CENTER FOR CRIMINAL JUSTICE TECHNOLOGY

Commercial Wireless Technologies For Public Safety Users

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1.0 Introduction

Interoperability of wireless communications among public safety agencies is a nationwide issue. Numerous designs and programs addressing the challenge have been developed based on specialized radio technology. Wireless communications technologies are entering an era of explosive growth where new commercial products and services are being announced almost daily. Commercial capabilities offer new opportunities for the public safety community to implement innovative applications and approach greater interoperability and universal coverage.

Mitretek Systems, Incorporated, and the Center for Criminal Justice Technology prepared this report.

1.1 Background

Wireless communications interoperability between public safety agencies is a nationwide issue. Interoperability problems stem from institutional impediments (historical or territorial motivations, for example), as well as technical incompatibilities. Telecommunications interoperability issues have been addressed in significant depth in many programs including the Public Safety Wireless Network (PSWN), the Federal Wireless Users Forum, the Public Safety Wireless Advisory Committee, and the Public Safety National Coordinating Committee. Solutions range from making modifications to the systems already owned by the cooperating agencies, to migrating from an agency's own communications system to a larger communications network (for example, one operated by the State Government). In other cases, public safety agencies have become subscribers to commercial networks. The programs addressing interoperability have concluded that there is no single solution for public safety. Many factors will determine what is the best choice for a given organization or region.

The Federal Communications Commission (FCC) has recently made many new frequency allocations for both commercial and public safety wireless systems. The number of wireless communications technology choices is growing rapidly, and many new protocols are being introduced making interoperability more elusive than ever.

Wireless technology is advancing rapidly, as well. Wireless personal area networks (PANs) can eliminate the traditional cables and wires that are used to connect headsets, transceivers, personal digital assistants (PDAs), laptop computers, and mobile data terminals (MDTs) over ranges on the order of 10-100 meters. Wireless local area networks (LANs) are designed to connect laptops, PDAs, and MDTs to an installed infrastructure. Designed primarily for portable communications within office buildings, warehouses, and factories, the communications ranges of these devices are on the order of 100-1000 meters. Wireless wide area networks (WANs) are used to provide service to vehicle-mounted and other portable equipment, throughout a metropolitan, or larger, coverage area. These systems use multiple base stations with coverage areas on the order

of several kilometers and usually provide continuous communications as a terminal travels across the coverage areas of the base stations.

These three types of networks are not mutually exclusive. There is great potential to integrate them for a single application. For example, a PAN can be used to connect a wireless voice-activated headset to a radio, or allow an officer to use a portable data device to exchange data with a mobile data terminal mounted in a vehicle, untethering the officer from the vehicle. The LAN can be used to network mobile terminals among public safety vehicles that have arrived on the scene of an incident. The wide area network can connect the vehicles' MDTs to the dispatch center and, from there, by land lines to criminal justice and public safety data resources across the nation.

1.2 Purpose

The purpose of this paper is to inform Federal, State, and Local public safety users about their choices in commercial wireless technology. It should help agencies become familiar with the new possibilities for wireless communications among public safety officials in the field and between officials in the field and essential resources in fixed installations. The discussion summarizes current and emerging commercial options and highlights issues that should be considered when employing commercial communications for public safety purposes. It also includes a brief discussion of a new public safety frequency band.

1.3 Scope

This report covers current and emerging commercial wireless data technologies and services that should be available in many areas by the spring of 2003. Although the paper describes many of the commercial technologies offered across the nation, it is intended to be indicative of the technologies and services that are emerging to aid in understanding the market and planning technology projects. It should be noted, therefore, that not all services discussed are yet available, and those that have been fielded may not be available in all areas of the country. The data technologies and enhanced data services, especially, are often not currently available, although they should be introduced soon in most areas of the country. Many of the technologies discussed are upgrades to current systems, so availability will improve over time. The study underlying the report was completed in early 2000 and the level of development and terminology used are based on the information available at that time.

This study is directed toward the needs of the public safety community very broadly defined, including Federal, State and Local law enforcement, fire, emergency medical, forestry and conservation, highway maintenance, among other state and local government personnel.

1.4 Structure

The following table provides a guide to the wireless services and systems described in this document:

Wireless Application	Section
Technology issues and challenges	2.0 Issues
Data-only / large region	3.0 Wide Area Data Services
Voice and data / large region	4.0. Cellular, PCS and 3G
Data / local	5.0. PANs and LANs
High-speed collaborative / At-the-scene to wide-area	6.0. LMDS and MMDS
Widespread emergency and natural disaster	7.0. Satellite Communications
Commercial dispatch services	8.0. Enhanced Specialized Mobile Radio
Evolving spectrum needs	9.0. Future Public Safety Radio

Table 1. Section Guide to Wireless Services and Systems.

The next section outlines some of the significant issues that public safety organizations must address in selecting and adopting wireless technology.

2.0 Issues

Wireless communications, an essential lifeline for public safety personnel of all types, should be part of a carefully planned, comprehensive telecommunications solution. Selecting and implementing wireless communications solutions for public safety systems has become increasingly challenging with continuous technology advances and regulatory modifications. However, the capabilities and benefits that wireless technologies provide to public safety efforts make the investment in acquisition processes worthwhile. Basic services like two-way radio, cellular, and paging abound. The use of MDTs, car-to-car messaging, remote report transmission, and mobile access to records management systems (RMS) and criminal justice databases become a reality with wireless technologies. Mobile image transmission of fingerprints and mugshots via wireless communications provides a valuable tool to the criminal justice community. Position reporting and geographical information systems (GIS) are saving crucial time and facilitating better resource allocation.

Improving an agency's wireless communications capability will increase interoperability (which in turn reduces the requirements of some officers to carry multiple radios), enhance coverage (reducing "dead air" vulnerable spots), and extend data transmission options (permitting the integration of vehicle locators and computer aided dispatch).

Public safety organizations may choose to build their own wireless technology solution, share a private network with other organizations, or subscribe to commercial network services. Regardless of the basic strategy, it is important to ensure that current technology procurements will evolve to meet future needs (scalability, technology upgrade, etc.) and that current implementations will not create "stovepipes" that are incapable of interfacing to other technologies (interoperability issues). In addition, issues like coverage areas, response time, cost, terrain, and mutual-aid interfaces will be factors in a particular organization's decision-making process.

2.1 Using commercial services

Services such as CDPD and cellular telephone are widely used for non-mission critical functions by public safety. Two commercial wireless technologies are in particularly wide use by public safety agencies. By far, Cellular Digital Packet Data (CDPD) is the commercial packet data system most frequently used. Cellular and Personal Communications Systems (PCS) telephones are widely used for voice, with broad recognition in public safety of the advantages of PCS in expanded services and greater mobility.

These systems provide good voice quality and acceptable data services. Some of the carriers are sensitive to public safety needs and can provide portable base station equipment to deal with disaster relief. Commercial services are sometimes used to overcome interoperability problems because all of the units on the system can communicate with each other, and network connectivity does not require institutional agreements between agencies.

There are some common complaints that agencies have that are typical of most commercial services. Gaps in the coverage affect public safety operations because they are frequently drawn to areas that may be lightly populated. In the case of PCS, some networks are still in the construction phase, so coverage is improving. Since there is no channel priority function on these commercial systems, there are occasions where the base station is congested and there are no channels available. With multiple access services like CDPD, when the service becomes congested, response can be very slow. There are occasional (but rare) disruptions to service when network upgrades are performed. If calling plans are not carefully selected, monthly charges can become excessive.

2.2 Availability

Both commercial and public safety systems are subject to failure, particularly during natural disaster events and precisely when they are needed the most. Often, using a suite of technologies, rather than trying to use a single system can meet communications availability requirements. Communications that rely on independent network structures can combine to provide extremely high availability. For example, a small number of satellite-based communications terminals can be retained for emergency backup use. Although they are too expensive to use in day-to-day operations, they can be

invaluable if a network such as a cellular telephone network (both voice and CDPD) were to experience failure.

2.3 Technology migration

One of the advantages of commercial networks is that the subscriber does not pay capital costs for the technology upgrades made to the network. In some cases, the network provider upgrades subscriber units, as was done in Washington when Sprint converted from a GSM-based network to a CDMA network. Sprint PCS provided free replacement handsets.

The pace at which wireless technology is improving is becoming more rapid, which means that data users in particular need to consider the design of the applications that they are using. Although a service provider may provide upgraded equipment and services, there is no guarantee of backward compatibility between the new system and the old. As a rule, data applications should be crafted to be independent of the wireless transmission media. This will not only permit simpler adaptation to network upgrades, but make it easier for the subscriber to change service providers (which may not use the same RF technology) if the service proves unsatisfactory or too expensive.

2.4 Using unlicensed services

Development of advanced data communications in communications bands not requiring FCC licenses is extremely popular. Unlicensed operation is allowed in the Unlicensed National Information Infrastructure (U-NII) band at 5.2-5.3 GHz, in portions of the 1.9 GHz PCS band, and under Part 15 of the FCC rules in three industrial, scientific and medical (ISM) bands. Wireless local area network devices, wireless Internet access, and long distance point-to-point links are becoming widely available using these devices. Most of these devices use some form of spread spectrum, and a limited number of systems can operate within line of sight and not suffer degraded operations from interference. However, interference depends on the number of transmitters that are operating in the same vicinity at a given moment, and there is no protection from interference in these services. These systems, in general, operate extremely well. There is a potential that harmful interference could develop as unlicensed systems proliferate, and the users need to be aware of this possibility and what remedies are available.

2.5 Security

Wireless networks are subject to many security threats. The new generation of wireless communications provides applications such as trading stocks and exchanging e-mails, which require protection from these threats. The Wireless Application Protocol (WAP) Forum is promoting an industry standard for Internet services and advanced telephony services on digital mobile phones, pagers, personal digital assistants and other wireless terminals. Within WAP, the WAP Security Group (WSG) has defined several standards to enable applications security.

Public safety agencies may require safeguards such as data integrity, transmission privacy, user authentication, and access controls. Spread Spectrum systems can provide protection against casual eavesdropping, however do not offer an end-to-end security. For most systems, it is agencies' responsibility to choose appropriate security technologies for their mobile computing systems.

Many tools are available for securing end-to-end communication. Diversinet's Passport line of products, Baltimore Technology's security solutions, and RSA's security initiative are only few of products available. Using security tools however introduces another requirement for interoperability. When data is secured by mechanisms such as encryption, all users must have the proper security devices installed to access the information.

2.6 Mutual Aid

Public safety organizations frequently call upon neighboring jurisdictions for mutual aid. Some agencies explore the possibility of jointly procuring communications technologies with neighboring agencies. A technology purchase in partnership affords greater leverage with vendors on price and features and assures compatibility among multiple dispatch areas and when sharing public safety information.

2.7 Frequency Coordination

A critical obstacle to obtaining mobile data capability is often frequency coordination for the region of operation. This can be a long, bureaucratic, and political process and should be started early in preparation for MDT hardware procurements. If obtaining assigned bandwidth is not possible, then it will be necessary to lease time on a commercial network. Since MDT wireless modems must be acquired to fit the frequency that an agency is able to secure, the outcome of this process must be known before they can be purchased.

2.8 Other issues

Although this paper addresses primarily new technology and best practices in use of commercial systems, many issues influence viability of technology choices.

- Legacy systems in use by agencies involved

  Public safety agencies usually have a significant investment in their own land mobile radio systems. Leveraging off this investment in any solution to an interoperability problem is important.

- Public Safety systems in planning or procurement cycle

  Planned upgrades and future improvements in public safety land mobile systems should also be considered when examining interoperability problems.

- Developing operational and interoperability requirements

  Agencies requiring interoperable communications need a good understanding of their current and future requirements.

- Evaluation criteria

  Sound evaluation criteria need to be developed to enable public safety agencies to make good choices among the many systems and devices available. For example:

  Systems Integration. How does the proposed system fit into the current or planned "big-picture" system?

  Openness. Does the system comply with standards appropriate for its mission? Are proprietary methods used, creating a closed system that only functions properly within itself? Will the system interoperate with other deployed or neighboring systems?

  Reliability. What are the availability requirements of the system? How mission critical is the system? What alternative-path requirements are needed when using the system?

  Scalability. How will the system grow with the organization's needs? What will the training impact be?

  Stability. Is the system self-sufficient, or does it require endless manual care?

  Performance. Is the system fast enough, robust enough, "big" enough (network bandwidth)?

  Marketplace. What do other users think of the system? How is it being used elsewhere (Is it being used elsewhere)? Is the vendor going to be around down the road to support the product?

  Usability. How friendly is the system? Is substantial and frequent training of users required? Are human factors elements appropriately considered?

- Impact of other programs addressing interoperability

  Lack of equipment interoperability has existed since the FCC allocated more than one band to public safety. Major events such as the Oklahoma City bombing and the Columbine High School shootings have significantly raised the issue of interoperability between public safety agencies. Several national level programs that are addressing these issues and have made a significant amount of information available on both public safety and commercial communications systems and experiences the users have had in building and using them. The Public Safety Wireless Network (PSWN), the Federal Wireless Users Forum (FWUF) and National Coordinating Committee (NCC)

are all actively involved in addressing these issues and have resources that can be used.

3.0 Wide Area Data Services

The systems described in this section are designed to provide data-only communications over a large region, and most of these systems are operational nationwide.

3.1 Cellular Digital Packet Data (CDPD)

CDPD is a protocol for the wireless transmission of packetized data over the analog cellular voice network. It is based on the Internet Protocol (IP) suite. Transmissions can be encrypted between the mobile terminal and the base station. The transmission rate is 19.2 Kbps, and the maximum throughput on a dedicated channel is approximately 13 Kbps. Each channel is shared with all users in range of the base station, so individual throughput is a function of the number of people using the service in that cell at any given instant. Throughput is also dependent on how the carrier has assigned channels at each base station. CDPD modems can send data on designated voice channels when they are idle, however voice traffic has priority. The service provider can also allocate channels dedicated to CDPD.

CDPD applications include downloading files, e-mail, data verification, Internet access, mobile dispatch and field service messaging, and database query. CDPD is used by several public safety agencies across the country. Law enforcement officers can remotely access data such as car registration information, stolen vehicle information, and NCIC and other databases from a laptop or MDT using CDPD. Agencies are also experimenting with other applications such as image transfer.

3.2 ARDIS

Advanced Radio Data Information Systems (ARDIS) is a hierarchical two-way packet network based on the Radio Data Link Access Procedure (RD-LAP) protocol. ARDIS provides mobile data communications for short-length messages in urban and in-building environments, and for users traveling at low-speeds. ARDIS has been deployed to provide communications with good in-building penetration in more than 400 metropolitan areas.

ARDIS provides transmission rates from 4800 bps to 19.2 Kbps, with an effective throughput of 2400 bps to 9600 bps. The service is suitable for transmission of files up to 10 Kbytes long. ARDIS is used in support of computer-aided dispatching (CAD) systems, such as is used by field service personnel, often when they are at a customer's premises.

ARDIS has low user capacity for two reasons. The first is because the system routes all messages through a central message switch. The second is because all cells in a given area share a single frequency with overlapping coverage so neighboring transmitters must be turned off for 0.5 to 1 second when a forward link transmission occurs. American Mobile Satellite Wireless Data Service is the service provider for the ARDIS data network.

3.3 BellSouth Wireless Data (BSWD)

BellSouth Wireless Data, formerly known as RAM Mobile Data, is a joint venture of Bell South and RAM Broadcasting Corporation. The network, which conforms to the Mobitex system specification, covers almost 100 metropolitan areas, and has around 30,000 users in the US. The Mobitex system is used internationally. The Mobitex Operators Association (MOA) manages the Mobitex system specification.

The BSWD network is hierarchical. At the top of the hierarchy is the Network Control Center, from which the entire network is managed. There is a national switch that routes traffic among service regions. Local switches handle traffic within a given service area. Many features are implemented to enhance reliability, such as alternate network pathways, autonomous operation at each network level, multiple connections between nodes, and a backup network control center.

Mobitex operates in the Specialized Mobile Radio (SMR) band (896-901 MHz for the reverse link; 935-940 MHz for the forward link). The transmission rate is 8 Kbps half-duplex. Mobitex supports TCP/IP through a gateway, since it is based upon proprietary protocols. The connection setup time can take as long as 30 seconds and multiple simultaneous connections cannot be made. The effective throughput is about 8 Kbps. This system is best suited for transmitting large amounts of data infrequently, where setup time is not a concern. Several law enforcement agencies across Europe have deployed Mobitex-based services.

3.4 Metricom's Ricochet

The Ricochet Network is a wide-area wireless system using frequency-hopping spread-spectrum (FHSS) to send packet-switched data. The network operates within the license-free ISM-band (902-928 MHz and 2.4 GHz).

The Ricochet wireless MicroCellular Data Network consists of shoebox-sized radio transceivers, also called Microcell Radios, which are typically mounted to streetlights or utility poles. The microcells require only a small amount of power from the streetlight itself and are essentially self-contained units. They are placed every quarter to half mile in a checkerboard pattern.

The Ricochet modem weighs 13 ounces, has the general dimensions of a small paperback book (but less than a half-inch thick), and plugs directly into a desktop, laptop

or PDA standard serial port. Ricochet modems can also communicate with other Ricochet modems on a peer-to-peer basis outside the service area.

Currently, Ricochet supports gateways to the Internet, to the telephone system, to an X.25 network and to corporate Intranets or LANs. The telephone system gateway provides telephone modem access that can be used to connect to on-line services such as AOL and CompuServe. Ricochet was specifically designed for stationary, portable operation. There is no cell-to-cell handoff, and throughputs are significantly reduced for terminals moving at highway speeds. Ricochet currently provides a transmission rate of 28 Kbps. They plan to increase this to 128 Kbps starting in the summer of 2000. The data rate may be significantly reduced for terminals moving at highway speeds.

3.5 Summary of Wide Area Data Services.

The following table summarizes the wide area data services.

Service	Protocol or Standard	Typical Raw Data Rates (Kbps)	Equipment Availability	Intended Use
CDPD	CDPD spec.	19.2	now	fixed and mobile subscribers
ARDIS	MDC 4800	4.8	now	fixed and low speed
	RD-LAP	19.2	now	mobile terminals
RAM	Mobitex	8.0-14.4	now	fixed and mobile;
	TCP/IP via gateway	144-2048	now	large/infrequent data transfer
Ricochet	MDCN (proprietary)	28.8	now	fixed and portable,
		128	Summer 2000	reduced rate at highway speeds

Table 2. Summary of Wide Area Data Services.

4.0 Cellular Radio, Personal Communications Systems and 3G Systems

The cellular systems described in this section are designed to provide both voice and data communications over a wide area. Some of these systems provide national coverage, and some provide regional coverage only.

There are three generations of cellular service. The first generation of cellular radio is the familiar analog cellular service in the 800 MHz band. The FCC licenses two providers in each metropolitan area. The second generation services are the PCS services in the 1.9 GHz band and cellular radio services in the 800 MHz band that have been converted to digital. Enhanced packet data services are planned for some of these networks, and these are referred to as the 2.5G systems. 3G, or third generation systems,

are future systems with much higher capacity and data rates available than the 2G systems.

One major difference for the consumer between the first generation systems (analog cellular) and the second-generation systems is that the different service providers do not use the same technology. Unless dual mode equipment is purchased, phones designed for one network, for example, Sprint PCS, will not work on another provider's network, for example, the ATT wireless network. This impacts the consumer's ability to roam to another network outside of the subscriber's home service area.

The 3G systems will not solve this interoperability problem, and there are several different 3G protocols. To protect their investment, the service provider's choice of advanced technology is based on compatibility with their current technology. However, all of these networks are connected to the public networks (like the public switched telephone network), so even though the handsets will only communicate with one service provider's network, they will be able to communicate with fixed telephones, fixed data networks, or mobile terminals on competing networks.

It is important to note that many of the 2.5 and 3G protocols being implemented and planned have data communications modes. This however, does not mean that a service provider has implemented the service, or has made it available in a manner that meets the requirements of public safety users. For example, some of the newer data services on the PCS networks are used only for Internet access for the new web-enabled telephones.

4.1 Analog cellular

Analog cellular radio is the first generation cellular technology. It has the widest implementation in the United States, and the most widely available set of roaming agreements. Two common carriers offer this service in every license region.

There are two widely used data services available on analog cellular networks. One service is CDPD, which was previously discussed, and the other service is circuit switched cellular. Circuit switched cellular is the wireless equivalent of using a computer modem on the public switched telephone network. It uses a full voice channel for the entire time the connection exists. Dial-up data circuits are charged by minute of connect time, not by how much data is being actually sent. Unless the application is efficient, and the connect time is held to a minimum, the charges for connecting to the analog cellular system can be very high.

Due to the harshness of the wireless environment, the user can expect to get approximately 4800 bps throughput using a standard cellular modem. Newer protocols, most notably Enhanced Throughput Cellular (ETC), were introduced to correct for the noise and distortions encountered on a cellular channel. For best performance, ETC should be used at both ends of the connection. With ETC at each end, users can expect 9600 bps under most circumstances and 14,400 bps in areas of very good coverage.

4.2 Personal Communications Systems (2G Cellular)

PCS systems include wireless communications systems that operate in the 1.9 GHz band and conventional cellular systems operating the 800 MHz band that have converted to digital. Digital cellular operators implement the service by converting channels from analog to digital on the existing 800 MHz cellular system.

PCS Protocols

The FCC did not set rules and regulations concerning the carriers' selection of protocols for the service, and several incompatible over-the-air protocols, as well as network-based protocols, emerged. There are three radio transmission protocols and two network protocols in wide use in the US for PCS services. The radio transmission protocols are Global System for Mobile Communications (GSM), IS-136, and IS-95. The network protocols are IS-41 and MAP.

GSM is a European-based standard that is widely implemented in many countries. The European version operates in the 1.8 GHz band. It is based on a time division multiple access (TDMA) protocol that puts 8 voice circuits in a 200 KHz channel. Circuit switched data is possible at either 9.6 or 14.4 Kbps. There is also a short message service available that is primarily used for text messaging and paging functions on the mobile handsets. GSM uses the MAP network protocol.

IS-136 is a TDMA protocol standard that uses the same channel bandwidth used by analog cellular systems. This protocol allows three digital voice circuits in each channel. Although an earlier version of this protocol, IS-54, did not support data services, IS-136 includes a specification for 9.6 Kbps circuit switched data and a short message service similar to GSM. IS-136 uses the IS-41 network protocol.

Code division multiple access (CDMA) is a form of spread spectrum developed for commercial use by Qualcomm. It is also known as cdmaOne. In terms of standards, the original standard was IS-95. It was revised as IS-95A in 1995, and addresses the air interface for digital cellular systems in the 800 MHz band. J-STD-008 specifies this protocol for the PCS systems operating at 1.9 GHz. In CDMA, many users access a channel that is 1.25 MHz wide. They are separated by codes, as opposed to being separated in time or frequency. There is no hard limit on the number of users that can operate concurrently, but the channel will gracefully degrade as it approaches an overloaded state. CDMA networks also use the IS-41 network protocol. Maximum circuit-switched data rates of 14.4 Kbps are specified in the standard.

PCS Coverage

When using commercial PCS services, the coverage area must be carefully examined. Some of these networks are still in the construction phase, and full coverage may not be available. Also, unlike analog cellular, there are some limitations in roaming. Not only do agreements have to be in place between the carriers to enable roaming, but

also the transceiver being used to access the network (either a phone with a data port or a PC card) has to have the proper air interface (CDMA, TDMA, or GSM). The carriers usually keep maps on their websites that display current and planned coverage for both the local network and the national network.

4.3 2.5G Systems

As the International Telecommunications Union (ITU) is addressing various protocols for the next generation cellular (3G) systems, some of the proposed data services can be implemented on existing PCS and digital cellular systems. These services, implemented with 2.5G protocols, provide a significantly higher data rate than currently available, and the hardware and software needed to implement them is scheduled to be ready within the next 12 months. However, it should be noted that it takes time for a service provider to implement a new capability over their entire coverage area.

There are two data transmission technologies considered to be part of the 2.5G CDMA capabilities. They are IS-95B and High Data Rate (HDR). IS-95B allows the aggregation of eight CDMA traffic channels for the transmission of packet data. The maximum data rate capability is 115.2 Kbps, however, in the early stages of implementation, forward link speeds of 28.8 to 57.5 Kbps and reverse link speeds of 14.4 Kbps are expected.

HDR is a technology that can be overlaid on existing CDMA cell sites. HDR uses a full 1.25 MHz CDMA channel to support a maximum data rate of 1.8 Mbps per sector, per cell, in a three-sector cell site. The individual peak rate to the subscriber ranges from 38.4 Kbps to 1.8 Mbps. In the reverse direction, the total maximum data rate is between 200 and 600 Kbps, with the data rate available to an individual user ranging from 9.6 to 307.2 Kbps.

GSM networks have two data modes to offer. One is a circuit switched service called High Speed Circuit Switched Data (HSCSD). This service offers circuit switched connections that can support 57.6 Kbps. The other data service is a packet data service called General Packet Radio Service (GPRS), which will support both IP and X.25 protocols. The advantage of GPRS is that there will be no call setup time; channel acquisition time will be approximately a few hundred milliseconds. GPRS has a theoretical maximum data rate of 171.2 Kbps using 8 TDMA timeslots. At full mobility over a wide area, the maximum data rate is 115.2 Kbps. It is unlikely that all 8 timeslots in a frame will go to one user; the actual individual throughput will be likely based on the use of one to three timeslots. GSM operators are claiming that terminals should be available by 2001 with individual user throughputs of 28.8 Kbps. In 2002, a data rate service of 56-112 Kbps should be available.

Similar to the evolution of GSM data services, IS-136-based networks have an interim 2.5G capability under development. Known as IS-136 Revision B, or IS-136+, two high speed data services will be implemented by aggregating time slots and using a

new modulation. Circuit switched data will be offered at 28.8 Kbps. A packet switched service based on GPRS will permit useable data rates between 14.4 and 43.2 Kbps.

4.4 3G Systems

3G systems are third generation wireless communications systems being standardized by the ITU as part of the International Mobile Telecommunications for the year 2000 (IMT-2000) effort. The goals of IMT 2000 are to provide voice comparable to the public switched telephone network, and to provide high-speed circuit switched and packet switched data services. These systems will provide a minimum data rate of 144 Kbps for users in motor vehicles moving over a large area at highway speeds, a data rate of 384 Kbps for users that are stationary or moving at pedestrian speeds, and a data rate of 2.048 Mbps for office use.

Companies wishing to protect their investment in 2G systems, and desiring a simplified migration path to 3G, have promoted 3 different radio standards. IMT-Multi-Carrier(MC), formerly cdma2000, is the protocol that evolves from the IS-95 CDMA standard. IMT-Single Carrier (SC), formerly UWC-136, evolves from the IS-136 TDMA standard. IMT-Time Coded (TC) evolves from the GSM standard.

The importance in monitoring these developing standards is in understanding which path each local carrier is likely to take. The carriers may start upgrading their networks as early as 2001 to implement the 3G technologies. They often provide free or low-cost equipment replacement programs for subscribers. When evaluating data services, the expected coverage and service offerings for the 3G systems may factor in the decision of which carrier to select.

4.5 Summary of Cellular/PCS Wide Area Data Services

The following is a summary table of the cellular and PCS data services, including the 2.5 and 3G technologies. There is a considerable amount of information being released on the future technologies, and conflicting availability dates are being quoted. It should be noted that implementation of these services depends on both equipment availability, and a business decision by the carrier to install and offer the service.

*these services may not be offered for applications

Technology	Standard	Typical Raw Data Rates (Kbps)	Equipment Availability	Service Availability
Analog	Amps	4.8-9.6	now	now
	CDPD	19.2	now	now
CDMA	IS-95	9.6-14.4	now	now*
	IS-95B	28.8-115.2	2000-2002	2001-2002
	HDR	38.4-1800	2000-2002	2001-2002
	IMT-MC	144-2048	2002-2004	2003-2005
TDMA	IS-136	9.6	now	now*
	IS-136+(GPRS)	14.4-43.2	2000-2002	2001-2003
	IMT-SC	144-2048	2002-2004	2003-2005
GSM	GSM	9.6	now	now*
	GPRS	28.8-115.2	2000-2002	2001-2003
	HSCSD	57.6	2000-2002	2001-2003
	IMT-TC	144-2048	2002-2004	2003-2005

other than Internet access in some market areas.

Table 3. Summary of Cellular/PCS Data Technologies.

5.0 Personal Area Networks and Local Area Networks.

PANs are used to create a very localized wireless network to replace the cables needed to integrate devices such as PDAs, MDTs, internet-enabled wireless phones, and in the future, a standard in-vehicle data bus.

Wireless LANs are useful in factories, warehouses, retail establishments, and offices where wiring computers into the corporate network is not cost effective. Wireless LANs have several potential applications in public safety. This technology can be used to create ad-hoc networks for direct vehicle-to-vehicle communications between units responding to an incident. It can also be used to allow an officer to take a device such as a fingerprint reader or an MDT up to 300 meters from his vehicle and still maintain data connectivity.

Most of these technologies operate under Part 15 of the FCC rules and regulations. The main advantage of this operation is that no FCC license is required. However, operation under Part 15 places several restrictions on the design and capabilities of these products.

5.1 Part 15 Operation

One of the restrictions of Part 15 is that the license-free devices must not interfere with other authorized services in the frequency band, and must accept any interference received from these services. They must also accept interference from other Part 15 devices. If a Part 15 device causes harmful interference to an authorized service, it must cease operation until the interference is corrected. In order to decrease the likelihood of interference as well as permit operation at higher power levels, the FCC requires the use of spread spectrum modulations for these devices in the ISM frequency bands. The maximum transmitter output power is 1 watt and the maximum effective radiated power is 4 watts.

5.2 Bluetooth

Bluetooth is a new industry standard intended to provide radio-based wireless connections for devices such as mobile computers, personal digital assistants, mobile phones, and devices connected by short cables. Bluetooth devices create a very small network, called a piconet, which operates near the user or a device. A piconet has at least two connected devices, and may grow to eight connected devices. When establishing a piconet, one unit will act as a master and the rest will act as slaves for the duration of the connection. Multiple independent and non-synchronized piconets form a scatternet. Devices can be registered in more than one piconet, but only eight devices can be active at any one time.

Bluetooth radios use spread spectrum modulation in the 2.4 GHz ISM band. They can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel simultaneously supporting asynchronous data and synchronous voice. Each voice channel supports a 64 Kbps synchronous (voice) link. The asynchronous channel can support an asymmetric link with a maximum data rate of 732 Kbps while permitting 57.6 Kbps in the return direction, or a 432.6 Kbps symmetric link. In multipath or interference-prone environments, higher rate coding and correspondingly lower data throughput rates will be used. The nominal link range is 10 centimeters to 10 meters, but in the future, may be extended to 100 meters with increased transmit power. Devices incorporating this technology are expected in the US starting later this year.

5.3 802.11 Systems

The 802 Committee of the IEEE publishes standards for LANs and this committee has standardized many protocols. For example, the common Ethernet LAN standard is 802.3. Wireless LANs are incorporated in 802.11. There are currently 3 different suites of IEEE 802.11 wireless LANs: 802.11, 802.11a, and 802.11b. The reason there are multiple suites is due to improvements in capabilities and data rates.

802.11

802.11 LANs are built around cells called basic service sets. The base station in each cell is called an access point. Laptop computers and other devices communicate via

the access point using small wireless LAN cards that are in PC card (or PCMCIA) form. Devices can communicate directly, without going through an access point, in what is called the ad-hoc mode. These LANs support either 1 or 2 Mbps data rates and use spread spectrum or infrared links.

These LANs, intended to be wireless replacements for Ethernet, were designed for access points and user terminals to be fixed or portable, but stationary when in use. Some users have mounted these devices in moving vehicles, but discussions with the IEEE 802.11 committee indicate that performance is not guaranteed in this mode, and effective operation at speeds above 30 MPH may not be feasible.

802.11 (a)

802.11 (a) is a very high data rate wireless LAN intended for use in the U-NII Band at 5.15-5.35 GHz and in the 5.8 GHz ISM band. Data rates can range from 6 to 54 Mbps. These products are being developed.

In January 2000, a company called WiLAN, in partnership with the California Department of Transportation (Caltrans) demonstrated support of 20 Mbps data services to a vehicle moving at 70 mph over a 1.3-mile stretch of US Highway 101 in Goleta, California. The equipment used is a commercial product that is a precursor to the company's 802.11(a) design. They discovered through proof of concept testing that the protocol, although it was designed for portable use, is very resilient in the mobile multipath environment. They have demonstrated that there is potential to offer very high data rate connections in a mobile environment using a commercial off the shelf, license-free device.

802.11 (b)

802.11 (b) is based on a proposal submitted to the 802.11 committee by Harris and Lucent. It is a standard for high-speed wireless LANs with data rates of 5.5 Mbps and 11 Mbps. It will be backward compatible with existing 802.11 equipment. If the signal between a station and an access point is too weak to support the higher data rates, the transmission rate will "downshift" to a lower rate in an effort to maintain the channel. This standard was approved in September 1999 and products are just becoming available.

5.4 HIPERLAN

HIPERLAN is a European Telecommunications Standards Institute (ETSI) standard for a high speed, high performance wireless LAN. In the US, HIPERLAN products are designed for use in the U-NII Band.

HIPERLAN is a family of standards. There are currently four (4) types of HIPERLAN, each intended for a different set of applications. HIPERLAN Type 1 is similar in operation to the 802 family of LAN standards and is designed for local area multimedia communications. HIPERLAN Type 2 standards address wide area networking applications. The third type is called HIPERAccess and is designed to meet

the needs of the wireless local loop. The fourth type, called HIPERLink, is designed for high-speed (155 Mbps) point-to-point links. HIPERAccess and HIPERLink have been incorporated into a new project known as the Broadband Radio Access Network (BRAN) project.

One of the features that makes HIPERLAN 1 technology unique is that it incorporates priority. There are two levels of user priority (normal and high) and an assigned residual packet lifetime. The packet lifetime determines how long a packet can remain before being discarded. The channel access priority is calculated at each transmission attempt using the residual packet lifetime and the user priority. These priority levels are updated constantly until a packet is transmitted (out of the queue).

HIPERLAN 1 has a transmission rate of 23.5 Mbps and a maximum user data rate of 18 Mbps. It uses the same type of modulation as the GSM-based European cellular network and as some PCS networks in the US.

6.0 Broadband Wireless Data Networks

Broadband wireless networks provide services that traditionally would be offered with wired installations of fiber cables.

6.1 LMDS

Local Multipoint Distribution Service (LMDS) is a bi-directional, high-speed, fixed wireless service intended to support many different applications. LMDS was not intended to serve mobile users; however, transportable users (i.e., field units at the scene of an incident) could be supported with properly designed systems.

There are two predominant architectures for LMDS—point-to-point and point-to-multipoint. Many providers will use hybrids of these architectures depending on technical and economic tradeoffs.

Channel bandwidths vary from approximately 10 to 50 MHz and can deliver aggregate channel data rates of up to 155 Mbps. The maximum data rate for an individual user will likely be 1.544 Mbps. Some service providers are looking to offer users rates compatible with 10 Mbps Ethernet.

LMDS requires line of sight between transmitter and receiver. This limits the potential coverage area of a single cell site and the distance between point-to-point transceivers. The range for coverage depends on many local environmental characteristics, particularly rainfall and terrain. In climates where heavy rainfall is common, shorter link distances are required to achieve desired performance and availability. Field trials suggest an average coverage range of 5 km.

6.2 MMDS

Multichannel Multipoint Distribution Service (MMDS), like LMDS, will provide wide-area, high-speed, bi-directional wireless networking. Intended applications include high-speed Internet/Intranet access and dedicated digital services, video teleconferencing, video on-demand, interactive video, and telephony.

Currently, MMDS 6 MHz channels are to be used for transmissions only to the subscriber. The license also includes a group of thirty-one 125 KHz channels for MMDS transmissions from the subscriber, but the FCC only recently permitted the transmission of digital information on these channels. Because of several petitions, the FCC is expected to approve high-speed bi-directional transmissions on the 6 MHz channels. The FCC rules should receive final acceptance in summer 2000.

Like LMDS, there are two predominant architectures for MMDS systems; point-to-point and point-to-multipoint. There are currently two approved methods for providing bi-directional data. One uses the 6 MHz channels for high-speed downstream transmissions and a common telephone line for upstream transmissions. A second approach uses the 125 KHz channels for the upstream transmissions. Once the FCC has approved bi-directional transmissions on the 6 MHz channels, a third technique will use these channels for both upstream and downstream transmissions. This will be the primary method for most systems deployed over the next several years.

Each 6 MHz channel can be used to support data rates up to 37 Mbps. A pair of 6 MHz channels will be used for full duplex communication. The maximum data rate per user or subscriber will depend on the application and the available bandwidth, but these rates will range from 64 Kbps to as much as 10 Mbps. Most MMDS systems require line of sight between transmitter and receiver, and the potential coverage area is limited. Services can be provided at distances up to 30 miles from the hub.

7.0 Satellite Communications Systems

Increasingly, public safety agencies are relying on satellite services in emergencies. These systems can be used where no wireless coverage exists, or during a disaster where there may be damage to the infrastructure. Public safety agencies have been able to use satellite services effectively in assisting communities in natural disaster cases such as hurricane or flooding. Furthermore, the incorporation of other applications such as data over the satellite networks and its integration with the landline network such as the Internet and Intranets have added value to satellite's traditional voice service. There are several providers available, however, there has also been a wave of bankruptcy filings. Several of the more prominent providers are briefly described below.

7.1 American Mobile Satellite Corporation (AMSC)

The American Mobile Satellite Corporation (AMSC) offers voice, data, and location service with its Skycell system, a series of three satellites in geostationary orbit. The portable satellite telephone provides voice and data communications anywhere in North America. Because of the power requirements needed to communicate with geostationary satellites, hand held terminals are not offered. AMSC terminals have been designed to seek cellular radio coverage, and will transition to the satellite system when the calls are outside the range of cellular services. Fleet management services offer private voice network services and mobile data services via the AMSC-1 satellite. Private voice network services allow fleet managers to communicate with a fleet of vehicles simultaneously. The mobile data services consist of store-and-forward text-message communications.

7.2 Globalstar

Globalstar is a consortium of international telecommunications companies originally established in 1991. As a wholesaler, Globalstar sells access to its system to regional and local telecommunications service providers around the world. The company provides mobile and fixed satellite-based services such as telephony, data transmission, paging, facsimile, and position-location information.

Globalstar has deployed a 48 satellite low earth-orbiting (LEO) constellation providing multiple satellite coverage (2-4 satellites will usually be visible at any time). Globalstar employs CDMA spread spectrum access techniques. The system will be fully integrated with existing fixed and cellular networks; therefore, Globalstar's dual-mode handset units will be able to switch from conventional cellular telephony to satellite telephony as required. Calls will be routed to customers through existing public and private telephone companies.

7.3 Inmarsat

Inmarsat was established in 1979 to serve the maritime industry by developing satellite communications for ship management, distress, and safety applications. Inmarsat currently operates a global satellite system which is used by independent service providers to offer voice and multimedia communications. While serving its original mandate, Inmarsat has expanded into land, mobile, and aeronautical communications, so that users now include thousands of people who live or work in remote areas without reliable terrestrial networks. Typical Inmarsat subscribers include disaster relief workers, land transport fleet operators, airlines, air traffic controllers, government workers, and national emergency and civil defense agencies.

Currently, Inmarsat is offering mobile data speeds at rates of 64 Kbps for voice, data, and video using small, notebook-size mobile units. By mid-2000, the company will also offer a packet data service called Inmarsat Mobile IP.

The Inmarsat System consists of nine geostationary satellites. Four of these satellites, the latest Inmarsat-3 generation, provide overlapping operational coverage of the globe (except for extreme polar areas). The others are used as in-orbit spares or for leased capacity. The future Inmarsat program includes deployment of Inmarsat-4 satellites in 2004. This generation of satellite system will serve as a high-bandwidth infrastructure for services such as Internet access.

7.4 ICO

ICO Global Communications was established in January 1995 as a private company to provide global mobile personal communications services by satellite, including digital voice, data, facsimile, and messaging services. ICO Global Communication plans to offer low cost global satellite phone service, as well as other services using hand-held pocket-sized terminals. This service, planned for 2000, will be a complementary service to cellular/PCS. ICO will operate a constellation of satellites in medium earth orbit (MEO). The satellites will communicate with the ICONET, which consists of 12 terrestrial-based satellite access nodes located around the world. Each satellite is designed to support at least 4,500 telephone channels using TDMA.

The company filed for Chapter 11 protection in August 1999. ICO announced in February 2000 that Eagle River Investments LLC had entered into a definitive agreement with ICO to acquire control of the company.

7.5 Teledesic

The Teledesic Network will consist of 288 operational satellites, divided into 12 orbital planes with 24 satellites each. Teledesic, technically and financially the most ambitious of the LEO systems, is planned for operation in the 20/30 GHz band.

Teledesic will provide users with two-way connections that provide up to 64 Mbps on the downlink and up to 2 Mbps on the uplink. The ability to handle multiple channel rates, protocols and service priorities provides the flexibility to support a wide range of applications including the Internet, corporate Intranets, multimedia communication, and LAN interconnect.

8.0 Enhanced Specialized Mobile Radio (ESMR)

Specialized Mobile Radio (SMR) service providers are commercial systems operators that serve primarily small businesses and companies that require dispatch services. Enhanced SMR (ESMR) refers to the new digital SMR systems that offer advanced features such as paging, talk groups, and connection to the public switched telephone network. The ESMR systems are popular with public safety agencies primarily due to the ability to create talk groups and get a direct connection with a group using a push-to-talk function. This is one feature that is not available from either cellular or PCS systems.

The main provider of ESMR service is Nextel. Nextel is building a nationwide system based on a technology called integrated dispatch enhanced network (iDEN). This is a TDMA-based digital technology that is proprietary and is available only from Motorola or a licensed representative.

Nextel offers cellular telephone service, private and group dispatch, and text messaging using a single handset. The Direct Connect feature uses push-to–talk dispatching to set up a private one-on-one or group call. Up to 100 private call entries can be programmed. Also, since this is a national network, there are no roaming charges, and there are no roaming agreements with other cellular carriers.

The only data services currently available are various forms of text messaging. Messages can be sent from a PC, from the Nextel website, by Internet e-mail, or with operator assistance that will provide a voice to text conversion. Numeric paging is also available.

Nextel caters to the public safety community and has been used by Federal Government agencies, local government agencies, and police departments. There are several planned enhancements of special interest to public safety that are part of a system upgrade called Advanced iDEN. They include 16 levels of priority access, which will be granted by the system operator. An emergency call function will, if necessary, pre-empt an existing call in the cell. The upgrade will allow isolated site operation, which will allow calls to continue even if the site loses connectivity to the switching center. There is also a talk group scan function planned that will enable a user to monitor up to four talk groups. Nextel often solicits input from the public safety community and is aware that two additional services the community would like to see added are high-speed data access, and the ability for two handsets to talk directly to each other if they are out of range of a base station.

9.0 Future Public Safety Radio Systems

In 1995, a Federal Advisory Committee called the Public Safety Wireless Advisory Committee was formed to advise the FCC on the spectrum needs of the Public Safety Community through the year 2010. One of the recommendations of the committee was that 25 MHz of new spectrum was needed immediately to relieve spectrum availability problems. The FCC responded in a Report and Order in WT Docket 96-86 by allocating 24 MHz of spectrum in the 700 MHz band, the former UHF television channels 63, 64 (764-776 MHz), 68, and 69 (794-806 MHz). The Public Safety National Coordination Committee (NCC) was formed to help plan and administer the use of this new spectrum.

Ten percent of the allocated spectrum was designated for interoperability channels. The NCC decided that the first order of business was to provide the FCC with recommendations for these channels in an effort to make them available for licensing as soon as possible. It should be noted that there are still television stations operating in various locations on these channels. The availability of spectrum depends on whether

there is an active TV station in the desired region. These stations will eventually be required to vacate the band, and are expected to do so within the next 6 years depending on the success and market penetration of High Definition Television (HDTV).

The 700 MHz band plan in the FCC First Report and Order shows four groups of five 12.5 KHz interoperability channel sets and two groups of six 12.5 KHz channel sets, with each set consisting of two 6.26 KHz channel pairs. This makes a total of sixty 6.25 KHz channels available for tactical interoperability and two 12.5 KHz channels available as calling channels.

In February 2000, the NCC technology subcommittee submitted a recommendation to the FCC for a data standard for the narrowband interoperability channels. The standards recommended are as follows:

- ANSI/TIA/EIA 102.BAAA Project 25 FDMA Common Air Interface
- IS-102.BAEA Project 25 Data Overview
- IS-102.BAEB Project 25 Packet Data Specification
- IS-102.BAEC Project 25 Circuit Data Specification
- IS-102.BAEE Radio Control Protocol

The recommended modulation is the 12.5 KHz bandwidth version of Project 25. The NCC also recommended that two channels be dedicated to data operations with a channel rate of 9.6 Kbps.

10.0 Summary

CDPD is the commercial wide area data service most frequently used by public safety agencies. Few users have attempted to integrate wide area services such as CDPD with wireless LAN equipment to extend the mobility of the subscriber, or to network vehicles independent of infrastructure. Some EMS and criminal justice users have experimented with wireless LAN transmissions to moving vehicles.

Cellular and PCS service providers, reacting to the popularity of Internet access, are rushing to implement higher rate data services. Both enhanced circuit switched and packet switched data services may be available by the end of 2000. New wireless LAN equipment with very high data rates is currently available. In addition, introduction of technologies like Bluetooth is expected in 2000, providing hands-free operation of many devices and wireless connection for peripherals.

Wireless devices, systems, and services play a very important role in the mission of public safety organizations. Although there are many options across a variety of networks, wireless capabilities will only become increasingly crucial to the public safety community's communications infrastructure. It is important to carefully consider both short- and long-range goals when acquiring any technology and interoperability and scalability issues should be examined as part of any acquisition.