# MOBITEX and Mobile Data Standards

**The developers of wide-area wireless packet networks for mobile users have taken the approach of creating new protocols that are specifically tailored to tackle the unreliable RF environment, while providing the characteristics and efficiencies of a packet-switched network.**

*Mobeen Khan and John Kilpatrick*

Standards play a vital role in bringing an industry to widespread commercial use. Without standardization, interoperability of comparable systems and services is impossible, and economies of scale are never reached for manufacturing and investment. Historically, the standards are established either by a dominant player in a particular industry, e.g., IBM/Microsoft's development of DOS™, or by coordination among multiple, non-dominant vendors, as was the case with GSM (Global System for Mobile Communications) or UNIX™.

This article delves into the existing and emerging standards in the mobile data industry, with Ericsson's MOBITEX® system used as an example. It will show how wireline standards are being adapted to wireless, how this strategy compares to the development of new protocols and standards, and how the computer industry and its associated standards bodies are working to effectively hide the underlying wireless protocols.

## The Need for Mobile Data Standards

The majority of applications and communication platforms in existence today were designed for wireline access. The interfaces required and used for wireless communications differ significantly from the traditional wireline protocols. This is primarily due to: the unreliability of the RF propagation environment; and the limited RF channel bandwidth available to each user. The wireless protocols therefore must account for the unreliability of the communication medium by introducing link layer protocols with error correction capabilities, tolerance for relatively long delays and intelligent retry schemes, while at the same time trying to minimize delays and limiting the amount of overhead to improve the efficiency and message throughput of the system.

Traditionally, communication standards, especially in the wireless world, have been classified into two categories: packet-switched and circuit-switched protocol suites, as shown in Fig. 1. For the circuit-switched model, an analog channel is provided end-to-end and compatible modems must exist at both ends to modulate and demodulate the data across the channel. Only Layers 1 and 2 are addressed in the modems. An example of this is cellular data, where special error correcting modems are used to maintain the cellular connection for the duration of data transfer. There are a number of protocols in existence today, both proprietary (e.g., Microcom's MNP-10, AT&T's ETC) and standardized (e.g., V.42, V.34), that attempt to fulfill this objective. The cellular modems using these protocols may accommodate cell hand-offs and provide error correction, but do not account for data packetization or packet delays, and do not provide a network layer for packet routing.

Packet switching, on the other hand, is inherently digital and introduces a variety of interfaces and protocol stacks, each addressing the capabilities and difficulties of the particular link. The protocols used to connect a host computer to a wireless network can be the same as those used in wireline networks, e.g., X.25, frame relay, ATM, or TCP/IP. The air link protocols in the packet-switched wireless data networks, however, can use none of these standards very effectively. Some of the most popular interfaces, including TCP, IP, MNP, Hayes-compatible AT Command set, and X.25, have been less than ideal in the wireless environment, even after several modifications and optimizations. These wireline protocols and interfaces tend to be "chatty," assume predictable transfer delays, and tend to have extra overhead in order to support wide application.

## Established Mobile Data Standards

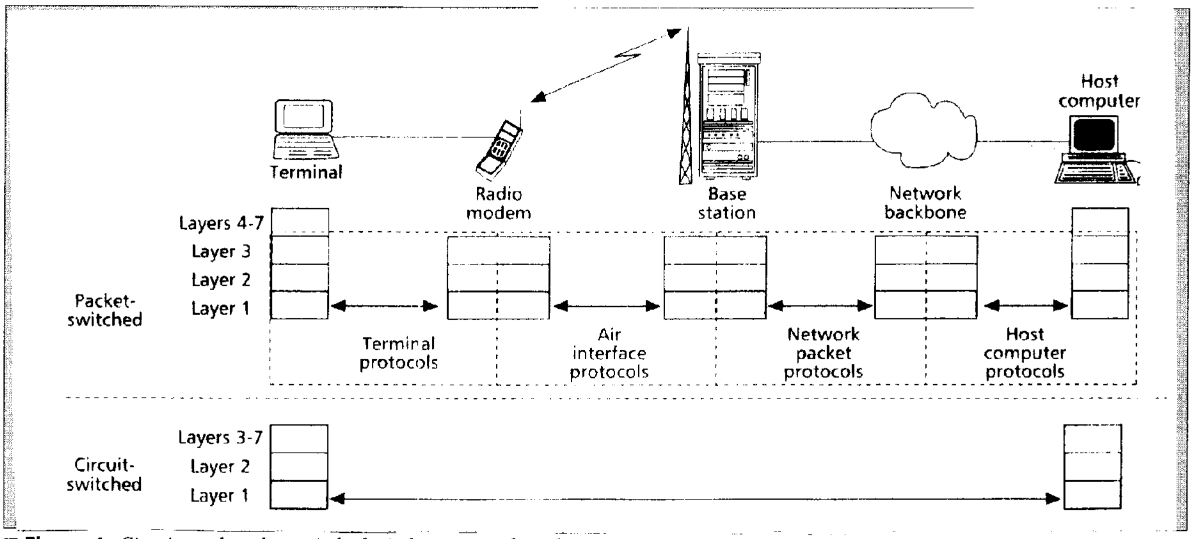
Mobile data today can claim its roots in several wireless systems of the past decades. These include the satellite data communication systems, various Specialized Mobile Radio (SMR) systems, and simulcast paging networks. Most of these systems, however, currently use relatively older technologies and are now in the process of renovation and expansion to provide higher capacity and better

*JOHN A. KILPATRICK is director of System Technology at RAM Mobile Data.*

*MOBEEN KHAN is a senior systems engineer with RAM Mobile Data.*



0163-6804/95/$04.00 1995 © IEEE




■ **Figure 1**. *Circuit- and packet-switched wireless protocol stacks.*

quality of communications. A significant effort is also underway to provide high-speed, low-mobility, localized wireless data services, e.g., the IEEE 802.11 standard.

The developers of wide-area wireless packet networks for mobile users have taken the approach of creating new protocols that are specifically tailored to tackle the unreliable RF environment while providing the characteristics and efficiencies of a packet-switched network. Ericsson's MOBITEX standard, Motorola's RD-LAP, and, to some extent, Cellular Digital Packet Data (CDPD) are examples of this strategy. These efforts have materialized into a number of systems that are either in operation or currently being deployed. These systems, together with their technologies and protocols, are reviewed below.

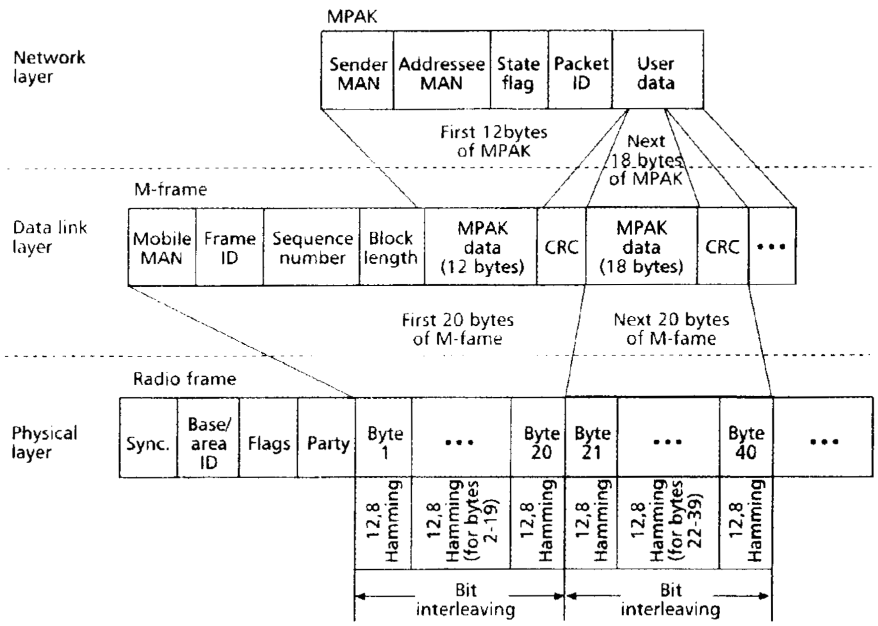
### *MOBITEX*

MOBITEX is a mobile data technology created by Ericsson that has been in existence for approximately ten years. Originally designed as a low-speed (1.2 kb/s) data system with a voice dispatch overlay, it was significantly enhanced in 1990 for use in North America and the United Kingdom. The enhanced system is a data-only system using cellular architecture and multichannel frequency reuse, store-and-forward capability, and an 8 kb/s over-the-air data rate. The air interface, known as ROSI (RadiO SIgnaling), uses GMSK0.3 (Gaussian Minimum Shift Keying with BT=0.3) modulation in 12.5 kHz channels with block interleaving, error detection (16 bit Cyclic Redundancy Check), a reduced (15,11) Hamming code for error correction, and selective ARQ (automatic repeat request) [1]. A reservation-slotted ALOHA-type scheme is used for channel access that provides a good balance between efficiency and responsiveness. Figure 2 shows the packet structures at various layers in the MOBITEX network.

MOBITEX uses a proprietary network layer protocol (called MPAK) with up to 512 bytes of user data per packet and 24 bit addressing (MOBITEX Access Number). A transport protocol, MTP/1, optimized for the radio environment, has been introduced by the MOBITEX Operators Association (MOA) to facilitate effective development of multi-packet and session-based applications. MOBITEX was also the first, and is still the only, wireless technology to offer true seamless roaming throughout the network and a battery-saving protocol to extend battery life of the radio modems. The standard MOBITEX terminal interface is called MASC (MOBITEX ASynchronous Communication). This interface provides for both the reliable transfer of data to/from the radio modem, and the control and status monitoring of the modem. Figure 3 shows the different protocol layers in the MOBITEX network with a host computer using MPAKs or MTP/1 to communicate with the network. A gateway between the local switch and the host computer can provide translation between MPAKs and the user's protocol of choice.

The network is organized hierarchically and has many reliability features, such as host group addressing, alternate network pathways, autonomous operation at each network level, multiple connections between nodes, and a backup network control center.

As shown in Table 1, MOBITEX is the most widely deployed packet switched mobile data technology in the world today, and has become a true worldwide *de facto* standard. In the United States, RAM Mobile Data operates MOBITEX systems nationwide in 7500 cities and towns with automatic seamless roaming across all service areas. MOBITEX networks are either installed or being deployed in 13 countries, and there is a MOBITEX Operators Association to oversee the specifications, coordinate software and hardware development, and work with Ericsson and other manufacturers on technology evolution. Work is already in progress to further increase capacity and speed by introducing higher inter-node and over-the-air data rates. The use of connected subnetworks and multiple network control centers in the future will also allow for the anticipated rapid growth in subscribers, and enhance the ability for users to roam internationally.

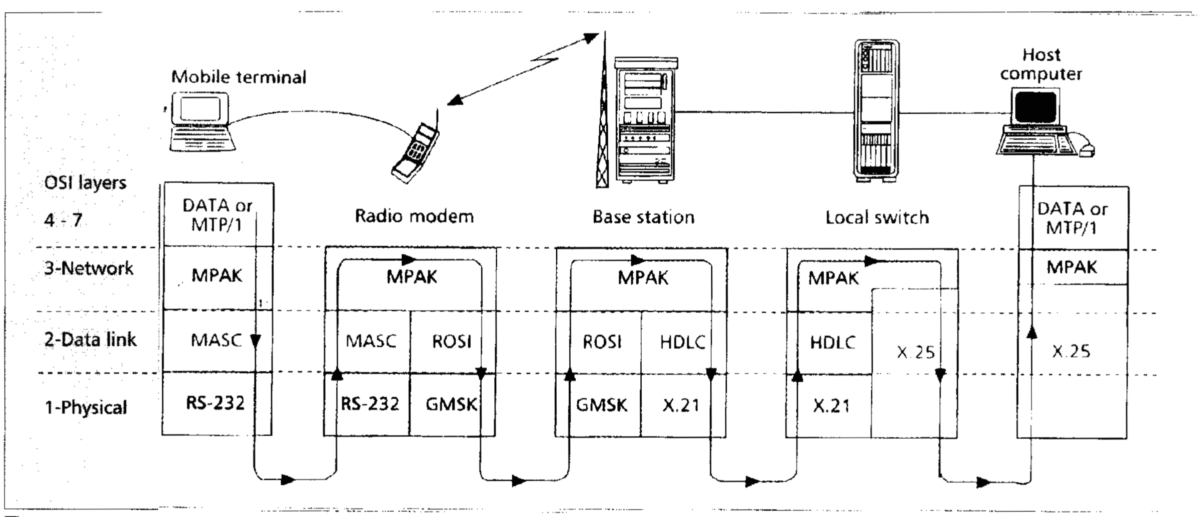



■ **Figure 2.** *MOIBITEX frame structures.*

### *RD-LAP & MDC-4800 (ARDIS)*

ARDIS is now a fully owned subsidiary of Motorola [2] and one of only two nationwide wireless data service providers today. It was created as a private network for IBM, and was later offered for public use (as a 50/50 joint venture between Motorola and IBM). IBM is still ARDIS' largest customer, with more than 12,000 field engineers using the ARDIS network. The ARDIS network architecture is based on a single messaging and routing switch that is connected to several Network Control Processors (NCP) [3]. Each NCP controls several base stations. Unlike cellular telephony and MOBITEX, ARDIS uses a concept known as single frequency reuse where all cell sites in a given area share a single frequency. Therefore, radio modems and base stations in adjacent cells cannot operate simultaneously. This allows the system to be deployed using very little spectrum, but significantly limits capacity.

ARDIS began deploying MDI's (Mobile Data International Inc.) MDC-4800 protocol nationwide. This standard is based on somewhat older technology that transmits data at 4.8 kb/s in a 25 kHz channel. In the past few years, Motorola developed and offered the RD-LAP protocol for ARDIS [4]. RD-LAP offers 19.2 kb/s signaling in the same 25 kHz channel bandwidth with significantly less overhead, nationwide roaming, more robust link layer protocols and coding schemes, and better overall message throughput. The ARDIS network




■ **Figure 3.** *MOBITEX protocol layers.*

uses both MDC-4800 and RD-LAP protocols and offers modems that may be configured to operate with either of them. The RD-LAP deployment, however, has been very limited and slow [5].

### *Cellular Digital Packet Data*

CDPD is a technology standard sponsored by a consortium of several Regional Bell Operating Companies (RBOCs) and McCaw Cellular. CDPD technology was introduced by IBM as a packet-switching overlay to the existing analog cellular voice network and frequencies. The original plan was to use idle voice channels to multiplex short data messages and to hop among the available frequencies to find those idle channels. However, this scheme is proving fairly complex and has been shown to cause interference and reduce voice quality of the existing cellular calls [6]. CDPD technology and services have to be implemented within the regulatory structure of the cellular industry, which requires regional cellular networks to operate independently. This in turn requires that nationwide CDPD service be provided as a collection of inter-operating discrete networks. Therefore, a major goal of CDPD architecture is to provide modularity with structured interfaces. Every CDPD network needs to be self-contained and includes modules for administrative functions, such as accounting and billing. The CDPD air interface operates at a raw data rate of 19.2 kb/s and provides forward error correction to combat the interference and fading in cellular channels.

The first draft specification of CDPD called for a new protocol stack optimized for the wireless environment, much like MOBITEX (with the exception of frequency hopping). However, comments from the computer software industry caused a revision of the specification [7] which now supports the IP and OSI protocols at the network layer and only adds a robust physical and link layer for the air interface. This simplifies the task of modifying an application for use in a mobile environment, but increases the packet overhead. The TCP transport layer is not as efficient for a wireless environment as MTP/1, which was specifically designed and optimized for wireless networks.

By the end of 1994, CDPD networks had been deployed in roughly a dozen cities by GTE, McCaw, and several RBOCs. Interoperability testing between CDPD networks and vendors is also underway.

### *Data Over Cellular*

Data over cellular refers to sending data using a modem over AMPS (analog) channels. Advanced Mobile Phone System (AMPS) is the cellular standard that has been extensively deployed in North America, primarily for voice transmission. The system hands off ongoing calls to different cells to maintain signal strength at an acceptable level. During these hand-offs, cellular modems need to stop and restart transmission. The signals also undergo fading, which requires the modem to correct or ask for retransmission of some of the data that may not have been received properly. Several different techniques to combat these effects and to provide higher throughput using compression are now available, such as MNP-10, ETC, and V.42bis. Data over cellular has become more robust in the last few years, with several manufacturers providing these modems. The user throughput in a good channel may reach 9.6 to 14.4 kb/s.

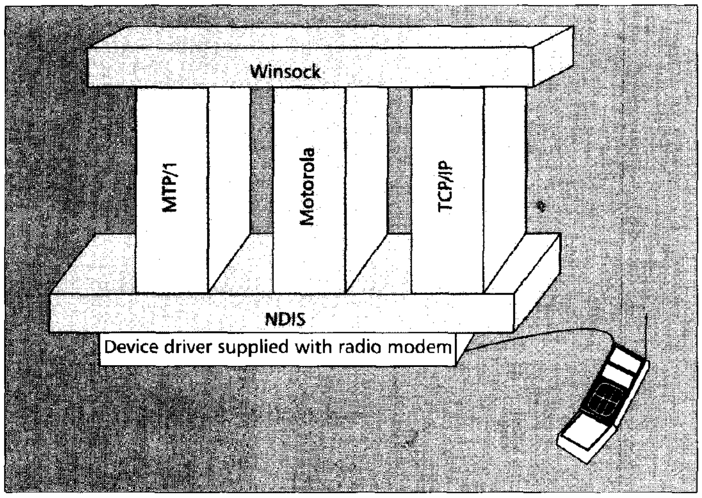
| Country | MOBITEX | RD-LAP | CDPD |
|---|---|---|---|
| U.S. | **RAM Mobile Data** | **ARDIS** | **Cellular operators** |
| Canada | Rogers Cantel | **Bell-ARDIS** | |
| U.K. | **RAM Mobile Data** | License unused | |
| France | France Telecom and TDR | | |
| Germany | GfD | German Bundespost | |
| Sweden | Telia Mobitel | | |
| Finland | Telecom Finland | | |
| Norway | Tele-Mobile | | |
| Belgium | BellSouth Mobile Data | | |
| Netherlands | RAM Mobile Data | | |
| Switzerland | | License awarded | |
| Australia | BellSouth | | |
| Chile | CTC Cellular | | |
| Thailand | | Operator not known | |
| Malaysia | | Operator not known | |
| Mexico | In regulatory process | | |
| Singapore | ST Mobile Data | Singapore Telecom | |
| Hong Kong | | Hutchinson | |
| Total | 14 operators in 13 countries | 7 | 1 |

■ **Table 1.** *International deployment of major mobile data standards.*

However, lack of standards, complexity and variety of modem operation, interoperability difficulties, long call set-up times, and costly air time has hampered the widespread use of cellular modems. To counter these drawbacks, several cellular operators have introduced banks of modems supporting various protocols at the cellular switch (MTSO). These modem banks connect several types of cellular modems on the radio side with standard wireline modems [8]. Cellular operators are also trying to attract users by offering price breaks for data usage.

### *Destineer*

Several paging network operators are looking into providing two-way messaging services using the narrowband PCS channels. Mtel's Nationwide Wireless Network (NWN), now known as Destineer, is one of the first. Destineer's system architecture will consist of two discrete nationwide networks, one for outbound traffic and one for inbound traffic. The two networks are to be coordinated by a Network Operations Center. The outbound network will consist of high-powered paging transmitters providing nationwide metropolitan coverage. These paging transmitters are linked to the Network Operations Center by satellite. The unique feature of the architecture is that the two networks will simultaneously share the same 50 kHz channel on a time division basis (Time Division Duplex) [9, 10]. Within the time divi-




■ **Figure 4.** *Example of device driver supporting multiple protocol stacks.*

sion frame, there will be timeslots for both outbound and inbound traffic. Destineer's architecture efficiently uses a small slice of spectrum at the expense of response time.

### Metricom

Metricom was founded in 1985 to provide wireless data acquisition to electric utilities. The company is now expanding into consumer applications, such as local loop bypass, e-mail, and Internet access, with a high-speed (up to 100 kb/s) Micro-Cellular Data Network (MCDN) marketed as Ricochet™. MCDN uses frequency hopping spread spectrum technology in the unlicensed 902-928 MHz band, with each cell supporting one channel in a half-duplex fashion. Due to the Effective Radiated Power (ERP) limitations of this unlicensed band, each cell is on the order of 1/4 to 1/2 mile in radius [11].

The radio network uses a mesh topology, with each cell communicating wirelessly with all of its neighboring cells using frequency hopping to reduce interference internally and among all users of this unlicensed band. Information is transmitted from the originator to the destination through cells in the network. Incoming information is transferred to neighboring cells that are progressively closer to the destination or wireline gateway. The network uses airlink capacity to carry both direct and transit traffic. This increases the traffic handling requirements of each cell and reduces the capacity and throughput. Like CDPD, Metricom has chosen to support TCP/IP and the AT command set, and also supports Appletalk.

## Migration Paths

So here we are in the beginning of 1995, poised for the wireless revolution, but burdened with a variety of options, protocols, carriers, services, and standards. How will (can) the revolution materialize with so much confusion? The answer may not be as bleak as it might appear. Already there are several significant forces working to overcome these problems.

Most wireless network operators provide gateway services that enable standard computer communications protocols to connect to the network. For example, RAM Mobile Data has developed the Mobigate™ gateway platform, which enables TCP/IP, X.25, and SNA 3270 hosts to extend their reach to wireless terminals without the need to know the MOBITEX protocol stack. It also offers asynchronous PSTN dial-up connectivity for smaller host configurations. In addition, third-party gateways are available to support AS400, DECnet, and SNA hosts.

In parallel, the Portable Computer and Communications Association (PCCA) has brought together the principal modem manufacturers, computer manufacturers, and service providers to develop interoperability standards. The first such standard to be introduced was a wireless extension to the AT command set. With this standard, computer software written for Hayes-compatible modems can be migrated to interface to an AT-style wireless modem. This extension to the wireless AT command set will be submitted to the TIA TR-30.4 committee to make it an official American National Standard Institute (ANSI), Telecommunication Industry Association (TIA), and Electronics Industry Association (EIA) standard. A number of products/specifications are already available using an extended AT interface (with varying degrees of compliance to the PCCA standard [12]): Ericsson's AT Mobidem; Metricom's Ricochet radio modem; Pinpoint's radio modem; CDPD System Specification V1.0; and Research in Motion's (RIM) RAD-AT (AT command set emulation).

At a bit higher level in the protocol stack (the so-called middleware), the PCCA is coordinating its efforts with the Winsock Forum to establish standard extensions to the Winsock interface. The Winsock Forum is an open, industry-wide work group focused on defining an extended version of the Winsock Interface called Winsock 2 (network programming interface at the transport level in the ISO reference model). Virtually all vendors of the TCP/IP protocol stacks supply a Winsock 1.1 programming interface for their stacks. The Winsock Forum's stated objective is to finalize the Winsock 2 specifications by April 1995 and have the needed Software Development Kits (SDKs) available (for both 16 and 32 bit operating environments) during the second half of 1995. This will allow radio modem manufacturers to develop and distribute device drivers that enable Winsock-compliant applications to interface with the radio modem with minimal modification, and to develop new applications that are specific to wireless data networks.

In parallel activities, the proposed extensions to standard Applications Programming Interfaces (APIs), such as Microsoft's Network Driver Interface Specification (NDIS) and Novell Inc.'s Open Data Link Interface (ODI), could, in the future, provide connectivity between multiple Upper Layer Protocols (ULPs), as well as multiple MAC layer protocols (Fig. 4). The device drivers will then need to deal with only a standard API.

Finally, major software developers are modifying their existing applications to be able to support wireless networks. As a first step, Lotus and Microsoft modified their e-mail packages to work over wireless networks through the use of the AT interface. In this way, a mobile computer can be configured to talk to either a landline or radio modem by setting registers and varying the destination address/phone number. Although this addresses the "standardization" problem, it is not the optimal solution for wireless. There are still a number of packets exchanged during a typical log-in, and the benefits of a sessionless datagram network are lost since only a single session application is supported at a time by the radio modems.

A better methodology is exemplified by Oracle In Motion (OIM), which uses a client-agent-server architecture and the native packet protocol to the wireless modem (as opposed to the AT interface). The agent software isolates the dissimilar requirements of the mobile and host environments and streamlines the data exchange. This allows single packet requests and responses to/from the mobile terminal with no call setup. Use of the native packet protocols allows all network functions to be supported for the application, and permits true sessionless communications. Oracle has developed this software to run on RAM Mobile Data's MOBITEX network using the store-and-forward network feature to notify the client software when the response is available. Oracle will release subsequent versions to be compatible with other major wireless networks.

## Future of Wireless

With all this said, what does this hold for the future of wireless communication standards? If current trends hold, it is probably safe to make the following predictions:

1) There will be a variety of standards and choices for wireless communications. There are several reasons for this:

- The requirements for wireless LANs, MANs, and WANs are so diverse that it is not realistic to think there will be a merging of technologies.
- There is no one dominant player in the wireless industry that can dictate the standard. Ericsson, Motorola, AT&T, the cellular operators, and the paging networks are each strong enough to build and maintain a market share.

A variety of choices and standards is not at all a bad thing. It may lead to some initial confusion as users and developers sort out the options, but in the end the users benefit from a more diverse set of features and capabilities. There will always be varying requirements for mobility, coverage area, international access, throughput, and data volume. There are also very likely to be more choices and competing standards, rather than less, by the turn of the century as the acknowledgment paging, digital cellular and PCS networks evolve.

2) Much like current software products that appear in DOS, Windows, and Apple flavors, most major applications aimed at the mobile user will support the leading wireless network options. This is certainly true today with RadioMail™ offering messaging services through RAM, ARDIS, and eventually some of the CDPD operators. OIM is another such example.

In addition, with the middleware solutions currently under development, the applications will only have to be written to Winsock or a standard API.

3) Wireless standards will migrate internationally. As GSM has done for cellular voice, MOBITEX has become the *de facto* mobile data standard in Europe and continues to migrate through Asia and the Western Hemisphere. MOBITEX networks are being initiated at a rate of two-to-three per year, with the MOBITEX Operators Association performing the role of administering the open interface specifications to assure the continued compatibility and stability of the standards. International roaming and messaging has already been demonstrated.

RD-LAP has, to a lesser extent, migrated internationally, and has the Motorola WorldWide Users Group working on interoperability issues. CDPD has less opportunity for international acceptance since it is specifically designed for AMPS. The digital standards including GSM, IS-54 (TDMA), and IS-95 (CDMA) all have plans for some packet data capabilities, making CDPD less attractive. MTel and Metricom are also marketing their technologies overseas.

4) There will be limited interoperability between *similar* wireless networks. Each current mobile data system operates in a different part of the spectrum, uses different protocols, and has similar coverage strategies. Therefore, there would be limited benefit and considerable cost to build multi-mode access devices. Instead, interoperability between mobile data services will occur primarily through gateways [13], or between networks with different service strategies and/or performance objectives, e.g., mobile satellite with MOBITEX.

***Much like current software products that appear in DOS, Windows and Apple flavors, most major applications aimed at the mobile user will support the leading wireless network options.***

### References


[1] RAM Mobile Data System Overview, Release 5.2, RMDUS 031-RMDSO-RM, Oct. 1994.
[2] "Mobile Computing 'In Brief,'" *Communications Week*, Nov. 7, 1994, pp. 47.
[3] Proc. Wireless Data Conference and Exposition, Santa Clara, CA, Oct. 14, 1992.
[4] RD-LAP Specifications, Motorola.
[5] Yankee Watch White Paper on Wireless/Mobile Communications, vol. 2, no. 8, June 1994.
[6] W. C. Y. Lee, "Data Transmission via Cellular Systems," Proc. 43rd IEEE Vehicular Technology Conference, Secaucus, NJ, May 18-20, 1993, pp. 778-787.
[7] Cellular Digital Packet Data System Specification 1.0, July 19, 1993.
[8] B. Davis, "Airtouch Offers Modem Pooling," *Communications Week*, Oct. 31, 1994, pp. 37.
[9] Company Facts & System Architecture provided by Destineer Corp., Dec. 1994.
[10] S. Hamm, "Mississippi Megahertz," *PC Week*, July 26, 1993.
[11] "Analysis of Metricom, Inc.," Pennsylvania Merchants Group Ltd., March 24, 1994,
[12] PCCA XSTD-101 Specification, "Data Transmission Systems and Equipment - Serial Asynchronous Automatic Dialing and Control for Character Mode DCE on Wireless Data Services."
[13] J. Schwartz, "Wireless Network Offerings Remain Proprietary for Now," *Communications Week*, Sept. 19, 1994, pp. 53.


### Biographies


JOHN A. KILPATRICK [M '86] received his B.A. in applied mathematics from Gordon College in 1978 and an M.S.S.E from the University of Lowell in 1981. He started his career at Raytheon working on the Patriot command and control system. He spent the next eight years at Signatron, working in such areas as satellite and meteor burst communications, radio network architectures fading channel simulators, multiple access techniques, and digital modem design. He joined RAM Mobile Data, Woodbridge, New Jersey, early in 1991 and is now director of System Technology, responsible for the planning of the evolving RAM MOBITEX system, how it is configured for optimal performance, its test and evaluation, and the analysis of competitive technologies. His e-mail address is: jkilpatrick@ram.com.

MOBEEN KHAN received B.S.E.E. and M.S.E.E degrees from Rutgers University in 1990 and 1993, respectively. He joined Wireless Information Network Laboratory (WINLAB) in 1990 as a research assistant. He joined RAM Mobile Data L.P. in 1993 and is currently a senior systems engineer in their Strategy & Technology Department in Woodbridge, New Jersey. His work includes evaluation of network technology and infrastructure equipment for RAM's MOBITEX network, optimization of network configurations, competitive analysis, and providing technical support to sales, marketing, developers, and prospective customers. His research interests include data network protocols, performance analysis of wireless systems, evaluation of personal communications technology, and radio access protocols. He is a member of Tau Beta Pi and Eta Kappa Nu. His e-mail address is: mkhan@ram.com.