Wireless Data Communications

A Technology Primer

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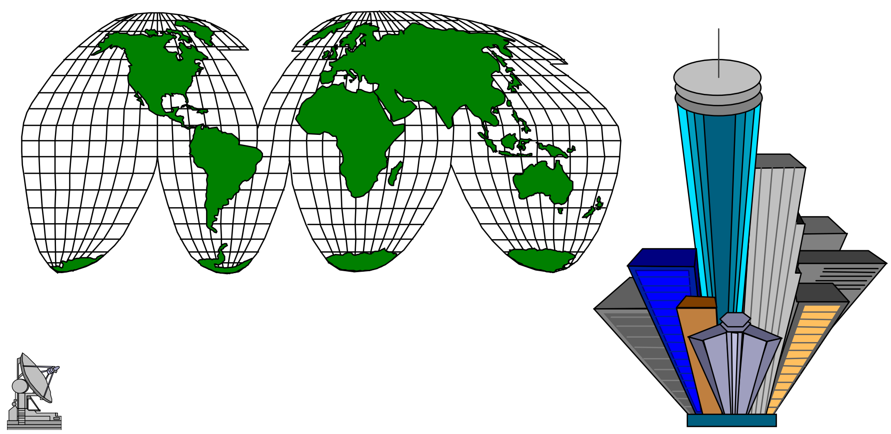


Welcome to the Age of Wireless Computing

With advances in telecommunications technology over the past 10 years, computer users now enjoy virtually unlimited access to any kind of information they need. Data of every possible type is truly at our fingertips. Until recently, however, such access to information has been available only while we were within the walls which house our hard-wired infrastructure.

Now, a new communications revolution is underway. Over the next decade we will see an explosion in what the industry calls the **Wireless Evolution**.

The New Mobile Workforce

Businesses of all kinds are discovering a powerful new way to compete: the mobile workforce. The "virtual office" is fast becoming a commonplace reality. Corporate professionals are beginning to exercise the same control over information on the road as they enjoy in their offices. Wireless technology is being used to link portable computer equipment to corporate databases and other sources of necessary information.

The Shift to Wireless Technology

A definite shift is taking place -- from systems based on hard-wired, location-dependent infrastructures serving stationary clients to systems using wireless, location-independent technology to serve clients who are constantly on the move.

Industry analysis confirms this shift from the office-based worker to the mobile professional. During 1993 alone, sales of portable computing equipment such as laptops exceeded unit purchases of desktop equipment by 20% or more.

The Wireless Evolution will enable mobile professionals to send and receive data anytime, anywhere, so they can do business more efficiently and effectively than ever before. Crucial to the success of this evolution will be technology that provides mobile professionals with the same ease of use, reliability, and robust service they have come to expect in the office.

Directions Wireless Technology Is Taking

The wireless marketplace can be divided into two general methods of wireless service. The first is lower-speed, wide-area access which is known as Mobile Data or Wireless Wide-Area Networks (WWANs). The second method is higher-speed, local-area access which is referred to as Wireless Local Area Networks (WLANs).

Wireless Wide-Area Communications (WWANs) -- Mobile Data

Much has been written about the various forms of two-way, wireless, wide-area services. A potential user of wireless technology, seeking to understand whether a particular offering best suits his application, can easily be frustrated when attempting to sort out the different offerings.

Wireless data services can provide benefits to three types of mobile user applications:

1. Transaction Processing - Includes applications such as taxi dispatch and credit card verification.
2. Information Distribution - Includes providing advisory services for traffic, weather, public safety and multicast sales updates.
3. Interactive Access - Provides connectivity from remote clients to central host computers such as connecting field service personnel to headquarters.

WWAN services require the use of a large infrastructure which can provide wireless radio coverage throughout the service area. The mobile professional does not want to have to worry about being within a defined area of service, but rather wishes to be productive regardless of geographic location.

There are two ways one can approach this problem. The first, and more complex from an software perspective, is to provide the capability of disconnected operations. Using this approach, the mobile professional works on files which are later synchronized with the central host database. The mobile professional may also download optionally filtered files such as mail, and generate responses for transmission when wireless coverage has been established. Digital Equipment’s Mobile User Services provide this type of solution.

The second solution to this problem is to install wireless base stations which can provide continuous radio coverage as well as seamless connectivity throughout a service area. This requires significant infrastructure costs as well as innovative network software to handle billing, roaming, and authentication issues. For mobile professionals in the United States this would imply seamless coverage throughout the contiguous 48 states. However, in each of the public service areas there are at least two competitors who provide a wireless infrastructure which can be used for mobile data. And in many areas there are packet radio systems, such as ARDIS™ and MOBITEX®, which are also available for mobile data. This suggests another problem for the mobile professional: inter-system protocol compatibility. Digital's RoamAbout™ Transporter product provides an application-independent solution for the inter-system communication problem.

WWAN Technology

In this section we will explore the major WWAN infrastructures available for data communication for the mobile professional: analog cellular systems and packet radio systems. We will also discuss some technologies just on the horizon.

Analog Cellular Systems

Potential data subscribers view existing analog cellular telephone systems as having an advantage over specialized packet radio systems -- ARDIS, MOBITEX, or other private Special Mobile Radio (SMR) services -- in providing future WWAN data service. The advantages of the existing cellular system are that it provides the widest geographic coverage, reliability of existing service, and fundamental network intelligence. These advantages are perceived by many industry analysts as reducing the cost of deployment in utilizing this service as a reliable, integrated voice/data system in the future.

At the same time, analog cellular systems have certain shortcomings. These include limited system capacity and inefficient deployment of fast, reliable, and available data services. Furthermore, these systems were designed primarily to provide voice service only. Such shortcomings will continue to exist, regardless of the variations or extensions that are implemented in this system technology.

For example, the primary advances in cellular infrastructure technology -- N-AMPS and CDPD -- are designed to increase overall system capacity. Data applications capability for the mobile professional remains inherently limited.

Providing an effective, integrated voice and data wireless wide-area network depends upon the development and deployment of digital radio techniques. As will be seen later, the Group Special Mobile (GSM) service, a digital cellular system which has been widely accepted in Europe and Asia, will provide significant benefits to the mobile data professional. In the United States, however, we are faced with multiple variant expansions of the existing analog technology, and at least two adopted digital systems which are referred to as Digital-TDMA (NTIA IS-54) and Digital-CDMA (NTIA IS-95).

Analog Cellular Radiotelephone

Existing analog cellular standards in use worldwide include the following:

1. NMT - The Nordic Mobile Telephone service. This system has two variants based on the frequency of allocation. NMT450 operates on 450 MHz, while NMT900 operates on 900 MHz. Due to its standardization throughout the Nordic countries, this system is the only analog system which allows roaming through multiple European countries.

2. TACS - Total Access Communications Systems. This is a cellular system based in the U.K. The TACS system has several variants in use: JTACS in Japan (which is similar to theU.S. AMP system), E-TACS, or Expanded TACS of the U.K. system, and J-TACS, a Japanese cellular specification similar to N-AMPS in the U.S.

3. N-AMPS - Narrowband Advanced Mobile System. This provides three times the current capacity of the AMPS system in the U.S. by using 10KHz channel bandwidths instead of the standard 30 KHz channel bandwidths used in the AMPS system.

4. Intersitial cellular, proprietary to Cellular Data Inc. This is a technique for transmitting data on unused cellular frequency allocations, known as guard bands or buffer zones, that separate the regular voice channels. The result is a 2400 bit/s, X.25 data network which is optimized for short duration data transmissions.

Some of the specifics of these analog cellular systems are shown in Table 1.

Table 1 - Analog Cellular Systems

	AMPS	N-AMPS	NMT-450	NMT-900	TACS	JTACS
Frequency Band (MHz)	824-894	824-894	453-467.5	890-960	890-950	870-940
Allocated BW (MHz)	50	50	9	50	30	30
Base to Mobile Mobile to Base	869-894 824-849	869-894 824-849	463-467.5 453-457.5	935-960 890-915	935-950 890-905	870-885 925-940
Access Scheme	FDMA	FDMA	FDMA	FDMA	FDMA	FDMA
Duplex Method	FDD	FDD	FDD	FDD	FDD	FDD
Channel BW (KHz)	30	10	25	12.5	25	30
Total Channels	832	2456	180	2000	600	600
Voice Modulation	PM	PM	PM	PM	PM	PM
Trans. Rate (Kbps)	10	10	1.2	1.2	8	?

notes: BW means bandwidth

All these systems were designed primarily to support voice communications via analog technology. As such, they all share fundamental characteristics with the U.S. Advanced Mobile Phone Services (AMPS) system with regard to implementing mobile data. For this reason the U.S. AMPS system will be used as a model for exploring the use of cellular telephone infrastructures for mobile data.

Cellular Infrastructures for Mobile Data

The AMPS system employs analog technology and was designed for point-to-point, circuit-switched, radio/telephone voice communications for mobile professionals. The emergence and deployment of one standard system in the U.S. has allowed easier development of both intra-system and inter-system roaming around the country for voice-based mobile professionals. However, this service convenience may be short-lived due to the recent deployments of incompatible cellular telephone variants such as N-AMPS, CDPD, and Intersitial Cellular.

European analog cellular system subscribers have not enjoyed a similar robust roaming service advantage. The European system has been composed of several standards as shown in Table #1, usually divided by country borders. As we will see later, the European Group Special Mobile (GSM) standard, a digital cellular technology, provides a major step towards a total solution of this cellular system shortcoming for both the voice and data mobile professional.

In the United States the Federal Communications Commission (FCC) has allocated 50 MHz in the 800 MHz band which is divided among two different providers for each service area of the AMPS system. The 25 MHz allocated to each provider is divided into 832, 30-KHz wide channels.

Cellular communications techniques are based on dividing the coverage areas of a central radio base station control center into terrestrial zones known as cells. The size of a cell is determined by several factors, including:

- Local propagation environment
- Mobile traffic distribution and management
- Geographic topology

In Figure 1 cells are represented as idealized areas in the form of hexagons with no overlaps or gaps. Each cell uses at least two frequencies or channels to communicate with mobile stations. Cell channel allocations are arranged in regular patterns to maximize frequency reuse of the radio spectrum and minimize interference between adjacent cells.

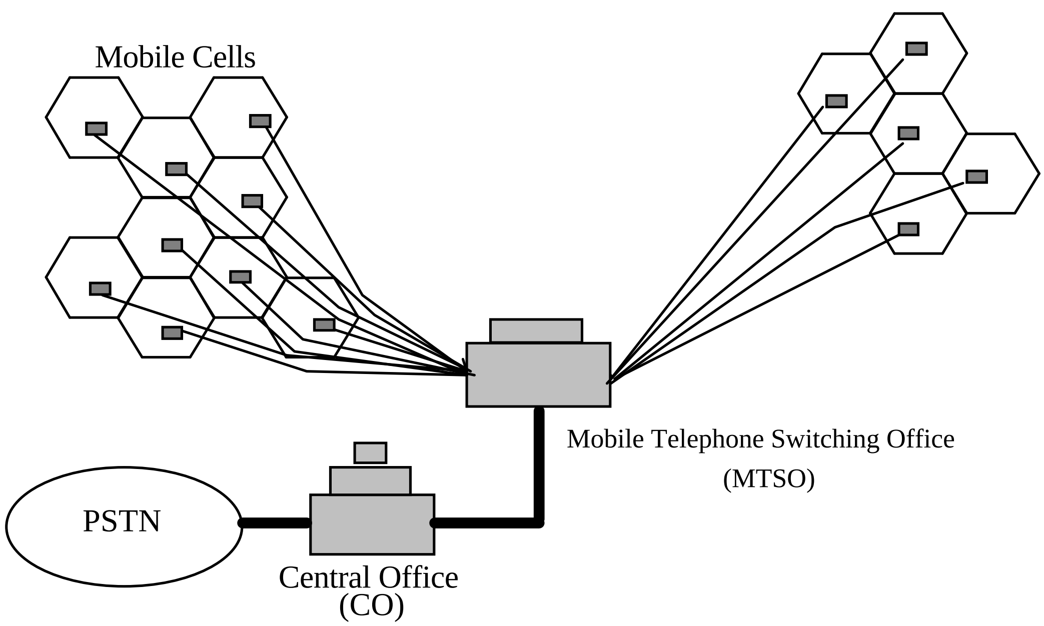


Figure 1 - Cellular Infrastructure Overview

Cell sizes can vary, providing coverage from less than a square mile to over 50 square miles in sparsely populated areas. To increase capacity, cells can be further divided into sectors (three sectors are common) using directional antennas.

The base station control radio is connected to a mobile telephone switching office (MTSO) using wired or point-to-point wireless technology such as microwave radio. The MTSO is responsible for supervision, signaling, switching, and allocating Radio Frequency (RF) channels to the cells.

The MTSO maintains a list and status of connected customers, including the signal-to- noise ratio of the established connection. As a subscriber signal becomes weak, the system noise becomes a more appreciable percentage of the total signal received at the central base station. When the connection approaches a minimum acceptance level, the customer is "handed-off" to an adjoining cell. The subscriber unit, referred to as a mobile end station, may also be handed off to another cell for traffic handling management.

Cellular Data Transmission

The analog cellular network can be used for data transmission; however, the radio link performance for data is considered marginal. This is due to the limitations imposed by this technology. Radio channel dynamics such as dropouts, signal fades, and multipaths, which can be tolerated during a voice connection, can be disastrous to a mobile data subscriber. For example, "clicks" which occur during cell hand-off -- caused by the analog system using a technique known as "block and burst mode" -- can cause a complete disconnect or garbled data. These problems will become much more manageable when digital cellular transmission in the United States and GSM in Europe (both digital radio transmission standards) become widely available. Digital Signal Processing (DSP) techniques, which are used as part of the process of transceiving information in digital form, will eliminate much of the noise-based interference in the data channel and will enhance signal recovery.

Subscriber data rates of 2400 baud or less can be sustained using standard modems -- similar to those used for the commonplace wireline connection -- with some adaptation for connection to the cellular network. Using special, high-level, error-correcting modems and data transmission techniques targeted for use in the cellular radio infrastructure, data throughputs have approached >20K bits from a stationary user.

Cellular systems charge mobile professionals by "air" time used, rather than by the amount of data (packets) transmitted, as is the case with packet radio systems. For relatively low-duty-cycle data communications -- which do not require a dedicated full-time connection -- subscribers pay for real-time, dedicated, two-way, point-to-point connections. Connection set-up times can be long, especially when compared to the actual time required for the mobile professional to send only a few kilobytes of data.

Short cellular data messages can be very expensive to send, as compared to those sent through packet radio systems. The bottom line is that current analog cellular infrastructure systems are generally not an efficient means of sending data due to limited capacities available, limitations of data recovery, low security, and the high cost of use for many applications.

Cellular Digital Packet Data (CDPD)

Developed by a consortium of eight U.S. companies, CDPD is a technique which allows data transmission to be overlaid onto the existing AMPS analog cellular channels. CDPD provides two significant enhancements to the existing analog cellular radio/telephone system: increased total system capacity and specifications for implementing data.

CDPD uses a channel-hopping technique to transmit data in short bursts during idle times in the existing 30 KHz-wide analog cellular channels (AMPS channels). Given sufficient capacity, no degradation in system capacity for voice calls should occur, since voice calls on the system still maintain priority. Voice and data are digitized and sent through the infrastructure. Digitalization also allows for encryption, which increases data and voice security.

The CDPD Airlink Interface specification defines all procedures and protocols necessary to allow effective use of existing analog cellular channels for data communications.

The CDPD architecture provides for mobility management and inter-networking between separate CDPD network providers. This will result in seamless access for the mobile professional when moving between cells and between different providers. Mobile subscribers will be handed off gracefully using soft transfer techniques, reducing the chance of corrupted data or lost connection as is common in the AMPS system.

The CDPD standard specifies support for CLNP, the Connectionless Network Protocol defined in ISO-8473, and the Internet Protocol as defined in RFC-791. CDPD does not provide protocol translation; therefore, each station must use the same network layer protocol. Application compatibility between the wireless mobile professional and standard wired data network topologies are made easier with the decision of CDPD to adapt the Internet Protocol (IP).

According to a report from the Yankee Group, the key advantages of CDPD include the following :

- **Efficiency:** The specifications of CDPD will allow the use of hardware components found in standard cellular telephones.
- **Open protocol:** CDPD will contribute to the system's low cost and wide availability.
- **Speed:** CDPD will support 19.2Kb/s transmission rates. Overhead for coding and channel management to handle frequency hopping, however, will reduce actual throughput.
- **Capacity:** Cellular carriers control more than 800 channels nationwide as compared with ARDIS, which has an average of one-to-five channels per city.
- **Preservation of voice transmission quality:** Use of idle channels will prevent degradation of voice quality and reduction of network capacity.
- **Feature enhancements to regular cellular service:** These include encryption, message broadcast, roaming, compression, and authentication.

CDPD availability is dependent upon the aggressiveness and financial commitment of its provider companies. In the short term CDPD may become a serious competitor to packet radio systems such as ARDIS or MOBITEX in the United States. More than likely, however, CDPD will prove to be merely an interim solution until digital cellular radio is available.

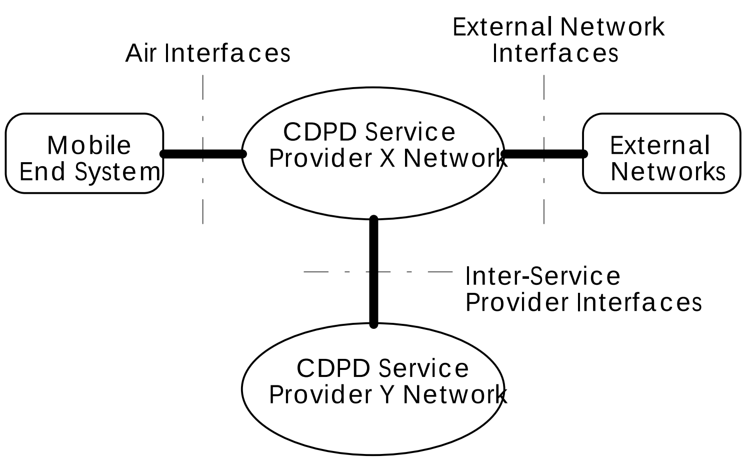


Figure 2 - CDPD Network Interfaces

Packet Radio Systems

A packet radio system is a type of specialized mobile radio system which functions as a wireless wide-area data network for the mobile professional. Two packet radio systems are gaining popularity and acceptance for reliable data transmission. These are ARDIS, provided by Motorola/IBM, and MOBITEX, provided by RAM Mobile Data/Bell South Industries in the U.S. and by Ericsson in Europe.

Like cellular radio/telephone systems, these packet radio systems use analog radio technology. Unlike cellular systems, however, these networks offer connectionless support. Subscribers do not maintain a dedicated, point-to-point connection to the destination station, but share radio channel access by time, transceiving data between source and destinations.

Subscribers using the packet radio system are billed a monthly fee, plus a usage fee based on the amount of information (packets) transmitted through the system.

From a subscriber point of view, ARDIS and MOBITEX have more similarities than disparities. Some commonalities are:

- Analog radio channel technology, with narrowband modulation
- Low data rate throughput (<2400 bit/s)
- Smaller infrastructure than public cellular systems; therefore, limited service availability
- Special radio channel protocol (applications must know how to "talk" to each system)
- Packet format data transmission
- Usage fee based on packets transmitted
- Requirement for special radios dedicated to each service

We will now take a closer look at these systems and describe some of their specifics.

ARDIS

Using 1,100 radio base stations, ARDIS operates as many as 600 two-way radio data channels in about 8,000 cities in the U.S. The system widely utilizes a raw data rate of 4800 bits/s, resulting in a theoretical subscriber data throughput of 2080 bit/s. The ARDIS system operates in 30 MHz of spectrum: between 806-821 MHz for receiving and 851-866 MHz for transmitting, with 25 KHz channel spacing. ARDIS is currently working on a system upgrade to 19,200 bit/s without overhead. Due to overhead burdens associated with the radio channel protocol and error correction, subscriber data throughputs will theoretically be something less than 8000 bit/s. In actuality, subscriber data rates will be much lower, due to packet collisions which occur at the base stations. These collisions necessitate data retries, which cause added system overhead.

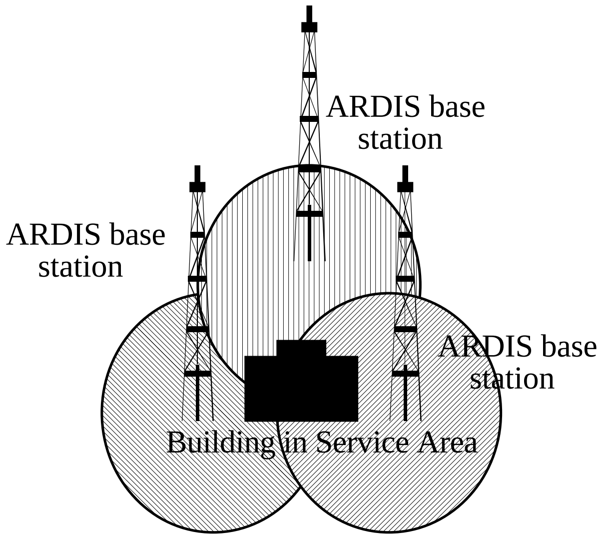


Figure 3 - ARDIS Base Stations are positioned around metropolitan areas

Customer host systems or remote data sites connect to the ARDIS system via leased lines or X.25 packet services. The ARDIS radio base stations are generally positioned in a triangular fashion, with multiple cell coverage areas, as shown in Figure 3. Positioned in this way around business centers, they provide reasonable in-building coverage.

Originally deployed in support of IBM field personnel, the ARDIS system has been in use for many years. It was not commercialized until recently. ARDIS is now being deployed in Europe, beginning in Germany.

MOBITEX

MOBITEX is available in many cities throughout the United States, Canada, and Scandinavia. It operates in 10 channels at 934 MHz, using a Time Division Multiple Access (TDMA) technique. MOBITEX base stations have been widely upgraded to support 19.2 kbit/s. However, subscriber radios largely continue to support a nominal raw data rate of 8000 bit/s. Similar to ARDIS, the customer data rate is much less than the raw data rate due to data transmission overhead. Subscriber data throughputs of 800 baud are common.

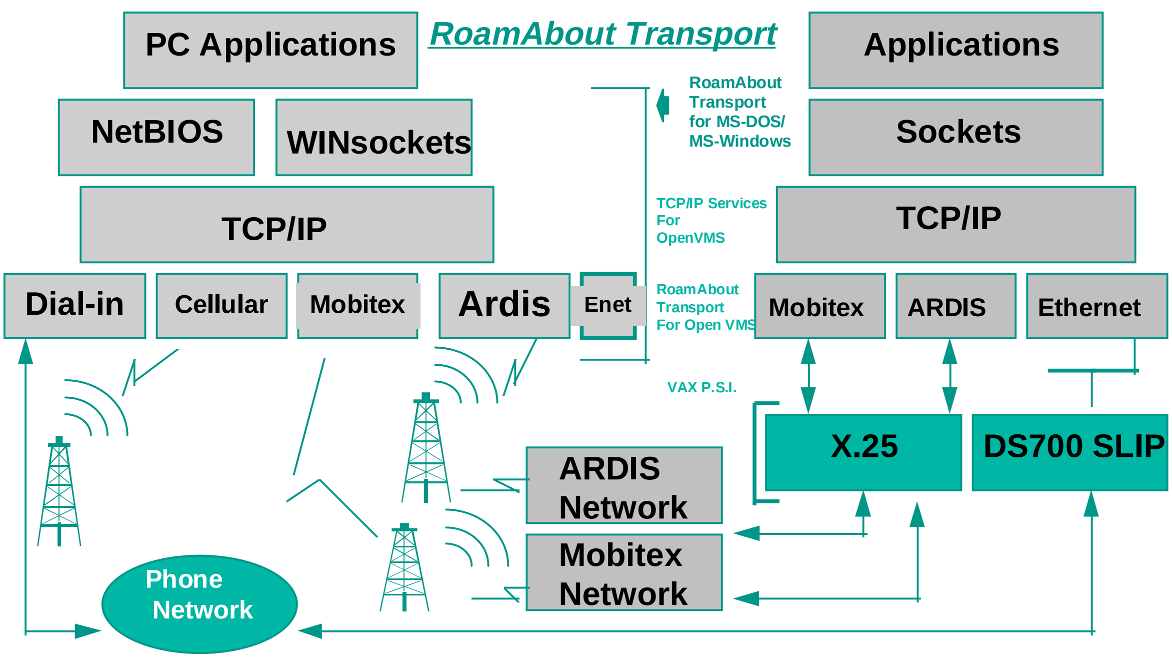
MOBITEX base station radios are generally positioned at locations with above-average terrain characteristics throughout the service area. Triangularity of the base stations around a coverage area, seen in the ARDIS system, is generally absent in the MOBITEX installations, which indicates that the in-building coverage may not be as good as with the ARDIS system.

Both the ARDIS and MOBITEX systems use portable radio transceivers, which are generally expensive and heavy. The transceivers connect to a portable data host, such as a laptop computer, to access the systems. This approach is an artifact of long deployment and low volumes and is not inherent in the technology. Several vendors are working to integrate radio technologies into smaller form factors, such as the industry standard for credit card sized devices, PCMCIA.

As mentioned earlier, the ARDIS and MOBITEX systems each have their own specific radio channel protocol. This requires that subscriber client and host stations -- and more specifically, the applications -- know how to talk to client radios. Two solutions to this problem are currently available.

The first solution uses programs written by vendors who have developed specific applications to support mobile professionals on each of these networks. This limits the flexibility of the mobile professional by constraining the use of these systems to that which is specific, both to the network and to the application in use by the mobile professional.

Digital Equipment's RoamAbout Transporter product provides a more flexible, cost-effective solution to this network compatibility issue. Transporter facilitates the selection of the best carrier for the mobile professional, and quickly enables the change of a carrier as needed. This capability provides both investment protection and flexibility. Transporter also supports TCP/IP-based applications written to industry-standard NetBIOS™ and WINsockets APIs. This saves development resources, since applications do not have to be rewritten for mobile use or modified for each service carrier.



Digital Cellular Technology = The Future

During the next decade the current AMPS cellular infrastructure, an analog technology, will be replaced by an all-digital system. Digital cellular technology provides many advantages for both the voice- and data-based mobile professional.

Some of these advantages are:

- Increased security against casual eavesdropping
- Increased system capacity
- Better recovery of the radio signal under all conditions, including high noise environments
- Superior cell hand-off and roaming of mobile end-stations
- Significant increase in reliable data rates for mobile data professionals

Table 2 - Technical Summary of Digital Cellular Techniques for WWANs

|-----Europe -----|---------------------United States ---------------------|

	GSM	TDMA	E-TDMA	CDMA
Frequency Band	890-960 Mhz	824-894 Mhz	824-894 Mhz	824-894 Mhz
Base to Mobile Mobile to Base	935-960 890-915	869-894 824-849	869-894 824-849	869-894 824-849
Allocated BW	50	50	50	50
Access Scheme	TDMA	TDMA	TDMA	CDMA
Duplex Method	FDD	FDD	FDD	TDD
Channel BW	200 KHz	30 KHz	30 KHz	1250 KHz
# of voice (full/half rate) Channel/Freq.Ch.	8/16	3/6	11/15	? / ?
Total Traffic Ch.	1000 / 2000	2496 / 4992	9152 / 12480	? / ?
Channel Bit Rate (kbps)	270.833	48.6	48.6	vendor dependent
Voice Coding (kbps)	22.8	8/4.5	4.5	8

Two digital cellular standards have been adopted in the U.S.: IS54-TDMA and IS95-CDMA. The IS54-TDMA standard employs Time Division Multiple Access techniques, which provide for packetized voice and data to be transmitted on a time-shared channel. IS95-CDMA uses Code Division Multiple Access techniques. These two digital technologies are not compatible, and will not interoperate with each other.

One difference between the two technologies is that in using CDMA all subscribers share an entire channel simultaneously. Each subscriber's data is transmitted using orthogonal data patterns, providing unique discrimination between each subscriber's data in the radio channel. Subscriber radios "see" other data patterns in the shared radio channel as simply another form of ambient noise, and therefore cannot process that data.

TDMA, on the other hand, allocates time-slots for each subscriber to use the channel. The radio channel carrier is subdivided into time-slots, which are then accessed sequentially by a number of different subscribers.

Because two incompatible U.S. digital standards have been developed, the U.S. consumer may soon face some of the frustrations that existed before the adoption of the GSM singular standard throughout Europe. These frustrations include incompatible systems across service areas, as well as the transition phase noted above in which customers will be required to use dual-mode phones. In Europe a decision has been made that no dual-mode phones will be offered.

The move to all-digital in the United States will be gradual. This means customers will be using an analog/digital hybrid infrastructure, known as D-AMPS. Subscriber capacities of three-to-six times are envisioned, with more effectiveness for the data customer than with the AMPS system.

Wireless Local Area Networks

Office professionals should not be tied to their desks in order to have robust computing power at their fingertips. Wireless local area networks (WLANs) will probably never replace the classical wired LAN; however, a WLAN can be a very effective means of extending the flexibility of a wired LAN. A WLAN can offer reasonable performance and reliability while providing mobility in the work environment.

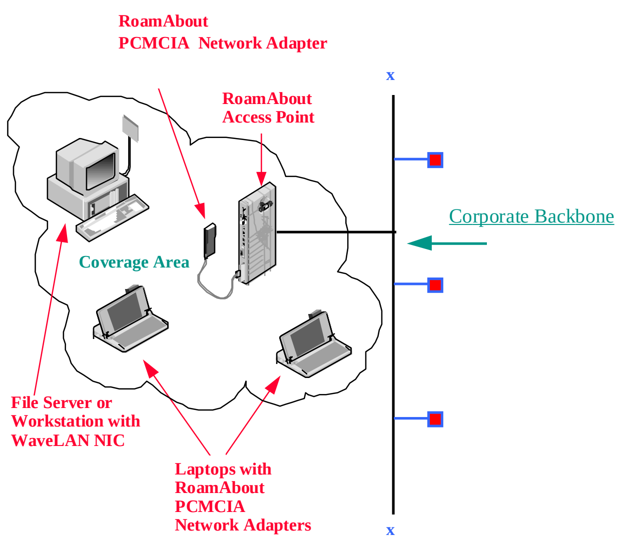


Figure 5 - Example of a Wireless LAN network

Additionally, WLANs can provide benefits for temporary work environments or hard-to-wire buildings. A WLAN can be operational in a matter of minutes at lower costs. Using

WLAN technology, reliable, collaborative workgroups can be set up and made operational with little effort or planning time.

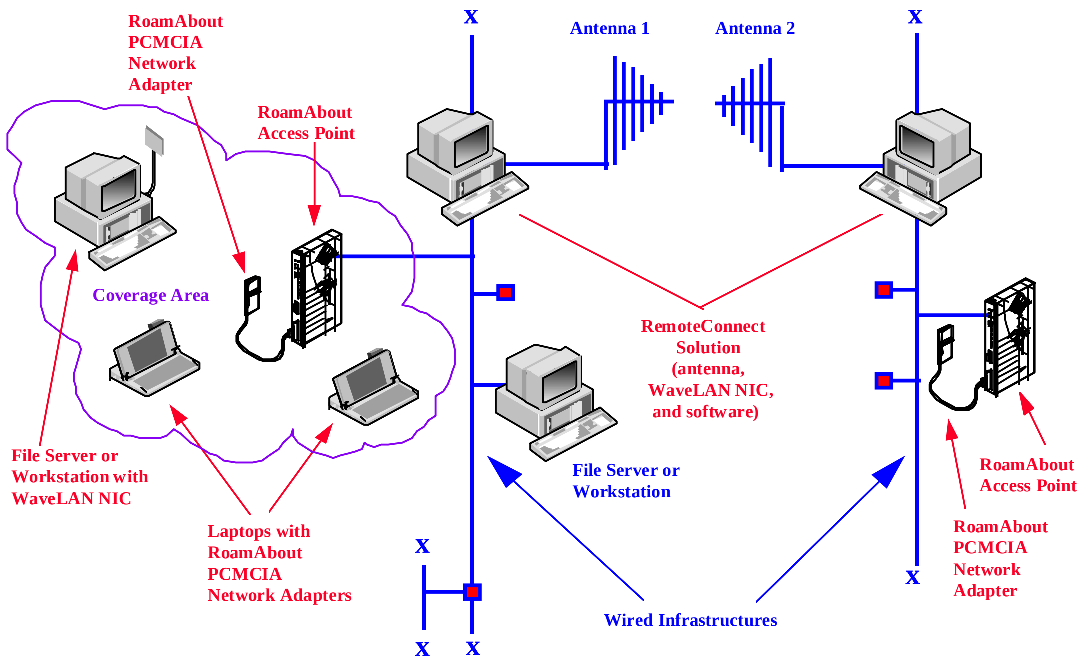


Figure 6 - Wireless LAN configuration for connecting two Buildings

Many people are using WLANs for building-to-building or campus-bridge configurations. The building-to-building configuration has been used both as the primary link between two facilities, and as a back-up to a primary wired connection. In the figure above, a wired LAN infrastructure in one building is connected to a second building by directional antennas. The second building uses both wired and wireless LAN systems, demonstrating the true versatility of WLAN technology.

Technology Types

Two types of technologies are available for Wireless Local Area Networks: Radio Frequency (RF) and infrared. RF offers high speed, along with reasonably secure communication data links. These links can penetrate, to some degree, walls, floors and ceilings.

Infrared technologies can provide high-speed wireless services, although the operational distance is limited to a single room. This can be a security advantage over radio frequency technology.

Security

Most RF WLANs employ a radio technology know as “spread spectrum”. Spread spectrum is a method of communications technology which was developed by the military to guard against casual eavesdropping and jamming by non-allied forces. RF WLANs that employ spread spectrum modulation techniques have some inherent security, but can still be penetrated by a intruder using a compatible device. Unlike infrared intrusion, the RF intruder need not be physically inside the service area of the RF WLAN. To guard against illegal access to the network, high-quality RF WLAN manufacturers provide additional scrambling of data using techniques like DES.

Other WLAN technologies are available which use narrowband modulation techniques, or low-power, wideband FM technology. These methods tend to be low-cost, and provide low data speeds. They are deficient because other devices -- walkie-talkies, cellular phones, and even nearby computers, cabling and various industrial machines -- can easily interfere with them.. These systems also generally lack any sophisticated security capabilities.

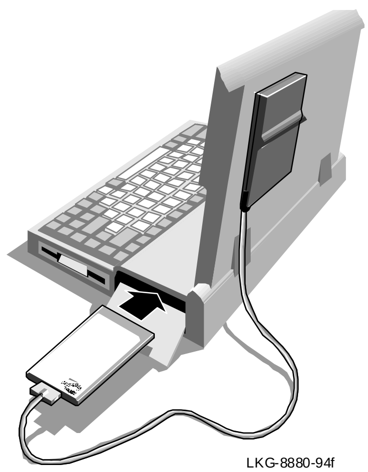


Figure 7- Digital’s RoamAbout Wireless Network Adapter Solution. Digital Equipment Corporation’s RoamAbout wireless network adapter is shown in the figure above. The RoamAbout network adapter is a type 2, PCMCIA-compatible card set which operates at 900 Mhz. It uses direct sequence spread spectrum technology, and provides a raw data rate of 2 Mb/s.

Licensing and Safety

Manufacturers of RF WLANs must meet stringent emission levels, specified in the U.S. by the FCC, Part 15.247. European technical specifications are set forth in ETSI 300-328. Specific country regulations must be met where the product is to be marketed. Some countries, such as the U.K., require users to mail away for an operating permit in order to deploy a WLAN. Except for a system marketed by Motorola, most RF WLANs today do not require a user license.

RF WLAN devices emit very low levels electromagnetic energy, and generally are exempt from local and federal health guidelines. However, RF WLAN manufacturers should ensure that the devices meet the specifications set forth in ANSI C95.1-1992. It should be noted that there is very little comparison between the levels of energy and methods of use of RF WLANs and portable cellular telephones.

Infrared systems must meet certification specifications for non-intentional emissions, as must all computing devices. They also do not require operating licenses.

Radio Wave Technology

The Wireless Evolution will see the development of radio technology aimed at high-speed data, voice, and video communications. Robust connectivity, high system availability, reliability, and system security are the requirements for a WLAN. Customers are demanding response times which rival those they are accustomed to receiving from wire technologies. However, higher speeds of raw data demand wider bandwidths in the radio spectrum. In theory, the radio spectrum is a limitless resource. However, in reality, the availability and use of the spectrum is not limitless. This is due to the following factors:

- The availability of technology at reasonable costs in radio devices that operate beyond 5 GHz. Advancements such as Gallium Arsnide technology will make this a less severe obstacle over time.
- The difficulty of propagating through walls, around corners, over tall radio-path obstructions, and over office partitions. Improvements in digital signal processing will continue to improve these limitations.
- Clear spectrum allocations. The regulatory environments continue to evolve rapidly worldwide.

The fastest WLANs marketed today provide mobility, offer raw data rates of 2mb/s, and can support a user moving at speeds of up to 4 mph. People exploring the possibility of using this technology are sometimes concerned about this data rate, due to their belief that they have been using 10mb/s for their wired LAN connections. (In reality, customers in wired LAN topologies often have access to much less bandwidth than 10mb/s.) WLAN topologies can be designed to provide Ethernet-like response time, even though the shared bandwidth is less. One way to do this is to provide access points through a coverage area, operating with a different radio channel and NET-ID.

Faster data rates will become increasingly necessary as applications for real-time voice and video increase and the number of deployed WLAN data clients increases. For this reason it is paramount that clear spectrum be made available by the appropriate legislative bodies worldwide.

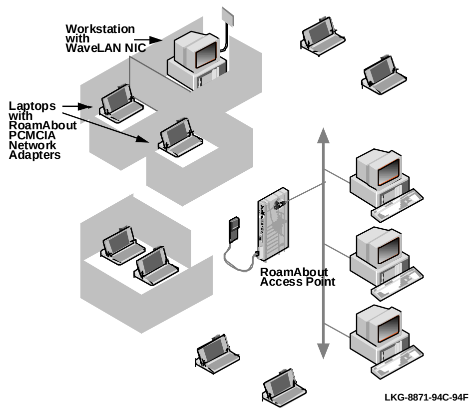


Figure 8 - Digital's RoamAbout Access Point provides wireless connectivity to portable laptops as well as desktop systems.

Radio Technology Types

Two types of radio technologies are approved for WLAN applications in the 915 Mhz, 2.4 Ghz, and 5.7 Mhz ISM bands in the U.S., and in the 2.4 Ghz band in Europe and Japan. They are both digital techniques and are known as:

- Direct Sequence Spread Spectrum (DSSS)
- Frequency Hopped Spread Spectrum (FHSS)

Direct Sequence Spread Spectrum Radio Technology

Direct Sequence Spread Spectrum technology combines the data with a higher rate bit sequence, known as a chip sequence. This higher rate bit sequence, divided by the user data rate, determines a figure of merit for DSSS systems known as processing gain, or spreading ratio. (The minimum specified processing gain in the United States and Japan is ten.) Since the spreading process is applied to each data bit, this method is known as direct sequence. The combination of required processing gain and allocated bandwidth are two major factors which limit the possible raw data rates which can be used in an allocated frequency band.

Because the total transmitted power is spread across a wide frequency band as a result of this spreading process, power spectral density is much lower than with narrowband transmitters such as cellular telephones. One of the effects of a lower spectral density isthat since other radios in near proximity will be subjected to less interference, some level of co-existence results. Futhermore, "normal" narrowband radios, which could be used to eavesdrop, cannot detect signals transmitted using this process. The reverse is also true. Narrowband radios will not interfere with a WLAN unless the WLAN receiver becomes overloaded.

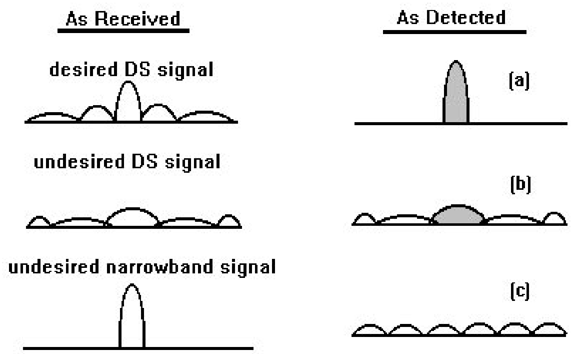


Figure 9 - Some examples of detected signals using spread spectrum radio techniques.

The receiver uses the same chip sequence, and is synchronized to the transmitter in order to despread the desired signal. As shown in the figure above, other DSSS signals with different chip sequences, and other narrowband signals, become suppressed relative to the desired signal during the detection process by the digital signal processing circuitry.

Frequency Hopped Spread Spectrum

Instead of chopping each data bit into small pieces of the frequency domain, frequency hopped technology spreads transmitted energy in the time domain. One or more of the raw data bits are transmitted on a signal narrowband frequency. The transmitter then "jumps" to another frequency, where another few bits are transmitted. This is similar to using the frequency scan feature of an automobile radio, where the radio automatically jumps from one frequency to another and pauses only for a short time when a signal is detected. FHSS systems hop in a random, but known, sequence, and pause for a very short time to detect and process data.

The group of frequencies among which the transmitter jumps are known as hop sequences. A hop sequence is also referred to as a channel. The receiver must have knowledge of the hop sequence, and, as in DSSS, must be able to synchronize. A narrowband interferer such as a police radio transmitter may cause data transmission on a hop frequency to be corrupted. The data will then be re-sent on a different channel, or the corrupted frequency will be omitted from the hopping sequence.

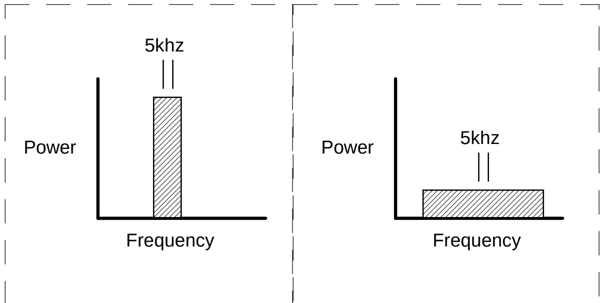


Figure 10a. Figure 10b.

The figure above shows a relative comparison between the transmitted power of a narrowband system, such as a walkie-talkie, and a WLAN.

FHSS and DSSS Compared

The performance of DSSS systems is generally acknowledged to be better in terms of multipath interference. In-building WLANs must overcome deep channel fades that can occur between the source and destinations on the wireless data path. For example, a transmitted signal can have multiple paths between the source and destination. This results in the same signal arriving at the destination with different signal levels, and with slight shifts in time. Sometimes these signals add together; sometime they subtract.

FHSS systems tend to be less costly to implement, and are more easily designed to run on lower power consumption. From a performance viewpoint, FHSS is generally considered to be less tolerant of multipath and other interference sources. If data is corrupted on one frequency hop, the system must re-send the data on another frequency. In DSSS systems, interference within a small portion of the channel (resulting in only partial data corruption) can often be recovered in the DSP circuitry.

The price paid for the sophistication of DSSS technology comes in the form of increased power consumption. DSSS systems tend to consume two-to-three times the power of an equivalent FHSS system. DSSS systems, while generally able to provide good resistance to interference such as multipath and lower level interference sources, tend to be weaker than FHSS systems when the interferer has significant power bandwidth. This condition can occur when an interferer is in near proximity to the WLAN. Should the interference occupy a significant portion of the band on which a WLAN is operating and be very strong (e.g., nearby), neither FHSS nor DSSS systems will be able to operate.

Standards Activities

Most devices for high-speed, local-area, wireless data communication on the market today, and those in development for the foreseeable future, are designed to operate in the Industrial, Scientific and Medical (ISM) Bands. Devices designed to operate in these bands in North America require no user licenses from regulatory officials. Manufacturers of these devices are granted type certification from the regulatory officials by supplying test data to the appropriate regulatory agency.

In the United States the technical regulations for wireless LAN technology which uses the ISM bands as noted earlier is specified under Part 15, Section !5.247. In Europe the technical specifications are set forth in ETS-300-328. The ETSI standard seems to be favored in many countries in the Pacific Rim.

United States

In the United States the IEEE 802.11 committee is hard at work generating a standard which will provide interoperable capability between WLANs sold by different vendors. During the last six months the group has adopted a MAC foundation, and PHY modulations specification for both DSSS and FHSS systems. The DSSS system provides for 2 Mb/s capability, while the FHSS PHY is standardized for 1Mb/s operation and 2 Mb/s as an option. Some formidable challenges lie ahead in this standards group, such as providing for a standardized MAC/PHY interface. The document is due for balloting in the November 1994 timeframe.

In the fall of 1993, the FCC, acting on a directive from Congress, allocated 60 Mhz of spectrum in the 2 GHz area for the use and deployment of what is known as the Personal Communications Services (PCS). These systems tend to be targeted as new versions of the cordless telephone. They use digital technology, and are planned to provide data capability. There are currently several licensed incumbents of this band, who must be moved before this clean spectrum can be used for PCS. Potential manufacturers through a CBEMA task force known as UTAM are coordinating the fees and administration of the spectrum clearing. It may be more than two years before this clean spectrum becomes available for use by PCS.

Europe

As mentioned earlier, Europe already has a technical standard in place for WLANs operating in the 2.4 Ghz band. The most important work being done in Europe, which in some respects is a parallel to the U.S. effort, is being done in Hiperlan. This group has just released their architectural specification. While the U.S. standard is focused on 1-2Mb/s data rates, the Hiperlan work is targeting speeds in excess of 10 Mb/s.

Summary

Mobile and wireless technology has certainly become a reality. Wireless LAN technology is solving real customer needs for extending wired LANs; enabling untethered computing for office, warehouse, and production environments; and providing inexpensive, reliable solutions for hard-to-wire buildings, and inter-building data links.

Wide-area wireless systems such as those using the existing cellular infrastructure can achieve data rates to 9600 bit/s. Bursty in nature, they provide a mobile professional with perhaps an average of 1200 bit/s performance. Cellular systems technology is almost impossible to use when in motion and can be very expensive due to point-to-point connection configurations which monopolize air time. Packet radio systems and other SMR-type systems offer an alternative to cellular for the mobile professional; however, the smaller infrastructure may leave a person without coverage. While the data throughputs tend to be below 1200 bit/s at this time, professionals are charged on a per-packet basis.

System architects must view the wireless technologies of radio, air data protocols, and networking as integrated entities. All of these technologies must merge to create an effective, integrated wireless communication system. Many of the challenges are best overcome by cognizant design within the physical media, data link, and transport layers of the IEEE Open Standards Interface (OSI) model. This will enable the higher level network protocol and application layers to be used with little or no modification in the new wireless environment.

Advances in technology and evolving customer needs will help drive these technologies to provide higher speeds, and lower cost of deployment and utilization in the not too distant future.

References

1. Wireless Nets Not Yet Unplug And Play - Datamation - September 1, 1993.
2. Wireless and Mobile Data Networks: From In-Building to Wide-Area Solutions - The Yankee Group - 1993.
3. Digital Cellular Radio - George Calhoun - Artech House - 1988.
4. Wireless Access and the Local Telephone Network - George Calhoun - Artech House - 1992.
5. Mobile Communication Technologies, Applications and Regulations - Ira Brodsky - Datacomm Research Company -1993.
6 - Cellular Digital Packet Data System Specification - Release 1.0, July 19,1993.

Biography

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