Comparison of Technology and Capital Costs for New Home Services

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ABSTRACT

This paper compares on a per subscriber basis the capital cost requirements of several new home services provided via a number of delivery system alternatives. The study was limited to alarm monitoring, electronic information, messaging, energy load management and pay-TV services, since it is expected that these services will play an important role among new telecommunicatin services offered to homes during the 1980's. Since the role and penetration of new network architectures and technologies in the local distribution plant during the 80's is uncertain only existing off-air broadcast, telephone and coaxial cable networks and their suitably augmented versions have been considered as delivery network alternatives.

The studies main conclusions are, that the major cost component for most of the services is the subscriber premises equipment and that there are no significant cost differences between delivery system alternatives for a given service. Also some indication is provided, that cost savings could be achieved through sharing of facilities.

1. INTRODUCTION

The late 1960's and early 1970's witnessed a significant interest in new telecommunication services that could be offered to both business as well as residences. The rapidly declining cost of silicon devices and the accelerated introduction of coaxial cable facilities into U.S.A. urban centres sparked the imagination of a great number of engineers, scientists, sociologists and economists leading to concepts like "the wired city", "cashless society" and many more. Forecasts of services either replacing existing ones or entirely new ones were made with predictions about their introduction dates, penetration rates and costs.

Nearly ten years after this wave of enthusiasm one observes today that only relatively little has actually happened compared to these earlier predictions. Whereas some services did not emerge at all, other services have been introduced or will shortly be introduced which were not even mentioned at that time.

The purpose of this paper is to provide an assessment of certain new telecommunication services which are likely to be introduced in the decade 1980-1990, based on existing technologies and current market indications. Secondly, the paper provides a summary and estimate of capital costs, such as terminal, transmission facility and service centre costs for various delivery systems. Operational and ongoing costs are not discussed. From indications in the literature, activities in the industry and interests at various levels of governments nationally and internationally, five broad types of services appear to be of greatest interest from points of view of commercial-viability:

Pay-TV
Alarm Reporting and Monitoring
Electronic Information (Videotex)
Electronic Messaging
Energy load Management

Some of these services have already been introduced either commercially or on a trial basis in various countries.

Many of the five services can be provided in different ways at the detail level, all of which would accomplish the main objective but may give in some instances quite different levels of quality of service. The possible implementation alternatives of the five services are as follows:

1 - Pay-TV
  i) Pay-per-channel
  ii) Pay-per-program
    a) By request
    b) Metered

2 - Alarm Reporting and Monitoring
  i) Continuous monitoring
  ii) No monitoring

3 - Electronic Information
  i) Non-interactive (Broadcast Videotex)
  ii) Interactive (Interactive Videotex)

4 - Electronic Messaging of the Store and Forward Type

5 - Energy Load Management
  i) Selective power denial
  ii) Time-of-day metering

Reprinted from CCTA 1980

Only existing telecommunications networks or their somewhat augmented versions are considered here as delivery alternatives. These are:

Off-Air Radio and TV Broadcast Networks
The Twisted Pair Local Telephone Distribution Network
The Tree-structured Coaxial Cable Network

New local distribution network architectures and technologies such as switched broadband coaxial cable networks and fibre optics will not be considered here, since it is not clear whether or not their penetration and hence impact during the decade 1980-1990 will be significant at the local distribution plant level.(1,2)

Since some services can be provided by more than one delivery network alternative, all reasonably possible alternatives have been considered to provide a basis for comparison, at least from an initial capital investment point of view.

2. ASSUMPTIONS

Several of the services which have been studied are at a market trial or initial commercial offering only. Others have not been introduced at all. Therefore very little actual data with respect to eventual penetration and usage does exist with the exception of Pay-TV in the U.S.A. For the purpose of this study a number of assumptions of penetration were necessary in order to develop some cost estimates. In addition, in order to provide a basis for cost comparison, to the largest extent possible, the same assumptions on penetration were used for an existing base of subscriber residences, delivery system alternatives and services. In particular following assumptions on penetration were made for a hypothetical metropolitan area of 100,000 residences (Many of these assumptions are based on data resonably representative of conditions in Canada and the U.S.A. but may have to be modified for other countries):

i) Telephone network penetration and subscription - 100%
ii) Cable TV network penetration - 100% (Actually this is not correct on the average for Canada. However, in order to make service penetrations independent of the delivery system availability constraint such an assumption is made)
iii) Basic cable TV subscription - 70%
iv) Pay-TV subscription - 25% of residences for off-air provided service and 25% of basic cable TV subscribers for cable provided service.
v) Alarm reporting and monitoring service subscription - 35%
vi) Electronic information service subscription - 10%
vii) Message service subscription - 10%
viii) Utility load management penetration - 100%

The foregoing assumptions for penetration and subscription for basic cable TV are within 3% of national averages based on Statistics Canada data(3,4). The assumption of pay-TV penetration was based on estimates of 1978 in major U.S. pay-TV markets(5) and may prove in the future to be too low. Estimates of alarm service subscriptions vary widely. In a Canadian market it has been estimated that a 10% penetration can be achieved within a few years. On the other hand, in The Woodlands, (Houston) Texas, admittedly a non-typical urban community, it has been reported that the alarm service subscription rate is as high as 65%(6). For the purpose of this survey, an arbitrary figure of 35% was assumed. The other service penetration assumptions are based on predictions in recent as well as earlier studies(7,8) and of course may be much too low in the light of the Telidon and other Videotex system developments. One other general assumption in deriving costs, was to account only for additional facilities required by each service, but not to allocate cost from already existing facilities to the new service. Also no cost-sharing of facilities between new services was assumed.

Further assumptions relating to each individual service and delivery network alternative will be given in later sections.

3. TECHNICAL REQUIREMENTS

Provision of each of the various types of services imposes certain technical requirements on particular delivery systems. In order to obtain a view of requirements, four broadly defined essential parameters were considered. These are:

i) Upstream/downstream signalling requirement
ii) Upstream/downstream message content or bandwidth
iii) Upstream/downstream traffic or usage
iv) Security and/or privacy requirements

The results of such an assessment are given in Table 1. The last column of this table provides a cross-reference to service categories as they were defined in an earlier study by Baer (9). The terminology "Upstream" and "Downstream" refers to signals originated from the subscriber location and delivered to the subscriber location respectively. In this study, "security and privacy" means that the signals designated to one or a group of subscribers should not be receivable by non-authorized subscribers.

If for both upstream and downstream signalling only required bandwidth is considered, two broad classes of services can be defined:

Class I: Telecommunication services requiring less than voiceband data rates both upstream and downstream.

Class II: Telecommunication services requiring full video bandwidth capability downstream but less than voiceband data rates upstream.

By this definition except Pay-TV which is a Class II service, all other four services fall into Class I services.

TABLE I

TECHNICAL REQUIREMENTS OF NEW SERVICES

SERVICE			SIGNALLING REQUIREMENT		MESSAGE CONTENT/BANDWIDTH		USAGE/TRAFFIC		SECURITY REQUIREMENT	USER'S SERVICE CATEGORY
			UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM		
PAY-TV	PAY-PER-CHANNEL		NO	YES	—	6 MHZ VIDEO/CHANNEL	—	BROADCAST SEVERAL HOURS	NO	ONE-WAY BROADCAST
PAY-TV	PAY-PER PROGRAM	BY REQUEST	YES	YES	NARROWBAND RESPONSE DIGITAL DATA OF 100 OR FEWER BITS	6 MHZ VIDEO/CHANNEL	SHORT, PEAKY	BROADCAST SEVERAL HOURS	NO	NARROWBAND SUBSCRIBER RESPONSE
PAY-TV	PAY-PER PROGRAM	METERED	YES	YES	NARROWBAND RESPONSE DIGITAL DATA OF SEVERAL 100 BITS	6 MHZ VIDEO/CHANNEL	SHORT, RANDOM NON-PEAKY	BROADCAST SEVERAL HOURS	NO	NARROWBAND SUBSCRIBER RESPONSE
ALARM REPORTING	CONTINUOUS MONITORING		YES	YES	NARROWBAND RESPONSE DIGITAL DATA OF LESS THAN 100 BITS	NARROWBAND DIGITAL DATA OF LESS THAN 100 BITS	CONTINUOUS, PEAKY	CONTINUOUS, PEAKY	YES	NARROWBAND SUBSCRIBER RESPONSE
ALARM REPORTING	NO MONITORING		YES	NO	NARROWBAND RESPONSE DIGITAL DATA OF LESS THAN 100 BITS	—	SHORT, RANDOM NON-PEAKY	—	YES	NARROWBAND SUBSCRIBER RESPONSE
ELECTRONIC INFORMATION	NON-INTERACTIVE		NO	YES	—	DIGITAL DATA OF SEVERAL THOUSAND BITS. BANDWIDTH DEPENDENT ON TRANSMISSION RATE	—	BROADCAST, CONTINUOUS	NO	ONE-WAY BROADCAST
ELECTRONIC INFORMATION	INTERACTIVE		YES	YES	NARROWBAND RESPONSE DIGITAL DATA OF LESS THAN 100 BITS	DIGITAL DATA OF SEVERAL THOUSAND BITS. BANDWIDTH DEPENDENT ON TRANSMISSION RATE	SHORT, RANDOM NON-PEAKY	SHORT, RANDOM NON-PEAKY	YES	SUBSCRIBER INITIATED
MESSAGING			YES	YES	DIGITAL DATA OF SEVERAL THOUSAND BITS. BANDWIDTH DEPENDENT ON TRANSMISSION RATE	DIGITAL DATA OF SEVERAL THOUSAND BITS. BANDWIDTH DEPENDENT ON TRANSMISSION RATE	RANDOM NON-PEAKY	RANDOM NON-PEAKY	YES	SUBSCRIBER INITIATED
LOAD MANAGEMENT	SELECTIVE POWER DENIAL		NO	YES	—	NARROWBAND DIGITAL DATA OF LESS THAN 100 BITS	—	BROADCAST, SHORT	NO	NARROWBAND SUBSCRIBER RESPONSE
LOAD MANAGEMENT	TIME-OF-DAY METERING		YES	YES	NARROWBAND RESPONSE DIGITAL DATA OF SEVERAL 100 BITS	NARROWBAND DIGITAL DATA OF LESS THAN 100 BITS	SHORT, RANDOM NON-PEAKY	BROADCAST, SHORT	NO	NARROWBAND SUBSCRIBER RESPONSE

TABLE II

TECHNICAL CHARACTERISTICS OF EXISTING TELECOMMUNICATION NETWORKS

NETWORK		SIGNALLING		AVAILABLE BANDWIDTH		TRAFFIC CAPABILITY		SECURITY
		UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
BROADCAST	RADIO	NO	YES	—	4 KHZ FOR AM 15 KHZ FOR FM	—	BROADCAST, CONTINUOUS	NO
BROADCAST	TELEVISION	NO	YES	—	6 MHZ FOR VIDEO	—	BROADCAST, CONTINUOUS	NO
TELEPHONE		YES	YES	4 KHZ VOICEBAND	4 KHZ VOICEBAND	3-5 CCS	3-5 CCS	YES
COAXIAL CABLE		NO	YES	—	300 MHZ TOTAL 6 MHZ/CHANNEL	—	BROADCAST, CONTINUOUS	NO

The main technical capabilities of the three currently available telecommunications networks can be characterized considering the same four parameters used to characterize the five services. The results of such a characterization are given in Table II. Such a characterization allows an immediate assessment of the suitability of using any one of the networks to provide a given service.

4. DELIVERY NETWORK ALTERNATIVES

The basic three networks may be used as they exist today for the carriage of some of the new services. However with some augmentation and combined usage their capabilities can be increased by introducing multiplexing equipment both at the subscriber as well as at the serving central office level of the subscriber telephone loop, thereby allowing services of a non-voice nature to be offered simultaneously. Similarly by introducing additional equipment the one-way tree-structured cable TV network can provide an upstream signalling path from each subscriber to the cable system headend making use of currently unused parts of the spectrum as has been demonstrated in recent years.

Another possibility for offering services is to jointly use two of the basic networks to form a hybrid network. The telephone network by itself offers capability for only narrowband two-way communication. On the other hand broadcast and most coaxial cable networks with their present architecture provide only one-way communication but with a larger band-width in the case of television. In a hybrid arrangement of broadcast or coaxial cable networks combined with the telephone network the downstream signalling would still be provided by the broadcast and coaxial cable networks but the telephone network could provide an upstream path from each subscriber.

In summary, the following delivery system alternatives are possible:

1 - Broadcast Network

2 - Telephone Network
- i) Non-Simultaneous Voice/Data
- ii) Simultaneous Voice/Data

3 - Coaxial Cable Network
- i) One-Way
- ii) Two-Way

4 - Hybrid Networks
- i) Broadcast - Telephone
- ii) Coaxial Cable - Telephone

In the following sections the capital cost requirements for each of the services using applicable delivery system alternatives will be examined.

5. TECHNOLOGY AND CAPITAL COSTS OF NEW SERVICES

5.1 Class I Services

5.1.1 Alarm Reporting and Monitoring

The "No Monitoring" version requires that a signal is transmitted from the terminal of a protected subscriber to the central station only when an alarm occurs. In contrast to this, in the "Continuous Monitoring" version the sanity of the system from each subscriber to the central station has to be monitored at least every 200 seconds (NFPA Code 71, Article 4.1.1.2 (10).

The "No Monitoring" type of alarm system can be implemented on the non-simultaneous voice/data telephone network. The required facilities consist of an automatic dialling transmitter at the subscriber terminal, sending digital codes in case of an alarm condition, a central station and distribution loop pairs between the central station and the serving C.O. The system block diagram is shown in Figure 1. Based on information obtained from the industry (ADT, Ottawa Branch) following costs are estimated:

Alarm transmitter (one per subscriber)	$ 200
Central station (per 500 subscribers)	12,000
Telephone trunk (one per central station)	450

For our assumed urban model, this yields a cost per subscriber of about $ 225.

The same service could also be provided via a simultaneous voice/data telephone network or a two-way coaxial network. However since for most of the proposed delivery systems continuous scanning and monitoring is inherent, there does not appear to be any particular advantage in implementing no monitoring type alarm systems since the cost would not be reduced.

The continuous monitoring type of alarm systems can only be implemented via a simultaneous voice/data telephone network or a two-way coaxial cable network.

It will be assumed that the average class 5 central office in the hypothetical urban model handles 20,000 subscribers. Based on the general assumptions made above in section 2 there would be 7,000 alarm service subscribers per central office.

The additional facilities required are (i) an alarm transmitter with interface to the telephone loop at each subscriber, (ii) a new services switch/multiplexer at each central office, (iii) trunking facilities between each central office and the central station. A system block diagram is shown in Figure 2. Based on information obtained from the industry following costs are estimated:

Alarm transmitter (one per subscriber)	$ 150
New services switch (one per central office)	135,000
Central station (per 35,000 subscribers)	301,500
Interoffice trunk (one per central office)	1,500

This yields a per subscriber cost of $ 178.

As one illustration of such facilities, we consider a system currently available from Control Devices Limited in Edmonton, Alberta, which is similar to the above system, except that the date is not transmitted above voice band but rather within the voice band itself. It therefore represents a non-simultaneous voice/data implementation of an alarm system. However, by shifting the data carriers above voice it could be converted into a simultaneous voice/data system. It has the capability to scan every subscriber in less than 60 seconds thereby complying with NFPA requirements.

The implementation of a continuous alarm monitoring service via a two-way coaxial cable network can either use the listening-area multiplex or the interrogation-response method. The principle difference between these two systems is that the former does not allow any commands to be sent from the service centre to the subscriber. Therefore in the listening-area multiplex method no receiver is required thereby reducing the cost of the subscriber premises interface unit. A block diagram showing the principle components is given in Figure 3. The Code Operated Switch (C.O.S.) is only required for a listening-area multiplex system.

The service implementation requires upgrading a one-way cable system into a two-way system. According to a Cablesystems Engineering Ltd. study(11) the average cost per mile of cable plant to upgrade to two-way transmission capability is \$ 783 for densities of 110 households per mile (passed by cable). Other costs include the subscribers home terminal and the central station equipment at the service centre. According to Reference (11) total costs for a listening-area multiplex system are as follows:

Home terminal (one per subscriber)	\$	50
Transmission facility (per mile)		783
Central station equipment		160,000

With the assumed 35% penetration rate of this service in the hypothetical metropolitan area of 100,000 residences, the cost per subscriber becomes \$ 75.

When an interrogation-response system is used, such as for example the TOCOM system, the main cost difference is in the home terminal(12). The total system costs are estimated as follows:

Home terminal (per subscriber)	\$	150
Transmission facility (per mile)		783
Central station equipment		325,000

(The latter could include some distributed control equipment other than at the central station location). The cost per subscriber becomes \$ 180.

A summary and comparison of costs for different delivery system alternatives is given in Table III.

5.1.2. Electronic Information

5.1.2.1 Non-Interactive Information Service (Broadcast Videotex)

Textual and graphical material can be transmitted in a digital format and displayed on a consumer TV set or a commercial computer terminal. In the Broadcast Videotex version a limited number of information pages (frames) are assumed to be transmitted sequentially. Each page can be captured and stored in the subscribers local decoder and displayed on the TV set or terminal.

When Broadcast Videotex service is provided through off-air TV transmitters only a few lines during the vertical blanking interval are used, resulting in a rather limited information library of only a few hundred pages. The additional costs to implement this service consist of the subscriber decoder and the Broadcast Videotex library generation, storage and transmission equipment at the TV broadcast station. Studies made in Canada for Telidon type decoders with high resolution and using custom LSI circuits project costs for larger production quantities in the order of \$ 400. Similar studies made in the U.K. (13) for their alphamosaic system decoders project a cost of about \$ 300 at larger quantities. It should be noted, that the cost difference is mainly due to the additional memory required for the higher resolution of a Telidon decoder. However the cost would reduce to that of an alphamosaic decoder if the resolution would be made comparable. Considering that memory cost is decreasing rapidly this cost differential will become negligible in the future. Therefore for this study here a subscriber equipment cost of \$ 300 will be assumed. Other costs are estimated as follows:

Subscribers decoder (per subscriber)	\$	300
Transmission facility		0
Broadcast Videotex		50,000-120,000

With a 10% penetration into a metropolitan area of 100,000 residences the cost per subscriber for Broadcast Videotex service becomes \$ 305-312.

The same service could be provided via a one-way coaxial cable TV system. However, assuming that there is unused channel capacity available, a full-channel Broadcast Videotex service could be provided by using all displayed and undisplayed horizontal lines of a TV picture. With an average waiting time of 10 seconds for a page to be displayed after a selection has been made, a 10,000 page information library per channel can be provided. There would be no significant cost difference for the subscribers decoder over that for the two line Broadcast Videotex decoder. Another possibility is to use a TV channel capacity to transmit data in packet mode. The cost of such a decoder is also expected to be in the order of \$ 300 at larger quantities. However, an increase in cost for the Broadcast Videotex generation and transmission equipment is to be expected because of the larger library. For the purposes of this paper, an increase of 20% for this cost will be assumed. (An error in this estimate will not have a significant effect on the overall cost per customer projection). With this assumption, the head-end

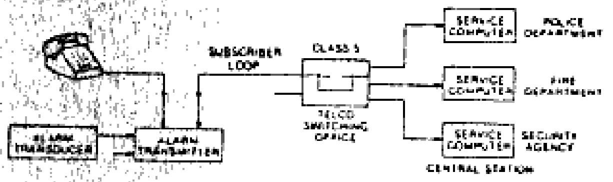

Figure 1 - System block diagram of a no-monitoring type alarm reporting service using a non-simultaneous voice and data telephone network.

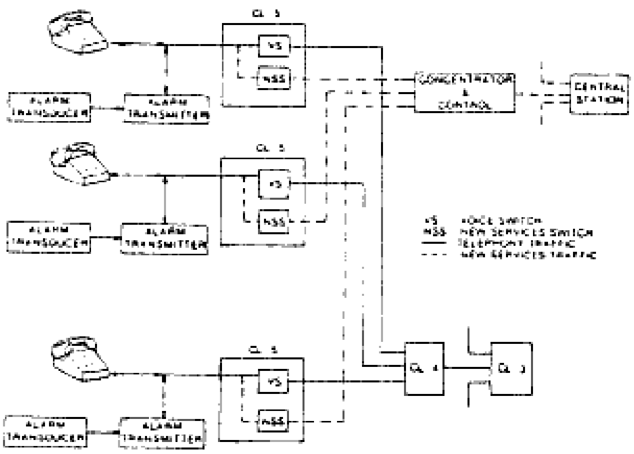

Figure 2 - System block diagram of a continuous monitoring type alarm reporting service using a simultaneous voice and data telephone network.

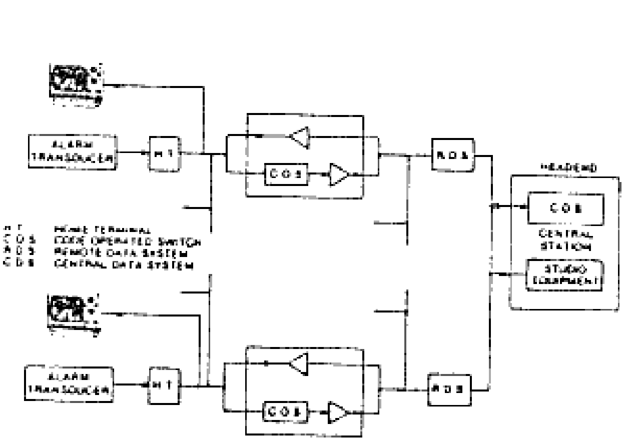

Figure 3 - System block diagram of a continuous monitoring type alarm reporting service using a two-way coaxial cable network.

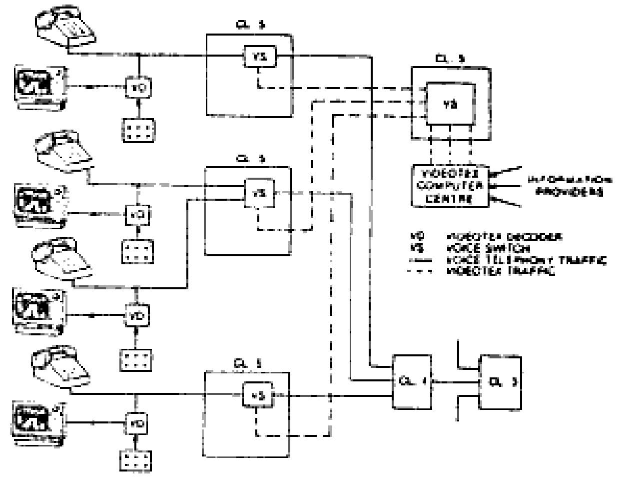

Figure 4 - Block diagram indicating trunking requirements to provide interactive information (interactive videotex) service via a non-simultaneous voice and data telephone network.

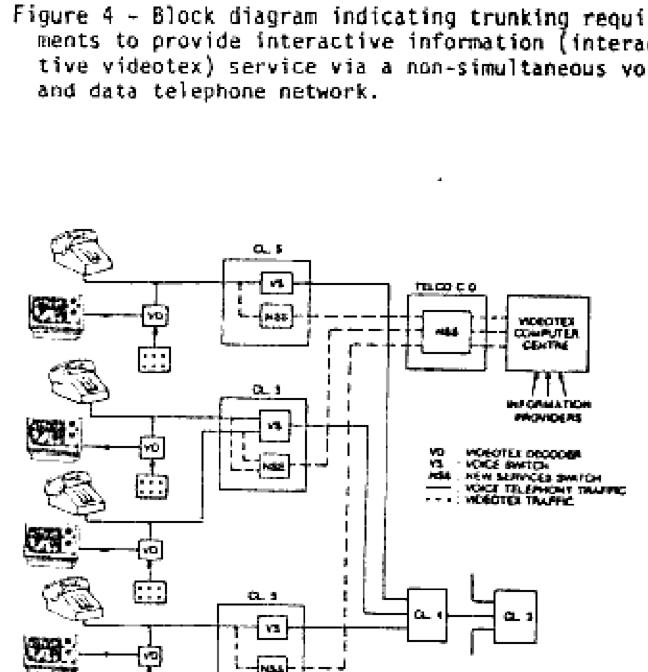

Figure 5 - System block diagram of an interactive electronic information (interactive videotex) service using a simultaneous voice and data telephone network.

Broadcast Videotex equipment is estimated to cost $ 60,000 to $ 145,000 giving the cost per subscriber to be $ 306-$315.

5.1.2.2 Interactive Information Service (Interactive Videotex)

An interactive electronic information service (Interactive Videotex) is one of the services which has attracted much attention in many countries, following the development of the Prestel service in the U.K. Currently, Prestel uses the telephone network in a non-simultaneous voice and data form. A subscriber can retrieve information from a library of unlimited number of pages. The content of the library is not continuously transmitted as in the Broadcast Videotex Service. A particular page is transmitted only as a result of a subscribers request.

It can be readily appreciated that the particular delivery system alternative chosen by the British Post Office is only one of many ways in which interactive information services could be provided. For example, the telephone network could also be modified to permit simultaneous voice and data transmissions to take place. Videotex data could be multiplexed above the voice band. Alternately, two-way coaxial cable or both forms of hybrid networks cable-telephony and off-air broadcast-telephony can be used. The availability of a coaxial cable distribution plant to a large segment of the Canadian population is allowing the development of Telidon systems on cable as well as telephone networks.

As far as the data bank configuration goes, the present U.K. model represents a highly centralized model. However, more distributed data bank configurations are likely in North America. Current Telidon system developments in Canada indicate toward such a direction. For simplicity reasons a centralized system will be used here for estimation purposes. By aggregating individual system costs, total costs can be derived if needed, to compare with a centralized system.

Before discussing the particular network configurations and their costs, further underlying assumptions of our analysis will be presented. It is assumed that no more than 3% of subscribers will require simultaneous access to the data base and that each data base computer can handle 300 simultaneous requests or, in other words, can support 300 ports. The average connection time per subscriber and per session is assumed to last only a few minutes with a page retrieval rate of not greater than one page every 15 seconds. The assumptions are based on projections and early experience with the Prestel service in the U.K. and estimates of what the average subscriber may be willing to spend(14,15).

The non-simultaneous voice/data telephone network delivery system alternative block diagram is shown in Figure 4. Because of the relatively low traffic predicted to be generated by an electronic information retrieval service, it is assumed that no additional switching facilities will be required at the subscribers serving central offices. However it is assumed that for technical and transmission quality reasons additional trunking facilities might be required between the central offices serving subscribers and the central office serving the videotex computer centre.

In the U.K., where the Prestel service is operated by the B.P.O. the videotex computers may be co-located with a telephone switching centre and therefore no connecting loops would be required. The system does however have the capability to connect to other computers as well. In North America, it is more likely that videotex computer centres will be operated by non-telephone company entrepreneurs, requiring connecting loops to central offices. The cost of an average subscriber loop is again estimated at $ 450. Trunk costs vary with distance. In larger metropolitan areas this cost may be around $ 1,500.

The videotex computer centre cost with a capability to simultaneously serve 300 subscribers and a library of 250,000 pages has been estimated by B.P.O. at about $ 1,000,000(14) (this includes building and other facilities). This cost is likely to be too high for North America, however, it will be used as a conservative figure.

The videotex decoder cost depends on annual production volume, degree of use of custom integrated circuits and also the particular videotex implementation method (Prestel, Antiope Telidon, etc.). Cost estimates for larger quantities of production for a high resolution Interactive Videotex Telidon terminal are in the order of $ 400 and for an alphamosaic Interactive Videotex terminal in the order of $ 300. For an alphamosaic comparable quality of resolution the cost of a Telidon terminal will also reduce to about $300. As mentioned before with the rapidly declining cost of memory costs, the price differential will become negligible. Therefore the lower cost of $ 300 will be used.

With the above assumptions and estimates the cost to provide interactive electronic information service to 10% of the 100,000 residences of the metropolitan model will be as follows:

Videotex decoder (per subscriber	$	300
Interoffice trunks (300 at $ 1,500)		450,000
Connecting loops (300 at $ 450)		135,000
Videotex computer centre		1,000,000

The cost per subscriber becomes:

Videotex decoder	$	300
Transmission facilities		58
Videotex computer centre		100
TOTAL	$	458

For the simultaneous voice and data usage of the telephone network the data portion has to be separated from voice and routed independently before it enters the central office switching machine. A system block diagram is shown in Figure 5 (this is very similar to the system for alarm services

With the above information the estimated cost per subscriber for each of the hybrid networks will be as follows:

For the broadcast-telephony hybrid network

Subscriber terminal	$ 350
Telephone network transmission facilities	58
Videotex computer centre	100
TV transmitter	30
TOTAL	$ 538

For the coaxial-telephone network the itemized costs are as above except that no TV transmitter is required. Therefore the cost per subscriber drops to about $ 508.

A comparison of costs for different electronic information services and delivery system alternatives can be made using the summary in Table III.

5.1.3 Messaging

The messaging service which is considered here is essentially based on use of facilities developed for interactive electronic information systems. Messages would not be transmitted directly from originator to destination. Messages would first be stored at the videotex computer centre, in a fashion similar to that of an information page, and retrieved by the recipient only upon his first interrogating the computer centre for his stored messages. For the home or small business it could become the low-cost version of an electronic mail box system currently being used by larger businesses.

If the user is willing to add memory facilities, such as a tape casette recorder with comparable facilities of telephone answering machines, than terminal to terminal messaging service between users can be provided.

Since the volume of upstream information sent by the subscriber is considerably more than the amount of data sent for regular videotex page retrieval requests the multiplexed systems used in cable systems for upstream signalling would be inadequate, except for short proforma-type messages. Also broadcast systems to send messages to subscribers may not be suitable in many cases since they provide very little privacy. Therefore for the purposes of this paper, only the telephone network-based interactive electronic information systems will be considered for messaging services.

Assuming that mail box type messaging will be used by subscribers who subscribe to an interactive electronic information service the additional terminal equipment required is a full alphanumeric keyboard instead of a simple control pad. The cost of a keyboard could be as low as $ 25 in large quantities(17). If it is assumed that this service will create additional traffic rather than replacing videotex traffic, than also additional transmission and videotex computer facilities will be required. If the traffic characteristics of messaging services are assumed to be relatively low, and with patterns similar to that of interactive videotex service, transmission and videotex computer facility costs will be identical to those of electronic information services.

In summary the messaging service costs per subscriber for the two telephone network alternatives will be as follows:

Non-simultaneous voice and data telephone network:	$ 183
Simultaneous voice and data telephone network:	
With circuit switching	483
With packet switching	600 / 1,250

A summary of costs for messaging services is given in Table III. For a terminal to terminal messaging system the videotex computer cost would be replaced by the cost of a recording device attached to the subscribers terminal.

5.1.4 Load Management

In various parts of Canada, electrical power utilities are increasingly interested in load management. One objective of load management is to obtain a constant energy demand throughout the day, by shifting some of the peak energy requests to low consumption times. One way of achieving this is to turn off certain appliances such as water heaters and air conditioners at the discretion of the utility. It has been defined here as "Selective Power Denial". The other method is to discourage the user from consumption of energy at peak demand times by applying higher rates. This requires a "Time-of-Day Metering" scheme. Possibilities exist to implement either of these methods through systems that are based on the use of only the power distribution network or standalone facilities. Here, we summarize several alternative methods using communications networks.

5.1.4.1 Selective Power Denial

The method of selective power denial requires signals to be sent from a utility control point to all subscribers which will be used to turn off selected "non-essential" loads. Since this is a multipoint signalling requirement, broadcasting methods are most suitable. With the use of off-air broadcasting or the CATV coaxial cable network a receiver at each subscriber would be required. At the utilities control location a transmitter and a load management minicomputer is required. Based on an experimental system developed by Motorola the cost of each receiver is estimated at $ 75, the control transmitter at $ 4,000 and the control computer with its peripherals at $ 12,000(18). With an assumed 100% penetration of this service, the significant cost per subscriber for both the broadcast and the coaxial cable alternative is the cost of the receiver, or about $ 75.

The simultaneous voice and data option of the telephone network could also be used for this service if, at and beyond the class 5 switching offices a fast scanning type overlay switching and trunking presented in Figure 2). However, since for videotex the amount of data flowing between the subscriber and the videotex computer center is far more than is required for an alarm system, the nature of the data switch New Service Switch (NSS) is different from the one discussed in Section 5.1.1. Again it will be assumed that five central offices with an average capacity of 20,000 telephone subscribers will serve the needs of the urban metropolitan area. With a 10% penetration of this service, at each central office data switching facilities for 2,000 subscribers are required. For cost comparison purposes, both circuit switching and packet switching technologies have been considered.

With presently-available products an installed small digital circuit switch would cost about $ 600,000. (The subscriber equipment, transmission facility and videotex computer centre costs remain the same as was discussed for the non-simultaneous voice and data telephone network option.)

The cost per subscriber therefore becomes:

Videotex decoder	$ 300
Switching facilities	300
Transmission facilities	58
Videotex computer centre	100
TOTAL	$ 758

The cost of a packet switch has been estimated to be $ 950,000 (if a circuit switch is used as a concentrator, before actual packet switching) or $ 2,250,000 (if no concentration takes place). The advantage of packet switching is, that it significantly reduces the number of trunks required, to the point that transmission cost per subscriber are essentially zero and can be neglected. The cost per subscriber becomes:

Videotex decoder	$ 300
Switching facilities	475 / 1,125
Transmission facilities	0
Videotex computer centre	100
TOTAL	$ 875 / 1,525

Comparison of these costs with those for digital circuit switching (above), shows that the cost savings obtained by the virtual elimination of additional transmission facility requirements due to the use of packet switching is more than offset by that switches cost.

Interactive electronic information services, with a library of unlimited number of pages, can also be delivered using a two-way coaxial cable system. In this case, instead of transmitting a fixed "magazine" of pages via one channel, pages are changed dynamically as users request information pages. As was discussed for the telephone network based interactive videotex systems, centralized or distributed data base configurations are possible. For simplicity reasons again only the centralized data base option will be considered. From earlier assumptions, at any given time only 300 subscribers would be requiring information from the data base. Since one full TV channel can provide 10,000 pages (with an average waiting time of 10 seconds) or 1,000 pages (with an average waiting time of one second) it appears feasible to serve all request dynamically via one channel. The upstream transmission capability of the two -way cable network is only required for transmission of a relatively small amount of data page requests from subscribers. Present evidence suggests that this could be handled by either the listening-area multiplex or the interrogation-response type system. However, further detailed studies are required.

With the lower cost listening-area multiplex system the subscriber terminal cost consists of a videotex decoder or a packet mode decoder as the case may be and that of a home terminal (described for alarm services in section 5.1.1) to transmit user page requests. The transmission cost consists of the costs of upgrading one-way cable to two-way. This is estimated to be $ 783 per mile. This cost would have to be shared by only 10% of the residences (and no other services share the costs of this additional plant).

The cost per subscriber becomes:

Subscriber terminal	$ 350
Transmission facility	71
Videotex computer centre	100
TOTAL	$ 521

Finally hybrid networks could be used to deliver interactive electronic information services. The off-air broadcast network and the coaxial cable network would provide the downstream transmission medium and the telephone network would be used for upstream transmission of the subscribers requests. In this paper, it will be assumed that a full TV channel is dedicated to such a service. In the broadcast/telephone hybrid network case, it would require a TV transmiter to be dedicated to interactive videotex service only.

For this interactive videotex service, the subscribers decoder would require all the circuits of a broadcast videotex decoder or a packet decoder as mentioned earlier and, additionally, a transmit only modem, a dialler and telephone loop interface circuits to provide access to the telephone network. Since up to this point in time, very little broadcast and interactive videotex development activities have been in this direction, the cost of such a decoder are unknown. It may be estimated at $ 350 for large volumes, which allows for the additional circuits $50 above that of a single network decoder.

For the hybrid networks, the costs of the videotex computer centre and the telephone network transmission facility will remain essentially the same as those provided earlier. In the coaxial cable case, no additional transmission cost will incur since it is assumed that the additional cost of a channel is negligible (at least until the last channel available has commercial value to the cable operator). In the broadcast case as a minimum a VHF or UHF transmitter and an antenna are required. The cost for a 10KW transmitter and antenna have been estimated to be about $ 300,000(16).

network were implemented. This would allow all subscribers to be accessed within a very short time period, that is, a quasi-broadcast capability to send power denial commands would be possible. Using facilities similar to those of the system available from Control Devices Limited in Edmonton, Alberta (see Section 5.1.1 above) gives the following costs:

Subscriber terminal	$ 150
New services switch (one per central office)	280,000
Transmission facilities (two trunks per central office)	3,000
Load management centre (for 100,000 subscribers)	319,000

From these figures the cost per subscriber is estimated to be:

Subscriber terminal	$ 150.00
New services switch	14.00
Transmission facilities	0.15
Load management centre	3.19
TOTAL	$ 167.34

5.1.4.2 Time-of-Day Metering

For time-of-day metering of electrical loads, there is no need to address all subscribers at once. Consumption data, including date and time, can be stored locally and read out remotely at infrequent intervals when particular lines are free. This allows the use of the telephone network, without the need to add a capability for simultaneous data and voice transmission.

One possible method to implement this system would make use of subscriber loop access arrangements for maintenance and test purposes provided by telephone company automatic loop reporting systems. These have the capability to reach a subscriber without ringing the telephone. Based on a Porta Systems "Loop Condition Reporting" system the additional equipment costs to serve 100,000 subscribers are as follows:

Subscriber terminal	$ 150
Transmission facilities (9 trunks)	13,500
Secondary test centres (two for 100,000 subscribers)	48,000
Primary test (service) centre	160,000

The cost per subscriber becomes:

Subscriber terminal	$ 150.00
Transmission facilities	0.13
Test (service) centre	2.08
TOTAL	$ 152.21

Time-of-day load management can also be implemented in a simultaneous voice and data telephone network. All facilities and costs as were derived for the selective power denial service remain identical for this service except that the subscriber terminal would require some memory instead of control relays as would be the case for the selective power denial situation. However it is not expected that this would have any significant effect on cost. For simultaneous voice/data networks, estimated cost per subscriber for the time-of-day metering service becomes $ 167.

This service can also be provided via a two-way coaxial cable network. To implement the system, facilities similar to those for a continuous monitoring alarm system could be used. However, since under the assumption of 100% penetration, 100,000 subscribers would have to be serviced instead of 35,000, more distributed and centralized service facilities would be required. The costs, based on TOCOM Ltd. type equipment, are estimated as follows:

Subscriber terminal	$ 150
Transmission facility (per mile)	783
Service central equipment (all subscribers)	755,000

The cost per subscriber becomes $ 164. Since this system continuously scans every subscriber in the order of every 10 seconds there is no need to store data at the subscriber. All data can be stored centrally.

A comparison and summary of costs for different types of load management is provided in Table III.

5.2 Class II Services

5.2.1 Pay-TV

Pay-TV service could be offered to the subscriber either on a pay-per-channel basis for a fixed monthly rate with unlimited viewing of one or more channels in addition to the regular CATV service, or on a pay-per-program basis. As is well known, the latter type of pay-TV requires more sophisticated facilities and billing procedures, but it provides also more flexibility and choice to the subscriber.

5.2.1.1 Pay-Per-Channel TV

Pay-per-channel TV can be achieved on off-air broadcast networks by transmitting a scrambled signal and providing authorized subscribers with a descrambler. Descramblers are available at costs of between $ 8 and $ 45(5,11) depending on the scrambling method. Facilities at the broadcast centre include a transmitter (with an estimated cost of $ 300,000(16)), studio equipment (with a cost of about $ 30,000) and if programs are distributed to broadcast centres by satellites a TV receive-only ground station (with a cost of $ 30,000(19)). In our model, the total cost of $ 360,000 will be shared by 25,000 subscribers. The total cost per subscriber therefore becomes $ 23 to $ 60.

The same service can also be delivered on a one-way coaxial cable network. Excluding the costs of the TV broadcast transmitter, all other costs remain about the same. In our model the number of pay-TV service subscribers is taken to be 17,500 since only 70% of households subscribe to basic cable service. The cost per subscriber is estimated to range from $ 12 to $ 49.

(The alternate method of using traps instead of descramblers at the subscriber location has not been considered here, because the cost for low penetration rates is higher. Also due to envelope delay distortion introduced, only a few traps can be cascaded limiting the number of pay-TV channels(11)).

5.2.1.2 Pay-per-Program TV

For pay-per-program TV two options are possible. For the first of these options, each time the subscriber desires to view a program he makes a request to the pay-TV distribution centre, which in turn sends a command to enable the subscribers equipment to allow viewing of the chosen program. In the second of these options the subscribers equipment is always enabled, and whenever the equipment is tuned to a pay-TV channel, the date, time, channel number and duration of viewing are stored. The "metered" viewing information is subsequently used for billing purposes. Pay-per-program by request pay-TV requires almost simultaneous access by the program distribution centre to many subscribers. The only delivery network capable of providing all the required features is a two-way coaxial cable system. An interrogation-response type two-way coaxial cable system is required. A block diagram of such a system is shown in Figure 6. The home terminal, the remote and central data systems are the same as were discussed for continuous monitoring alarm systems in section 5.1.1.2.

The subscriber premises equipment and their estimated costs are as follows:

Descrambler	$ 8-45
Home terminal	150
Keypad	10
TOTAL	$ 168-205

The distributed and centralized data collection equipment, additional studio and program reception facilities to serve the 17,500 subscribers are as follows:

Remote and centralized data systems	$ 255,000
Studio equipment	30,000
One channel TVRO satellite ground station	30,000
TOTAL	$ 315,000

The $ 783 transmission facility cost would be shared on average, by 20 pay-TV subscribers per mile. From this, the costs per subscriber are found to be:

Subscriber terminal	$ 168-205
Transmission facility	41
Service centre	18
TOTAL	$ 227-264

Metered pay-per-program pay-TV can be provided through a two-way coaxial cable network as well as both types of hybrid networks. Metered pay-per-program pay-TV option does not require commands to be sent from the program centre or cable head-end to each subscriber. Therefore a listening-area multiplex type system would suffice. The data collection system cost is $ 160,000, the same figure derived in section 5.1.1.2 for continuous alarm monitoring services. The other programming facility costs are the same as those discussed for the pay-per-program by request pay-TV. The costs of facilities at the subscriber level could be significantly lower consisting of a receiver at an estimated average cost of $ 50 plus a descrambler at a cost of between $ 8-45. Furthermore, no control keyboard at the subscriber would be necessary. The cost per subscriber for this service is calculated as follows:

Subscriber terminal	$ 58-95
Transmission facility	41
Service centre	13
TOTAL	$ 112-149

When the off-air broadcast-telephone hybrid network is used for metered pay-per-program pay-TV service the telephone network would be used only to collect viewing data stored locally at the subscribers premises. Information to indicate program, date and time would be provided through the transmission of signals added to the video signal. The metering information can be read out infrequently, and therefore a system identical to the one discussed for time-of-day metering could be used. The system components are shown in Figure 7. The subscriber premises terminal is assumed to contain all the necessary metering, descrambling and telephone loop interfact circuits. In large quantities the cost of such a terminal is estimated to be between $ 130-160 depending on complexity of descrambling and use of custom LSI circuits. Other service facility costs are as follows:

Transmission facilities (nine trunks)	$ 13,500
Secondary test centres (two, to serve five central offices)	48,000
Primary test centre	160,000
Studio equipment	30,000
One channel TVRO satellite ground station	30,000
TV transmitter	300,000

From the above information and for a total of 25,000 subscribers, the costs per subscriber are found to be:

Subscriber terminal	$ 130.00-160.00
Transmission facility	0.54
Centralized service facilities	22.72
TOTAL	$ 153.26-183.26

The system facilities to provide metered pay-per-program pay-TV service via a coaxial cable-telephone hybrid network would be essentially identical to those required for an off-air broadcast-telephone hybrid network with the exception that no TV transmitter and antenna would be required. In our model the total number of pay-TV subscribers are only 17,500 (25% of 70% of 100,000 residences), which

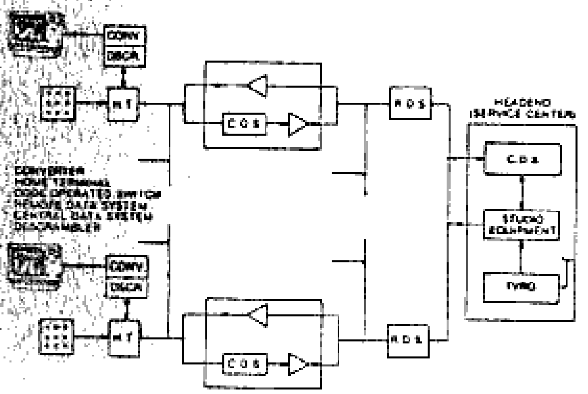

Figure 6 - System block diagram of a pay-per-program-by request type pay-TV service using a two-way coaxial cable network.

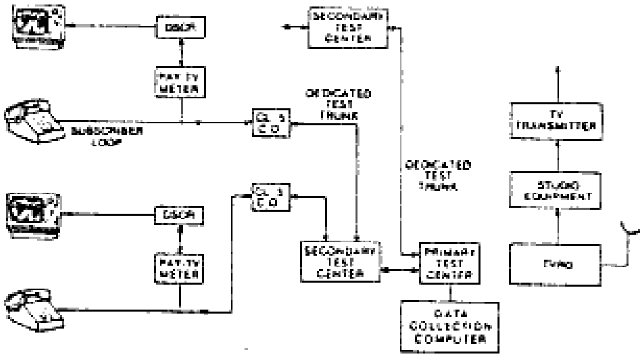

Figure 7 - System block diagram of a metered pay-per-program type pay-TV service using a broadcast-telephone hybrid network.

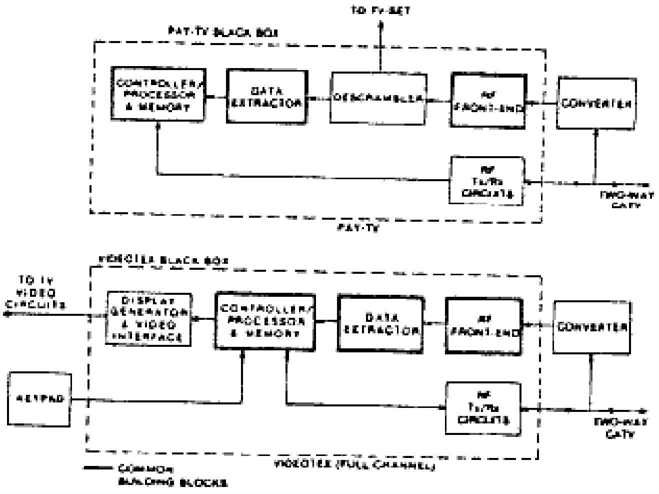

Figure 8 - Detailed block diagrams of a pay-TV and an interactive videotex subscriber terminal equipment for use on a two-way cable network.

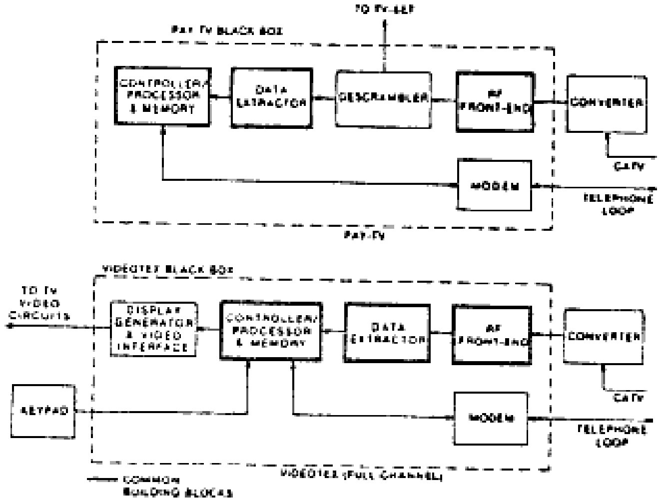

Figure 9 - Detailed block diagrams of a pay-TV and an interactive videotex subscriber terminal equipment for use on a telephone - one-way cable hybrid network.

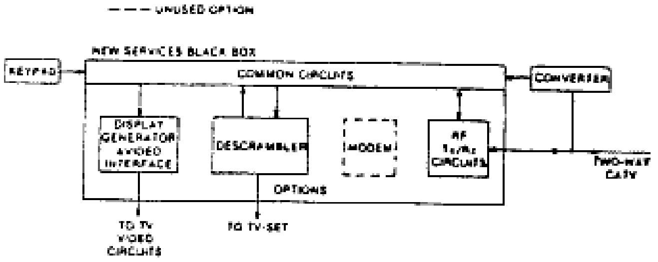

Figure 10 - Detailed block diagram of a modular, combined pay-TV and interactive videotex subscriber terminal equipment for use on a two-way cable network.

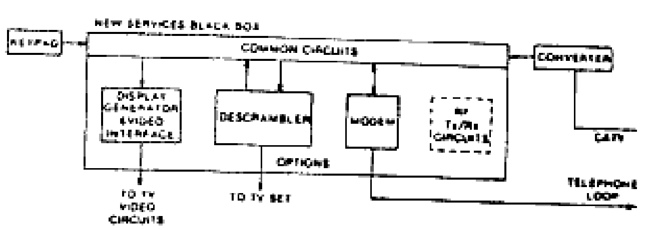

Figure 11 - Detailed block diagram of the same modular, combined pay-TV and interactive videotex subscriber terminal equipment as in Figure 10 but with modules for use on a telephony - one-way cable hybrid network.

gives costs per subscriber as:

Subscriber terminal	\$ 130.00-160.00
Transmission facility	0.77
Centralized service facilities	15.31
TOTAL	\$ 146.08-176.08

A comparison of total costs for different types of pay-TV service is available in Table III.

6. CONCLUSIONS

From a comparison of costs in Table III and their breakdowns as was derived in section 5 and from the descriptions of the systems some general conclusions can be drawn. It should be kept in mind however that these conclusions are based on results obtained from system alternatives which have important underlying assumptions such as size, penetration rate and quantity dependent costs of hardware. It should also be taken into account, that in particular costs are based on current equipment and technologies and only slight extrapolation into the future. With these limitations following observations can be made:

1. For most services and delivery system alternatives, the dominant hardware cost per subscriber is the subscriber premises equipment.

2. The simultaneous voice/data version of the telephone network as a delivery system alternative gives the highest cost per subscriber for interactive electronic information and messaging services, mainly due to the additional switching facility costs. It is however likely that such costs could reduce, once digital switching offices with stored control are widely introduced into the telephone network enabling simultaneous voice/data switching capability at only a marginal higher cost.

3. For most services the cost differences for various delivery system alternatives are not significant and can be considered within estimation uncertainties.

4. The notable exception to conclusion 3 appears to be Pay-TV where cost differentials are appreciable enough to favour a pay-per-channel approach from an initial capital investment point of view only. This known result explains to a great extent the preference given to pay-per-channel option by a majority of cable operators in the U.S.A. who provide Pay-TV service. Once more it should be noted, however, that there is a difference in service quality between per-channel and per-program pay-TV, and therefore a comparison based solely on capital costs may not be justified.

The above conclusions also indicate, that preference for the choice of a particular delivery system alternative for particular services could be governed by factors other than capital costs per subscriber. The networks capabilities for aggregation of new services, the possibility to share facilities and/or operating costs, their availability and the interest in exploiting particular market opportunities may turn out to be more important considerations.

The possibility to share facilities has not explicitly been dealt with in this study. However it can be observed that in several cases for different services some hardware examples were used to estimate costs. For example, videotex and metered pay-per-program pay-TV systems could in principle, share many common subsystems and modules. Because of the dominance of subscriber terminal costs for most services, any facility sharing that can be done at the subscriber terminal level in particular would bring the greatest benefits with respect to cost per service and per subscriber. As an example a proposed version for a pay-TV meter and a videoex decoder for a two-way cable network and a telephone - one-way cable hybrid network are shown in figures 8 and 9 respectively. Figures 10 and 11 indicate how a single piece of equipment with optional modules could be built for use for two services and in either of two different delivery systems. Although no estimate on the possible cost savings are offered here, it is likely that they will be worthwhile. Some currently available systems have the capability to provide a number of the services described in this paper. (i.e. TOCOM (Canada) Ltd. and Control Devices Ltd. systems and the Telidon system currently being developed in Canada). However it is this authors belief based on some preliminary investigations, as indicated by the above examples, that a much wider spectrum of services could indeed successfully and efficiently share common hardware and facilities. This however requires a total systems approach to the problem of new services, considering marketing and other issues in addition to those of technology and its costs.

7. ACKNOWLEDGEMENTS

This paper has drawn heavily from fruitful discussions and information provided by numerous people in the industry. The author would like to thank all those who contributed to this study. In particular I would like to mention R. Short of TOCOM (Canada) Ltd., R. Bertrand of Ottawa Cablevision Ltd., Msrs. R.Treleavan and T. Diardichuk of Northern Telecom Ltd., J. Lumsden of Control Devices Ltd., R. Maguire of ADT Ottawa branch for providing technical and cost information. Last but not least my thanks go to Dr. G. Jull of the Department of Communications for his many discussions which have helped to clarify many details.

Although the study is based on many technical and cost information provided by the industry, the results and conclusions are the sole responsibility of the author. In particular, it should not be implied that the conclusions reflect Department of Communications policy.