Wireless Technology: Current Status and Future Directions

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Abstract

Wireless Technology is expected to be the dominant mode of access technology in the future. Besides voice, a new data range of services such as multimedia and high speed data are being offered for delivery over wireless network. Mobility will be seamless, realizing the concept of persons' being in contact anywhere, at any time. Throughout this paper, we review the long, interesting development of wireless communication in the past, examine the current progress in standards and technologies, and finally discuss possible trends for wireless communication solutions.

1. Introduction

The origins of wireless communications date back to the 1890s with Marconi's work in radio and wireless telegraphy. Since then, advances have come through a sequence of discoveries and advancements. Wireless technology a key for mobile multimedia services of the future while also facilitating rapid/flexible deployment of high-speed access to fixed computing devices in the near-term. It describes a wide range of communications services and portable devices that send and receive data, text, voice and video. Cell phones and pagers are the most widely used mobile wireless products today, and many routine daily activities rely on the voice communications and messaging services supported by these devices. New technologies are emerging that will support wireless remote monitoring, wireless financial transactions, wireless Internet access, and wireless control of appliances and devices. Mobile wireless developments are evolving so rapidly, that it is difficult to keep up with the latest advances and to make purchasing decisions. This paper provides a brief background on the history of wireless development, a general overview of mobile wireless technologies that are available today, and some predictions for the future.

1.1 Historical overview

Transmitting information wirelessly was a scientific curiosity for the last half of the nineteenth century. Signaling and audio communication using electromagnetic radiation was first utilized as a wireless telegraph where telegraph lines were impractical or unreliable. Electromagnetic radiation is the formal term that was introduced by Heinrich Hertz, but other terms were quickly instituted to describe early radio. Terms such as electric waves, Hertzian waves, ether waves, spark telegraphy, aerography and wireless entered the vocabulary at the beginning of the 20th century. Credited with the invention of the radio, Marconi actually developed a functional transmitter and receiver and became the first person to successfully transmit and receive long range radio signals. He is an Italian electrical engineer and Nobel laureate who sent the first wireless message more than 100 years ago. By 1895, he had developed an apparatus with which he succeeded in sending signals to a point a few kilometers away by means of a directional antenna. In 1897, he used his radio apparatus to create the first radio transmitter, thus, the birth of radio. In 1898, Marconi was awarded a patent for his wireless telegraph system for tuned communication. In 1901, Marconi successfully transmitted the first wireless telegraph signal via radio across the Atlantic Ocean from Cornwall to Newfoundland. In December of 1900, the first voice radio link was demonstrated. Radio communications were of natural interest to the shipping industry, and the government established ship to shore communications requirements in 1910. By 1918, 5700 ships had wireless telegraphy. The radio broadcasts for news and entertainment became popular in the early 1920s. The advent of Frequency Modulation (FM) radio in 1935 brought reductions in the size and improvements to the quality of radio equipment. It has not been until the past decade that mobile telephone service has become widely available and affordable. These early wireless phone services were expensive and unavailable. Improvements in the 1960s and 70s generated renewed interest in wireless producing the Advanced Mobile Telephone Service (AMPS). The distinguishing features of wireless communications systems compared to wireline systems are ; the extreme variability of the channel and the inherent multiple access nature. The latter stems from the fact that the band of frequencies that can be used for any given wireless service is limited, and thus users must contend for access. In this course we will briefly describe some of the multiple access approaches in common use, but our focus will be on the time-varying channel: the physical reasons for the variability, the impact on performance, and means of mitigating the performance effects.

Wireless systems have assumed increased importance in the 1990's, from systems as simple as television remotes which employ infrared signalling to international cellular radio networks. Pagers, cordless phones, cell phones,

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and direct broadcast satellite systems have all enjoyed large commercial success, and there is every reason to believe that some of the emerging wireless communications systems will also find widespread acceptance. Among the possibilities are wireless home distribution of multimedia services, distributed sensor networks, and global satellite systems. All of this activity leverages the continued advances in semiconductor technology, which enables ever more sophisticated systems to be realized at low cost. Additionally, while until quite recently most wireless systems were analog in nature (apart for satellite systems and paging), now almost all new designs are digital, because of the increased flexibility it affords for security and performance.

Communication remains by far the most popular application of mobile wireless technology today with over 100 million cell phones and 30 million pagers in the United States alone. In addition to the traditional modes of voice and text paging, new communication applications are emerging with mobile email and instant messaging. Another important new mobile wireless application, mobile Internet access, makes information available everywhere. Internet access to news, weather, health, sports, shopping, business, education, and entertainment is becoming available on a variety of different portable devices and supported through several competing types of wireless service. Mobile Internet access is available on laptop computers and personal digital assistants through local area networks using 802.11b wireless Ethernet and competing Bluetooth network access. New cell phones, two-way pagers, and convergence devices are also beginning to support Internet access through wide area cell phone networks.

Today, wireless applications for remote control are most popular in TV/VCR remote controls and garage door openers, but new wireless control standards are emerging that can support remote control of a wide range of devices in the home and community. For example, wireless devices may open doors, adjust room lighting and temperature, call an elevator, purchase a soft drink, and operate an Automatic Teller Machine. Mobile wireless monitoring applications send information and sensor data that can help in healthcare management, equipment maintenance, and security. Wearable products are available today that can track patients who may wander away from home or send emergency alerts with vital signs data. Equipment maintenance information - battery life, service alerts, component status - can also be monitored and sent wirelessly.

Location finding is the final mobile wireless application on the list. Inexpensive, portable, and wireless devices can now link into the international satellite-based Global Positioning System (GPS) to obtain location coordinates to assist in navigation and emergency tracking. Other location finding technologies are emerging that are based upon cell phone and networking technologies.

1.2 Evaluations of Wireless standard

An explosion in the use of wireless technology to exchange information between people, systems and devices. It is a revolution because it has resulted in businesses, governments, nations, communities and individuals undergoing rapid and far reaching change in the way they communicate. The development of computing devices that will increase exponentially in speed and capacity while decreasing in size and cost. The delivery of information and instructional materials "anytime" and "anyplace" as a result of advances in broadband and wireless technology such as Communications (GSM, Microwave, Mobile Radio, Satellite). Audio broadcasting, TV Broadcasting, Fleet management, Vehicle tracking and WLAN. Figure.1 Shows some of the major cellular mobile phone standards in North America and Europe The use of wireless technology in the day-to-day transfer of information is increasing rapidly, and new developments are continually expanding its role in modern communication. Even so, the majority of wireless technologies do not yet provide as much bandwidth or accessibility as landlines. This is especially true for cell phones and two-way radio. Furthermore, the transmission range for wireless technologies usually is inversely related to the data transmission speed. That is, the further the wireless signal has to travel, the less data it can carry per second.

The gap between landline and wireless technologies is narrowing, though. The most advanced developments of wireless broadband deliver downstream data transfer speeds of up to 1.5 Gbps (gigabits per second) and upstream speeds around 200 Mbps (megabits per second). These data transfer rates are comparable to today's fiber optic speeds. At this time, however, wireless broadband initiatives typically require fixed, rather than mobile, receivers.

Another technology, Free Space Optics, may be able to offer even higher data transmission rates than wireless broadband. This technology also requires fixed-position receivers, however, and is only in the beginning stages of implementation in select markets.

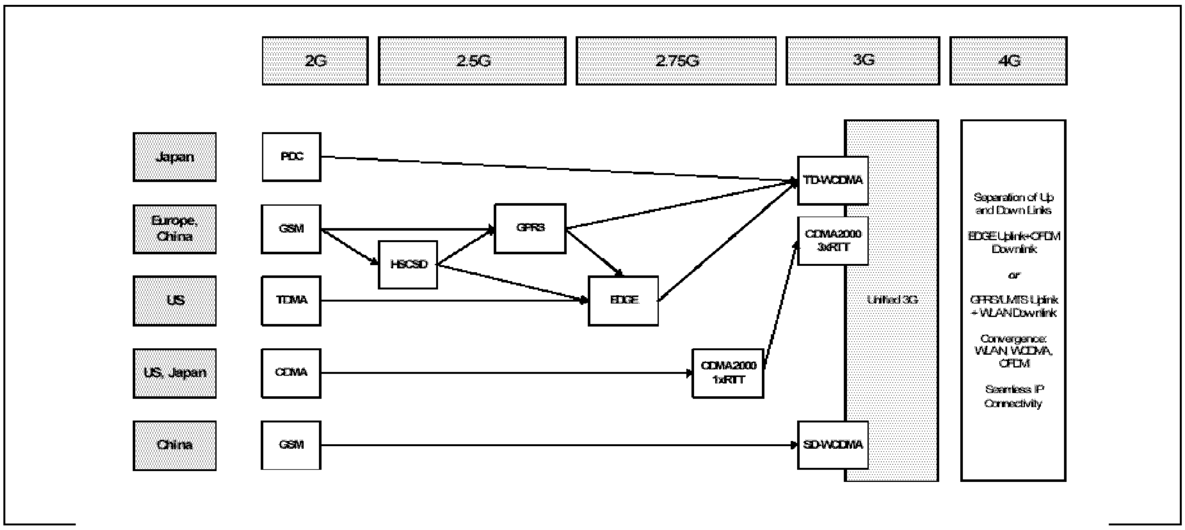

Figure.1 Some of the major cellular mobile phone standards in North America and Europe.

2. Cellular Mobile telephone

Lars Magnus Ericsson was one the most influential persons behind the early years of telephone manufacturing. He opened his electro-mechanical workshop in rented premises in Stockholm in 1876. His assets were not extensive but consisted of an instrument-maker's lathe and a twelve year old assistant. In the early days of his venture he was involved in the repair of telephone equipment and other electrical devices, but he soon began to produce improved equipment of his own design - designs such as a dial telegraph instrument for use in railway systems, and a fire telegraph system for small communities. Such developments won him recognition for his work in this field. Ericsson's reputation for quality work soon enabled him to obtain orders from a wide variety of public and private authorities in areas such as telegraphy, fire protection, police administration and railway systems. The major event of 1878 was the delivery of the first telephones of Ericsson's manufacture and Ericsson contributed substantially to the design of early telephone exchanges, designing and producing the first 'multiple desk' in Europe in 1884.

In December 1947 Bell Laboratories articulated the cellular concept for mobile telephony in an internal memorandum. In a cellular system one needs to transfer the call from zone to zone as the mobile travels, and you need to *switch* the frequency it is placed on, since frequencies differ from cell to cell. Frequency re-use is the critical and unique element of cellular, not handoffs, since conventional radio telephone systems used them as well.

In mobile telephony a channel is a pair of frequencies. One frequency was to transmit on and one was to receive. It makes up a circuit or a complete communication path. Yet the radio spectrum was extremely crowded. In the late 1940s little space existed at the lower frequencies most equipment used. Inefficient radios contributed to the crowding; using a 60 kHz wide bandwidth to send a signal that can now be done with 10 kHz or less. Radio waves at lower frequencies travel great distances, sometimes hundreds of miles when they skip across the atmosphere. High powered transmitters gave mobiles a wide operating range but added to the dilemma. Telephone companies couldn't reuse their precious few channels in nearby cities, lest they interfere with their own systems. In 1947 AT&T began operating a highway service, a radio-telephone offering that provided service between New York and Boston. It operated in the 35 to 44MHz band and caused interference from to time with other distant services. Also in 1947 the Bell System asked the FCC for more frequencies. The FCC allocated a few more channels in 1949, but gave half to other companies wanting to sell mobile telephone service. On March 1, 1948 the first fully automatic radiotelephone service began operating in Richmond, Indiana, eliminating the operator to place most calls. For the late 1940s and most of the 1950s, however, most radios would still rely on tubes. In 1954, Texas Instruments was the first company to start commercial production of silicon transistor instead of using germanium. Silicon raised the power output while lowering operating temperatures, enabling the miniaturization of electronics. In 1964 the Bell System began introducing Improved Mobile Telephone Service or IMTS, a replacement to the badly aging Mobile Telephone System. Across the ocean the Japanese were operating conventional mobile radio telephones and looking forward to the future as well. In 1967 the Nokia group was formed by consolidating two companies: the Finnish Rubber Works and the Finnish Cable Works. Finnish Cable Works had an electronics division which Nokia expanded to include semi-conductor research. Currently the Second-Generation

(2G) wireless mobile system is under deployment all over the world. However, soon the Third Generation (3G) systems start replacing the 2G systems. Several versions and early 3G systems are almost available.

Third generation (3G) wireless communications is the evolution of second generation (2G) wireless with increased data rates as well as increased flexibility. This allows a wide range of advanced services to be provided. 3G systems user services will range from the traditional voice and paging services to interactive multimedia including high quality teleconferencing and Internet access. Although the International Telecommunications Union's (ITU) original goal was a single worldwide air interface standard for 3G, achieving that goal has proven difficult and a family of approved radio transmission technology (RTT) recommendations is likely. Nine RTT proposals for 3G were submitted to the ITU during June 1998. Both time-division (TDMA) and code-division (CDMA) multiple access technologies have been proposed although the majority of the proposals were based upon wideband CDMA (WCDMA) technology. The WCDMA proposals are similar in many respects and may therefore be combined into at most two WCDMA proposals for the final ITU recommendation. Fourth Generation (4G) system will be a further extension of 3G systems with higher data rates and better utility of the precious RF bandwidth.

3. Wireless Communications Today

Communication remains by far the most popular application of mobile wireless technology today. In addition to the traditional modes of voice and text paging, new communication applications are emerging with mobile email and instant messaging. Another important new mobile wireless application, mobile Internet access, makes information available everywhere. Internet access to news, weather, health, sports, shopping, business, education, and entertainment is becoming available on a variety of different portable devices and supported through several competing types of wireless service. Mobile Internet access is available on laptop computers and personal digital assistants through local area networks using 802.11b wireless.

Figure 2 illustrates the relationship between 2G, 3G, and 4G wireless systems. The boundaries illustrated in this figure are indicative only. 2G wireless systems include the Global System for Mobile (GSM) Communications, the CDMA system defined by the IS-95 series of standards in the United States, the U. S. Digital Cellular (USDC) system, and the Japanese Personal Digital Cellular (PDC) system. 2G systems can transport at most 100 KBPS of data. This includes enhancements of GSM to the GSM Packet Radio System (GPRS) and the Enhanced Data Rates for GSM Evolution (EDGE) to GPRS. 3G systems are currently being standardised and operation is expected in the year 2001 in some markets. Third generation systems will increase user information rates to approximately 2 MBPS in local areas with limited mobility. Broadband fixed wireless access or wireless local loop (WLL) is also included in 3G concepts. 4G systems are expected to follow 3G systems further increase in information rates at high mobility. Ethernet and competing Bluetooth network access. Today, wireless applications for remote control are most popular in TV/VCR remote controls and garage door openers, but new wireless control standards are emerging that can support remote control of a wide range of devices in the home and community. For example, wireless devices may open doors, adjust room lighting and temperature, call an elevator, purchase a soft drink, and operate an Automatic Teller Machine. Mobile wireless monitoring applications send information and sensor data that can help in healthcare management, equipment maintenance, and security. Wearable products are available today that can track patients who may wander away from home or send emergency alerts with vital signs data. Equipment maintenance information - battery life, service alerts, component status - can also be monitored and sent wirelessly. Location finding is the final mobile wireless application on the list.

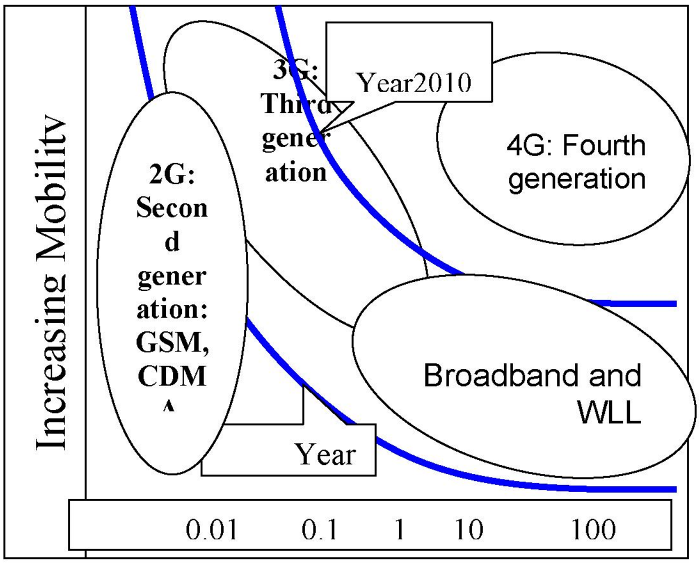

Figure 2 Mobility and information transfer rate relationships between second, third and fourth generation wireless systems.

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3.1 Third Generation Status

The development of 3G-radio interface technology has been the subject of major research efforts for the past many years. For example, the European Telecommunications Standards Institute (ETSI) has co-ordinated and funded a large number of technology development projects both under the RACE (Research on Advanced Communications Systems in Europe) and ACTS (Advanced Communications Technologies and Services) programmes. The combined RACE and ACTS projects span approximately ten years during which significant technology has been developed. The ETSI projects typically brought together technologists from both industry and universities in a major collaboration to solve difficult technical problems. One output of these ETSI programs was the detailed definition of radio interfaces using wideband CDMA, wideband TDMA, wideband time-division code-division (TD/CDMA), and orthogonal frequency division (OFDM) multiple access technologies. Detailed comparisons of these radio interface technologies were made and a consensus decision was made that the European recommendation to the ITU for the 3G RTT would be WCDMA for the frequency division duplex spectrum and TD/CDMA for the time division spectrum. At the same time, Japanese corporations were also developing radio interface proposals. The Japanese efforts included the development of proof-of-concept models for critical hardware components and subsystems as well as theoretical studies. The output of these significant research efforts was a detailed radio interface definition using WCDMA technology, which was submitted to the ITU during June 1998. The Japanese and the European WCDMA proposals are similar. Since June 1998, technologists for these two proposals have collaborated and now have a nearly common WCDMA specification for the ITU.

In the United States efforts to develop a 3G RTT proposal to the ITU are more recent. Nevertheless, collaboration between a large number of corporations has resulted in a major detailed RTT submission to the ITU during June 1998. The Telecommunications Industry Association (TIA) approved this proposal. The USA proposal also recommends wideband CDMA but differs from the European and Japanese in a number of aspects. The USA proposal is an evolution of the 2G CDMA system as defined in IS-95B.
Table 1.1 presents a number of parameters of the European, Japanese, and USA wideband CDMA proposals. The ITU received a total of nine RTT proposals in June 1998. Seven of these utilised WCDMA technologies; the other proposals used wideband TDMA. Currently, all of these proposals are being evaluated and technologists are attempting to combine similar proposals to obtain a small number of radio interface specifications for the 3G family of standards. This harmonisation of proposals has continued during the years 1999 and 2000. However, ITU was unable to recommend any one proposal. Therefore, they have left the field wide open and have allowed to companies to implement the proposals that they have sent.

3.2 Bluetooth Technology

The name Bluetooth is actually the nickname for Harold Blaatand "Bluetooth" II. "Bluetooth" was the King of Denmark from 940 – 981 A.D. In 1994, Ericsson, the Swedish inventor of the technology decided to name the technology. Bluetooth is the next generation of information transportation across the globe. The old way to transport information was across a cable, being either a phone line or even a coaxial cable. But this next generation of transferring information is wireless. This technology is emerging as a very popular choice for short-range wireless networking. Bluetooth technology and standards provide the means for the replacement of cable that connects one device to another with a universal short-range radio link
The technology was initially developed for replacing cables, but has now evolved into not only being a cable replacement technique but also a technique to establish connection between several units. For instance, it shows how to create small radio LANs. A study was initiated at Ericsson Mobile Communications in 1994 to find a low power and low cost radio interface between mobile phones and their accessories. The requirements regarding price, capacity and size were set so that the new technique would have the potential to better all cable solutions between mobile devices. Initially a suitable radio interface with a corresponding frequency range had to be specified. A number of criteria for the concept were defined regarding size, capacity and global uniformity. The radio unit should be so small and consume such low power that it could be fitted into portable devices with their limitations. The concept had to handle both speech and data and finally the technique had to work all around the world.
The study soon showed that a short-range radio link solution was feasible. When designers at Ericsson had started to work on a transceiver chip, Ericsson soon realized that they needed partners to develop the technique. Attempts were made not only to improve the technical solutions but also to get a large market support in the areas of PC hardware, portable computers and mobile phones. Avoiding a market situation with a many non-standard cable solutions, where one cable is designed specifically for one pair of devices, was one of the motives that made competing companies join the project. Ericsson Mobile Communications, Intel, IBM,

Toshiba and Nokia Mobile Phones formed a Special Interest Group (SIG) in 1998. This group represented the diverse market support that was needed to generate good support for the new technology. In May of the same year, the Bluetooth consortium was announced. The intention of the Bluetooth SIG is to form a de facto standard for the air interface and the software that controls it. The purpose is to achieve interoperability between different devices from different producers of portable computers, mobile phones and other devices.
But this next generation of transferring information is wireless. It eliminates the need for inconvenient cables. The more peripheral devices attached to your old network, the more cables that will be bunched up and in the way for employees to trip over. The Bluetooth technology works by inserting the Bluetooth microchip into each peripheral device such as printers, PDA's, desktops, fax machines, keyboards, and almost any other digital devices can be part of the Bluetooth system on your network. Once enabled, each connection is made instantly and the devices do not even have to be within line sight of each other. The frequent is globally recognized so that when this technology spreads, it can be a standard. This technology is fast, efficient, and can be incorporated in all digital devices.

3.3 IEEE 802.11

We describe below the IEEE 802.11 technology for short-range wireless networking. This is given as another example of short-range wireless networking standard. In 1997, the Institute of Electrical and Electronics Engineers (IEEE) ratified the 802.11 specifications for wireless Ethernet. IEEE 802.11 serves the same purpose as the IEEE 802.3 standard for wired Ethernet: establishing standards for vendor-to-vendor interoperability.

IEEE 802.11 was devised by vendors who perceived computer local area networks (LANs) as the largest potential market for their wireless products. Consequently, the 802.11 specifications enable wireless devices to operate with computers using standard operating systems for applications that require the transmission of large files. It is often assumed that wireless LANs are computer networks for office applications. IEEE 802.11 is a set of requirements for wireless products to ensure interoperability among similar devices. The standard is sought to achieve the following goals:
Define a class of wireless products suitable for computer LANs.
Continue to serve existing mobile user applications (e.g., bar code data collection).
Reduce costs by encouraging competition among wireless product vendors.
IEEE 802.11 was intended to create an open standard for wireless networks in place of many proprietary technologies. Basic specifications of this standard are shows in table.2.

Table 1: Proposed 3G standards

	Japan (ARIB)	**Europe (ETSI)**	**USA (cdma2000)**
Multiple Access Scheme	WB DS-CDMA		
Duplex Scheme	FDD & TDD		
Channel Spacing	1.25/ 5.0/10.0/20.0 MHz	5.0/10.0/20.0 MHz	1.25 MHz
Chip Rate	1.024/4.096/ 8.192/16.384 MCPS	4.096/8.192/ 16.384 MCPS	1.23/3.69/ 7.37/11.1/14.7 MCPS
Frame Length	10 ms		5 and 20 ms
Spreading Modulation – Forward	Complex-QPSK	QPSK	Complex-QPSK
Spreading Modulation - Reverse	Complex-QPSK		
Pulse shaping	Root-raised cosine (RRC)		IS-95 -B
User identification - Forward	OVSF chanelization code assignment is user specific		long m-sequences XOR with data (length 2^{41})
User identification - Reverse	Reverse GOLD scrambling code is user specific		long m-sequences XOR with scrambling code (length 2^{41})
Data Modulation - Forward	QPSK		
Data Modulation - Reverse	BPSK	QPSK	BPSK
Data Rates Supported	8 KBPS to 4.096 MBPS		**9.6 to 76. 8 KBPS and** 1036.8 and 2073.6 KBPS
Pilot Channel Strategy	Time-multiplex		Code-multiplex (common or auxiliary)
Data Demodulation	Coherent scheme	Coherent using time	Coherent using continuous code

	using time multiplex pilot symbols	multiplex pilot symbols	multiplex pilot
Error Control	Convolution code and turbo codes	Convolution code, Concatenated RS & CC, Turbo codes	Convolution code and Turbo codes
Interleaving Depth	10, 20, or 80 ms	10, 20, 40, 80 ms	20 ms
Power Control	Forward & Reverse		
Power Control Rate	1600 Hz		800 Hz
Power Control Step	1 dB	0.25-1.5 dB	0.25, 0.5, 1.0 dB
Power Control Range – Forward and reverse (in bracket)	TBD	30 dB (80 dB)	128 dB +/- 24 dB (fast)

Table.2 Basic specifications of the standard

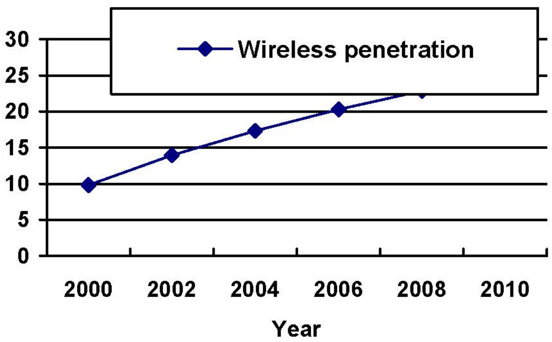
Physical Class	Data Rate	Channel Capacity
2.4 GHz Band radio		
Frequency Hopping Spread Spectrum (FHSS)	1 Mbps to 2 Mbps	79 numbers of 1 MHz band channels
Direct Sequence Spread Spectrum (DSSS)	2 Mbps to 1 Mbps	11-13 overlapping channels
Light Waves		
Diffused Infrared	1 Mbps to 2 Mbps	N/A

802.11 also specifies how a roaming transceiver can establish communications with a new access point as it moves from one coverage area to another. However, 802.11 does not define how access points should negotiate the hand-off of that transceiver. This means that each vendor's roaming negotiations will be proprietary. Wherever roaming is required, all access points will need to be provided by one vendor, even if there is interoperability between multiple brands of transceivers and access points. Customers will not get the vendor independence that they expect when buying products that claim adherence to the 802.11 standard. 802.11 vendors are working on technology that transmits data at a rate of 10 Mbps or higher. Infrared offers the most conventional migration path, claiming that it can increase transmission speeds while still maintaining downward compatibility to existing slower speed transceivers.

Radio technologies have more difficult issues. With frequency hopping spread spectrum technology, 2 Mbps may be the upper limit in the 2.4 GHz spectrum. To go to 10 Mbps, frequency hopping systems need 5 MHz bands. Other frequencies with a possibility to raise transmission speed to 10 Mbps or higher are being explored by various agencies. Unfortunately, no migration path is available for 802.11 products. Direct sequence products currently are being introduced at 11 MBPS in the 2.4 GHz spectrum (outside the scope of the current 802.11 standards). Vendors are providing downward interoperability with 802.11 transceivers, as long as the entire wireless network is run at 2 MBPS speed. The IEEE 802.11 specification was intended to create a standard for the entire wireless data industry. Unfortunately, the attempt to define a wireless standard for three different technologies and for applications as diverse as computer LANs and bar code data collection has resulted in a compromise. Radios compliant with IEEE 802.11 in its current form offer neither Ethernet data rates for wireless computer LANs or reliable, long-range transmission of small communications packets appropriate for other wireless data connectivity applications. Modifying the 802.11 specifications to more adequately address either of these requirements will make the standard less useful for the other.

4. The Future of Wireless Technology

Specific predictions about which devices or network technologies will dominate the market in years to come cannot be made with confidence, but it is quite certain that the future will be increasingly wireless. Wireless products and services are striving to make access available any time and everywhere. In the near term, there will be a continuing integration of wide-area (carrier) service to local and individual user wireless networks. More Cellular/PCS phones will support short messaging service (SMS) and data delivery applications. Per minute costs will continue to drop, but service providers will push more applications that use more minutes. Email will follow people across the network between home, office, and mobile, hand-held devices. Interoperability and coverage among wireless network service providers remains a problem for the near future, but will improve over time to the point where all devices can communicate anywhere. Technology advances in signal processing, components miniaturization and battery-life extension have made devices smaller and cheaper, and this trend is expected to continue for the foreseeable future. Wireless Ethernet, also know as "Wi-Fi" or 802.11b, will continue to grow. Bluetooth cable-less device communication functions will coexist with 802.11, and it may offer competition for wireless Internet access.Telemetry (one way) will be major driver for medical applications. PDA-driven wireless for healthcare will continue to expand but interoperability still an issue over distant networks. Five or more years out will see home wireless and mobile networks will be common and there will be near ubiquitous service availability. Emergency mobile medical support will be in place. Non-line-of- sight capabilities will be vastly improved. Sensor connected with geo-location to provide quality of life support. Wireless will begin to approach “Star Trek” communications, extremely small, all-ways on connections with smart web and environment-aware features. The wireless penetration worldwide is expected to increase from 7.56% in 1999 to 20% in 2005 and 25% in 2010. The US customers alone are expected to increase by 21% during 2000 – 2010, to 105 million.



Conclusions and Discussions

In this paper, we have outlined the development of some major wireless communication devices. It is noted that the advancement of this technology has been a cumulative efforts from many individuals, rather than work of sole individual. History has proven that wireless communication have already changed the way people communicate with each other. While the progress has been impressive, much more is yet to come that will revolutionize communications as we know it, leading eventually to communicating with anyone or any device at any time. The demands of the next-century customer are difficult to anticipate. It is clear, however, that in the next years to come, people will communicate with more means than just voice. There is a desire to communicate simultaneously using speech, viewing, and data. The speed of the communication will also be important. In summary, wireless technologies are capable of meeting the challenge to provide a wide range of new services and therefore have the potential to be the dominant mode of access in the future.

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