Surveying the wireless landscape

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In the conclusion of this overview, we'll go over the current and emerging wireless standards. The fundamentals of wireless Wide-Area Networking technologies, such as cell-based networks, are discussed as a companion to last week's introduction to the basics of Wireless LAN standards.

Wireless technologies are currently being employed for personal, home, local, and Wide Area Networks. I'll discuss the wireless standards in these arenas, covering such topics as the frequency bandwidth, data bandwidth, range, and security solutions implemented, if any. Wireless is primarily for, but not limited to, transmitting Internet/e-mail and voice information.

Wide load, coming through!
Last week, I focused on networks that cover short distances. This time around, we're talking about wireless Wide Area Networks. A Wide Area Network, or WAN, broadens the idea of "internal" to include other corporate locations, usually across a state, country, or the world, by using telephone lines, satellite transmissions, and the like. One of the important qualities that define the value of a wireless WAN is the area the network covers -- if you can't connect, all the infrastructure in the world won't help you.

The world in the palm of your hand
Cell phone companies aren't the only wireless providers for Wide Area Networks. There are a handful of standards in use for handheld PDA devices, such as wireless-enabled PalmOS and WinCE/PocketPC devices.

Mobitex
Mobitex is the technology behind the Cingular Intelligent Wireless Network. Mobitex is a lower-speed, lower-cost solution. Cingular also operates a GSM1900 network, which will be discussed later in this article.

Standard	Mobitex
Frequency wavelength	Transmit 896-902 MHz Receive 935-941 MHz
Data bandwidth	8 kbps
Security measures	Modulation is a modified GMSK type
Best suited for a specific purpose or device type	Handheld devices with near-100% availability

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Devices currently using the standard	Ericsson modems and base stations, Palm.Net for PalmVII, and PalmOS devices with Mobile Internet Kit and Palm.Net services installed. Also used for Blackberry.Net
Coverage	Widely available in North America, also available internationally

DataTAC
DataTAC is a packet-switched narrowband PCS network, designed for wide-area wireless data communications. Service providers such as Motient in the United States, Bell Mobility in Canada, and others throughout the world operate 800 MHz DataTAC networks.

Standard	**DataTAC**
Frequency wavelength	806 - 825 MHz Receive Range 851 - 870 MHz Transmit Power 2.0 Watts
Data bandwidth	4.8 kbps satellite, 19.2 kbps terrestrial
Security measures	Elliptical Curve Cryptography
Best suited for a specific purpose or device type	Laptops and small handheld devices
Devices currently using the standard	RIM 950 and 957
Coverage	North America, some European coverage, Asia, and Australia

For security measures, the RIM devices employ Elliptical Curve Cryptograpy in hardware. The RIM Enterprise Server employs Triple DES key authentication, with the key changing once every month by default. A new key can be generated more frequently by either automation or manual requests.

CDPD
CDPD started out as a pure packet data standard, but developed into a hybrid. In its pure form, it's a packet data solution. Remembering that the biggest asset a telecom has is its installed network, the designers of the standard made CDPD function on AMPS, a circuit switched non-digital cellular phone network. As a hybrid, it has the ability to switch between packet data and circuit-switched data transactions.

In the event that the user can't establish a CDPD connection, or the network can't find the user's IP address on the network, the circuit-switched technology maps the end user's address against a modem's AMPS terminal telephone number and attempts to send the call transparently through a cellular modem bank to its destination. The biggest backers of CDPD are AT&T Wireless and Verizon.

Standard	**CDPD**
Frequency wavelength	800-900Mhz
Data bandwidth	19.2 kbps
Security measures	Elliptical Curve Cryptography
Best suited for a specific purpose or device type	Palm, PC cards, TDMA WAP phones
Devices currently using the standard	Palm, PC cards, TDMA WAP phones
Coverage	Large North American availability

Ricochet
Metricom owns the Ricochet standard, which they sell service to, and allows resellers to sell service to the network. The current devices are an external modem that connects to a laptop, and a PC card -- that's for

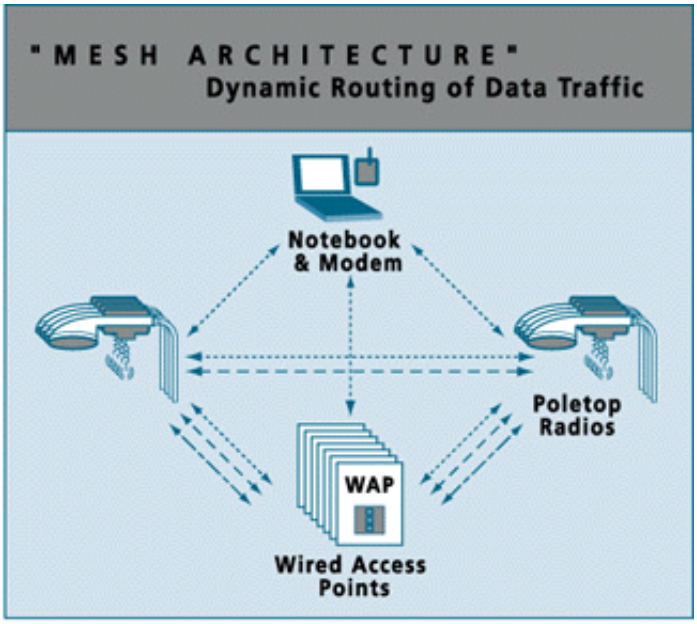
users who don't like lugging an external modem about and who can afford to spend the higher price that the PCMCIA card carries.

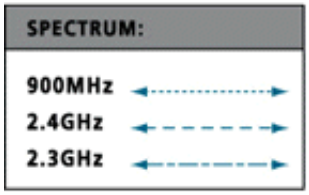
Standard	**Ricochet**
Frequency wavelength	The 900 MHz band and the 2.4 GHz band in addition to the licensed 2.3 GHz Wireless Communications Systems (WCS) spectrum.
Data bandwidth	128 kbps
Security measures	Frequency Hopping Spread Spectrum
Best suited for a specific purpose or device type	All work with a variety of PC, Macintosh, and handheld devices. They use USB, standard serial and PC Card (PCMCIA)
Devices currently using the standard	Metricom's external Ricochet modem, and PCMCIA card
Coverage	

According to the network overviewof Ricochet (see Resources):

> "The basic structure of the Ricochet network consists of microcell radios strategically placed every quarter to half mile in a checkerboard pattern. This 'mesh' architecture routes data traffic between the modems and the Wireless Access Points. A higher density design like this ensures the safe, efficient transmission of data, and better indoor penetration of the radio signals. It also offers the reliability and handoff capability necessary to eliminate dropped connections, even when moving.
> "Our mesh architecture provides advantages over the more typical network topology, known as the star topology, in which all communications are required to pass through one or more central base stations or hubs. In this system, congestion and impaired signal communications resulting from weak signal strength are generally addressed by installing another hub, typically a costly and time-consuming process. With the Ricochet network, we can reduce system congestion and increase network coverage and capacity by installing one or more relatively inexpensive poletop or wired access points where needed."

The best way to illustrate this topology is with a picture taken from Ricochet's Web site:





Creating networks requires careful planning, whether wired or wireless. Each system has its own requirements and equipment. With Ricochet networks, wireless access points are strategically placed within a 10- to 20-square-mile area, and collect and convert the radio frequency packets into a format for transmission on a local wired IP network. All access points in a region are connected to the local Network Interface Facility (NIF). The NIF's house gateways that link the Ricochet wired network to the Network Operations Center (NOC) and other major networks of Metricom's channel partners. Two NOCs serve the entire Ricochet system, simultaneously splitting the load across the country. If one of the NOCs needs an upgrade or experiences an outage, the other NOC will take over all traffic.

Phoning home

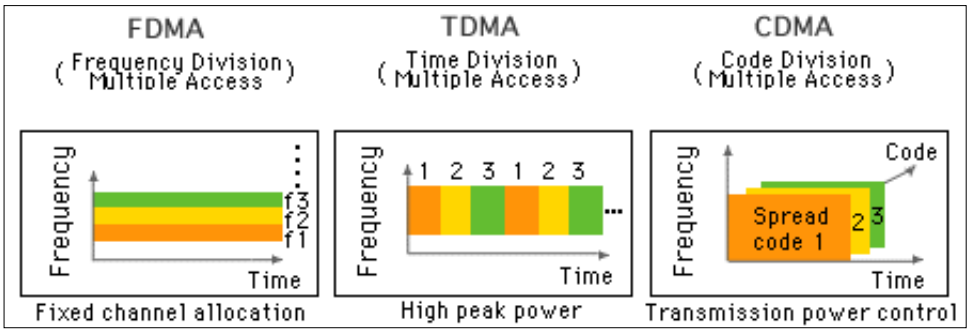
Many of the wireless services being sold involve passing data over mobile phone technology. North American companies are divided between using CDMA, TDMA, and GSM1900. Europe and Africa rely on GSM900 and GSM1800. The Middle East has CDMA, TDMA, and GSM900 networks. Japan is dominated by NTT DoCoMo's iMode and PHS.

Even where the same type of network is being employed, the frequencies from continent to continent aren't guaranteed to be the same. For manufacturers, this means another marketing niche to fill -- the World Phone. However, most manufacturers make wireless devices that aren't dual-band or dual-mode, the exception being phones that have PDA or browser functionality incorporated in the handset.

Much of the existing systems in place are packet networks that carry data only, as opposed to networks that are circuit-switched and carry voice and data alike. As more mobile phones become data-enabled, and incorporate e-mail, browsers (WAP or otherwise,) and PDA features, circuit-switched networks may outnumber packet networks.

The following tables explain the differences between FDMA, TDMA, and CDMA in such a clear manner that I am compelled to include them. They are from NTT DoCoMo's Web site (see Resources):

Multiple access



Item	FDMA	TDMA	CDMA
Frequency use	Frequency reuse according to interference	Repeated use of same frequency based on interference	Same frequency use
Transmit mode	Continuous transmission	Burst transmission (mobile station) Continuous transmission or burst transmission (base station)	Continuous transmission
Handling of different transmission rates	Difficult (use of multiple carriers) Equalizer, interference suppressor necessary for higher transmission rates	Easy (use of multiple slots, variable slot length)	Easy (use of multiple codes)
System characteristics	Equalizer, interference suppressor necessary for higher transmission rates. Control channels (downlinks) generally need to be synchronized.	Equalization and interference suppression needed as the degree of multiplexing increases.	With DS-CDMA, control of transmission power is essential, RAKE reception for enhanced quality and interference suppression for increased capacity are also used.
Inter-BS synchronization needed	Control channels(downlinks)	Synchronization needed	Synchronization needed for soft handover.
Example applications	Analog vehicle phones, handheld phones	TDMA-TDD:PHS, TDMA-FDD:PDC,GSM	CDMA-FDD:IS-95

CDMA

Qualcomm!, Eudora e-mail client, and cell phones. (Did this strike anyone else as an odd combination? It must have seemed so to Qualcomm, too, because they sold the phone handset division to Kyocera.) Qualcomm supplies chipsets to CDMA handset and infrastructure manufacturers around the world. Qualcomm owns patents that are essential to all of the CDMA wireless standards that have been adopted or proposed for adoption by standards-setting bodies.

Standard	**CDMA**
Frequency wavelength	800Mhz, 1900Mhz
Data bandwidth	14.4 kbps (typically set to 9600bps by most providers)
Security measures	DSSS
Best suited for a specific purpose or device type	Mobile phones, PDA-phone hybrids
Devices currently using the standard	Mobile-phones, PDA-phone hybrids like the Kyocera QCP 6035

Coverage	North America and South America, Europe, Russia, Middle East and Africa, Australia, Asia Pacific.

CDMA is a form of spread spectrum, a family of digital communication techniques that have been used in military applications for many years. The core principle of spread spectrum is the use of noise-like carrier waves, and, as the name implies, bandwidths much wider than those required for simple point-to-point communication at the same data rate. Originally there were two motivations: either to resist enemy efforts to jam the communications (anti-jam, or AJ), or to hide the fact that communication was even taking place, sometimes called low probability of intercept (LPI). It has a history that goes back to the early days of World War II.

TDMA

Time division multiplexing, or TDMA, on its own, doesn't have data other than two-way SMS. Cell phones with WAP browsers in them that are used on a TDMA network will be equipped to use TDMA for voice and CDPD for the WAP data connection. TDMA is important to note here, because it gets employed in creating what's known as GSM.

GSM

Standard	**GSM**
Frequency wavelength	400 MHz, 900 MHz, 1800 MHz, 1900 MHz
Data bandwidth	9600bps
Security measures	Spread spectrum
Best suited for a specific purpose or device type	Mobile-phones, pc cards for laptops, PDAs
Devices currently using the standard	Mobile phones, connections between mobile phones and laptops, and PDAs.
Coverage	169 countries

Throughout Europe, GSM has been allocated a specific 50 MHz of spectrum divided into transmit and receive bands. The International Telecommunication Union (ITU), which manages the international allocation of radio spectrum (among other functions) allocated the bands 890-915 MHz for the uplink (mobile station to base station) and 935-960 MHz for the downlink (base station to mobile station) for mobile networks in Europe.

Some experimentation has been done with transmitting signals in the 400 MHz range in Europe. Such a low range would allow for lower power requirements and farther range between antennae. Europe, the Middle East, and Africa use GSM in the 900 MHz. Europe also deploys GSM in the 1800 MHz range. In North America, the signals are broadcast in the 1900 MHz range. Currently, dual-band and tri-band handsets exist for world travelers. Such phones are sold by Siemens and Ericsson, to name a few.

GSM is a combination of Time and Frequency Division Multiple Access (TDMA/FDMA). This is done to conserve bandwidth. The FDMA part involves the division by frequency of the total 25 MHz bandwidth into 124 carrier frequencies of 200 kHz bandwidth. One or more carrier frequencies are then assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme, into eight time slots. One time slot is used for transmission by the mobile and one for reception. They are separated in time so that the mobile unit does not receive and transmit at the same time, a fact that simplifies the electronics.

Security:

"Since the radio medium can be accessed by anyone, authentication

Packet networks versus circuit-switched networks...

Much of the existing systems in place are packet networks that carry data only, as opposed to networks that are circuit-switched and carry voice and data alike. As more mobile phones become data-enabled, and incorporate e-mail, browsers (WAP or otherwise,) and PDA features, circuit-switched networks may outnumber packet networks.

For efficient transfer of data over radio waves, the Ricochet network, for

of users to prove that they are who they claim to be is a very important element of a mobile network. Authentication involves two functional entities, the SIM card in the mobile, and the Authentication Center (AC). Each subscriber is given a secret key, one copy of which is stored in the SIM card and the other in the Authentication Center. During authentication, the AC generates a random number that it sends to the mobile. Both the mobile and the AC then use the random number, in conjunction with the subscriber's secret key and a ciphering algorithm called A3, to generate a number that is sent back to the AC. If the number sent by the mobile is the same as the one calculated by the AC, the subscriber is authenticated.

"The above calculated number is also used, together with a TDMA frame number and another ciphering algorithm called A5, to encipher the data sent over the radio link, preventing others from listening in. Enciphering is an option for the very paranoid, since the signal is already coded, interleaved, and transmitted in a TDMA manner, thus providing protection from all but the most persistent and dedicated eavesdroppers.

"Another level of security is performed on the mobile equipment, as opposed to the mobile subscriber. As mentioned earlier, each GSM terminal is identified by a unique International Mobile Equipment Identity (IMEI) number. A list of IMEIs in the network is stored in the Equipment Identity Register (EIR). The status returned in response to an IMEI query to the EIR is one of the following:
*Whitelisted:*The terminal is allowed to connect to the network
*Greylisted:*Under observation from the network, possible problems
Blacklisted: The terminal has either been reported as stolen, or it is not type approved (the correct type of terminal for a GSM network). The terminal is not allowed to connect to the network."
-- John Scourias, Technical Analyst

instance, transmits data by segmenting and routing information in discrete data units called "packets." Each packet has its own control information for routing, sequencing, and error checking. Packets are routed from radio to radio across the wireless network. This means that multiple communications between radios can occur simultaneously. With packet-switching, a communications channel can be shared by multiple users, with each using the channel only for the time required to transmit a single packet -- typically no more than 20 milliseconds. In conjunction with frequency hopping, packet switching provides these networks with a tremendous amount of capacity.

Together with international roaming, and support for a variety of services such as telephony, data transfer, fax, Short Message Service, and supplementary services, GSM comes close to fulfilling the requirements for a personal communication system: close enough that it is being used as a basis for the next generation of mobile communication technology in Europe, the Universal Mobile Telecommunication System (UMTS).

3G
3G is the name for so-called third-generation mobile phones offering video, voice, and very fast data services over IP, the Internet Protocol. CDMA, GSM, and others have different solutions for how best to provide 3G products, and what sort of data rates they'll achieve.

GPRS
GPRS is based on a modulation technique known as Gaussian minimum-shift keying (GMSK). EDGE is based on a new modulation scheme that allows a much higher bit rate across the air interface -- this is called eight-phase-shift keying (8 PSK) modulation. Since 8 PSK will also be used for UMTS, network operators will need to incorporate it at some stage to make the transition to third-generation mobile phone systems.

Standard	**General Packet Radio Service**
Frequency wavelength	400 MHz, 900 MHz, 1800 MHz, 1900 MHz
Data bandwidth	9600bps to 115 kbps
Security measures	GMSK
Best suited for a specific purpose or device type	3G devices

GPRS is a packet-linked technology that enables high-speed (115 kilobit per second) wireless Internet and other data communications. GPRS will offer a tenfold increase in data throughput rates, from 9.6 kbps to 115 kbps. Using a packet data service, subscribers are always connected and always online. The likelihood is that GPRS will give way to EDGE, which reaches even higher data rates.

EDGE

Standard	Enhanced Data rates for Global Evolution (EDGE)
Frequency wavelength	400 MHz, 900 MHz, 1800 MHz, 1900 MHz
Data bandwidth	384 kbps
Security measures	8 PSK
Best suited for a specific purpose or device type	3G devices

To get 3G networks up and running, GSM will evolve into GPRS, and into the implementation of EDGE (Enhanced Data rates for Global Evolution). This will allow GSM operators to use existing GSM radio bands to offer wireless multimedia IP-based services and applications at speeds up to 384 kbps. EDGE will allow the advantages of GPRS to be fully explored, with fast connection setup and higher bandwidth than traditional GSM. The combination of GPRS and EDGE will also result in much improved utilization of the radio network.

Introducing EDGE will have almost no technical impact, given that it is based on GSM, and needs only small changes to network hardware and software. Providers do not have to make any changes to the network structure, or invest in new licenses. To keep things simple, EDGE uses the same TDMA (Time Division Multiple Access) frame structure, logic channel, and 200 kHz carrier bandwidth as the current GSM networks.

UMTS

UMTS is simply a standard for providing the services that make 3G so enticing. Universal Mobile Telecommunications System (UMTS), will give GSM operators the potential for a whole range of mobile multimedia services. Electronic postcards, Web surfing, access to corporate LANs, and e-mail from a mobile terminal, are just a few of the things people will be able to do from a handset. Hopefully most folks won't attempt to use these services while driving. I imagine a day will come when mobile handsets come with the same yellow caution sticker that's placed on prescription medicine: Don't operate heavy machinery while using this device!

WCDMA

Wideband Code Division Multiple Access, or WCDMA, allows very high-speed multimedia services such as voice, Internet access, and videoconferencing. WCDMA technology provides access speeds at up to 2 Mbps in the local area and 384 kbps wide area access.

Standard	**WCDMA**
Frequency wavelength	1920-1980 and 2110-2170 MHz
Data bandwidth	144 kbps at mobile speeds, 384 kbps at pedestrian speeds, and 2 Mbps in a stationary environment.
Security measures	Frequency-division duplex (FDD) operation.
Best suited for a specific purpose or device type	3G devices

These higher data rates require a wide radio frequency band, which is why WCDMA with 5 MHz carrier has been selected. Ericsson has signed a contract with Japanese operator NTT DoCoMo to deliver phones and base stations for the worldâ€™s first commercial WCDMA network. WCDMA is just one of the technologies to deliver on the promise of UMTS, and i-mode services.

cdma2000

cdma2000 is a narrowband CDMA standard. Spectrum will continue to be a scarce resource, making 1.25

MHz systems significantly more attractive compared to 5 MHz systems, as long as comparable performance can be achieved. Operators and subscribers will benefit from these systems via high speed and higher capacity packet data transport systems.

Standard	**cdma2000**
Frequency wavelength	2.1 GHz, 800 MHz, 1800 MHz and 1900 MHz
Data bandwidth	64 kbps to 144 kbps, eventually up to 2 Mbps
Security measures	QMSK, or Walsh code masking
Best suited for a specific purpose or device type	3G Devices
Coverage	Not implemented yet

Table 1 - Information Data Rate and Capacity Requirements

	Phase 1		**Phase 2**	
	Forward	*Reverse*	*Forward*	*Reverse*
Voice Capacity	N/A	N/A	N/A	N/A
Outdoor Peak Data Rate	1.25 Mbps	300 kbps	1.25 Mbps	1.25 Mbps
Outdoor Average Data Rate	600 kbps	144 kbps	600 kbps	600 kbps
Indoor Data Rate 3	2 Mbps	300 kbps	2 Mbps	2 Mbps
Fixed Indoor Data Rate	TBD	TBD	TBD	TBD

1. *Outdoor Peak Data Rate* is defined as the maximum instantaneous information data rate available to any given user in a high-speed handoff mobile application.

2. *Outdoor Average Data Rate* is defined as the system-wide average information data rate available per sector in a fully-loaded system with all users moving at vehicular speed.

3. *Indoor Data Rate* is defined as the information data rate available to any given indoor user moving at pedestrian speed.

The 1xEV standard shall be written such that system throughputs can be maximized to allow the largest possible number of users to run voice (Phase 2) and/or high-speed packet data applications. It is desired that these improvements be transferrable to IMT-2000 MC 3X in the future.

Third-generation (IMT-2000) air interfaces provide significant improvements to average system spectrum efficiency. CDMA2000 will double the voice capacity (bps/Hz) over IS-95 (the current CDMA standard in use) and will increase packet data rates by four to six times. 1xEV shall meet or exceed the CDMA2000 standard for capacity as indicated in the above table.

The debate about cdma2000 and WCDMA convergence has been based on the fact that these CDMA-based proposals have certain parameter definitions that present an opportunity for compromise. The most discussed and debated parameter is the system chip rate. WCDMA uses a chip rate value of 4.096 Mbps. cdma200 uses 3.6864 Mbps. WCDMA proponents liken the higher rate to more horse power and claim the lower cdma2000 rate degrades performance. This falsity requires clarification.

PHS

Standard	**PHS (Personal HandyPhone System)**
Frequency wavelength	800 MHz
Data bandwidth	64 kbps ISDN
Security measures	TDMA-TDD

Optimum operating range	30m-150m on in-house network- coverage in public areas in Japan
Devices currently using standard	Compact flash PHS units for handheld organizers and cell phones in Japan
Best suited for a specific purpose or device type	handheld wireless connected devices

PHS is a standard that has been employed with great success in Japan. It can be used in a public environment for high quality voice calls as well as high speed data transmission. It also has a split personality, in that it can be run in a home or office environment, and be used to digitize the cordless phones in the building. In this deployment, a regular cordless telephone can provide an extension-call capability for reaching the public PHS network. It can also be used in conjunction with the in-house LAN, and carry out communications as long the device is within range. The basic setup relies on a PBX and base station, with a range of 30 meters to 150 meters. The device for this sort of network is a kind of data terminal and has adapters to work with the in-house LAN. The device can also be used for dial-up access when in an outdoor public PHS coverage area. PHS is a TDMA-TDD based system.

Tetrapol
Tetrapol is a standard with high security capabilities, and has high compatibility with networks installed around the world, both digital and analog. It allows transmission via UDP of long datagrams (downlink in connectionless) with notification. It allows Broadcast without notification (Connectionless, point to point or multipoint), which lends it self to short message service, file consultation, of up to 1.5 Kbytes.

TETRAPOL optimizes the data throughput: The network behaves like an IP router, in that the application can choose a protocol over an IP -- TCP or UDP. UDP is recommended for short data transmission (GPS, data base query and answer...) in connectionless mode (Datagram). TCP is used for large file transfers of more than 10 Kbytes in connected mode; the level 2 correction feature has to be complemented by level 4 mechanisms for large file transfers.

Standard	**TETRAPOL**
Frequency wavelength	70 MHz - 933 MHz
Data bandwidth	
Security measures	FDMA access, GMSK modulation at 8 kbps, as well as end-to-end encryption, authentication of users, SIM personal file and storage, Automatic Key Management as OTAR, Detection of Intrusion, and Data integrity.
Best suited for a specific purpose or device type	UMTS devices, analog devices

Typical applications use very little data per second in transmission.

Messaging: 2 Kbytes, average 430 bytes.
Data base query:
- query: maximum 641 bytes;
- answer: maximum 952 bytes;

Fingerprint queries: average 500 bytes.
Picture: 2 Kbytes.
Slow-moving video: one picture every 1.5 seconds (5kbits/s).

In conclusion
These standards aren't always easy to find information on, or easy to reduce to a simple description for the purposes of this overview; many are in constant states of revision, are hundreds of pages long, and are costly to gain access to for the standards. When researching these standards, I used, whenever possible, the technical information from the standard itself. When this was difficult, I used academic papers and white papers that referenced the standard, as well as Web sites put forth by the organizations who proposed the standards. I submit that there is enough information to compose several articles about the technical details

of each standard.

Resources

- Check out the informative Developer's Guide for Blackberry on DataTAC.
- See the NTT DoCoMo's Web site.
- See this great article on CDPD, at AmericasNetwork.com.
- TeleAdaptUsa.com has a handy list of devices and networks that use the CDPD standard.
- Refer to the tables from NTT DoCoMo, which show some of the characteristics of FDMA, TDMA, and CDMA.
- Get an explanation of how cdma works, using a noise-like signal as a carrier.
- John Scourias,Technical Analyst for Bell Mobility in Toronto Canada, has two excellent articles on GSM technologies at http://www.shoshin.uwaterloo.ca/%7Ejscouria/GSM/index.html and http://www.iassid.ro/gsm/en/gsmreport.html.
- See the writings on CDMA 3G technologies under development.
- Download a PDF file describing the cdmaOne/cdma2000 technology in detail.
- See the CDMA Development Group White Paper: 3G Systems
- Read up on GPRS vs CDMA's approach to 3G.
- See NTT DoCoMo's information on PHS and other wireless technologies.
- An overview of EDGE is available from Nortel Networks.
- An overview of CDMA is available from the CDG group.
- See the CDMA Development Group White Paper: 3G Systems
- The WebSphere Everyplace Suite SDK allows you to create and test wireless applications.
- Visit the IBM pervasive/wireless home page for links to wireless development solutions.

About the author

L. Victor Marks works at IBM, and enjoys hands-on experiences with wireless technologies. He is currently using an 802.11b network at home and looking to introduce Bluetooth and other emerging technologies. He spends the rest of his time restoring a 1962 Chevrolet Impala. He happily responds to e-mail at lvmarks@us.ibm.com.