Lesson NINE

Specific Objectives

By the end of the lesson the learner should be able to:

(i) Categorize wireless networks

(ii) Explain wireless communication strengths and weakness

(iii) Describe cellular networks

Mobile and Wireless Computing

Introduction

Terms:

***Wireless**:* communication over wireless link

***Mobility**:* the mobile user changes point of attachment to network

Wireless networks, as the name implies, interconnect devices without using wires – instead they use the air as the main transmission medium. Wireless networks are enjoying widespread public approval with a rapidly increasing demand. The unique features of the wireless networks are:

- The *bandwidths*, and consequently *data rates*, of communication channels are restricted by government regulations. The government policies allow only a few frequency ranges for wireless communications.
- The communication channel between senders/receivers is often impaired by *noise*, *interference* and *weather fluctuations.*
- The senders and receivers of information are not *physically connected* to a network. Thus the location of a sender/receiver is unknown prior to start of communication and can change during the conversation.

A very large body of work on wireless networks exists, with emphasis on different aspects such as radio transmission technologies, standards, protocols, systems engineering, and carriers.

The term “wireless” is very broad. It encompasses at least four different categories, depending on the type of wire being replaced:

- **Cellular/Personal Communication Service (PCS) wireless,** which replaces phone lines.
- **Fixed wireless,** which replaces the “last-mile” fiber cables connecting homes, businesses and neighborhoods to the central station.
- **Wireless local area networks (WLANs),** which replace the cables connecting Ethernet LANs. *Example:* WiFi (802.11b).
- **Personal area networks (PANs),** which replace the cables connecting electronic devices (PCs to printers, for example). *Example:* Bluetooth.

Wireless Communication

Fixed Wireless

Fixed wireless replaces the fiber lines that bridge the so-called "last mile" – the distance from the network operations center to the end user. It uses microwaves, lasers or radio frequency (RF) to beam data from one fixed point to another. The typical setup involves dishes or antennas mounted on rooftops. It is typically a point-to-point technology, not a point-to-multipoint (broadcast) solution.

Classification of Wireless Networks in terms of distance

Wireless networks can be broadly classified in terms of distance covered:

a) Wireless LANs (WLANs) allow workstations in a small area (typically less than 100 meters) to communicate with each other without using physical cables. The most popular example of Wireless LANs are the IEEE 802.11 LANs that deliver between 11Mbps to 54 Mbps data rate. Another example is the Bluetooth LANs (for the data rates in the 1 Mbps range over 10 meters).

b) Wireless Personal Area Networks (WPANs)

Very short range LANs such as Bluetooth are also known as Wireless Personal Area Networks (WPANs). The **UWB (Ultra Wideband)** is a relatively new technology and is stronger than the other short-range wireless systems (such as Bluetooth) because of its simpler device designs, lower power consumption and higher data rates. Another player in the short-range radios is the **wireless sensor networks (WSNs)** that are formed between small, low-powered sensor

c) Wireless metropolitan area networks (WMANs) have been used in traditional packet radio systems often used for law-enforcement or utility applications. An interesting area of growth for wireless MANs is the wireless local loop (WLL) that is quite popular with long distance telephone companies. WLLs are ***fixed wireless networks*** where the devices being connected are stationary.

d) Wireless WANs (WWANs) provide wireless support over long distances. Traditional examples of wireless WANs are paging networks and satellite systems. However, a great deal of wireless WAN activity at present revolves around the cellular networks that provide support for cellular phones and other handheld devices such as PDAs and laptops.

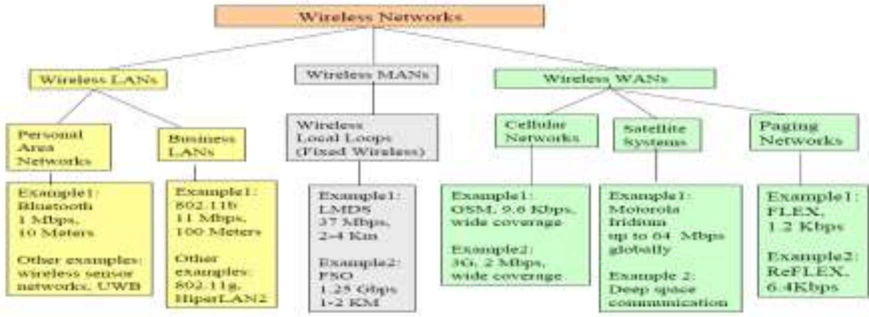

Fig 9.1 A View of Wireless Network Landscape

STRENGTHS AND WEAKNESSES OF WIRELESS

Strengths and Drivers of Wireless

Mobile computing and wireless communication networks are playing an increasingly important role in our professional and personal lives. For example, large numbers of subscribers to mobile telephones use mobile devices on a daily basis for personal and business communications. In addition, Wireless Ethernet (also known as Wi-Fi, abbreviation of Wireless Fidelity) LANs are being rapidly deployed in offices, homes, shopping malls, "hotspots," and apartment buildings. The result is a very large number of business, government, military, educational, and social applications.

The strengths of wireless systems that are driving their growth are:

a) Social and cultural factors. Wireless systems conform to our inherently mobile lifestyles. In our personal and business lives, our employees, partners, customers, relatives and friends are always moving around. Wireless systems fit well in this increasingly mobile environment with the need for information/transactions anytime and anywhere.

b) Advances in wireless networks. A particular appeal of wireless systems, in addition to their flexibility, is the steady increase in wireless data rates. Higher data rates are achievable with broadband wireless technology for applications such as graphics, video, and audio. Broadband wireless networks give higher data rates that compete with wired networks, plus they enjoy convenience and reduced cost. For example, 802.11g wireless LANs yield data rates in the range of 50 Mbps (million bits per second) that compete with similar wired data rates. But broadband wireless services can be deployed faster than wired services with no cost of cable plants. In addition, service is mobile, and can be deployed almost anywhere.

c) Niche applications. In some cases, wireless is the *only* option. For example, wired communications over very long distances (between the US and Australia, for example) are virtually impossible, and wireless is the only choice for space explorations. In addition, many law enforcement and battlefield applications can only work with wireless communications. For example, it is difficult to lay cables in a battlefield, or to carry a wired device when chasing a criminal.

d) Special situations. Wireless communications make more sense in several situations. For example, satellite communication is a good choice to connect far-flung and hard-to-reach areas. In addition, it may be difficult to lay cables in hostile environments. In the war-torn country of Syria, for example, it was hazardous for the workers to lay cables along roads between major cities; so wireless links were used instead.

e) Wireless for older buildings. In many cases, wireless is chosen because the buildings are too old for installing cables.
The University of Texas at El Paso, for example, deployed wireless networks at several campus locations because it was difficult to wire historical buildings and remote locations.

f) Developments in mobile devices. The new breed of wireless handsets have many attractive features such as digital cameras, and pictures. The availability of new mobile devices such as powerful laptop computers, PDAs, and cellular telephones with Internet and wireless data access capabilities is also driving the growth.

g) Increased revenue and productivity possibilities. The revenue opportunities created via location-based services and m-commerce have lured several companies and investors into this area. In addition, the productivity improvements to be gained via wireless extensions to enterprise applications and processes are tremendous. For example, mobile customer relationship management systems can capture customer information in real time and allow marketing reps to be more productive.

h) Industrial and regulatory factors. The convergence of telecommunications and software industries coincides with the adoption of wireless standards such as WAP and Bluetooth, along with the cultural and regulatory drivers in various countries.

Weaknesses and Issues

Wireless is convenient and less expensive but some business, political and technical difficulties inhibit wireless technologies. A major limitation is security of wireless systems because wireless communications are technically easier to eavesdrop and intrude. There are also some additional limitations. These include lack of industry-wide standards, data rate limitations as compared to wired networks (despite progress), and device limitations. For example, small LCDs on mobile telephones can only display a few lines of text, and browsers of most mobile wireless devices use specialized languages such as wireless markup language (WML) instead of HTML, making application development harder. These weaknesses can be discussed in terms of social, business, and technology issues.

a) Social Issues

Wireless systems, despite their popularity, have raised some social issues. Privacy and security are among the top. Consider, for example, the privacy issue raised by location-based services (LBSs). Wireless networks have to keep track of the user location to direct the messages to the users as they move around. For example, cellular networks keep a Visitor Location Register (VLR) – a database – that records the location of a user as she moves from one cell to another. Suppose you take a train from Philadelphia to New York and turn on your cellular phone when you get on the train.

b) Business Issues

From a business point of view, the major hurdle is a good business case for m-business. There have to be compelling business reasons for adopting mobile communications at the enterprise level. The two important questions are:

- What can the customer do that could not be done before?
- What can a business do that it could not do before?

c)Technology Issues

Wireless systems, although improving steadily, encounter several technical barriers that deter the adoption of wireless technologies. For example, lack of security solutions at the enterprise level is a major concern. In addition, there are diverse standards for mobile computing applications, mobile computing platforms, and wireless networks that hinder adoption. The multitude of mobile devices with different form factors and capabilities, and slow and error-prone networks also do not help the cause of rapid adoption. In particular, it is difficult for wireless networks to compete with the data rates of fiber optic networks, especially if two sites can be connected easily with a fiber cable.

CELLULAR Networks

The cellular network consists of many "cells," where each cell is managed by a Base Station (BS). A Mobile Switching Center (MSC) controls the entire cellular network**.** Frequency allocations and location management are two of the most important issues in cellular networks.

Cellular networks are wireless WANs that establish a connection between mobile users.

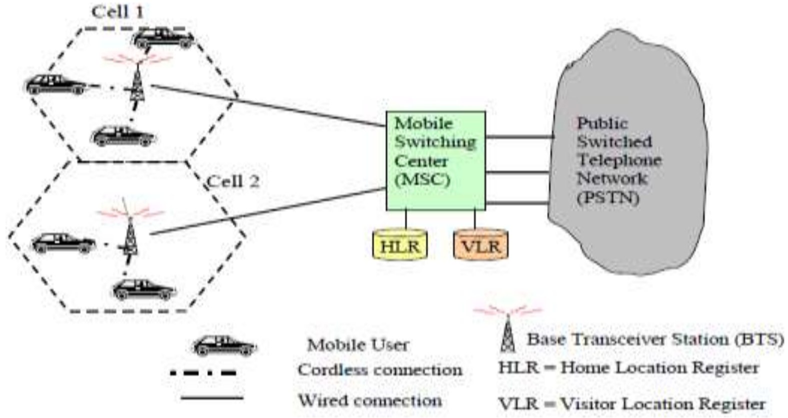

Figure 9.2 shows a high level view of a cellular communication network.
The cellular network is comprised of many ***"cells"*** that typically cover 2 to 20 miles in area. The users communicate within a cell through wireless communications.

A ***Base Transceiver Station (BTS***), also known as a ***Base Station (BS),*** is accessed by the mobile units in each cell by using wireless communications. One BTS is assigned to each cell.
Regular cable communication channels can be used to connect the BTSs to ***the Mobile Switching Center (MSC),*** also known as ***Mobile Telecommunications Service Center (MTSC)***. The MSC is the heart of cellular networks – it determines the destination of the call received from a BTS and routes it to a proper site, either by sending it to another BTS or to a regular telephone network. Keep in mind that the communications are wireless within a cell only.
The bulk of cell-to-cell communication is carried through regular telephone lines (wireless local loops can be used but are not essential). The MTSC uses two databases called ***Home Location Register (HLR)*** and ***Visitor location Register (VLR)*** to locate the mobile users.

The cellular/PCS space is plagued by overcapacity and a difficult transition to next-generation technology.

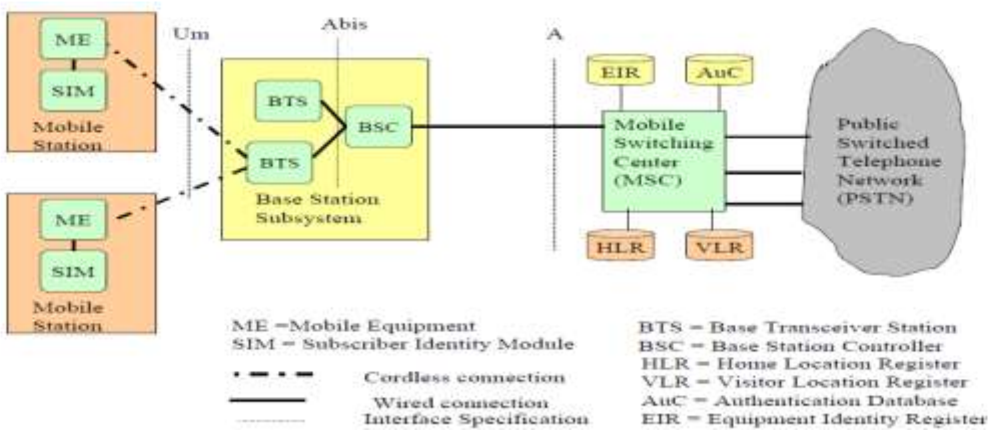

Figure 9.3 : 2G CDMA (IS-95) Network Architecture

But, there are some drawbacks of CDMA cellular also:

- **Relatively immature**. As compared to TDMA, CDMA is a relatively new technology; but it is catching up fast.
- **Self-jamming**. CDMA works better if all mobile users are perfectly aligned on chip (code) boundaries. If this is not the case, then some interference can happen. This situation is better with TDMA and FDMA because time and frequency guard bands can be used to avoid the overlap.

- **Soft handoff**. An advantage of CDMA is that it uses soft handoff (i.e., two cells can own a mobile user for a while before the handoff is complete). However, this requires that the mobile user acquires the new cell before it relinquishes the old – a more complex process than hard handoff used in FDMA and TDMA schemes.

The main advantage of CDMA is that the frequency reuse can be very high and many more users can be supported in a cell as compared to TDMA. Although this leads to a soft handoff that is more complicated than the hard handoff used in TDMA, the advantage of supporting more users far outweighs the disadvantage of added complexity.

Challenges facing Cellular Networks

Besides multiple access considerations, the other problem cellular networks face is the unpredictable transmission characteristics of typical cellular channels. Unlike WLANs that operate in office buildings, cellular networks have to deal with the wireless transmissions in open air. This introduces extreme variability in received signal strength (fading) and arrival time.

The core problem is that multipath propagation occurs as a result of transmitted signals being reflected off objects (most commonly buildings) before they reach the receiver. Thus multiple copies of the transmitted signal arrive at the receiver at different times. Some of these signals have constructive effects (they strengthen each other) while others have destructive effects (they cancel each other).

The challenge in current cellular network designs is that the available frequency spectra are limited and the capacity of the system is increased by exploiting frequency reuse, at the expense of signal interference. This, and other signal quality challenges are addressed, to varying degrees of success, through the use of FEC (forward error correction), adaptive equalization, and spread spectrum.

Evolution of Cellular Networks

The cellular networks are evolving through the following stages:

1G: First-generation wireless cellular: These systems, introduced in the early 1980s, use analog transmission, and are primarily intended for speech. These networks are very slow (less than 1 kilobits per second).

2G: Second-generation wireless cellular: Introduced in the late 1980s, these systems use digital transmission and are also intended primarily for speech. However, they do support low bit-rate data transmissions. The high-tier 2G systems use GSM and the low-tier systems are intended for low-cost, low-power, low-mobility PCS. These systems, most prevalent at present, operate at 9.6 Kbps.

2.5G Systems are essentially 2G systems that have evolved to medium-rate (around 100 Kbps) data. As part of the 2.5G initiative, GSM is being extended by the General Packet Radio System (GPRS) to support data rates of 112 kilobits per second.

3G Systems are broadband multimedia applications can operate at 2 million bits per second. 3G systems will be based on evolution from 2G; they build on the success of GSM, and dual-mode terminals to ease migration from 2G to 3G are commercially available.

3G technologies

One goal of 3G was a single standard so you could use **one phone anywhere in the world**. Many carriers are moving to compromised "2.5G" systems. And even those attempting full-scale 3G implementations haven't been able to agree on a standard. The two leading 3G technologies are **wireless CDMA (Code Division Multiple Access)** and **UMTS (Universal Mobile Telecommunications Service).**

4G systems are the next generation of cellular networks that promise to deliver up to 20 Mbps and beyond. 4G is mainly a marketing buzzword at present. The high data rate of 4G cellular phones could allow users to watch high-resolution movies and television programs on their cellular phones.

A natural question is: why interest in 4G when 3G is not settled yet? The enthusiasm for 4G is occurring because the 3G services have proven so disappointing with multitudes of standards and specifications. It is nontrivial to develop a 4G architecture that utilizes the best features of W-CDMA, OFDM, smart antennas, and multi-band software-controlled radios.

5G Cellular Networks

Some futuristic work on 5G cellular should be mentioned here briefly. The idea is to investigate cellular networks that could deliver data rates above 50 Mbps.

Thus the handset could choose, instead of the common cellular frequency of 800 to 900MHz band, automatically an ISM band. The handset could also automatically switch between the type of network (cellular, 802.11, or Bluetooth) based on the type of applications.

Another aspect of 5G networks is value added services such as location-based services are automatically activated when needed. There is more emphasis on smart antennas, error correction through turbo codes, and improved signal encoding techniques.

One of the main emphasis of 5G cellular is collection of information that can be used to make decisions. For example, it could record the path from your home to work. It could also be measuring the radio propagation, signal strength, and the quality of the different bands as you use your cellular device during the day. It builds an internal database of what it can do when and where.

6G Technology - Just a rumor or it exist?

6G mobile technology in upcoming name in field of mobile communication technologies, it is based on set of standards which enable devices to connect internet with broadband wireless access.

CELLULAR Networks explained

What is GSM?

Definition: GSM, which stands for Global System for Mobile communications, reigns as the world's most widely used cell phone technology. Cell phones use a cell phone service carrier's GSM network by searching for cell phone towers in the nearby area.

For practical and everyday purposes, GSM offers users wider international roaming capabilities than other U.S. network technologies and can enable a cell phone to be a "world phone". More advanced GSM incorporates the earlier TDMA standard.

GSM carriers have roaming contracts with other GSM carriers and typically cover rural areas more completely than competing CDMA carriers (and often without roaming charges, too).

GSM also has the advantage of using SIM (Subscriber Identity Module) cards in the U.S. The SIM card, which acts as your digital identity, is tied to your cell phone service carrier's network rather than to the handset itself. This allows for easy exchange from one phone to another without new cell phone service activation.

GSM uses digital technology and is a second-generation (2G) cell phone system. GSM, which predates CDMA, is especially strong in Europe. EDGE is faster than GSM and was built upon GSM.

- GSM stands for **G**lobal **S**ystem for **M**obile Communication and is an open, digital cellular technology used for transmitting mobile voice and data services.
- The GSM emerged from the idea of cell-based mobile radio systems at Bell Laboratories in the early 1970s.
- The GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard.
- The GSM standard is the most widely accepted standard and is implemented globally.
- The GSM is a circuit-switched system that divides each 200 kHz channel into eight 25 kHz time-slots. GSM operates in the 900MHz and 1.8 GHz bands in Europe and the 1.9GHz and 850MHz bands in the US.
- The GSM is owning a market share of more than 70 percent of the world's digital cellular subscribers.

- The GSM makes use of narrowband Time Division Multiple Access (TDMA) technique for transmitting signals.
- The GSM was developed using digital technology. It has an ability to carry 64 kbps to 120 Mbps of data rates.
- Presently GSM support more than one billion mobile subscribers in more than 210 countries throughout of the world.
- The GSM provides basic to advanced voice and data services including Roaming service. Roaming is the ability to use your GSM phone number in another GSM network.

A GSM digitizes and compresses data, then sends it down through a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1,800 MHz frequency band

GSM basics

The GSM cellular technology had a number of design aims when the development started:

- It should offer good subjective speech quality
- It should have a low phone or terminal cost
- Terminals should be able to be handheld
- The system should support international roaming
- It should offer good spectral efficiency
- The system should offer ISDN compatibility

Why GSM?

The GSM study group aimed to provide the followings through the GSM:

- Improved spectrum efficiency.
- International roaming.
- Low-cost mobile sets and base stations (BSs)
- High-quality speech
- Compatibility with Integrated Services Digital Network (ISDN) and other telephone company services.
- Support for new services.

GSM system overview

The table below summarises the main points of the GSM system specification, showing some of the highlight features of technical interest.

Specification Summary for GSM Cellular System

Multiple access technology	FDMA / TDMA
Duplex technique	FDD
Uplink frequency band	933 -960 MHz (basic 900 MHz band only)
Downlink frequency band	890 - 915 MHz (basic 900 MHz band only)
Channel spacing	200 kHz
Modulation	GMSK
Channel data rate	270.833 kbps
Frame duration	4.615 ms

GSM signal and GMSK modulation characteristics

The core of any radio based system is the format of the radio signal itself. The carrier is modulated using a form of phase sift keying known as Gaussian Minimum Shift Keying (GMSK). GMSK was used for the GSM system for a variety of reasons:

- It is resilient to noise when compared to many other forms of modulation.
- Radiation outside the accepted bandwidth is lower than other forms of phase shift keying.
- It has a constant power level which allows higher efficiency RF power amplifiers to be used in the handset, thereby reducing current consumption and conserving battery life.

Note on GMSK:

GMSK, Gaussian Minimum Shift Keying is a form of phase modulation that is used in a number of portable radio and wireless applications. It has advantages in terms of spectral efficiency as well as having almost a constant amplitude which allows for the use of more efficient transmitter power amplifiers, thereby saving on current consumption, a critical issue for battery power equipment.

GSM EDGE evolution specification overview

It is worth summarizing the key parameters of GSM EDGE cellular technology.

Parameter	Details
Multiple Access Technology	FDMA / TDMA
Duplex Technique	FDD
Channel Spacing	200 kHz
Modulation	GMSK, 8PSK
Slots per channel	8
Frame duration	4.615 ms
Latency	Below 100 ms

GSM EDGE specification highlights

GPRS technology

GPRS technology or the General Packet Radio Service is the GSM upgrade technology used to provide data capability.

GSM was the most successful second generation cellular technology, but the need for higher data rates spawned new developments to enable data to be transferred at much higher rates. The first system to make an impact on the market was GPRS. The letters GPRS stand for General Packet Radio System, GPRS technology enabled much higher data rates to be conveyed over a cellular network when compared to GSM that is voice centric.

GPRS benefits

GPRS technology brings a number of benefits for users and network operators alike. It was widely deployed to provide a realistic data capability via cellular telecommunications technology.

GPRS technology offered some significant benefits:

- ***Speed:*** One of the headline benefits of GPRS technology is that it offers a much higher data rate than was possible with GSM. Rates up to 172 kbps are possible, although the maximum data rates realistically achievable under most conditions will be in the range 15 - 40 kbps.
- ***Packet switched operation:*** Unlike GSM which was used circuit switched techniques, GPRS technology uses packet switching in line with the Internet. This makes far more efficient use of the available capacity, and it allows greater commonality with Internet techniques.
- ***Always on connectivity:*** A further advantage of GPRS is that it offers an "Always On" capability. When using circuit switched techniques, charges are based on the time a circuit is used, i.e. how long the call is. For packet switched technology charges are for the amount of data carried as this is what uses the services provider's capacity. Accordingly, always on connectivity is possible.
- ***More applications:*** The packet switched technology including the always on connectivity combined with the higher data rates opens up many more possibilities for new applications. One of the chief growth areas that arose from GPRS was the Blackberry form of mobile or PDA. This provided for remote email applications along with web browsing, etc.

The GSM and GPRS elements of the system operate separately. The GSM technology still carries the voice calls, while GPRS technology is sued for the data. As a result voice and data can be sent and received simultaneously.

GPRS network

GPRS and GSM are able to operate alongside one another on the same network, and using the same base stations. However upgrades are needed.

Key GPRS parameters

The key parameters for the GPRS, General Packet Radio System, are tabulated below:

Parameter	Specification
Channel Bandwidth	200 kHz
Modulation type	GMSK
Data handling	Packet data
Max data rate	172 kbps

The SGSN or Serving GPRS Support Node element of the GPRS network provides a number of takes focused on the IP elements of the overall system. It provides a variety of services to the mobiles:

- Packet routing and transfer
- Mobility management
- Attach/detach
- Logical link management
- Authentication
- Charging data

There is a location register within the SGSN and this stores location information (e.g., current cell, current VLR). It also stores the user profiles (e.g., IMSI, packet addresses used) for all the GPRS users registered with the particular SGSN.

WIRELESS LANs explained

IEEE 802.11

IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 5 GHz and 2.4 GHz public spectrum bands.

Protocols = 802.11-1997 (802.11 legacy)

Legacy 802.11 was rapidly supplemented (and popularized) by 802.11b.

802.11a

Release date	Op. Frequency	Net bit rate (Typ)	Net bit rate (Max)	Gross bit rate (Max)	Range (Indoor)
October 1999	5 GHz	23 Mbit/s	54 Mbit/s	72 Mbit/s	~35 m

The 802.11a standard uses the same data link layer protocol and frame format as the original standard, but an OFDM based air interface (physical layer). It operates in the 5 GHz band with a maximum net data rate of 54 Mbit/s, plus error correction code, which yields realistic net achievable throughput in the mid-20 Mbit/s.

802.11b

Release date	Frequency band	Data rate (typical)	Data rate (maximum)	Range (indoor)
October 1999	2.4 GHz	4.5 Mbit/s	11 Mbit/s	~38 m

802.11b devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: microwave ovens, Bluetooth devices, baby monitors and cordless telephones.

802.11g

Release date	Op. Frequency	Net bit rate (Typ)	Net bit rate (Max)	Gross bit rate (Max)	Range (Indoor)
June 2003	2.4 GHz	19 Mbit/s	54 Mbit/s	72 Mbit/s	~38 m

Like 802.11b, 802.11g devices suffer interference from other products operating in the 2.4 GHz band. Devices operating in the 2.4 GHz range include: microwave ovens, Bluetooth devices, baby monitors and cordless telephones.

802.11n

Release date	Op. Frequency	Data rate (Typ)	Data rate (Max)	Range (Indoor)
Pending	5 GHz and/or 2.4 GHz	74 Mbit/s	300 Mbit/s (2 streams)	~70 m

802.11n is a proposed amendment which improves upon the previous 802.11 standards by adding multiple-input multiple-output (MIMO) and many other newer features.

Bluetooth

Bluetooth uses short-range radio waves over distances of 9 meters. For example, Bluetooth devices such as a keyboard, PDA, cell phone, mouse or computer can connect to each other wirelessly and the distance can be up to 10 meters (33 feet). Some of the Bluetooth devices can support headsets and printers.

Use this chart to get some quick information to help you differentiate between the available wireless networking standards and choose which standard might be the right fit for your business. See the links below the chart for further information on wireless networking standards.

Standard	Data Rate	Modulation Scheme	Security	Pros/Cons & More Info
IEEE 802.11	Up to 2Mbps in the 2.4GHz band	FHSS or DSSS	WEP & WPA	This specification has been extended into 802.11b.
IEEE 802.11a (Wi-Fi)	Up to 54Mbps in the 5GHz band	OFDM	WEP & WPA	Products that adhere to this standard are considered "Wi-Fi Certified." Eight available channels. Less potential for RF interference than 802.11b and

				802.11g. Better than 802.11b at supporting multimedia voice, video and large-image applications in densely populated user environments.
IEEE 802.11b (Wi-Fi)	Up to 11Mbps in the 2.4GHz band	DSSS with CCK	WEP & WPA	Products that adhere to this standard are considered "Wi-Fi Certified." Not interoperable with 802.11a. Requires fewer access points than 802.11a for coverage of large areas. Offers high-speed access to data at up to 300 feet from base station.
IEEE 802.11g (Wi-Fi)	Up to 54Mbps in the 2.4GHz band	OFDM above 20Mbps DSSS with CCK below 20Mbps	WEP & WPA	Products that adhere to this standard are considered "Wi-Fi Certified." May replace 802.11b. Improved security enhancements over 802.11. Compatible with 802.11b.
IEEE 802.16 (WiMAX)	Specifies WiMAX in the 10 to 66 GHz range	OFDM	DES3 and AES	Commonly referred to as WiMAX or less commonly as WirelessMAN or the Air Interface Standard, IEEE 802.16 is a specification for

				fixed broadband wireless metropolitan access networks (MANs)
IEEE 802.16a (WiMAX)	Added support for the 2 to 11 GHz range.	OFDM	DES3 and AES	Commonly referred to as WiMAX or less commonly as WirelessMAN or the Air Interface Standard, IEEE 802.16 is a specification for fixed broadband wireless metropolitan access networks (MANs)
Bluetooth	Up to 2Mbps in the 2.45GHz band	FHSS	PPTP, SSL or VPN	No native support for IP, so it does not support TCP/IP and wireless LAN applications well. Not originally created to support wireless LANs. Best suited for connecting PDAs, cell phones and PCs in short intervals.
OpenAir	Pre-802.11 protocol, using Frequency Hopping and 0.8 and 1.6 Mb/s bit rate	CSMA/CA with MAC retrans mission s	OpenAir no encryption at the MAC layer, but generates Network ID password (Security ID)	OpenAir is the proprietary protocol from Proxim. All OpenAir products are based on Proxim's module.