TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

The *Commercial Wireless Applicability Report* provides a tool for public safety communications system planners to help them make informed decisions when considering the use and purchase of commercial wireless services. This report identifies key characteristics of commercial wireless services, analyzes these services, and compares and evaluates these services based on the communication requirements of the public safety community.

1.2 Background

Commercial wireless services (commercial services) are most often used to supplement public safety land mobile radio (LMR) systems and to meet a portion of their communication requirements. Although commercial services do not replicate the reliability, availability, security, and functionality of LMR systems, they can provide key enhancements and capabilities for public safety wireless users.

Commercial services offer a range of functions, performance, and price packages that can support voice and data applications and requirements. These services are offered by a wide range of providers who have regional and national areas of service. Because of the variety of commercial services, this report analyzes, compares, and contrasts commercial services to identify key attributes, limitations, and differences. Given the wide range of characteristics, it is important for public safety organizations to evaluate commercial wireless service alternatives to determine their applicability to their specific operations.

1.3 Organization

In addition to this introduction, this report is organized into five sections and two appendixes. Section 2 discusses the public safety community's current use of commercial wireless technologies. Section 3 defines the criteria used for evaluating each service or technology. Section 4 analyzes the wireless services and technologies. Section 5 characterizes and compares the wireless technologies based on the evaluation criteria. Section 6 presents a summary of key points in the document.

2.0 PUBLIC SAFETY USE OF COMMERCIAL WIRELESS SERVICES

Public safety organizations use commercial services to supplement LMR networks and capabilities. The rationale for using commercial services varies among organizations. This section discusses some of the general applications of commercial services to support public safety operations.

2.1 Understanding the Role of LMR Systems

LMR systems are the core wireless capability for most public safety organizations. These systems are designed to provide the required reliability, availability, accessibility, control, security, and functionality to meet the emergency and tactical communication needs of public safety users. Exhibit 2-1 shows a sample list of the characteristics of LMR that makes this technology such a prevalent communications tool among public safety organizations.

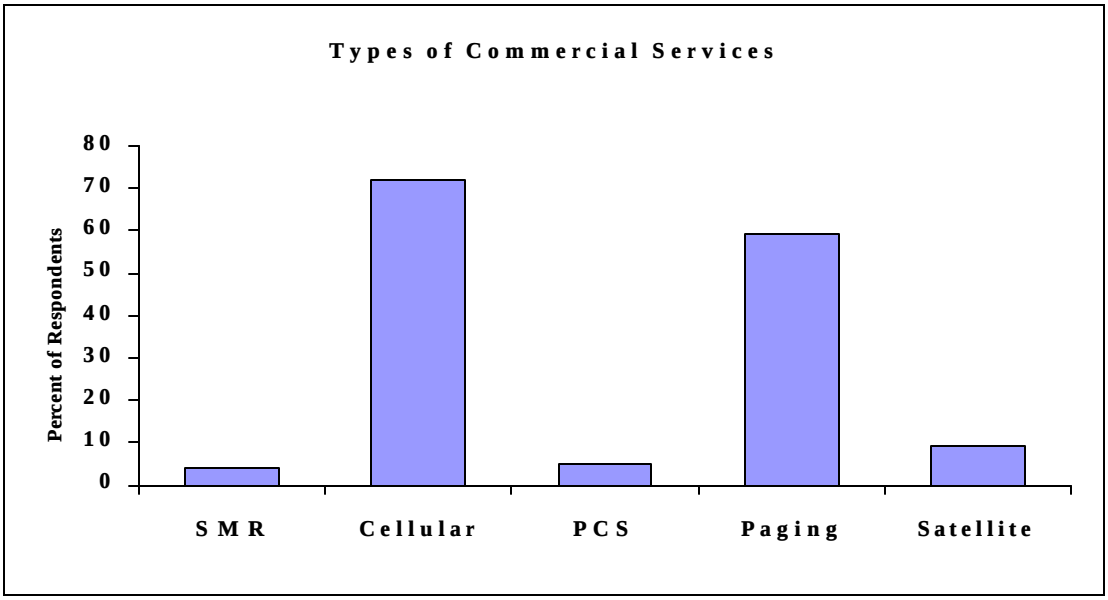
Exhibit 2-1
LMR Characteristics

Functional Requirement	LMR Characteristics
Sufficient Coverage to Support Component Missions	• Provides coverage in areas of public safety operations because it is specifically designed for public safety user needs • Provides in-building coverage, where needed
Sufficient Availability to Support Public Safety Operations	• LMR system capacity designed for availability during tactical operations and emergency conditions
Reliable Services to Ensure Support to Component Missions	• LMR systems are designed to provide the reliability and responsiveness needed by public safety operations
Ease of Addressing and Instant Communications	• Provides instantaneous push-to-talk functionality
Hands-Free Operations	• Provides hands free functionality for specialized public safety requirements
Component to Control Critical Assets	• Provides public safety organization control of assets, including over-the-air rekeying (OTAR) and over-the-air management (OTAM)
Security of Communications and Operations	• Provides high-levels of security (Type 1-Type 3) • Ensures that missions and agent safety is not compromised by providing mission intelligence to commercial vendors
Non-Dependency on Commercial Assets	• Ensures non-dependency on commercial assets that may be vulnerable to attack (physical and electronic)

2.2 The Application of Commercial Services

Although LMR systems are able to support tactical and emergency communications, many public safety organizations supplement LMR systems with commercial services to meet a subset of their requirements. The Public Safety Wireless Network (PSWN) Case Studies completed in the Washington DC, San Diego, and Pittsburgh metro areas determined that roughly 80 percent of the public safety organizations interviewed used commercial wireless services to fulfill some of their requirements. Typically, these organizations use commercial services to support nontactical and nonemergency communications, or to support emerging applications, such as data communications. Exhibit 2-2 breaks down the types of commercial services used by the public safety organizations interviewed, showing percentage of respondents using each type.

Exhibit 2-2
Use of Commercial Services by Public Safety Organizations



PSWN Case Studies results indicate that system planners use commercial services to meet several needs:

- Provide communications in areas where an LMR infrastructure does not exist.
- Support emerging applications, such as data applications, to minimize the risks associated with planning uncertain capacity in an existing LMR system
- Provide a less capital-intensive wireless capability to meet nontactical or day-to-day administrative requirements
- Provide different subscriber functionality than is currently offered on the LMR system.

The sections below discuss how commercial services can meet each of these needs.

2.2.1 Provide Communications in Areas where an LMR Infrastructure Does Not Exist

In some cases, public safety organizations are unable to expand system coverage in high growth areas. In these cases, system planners may need to use commercial services to meet their organization's communications needs until their system can be expanded to support these areas. As discussed in Section 2.2.3, system planners may use commercial services to defer or delay investment in an LMR system. In addition, system planners may attempt to place users on another organization's LMR system. However, in situations where an LMR system cannot be immediately expanded, system planners may choose to use specialized commercial services that have LMR-like functionality (e.g., PTT, talk groups) to better suit their operations. However, planners must be aware of the performance, reliability, and availability concerns and differences between specialized commercial service and organization-owned LMR systems. These differences are discussed in detail in Section 3 of this report.

2.2.2 Support Emerging Applications

Public safety organizations are adopting new communication applications to support their organization's missions. Applications may include data applications, such as National Criminal Information Center 2000 (NCIC 2000) database queries, global positioning system (GPS) navigation services, and vehicle location system (VLS) applications. More and more, these applications are being deployed in a mobile wireless environment to support public safety operations. The introduction of new applications within a wireless environment, however, may give rise to several uncertainties.

Uncertainties may include:

- How much capacity will be needed to support both new and legacy applications

- How much capital will be required to add capacity beyond the capital already expended on mobile data terminals (MDTs) or other user equipment.

To reduce the risk posed by these uncertainties, system planners can "offload" these applications to commercial systems until clear investment, adoption, and usage patterns emerge.

Users on the same system may adopt and use the applications at different rates. In essence, the rate of adoption and resulting traffic volumes are typically related to the performance improvements provided by the application, the similarity of the operation of new applications to legacy applications, and a user's willingness to accept operational and technology change. For example, users may realize a direct benefit from using data services to directly access the NCIC 2000. In this case, it may improve call response time from minutes (using a dispatcher to access information and relay it to a user) to less than a minute. Greater autonomy and time savings may directly benefit the user operational capabilities. The rate of adoption and usage may vary among users, therefore, system planners can only broadly forecast the overall effect of these applications on the legacy LMR system.

To integrate new applications into an existing LMR system, system planners may need to reengineer segments of the system to ensure that legacy and new applications can coexist on a single LMR system. Reengineering may focus on system improvements to support new applications or to ensure that legacy applications are not degraded. For example, to effectively support NCIC 2000 database queries, system planners may need to provide sufficient transmission speeds and capacity within the LMR system to limit the time it takes to transmit a query and receive the needed information. Several questions may need to be answered before a system planner can integrate a new application. If there is wide scale adoption of this application, how will this affect the legacy system and applications? Will it degrade the availability and performance of current services? What level of investment is needed to provide sufficient capacity and performance? How will dispatch operations need to be reengineered? If the necessary changes aren't made, will system performance degrade the new application and artificially impede adoption and usage?

Reengineering requirements may result in additional capital needs beyond the investment in end-user devices such as MDTs. Because the rate of adoption and usage

may be difficult to predict, system planners may need to manage the risk of both over-investment or under-investment. Over-investment may result in the allocation of too many resources to support a slower rate of adoption and may limit the funds available to invest in other public safety capabilities. Under-investment may use limited capital funds to implement changes that are insufficient to support faster-than-expected adoption and usage rates. In this case, the system planner may not realize a return on investment.

Some system planners have offloaded new applications, such as data communications, to commercial services to reduce risks and manage the transition from the early to wide-scale adoption of new applications. For example, system planners may look to cellular digital packet data (CDPD) service to provide approximately 10 kbps transmission speed to support data applications (CDPD is described in Section 4.2.7). An important element of risk management is the ability to use recurring funds to pay for commercial services instead of capital investment funds. A more detailed discussion of recurring and capital expenditures is presented in Section 2.2.3 of this report. As adoption and usage levels become clear over time, system planners may transition these applications back to their LMR systems if it becomes fiscally or operationally prudent. At that time, system planners will likely have a better idea how to reengineer their LMR network to support new applications as a result of the knowledge gained on the usage patterns of commercial services.

2.2.3 Provide a Less Capital Intensive Approach to Support a Percentage of Overall Requirements

Public safety organizations design and operate LMR systems to support a range of requirements, including tactical and emergency voice communication requirements. In some cases, increasing tactical and administrative traffic loads may stress the existing system and require additional investments to ensure sufficient capacity and performance. If additional spectrum is available, organizations need to marshal the needed capital to fund expansion. If additional spectrum is not available, system planners need to develop an approach to work within existing spectrum limitations; the priority would be to ensure appropriate capacity is available for critical tactical traffic. In either case, system planners can offload some administrative traffic to reduce overall traffic loading on the system and to use a less-capital intensive approach to support administrative traffic requirements.

LMR capacity planning considers the capacity needed to support normal levels of overall traffic and critical levels of tactical traffic. In some cases, system planners may face spectrum or capital limitations while their LMR systems may be experiencing increases in tactical and administrative traffic. In these cases, system planners must ensure the availability of capacity to meet critical tactical needs. Therefore, system

planners may look to commercial services to offload some administrative traffic. There are several advantages to this approach:

- Minimizes the need to request capital funds, particularly in areas where capital funds are not owned and disbursed by the public safety organization or where capital resources are scarce

- Provides public safety organizations the ability to defer, delay, or reduce capital expenditures by supporting some requirements (i.e., administrative traffic) using recurring funds until sufficient capital funds can be applied to the LMR system

- Allows public safety organizations to target capital expenditures for critical operations, including non-telecommunications investments.

This approach can be effective in supporting communication requirements that do not need the security and high performance of LMR systems. The benefit of this approach is that the limited spectrum and capital can be targeted at those communications requirements that need the reliability, availability, and security of LMR systems.

The allocation of some administrative traffic to commercial services may be the least capital-intensive approach, but it may not be the lowest cost approach. This is because to effectively compare the cost of commercial services and LMR systems, the commercial service costs must be projected across the full LMR system life cycle (e.g., 7 to 10 years). Using this comparison approach, overall commercial costs include equipment, monthly fees, and usage fees for all users within an organization.

Commercial services, although funded incrementally, may result in a 10-year expenditure by the public safety organization that exceeds a potential investment in an LMR system or LMR system capacity expansion. In this case, the investment plus operations and maintenance (O&M) requirements, added for a full 10 year life cycle may be similar to or less than the 10-year cost of purchasing commercial equipment and using commercial services. This is particularly the case if users select higher priced "specialized" services to gain LMR-like functionality (e.g., push-to-talk and talk groups) instead of "commodity" one-to-one voice services such as cellular and personal communications service (PCS).

For LMR, a significant spending spike occurs during the design and implementation phase because of the equipment and implementation costs. Spending decreases in the operational phases as equipment has been purchased and there is a lower level installation effort; the remaining life cycle should include generally similar O&M costs. For commercial services, annual costs are due to monthly service bills and

terminal lease or purchase payments. Costs for commercial services results in a steady increase of cumulative cost over 10 years. Usage and feature functionality will determine at which point commercial services exceed the investment in LMR. With the current long life cycle (+ 10 years), LMR systems may be the lower cost investment in the long run.

Commercial services may be ideal for use in certain instances where wireless communications are required for short term use. Under circumstances where LMR coverage is being expanded, during surge periods, or to evaluate a particular service, using a commercial services may be more cost beneficial than purchasing new equipment or expanding a network to support a temporary surge in communications traffic.

2.2.4 Provide Different Subscriber Functionality

LMR systems are designed to support an organization's public safety requirements. System attributes may include secure broadcast (one-to-many communications) and dispatch services. These attributes are not widely available on commercial systems. Similarly, there are some features that may not be available on a subscriber's LMR system. Commercial service subscriber features may include:

- Voice mail
- Public switched telephone network (PSTN) access without dispatch involvement
- One-to-one private conversations (not available for users on conventional systems)
- Caller ID
- Simple Message Service (SMS); for this report, simple message service is the application name used to describe simple e-mail (without attachments) and text paging.

In these cases, public safety users may choose commercial services to provide features not provided by the LMR system. Use of commercial services typically requires lease or purchase of different subscriber equipment.

3.0 ANALYSIS CONSIDERATIONS

This section describes analysis considerations that can be used to compare similar technologies or services. These analysis considerations were chosen to broadly reflect the requirements of the public safety community and provide a structure to highlight the attributes and characteristics of commercial wireless services. Public safety network planners can use them to evaluate each service in terms of their applicability and suitability for public safety communications.

Exhibit 3-1 broadly defines each consideration. The following sections further describe the analysis considerations that will be used to evaluate and compare the commercial services. Section 4 describes each wireless service. They are categorized according to the type of service each provides: voice or data. Section 5 provides a set of matrices that compare and contrast each service.

Exhibit 3-1
Analysis Considerations

Analysis Consideration	Description
Availability	Identifies whether a service can be acquired from a provider in a given region
Coverage	Identifies whether communication transmissions can reach users in a given service area
Accessibility	Identifies whether a service can be accessible and usable upon demand, even during peak periods or network disruption
Security and Privacy	Describes the level of inherent security and privacy of a service and the capability to add security measures
Transmission Speed	Measures the actual rate of successful transmission
Addressing Functionality	Describes the method by which a service is accessible (i.e., push-to-talk, dial-in, modem based)
Cost	Identifies handset and service costs
Type of Applications Supported	Denotes the range of communications offered, including one-to-one, conference calling, broadcast messaging, and dispatch services

3.1 Availability

Availability identifies whether a service can be acquired from a provider in a

given region or service area. Availability may vary by service or by service provider. For example, many commercial wireless networks are relatively new or are still being developed. Therefore, these services are not available in all areas of the United States. However, some services, such as cellular and CDPD are well developed and can be acquired in many areas throughout the United States and in selected international markets. Service providers are continually adding new service areas to their networks.

In addition, many commercial wireless service providers have developed roaming agreements with other providers, allowing them to extend their service areas. Certain service providers can more easily expand their service areas and availability because they operate using the same wireless air interface protocols as other service providers.

3.2 Coverage

Coverage identifies whether users can send and receive wireless transmissions in a particular area. Coverage for commercial wireless services varies depending on the type of service and provider. Even though some wireless services have coverage that spans the nation or the globe, subscribers to these services may still experience coverage gaps in service. These gaps may occur for three primary reasons: lack of assets, terrain interference, and building interference.

Service providers often deploy networks in areas with high population densities, such as metropolitan areas and along roadways. This is especially true when carriers first construct their networks. They typically construct them in areas that have high levels of anticipated demand for a service. Consequently, full coverage may not exist in rural areas or away from major roadways where public safety operations may be conducted.

Coverage gaps also exist where terrain interferes with the wireless signal. This may occur in mountainous areas or in valleys where the signal cannot reach users. When a user moves back into the coverage area of a signal, service can be restored.

Wireless signals may also be blocked due to buildings or structures that obstruct the signal. This may happen as users travel under bridges or operate their telephones while inside a structure, such as a parking garage or large building. In these cases, users cannot send or receive transmissions. If users are operating phones during these times, their conversation may be terminated.

3.3 Accessibility

Accessibility measures how readily users can access and use a service, especially during peak hours or in the event of a network disruption. Each wireless

network has a limited capacity. Users on wireless service networks compete with one another for access to these networks. If demand exceeds capacity, users may not be able to access the network. This may occur particularly during peak periods such as rush hour or in the event of an emergency. If public safety operations coincide with peak calling times, congestion may occur, and public safety users will not be able to access the network to place a call.

Accessibility depends in great part on whether the service is widely used by the general public or whether the usage is limited to a specific community. If the general public uses a particular service, there may be a greater number of users competing for network resources. These networks are typically more susceptible to congestion than those that serve the business communities.

3.4 Security and Privacy

Security and privacy describe the level of system vulnerability to transmission and computer-based electronic intrusion. There are different levels of security and privacy in commercial wireless networks. Each physical component and the radio frequency (RF) link of a commercial wireless service architecture represents a potential security vulnerability.

Many providers offer privacy features, such as automatic identification, authentication, and passwords to limit unauthorized, fraudulent access and data interception. In some commercial wireless networks, encryption can be applied to end user devices. Communications security is an important issue for public safety wireless users, particularly law enforcement.

3.5 Transmission Speed

Transmission speed is the rate at which data is transmitted through the network. The overall time required to transmit data is equal to the call setup time plus the transmission duration. Call setup time is the time it takes to access a transmission channel.

While each wireless service is engineered to support certain data speeds, various factors may slow the rate of transmission. Overhead information, such as error detection and correction, can reduce the effective data transmission speed. In addition, the modem a user chooses may not support the full data rate offered by a particular service.

Transmission speed can also be affected by the level of traffic on the network. A

packet-switched network is designed to support only a certain level of traffic. When traffic exceeds the engineered capacity, the network cannot support the additional traffic. As a result, the rate at which the transmitted data is accepted is reduced, and information is transmitted at a slower rate.

3.6 Addressing Functionality

Addressing functionality describes the method by which a service is accessed from the user point of view. Commercial wireless voice services can be accessed two ways: push-to-talk (PTT) and touch-tone dialing.

Certain wireless services such as specialized mobile radio (SMR) offer PTT addressing functionality, which is how LMR communication systems are accessed. Users push the transmit button on their radios, which initiates connectivity to other users on the network. Other services, such as cellular telephones, require users to dial a series of numbers on a multi-key pad in order to place a call. Dialing takes considerably more time than PTT to establish communications with other users. A user must either memorize a recipient's number or take additional time to look up a telephone number. In addition, dialing can be cumbersome to execute in time critical situations. It requires the user to see, locate, and push a series of numbers to execute a call.

In data communications, a user may access the network using a circuit or packet switched connection. In a circuit switched connection, a connection must be established every time information is sent. This can take up to a minute, depending on the type of network. Packet switched data involves a very small delay because a user may maintain a connection with the network rather than having to "dial in" every time to send data. The delay associated with packet data transmission may be imperceptible to users.

3.7 Cost

The costs for commercial services include user or subscriber equipment and service costs. Service costs for commercial wireless services vary by service provider and pricing plan. There are two major types of pricing plans for data and voice services, flat rate and usage based. For flat rate pricing, users pay a set amount for unlimited usage. This is advantageous to those who are heavy users of a particular service. Usage based pricing typically has users pay a set monthly price for a fixed level of usage and then pay incrementally beyond the fixed limit. Other fees may also apply depending on the service, such as long distance and roaming fees. Some service providers charge a fee for each call that connects to the wireline network. This fee can add a substantial amount to a user's monthly phone bill. Organizations with high

usage patterns may typically negotiate bulk rates with carriers.

The cost for subscriber equipment varies. Service providers frequently subsidize the cost of the end user devices to attract more users to the service. Often, end user devices can be acquired for free, depending on the type of service, or they can be leased from a service provider. The subsidized subscriber equipment is often combined with a long term service agreement.

Pricing of wireless services is also based largely on whether the service is viewed as a commodity or a specialized service. Specialized services are typically services that have recently been introduced to the market. They provide specialized functionality and features, such as PTT or talk groups. They are mainly adopted by the business community and government organizations rather than the general public. Therefore, the network is designed to support business use only. To some degree, this may leave these services less vulnerable to congestion during emergencies because there are fewer users to compete for network resources.

In contrast, commodity services are widely available and considered highly mature. Their costs are generally lower and they offer less functionality than specialized services. They are typically used by both business and general public sectors. Specialized services often evolve to commodity services as they mature and proliferate.

3.8 Type of Applications Supported

Type of applications supported denotes the range of communications that are offered by a particular service. Each wireless service can support different types of applications; these applications are classified as either voice or data. Voice services support point-to-point, dispatch, or point-to-multipoint communications. Data service applications support short message service (SMS), small and large file transfer, and PSN access. For this report, SMS includes email and text or alphanumeric paging services.

The applications that a particular service can support depends highly on the amount of spectrum allocated to a service. Each service provider is licensed by the Federal Communications Commission (FCC) to operate using a particular amount of spectrum. Each spectrum slot can hold a limited amount of information. Higher bandwidth services require more spectrum to send information through the network. High bandwidth services include imaging, video, and large file transfers. Low bandwidth services do not require such a large portion of spectrum. These include SMS and small file transfers.

For example, paging network operators are licensed by the FCC to operate using

a limited amount of spectrum. Therefore, they are limited in the types of services they can offer. Paging service providers can typically provide numeric or text paging services. Additional applications such as SMS (alphanumeric messaging) can be added to the network as service providers upgrade to digital technologies and make more efficient use of the spectrum.

4.0 COMMERCIAL WIRELESS SERVICES

Wireless communication services are rapidly evolving. The types of applications that are available to consumers vary depending on the service and service provider. Wireless commercial services may be voice or data applications. Some services offer both types of applications. There are key differences in wireless data and voice services in terms of their applicability and suitability to public safety. This section categorizes each service into voice or data application, and discusses the characteristics of each service.

4.1 Wireless Voice Services

Wireless commercial voice networks allow users to communicate when they travel away from a fixed location or operate in a mobile environment. Most commercial wireless voice networks connect to the PSTN, which allows users to communicate with other users on the PSTN. Users communicate in the same fashion as they would using a wireline phone. They can make local and long distance calls and use a variety of advanced features like call forwarding, call waiting, caller ID, and voice mail. Commercial wireless voice networks typically allow users to operate outside of their local calling area.

Wireless voice services include cellular, personal communication services (PCS), mobile satellite services (MSS), specialized mobile radio (SMR), and enhanced specialized mobile radio (ESMR).

4.1.1 Cellular

Cellular service is similar to the wireline voice service provided by local and long distance carriers. Commercial cellular networks provide one-to one voice and enhanced services to wireless subscribers. Enhanced services include voice mail, call waiting, caller ID, and call forwarding. Cellular service is offered in the 800 MHz frequency band.

Cellular service providers cover more territory than any other terrestrial wireless system. Cellular networks provide coverage to almost 95 percent of the US population, covering 70 percent of the US land mass. There are typically two cellular providers per region. Although providers have defined areas in which they can offer service, users can get almost nationwide service with roaming agreements negotiated between providers. However, some coverage gaps exist in the network due to low demand in certain areas or difficult geographic terrain.

Cellular is the most widely used commercial wireless service. This is due to the fact that it has appealed to and been marketed to a wider range of people than any other commercial wireless service, and costs for the unit and service have decreased substantially. Because cellular service is widely utilized by the general public, a large number of subscribers compete with one another for capacity on the network. When demand exceeds capacity, congestion may occur in the network. This may happen during emergencies in which public safety users may be responding. During congestion, subscribers may experience a delay in call setup or may be unable to place a call.

Satellite networks may serve as a secondary network when the cellular network is congested. Dual mode cellular telephones have been recently developed that automatically use a terrestrial wireless cellular connection when available, but switch to a satellite connection when in remote areas.

4.1.2 Personal Communications Services

PCS provides one-to-one voice services and a variety of enhanced features such as voice mail, call waiting, call forwarding, and caller ID to subscribers. Like cellular, PCS offers services and functionality similar to wireline voice services. PCS is an all digital service and often integrates other commercial wireless services such as paging, data, and e-mail access with voice communications.

The FCC licensed as many as six PCS providers to operate in each discrete PCS market area. However, the service is relatively new and not all providers have built out their networks in each area. Network buildout is occurring in mainly urban areas. Therefore, PCS users are more likely to experience coverage gaps than cellular users. Users who travel outside of the PCS network areas generally cannot place calls.

There are multiple PCS air interface technologies. These various air interface technologies make it difficult for users to communicate seamlessly across the nation with one terminal device. Some service providers are working to establish roaming agreements with other carriers using the same air interface technologies in order to expand their coverage areas. Others may integrate their services with existing cellular services to offer ubiquitous voice coverage to the end user. Providers accomplish this by furnishing dual mode cellular/PCS handsets to operate on either the cellular or PCS spectrum. In addition, satellite systems may serve as a secondary network to these systems in order to expand coverage areas or expand capacity when networks become congested.

Like cellular, PCS is considered a commodity service. Prices range from $.09 to $.37 per minute, although some service providers offer flat rate pricing. Because PCS is highly utilized by the general public, many users compete for access to the network at

any given time. When demand exceeds capacity, congestion may occur. Users may experience a delay in call setup or may not be able to place a call if the network becomes congested.

4.1.3 Mobile Satellite Services

MSS voice services are delivered via satellite to or from mobile users. They typically offer one-to-one voice services, but some have dispatch and broadcast capabilities. MSS systems are capable of offering global coverage except for the North and South poles. There are currently few active MSS providers. A number of providers are planning service deployments within the next year; however, most will not be operational until the year 2000.

MSS systems are categorized by their orbital altitude. There are three categories of MSS systems: geostationary orbit (GEO), medium earth orbit (MEO), and low earth orbit (LEO). GEO systems orbit approximately 22,300 miles from Earth. Geostationary systems provide coverage primarily to large regional areas. They have inherent transmission time delays because of the long distance from earth, causing delays in voice and data transmissions.

MEO systems orbit between 3,125 and 9,375 miles from the earth. They require about 12 satellites to provide global coverage. LEO satellites orbit at altitudes between 500 and 1,250 miles from the Earth, which require from 20 to more than 100 satellites to provide global coverage. Certain LEO systems are designed to provide low-speed data services, while others are designed to provide voice, data, and video services. LEO and MEO systems are not likely to experience transmission delays because they are located closer to Earth than GEOs.

The cost of MSS is relatively high compared with other cellular services. While market penetration will be a key factor affecting the price of the service, the cost is estimated between $0.50 and $3.00 per minute.

MSS is an emerging service. Therefore, its market potential is unclear. However, because the cost is relatively high, and it is a specialized service, it is likely that MSS will be utilized mainly by the business community. This means that users will compete with a smaller population of subscribers than cellular or PCS, which will limit the likelihood of congestion. In addition, users may have a number of satellites to access at one time.

MSS networks are less susceptible to shadowing from large buildings or difficult terrain than terrestrial wireless systems. MSS may serve as a secondary network when the cellular or PCS networks are congested. Dual mode handsets have been developed

that automatically use a terrestrial cellular connection when available but switch to a satellite connection when in remote areas.

4.1.4 Specialized Mobile Radio

SMR provides users with one-to-one, broadcast and dispatch capabilities. SMR systems allow users to talk on an individual, talk group, or fleet basis, much like traditional LMR service. There are approximately 8,000 SMR service providers in the United States. There are many local and regional service providers, but licenses are not awarded for national networks. No roaming agreements have been established. Therefore, users are unable to travel outside of their local network serving area.

In addition to having limited geographic service areas, SMR systems operate using many different technologies and are offered in three different frequency bands: 220, 800, and 900 megahertz. These various standards and frequency bands make it difficult for users to operate on networks other than their own. The SMR industry is working to develop a protocol that facilitates roaming capabilities.

SMR is used primarily by business users. The service, construction, and transportation industries are the main users of SMR service. Therefore, it is less susceptible to congestion than other commercial services, such as cellular or PCS because it is not widely used by the general public. Only about 20 percent of SMR networks are connected to the PSTN. Therefore, users may not be able to communicate with others outside their coverage areas.

4.1.5 Enhanced Specialized Mobile Radio

ESMR provides one-to-one, dispatch, and broadcast voice services and features comparable to the services currently offered by cellular subscribers. This includes voice and enhanced services such as three-way calling, caller identification, and voicemail. ESMR networks cover a larger geographic area than traditional SMR networks.

There are currently only two major ESMR service providers in the US. These providers offer service in limited markets around the United States and Canada. Because the networks are still being developed, the service is available predominately in urban areas and along major highways. These providers are planning to develop nationwide networks by acquiring additional spectrum and merging with other SMR operators.

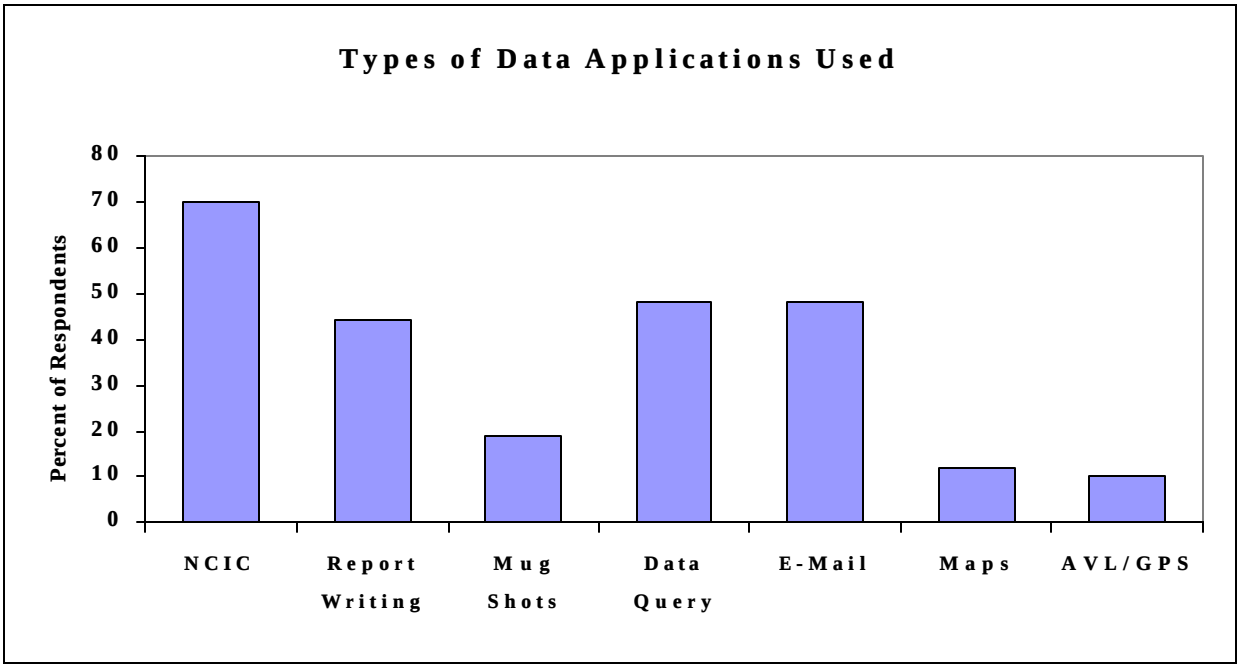
ESMR is used primarily by the business community. Because it is not widely used by the mass market, it is less likely to become congested than other user networks, such as cellular and PCS. However, the likelihood of congestion depends a great deal on how the network is engineered. ESMR is also subject to coverage gaps due to difficult terrain and building interference, much like other wireless services. When in these areas, users cannot receive service, or calls may be disconnected.

4.2 Wireless Data Services

Wireless data services allow users to send and receive data between subscribers, connect to wireline resources such as databases, and access the Internet. The services offered by commercial wireless data providers vary. Some commercial wireless data networks offer low bandwidth data services such as SMS and small file transfers. Other data services allow users to transmit high bandwidth data. This includes large files, such as imaging and video. Access to most commercial wireless data networks is achieved using a wireless modem.

Most commercial wireless data networks allow users to operate while traveling but some networks allow users to operate only from a fixed location. Fifteen percent of public safety organizations surveyed in the Washington DC and San Diego areas currently use some form of wireless data communications for user applications, such as automatic vehicle location (AVL). Exhibit 4-2 illustrates the types of data communications currently used by those organizations (4,5). Commercial wireless data services include cellular, PCS, MSS, ESMR, Paging, Wireless Data Services, and CDPD. The following sections describe these services in further detail.

Exhibit 4-2
Types of Data Communications


Types of Data Applications Used
Percent of Respondents
80
70
60
50
40
30
20
10
0
NCIC
Report Writing
Mug Shots
Data Query
E-Mail
Maps
AVL/GPS

4.2.1 Circuit-Switched Cellular

Circuit-switched cellular allows users to send low bandwidth data, such as SMS, faxes, and small files. The network covers almost 70 percent of the geographic US. Users must dial into the network using their cellular telephone and modem. This procedure may take up to about 45 seconds. Currently, only about 2 percent of all cellular voice customers use the cellular network for data communications. Users pay by the minute rather than for the amount of data communicated. Typical cellular phone charges apply.

The maximum data speed for cellular networks is 14.4 kilobits per second (Kbps), although actual user speed is from 9.2 to 12 Kbps, depending on the network conditions and type of modem used.

Because cellular phones operate over the air as radio signals, they are subject to performance impairments that naturally arise in any radio environment. These impairments include noise, interference, fading, and rapidly changing channel quality. These radio and network conditions can reduce modem transfer speed or drop a connection. Consequently, modems that are designed for landline data calls are not suited for the cellular network. Modem vendors have developed a number of protocols to address these performance issues. However, these protocols work effectively only if they are used by both modems in a data transfer session.

Circuit switched cellular users must contend with other voice and data users on the cellular network. Therefore, when the network is congested, users may have difficulty setting up a connection or sending information.

4.2.2 PCS

PCS data services that support applications such as large and small file transfers and PSN access are currently available only from providers that are operating using the Global System for Mobile Communications (GSM) air interface technology. Service providers using Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) technologies currently offer only SMS. PCS providers plan to offer two-way SMS to allow for interactive and transaction-based services. Eventually, providers will move into more robust data utilizing higher bandwidth, which will allow file transfers, and Internet access. Current PCS data services provide bandwidth up to 9.6 Kbps. However, the actual throughput is limited to 4.8 Kbps.

PCS data technologies are currently circuit-switched due to the fact that circuit switched service is similar to voice communications in terms of call handling and billing. Wireline service providers can offer circuit switched more readily than packet-

switched data service. However, packet switched data service will be available in the near future. Like cellular, PCS is also subject to performance impairments, such as noise and fading, which may reduce modem transfer speed or drop a data call.

4.2.3 MSS

Like other data services, MSS data users connect to the network by using a mobile computer attached to a wireless satellite telephone. MSS offers worldwide coverage, except for the North and South poles. The MSS data rate is 4.8 Kbps, but the actual transmission speed is 2.4 Kbps, which limits the types of information that can be sent over the networks. MSS is currently suitable for SMS and small file transfers. These services are priced from $.50 to $3.00 per minute.

There are more than a dozen new narrowband and broadband MSS systems being planned. Narrowband services, providing data rates up to about 100 kbps, will focus on global paging and mobile telephony. Broadband services, measured in megabits per second, will offer high speed data transfer and interactive video. MSS data service will not compete directly with terrestrial systems, but will instead complement them by offering service in areas without terrestrial coverage.

Although MSS data has almost worldwide availability, it has poor in-building coverage and can be susceptible to interference from geographic terrain.

4.2.4 ESMR

ESMR service providers currently offer only SMS. However, service providers plan to offer data services soon. These services will support a wide variety of applications ranging from SMS to small and large file transfers.

4.2.5 Paging

Paging services allow users to transmit messages to paging subscribers. Pages can be broadcast to a selected group of users simultaneously or to an individual subscriber. Messages reach subscribers in a voice, numeric, or text format. Text pagers are the most advanced units and can receive short message services, email, voicemail notification, and media content, including news headlines and stock quotes. Commercial paging networks operate at speeds up to 6.4 Kbps.

More recently, providers have begun to offer two-way paging capabilities. This service allows users to send and receive pages, send messages to multiple recipients, and create and manage an address book. Some can be customized to permit Internet and Intranet access. This service, however, is offered only by selected providers on a

limited basis.

Paging services are available in most of the areas throughout the US. Some providers have service areas that reach more than 90 percent of the population. Paging service providers offer limited roaming capabilities outside their particular service area. However, if users roam outside of their coverage areas and cannot receive service, messages will typically be stored until they return.

4.2.6 Wireless Data Services

Wireless data services allow users access to the Internet, remote wireless and wireline databases, and the PSN. Most commercial wireless data providers allow users to exchange data while moving within the network coverage area, while others require users to access the network from a fixed location. Call setup delays on wireless data services are minimal because they are packet switched, which does not require users to dial into the network each time they transmit data.

Commercial wireless data networks vary widely in coverage and transmission speed. Many commercial wireless data networks offer a patchwork of regional systems. However, some networks limit coverage to only a few major metropolitan areas. The transmission speed of commercial wireless data networks ranges from 9.6 Kbps in networks allowing mobile data transmission, to up to 126 Kbps in networks providing fixed data connectivity. Modems are typically compatible with only the commercial wireless data network on which a user operates.

Wireless data service plans may be flat rate or usage based. Wireless data is priced on the amount of data communicated, rather than the length of time spent on the network. The costs range between $.23 to $.45 per kilobyte. Fixed wireless network providers typically charge a flat rate for unlimited data transfer. These services are suited for Internet access and large file transfer.

4.2.7 Cellular Digital Packet Data

CDPD is a wireless mobile data network service that allows users to perform various data applications, such as remote database access and file transfer. CDPD uses channel hopping or dedicated voice channels on the cellular network to provide packet data capabilities. Packet data transmission allows CDPD service providers to charge customers based on the amount of data sent instead of the amount of time required for a transmission. Service plans vary, but costs are generally $.02 to $.10 per kilobyte.

CDPD may transmit data at speeds up to 19.6 Kbps, although actual user speeds are typically from 10 to 12 Kbps, depending on the level of traffic on the network. This

service uses a data format similar to the one used for Internet communications, which allows most data applications to be supported through CDPD services. CDPD response times for database inquiries average fewer than 5 seconds but can be more depending on network conditions. Because CDPD is a packet-switched cellular service, it takes minimal time for call setup.

CDPD service is available in half of the geographic areas of the US and in 30 international markets. However, the service is not available in all areas that offer cellular service. In addition, CDPD coverage may be spotty in areas with poor cellular coverage.

Since CDPD shares the resources of the cellular network, conflicts may occur between competing cellular voice traffic and packet data traffic. The likelihood of congestion depends on the type of CDPD network implemented. The two types of networks are channel hopping and dedicated. Channel hopping CDPD transmits information on the unused capacity of the cellular voice network. Users on a channel hopping network compete with cellular voice users. Conversely, dedicated CDPD sets aside certain channels for CDPD traffic. Therefore, CDPD capacity does not vary as cellular voice calls increase or decrease. However, users must still compete with other CDPD users for call setup and channel capacity.

5.0 TECHNOLOGY AND SERVICE CHARACTERIZATIONS AND COMPARISONS

This section analyzes and compares the various wireless voice and data technologies. To analyze and compare technologies and services, a set of matrices have been developed that include comparable technologies. Within each matrix, the specific technology is measured against the individual analysis consideration. Exhibit 5-1 analyzes wireless voice technologies, and Exhibit 5-2 analyzes various wireless data technologies.

Exhibit 5-1
Voice Technologies and Services

	Cellular	PCS	MSS	SMR	ESMR
Availability	• Covers 70% of US land mass • Available to over 95% of US population • 2 service providers in every area • Roaming agreements with other cellular carriers greatly expand coverage areas	• 2-6 providers licensed per region • Relatively new service • Less coverage area than cellular • Network expansion occurring in the largest and most populated geographical areas • Service not available in many smaller, rural areas • Roaming agreements are being established with PCS and cellular carriers to expand coverage areas	• Global availability, except for north and south poles • Few systems currently in operation • More will be phased in over the next few years • Most planned MSS systems will be operational in the next 5 years	• Approximately 8,000 systems in operation • Service providers offer service in specific regions • Different standards and frequencies make it difficult for users to roam outside service provider's coverage areas	• At this time, only 2 major ESMR service providers • Available only in selected markets throughout the US.
Coverage	• Mainly in urban areas and along rural highways • Has greater network buildout than other commercial wireless services • Coverage gaps exist due to terrain or building interference	• Mainly in urban areas • Service providers building out networks; over the next few years, PCS will be more widely available in small cities and rural • Coverage is planned to match cellular penetration in next few years • Multiple air interface standards may limit user's ability to communicate seamlessly across the nation with one user handset • Coverage gaps exist due to terrain or building interference	• Can provide communications in most areas where terrestrial networks are not available. • Weak in-building coverage • May provide improved line of sight to terrestrial systems; coverage gaps can still exist	• Available mainly in urban areas • Coverage gaps exist in areas where there are low levels of demand for service or where terrain or buildings interfere with the signal	• Coverage gaps exist in areas where there are low levels of demand or where terrain or buildings interfere with the signal • Providers are continuing to build out their networks; ESMR will be deployed in smaller cities in the next few years
Accessibility	• Subscribers compete with general public for channels • Demand may exceed capacity, particularly in analog cellular networks • Therefore, traffic surges and congestion may occur during emergencies in which public safety users may be responding • Subscribers may experience a delay in call setup or may be unable to place a call	• Subscribers compete with the general public for channels • Demand may exceed capacity • Therefore, traffic surges and congestion may occur during emergencies in which public safety users may be responding • Subscribers may experience a delay in call setup or may be unable to place a call	• Not widely used by the general public • Not as susceptible to congestion as other services such as PCS or cellular • MSS may serve as a secondary network for cellular service providers when users are out of services areas or demand exceeds capacity on those networks • Most service providers plan to offer a form of priority queuing access scheme, but these schemes will not circumvent congestion and may cost more • Can experience signal delay depending on the type of system	• Not widely used by the general public • Less susceptible to congestion than other commercial services, such as cellular or PCS • If all channels are in use, users receive a busy signal or calls are "queued" until a channel is free	• Mainly used by the business community • Less susceptible to congestion than other commercial services, such as cellular or PCS, but demand may still exceed network capacity during peak calling hours • Subscribers may experience a delay in call setup or may be unable to place calls
Security and Privacy	• Susceptible to unauthorized monitoring and fraudulent use • Encryption may be applied to handset	• Digital technology susceptible to monitoring, can be intercepted • Encryption may be applied to handset	• Encryption can be attached to the handset	• Encryption can be applied to some systems	• Privacy features include temporary IDs for subscriber units and authentication • Encryption cannot be applied
Addressing Functionality	• User must dial number from their handset • Requires user to know receiver's phone number • Increases time needed to complete call • Speed dialing functions available but may not be available when users roam	• User must dial a number from their handset • Requires user to know receiver's phone number • Increases time needed to complete call • Speed dialing functions available but may not be available when users roam	• Most provide dialing only • User must dial a number from their handset • Requires user to know receiver's phone number • Increases time needed to complete call • Speed dialing functions available but may not be available when users roam • Few provide push-to-talk	• Push-to-talk and dialing • Push-to-talk provides simplified addressing • User does not need phone number	• Push-to-talk and dialing capabilities • PTT provides simplified addressing and may be suitable for public safety operations
Cost	• Handset costs range from **$0-$300**, depending on whether phones are analog or digital • Many service plans • Usage based pricing plans • Price per minute ranges from $.05 to $.36 • Users pay for incoming and outgoing calls • Additional fees may be charged for roaming, enhanced features, and long distance • Service providers charge $.10 to complete landline telephone calls	• Handset costs range from **$75-$300** • Many service plans • Primarily usage based pricing, some offer flat rate calling plans • Price per minute ranges from $.05 to $.30 • Users pay for incoming and outgoing calls • Service providers charge $.10 to complete landline telephone calls • Additional fees may be charged for roaming, enhanced features and long distance	• Handset costs range from **$400-$5,000** • Service fees range from $.50-$3.00 per minute • Users pay for incoming and outgoing calls • No distinction between local, long distance, or international calling	• Handset costs range from **$150-$800** • Mostly flat rate pricing • Average monthly cost for dispatch service ranges from $12-$18 • No fee to complete calls to landline telephones in some cases	• Handset costs range from **$70-$300** • Dispatch only service is typically a flat rate for unlimited calls • Cellular pricing is usage based • Price per minute generally ranges from $.05 to $.50 • All parties in talk groups are charged for dispatch calls • Users pay for incoming and outgoing calls • No fee to complete calls to landline telephones in

	• Future pricing trends will most likely transition to flat rate for unlimited calls	• Future pricing trends will most likely transition to flat rate for unlimited calls			some cases • Additional fees for enhanced features and long distance may be charged
Type of Applications	• One-to-one voice, enhanced calling features such as caller ID, call waiting, and voice mail	• One-to-one voice • Enhanced calling features such as caller ID, call waiting, and voice mail	• Dispatch, one-to-one voice • Enhanced calling features such as caller ID, call waiting, and voice mail	• Dispatch and one-to-one and one-to-many voice, limited access to PSN	• Dispatch, one-to-one, one-to-many voice • Enhanced calling features such as caller ID, call waiting, and voice mail

Exhibit 5-2
Data Technologies and Services

	Cellular	PCS	Paging	MSS	CDPD	Wireless Data
Availability	• Covers 70% of US land mass • Available to over 95% of US population • 2 service providers in every area • Roaming agreements with other cellular carriers greatly expand coverage areas • Data offered for all cellular systems	• Limited availability • File exchange and PSN access offered only by certain network operators who use GSM air interface technology	• Available in most areas throughout the US • Some providers have service areas that reach more than 90% of the population • Limited roaming capabilities for terrestrial pagers	• Global availability, except for north and south poles • Few systems currently in operation • More will be phased in over the next year • Most planned MSS systems will be operational in the next 5 years	• Available in half of the geographic US and in 30 international markets	• Available exstensively in areas throughout the US • Particular providers offer service only in selected markets
Coverage	• Mainly in urban areas and along rural highways • Has greater network buildout than other commercial wireless services • Coverage gaps exist due to terrain or building interference • Weak in-building coverage	• Only in urban areas with service providers who offer GSM air interface technology • Service providers continually building out networks • Coverage gaps exist due to terrain or building interference	• Incomplete coverage in rural areas for terrestrial providers • Coverage gaps exist in areas with difficult terrain or where network system elements operate at different frequencies • Satellite providers offer global coverage	• Can provide communications in most areas where terrestrial networks are not available. • Weak in-building coverage	• Mainly available in metropolitan areas and along major roadways • Coverage gaps exist due to geographic terrain or where carrier's signal is non-existant or too weak • Weak in-building coverage	• Mainly available in metropolitan areas and along major roadways • Coverage gaps exist due to geographic terrain or where carrier's signal is non-existant or too weak
Accessibility	• Widely used by general public • Subscribers compete with one another for access to the network • Demand may exceed capacity, particularly in analog cellular networks • Congestion will prevent caller from accessing a line • Connection quality can vary widely during a session, causing data or an entire call to be dropped	• Widely used by general public • Subscribers compete with one another for access to the network • Demand may exceed capacity which may prevent caller from accessing a line or slow the data transmission rate • Connection quality can vary widely during a session, causing data or an entire call to be dropped	• Widely used by general public • Subscribers compete with one another for access to the network • Users may experience congestion if demand exceeds network capacity • Congestion may limit a caller's ability to place a page or slow the transmission rate of a page • Paging services sometimes rely on commercial satellite providers to deliver services • If an outage occurs in the satellite network, paging users may lose service	• Not widely used by the general public • Not as susceptible to congestion as other services such as PCS or cellular • MSS may serve as a secondary network for cellular service providers when users are out of services areas or demand exceeds capacity on those networks • Most service providers plan to offer a form of priority queuing access scheme, but will not circumvent congestion and may cost more • Can experience signal delay depending on the type of system	• CDPD users may share network resources with other voice and data users • Users may experience congestion if there is more demand than network capacity • Delays may occur in setting up a connection resulting in a slow data transmission rate • Dedicated channel CDPD networks set aside particular channels for users, which are less likely to be congested than channel hopping CDPD networks • Channel hopping CDPD networks compete with voice users and may be more susceptible to congestion than dedicated CDPD networks	• Wireless data users do not share network resources with other voice or data users • Mainly utilized by the business community • Congestion is less likely to occur than in other data networks that share resources with voice and data users • However, congestion may still occur, which may cause delays in setting up a connection and slow data transmission rate
Security and Privacy	• Not secure • Encryption may be applied to data by the user	• Not secure • Encryption may be applied to data by the user	• Not secure • Privacy features include PIN numbers to send and receive pages	• Not secure • Encryption may be applied to data by the user •	• Not secure • Privacy features include automatic identification and authentication	• Not secure • Privacy features include the use of passwords to limit unauthorized access
Transmission Speed	• Maximum data rate is 14.4 kbps • Actual user speed is typically 9.6 kbps depending on network conditions and modem used	• Maximum data rate is 9.6 kbps • Actual user speed is 4.8 kbps	• Maximum data rate for one-way paging is 6.4 kbps • Actual user speed is 0.5-6.4 kbps	• Maximum data rate is 4.8 kbps • Actual user speed is 2.4 kbps • Future system data rates projected to be from 9.6 kbps to 2 Mbps	• Maximum data rate of 19.2 kbps • Actual user speeds typically from 10-12 kbps, depending on vendor and level of traffic on the network	• Maximum data rate for mobile networks is 19.2 kbps • Actual user speeds range from 1.2 –9.6 kbps • Fixed wireless data network offer 14.4-28.8
Addressing Functionality	• User must dial number on their user terminal • Increases time needed to complete call • Requires user to know receiver's phone number • Call setup takes from 15-30 seconds	• User must dial the number on their user terminal • Increases time required to complete a call • Requires user to know receiver's phone number • Call setup takes from 15-30 seconds	• Pages may be sent from a phone; via an operator who enters a dictated message into the paging system; through a stand alone pager or via personal computer	• User must dial the number on their user terminal • Increases time required to complete a call • Requires user to know receiver's phone number • Call set up may take up to 40 seconds	• Can transmit information on demand • Exchange data by selecting recipient's IP address • No dialing required	• Can transmit information on demand • Exchange data by selecting recipient's IP address • No dialing required

	Cellular	PCS	Paging	MSS	CDPD	Wireless Data
Cost	• Subscriber unit costs range from **$0-$300**, depending on whether phones are analog or digital or hybrid • Users billed by the time connected, not by the amount of information exchanged • Many service plans • Price per minute ranges from $.05 to $.36 • Users pay for incoming and outgoing data transfer • Service providers charge $.10 to complete landline telephone calls • Future pricing trends will most likely transition to flat rate for unlimited connection	• Users billed by the time connected, not by the information exchanged • Subscriber unit costs range from **$75-$300**. • Many service plans • Price per minute ranges from $.05 to $.30 • Users pay for incoming and outgoing data transfers • Service providers charge $.10 to complete landline telephone calls	• Users billed on a flat monthly rate covering a certain number of messages. • Some providers offer unlimited pages for a flat rate • Monthly service prices range from $7 to $80.00 depending on the number of messages per month • One-way pagers may be included in the cost of the service • Two-way pagers cost **$300-$400**, but may be leased	• Currently $.50 to $2 per minute • Subscriber unit costs from **$2,000 to $3,000**	• Service plans may be flat rate or usage based • Sample costs range from $.02-.10 per kilobyte for usage based pricing plans • Modems range from **$450.00-$1,000**, depending on functionality and performance	• Service plans may be flat rate or usage based. • Based on the amount of data communicated rather than the length of time a connection is sustained • Sample costs range from $.23-$.45 per kilobyte for usage based plans • Modems range from **$100 to $600** depending on functionality and performance
Type of Applications Supported	• Short message service, low and high bandwidth file transfer, PSN access	• SMS available on all PCS networks • Data service for low bandwidth data limited to networks utilizing GSM PCS	• Mainly one way • SMS, information services such as traffic alerts or stock quotes. • Few paging service providers offer voice services and two way paging	• Currently paging, dispatch, SMS • Future services include high speed data, and interactive video	• SMS, low bandwidth file transfer, PSN access	• SMS, low bandwidth file transfer, PSN access • Fixed services are well suited for Internet

Exhibit 5-2
Data Technologies and Services, Continued

6.0 SUMMARY

Wireless technologies can serve as a supplement to the current private LMR networks. These wireless services and technologies provide a range of communication solutions for the public safety community. To take advantage of the changes and maximize their utility for public safety applications, these services should continually be evaluated, as wireless technology changes at a rapid pace. In addition, each public safety organization has different requirements based on the condition of their current communication system, their traffic types, mission, and various communication preferences. Additional documents regarding each of these voice and data services can be obtained by contacting the PSWN Program Management Office at 800-565-PSWN or at the PSWN home page at www.pswn.gov

APPENDIX A
LIST OF ACRONYMS

AVL	Automatic Vehicle Location
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
ESMR	Enhanced Specialized Mobile Radio
FCC	Federal Communication Commission
GEO	Geosynchronous Orbit
GSM	Global System for Mobile Communications
GPS	Global Positioning System
ID	Identification
Kb	Kilobyte
Kbps	Kilobits per second
LEO	Low Earth Orbit
LMR	Land Mobile Radio
MDT	Mobile Data Terminal
MEO	Medium Earth Orbit
MSS	Mobile Satellite Service
NCIC	National Criminal Information Center
OTAM	Over-the-air management
OTAR	Over-the-air rekeying
PCS	Personal Communications Service
PSTN	Public Switched Telephone Network
PSWN	Public Safety Wireless Network
PTT	Push-to-talk
SMR	Specialized Mobile Radio
SMS	Short message service
TDMA	Time Division Multiple Access
VLS	Vehicle Location System

APPENDIX B
REFERENCES

1. Washington DC TRC Analysis Report. March 1998, p. A-16

2. San Diego TRC Analysis Report. February 1998, p. A-16

3. Pittsburgh LMR Case Study Data Report. February 1998, p. 29

4. Washington DC TRC Analysis Report. March 1998, p. A-70

5. San Diego TRC Analysis Report. February 1998, p. A-70