Raytheon	Field Service Management	Crew availability, order status, dispatch
Utility Partners	MobileUP	Schedule, dispatch, data collect
	Field Sales	
Thinque Systems	Sales/Route/StoreTRAQ™	Order entry, sales history, merchandising
	Public Safety	
Cerulean Technology	PacketCluster Patrol/Rescue	NCIC, DMV, wants and warrants
HTE	More	Computer-aided dispatch (CAD)
InfoTech International	MOBILE-LINK	Retrieval, message routing
SCA	Premier MDT	Windows: database access, dispatch
	Finance	
Wireless Financial Services	Universal Trader	Proprietary: secure order entry, routing
	Insurance	
Mobile Data Solutions	Mobile Insurance Solutions	Scheduling calls
	Telemetry	
Ademco-Radscan	SafetyNet	Alarm monitoring backup
Profile Systems	Profile 2000	Billboard lighting control
Real Time Data	Vendlink	Vending machine monitoring

19.3   HORIZONTAL APPLICATION EXAMPLES: E-MAIL

19.3.1   The Search for the "Killer App"

History's first electrical mail system was the telegraph. Western Union coined that name[20] in 1851 and still has the registered trademark for the term *electronic mail*.

E-mail definitions alone could fill this chapter. In a broad sense it includes facsimile and both computer-based text and voice messaging. Long-term technology trends will permit a user to communicate regardless of source, format, or destination. Wireless is a long way from achieving these goals, but the drive has begun.

This section will focus primarily on what is being accomplished via wireless packet switched networks: essentially text transmission. Distinctions between "messaging" and "E-mail" are no longer crisp. Both can have mailboxes; only the location of that mailbox differs. Provided there are no security concerns, it is quite feasible to have one's messages held in the mailbox of an E-mail service provider. Often there are home and remote mailboxes, which can be a housekeeping headache if the home does not recognize activity on the remote. But there are some alternative offerings that keep only a home mailbox.

With wireless messaging, recipients need not be present when mail is sent to them. Messages are collected in the user's electronic mailbox; they either sign onto the mailbox when convenient or, if their battery life and messaging system will support it, are hunted down to receive their "mail-waiting" notification.

Computer-based messaging evolved in the 1970s and began to pick up speed with the development of the low-cost keyboard/display systems. The PC pushed the pace even more intensely. Ironically, within IBM the PC was initially in short supply as production was allocated to external users. In its place the 3270 interactive display-based system, tied to a mainframe executing PROFS (Professional Office System), swept through IBM. By 1982 more than 1000 large mainframes within IBM and 50 from interested universities were operational on VNET in 29 countries,[21] the largest E-mail system then in existence. By 1985 the capability had been extended to IBM employee homes. The AT command set was employed on dial-in modems, with PCs performing the role of 3270 emulator, aided by proprietary data compression algorithms.

E-mail is now the most pervasive general application in existence. Its growth is phenomenal, largely driven by Internet usage. There were nearly 15 million U.S. users in late 1992,[22] 31 million in 1994,[23] 42 million in January 1996,[24] and 120 million people (including "consumers") by January 1998.[25] About 102 of the 120 million users exchanged E-mail via TCP/IP systems.

In 1991 this already growing E-mail user count attracted the attention of Ericsson GE. It signed joint development and marketing contracts with RadioMail (then Anterior Technology) and RIM to develop a wireless E-mail gateway service and wireless enabled modems. The traffic was to be transported by RAM (now BSWD).[26] Ericsson GE did not fully understand their competition: "Mobitex is a store-and-forward system. . . . With cellular, if the modem and computer aren't turned on to receive a message when it's sent, the data aren't received."[27] This assertion surprised most of us who were happily using CompuServe E-mail via cellular.

In May 1992 DEC announced it would develop a version of its client/server Mobilizer software for its 3 million all-in-one integrated office system customers.[28] The wireless carrier would be BSWD. The system would be operational the first quarter of 1993. It actually went into internal beta test at BellSouth Mobility in June 1993[29] but sank without trace.

In November 1992 RAM staged a "coming out party" where several key E-mail alliances were announced.[30] One of those alliances produced an HIP/Mobidem/RadioMail-based offering. Euphoria reigned: "they're attacking the beach front of Corporate America"[31]; "This is an early warning to CIOs."[32] "Viking Express proves that E-mail is indeed a 'killer application' for wireless data networks."[33]

But there was no E-mail customer stampede. In November 1992 RadioMail announced[34] that it "had more than 200 paying customers on its E-mail gateway." By June 21, 1993, RadioMail had "assigned approximately 1500 mailboxes,"[33] and not all of them were for BSWD. RadioMail went out of service entirely in mid-1998.

Other efforts stalled: "[with Mobidem AT] Microsoft Mail turned out to be a dog . . . [because the] software . . . was very 'chatty.'"[36]

But BSWD kept fighting. By November 1994 it had enough alliances to claim that "83% of all LAN-based e-mail products have been RAM-enabled . . . including Lotus cc: Mail Mobile and cc: Mail Remote, Microsoft Mail Remote for Windows, and Novell GroupWise™."[37] In addition to RadioMail, BSWD gave strong support to both WyndMail and its own ZAP-it, founded in 1992. Nevertheless, by late 1995 its valiant E-mail efforts had been relegated to the back burner. WyndMail soldiers on; Zap-it, which was demonstrated by Bill Gates at the November 1996 Comdex as the first wireless E-mail subsystem for Windows CE,[38] was folded into GoAmerica in July 1998.[39]

Meanwhile, ARDIS—a latecomer to the E-mail game—began offering peer-to-peer messaging alternatives in early 1993 with Melard's Jetit.[40] Nearly simultaneously[41] it announced that it would also provide RadioMail service in the second quarter of 1993; in fact, because of Motorola modem problems, the service was not available until December. By February 1995, ARDIS was neck and neck with BSWD for Lotus cc: Mail via Motorola's AirMobile[42] support. It actually began to get a few cc: Mail customers, such as Armor All.

With all this pounding one waits for the door to finally swing open! It has not happened yet.

19.3.2 Limiting the Search

19.3.2.1 Overview From 50,000 feet electronic mail systems can be simplistically visualized[43] as in Figure 19-5. The *user agent* machine provides text editing and presentation services to the end user. It also is responsible for security, priority levels, delivery notification, and distribution subsets. The *message transfer* machine performs the actual routing. It has responsibility for the store and forward path, channel security, and actual mail routing. At least eight X.400–X.430
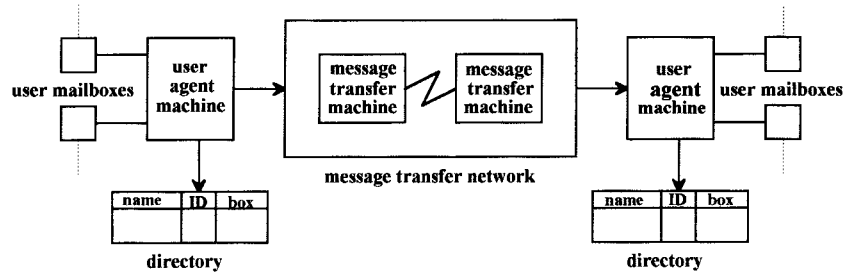
Figure 19-5 E-mail overview.

recommendations cover these three functions. The general representation shown here is symmetrical, but client–server configurations exist as well.

Messaging traffic also has a time value component that reflects itself in two ways: the type of device carried by the user and the urgency (or lack of it) to get at the information wirelessly. One thinkable representation is shown in Figure 19-6. That is, if the E-mail is a short headline or bulletin of high time value, it is very likely to go out as a page over a wireless system. If it is a large data base, and an hour does not make a difference, the laptop user will find a wireline port to take the traffic. The E-mail system must be able to handle the full range from high-speed LAN connection to alphanumeric pager.

19.3.2.2 Standardization Muddles If the simple diagram depicted in Figure 19-5 were to be replaced with real-world examples of possible wireless configurations, the variations would cover a wall. Both one-way and two-way systems exist, as well as many more vendor-specific, proprietary variants.

There are at least three classes of standards:

1. *Messaging*, such as CCITT's X.400 (ISO layer 7), which define how intersystem mail messages are addressed. First agreed in 1988, few programs
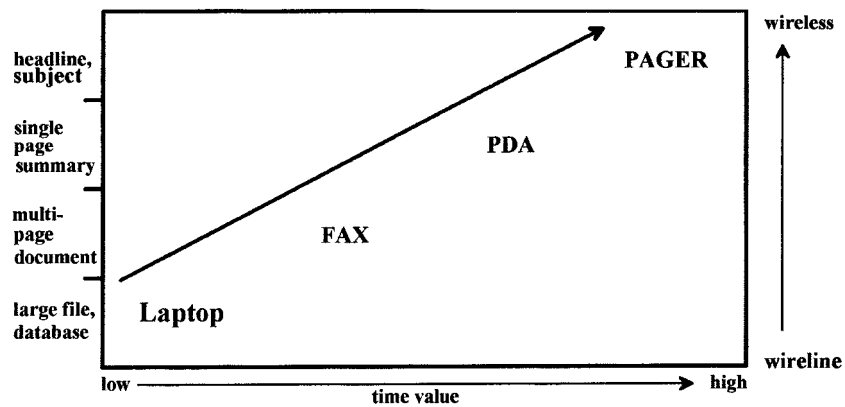
Figure 19-6 Messaging modes.

completely embraced it. Revised in 1992, a handful of U.S. programs were in full compliance by late 1998.

2. *Directory*, such as ISO's X.500 for X.400. With a fully functional system E-mail could be sent to a street address.

3. *Transport*, such as the Internet's RFC (request for comments) 822.

Serious alternatives, which are not precise maps to international standards, include:

1. IBM's SNA Distribution Services (SNADSs), which was dominant in legacy mainframe and AS/400 minicomputer environments.

2. Novell's Standard Message Format (SNE).

3. Unix's Simple Mail Transfer Protocol (SMTP), far and away the most popular TCP/IP-based message transport protocol. Ironically, the wide implementation variations of SMTP led to the rise of X.400 standardization work, but SMTP won the user base, if not the function race.

In addition, a series of de facto "standards" compete bitterly as open interfaces. The two main contenders are:

1. Lotus' Vendor Independent Messaging (VIM). Derived from Lotus' Open Messaging Interface, VIM is designed to let applications send messages without regard to the underlying protocols. Lotus Notes and cc: Mail use VIM.

2. Microsoft's Mail Application Programming Interface (MAPI) is a set of commands in Windows 95/98 that are used to communicate with other MAPI programs and mail systems. The program that coordinates the exchange of data between Microsoft mail and MAPI mail readers is Microsoft Exchange. Microsoft Mail is, of course, MAPI complaint.

Complicating the lack of uniform standards is the fact that some E-mail systems work on only a single computing platform such as Apple versus IBM-compatible PCs. Worse yet, because of exotic subtleties, some packages work on multiple platforms but do not behave in exactly the same manner. A series of bridges and gateway packages have been developed to deal with this mish-mash. For example, Lotus has released a VIM-to-MAPI driver (.DLL files); Gallagher & Robertson created the Glotus gateway that allows Lotus mail users to access the Gmail Internet, X.400, and fax gateways; and ReSoft provides connectors and gateways from Microsoft Exchange to SNADS, SNADS to Lotus Notes, SNADS to the Internet, PROFS to Lotus Notes, ad infinitum.

In the wireless world companies like RiverRun produce products such as Mail On The Run! that map to multiple possibilities. With a Windows CE client device River Run supports many terrestrial wireless networks, including AMPS cellular, ARDIS, CDPD, and GSM. There are some exclusions, notably BSWD and Ricochet. The client works with a RiverRun agent that handles the peculiarities of the particular wireless protocol and maps to most mail systems whether they are VIM or MAPI based.

19.3.3   Gateway Example: RadioMail

19.3.3.1   Structure Usually pictured with scores of lines entering its "cloud" from, for example, AT&T Easylink, CompuServe, and MCI Mail, RadioMail used the "network of networks," the Internet, for its connections and transport. Similarly, it used a single feed from Comtex[44] to obtain multiple news services, weather, and financial data for its Agent See/NewsFactory offering and the National Dispatch Center to connect with 220 one-way paging services.[45] The number and types of connections were so rich that they must be grouped in some logical manner, as shown in Figure 19-7.

19.3.3.2   Key Functions RadioMail considered "that it is not a wireless e-mail company. Instead it offers a new category of service: near real-time messaging, . . . a sort of electronic Post-It notes."[46] Nevertheless, core E-mail functions were at the heart of the package, including:

1. *Preparing mail*, including entering addresses, composing the message, and mailing it.
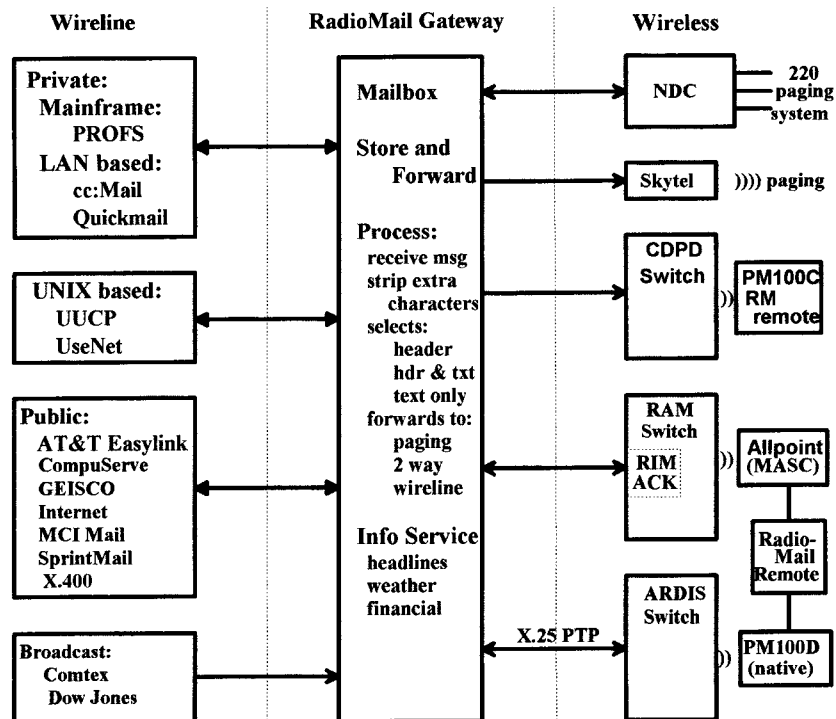
Figure 19-7   RadioMail gateway.

2. *Receiving and viewing mail*, including forwarding.

3. *Processing mail*, including verification of send/receive status, deleting, and copying text to another message or to a file.

They also provided several utilities such as a directory function that could obtain the addresses of other RadioMail subscribers.

RadioMail messages could be sent to any computer or account accessible through the Internet, including America Online, AT&T Mail, AppleLink, Bitnet, CompuServe, MCI Mail, Prodigy, and Sprintmail. Its "fax" capability was limited to sending a text message, via wireline, to a designated telephone number.

RadioWeb functioned by sending the URL of the page you wanted to view in the "subject" field of an inbound message. A RadioMail agent retrieved the web page, processed it to remove all graphics, and delivered the surviving text over the air to your device. Performance was slow, and utility was low—perhaps an omen for CDPD SmartPhone web inquiries.

19.3.4 Wireless E-mail Service Example: BSWD

BSWD has been engaged in E-mail alliance building since 1991. So much has been published about the alliances, and so much emphasis on interesting events such as the NewsCom demonstration at the 1992 Democratic National Convention,[47] that it is often hard to focus on what actually exists. Representative operational linkages are shown in Figure 19-8. This simplified diagram is not exhaustive, but it is meant to convey the fact that BSWD support exists for key LAN-based E-mail products as well as public services.

19.4 HORIZONTAL APPLICATION EXAMPLE: TWO-WAY PAGING

19.4.1 Introduction

"A real limiting factor of messaging is the uncertainty of message delivery."[47] This problem was clearly understood in the early 1980s when Millicom's Metagram service was being planned. The IBM team at work on the initial, failed attempt to take DCS public (1983) saw "ack-back paging" as a natural application. This thrust was fought energetically, and successfully, by Motorola, which had a very different business plan in mind for paging.

In 1991 telecommunication providers began to realize that the paging market was growing far more rapidly than had been forecast. In particular, 1989 and 1990 were "enormously successful years."[48] The long-term forecast predicted 23 million paging users by 1996. (*Note*: There were actually more than 36 million). In October 1991 Dial Page petitioned the FCC for spectrum rulemaking for "a new enhanced paging service called Acknowledgment Paging."[49]
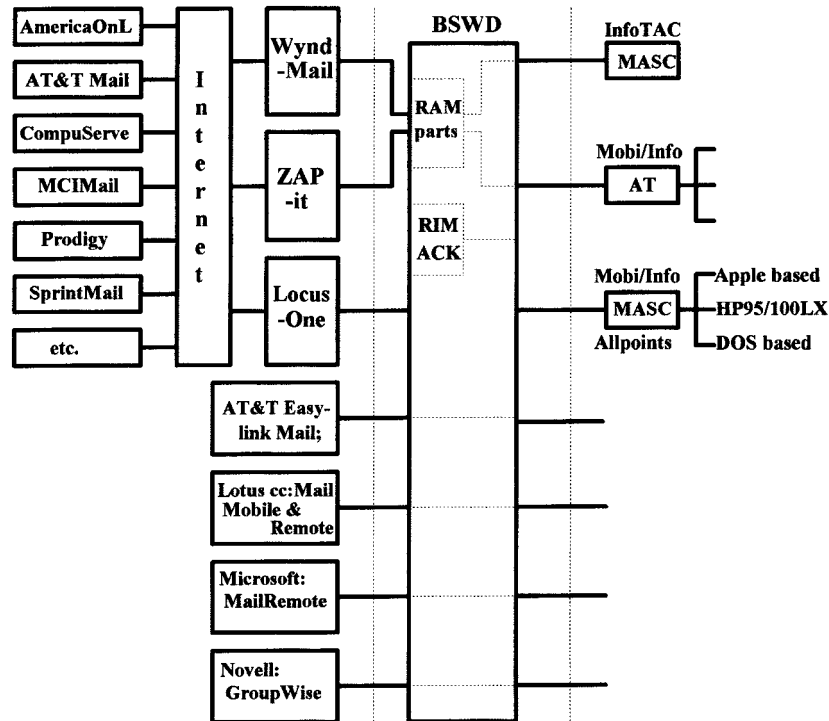
Figure 19-8   Representative BSWD E-mail offerings.

In early 1994, with the writing on the wall, Motorola formed its Advanced Messaging Systems Division "specifically to develop technologies and products (for) . . . the narrowband PCS market. . . . The development strategy is based on the FLEX™ family of high-speed protocols which includes ReFLEX™, the transport protocol enabling two way messaging."[50] In July 1994 the FCC held initial auctions for *nationwide narrow-band personal communications services.* BellSouth Wireless obtained one of the 10 licenses.

19.4.2   BSWD Makes Its Move

At year-end 1996 Yankee Group, GIGA, and Bear Steams made a series of paging market projections,[51] which are summarized in Table 19-4.

The growth predictions for the total two-way paging market caught BSWD's eye, especially since a separate MTA-EMCIA PageTrac study indicated that the fastest growing, two-way messaging segment might command a monthly premium of $15. BSWD envisioned a series of offerings where their technology could compete at the high-function point (see Figure 19-9).[52]

There were at least three problems to master:

Table 19-4   Paging market projections (in millions)

Subscriber Type	1996	2001	CGR (%)
Paging	36.2	57.8	9.8
Two-way paging	0.7	11.0	73.4
ACK paging	0.5	5.3	60.0
Two-way messaging	0.2	5.7	95.4

1. Create the right, full-function gateway.
2. Obtain the right device: small size, competitive price, good battery life.
3. Build the right network to obtain coverage comparable to one-way paging.

The gateway was easiest to master, because BSWD had an excellent running start. RAMparts had existed since 1992, the initial gateway was commercially operational in 1994, and it was the base for Wynd, DTS (Zap-it), and LocusOne operation. Extensions for two-way paging were actually under development by December 1995.

The right device would be provided by RIM. With BSWD development dollars, a phased schedule (the I@P, then the I@P950), and the excellent battery-saving
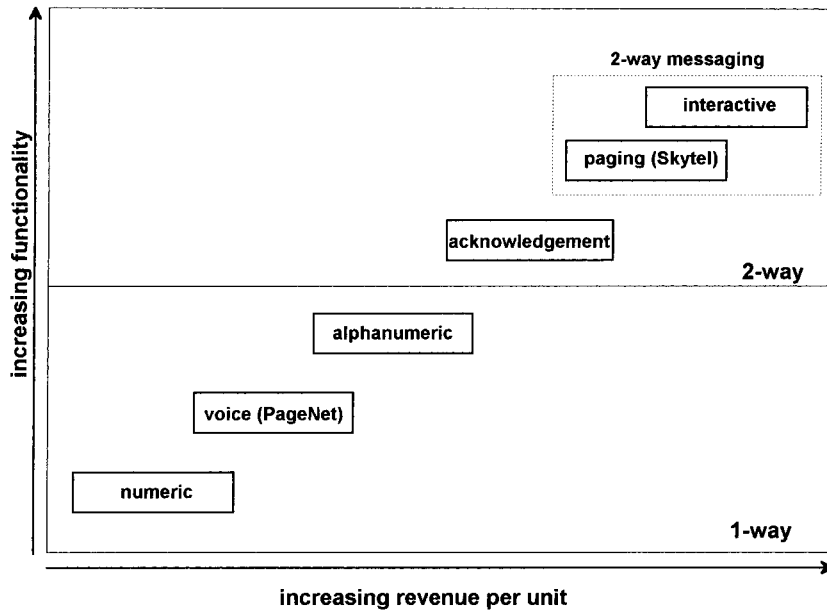
Figure 19-9   Paging service offerings.

protocol that is a characteristic of Mobitex, RIM was able to produce good units at competitive prices.

The network issue was vastly more complex. Before the total RAM takeover by BellSouth, the parent company had been studying what seemed to be the only authentic competition: systems using Motorola FLEX technology. There was, however, a reasonable caveat: "Serious, capable competitors will emerge in every attractive new market."[53]

BellSouth concluded that BSWD had several advantages, among them:

1. It had the highest *unencumbered* national spectrum of any industry player.
2. Device battery life was far superior. To achieve similar performance, FLEX latency was as long as 4 minutes, unacceptable for anything remotely interactive.
3. The operating costs for full two-way, as opposed to simple acknowledgment, should be superior.

But FLEX (read Skytel) had one clear advantage: Its simulcast in-building coverage was "excellent." For BSWD to achieve similar results, the number of base stations would have to be driven to 4000—an unacceptably high figure. Working principally with Ericsson, but also with RIM, BSWD found ways to improve network performance with retrofits to existing base stations. Now, it was predicted, BSWD could achieve the required coverage with a total of just 2500 base stations, still more than doubling the existing count.

Considering the magnitude of the investment, BellSouth hesitated very little. Authorization was given for a phased rollout of 1300 new base stations, a $120 million cost-to-deploy. This included $80 million for just the base station hardware.[54] As an aside, my personal experience in the Greater New York City metropolitan area, including all of the state of Connecticut, has been exceedingly good. The augmentation appears to work as planned.

19.4.3 ARDIS Counterattacks

All during 1997 ARDIS sat nearly immobilized in the face of obvious signs that BSWD was going to build out its infrastructure. There were refrains of "I've heard that song before" to "even if they do it, they still won't be as good as we are" to "how can it be profitable?" Nevertheless, ARDIS did work out an arrangement with IKON Office Solutions for a two-way paging gateway, lined up three distribution partners (ConectUS, Paging Dimensions, and ProNet), and formally announced the Interactive Pager on August 25, 1997. The service, however, was not well priced.

In fairness, ARDIS was also trying to hold down all capital investment to reach the financial break-even point by year-end. This was achieved, and on December 31, 1997, ARDIS was purchased by AMSC. The search for new investment money began at once. On March 31, 1998, AMSC announced that it had "completed a $335 million debt offering . . . to fund . . . growth needs."[55]

The money was quickly put to use. In September AMSC announced first that the RD-LAP rollout had accelerated and that it "has an aggressive program to enhance our network services and . . . continue to expand the ARDIS network."[56] This was immediately followed by announcements of two-way paging customers (e.g., Genicom, IBM, Santa Monica Police, Shure Group, Sullivan-Schein Dental), of a $50-million-dollar, 18-month contract with RIM for the new (no lid) pager and OEM radio modems.

19.4.4   Meanwhile, At SkyTel . . .

If the predictions summarized in Table 19-4 were accurate, SkyTel would have the lion's share of ~1 1/2 million ACK-back pagers installed by mid-1998. There would be another million true interactive messaging pagers operational for ~2 1/2 million total two-way paging units. In fact, all of SkyTel's Advanced Messaging devices combined equaled 295,500 units on June 30.[57] The vast majority were Skyword+ units, which provide no sender confirmation, no ability to respond to received messages, and certainly no ability to originate a message at the device. The residual SkyTel two-Way units totaled 80,000, up from 21,600 at year-end 1996. This is a terrific CGR of 139%, common when the starting point is so low. If this growth rate is maintained for the full five years, SkyTel would account for 15% of the 11 million two-way paging units in Table 19-4.

19.5   SUMMARY

At the close of 1998 the only real quantity successes in packet radio have been in vertical markets. These are slow and costly to develop, and the users are generally of sufficient volume to demand highly favorable contract terms for themselves. Even smartphones show up in taxi dispatch applications. Field sales remains a tantalizing opportunity for vertical market development.

In horizontal markets, E-mail has proven not to be the "killer app" if, indeed, such a thing exists at all. The E-mail focus has now shifted to two-way paging—except for the device, not all that different from the messaging applications of the past. Point-of-sale is not a barn burner, and little wireless Web browsing is occurring. This is a tough, slow business.

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20

NETWORK MYTHOLOGIES

20.1 INTRODUCTION

As we reach the end of the book, it is useful to consider the veracity of some of the common old wives' tales that abound in the packet radio arena. These pronouncements are often accepted as gospel when they are anything but. A realistic appraisal of some of these claims will surely help one make more hard-eyed, useful business decisions. Given the state of the wireless data business, a little realism will be a refreshing conclusion.

20.2 CDPD IS AN OPEN STANDARD; ARDIS AND BSWD ARE PROPRIETARY

The claim is ubiquitous. AT&T Wireless says: "AirData is based upon an open, nonproprietary standard."[1] Echoing this theme, Bell Atlantic claims that "AirBridge Packet was designed to provide . . . (an) Open Industry Specification . . . [with a] large variety of vendors designing and building products . . . [so that] end users and customers have a wide variety of choices. . . . Unrestricted competition fosters competitive prices."[2] The CDPD Forum was slightly more nuanced: "The open CDPD Specification means that multiple equipment vendors are able to provide equipment. . . . The . . . user is not restricted to a small number of 'licensed' manufacturers."[3] Consultants are happy to pile on: "CDPD was offered [as] an open specification, permitting anyone to design and manufacture subscriber and/or infrastructure products."[4]

We must ask ourselves two questions concerning these claims:

1. Are they uniquely true?

2. If so, have they had the desired result?

The answer to the first is: Generally no. Mobitex has been an open, nonproprietary protocol for user devices since at least 1988, before IBM even thought of proposing CDPD to McCaw. In 1989—two years before I had heard of CDPD—I received my first terminal specification manuals for the 8-kbps North American system. Mobitex specifications are available to any manufacturer desiring to produce modems or terminals or any programmer wishing to write application software. There are no license fees. Worldwide standardization and compatibility are handled by MOA, the independent Mobitex Operator's Association. Development of infrastructure, however, may well be a sticking point with Ericsson.

The DataTAC (Motorola) situation is now nearly identical to Ericsson. After mistakenly (and stupidly) stonewalling CDPD in 1991, Motorola moved to an open standard, similar to the Mobitex approach in 1992. The specifications have no license fee, but there is a caveat. Assume I am licensed and discover some neat trick while making a device for, say, RD-LAP. I must share this intellectual property with Motorola, who has shared theirs with me, on the same no-charge basis. The DataTAC specifications are managed by WWDNOG, the Worldwide Wireless Data Network Operator's Group. The published WWDNOG objectives[5] are at least as sweeping, arguably even more open and nondiscriminatory, than CDPD's.

The answer to the second question—Does CDPD have more hardware providers than ARDIS or BSWD?—is no. None of the main service providers have a plethora of manufacturers building for them. Recalling Chapter 16, there are basically only seven (some shaky) radio modem vendors for public packet systems. Three (NovAtel, Sierra Wireless, Uniden) deliver products for CDPD. Three (Ericsson, Motorola, RIM) equip BSWD. Two (Motorola, RIM) concentrate on ARDIS. Metricom takes care of Ricochet. There are a number of Australian, European, and Korean manufacturers of DataTAC radio modems, but their concentration on RD-LAP to the exclusion of MDC4800 make them of little value to ARDIS.

The real value of multiple hardware suppliers is competitive pricing. But the high price leader in packet radio modems is Sierra Wireless. No small, relatively inexpensive device such as RIM's I@P can be contemplated for CDPD.

The practical worth of this CDPD claim—zip.

20.3 ARDIS HAS LIMITED CAPACITY

This claim has been made by BSWD for years.[6] It may well be true in some obscure backwater where BSWD has 10 lightly loaded (even unused) half-wide channels and ARDIS has only one full-width channel. But that is just the location where there is no real capacity problem. In intense urban areas such as New York City, ARDIS matches BSWD in capacity potential (see Section 12.5 for details).

BSWD might be better served to give thoughtful attention to CDPD. Without massive infrastructure investments, CDPD *really* has capacity constraints. Even the

use of TCP/IP works against it. You simply have not lived until you have tried to use CDPD in Connecticut's Gold Coast during the rush hour. Will this CDPD constraint be solved by taking over voice channels? We will soon see.

20.4   ARDIS IS OLD TECHNOLOGY

This is another charge levied by BSWD in its customer presentations. It is absolutely true that MDC4800 is a 1982 design. Its bit rate is slow, and its efficiency is low. But MDC4800 is on the way out.

During the third quarter of 1998 ARDIS had 410 operational RD-LAP sites positioned to reach more than 50% of the business population. Installation of the new, faster, more efficient base stations was underway in 11 additional metropolitan areas for fourth quarter 1998 operation. Of the top 25 CSMA/MSAs only Sacramento (area 25) did not yet have RD-LAP, but Portland-Vancouver and Cincinnati-Hamilton (areas 26 and 27) are up, 6 of 10 MSAs in the 30s, some in the 40s, 50s, and 60s—even Sarasota, Florida (area 123) are also up on RD-LAP. The oldest MDC base stations are being scrapped (and cannibalized), with ~200 being replaced with RD-LAP infrastructure in just the Greater New York City and Los Angeles areas.

In truth, the oldest technology is now Mobitex, an ironic twist on the BSWD marketing claim.

20.5   BSWD HAS INFERIOR IN-BUILDING COVERAGE

ARDIS repeats this claim almost as a mantra: "ARDIS Value: Deep In-Building Coverage."[7] In the past the assertion was unmistakably true in those locations having multiple, supporting base stations. But in areas that BSWD has built out for two-way paging, the in-building advantage has disappeared. It is possible to match the ARDIS single-frequency reuse penetration capability with sheer numbers of base stations. There are indications that in the northeast United States, at least, BSWD has begun to do just that (see Section 12.4.3).

20.6   PACKET PROVIDES FASTER ACCESS THAN CIRCUIT BECAUSE IT IS ALWAYS CONNECTED

According to NYNEX promotional literature: "Best of all, CDPD is easy and efficient because it is connectionless—there is virtually no setup time. Once you're on the system there is no need to dial-in to send or receive a data call. This is particularly useful for those . . . who need to remain in constant contact . . . and don't have time to repeatedly dial into the network."[8] Right! If the device you are using has a car battery.

Most devices used with packet systems have inadequate battery life. Some fully charged batteries on CDPD external modems will support only an hour or two of continuous activity, hence end up being plugged into the cigarette lighter all day. If

you want anything approaching a full day of pedestrian activity, you must carry two to three spares—if the device has a pluggable replacement battery!

Short battery life "forces you to change your behavior significantly. . . . Rather than leaving the unit on all the time so that it can receive mail on the fly, there is a tendency to turn it on and off at regular intervals to do mail checks."[9] This is a usage profile more suitable for circuit, not packet, switched data.

CDPD registration times tend to be long, varying somewhat by device. Just think how long it takes your application to come up even if you are using an IBM laptop with the Suspend feature. Many laptops do not have this capability, and the loading of TCP/IP stacks, modem microcode, and application icons can easily take two minutes, often slower than circuit switched dial access time.

The source problem—unacceptable battery life—is decidedly worse on CDPD than ARDIS. The PM100D can survive a long day powered up if 9-volt alkaline batteries are used. The I@P can go a few days powered up, with recharge coming from much cheaper AA batteries. The king of battery performance, however, is BSWD, whose battery-saving protocols extend I@P950 power on time to 500 hours.[10] With that kind of battery life, one really can leave the device turned on all day, something that is just not possible with CDPD.

20.7   CDPD HAS HIGH USER BIT RATES

20.7.1   Big Claims and Shrinking Claims

Glossy Baseline: "AirData is fast—19,200 bits per second—the fastest wide-area wireless data network on the market."[11]

Uninformed "Technical" Limit: "The net bandwidth available to users is 14.4 k/bit/s after overhead is accounted for."[12]

User Qualifier: "Rates of 11 kb/s to 12 kb/s were achieved when CDPD was tested in the San Francisco Bay area."[13]

Informed Technical Estimate: "CDPD's . . . continuously transmitted [outbound channel] . . . yields a 'net rate' of 9.618 kb/s."[14]

Random Measurements: "(Using the Sierra Wireless AirCard) it took nearly 7 minutes to download a 414K file via CDPD."[15] This equates to an effective data rate of ~7.9 kbps.

20.7.2   Combinatorial Pinging: A CDPD Static Bit Rate Test

We know that AT&T Wireless' "fastest on the market" claims are inaccurate; ARDIS brought RD-LAP up operationally in Las Vegas before AT&T could demonstrate CDPD at Comdex. But when will the shrinking stop? Who is right here? How can the user do independent tests, without special equipment, to form a separate opinion?

To obtain some insight, CDPD tests were conducted under extremely favorable conditions: The device was static, an external modem was mounted high in a building

with direct line of sight to a nearby base station, the received signal strength indicator was never less than –69 dB, and the transmit power never had to go beyond level 2. There is no evidence the radio environment was ever hostile.

In the evening, assured by the carrier that other test users had left the system, simple static stress testing was performed with multiple subscriber units. Each of the devices were used to ping the same base station at 1-second intervals with a 2-second time-out. Note that the Chameleon "ping" routine is not precise about time. If one specifies 2 seconds as a permissible time-out, failures will begin to occur at some time greater than 1.8 seconds. The packet loss = 0 point occurred with all three units running 300-octet messages. The statistics are: minimum time 0.933 seconds, average time 1 seconds, and maximum time 1.263 seconds.

Since ping messages have only 32 bytes overhead, this is an effective combined outbound data rate of 996 octets per second: 7968 bps. This is remarkably close to the figure reported in the "random measurement" of Section 20.7.1. User messages have more address overhead than pings, but a best-case rule of thumb of ~8 kbps probably represents an upper limit for CDPD under ideal conditions. Try it yourself at 3:00 AM with your own TCP/IP stack.

20.7.3   Realistic CDPD Bit Rates in a Busy Channel

First, how can anyone have seen an 11–12-kbps rate? Answer: By sending a single, one-way, ~1375-character UDP message, without contention, and measuring just its transmission period. It may well complete in just 1 second, an instantaneous rate of ~11 kbps. But the full second consumed adds to the response time of a contending message waiting to go next.

CDPD airtime protocols were designed to ensure that no single user can dominate network resources. Each carrier can set a parameter for its own system called MAX_BLOCKs. The default setting is 64, which is roughly 2000 bytes. For sake of argument, assume that the carrier has set MAX_BLOCKS to 44, and 1375 user bytes can be delivered in 1 second before control must be relinquished to the next in queue. Assume there are three users on the channel, each asking for a Web site response of several thousand bytes. Then the multisegment responses will look like Figure 20-1.

Over the long haul, with a busy channel, message segments are delivered at an average rate of 1375 bytes every 3 seconds, an effective data rate to each user of 3665 bps. If you gave up on your 14.4-kbps landline modem for Web access and are barely content with 33.6–53 kbps, consider how you will feel at the CDPD rates. In truth,
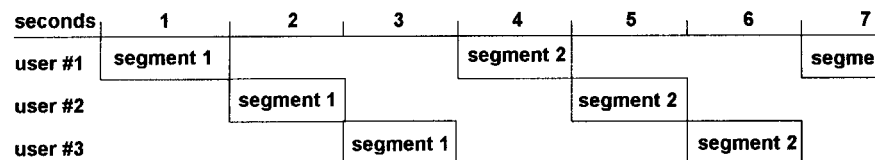
Figure 20-1   Resource competition: outbound channel.

Web access is a lousy way to use CDPD from a user's point of view. You would be better served on circuit switched cellular (or Ricochet). But the carriers would rather have three users paying for this channel than one. If you can stomach it, they will take your money.

20.8   CDPD WILL MOVE TO HIGHER BIT RATES WHEN THEY ARE AVAILABLE

This is conceivable, but only if a new airtime protocol—and new radio modems and base stations—are staged into place. The technical task would be akin to the ARDIS migration to RD-LAP, but on a far grander scale, especially for infrastructure. The magnitude of the effort is such that migration to something totally different, such as the winning technology resulting from the ITU's IMT-2000 initiative, is more likely.

Why would a new airtime protocol be required? The answer is because of the choice of Reed-Solomon coding for forward error correction. Recall from Section 13.2.3 that CDPD's Reed-Solomon implementation takes 35 1/4 bytes, 282 bits, and converts it into exactly forty-seven 6-bit symbols. These are then error encoded to produce exactly sixty-three 6-bit symbols—an efficiency of 47/63 = 74.6%. The resulting 63-symbol block can theoretically withstand 8-symbol errors anywhere in the block. In fact, the undetected error rate is so high at this level that some carriers back off to the better 7-symbol correction. Errors can manifest themselves as 7 random hits, a burst error 7 symbols long, or any combination in between, as shown in Figure 20-2.

Under ideal conditions (no random errors), a CDPD block can withstand a burst error that is

$$19.2 \text{ kbps } 7 \text{ symbols} \times 6 \text{ bits} = 2.19 \text{ milliseconds long}$$

This is just marginally acceptable. Recall that Mobitex (BSWD) can withstand fades of 2.5 milliseconds, and creaky old MDC4800 (ARDIS) can take a 3.3-millisecond hit. One certainly would not want to take CDPD below its current design point.

Now suppose CDPD's raw bit rate could magically be doubled to 38.4 kbps, which, frankly, still is not all that interesting. If the airtime protocol is employed unchanged, the best case fade protection would fall to 1.1 milliseconds—unacceptable! The
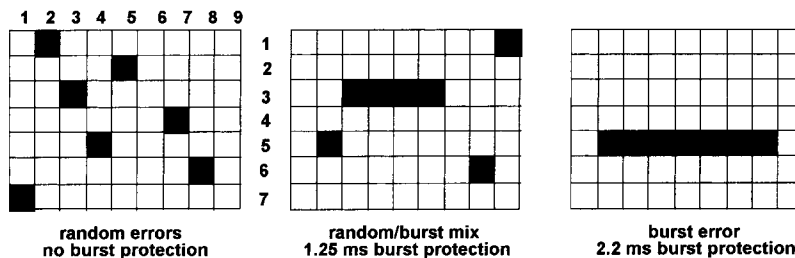
Figure 20-2   Reed-Solomon error correction: CDPD.

protocol, the base stations, and the user radio modems must be changed to accommodate the new error correction scheme. That is truly unlikely.

20.9 ARDIS, BSWD, CDPD (PICK A NAME) WILL BE OUT OF BUSINESS SOON

This claim, referring to ARDIS and BSWD, was first floated in 1991 by members of the carrier consortium that had signed up UPS for a circuit switched cellular solution. The predicted end date was 1992. Now UPS has gone to ARDIS, and each of the carrier presenters have long since left the wireless data business (some with temporary stopovers at CDPD).

Recall the consultant who predicted that "ARDIS and (BSWD) . . . will reach their peaks in total subscribership in 1996 . . . then will suffer rapid business declines . . . and go dark around 2000."[16] Instead, both carriers are having a fine 1998.

In the past BSWD has hinted darkly that ARDIS has an "uncertain future."[17] Don't we all. But in the first quarter of 1998 venture capitalists thought prospects good enough to lend AMSC $335 million "to fund the . . . growth needs of the combined company."[18]

Now it is CDPD's turn: "[The] window of opportunity is closing at the end of [1998]."[19] Or "integrating data into a voice phone is a very good idea, but I believe the idea will succeed in digital cellular and PCS rather than CDPD. . . . CDPD . . . will simply fade away as other networks capture the customers, such as RAM, ARDIS, digital cellular, PCS and Nextel."[20]

There is no question that wireless data is a vicious, tough business—and there have been more than enough casualties—but it is a bit early to call it quits for these three players.

20.10 WHEN WIRELESS DATA SUCCEEDS, IT WILL BE A GREAT BUSINESS!

The one sure consequence of this perception has been to draw in too many players. The wreckage of failed attempts—from CoveragePLUS to Geotek—is stark evidence of how hard this game is. The surviving players engage in fierce price battles to win market share. At these cost points, is there any profit left for anyone?

20.10.1 ARDIS

Before its acquisition by AMSC at the close of 1997, ARDIS claims to have reached the break-even point. But new high-traffic wins at customers such as UPS, and the stinging realization that BSWD had clearly improved its in-building coverage in key metropolitan areas, kicked off a new round of infrastructure expansion. If we could examine just ARDIS, free from its money-losing parent company AMSC, how near is ARDIS likely to be to break even in 1998?

A key expense parameter is the amount of infrastructure employed. ARDIS had 1750 base stations at the close of 1998. About 1000 were DCS vintage, installed in 1983–1985, and are long since amortized. But the balance is much newer, with a rich RD-LAP mix. To simplify the case, assume that the total cost to buy and install a new base station is $60,000. Assume further that an amortization interval of 10 years can be justified. The monthly amortization per new base station is $500; the annual amortization cost for the 750 new base stations is $4.5 million.

Unfortunately, equipment amortization is just the beginning. All 1750 base stations must be maintained, at an annual cost estimated to be ~10% of the original purchase price. This is a nontrivial expense of $10,500,000.

Until recently, each base station had to be served by a unique leased analog line. With modems, and the prorated share of the AT&T licensed space arrangements, it was not out of line to say that each base station cost $500 per month in "Telco" costs. To reduce these charges, consolidation of multiple base stations at one physical location permits the judicious deployment of T1 lines, and even frame relay—though single-frequency reuse timing constraints and dial backup can be a problem with the latter. The average monthly line costs are now estimated to be $400 per base station.

Each base station sits on a rooftop. Some of these are very rural and inexpensive. But most are in premium metropolitan areas commanding top dollar. Further, even the rural rooftop/backyard owners have begun to realize that antenna space is worth money. Assume that the average monthly rooftop cost per base station is $400.

ARDIS also has a payroll to meet. Smaller than its competitors, this "nut" is not out of sight but must be at least $30 million, including benefits. Missing from the equation is the cost of buildings, computers, test equipment, and so on, at Lexington and Lincolnshire. We will add a 20% contingency to pick up at least some of the missing items.

These figures mean that ARDIS needs the following annual revenue to break even:

Wages, salaries	$30,000,000
Contingency (20%)	6,000,000
Base station amortization ($750 \times \$500 \times 12$)	4,500,000
Base station maintenance ($1750 \times \$6000$)	10,500,000
Leased-line costs ($1750 \times \$400 \times 12$)	8,400,000
Rooftop rentals ($1750 \times \$400 \times 12$)	8,400,000
	$67,800,000

We know from the AMSC quarterly report[21] that ARDIS average monthly revenue per subscriber dropped to $52 in the third quarter of 1998, down from ~$75 in 1996. To reach break-even, ARDIS must have

$$\frac{\$67,800,000}{\$52 \times 12} = 108,653 \text{ subscribers}$$

AMSC actually had 101,500 subscribers as of September 30, 1998. Of these, 12,400 were voice users, a slow-growing category not germane to ARDIS. The 89,100 data

subscribers contain a segment that is satellite only, no ARDIS involvement at all. It is probably safe to say that core ARDIS had 80,000 subscribers at the close of the quarter and might approach 85,000–90,000 subscribers by year-end. Core-ARDIS will fall short of break-even in 1998. The coming of UPS quantities in 1999 will drive the subscriber counts well above the target, but there will also be additional base station costs to absorb. Nevertheless, ARDIS will flirt with the break-even point and can be visualized as going into the black, on a period basis, at the millennium—10 years after its beginning.

20.10.2   BSWD

Let us project ahead to the 2500 base station goal BSWD has for two-way paging. Mobitex base stations are often multichannel and more expensive than the ARDIS single-channel units. There is also little, perhaps no, colocation. For this analysis an installed cost of $70,000 per base station with a 10-year amortization period is assumed. The BSWD wireline back-haul problem can actually be more difficult than ARDIS. But some base station line costs will likely be absorbed by parent Bell South mobility in areas where it has cellular service. Thus, a monthly leased line cost of $400 is assumed.

The BSWD payroll is larger than ARDIS, with 330 employees in February 1997.[22] The 1998 payroll cost is almost certainly greater than $35 million.

BSWD has always priced aggressively; its drive toward two-way paging is certain to keep the average revenue per subscriber down. We will assume $48 per month, the price for the (barely) discounted 400-message, two-way pager plan.[23] The BSWD annual costs look something like this:

Wages, salaries	$35,000,000
Contingency (20%)	7,000,000
Base station amortization (2500 × $7000)	17,500,000
Base station maintenance (2500 × $7000)	17,500,000
Leased-line costs (2500 × $400 × 12)	12,000,000
Rooftop rentals (2500 × $400 × 12)	12,000,000
	$101,000,000

The subscriber break-even point is thus

$$\frac{\$101,000,000}{(\$48 \times 12)} = 175,347$$

BSWD may close 1998 at ~50% of that mark and will need three to four more growth years to approach the break-even point. Another approach is to charge off much of BSWD's cost to its own field service users. This is good book-keeping, but not necessarily good business.

20.10.3   CDPD

"The cost is truly trivial," said some CDPD proponents.[24] But this is simply not true. The 1994 average cost to install a CDPD base station was "$50,000 to $75,000 per cell site."[25] We know every cell site in the nation will not be fitted out for CDPD, but suppose the four leading carriers try to convert 30,000 cell sites—possibly half the current nationwide total. Then the combined carriers will face a capital outlay of $1.5–$2.2 *billion*. That is unlikely to happen in a world where money must now be allocated for digital cellular and PCS.

Thus, CDPD is likely to be employed only in regional areas where there is a reasonable shot at (someday) making a period profit—never mind the lost years of earlier investments. The Greater New York City CSMA is one such area. With a population approaching 20 million—8% of the nation—it is not too difficult a task to project a pool of ~300,000 potential two-way wireless data users. Some of this potential will be picked off by circuit switched cellular, some by ARDIS and BSWD (both very strong in field service, about 8–9% of the potential), some by SkyTel2, some by Nextel, some by Omnipoint, but the pool is large and there should be some left for CDPD.

To compete, the two leading carriers must at least complete the infrastructure rollout, and dedicate the necessary channels, in the business area. There also may be unusual business arrangements. AT&T Wireless is unlikely to leave Southern New England to SNET and may strike some sort of CDPD lease arrangement with SNET's new owner, SBC, which will become a CDPD participant with the acquisition of Ameritech.

To estimate the size of the required investment, we will examine just the five boroughs of New York City and the surrounding counties of Connecticut, New Jersey, and New York State. This will be limited. We will exclude counties such as Monmouth in New Jersey, areas of Orange and Putnam Counties in New York, and parts of Pennsylvania, even though they are included in the CSMA definition.

To estimate the number of cell sites, we will divide the geographic area by the cell coverage. The areas of the counties of interest can be obtained at a good library.[26] Cell site radii in New York City tend to be short. One need only drive the Brooklyn Heights, Borum Hill, and Red Hook sections of New York City's most populous borough, look at the rooftops, and watch the odometer to see that a 1/2-mile radius is not uncommon. We'll use 3/4 mile as an average radius for the boroughs. In the border counties we will back off to an average 3-mile radius. Thus, each carrier must erect 304 trisectored CDPD cells, as indicated in Table 20-1. This is not a fantastic number given that NYNEX (pre-BAM takeover) rolled out 176 base stations in its first wave.

Drawing upon the calculations made in Section 11.4.5, each carrier needs 25.4 data users to break even with voice. For CDPD to make sense in Greater New York City, 23,165 subscribers are needed by *each* carrier (25.4 subscribers × 3 sectors × 304 sites). This is a major stretch and will simply not be met short term. If achieved in, say, five years, CDPD would account for ~20% of all two-way data users in the city.

Table 20-1 CDPD base station requirement: New York City CSMA

County/Borough	Square Miles	Number of Cells		Total Cells
		Radius 3 miles	Radius 3/4 mile	
Connecticut				
Fairfield	626	22.1	—	22.1
New Jersey				
Bergen	234	8.3	—	8.3
Essex	126	4.5	—	4.5
Middlesex	311	11.0	—	11.0
Passaic	185	6.5	—	6.5
Union	103	3.6	—	3.6
New York				
Nassau	287	10.2	—	10.2
Suffolk	911	32.2	—	32.2
Rockland	174	6.2	—	6.2
Westchester	433	15.3	—	15.3
New York City				
Bronx	42	—	23.8	23.8
Brooklyn	81	—	45.8	45.8
Manhattan	23	—	13.0	13.0
Richmond	60	—	34.0	34.0
Queens	120	—	67.9	67.9
				304.4

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VI

APPENDIXES

Appendix A

ACRONYMS

ACESS   Pitney-Bowes Automated Customer Support System.

ACK   Acknowledgment. A short-return indication of the successful receipt of a message.

ALOHA   The University of Hawaii data radio system featuring unconstrained contention access on the inbound side. Along with slotted ALOHA, the names given to a class of inbound techniques.

AMPS   Advanced Mobile Phone System. The U.S. standard for analog cellular service.

AMSC   American Mobile Satellite Corporation. A voice and data, geosynchronous satellite system that now owns ARDIS.

AMTA   American Mobile Telecommunications Association.

API   Application program interface.

ARDIS   Advanced Radio Data Information System. A nationwide, packet switched, two-way data radio network. It provides host and third-party connectivity, as well as E-mail and messaging services. Founded in 1990, it is now owned by AMSC and employs Motorola protocols and infrastructure.

ARQ   Automatic repeat request. Retransmission of messages or message segments when an error has been detected.

AVL   Automatic vehicle location.

BAMS   Bell Atlantic Mobile Systems. Formed with the absorption of NYNEX Mobile

BLS   Bureau of Labor Statistics.

bps   Bits per second.

BSC   Binary Synchronous Communication.

BSWD   BellSouth Wireless Data. A subsidiary of BellSouth that is comprised of all the assets of the former RAM Mobile Data. Like ARDIS, it is a nationwide, packet switched, two-way data radio network. Founded in 1990, it employs Ericsson protocols (see Mobitex) and infrastructure.

BTAM   Basic telecommunications access method.

CAD   Computer-aided dispatch.

CAL   Canadian Aeronautics.

CCITT   Consultative Committee International Telegraph & Telephone.

CDI   Cellular Data Incorporated.

C/N   Carrier-to-noise ratio. A power ratio of wanted to unwanted signal, expressed in decibels (dB).

C/I   Carrier to (co-channel) interference ratio in decibels. Interference arising from a nonadjacent identical channel. To satisfy the AMPS quality objective, a system must provide a C/I of 17 dB or greater over 90% of its coverage area.

CDLC   Cellular Data Link Control. A protocol developed by Racal and used by Millicom (among others) to transmit data via cellular connections.

CDPD   Cellular Digital Packet Data. The name employed for systems that are able to share cellular spectrum with voice. It can, and increasingly does, also operate on dedicated spectrum. When sharing, voice has priority. The system is not digital in the sense of being modemless. Its over-the-air modems are GMSK modulated. The systems are regional in nature.

CDMA   Code division multiple access. An approach to sharing radio spectrum in which individual transmissions are separated by encoding. Two common means of encoding are frequency hopping or direct sequence spread spectrum. CDMA is used by Qualcomm in its OmniTRACS system and is one of the technologies used in digital cellular telephone systems. See also FDMA and TDMA.

CGR   Compound Growth Rate.

CRC   Cyclic redundancy check. A mathematical operation applied to data when transmitted. The result, usually two (CRC-16) or four (CRC-32) octets long is appended to the core message. Upon receipt, the same mathematical operation is performed and checked against the CRC. If there is a mismatch, an error has occurred.

CS   Customer service.

CS-CDPD   Circuit switched CDPD.

CSMA   Carrier sense multiple access. The technique used to reduce contention by listening for "busy" indicators before transmitting; an improved throughput technique over ALOHA variations.

CTA   California Trucking Association.

CTIA   Cellular Telecommunications Industry Association.

DBI   Data base interactive.

DCP   Diversified Computer Systems.

DCS   Digital Communication System. The IBM name for its field service system. It was folded into ARDIS in 1990.

DDS   Digital Dispatch Service.

DIAD   Delivery information and acquisition device.

DOJ   Department of Justice.

DRN   Digital Radio Network. Motorola's first public airtime service. Began in 1986 and was folded into ARDIS in 1990.

DSMA   Digital Sense Multiple Access. The "busy bit" implementation of CSMA philosophy.

EBCDIC   Extended Binary Coded Decimal Interchange Code. An 8-bit character representation developed by IBM in the early 1960s.

EC^2   Enhanced Cellular Control.

EDACS   Enhanced Digital Access Communications System. L. M. Ericsson's technology for enhanced SMR.

EMCI   Economic and Management Consultants International.

ERP   Effective radiated power.

ESMR   Enhanced SMR. The most noteworthy pioneer is Nextel, employing Motorola MIRS, or iDEN, integrated Dispatch Enhanced Network.

ESN   Electronic serial number. A unique number for devices, particularly cellular phones. It can be used to trace a phone's location and user.

ETC(2)   Enhanced transmission capability. The protocol employed by AT&T Paradyne for cellular data transfer and licensed by vendors such as U.S. Robotics. It claims fast, robust connection at high (typically ~14.4 kbps) transmission speeds.

FCC   Federal Communications Commission.

FDMA   Frequency division multiple access. A spectrum-sharing technique where the available spectrum is divided into a number of individual radio channels. Also see CDMA and TDMA.

FDX   Full duplex.

FE   Field engineering.

FEC   Forward error correction. Applied to classes of codes that are able to mathematically repair some damage that occurs during radio transmission, thus avoiding a resend.

F-ES   Fixed-end system. The server/host that handles a client device. Used in CDPD.

FLEX   A Motorola protocol employed on existing paging channels. It employs Bose–Chadhuri–Hocquenghem (BCH) coding, along with an interleaving process to minimize burst error effects, and transmits at 6400 bps.

FM   Frequency modulation. A method of transmitting information over a radio wave by changing frequencies.

FSK   Frequency shift keying. Easy to generate (modulate) and detect (demodulate), this simple technique typically causes each bit of data to change only the frequency parameter of the signal sinusoid. It is extravagant in its use of spectrum. At rates above 1200 bps a variety of alternative modulation techniques are usually chosen.

FTP   File Transfer Protocol for TCP/IP.

G   The symbol for offered traffic. The average number of attempted packet transmissions per packet transmission time.

GEOSs   Geostationary satellites. These fixed-position "birds" orbit at an altitude of approximately 22,300 miles.

GMSK   Gaussian minimum shift keying. A modification to FSK with a low modulation index.

GPS   Geographic positioning system. A U.S. government, satellite-based replacement for World War II techniques such as LORAN.

GSM   Groupe Speciale Mobile (Global System Mobile Communications). Pan-European standard for digital cellular telephone systems. GSM uses TDMA with eight slots per carrier, with the carriers spaced 200 kHz apart.

GVTS   Global Vehicle Tracking System.

HDLC   High-level Data Link Control.

HDX   Half duplex.

HTTP   Hypertext Transfer Protocol.

IN   IBM Information Network.

ISDN   Integrated Services Digital Network.

ISM   Industrial, Scientific & Medical Band. Usage requires FCC certification, for example the transmit power is less than 600 mwatts, but no license.

ITA   Industrial Telecommunications Association.

ITC   Interstate Truckload Carriers.

ITU   International Telecommunications Union.

LEAA   Law Enforcement Assistance Administration. The funding agent that stimulated the first commercial uses of data radio technology.

LAN   Local-area network.

LCD   Liquid crystal display.

LD   Locating device.

LEOSs   Low Earth-orbiting satellites. These variable-position "birds" are in polar orbits at altitudes of 420–1200 nautical miles above the earth.

LSA   Licensed space arrangement.

LTL   Less than truckload.

MAPI   Microsoft's Mail Application Programming Interface.

MCC   Meteor Communications Corporation.

MASC   Mobitex asynchronous communication.

MDC   The 4800-bps protocol first deployed by Motorola in 1981, and long the core of ARDIS. It is being phased out in favor of RD-LAP.

MD-BS   Mobile data base station. The term that identifies CDPD base stations as opposed to their voice cellular counterparts.

MDI   Mobile Data International. A Richmond, British Columbia, Canada firm. First (1982) to employ Reed-Solomon coding techniques in commercial devices, their most successful customer was Federal Express. Purchased by Motorola, the company was gradually folded in as a division and now no longer exists as an independent entity.

MD-IS   Mobile data intermediate system. The CDPD control element above the base station, usually located at the MTSO.

M-ES   Mobile-end system. The CDPD acronym for a device with a radio modem.

MHX   Mobitex higher (main) exchange.

MIN   Mobile information number.

MIRS   Motorola Integrated Radio System. An all-digital, high-speed (64-kbps) system for voice and data (including, e.g., paging, facsimile). The first user is Nextel, which brought Los Angeles live in August 1993 and now covers much of the nation.

MMP   The 4800-bps protocol first deployed by MDI in 1982, used by Federal Express, and now being phased out.

MNP   Microcom networking protocol. An error detection/retransmission scheme originally developed for wireline modems. A numbered series of increasingly rich offerings, it includes both data compression and cellular alternatives.

MOA   Mobitex's Operator's Association.

Mobitex   An L. M. Ericsson system that permits both voice and digital data over channels organized in a cellular manner. In the United States, the user is BSWD and voice is neither licensed nor employed.

MOX   Mobitex area exchange.

MRM   Motorola mobile radio modems.

MRNE   Mobile Radio New England. A street-level vehicular system.

MSA   Metropolitan statistical area. The broader area surrounding a given city. The New York City MSA is not just Manhattan but embraces portions of Long Island, Westchester, Connecticut, and New Jersey counties as well.

MTel   Mobile Telecommunications Technologies. SkyTel's parent company.

MTSO   Mobile telephone switching office. Located between a cell site and a conventional wireline switching office, the MTSO links cellular phone calls to the rest of the public landline telephone system. An MTSO also handles the routing of traffic within a system. Because of its hardened, secure facilities, with redundant power supplies, it is typically the site of choice for CDPD's MD-IS controller.

NABER   National Association of Business and Educational Radio.

NAK   Negative acknowledgement. This can be a deliberate signal that the message was received in error or can be inferred by time-out.

NIF   Network Interconnection Facility for Metricom's Ricochet System.

NCC   Network control center for Mobitex systems.

NCL   Native control language.

NCP   Network communications processor. Built originally by Motorola, it is now maintained and upgraded by ARDIS.

NPV   Net present value.

OEM   Other equipment manufacturer.

pACT   Personal Air Communications Technology. An AT&T wireless proposal for 2-way paging over narrowband PCS. The proposal failed in 1996 at great cost to prospective users.

PAD   Packet assembly/disassembly.

PAL   Personal access link. Term used for early PCSI implementation of "smart phone."

PCMCIA   Personal Computer Memory Card International Association. The industry group defining standards for PC cards (the name applied to the cards themselves). These roughly credit card-sized adapters for memory and modem cards, to name a few, come in three thicknesses: 3.3, 5, and 10.5 mm.

PCS   Personal communications services. An evolving term with many meanings. Narrow-band PCS is a term used to describe Skytel's data-only, two-way paging systems. More commonly, PCS refers to microcellular wireless services providing voice, paging, and short-message data communications. In selected areas it is a clear, viable alternative to conventional cellular offerings. PCS sometimes refers to one-number services that associate a number with an individual. The microcellular design permits low-power operation, allowing smaller, lighter telephones with a longer time between battery charges.

PCSI   Pacific Communication Sciences. An early participant in CDPD design, it offered a variety of multiprotocol modems. The company failed in May 1997.

PDA   Personal digital assistant. Common characterization of devices such as the 3Com PalmPilot, Everex Freestyle, or HP620LX.

PDN   Public data network.

PLMP   Private land mobile radio.

PPP   Point-to-point protocol.

PSK   Phase shift keying.

PSTN   Public switched telephone.

QAM   Quadrature amplitude modulation.

RAM   (a) The short name applied to RAM Mobile's public, two-way data radio service. RAM became operational in 1990 and, in steps, became wholly owned by BellSouth Mobility in 1998. See BSWD. (b) Random-access memory.

RAP   RIM's radio access protocol.

RBOC   Regional Bell operating company.

RD-LAP   Radio data link access procedure. The 19,200-bps Motorola protocol first deployed commercially by ARDIS in October 1992.

ReFLEX   A Motorola protocol used for narrow-band PCS. While there are many variants, a one-of-a-kind implementation, ReFLEX50, is used by Skytel. An unbalanced protocol, it uses high-speed FLEX outbound, employing simulcast to greatly improve building penetration. There are multiple, 9600-bps inbound receivers for each outbound transmitter. ReFLEX trades off long latency in order to greatly extend device battery life.

RFP   Request for proposal.

RFC   Request for comment.

RIM   Research-In-Motion.

RM   RadioMail.

ROM   Read-only memory.

RSSI   Received signal strength indicator.

S   The symbol for steady-state network throughput, the average number of successful transmissions per packet transmission time.

SABRE   American Airline's reservation system whose original heritage drew on the developments of the SAGE system.

SAGE   Semi-Automatic Ground Environment. The U.S. Air Force air defense system developed in the 1950s. A pioneer in data transmission, in 1956 it began to use data broadcast by radio from airborne early warning aircraft to land base stations.

SDLC   Synchronous data link control.

SEC   Securities and Exchange Commission.

SFR   Single-frequency reuse.

SMF   Novell's Standard Message Format.

SMRS   Special mobile radio. Originally an analog voice dispatch system, SMR frequencies are now being used to support digital voice and data. SMR was originally local but has become nationwide via carriers such as Nextel.

SMS   Short-message service.

SMTP   Unix's Simple Mail Transfer Protocol.

SNA   IBM's System Network Architecture.

SNADS   IBM's SNA Distribution Services.

SNET   Southern New England Telephone.

SSI   (a) Signal strength indicator. Sometimes called RSSI for received signal strength indicator. (b) Service Systems International.

TCM   Trellis-coded modulation. Additional (redundant) signal points added to a transmission, with only specific patterns of allowable sequences. If an impairment

occurs, the closest pattern is selected to correct errors without retransmission. It is backed up by a CRC in case the correction decision is incorrect.

TCP/IP   Transmission control protocol/internet protocol. Standard protocols that define both the reliable full-duplex transport level and the connectionless, "best effort" unit of information passed across an Internet. Developed for wireline systems, it is used with little change for CDPD applications.

TDMA   Time division multiple access. An approach to access control that subdivides the channel into multiple time slots. A particular form of TDMA was developed by L. M. Ericsson, and embraced by AT&T Wireless, as their voice technologies for digital cellular telephone service. See also CDMA and FDMA.

TRIB   Transfer rate of information bits. The number of information bits accepted and the total time needed to send all bits (sync, header, CRC) to get those information bits accepted.

TWX   Trans-Western Express.

UBER   Undetected bit (sometimes block) error rate. The percent of errors that escape error correction or detection and pass into the system.

UDP   User datagram protocol. UDP uses the underlying Internet protocol (IP) to transport a message. This is an unreliable, connectionless delivery scheme. It does not use acknowledgments to make sure that messages arrive and does not provide feedback to control the rate of information flow. UDP messages can be lost, duplicated, or arrive out of order. In addition to the data, each UDP message contains both a destination and source number; thus the user can construct a more reliable application.

UVL   United Van Lines.

VAN   Value-added network. Wireline transmission facility such as America On-Line, CompuServe, Geisco, Telenet, and Tymnet, which are employed to connect private computing facilities to data radio switching centers.

VIM   Lotus' Vendor Independent Messaging.

VLSI   Very large scale integrated.

VTAM   Virtual Telecommunications Access Method.

WAM   Wide-area mobile. As in WAM workers.

WAN   Wide-area network.

WAP   Wired access point for Metricom's ricochet system.

WRQ   Walker, Richer, and Quinn.

Xcvr   Transceiver. A combination radio transmitter and receiver.

Appendix B

IBM AUTO-ALERT

IBM EXTENDS THE RANGE OF THE COMPUTER

Many law enforcement agencies use computer installations to provide centralized data banks of "auto-alert" information on stolen or wanted vehicles. IBM can now extend the power of computer systems directly to the policeman in the patrol car, on motorcycle, or walking a city beat. Using a new low-cost mobile/portable keyboard entry system developed by IBM, police can submit motor vehicle queries to a central computer via standard police radio channels. Status replies from the computer are communicated to the officer through audio-response computer-generated words.
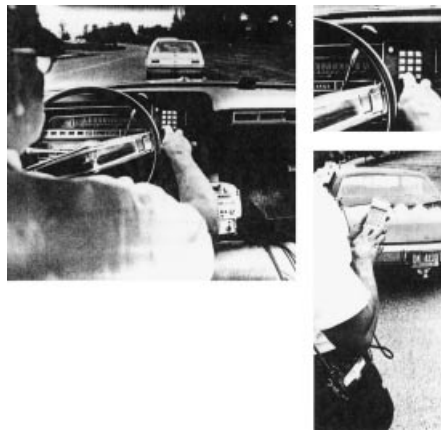
Figure B-1

Appendix C

TCP/IP COUNT: BAM INBOUND MESSAGE

Packet Number	In	Out	Partially Deciphered Content
1	47		198.223.16.187 199.74.157.30
2		46	199.74.157.30 198.223.16.187
3	43		198.223.16.187 199.74.157..30
4		159	220 mail.airbridge.net ESMTP server (Netscape Messaging Server—Version 3.0) ready Fri. 14 Aug 1998 15:58 18—0400
5	67		EHLO mail.airbridge.net
6		137	250 mail.airbridge.net..250-HELP..250EXPN..250-ETRN.. 250-PIPELINING..250-DSN..250-AUTH=LOGIN
7	68		AUTH LOGIN amt3b2xl
8		61	199.74.157.30 198.223.16.187
9	56		198.223.16.187 199.74.157.30
10		42	199.74.157.30 198.223.16.187
11		73	235 Authentication successful.
12	82		MAIL FROM:<jkwolek@mail.airbridge.net
13		86	250 Sender <jkwolek@mail.airbridge.net > OK
14	76		RCPT TO:<jkwolek@mobile.bam.com
15		42	199.74.157.30 198.223.16.187
16		86	250 Recipient <jkwolek@mobile.bam.com>OK
17	49		198.223.16.187 199.74.157.30 DATA
18		42	199.74.157.30 198.223.16.187

Packet Number	In	Out	Partially Deciphered Content
19		43	Ok Send data ending with <CRLF>.<CRLF>
20	471		Message-ID: <35D4971B.6B74064E@mail.airbridge.net> Date: Fri, 14 Aug 1998 15:59:24 –0400 From: "John P. Kwolek" <jkwolek@mail.airbridge.net> Reply To: jkwolek@mail.airbridge.net. Organization: Bell Atlantic Mobile..X-Mailer: Mozilla 4.04 [en] (Win95; IMIME–Version: 1.0. To: jkwolek@mobile.bam.com. Subject: $$$$$$ Content-Type: text/plain; charset=us-ascii Content-Transfer-Encoding: 7bit. Message sent with $$$$$$
21	37		198.223.16.187
22		42	199.74.157.30 198.223.16.187
23	47		198.223.16.187 199.74.157.30
24		42	199.74.157.30 198.223.16.187
25	37		198.223.16.187
26		107	250 Message received: 19980814195818.AAA7371@mail.airbridge.net
27	46		198.223.16.187 199.74.157.30 QUIT
28		42	199.74.157.30 198.223.16.187
29	42		198.223.16.187 199.74.157.30
30		42	199.74.157.30 198.223.16.187
31		42	199.74.157.30 198.223.16.187
32	42		198.223.16.187 199.74.157.30
	1,210	1,134	

Hex C0 = SLIP starter.
Hex '45' = TCP.
C0C0 = end/start packet.
Device address = 199.74.157.30.
Server address = 198.223.16.187.
Subject: $$$$$$.
Message: message sent with $$$$$$.

Appendix D

NUMBER OF ARDIS SUBSCRIBERS

Subscribing Company	1990	1991	1992	1993	1994	1995	1996	1997	3Q98
IBM Field Service	15,000[1]	14,250	13,500	13,00[2]	12,000[3]	11,750	11,500	11,250	11,000
Sears	600	600	600	600	600	1,000[4]	5,000[5]	7,000[6]	7,000[7]
UPS	475[8]	700[9]	1,500[10]	1,500	1,500	1,500	1,500	1,500	1,500
Motorola	234[11]	234	234	234	234	234	234	234	234
AT&T Global Information	153[12]	3,300[13]	4,000[14]	4,250	4,500[15]	4,500	4,500	4,500	4,500
Tandem Computer[16]	133	133	133	133	133	133	133	133	133
Xerox[17]	70	70	70	—	—	—	—	—	—
New York City Transportation Dept.[18]	60	60	60	60	60	60	60	60	60
City of Newark[19]	40	40	40	40	40	40	40	40	40
Otis Elevator	30[20]	1,000	2,000[21]	2,000	2,000	2,000	2,000	2,000	1,900[22]
City of New York[23]	28	28	28	28	28	28	28	28	28
Westinghouse Beverage Group[24]	20	20	20	20	20	20	20	20	20
Red Arrow Messenger[25]	17	17	17	17	17	17	17	17	17
Sorbus[26]	16	16	16	16	16	16	16	16	16
PARSEC #1[27]	15	15	15	15	15	15	15	15	15
City of Hermosa Beach[28]	12	12	12	12	12	12	12	12	12
BTI Midwest[29]	10	10	10	10	10	10	10	10	10
W.W. Grainger[30]	10	10	10	10	10	10	10	10	10
Matson Navigation[31]	10	10	10	10	10	10	10	10	10
Maersk	8[32]	8	24	40[33]	40	40	40	40	40
LA Dept. of Transportation[34]	8	8	8	8	8	8	8	8	8
Long Beach Container Terminal[35]	8	8	8	8	8	8	8	8	8
Charles River Computer[36]	7	7	7	7	7	7	7	7	7
Chicago Transit Authority[37]	6	6	6	6	6	6	6	6	6
Peoples Gas, Coke and Light[38]	6	6	6	6	6	6	6	6	6
United Air Lines[39]	5	5	5	5	5	5	5	5	5
AIC Security[40]	5	5	5	5	5	5	5	5	5

Subscribing Company	1990	1991	1992	1993	1994	1995	1996	1997	3Q98
Coast Club Service[41]	5	5	5	5	5	5	5	5	5
Wagstrom-Cartwright Computer[42]	5	5	5	5	5	5	5	5	5
Avicom International[43]	5	5	5	5	5	5	5	5	5
Citicorp TTI[44]	5	5	5	5	5	5	5	5	5
ADAQ Systems Corp.[45]	5	5	5	5	5	5	5	5	5
Group Health, Inc.[46]	5	5	5	5	5	5	5	5	5
Dow Jones[47]	5	5	5	5	5	5	5	5	5
Chicago Research & Trading[48]	4	4	4	4	4	4	4	4	4
INET[49]	4	4	4	4	4	4	4	4	4
Stay Green, Inc.[50]	4	4	4	4	4	4	4	4	4
Dial One AA Johnson Plumbing[51]	4	4	4	4	4	4	4	4	4
West Coast Express[52]	4	4	4	4	4	4	4	4	4
Metromedia Paging[53]	4	4	4	4	4	4	4	4	4
Honeywell[54]	3	3	3	3	3	3	3	3	3
CE Associates[55]	3	3	3	3	3	3	3	3	3
AMA[56]	3	3	3	3	3	3	3	3	3
Movie Express[57]	3	3	3	3	3	3	3	3	3
National Valet Service[58]	3	3	3	3	3	3	3	3	3
CBS[59]	3	3	3	3	3	3	3	3	3
SIE, Inc.[60]	3	3	3	3	3	3	3	3	3
NYC Marshals: Airday, Burko[61]	3	3	3	3	3	3	3	3	3
Databroker Systems[62]	2	2	2	2	2	2	2	2	2
Nielsen Market Research[63]	2	2	2	2	2	2	2	2	2
Baxter Healthcare[64]	2	2	2	2	2	2	2	2	2
Illinois Bell[65]	2	2	2	2	2	2	2	2	2
White Way Sign[66]	2	2	2	2	2	2	2	2	2
JAD Co.[67]	2	2	2	2	2	2	2	2	2

Subscribing Company	1990	1991	1992	1993	1994	1995	1996	1997	3Q98
CCC Development[68]	2	2	2	2	2	2	2	2	2
Alpha Page[69]	2	2	2	2	2	2	2	2	2
Port Authority of NY/NJ[70]	2	2	2	2	2	2	2	2	2
Carolyn O'Connor[71]	2	2	2	2	2	2	2	2	2
Quotron[72]	1	1	1	1	1	1	1	1	1
QED Ringmaster[73]	1	1	1	1	1	1	1	1	1
Pitney Bowes		3,200[74]	3,000	2,800[75]	2,800	2,800	2,800	2,800	2,800
Avis		157[76]	163	175[77]	175	175[78]	175	175	175
Fujitsu/ICL[79]		100	200	400	400	400	400	400	400
G.O.D.		25[80]	75[81]	—	—	—	—	—	—
AT&T Paradyne		15[82]	75[83]	700[84]	700	700	700	700	700
NYC Sheriff		10	55	100[85]	100	100	100	100	100
Dataserv, Inc.[86]		4	4	4	4	4	4	4	4
Fleet Maintenance[87]			110	110	110	110	110	110	110
Coca-Cola[88]			68	300	300	300	300	300	300
Jacob Sampson[89]			1	1	1	1	1	1	1
Unisys[90]				40	40	40	40	40	40
Great Western Bank[91]				18	18	18	18	18	18
Waste Management[92]				17	17	17	17	17	17
Liebert[93]				25	25	25	25	25	25
Sonic Air[94]				200	200	200	200	200	200
Willet Freight Services				25[95]	65[96]	65	65	65	65
National Guardian					1,000[97]	5,000[98]	5,000	5,000	5,000
RadioMail → 2way. net					600	720	610	500	380
Bank of America[99]					400	400	400	400	400
Viacom[100]					100	100	100	100	100
Old Dominion Freight Line[101]					65	65	65	65	65

Subscribing Company	1990	1991	1992	1993	1994	1995	1996	1997	3Q98
Wilson Sporting Goods[102]					52	—	—	—	—
Memorex Telex[103]					29	29	29	29	29
HomeBase[104]						79	79	79	79
Umthun Trucking,[105] 46 others[106]						400	8,200	8,200	8,200
JS Express[107]						70	140	210	285
Lanier[108]							200	200	750
CNF Transponation[109]									1,300
Schindler Elevator									800
Genicom									500
Sullivan-Schein Dental™[110]									360
Checkpoint Systems[111]									200
Colorado Springs Utility									75
Totals	17,087	24,194	26,200	27,060	28,596	33,363	45,073	46,783	49,038

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30. FCC Loading Records (licensed 7-24-90).
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Appendix E

NUMBER OF BSWD SUBSCRIBERS

Subscribing Company	1991	1992	1993	1994	1995	1996	1997	3Q98
Hoboken Fire Dept.	5[1]	5	5	5	5	5	5	5
MB Trucking	8[2]	8	8	8	8	8	8	8
National Car Rental[3]	80	165	335	670[4]	670	670	670	570
Orlando County Sheriff	20[5]	20	20	20	20	20	20	20
American Courier Express		2[6]	—	—	—	—	—	—
Chicago Parking Authority[7]		20[8]	20	20[9]	20	20	20	20
All Ways Courier			5	5	5	5	5	5
Bell Ambulance (Milwaukee)			5[10]	5	5	5	5	5
Burger King (MasterCard)			18[11]	18	18	18	18	18
California Highway Patrol			34[12]	34	34	34	34	34
Conrail			300[13]	300	300	300	300	300
G.O.D.			125[14]	125	125	125	125	125
Hobart Field Service			11[15]	25	25	25	25	25
RadioMail			750	1,400[16]	1,270	1,140	1,010	—
WyndMail				100	200	400[17]	1,000[18]	1,400
Zap-it (DTS Wireless)			50	100	200	400	800	1,200
Robison Oil (Elmsford)			40[19]	52[20]	52	52	52	52
Southwestern Gas Corp			10[21]	75[22]	180	287	287	287
Washington, DC Police			22[23]	330[24]	330	330	330	330
BASF (Field Sales)[25]				30[26]	30	30	30	30
Boston Edison				20[27]	55	90[28]	90	90
Charlotte Airport Mastercard				12[29]	12	12	12	12
GE Appliances[30]				1,000[31]	1,000	1,000	1,000	1,000
GE Computer Services[32]				125[33]	125	125	125	125
GE Consumer Services[34]				300[35]	300	300	300	300
Keebler				550[36]	550	550	550	550
Kodak[37]				160[38]	160	160	160	160
National Computer Systems[39]				200[40]	200	200	200	200
Oracle (Field Sales)[41]				200[42]	200	200	200	200

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Subscribing Company	1991	1992	1993	1994	1995	1996	1997	3Q98
Overland Park Fire Dept.				12[43]	12	12	12	12
Physician Sales & Services				300[44]	550	800	800	800
Regional Justice Information Service				175[45]	175	175	175	175
Roadway Global Airways				500[46]	500	500	500	500
Transus (Atlanta Trucking)				100[47]	100	100	100	100
Transys (Field Service)				20[48]	20	20	20	20
Unisys[49]				300[50]	540	540	540	540
Pepsi-Allied				10	25[51]	43[52]	43	43
Coca-Cola Bottling: Nashville					400	—	—	—
Bank of America					200[53]	200	200	200
Federal Express (Human Resources)					55[54]	60	60	60
Williams Brothers Lumber					40[55]	40	40	40
Quick Delivery Service					45[56]	45	45	45
Jacksonville Power & Light					35[57]	35	35	35
Illinois Power						400[58]	400	400
Caligor Medical Division						35[59]	35	35
Olivetti						325[60]	325	325
Southwest Gas Corp.						287[61]	287	287
Neopost						180[62]	180	180
Sears							1,000	5,000[63]
Time-Warner							200[64]	200
Pacific Gas & Electric							175[65]	1,200
Averitt Express							12[66]	12
Progressive Corp.								2,000[67]
MCI								1,200[68]
Virginia Power								800[69]
Henrico County, VA Police								400[70]
Detroit Edison								300[71]
Totals	113	220	1,758	7,321	8,811	10,323	12,580	21,995

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Appendix F

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NUMBER OF CDPD SUBSCRIBERS

Subscribing Company	1995	1996	1997	2Q98
Alltel Mobile				
Duke (NC) Power[1]				
Ameritech				
Clawson Concrete[2]			100	100
American Family Insurance[3]			1	1
SAFCO[4]				
Anderson Consulting[5]				
UAL ground service vehicles: O'Hare[6]				
AT&T Wireless				
Sabre Group[7]	8	8	8	8
Robison Heating Oil[8]		46	100	100
West Jordan, UT, police[9]		38	38	38
Seminole County, FL, Sheriff's Dept.[10]		136	136	136
Layton, UT, police[11]			37	37
Jacksonville, FL, police[12]			150	150
Business Class Transportation[13]				200
Texas Liquor Verification[14]				200
Dine One One[15]				55
McKinney, TX, police[16]				12
Seattle Community Corrections Officers[17]				

Subscribing Company	1995	1996	1997	2Q98
Bell Atlantic Mobile				
Groton, CT, police[18]	20	20	20	20
Bethlehem, PA, police[19]	5	22	22	22
Public Service Electric & Gas[20]		750	1,000	1,000
Somerville, NJ, police[21]		35	35	35
Philadelphia, PA, police[22]		70	250	600
Delaware State Police[23]		6	50	50
Alexandria, VA, police[24]		30	85	125
Columbia, PA, Gas (telemetry)		12	12	12
Walsh Messenger[25]		150	157	157
Hermitage, PA, police[26]			5	5
Greenville, SC, police[27]				30
Washington, DC, police[28]				14
Burns & McBride[29]				
Boston Edison[30]				
Clinton, NJ, police[31]				
Virginia Natural Gas[32]				
ConTel Cellular				
Virginia Natural Gas[33]	80	80	80	80
GTE Mobilecomm				
San Diego police[34]	41	41	41	41
Lakeland, FL, police[35]		140	140	140
Nashville, TN, police[36]				
San Francisco police[37]				
Southwestern Bell				
Richardson, TX, police			35	35
SNET Mobility				
39 Connecticut town police departments[38]			300	600
Total	154	1584	3102	4003

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Appendix G

NUMBER OF HIGHWAYMASTER SUBSCRIBERS

Subscribing Company	1996	1997	1998
Wal-Mart[1,2]	350	3,000	3,000
Contract Freighter, Inc[3,4]	50	50	300
AmeriTruck Distribution[5]	2,000	2,000	2,000
Sam Hedge (Midwest Coast Transport)[6]	10	10	10
Burlington Motor Carriers[7]	—	2,000	2,000
American Freightways[8]	—	2,000	2,700
Ryder Systems, Inc[9]	—	—	1,500
Total identifiable	2,410	9,060	11,510
Total reported	20,354	33,122	39,673
Percent identified	11.8	27.4	29.0

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Appendix H

NUMBER OF OMNITRACS SUBSCRIBERS

Subscribing Company	Omni-TRACS	Install		Source	Date
		Begin	End		
Schneider National Van	5,000	1988	8/89	Satellite News	12-5-88
Munson Transportation	1,000		10/90	Mobile Data Report	2-15-89
Direct Transit	1,300			Industrial Communications	10-27-89
R&D Trucking	200			Industrial Communications	10-27-89
Leaseway Technology	200			Industrial Communications	10-27-89
Waggoner's Trucking	200			Industrial Communications	10-27-89
Boyds Brothers	300			Industrial Communications	3-2-90
Roberts Express	1,150		12/90	Mobile Data Report	5-7-90
Star Delivery	250			Mobile Data Report	6/90
Northern Telecomm	40			Mobile Data Report	6-18-90
Arrow Trucking	250			Mobile Data Report	11-16-90
MNX	700			Mobile Data Report	12-3-90
Thermo King	400	12/90		Mobile Data Report	12-14-90
TRM Starcom	35		10/91	En Route Technology	2-5-92
U.S.Xpress	800			Mobile Satellite News	12/91
Victory Express	400	1991	3/92	En Route Technology	3-18-92
Buske Lines, Continental Express, Creech Brothers Truck, Pryslak Trucking, Rich Refrigerated Intl.	1,000			En Route Technology	3-18-92
J.B. Hunt	2,500	5/92	9/93	OmniTRACS Milestones 1993	Web site
KLLM Transport				En Route Technology	4-15-92
Star Delivery				En Route Technology	4-15-92
Interstate Distributor				En Route Technology	4-15-92
Navajo Express	675	4/92		En Route Technology	4-29-92
Maverick Transportation	200	2/92	5/92	En Route Technology	8-5-92
Digby Truck Lines, Goodway, Landair Transport, Dick Simon Trucking, Trans State Lines, Wiley Sanders	1,400			Mobile Satellite Report	9-14-92
Werner Enterprises	2,700			Mobile Satellite Report	10-12-92
Freymiller Trucking	700			Mobile Satellite Report	11-9-92
C.R. England & Sons	1,150			Mobile Satellite Report	2-17-92
Appalachian Freight, Daymark, Donco, Eaglewings Systems, Foreway Transportation, RTC	1,300			Mobile Satellite Report	12-21-92

Subscribing Company	Omni-TRACS	Install Begin	Install End	Source	Date
Prime	850			*En Route Technology*	12-21-92
CCC Express, North American Van Lines, Jevic Transportation, Westway Express				*Telecomm Report*	3-29-93
Marten Transport	735			*Telecomm Report*	4-5-93
Buford TV (Tyler, TX)	70			*Communcation Daily*	6-10-93
Builder's Transport	2,750	1993		*Edge On & About AT&T*	10-18-93
Clean Harbors Environmental, Cox Transportation, Van Eerden Trucking	261			*TelecomAlert*	9-3-93
Chemical Leaman Tank Line	500			*Communcation Daily*	11-2-93
Covenant Transport	800			*Communcation Daily*	11-16-93
Galaxy Cablevision	50			*Telecomm Report*	12-6-93
Thomas Transport	500			*Mobile Satellite Report*	12-20-93
M.S. Carriers	2,000			*Communcation Daily*	1-18-94
Epes Carriers	500			*Mobile Satellite News*	2-2-94
Trism Transportation	1,000		7/94	*Communcation Daily*	4-29-94
Celadon Transportation	625		5/94	*Mobile Radio News*	5-27-94
Anderson Trucking	540			*Mobile Satellite Report*	6-6-94
Manfredi Motors	150	9/94		*TeleComm World*	8-11-94
Independent Freightways, Ranger Transportation	1,000	12/94	1995	*Satellite News*	12-19-94
Tyson Foods	1,000	1/95		*OmniTRACS Milestones 1995*	Web site
Schneider	5,000			*Edge On & About AT&T*	1-23-95
Gainey Corp	1,500	3/95	9/95	*Satellite News*	3-21-95
Miller Transporters	350			*Mobile Satellite News*	4-6-95
Crete Carrier	4,000			*Edge On & About AT&T*	4-24-95
Lane Trucking	182			*Mobile Satellite News*	5-4-95
Tri-State Expedited	1,000	1995	1999	*Communication Today*	8-16-95
Amtrak	80			*Communication Daily*	9-7-95
Consolidated Freightways	1,000	11/95		*OmniTRACS Milestones 1995*	Web site

Subscribing Company	Omni-TRACS	Install Begin	End	Source	Date
Silver Eagle Transport	500	1996		*Communication Daily*	12-18-95
Bulldog Hiway Express	200	1996	1996	*MobileComm Report*	1-29-96
Ozark Motor Lines	1,000	1996	2000	*Communication Daily*	1-31-96
Bud Meyer Truck Lines	350	1996	1996	*Communication Daily*	1-31-96
G&P Trucking Line	500	1996	1996	*Communication Today*	2-22-96
R&J Trucking	500	1996	1996	*Communication Today*	3-6-96
J.B. Hunt (augmentation)	1,500		3/96	*OmniTRACS Milestones 1996*	Web site
P.A.M. Transportion Services	1,000	1996	2000	*Communication Daily*	5-2-96
Superior Carriers	700	1996	2000	*MobileComm Report*	7-15-96
Boatracs	15	1996	1996	*Communication Daily*	6-27-96
Global Van Lines	300	1996	2000	*Edge On & About AT&T*	7-29-96
National Freight	900	1996		*M2 Presswire*	8-12-96
Comcar	2,400	1996		*Communication Daily*	9-18-96
US Xpress	2,400	1996		*Traffic World*	11-4-96
Pacific Gas & Electric	200	1996	1997	*Communication Daily*	12-5-96
Matlack Systems	1,174	1997		*Communcation Daily*	1-7-97
Melton Truck Lines	500	1997		*Qualcomm Release*	3-10-97
Miller Transporters	350	1997		*Satellite News*	4-10-97
Transportation Services	360	1997		*Wireless Bus/Fin*	4-23-97
Schneider National (augment)	2,000	1997		*Communication Today*	7-2-97
Metal Transportation	660	1997		*Qualcomm Release*	7-22-97
Buford Television (augment)	230	1997		*Qualcomm Release*	7-22-97
Paschall Truck Lines	1,000	1997	2001	*Qualcomm Release*	7-30-97
FTI	1,000	1997		*Satellite News*	8-18-97
PST Vans	2,000	1997		*Qualcomm Release*	10-1-97
USA Truck	2,000	1997	2001	*Qualcomm Release*	10-9-97
Continental Express	750	1998	2002	*Qualcomm Release*	1-7-98
Penske Logistics	4,600		1998	*Qualcomm Release*	3-31-98
Covenant Transport	3,400	6/98		*Qualcomm Release*	7-22-98
Total	82,782				

Appendix I

CONNECTICUT BASE STATION SITES

A. *ARDIS Base Stations*

Site Number	Street	City	County	Latitude	Longitude
1	267 Grant Street	Bridgeport	Fairfield	41° 11'22"	73° 31' 0"
2	Bushy Hill Road	Danbury	Fairfield	41° 21'47"	73° 26'35"
3	289 Greenwich Avenue	Greenwich	Fairfield	41° 1'40"	73° 37'30"
4	4 St. Mary's Lane	Norwalk	Fairfield	41° 8'12"	73° 24'53"
5	101 Route 7 North	Norwalk	Fairfield	41° 9' 4"	73° 25'34"
6	40 Richards Avenue	Norwalk	Fairfield	41° 5'32"	73° 27' 0"
7	Tenneco Plant, 4.5 miles SW	Shelton	Fairfield	41° 15'37"	73° 8'30"
8	60 Strawberry Hill Court	Stamford	Fairfield	41° 3'39"	73° 32' 2"
9	515 Post Road East	Westport	Fairfield	41° 8'19"	73° 20'31"
10	Rattlesnake Mountain	Farmington	Hartford	41° 42' 2"	72° 49'57"
11	40 Woodland Street	Hartford	Hartford	41° 46'11"	72° 42' 6"
12	One Commercial Plaza	Hartford	Hartford	41° 46' 7"	72° 40'33"
13	123 Day Hill Road	Windsor	Hartford	41° 51'10"	72° 41' 0"
14	16 Ella T. Grasso Turnpike	Windsor Locks	Hartford	41° 55' 3"	72° 40'31"
15	Highland Ave. 600 ft east of west side	Torrington	Litchfield	41° 48' 8"	73° 9'50"
16	8 Harbor View South	Essex	Middlesex	41° 20'29"	72° 23'40"
17	Route 66 and Jackson Hill Road	Middlefield	Middlesex	41° 32'41"	72° 42'41"
18	1000 Middle Street	Middletown	Middlesex	41° 35'58"	72° 43'14"
19	54 Finney Street	Ansonia	New Haven	41° 19'57"	73° 3'36"
20	925 Mix Avenue	Hamden	New Haven	41° 22'41"	72° 55'10"
21	W. Peak Meriden Mountain	Meriden	New Haven	41° 33'52"	72° 50'36"
22	127 Boston Post Road	Milford	New Haven	41° 14'45"	73° 1'45"
23	265 College Street	New Haven	New Haven	41° 18'31"	72° 55'51"
24	IBM Building, Kettletown Road	Southbury	New Haven	41° 28'10"	73° 12'32"
25	Warner Tract Ext. Garden Hill Cir.	Waterbury	New Haven	41° 34'14"	73° 1' 0"
26	Egerton Road	Wallingford	New Haven	41° 25' 5"	72° 49'16"
27	428 Long Hill Road	Groton	New London	41° 21'25"	72° 3'39"
28	88 Fountain Street	Norwich	New London	41° 31'43"	72° 4'49"
29	Bumpin Hill White Rock Road	Pawcatuck	New London	41° 24'23"	71° 50'15"
30	2110 Hillside Road	Storrs	Tolland	41° 48'53"	72° 15'35"

Site Number	Street	City	County	Latitude	Longitude
	B.	*BSWD Base Stations*			
1	961 Main Street	Bridgeport	Fairfield	41° 10'39"	73° 11'24"
2	Corner of Westview and Beechwood	Danbury	Fairfield	41° 23'44"	73° 25'25"
3	36 Center Road	Easton	Fairfield	41° 15' 5"	73° 17' 1"
4	Greenwich Plaza	Greenwich	Fairfield	41° 1'15"	73° 37'30"
5	Guinea Road	Monroe	Fairfield	41° 20'28"	73° 16'31"
6	200 Connecticut Avenue	Norwalk	Fairfield	41° 6'15"	73° 26' 0"
7	South St. Town Transfer Station	Ridgefield	Fairfield	41° 17'27"	73° 29'16"
8	Peacable Ridge	Ridgefield	Fairfield	41° 17' 2"	73° 31'30"
9	Off Buddington Road	Shelton	Fairfield	41° 17'44"	73° 6'48"
10	44 Strawberry Hill Court	Stamford	Fairfield	41° 3'54"	73° 32' 4"
11	Intersection of Video Lane and Booth Hill Road	Trumbull	Fairfield	41° 16'46"	73° 11' 9"
12	Deer Run Road off Gilly Lane	Wilton	Fairfield	41° 14'30"	73° 28'15"
13	81 Montevideo Road	Avon	Hartford	41° 48'10"	72° 48' 4"
14	2 Oldtown Road	East Hartford	Hartford	42° 0' 1"	72° 54'23"
15	Route 6 Colt Highway	Farmington	Hartford	41° 42'13"	72° 49'57"
16	One State Street	Hartford	Hartford	41° 45'57"	72° 40'10"
17	16 Ella T. Grasso Turnpike	Windsor Locks	Hartford	41° 55' 3"	72° 40'31"
18	Midwood Farm Road	East Hampton	Middlesex	41° 36'10"	72° 31'43"
19	8 Harborview Street	Essex	Middlesex	41° 23'41"	72° 20'27"
20	333 Route 81	Killingworth	Middlesex	41° 22'12"	72° 33'52"
21	1055 Wintergreen	Hamden	New Haven	41° 20'58"	72° 58'27"
22	Meriden Mountain	Meriden	New Haven	41° 33'47"	72° 50'42"
23	500 Cooks Lane	North Guilford	New Haven	41° 25'10"	72° 42'45"
24	99 Garden Hill Circle	Waterbury	New Haven	41° 34'12"	73° 1' 2"
25	Off Old Colchester Road	Montville	New London	41° 27' 5"	72° 9'13"
26	281 Captain's Walk	New London	New London	41° 21'19"	72° 5'56"

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