Previous screen

53-10-20 Cellular Digital Packet Data: An Emerging Mobile Network Service

Nathan J. Muller

Payoff

In the wireless data market, major telephone companies are implementing cellular digital packet data (CDPD) service to meet the needs of a mobile work force. CDPD is an appealing method of transporting data over cellular voice networks because it is flexible, fast, available internationally, compatible with a vast installed base of computers, and has security features not found in other cellular systems.

Introduction

Cellular digital packet data (CDPD) is a data-over-cellular standard for providing LAN-like service over cellular voice networks.Cellular Digital Packet Data employs digital modulation and signal processing techniques, but it is still an analog transmission. The CDPD infrastructure employs existing cellular systems to access a backbone router network that uses the Internet protocol (IP) to transport user data. Personal digital assistants, palmtops, and laptops running applications that use IP can connect to the CDPD service and gain access to other mobile computer users or to corporate computing resources that rely on wireline connections.

Because CDPD leverages the existing $20 billion investment in the cellular infrastructure, carriers can economically support data applications and avoid the cost of implementing a completely new network, as most competing technologies would require. Cellular Digital Packet Data also offers a transmission rate that is four times faster than most competing wide area wireless services, which are limited to 4.8K b/s or lower.

CDPD Fundamentals

Unlike circuit-switched schemes, which use dialup modems to access the cellular network, Cellular Digital Packet Data is a packet-switched technology that relies on wireless modems to send data at a raw speed of 19.2K b/s. AlthoughCDPD piggybacks on top of the cellular voice infrastructure, it does not suffer from the 3-KHz limit on voice transmissions. Instead, it uses the entire 30-KHz radio frequency (RF) channel during idle times between voice calls. Using the entire channel contributes to CDPD's faster and more reliable data transmission.

Underlying Technologies

CDPD is in fact a blend of digital data transmission, radio technology, packetization, channel hopping, and packet switching. This technology lets the cellular network carry the 1s and 0s of binary digital code more reliably than is usually possible over cellular voice networks.

Digital Transmission Technology

Digital transmission technology is reliable and more resistant to radio interference than analog transmission technology. The digital signals are broken down into a finite set of bits, rather than transmitted in a continuous waveform. When signal corruption occurs, error-detection logic at the receiving end can reconstruct the corrupted digital signal using error correction algorithms. Digital technology also enables processing techniques that compensate for signal fades without requiring any increase in power.

Digital Cellular Radio Technology

Digital cellular radio technology is used for transmitting data between the user's mobile unit and the carrier's base station.

Packetization

Packetization divides the data into discrete packets of information before transmission. This approach is commonly used in wide area and local computer networks. In addition to addressing information, each packet includes information that allows the data to be reassembled in the proper order at the receiving end and corrected if necessary.

Channel Hopping

Channel hopping automatically searches out idle channel times between cellular voice calls. Packets of data select available cellular channels and go out in short bursts without interfering with voice communications. Alternatively, cellular carriers may also dedicate voice channels for CDPD traffic.

Packet Switching

Packet switching, using the Internet protocol (IP), accepts data packets from multiple users at many different cell sites and routes them to the next appropriate router on the network.

Applications for CDPD

The wireless-industry consortium that funded the development of theCellular Digital Packet Data specification includes Ameritech Cellular, Bell Atlantic Mobile, Contel Cellular Inc., GTE Mobilnet, Inc., McCaw Cellular Communications, Inc., NYNEX Mobile Communications, AirTouch (formerly PacTel Cellular), and Southwestern Bell Mobile Systems. Three principles guided their efforts: that emerging CDPD recommendations could be deployed rapidly, economically, and in conjunction with technology already available in the marketplace.
More specifically, the consortium's stated objectives include:

- Ensuring compatibility with existing data networks.
- Supporting multiple network protocols.
- Exerting minimum impact on end systems; existing applications should operate with little or no modification.
- Preserving vendor independence.
- Ensuring interoperability among service providers without compromising their ability to differentiate offerings with service and feature enhancements.
- Allowing subscribers to roam between serving areas.

Previous screen

· Protecting subscribers from eavesdropping.

Emerging Class of Remote Users

CDPD allows traditional wireline networks to reach a new class of remote user: the roaming mobile client. With the establishment of a wireless link to the cellular carrier's CDPD network, remote users can operate their terminals as if they were located on the desktop in a branch office. Mobile workers, for example, can regain much of the productivity they lose while away being from their main offices by using CDPD to send and receive E-mail from computers or personal digital assistants.

Another application example is a debit card. Commuters could purchase a debit card to run through a card-reading device on a bus or another transit system and the fare would be deducted automatically from the card's total. That fare information could be transmitted to a central processing center in less than a second for just a few cents. CDPD could also be used by service providers to monitor and control devices such as traffic lights, alarm systems, kiosks, vending machines, and automated teller machines.

Service Pricing

As an overlay to the existing analog cellular infrastructure, CDPD networks are easy and economical for carriers to set up and operate. Carriers estimate that it costs only 5% over the initial cost of a cell site to upgrade to CDPD. Cell sites typically cost about $1 million to set up, including the cost of real estate.

Users are the beneficiaries of CDPD's resulting economies and efficiencies. For many applications, initial CDPD service pricing is competitive with that of the proprietary analog wireless services of ARDIS and RAM Mobile Data. Exhibit 1 indicates that CDPD is best suited for transaction-oriented applications. Although these services might prove too expensive for heavy data base access, the use of intelligent agents can cut costs by minimizing connection time.

CDPD Services

Application	Bell Atlantic Mobile Systems (Per-User Pricing)	GTE Mobilnet (Per-User Pricing)
Data base Inquiry	$23 to $27/month	$20 to $28/month, 25 sessions a day, 5 days a week
Electronic Mail	$40 to $60/month	$45 to $60/month, 14 messages a day, 5 days a week
Dispatch	$13 to $17/month	$10 to $20/month, 1 to 2 jobs per hour, 9 hours a day, 5 days a week
Alarm Monitoring	$13 to $17/month	$10 to $20/month, 1 transaction per hour, 24 hours a day, 7 days a week
Field Service	$23 to $27/month	$16 to $22/month, 20 transactions a day, 5 days a week

Note:
Estimated per-user prices are based on sample applications and usage figures. All prices subject to change without prior notice.

Benefits to Mobile Users

Because CDPD uses the existing voice-oriented cellular network and off-the-shelf hardware for implementation, it is cost-effective. There are, however, additional benefits to users besides economy. These benefits include:

- **Efficiency.** CDPD transmits both voice conversations and data messages using the same cellular equipment. Using a single device, it is a versatile and efficient way to communicate. The digital data does not disrupt or degrade voice traffic, and vice versa.

- **Speed.** Having a maximum channel speed of 19.2K b/s—a four-fold increase over competing mobile radio technologies—CDPD is the fastest wireless technology available on the WAN.

- **Security.** With encryption and authentication procedures built into the specification, CDPD offers the more robust security than any other native wireless data transmission method, preventing casual eavesdropping. As with wireline networks, users can also customize their own end-to-end security.

- **Openness.** Because CDPD is an open, nonproprietary standard, it promotes low equipment costs and broad availability of hardware and software.

- **Flexibility.** Because it uses existing cellular radio technology, CDPD units are capable of transmitting data over both packet- and circuit-switched networks, allowing applications to use the best method of communication.

Previous screen

- **Reliability.** Because CDPD uses existing equipment on the network (i.e.,routers), as well as time-tested protocols based on TCP/IP, the highest quality of wireless data service is assured. CDPD also provides excellent penetration within buildings.

- **Worldwide Reach.** CDPD can be used in conjunction with existing cellular systems around the world. These systems already serve 85% of the world's cellular users.

Because CDPD allows the network to operate more efficiently by providing digital packet data over the voice network, carriers also realize maximum flexibility, simplified operations and maintenance, and cost savings. Carriers can offer enhanced messaging services such as multicast, cellular paging, and national short-text messaging. CDPD allows portable access to a variety of information services.

In effect, CDPD extends client/server-based applications from the LAN environment into the wireless arena. This extension provides nearly limitless possibilities for future wireless data services.

Equipment Requirements

CDPD is not without its problems. Even though Cellular Digital Packet Data takes advantage of the existing circuit cellular voice infrastructure to send data at up to 19.2K b/s, existing cellular modems cannot be used on CDPD-based networks. Modems designed for CDPD networks are still larger and more expensive than those designed for circuit cellular. CDPD-only modems cost about $500; modems that handle both CDPD and circuit cellular run about $1,000. When the cost of CDPD modems drops to the $200 range, expense will no longer be a barrier. Also, carriers are considering subsidizing the cost of Cellular Digital Packet Data modems, the way they currently do with cellular phones, when users sign up for service.

Network Architecture and Protocols

The Cellular Digital Packet Data specification defines all the components and communications protocols necessary to support mobile communications. Exhibit 2 shows the main elements of a CDPD network.

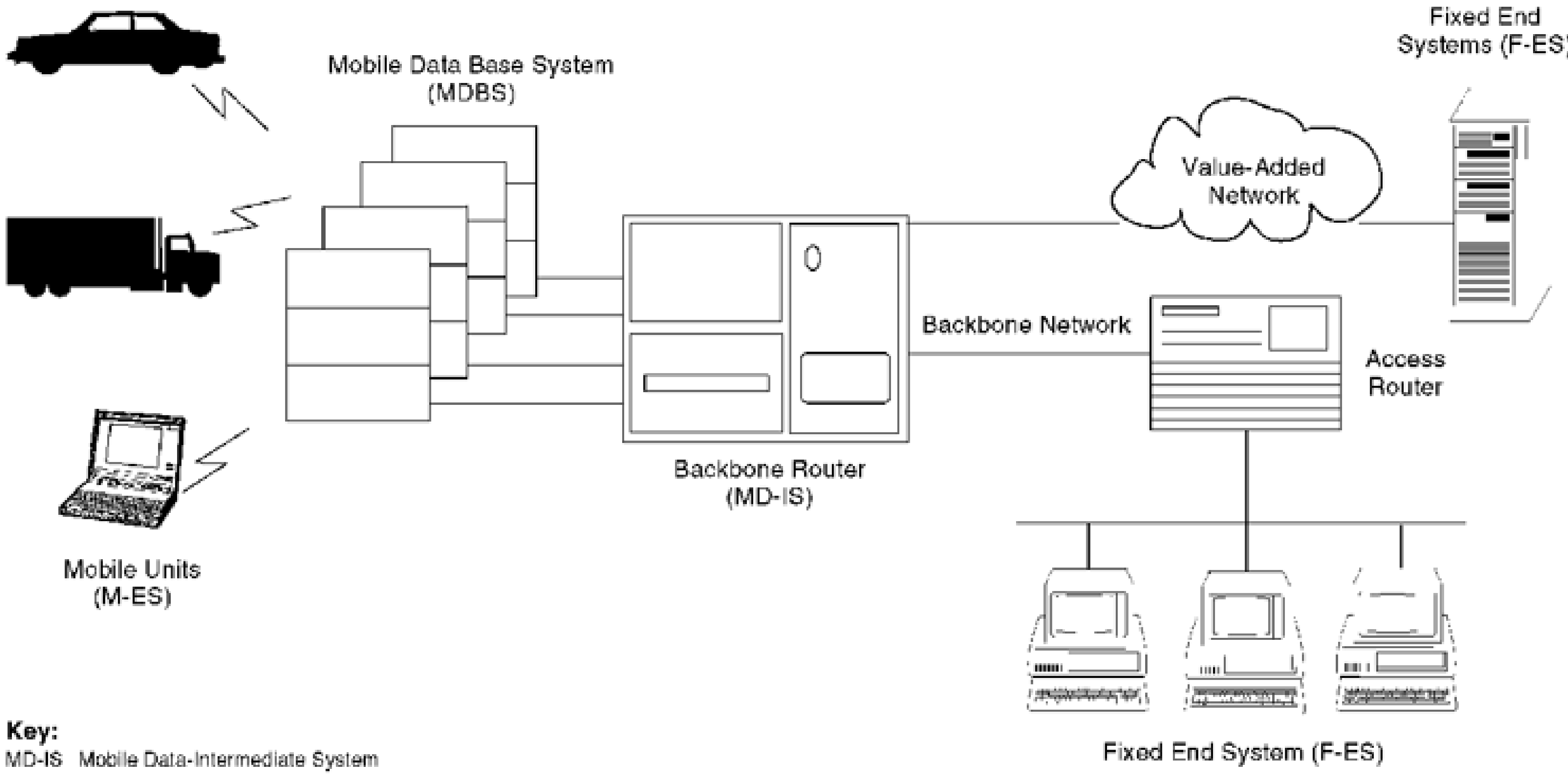
CDPD Network Architecture

Mobile Data-Intermediate Systems

The backbone router, also known as the Mobile Data-Intermediate System (MD-IS), uses the location information derived from the mobile network location protocol to route data to the mobile units, which are referred to as Mobile-End Systems (M-ES). Information on the link between the backbone router and a Mobile Data Base System is transmitted using a data link layer (DLL) protocol. Communications on the other side of the backbone router are handled using internationally recognized protocols. This ensures that standard, off-the-shelf systems can be used in the network infrastructure and that computer systems currently in use can be accessed by CDPD networks without modification.

Mobile Data Base Systems

The mobile data base system (MDBS) provides the relay between the cellular radio system and the digital data component of the CDPD network. The mobile data base system



Key:
MD-IS Mobile Data-Intermediate System
M-ES Mobile-End System

Previous screen

(MDBS) communicates with the mobile units through radio signals. Up to 16 mobile units in a sector can use the same cellular channel and communicate as if they were on a LAN. This communications technique is known as digital sense multiple access (DSMA). After the mobile data base system (MDBS) turns the cellular radio signal into digital data, it transmits the data stream to its backbone router, typically using frame relay, X.25, or the Point-to-Point Protocol.

Mobile-End Systems

Although the physical location of a mobile-end system, or mobile unit, may change as the user's location changes, continuous network access is maintained. The Cellular Digital Packet Data specification stipulates that there will be no changes to protocols above the network layer of the seven-layer Open Systems Interconnection (OSI) model, so that applications software will operate in the Cellular Digital Packet Data environment. At the network sublayer and below, mobile units and backbone routers cooperate to allow the equipment of mobile subscribers to move transparently from cell to cell, or roam from network to network. This mobility is accomplished transparently to the network layer and above.

OSI Protocols

The recommendations of the CDPD consortium were designed using the Open Systems Interconnection reference model (see Exhibit 3). The model not only provides a structure to the standardization process, it offers recommendations regarding protocols available for use in the CDPD network.

The OSI Reference Model

Network Layer Protocols

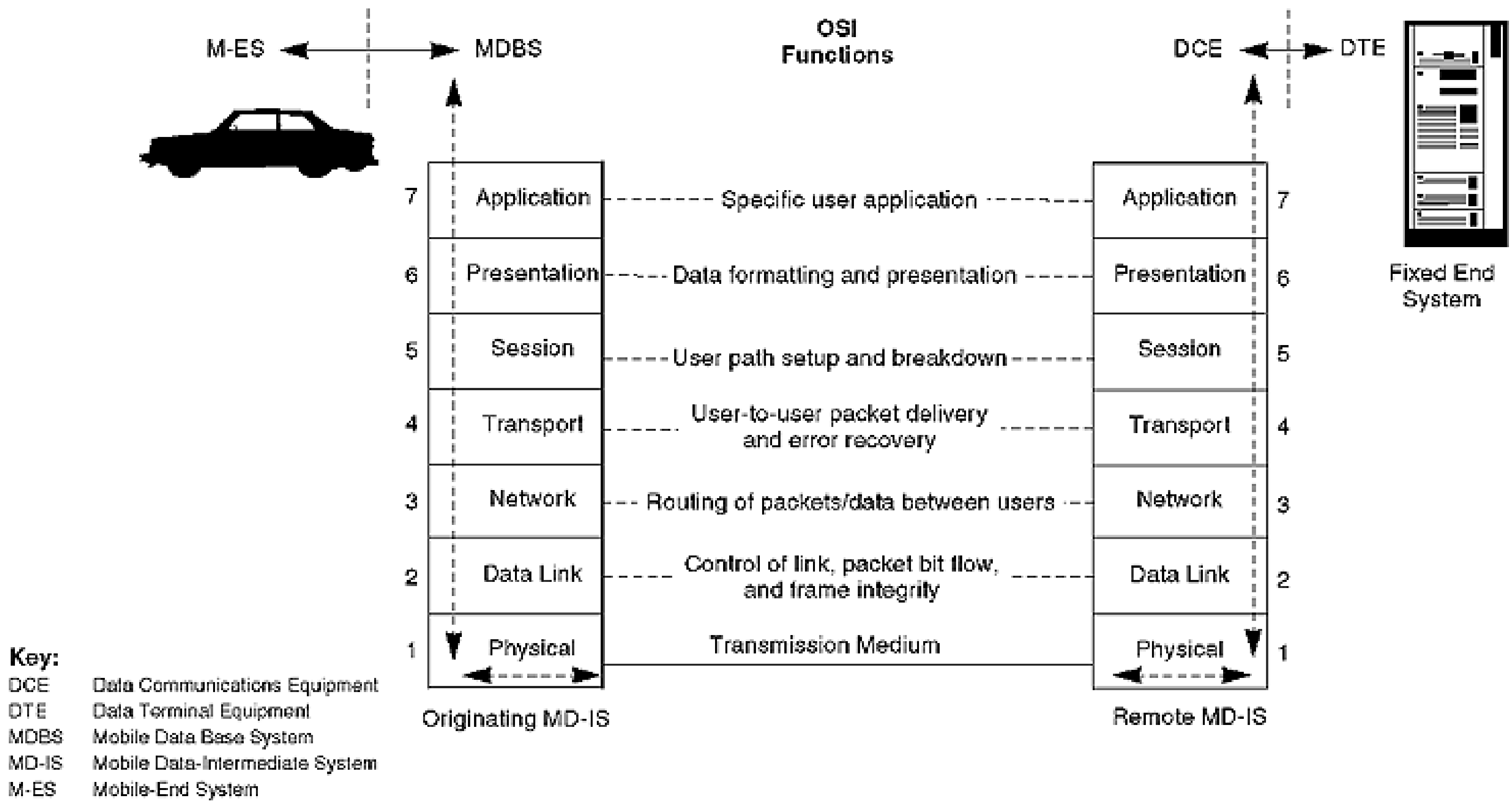
The CDPD overlay network may use either the OSI ConnectionLess Network Protocol or Internet protocol (IP) at the network layer. These protocols have virtually the same functionality: They both interpret device names to route packets to remote locations.

IP has been used for more than 10 years and is one of the most popular protocols today. Its inclusion in the CDPD specification is intended to accommodate the vast number of networked devices already using it.

Application Layer Protocols

Applications required to administer and control CDPD networks useOpen Systems Interconnection-defined protocols. OSI-defined application-layer protocols are widely accepted and have been tested to ensure robust, open communications among CDPD service providers. The use of these protocols provides a level playing field for manufacturers of the CDPD infrastructure equipment. Therefore, service providers can be confident that the various network elements will communicate together and that no single manufacturer can exert undue influence on the market.

Examples of OSI protocols that operate at the application layer and can be implemented for CDPD network administration and control are explained as follows:


M-ES
MDBS
OSI
Functions
DCE
DTE
Fixed End
System
7
Application
Specific user application
Application
7
6
Presentation
Data formatting and presentation
Presentation
6
5
Session
User path setup and breakdown
Session
5
4
Transport
User-to-user packet delivery
and error recovery
Transport
4
3
Network
Routing of packets/data between users
Network
3
2
Data Link
Control of link, packet bit flow,
and frame integrity
Data Link
2
1
Physical
Transmission Medium
Physical
1
Originating MD-IS
Remote MD-IS
Key:
DCE Data Communications Equipment
DTE Data Terminal Equipment
MDBS Mobile Data Base System
MD-IS Mobile Data-Intermediate System
M-ES Mobile-End System

- The Common Management Information Protocol is the object-oriented management standard for OSI networks developed by theInternational Standards Organization (ISO).

- The X.400 message handling system is a global messaging standard recommended by the International Telecommunications Union-Telecommunications Standards Section (ITU-TSS, formerly known as theInternational Telegraph and Telephone Consultative Committee) that defines an envelope, routing, and data format for sending E-mail between dissimilar systems.

- X.500 directory services are a standard for directory services recommended by the ITU/ISO that operate across multiple networks used to convey E-mail. It allows users to look up the E-mail addresses of other users they wish to communicate with.

Mobility Management

Traditionally, the network address of the end system has been used to determine the route used to reach that end system. Cellular Digital Packet Data is unique in allowing mobile units to roam freely, changing their subnetwork point of attachment at any time— even in midsession.

To find the best route for transmitting data to an end system, CDPD mobility management definitions describe the creation and maintenance of a location information data base suitable for real-time discovery of mobile unit locations. Three network entities— the mobile units, the home backbone router, and the serving backbone router—participate in mobility management.

Mobile units are responsible for identifying their unique network equipment identifiers (NEIs) or network layer addresses to the Cellular Digital Packet Data network. As the mobile unit moves from cell to cell, it registers itself with the new serving backbone router. Each NEI is permanently associated with a home backbone router. The serving backbone router notifies the home backbone router of a mobile unit when it registers itself in the new serving area. Mobility management makes use of two protocols: the Mobile Network Registration Protocol and theMobile Network Location Protocol.

Mobile Network Registration Protocol

MNRP is the method mobile units use to identify themselves to the network. This information is used to notify the network of the availability of one or more NEIs at a mobile unit. The registration procedure includes the information required by the network for authenticating the user's access rights.

The mobile network registration protocol (MNRP) is used whenever a mobile unit is initially powered up and when the mobile unit roams from cell to cell. In either case, the mobile unit automatically identifies itself to the backbone router so its location can be known at all times.

Mobile Network Location Protocol

MNLP is the protocol communicated between the mobile serving function and mobile home function of the backbone routers for the support of network layer mobility. Mobile network location protocol (MNLP) uses the information exchanged in mobile network registration protocol (MNRP) to facilitate the exchange of location and redirection information between backbone routers, as well as the forwarding and routing of messages to roaming mobile units.

Previous screen

Information Protection

To facilitate the widespread acceptance of Cellular Digital Packet Data by cellular service providers, the specifications define methods for ensuring the security of customer information, while still providing an open environment for mobile users. Cellular service providers are legitimately concerned about protecting information about their subscriber base from each other, yet the nature of the service dictates that carriers exchange information with one another to provide subscribers with full mobility.

For example, when a user who is usually served by Carrier X in Chicago roams to the Carrier Z service area in Boston, Carrier Z must be able to find out whether that user is authorized to use the network. To do that, Carrier Z queries the Carrier X data base about the user's access rights using the network equipment identifier. Carrier X provides a simple yes or no response. The details concerning the identity of the user, types of service the user has signed up for, rates being charged, and amount of network usage are all protected.

CDPD Network Backbone

The internal network connecting the backbone routers (i.e., MD-ISs) must be capable of supporting ConnectionLess Network Protocol and IP. The backbone routers terminate all Cellular Digital Packet Data-specific communications with mobile units andMobile Data Base System, producing only generic IP and connectionless network protocol (CLNP) packets for transmission through the backbone network.

Mobile-End Systems Protocols

As noted, the requirement that mobile units support IP is meant to ensure that existing applications software can be used in CDPD networks with little or no modification. However, new protocols below the network layer have also been designed for Cellular Digital Packet Data. These protocols fall into two categories: those required to allow the mobile unit to connect locally to an mobile data base system (MDBS), and those required to allow the mobile unit to connect to a serving backbone router and the network at large.

Digital sense multiple access is the protocol used by the mobile unit to connect to the local mobile data base system (MDBS). Digital Sense, Multiple Access is similar to the carrier sense multiple access (CSMA) protocol used in Ethernet. Digital Sense, Multiple Access is a technique for multiple mobile units to share a single cellular frequency, much as Carrier Sense, Multiple Access allows multiple computers to share a single cable. The key difference between the two, apart from the data rate, is that CSMA requires the stations on the cable to act as peers contending for access to the cable in order to transmit, whereas inDSMA the mobile data base system (MDBS) acts as a referee, telling a mobile unit when its transmissions have been garbled.

A pair of protocols permit communications between the mobile unit and the backbone router. The mobile data link protocol (MDLP) usesMedia Access Control framing and sequence control to provide basic error detection and recovery procedures; the subnetwork dependent convergence protocol (SNDCP) provides segmentation and head compression.

In addition to segmentation and header compression for transmission efficiency, other important features of Sub-Network Dependent Convergence Protocol include encryption and mobile unit authentication. While the cellular network provides a certain amount of protection against eavesdropping because of its channel-hopping techniques, the applications expected to be used on the CDPD network require definite security-competing

Previous screen

businesses must have the confidence that their information cannot be seen by competitors. SNDCP encryption uses the exchange of secret keys between the mobile unit and the backbone router to ensure that there can be no violation of security when transmitting over the airwaves. The authentication procedure guards against unauthorized use of a network address.

Transparent Operation

Complete mobility is one of the key goals of Cellular Digital Packet Data networks. Because applications software must be able to operate over the network, the network itself must make any required operational changes transparently.

For example, the mobile units must automatically identify themselves to the network using the Mobile Network Registration Protocol protocol, which recognizes the network addresses of mobile units whenever subscribers power on their computers or move to a new cell.

Data sent to a mobile unit is always sent through its home backbone router - another example of transparent operation. The home backbone router maintains an up-to-date table of the locations of the mobile units it is responsible for, thus making it possible to send connectionless data transmissions to a roaming mobile unit at any time. The home backbone router sends the data to the current serving backbone router. This scheme ensures that data reaches an end system regardless of its location, while keeping internal routing table updates to a minimum.

A connectionless service is one in which a physical connection need not be established in order to transmit data because the network is always available. In this scheme, each block of data is treated independently and contains the full destination host address. Each packet may traverse the network over a different path. A connection-oriented service, on the other hand, requires a destination address in the first packet only. Subsequent packets follow the path that has been established.

Sending Data from a Mobile Unit

Registration Procedure

Before a mobile unit can begin transmission, it enters into a dialogue, called the registration procedure, with the backbone router serving the area in which it is currently located. This dialogue identifies the mobile unit's Open Systems Interconnection network layer address to theCellular Digital Packet Data network. The serving backbone router tells the home backbone router responsible for that mobile unit that it is requesting service. The home backbone router authenticates the mobile unit, checking such things as the user's access rights and billing status. The registration procedure must be performed whenever the mobile unit is first powered on, or roams to a new serving backbone router.

Once the registration and authentication procedures are completed, the mobile unit begins sending data. The mobile unit is now on what appears to be a LAN connecting all such units operating within the cell of the telephone network. The LAN is really a single set of transmit and receive frequencies shared by the mobile units that access this cellular LAN using the digital sense multiple access technique.

The cells, or Digital Sense, Multiple Access LANs, are interconnected by the backbone routers in much the same way that routers connect Ethernet or token ring LANs. The serving backbone router examines the data sent by the mobile units, looking for the destination address. By comparing the destination address with those in its tables, the

Previous screen

backbone router can send the data to the appropriate destination by the best path available (see Exhibit 4). The user can now log on to the portable computer, access shared services such as CompuServe, or send information directly to other roaming mobile units. When sending data from a mobile unit to other computers, the CDPD network must only ensure that the user is allowed to transmit. Once the user is authenticated, data is sent in a manner similar to the way it is sent in current LAN internetworks.

Potential Data Paths

Sending Data to a Mobile Unit

On the return path, when data is sent to the mobile unit, the CDPD network must be prepared to deal with mobile units that are actively mobile - moving in a car, for example. In this case, it is likely that the mobile unit would move from one serving backbone router to another during the session. The CDPD network accommodates the roaming mobile unit by always sending its data to its home backbone router. The home backbone router always advertises itself as the destination router for the mobile units it serves.

Redirect Procedure

The home backbone router knows the current location of the mobile unit because of the registration procedure. When sending information to a mobile unit, the home backbone router encapsulates it into frames using the ConnectionLess Network Protocol protocol and sends them to the address of the current serving backbone router. Once the data arrives at the serving backbone router, it is de-encapsulated into its original form to be sent to the mobile unit. This method of handling data trans-missions at the home backbone router is called the redirect procedure (see Exhibit 5).

The Redirect Procedure

The redirect procedure takes advantage of the identification done during the registration procedure. The registration procedure serves two purposes:

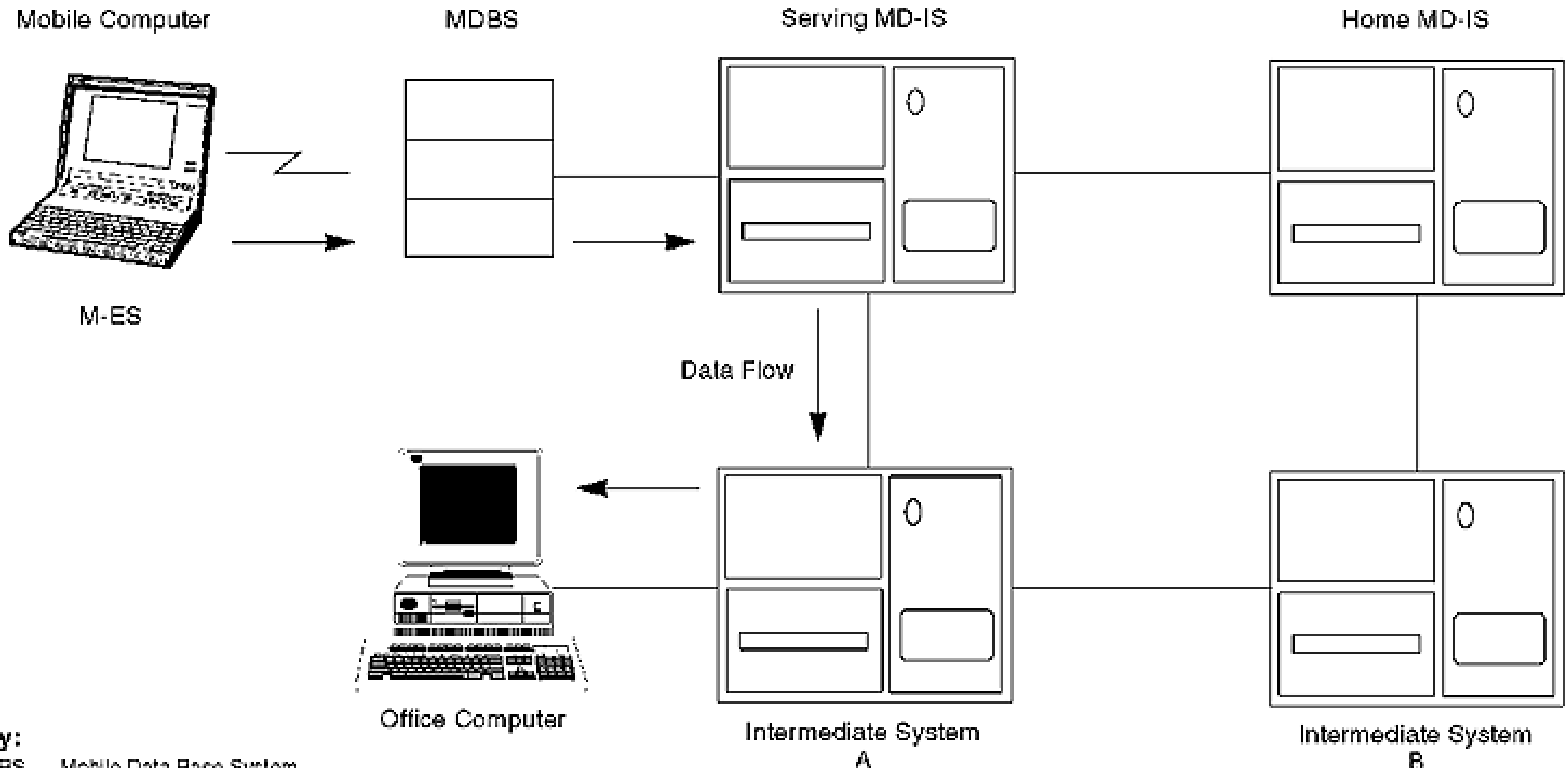
- To authenticate the user's access rights.

- To identify the current location of the user.

The redirect procedure uses this information to minimize network overhead. The alternative, in which all the backbone routers would update their global routing tables whenever a mobile unit moved, would saturate the network with overhead traffic. The CDPD network permits full mobility, but without imposing an undue burden on the network infrastructure.

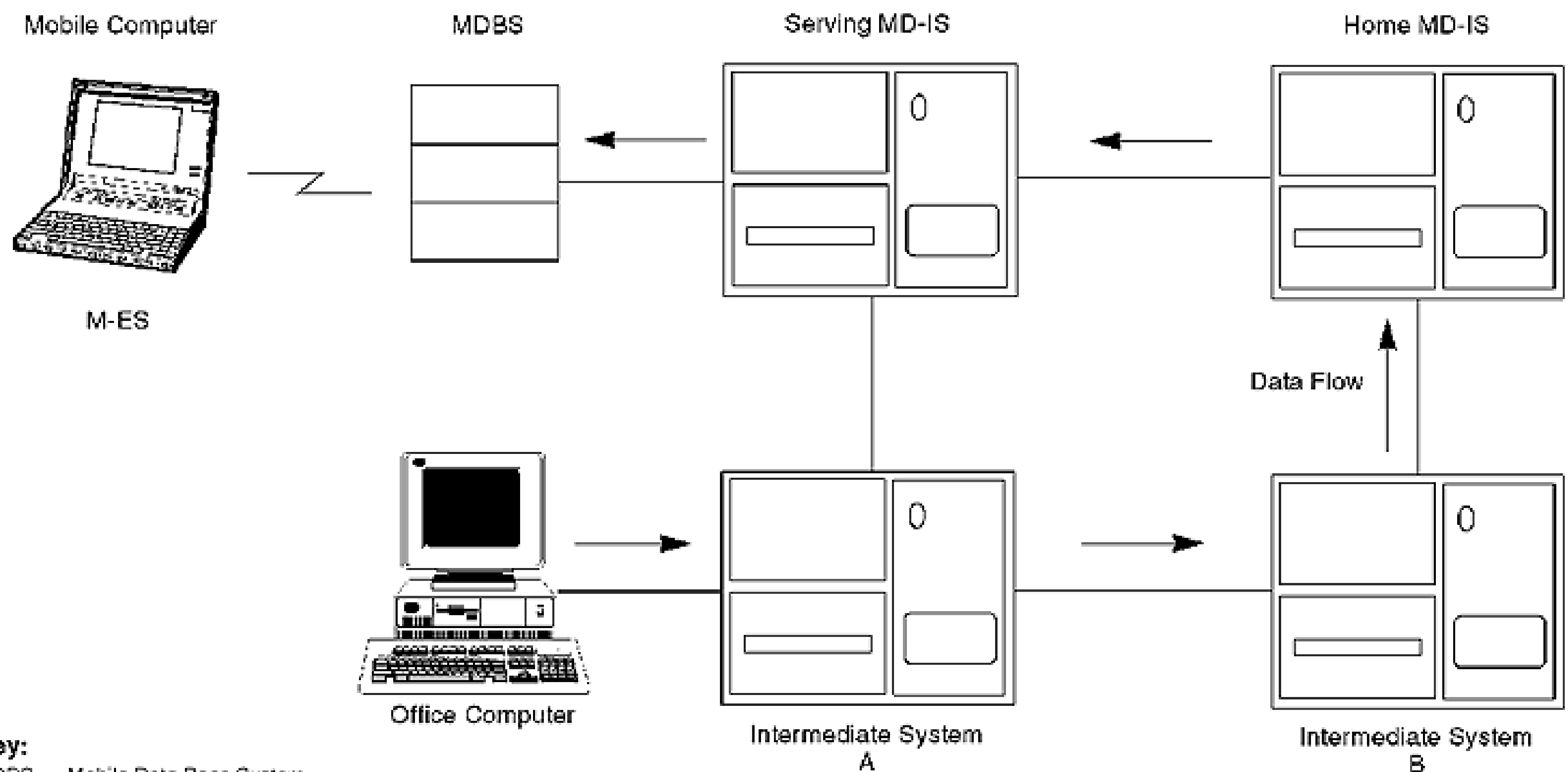
Is There a Mass Market for CDPD?

Industry analysts estimate that the wireless data market could be worth $10 billion by the year 2000, providing service to about 13 million mobile data workers. Bell Atlantic Mobile, an early provider of Cellular Digital Packet Data-based services, predicts that as much as a fifth of its cellular revenues could come from data services by the end of the decade.



Key:

MDBS	Mobile Data Base System
MD-IS	Mobile Data-Intermediate System
M-ES	Mobile-End System



Key:

MDBS	Mobile Data Base System
MD-IS	Mobile Data-Intermediate System
M-ES	Mobile-End System

Previous screen

The eventual availability of low-cost CDPD modems does not guarantee a mass market for Cellular Digital Packet Data. For this to happen, commonly used applications must be adapted to the technology using application programming interfaces (APIs). APIs are required to optimize new and existing applications for use over relatively low-bandwidth wireless links with their high overhead and delay. After overhead is taken into account, the wireless CDPD link will top out at 14.4K b/s. The average throughput falls between 9K b/s and 12K b/s, depending on the number of errors and retransmissions.

Although CDPD is ideal for vertical niche markets such as fleet dispatch and field service, the more popular applications include E-mail, facsimile, and Remote Data Base access. Several toolkits are available to give new and existing applications the capability to run over Cellular Digital Packet Data networks.

To improve application performance over low-bandwidth wireless links, middleware that uses intelligent agents is now available that allows laptop users to query a corporate data base using a software agent at the corporate site. If the user does not want to wait for a response to a query, or the connection is lost, the agent collects the information and sends it over the wireless network when the user makes the next connection.

Conclusion

Mobile users who are already committed to wireless data services are among the early users of Cellular Digital Packet Data service. As the price of CDPD modems fall, coverage increases, and more applications become optimized for CDPD, the technology will have even wider appeal.

Cellular digital packet data networks are appealing because they offer seamless nationwide availability; work with the vast installed base of computers, applications, and data networks; and make use of existing private and public network infrastructures, encompassing all products and user equipment. The ultimate success of CDPD is, of course, closely tied to industry efforts to standardize its implementation. A universal standard for cellular packet data would facilitate terminal capability, allow users to roam between service areas, and simplify the introduction of wireless data services.

Author Biographies

Nathan J. Muller

Nathan J. Muller is an independent consultant in Huntsville AL, specializing in advanced technology marketing and education. He has more than 22 years of industry experience and has written extensively on many aspects of computers and communications. He is the author of eight books and more than 500 technical articles. He has held numerous technical and marketing positions with such companies as Control Data Corp.,Planning Research Corp., Cable & Wireless Communications, ITT Telecom, and General DataComm, Inc. He holds an MA in social and organizational behavior from George Washington University.