HIGH-SPEED, NO-WIRES INTERNET ACCESS: HERE'S HOW.

Wireless network's fast, on-the-go access makes waves

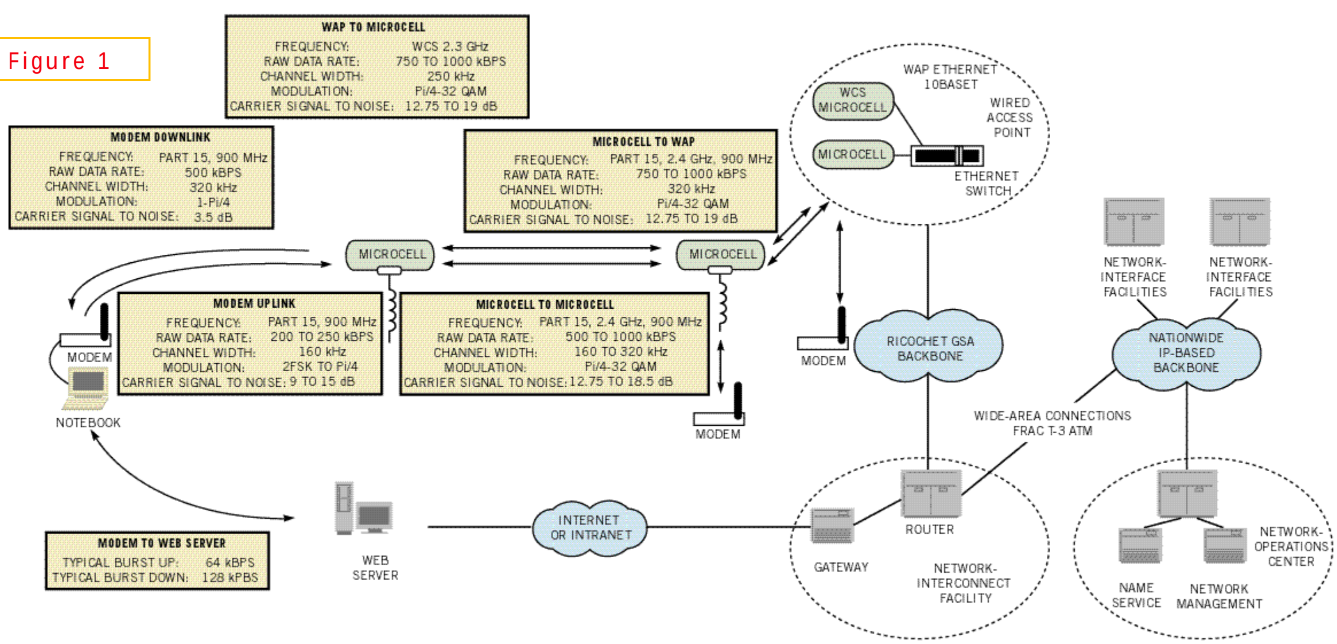
By Brian Dipert, Technical Editor

Imagine for a moment what your next system design could do if it provided wireless-network access via detachable PC Card, USB (Universal Serial Bus) or serial modem, or fully integrated chip set and antenna. Now imagine that the system provided:

- 128-kbps downloads and 64-kbps uploads for 80% of stationary users and two to three times that speed under best-case conditions;
- guaranteed 28.8-kbps download speeds, even when the system containing the modem is moving as fast as 70 mph;
- reliable communications between modems and radios at typical line-of-sight distances of 10 miles or more with unreliable interaction extending to eight times that distance;
- 128-kbit service in 14 coverage areas, representing 35 million people throughout the United States, with 28.8-kbit service in two other areas and 25 airports with dedicated service; and
- monthly flat-rate service charges of less than $70, particularly attractive for mobile users who also employ the network as their high-speed Internet-service provider at home.

Do you think that I'm dreaming, depicting a *Jetsons* cartoon rerun, or describing some perpetually delayed 2.5G or 3G digital cellular phone protocol? Actually, this technology was, until recently, available in the form of Metricom's (www.metricom.com) MicroCellular Data Network (MCDN), better known as the Ricochet network (Figure 1). Metricom is undergoing Chapter 11 bankruptcy-auction proceedings. The network is at least temporarily offline, but the company's financial woes stand in stark contrast to its technical achievements. (For more information, see sidebar "Hands-on happy

Figure 1



The MicroCellular Data Network employs a combination of wired and wireless technologies, and Metricom designed it with mobility in mind.

memories" at the Web version of this article at www.ednmag.com.)

The MCDN comprises one wireless modem per network client, arrays of mesh-topology, pole-top MicroCell radios, WAPs (wired access points), a network backbone that interconnects WAPs, a name service, a network-management system, and gateways (Figure 2). Low-cost, pole-mounted MicroCells communicate both with other MicroCells and with multiple WAPs (Figure 3). MicroCell density is usually five to six per square mile but can range as high as several dozen per square mile in areas of high user concentration or when necessary to surmount signal interference and sources of reflection, such as in crowded cities. WAPs are located every 10 to 20 square miles. Gateways strip the Ricochet protocol from IP (Internet protocol) packets headed beyond the MCDN and add MCDN information to incoming packets.

HIGH FREQUENCY; HIGH SPEED

Metricom's original wireless network, Utilinet, transferred data at 9600 bps. Both it and the follow-on 28.8-kbps first-generation Ricochet network operate exclusively within the unlicensed 902- to 928-MHz ISM (industrial, scientific, and medical), or "900-MHz," portion of the radio spectrum, with its requirements of less-than-1W transmission power and spread-spectrum physical layers. Both of these FCC regulations enable numerous broadcasting and receiving devices to coexist within the band, because the emissions of one appear as background noise to any other. Ricochet employs the frequency-hopping spread-spectrum technique, which arguably delivers lower throughput than the alternative direct-sequence approach. However, Metricom claims that you can use frequency hopping over longer distances than the direct-sequence approach supports. Two frequency-hopping radios talking to each other consume less than 1% of the available frequency spectrum at any time, and the pseudorandom frequency-hopping pattern across 50 upstream and 50 downstream channels in the 900-MHz band and 256 channels in the 2.4-GHz band provides transmission security.

With second-generation, 128-kbps Ricochet, transmissions between modems and MicroCells continued using the 900-MHz band to preserve backward compatibility and enable better building penetration. MicroCell-to-MicroCell intercommunication, as well as one-way communication from MicroCells to WAPs, migrated to the unlicensed 2.4- to 2.484-GHz ISM band. As a result, MicroCells became full-duplex, thereby delivering part of the generation-to-generation bandwidth speedup. Doubling the downstream-channel bandwidth to each modem in conjunction with an expanded set of modulation schemes provides the remaining performance increase (Table 1). First-generation Ricochet employed only GFSK (Gaussian frequency-shift-keying) bit encoding with a deviation of 70 kHz in a 160-kHz channel, HDLC (high-level-data-link-control) symbol encoding, and a 100-kbps transmission bit rate. Second-generation Ricochet also uses the licensed WCSs (wireless-communications-system) spectrum at 2.305 to 2.310, 2.315 to 2.320, and 2.345 to 2.350 GHz, accessible in roughly three-quarters of the United States, for optional one-way communication from WAPs back to MicroCells. The advantage of WCS is that it allows higher-power transmissions and, hence, longer distances between WAPs and nearby MicroCells.

TABLE 1—PHYSICAL-LAYER MODULATION SCHEMES

Modulation	Symbol rate (kbps)	Signaling rate (kbps)
FSK	100	100
4-FSK	100	200
8-FSK	100	300
QPSK	250	500
16 QAM	250	1000
32 QAM	250	2000

Figure 2

(a) (b) (c)

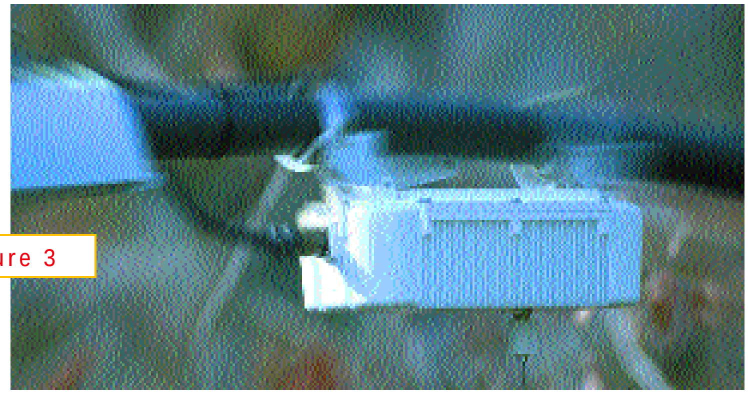
USB, serial (a) and PC Card (b and c) modems provide a variety of connectivity options (a, b, and c courtesy Metricom, Novatel Wireless, and Sierra Wireless, respectively).

how it works

Why did Metricom go to the expense of building a new wired and wireless network versus simply piggybacking a system onto the telecommunication-system infrastructure as cellular-service providers do? The reason is that cellular systems target voice services, which require minimum-delay bit delivery but tolerate high bit-error rates. Data services, in contrast, require low bit-error rates but, with the possible exception of streaming media, are forgiving of higher request-to-response delays. Ricochet also employs a packet-based rather than a circuit-switched approach. Packetization allows for as-needed interspersion of traffic from multiple devices on a single link, rather than wasteful preallocation of bandwidth that may end up unused. This approach, at an average of 500 bytes per packet, matches well the characteristics of data networks, where traffic to and from any one node tends to be "bursty" and have a low duty cycle (Figure 4).

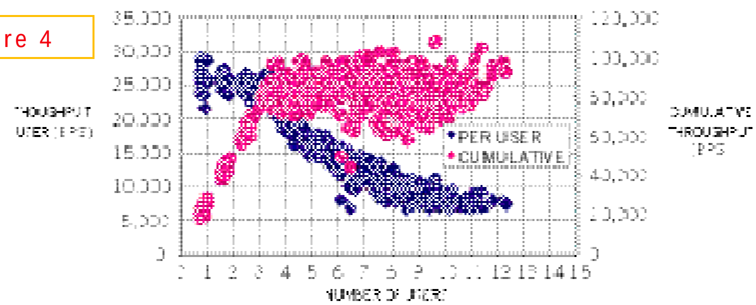
Other advantages of a packet-based network include a continuous network connection that consumes minimal network resources and the lack of a lengthy sign-on procedure. For these reasons, Ricochet competitors, such as CDPD (cellular digital-packet data), HSCSD (high-speed circuit-switched data), and GPRS (general packet-switched-radio service), as their names imply, are also migrating to packet-centric techniques that treat voice as just another data type. Existing competitors deliver much lower speeds than Ricochet, though, whereas those of the future are as yet unproved and have steadily slipping rollout schedules.

Figure 3



MicroCells are a low-cost, easily expanded means of ensuring sufficient network coverage (courtesy Metricom).

Figure 4



Packet-based networks are bandwidth-efficient for bursts of low-duty cycle data services (courtesy Metricom).

MOBILITY IS PRIMARY

When a new user logs onto MCDN, the registration packet it generates records the addresses of every MicroCell, WAP, and gateway the packet traverses on the way to the name server. The name server archives this path data, indexed by the user's MAC (media-access-control) address. Subsequent information exchange between users begins with a look-up packet that the initiator generates. The name server responds to this packet with routing information that combines the registration paths of the requesting and looked-up entities. All network entities monitor—and any network element can modify—this routing information, which the headers of subsequent data packets contain. Therefore, packet interchange remains possible even as both the sending and receiving entities roam throughout the network. Mobility of network entities, particularly when *both* communicating entities are roaming, creates routing overhead, which degrades performance compared with a static approach (Figure 5).

Keeping in mind that MicroCells can communicate both with each other and with multiple WAPs, the MCDN coordinates three types of "handoffs" in response to intranetwork movement. The first approach, instantaneous MicroCell handoff, assumes that a modem can "hear" multiple MicroCells. If the modem moves between the time it sends a look-up-packet request and it receives routing information back from the name server, it can update this routing information with the new MicroCell address before subsequently sending—or sending requests for—data packets. If the modem can no longer communicate with the old MicroCell, the network relies on the fact that, coincident with the modem's move, it sent the old MicroCell a route-forwarding message telling it where to redirect any packets it might receive. The old MicroCell holds forwarding addresses in its cache for a time exceeding the round-trip time of most packets before it "ages" them out.

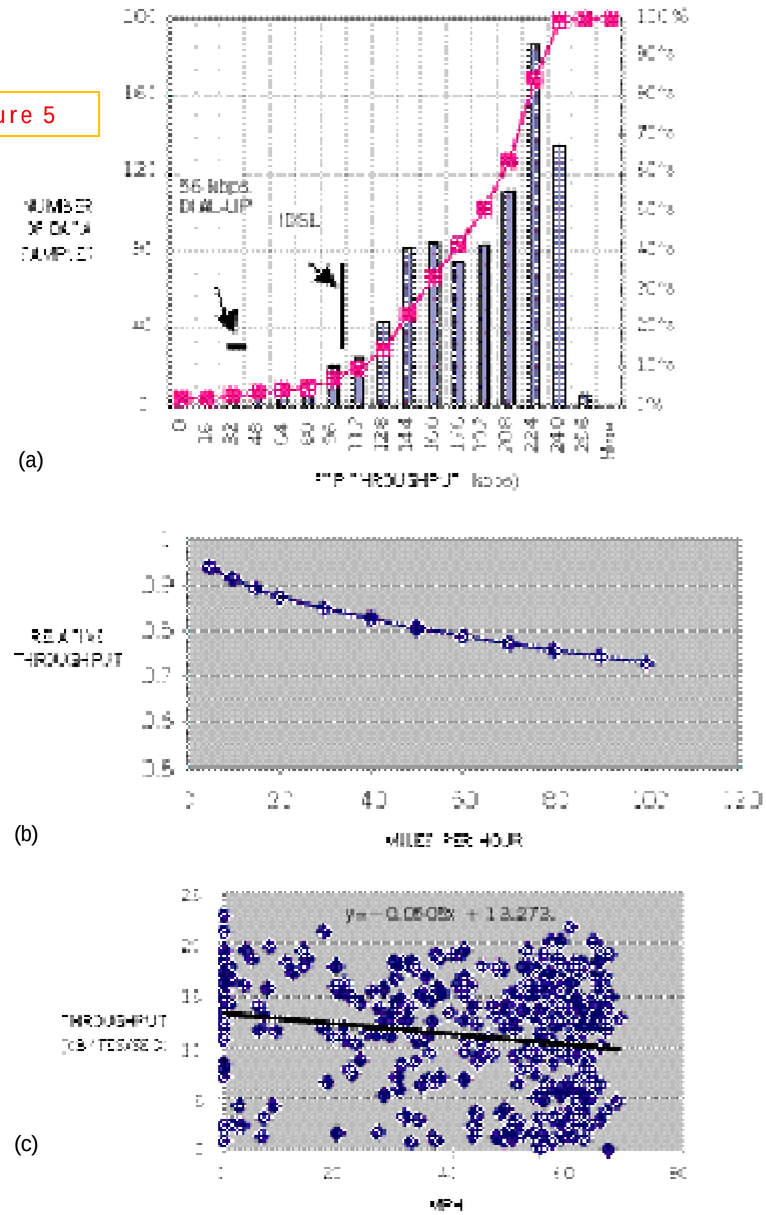
Eventually, a modem moves far enough in the network that the best path into the wired-network backbone is not through the original WAP. In this case, the MicroCell, not the modem, modifies the packet-return address to a more appropriate WAP, executing a function analogous to the one the modem performs in the "instantaneous-MicroCell-handoff" example. When routing between any two entities, the wireless network employs both geographical- and latency-based algorithms. Geographical algorithms take advantage of the fact that each MicroCell knows the longitude and latitude of all adjacent MicroCells, and self-configuring latency-based algorithms constantly update themselves, based on hop delays between each MicroCell and the closest WAP. With both the geographic and the latency algorithms, the MicroCell builds a scan table of the next-best MicroCells available, both to handle instantaneous load bursts and to route around MicroCells that are offline due to maintenance, random interference, and other problems.

FUTURE PLANS

Assuming that Metricom successfully resolves its current financial woes or that another company with the motivation of investing in Ricochet acquires it, two performance upgrades are on the future technology road map. The first, a near-term software upgrade to MicroCells and WAPs in conjunction with next-generation modem technology that Metricom is developing in partnership with National Semiconductor (www.national.com), will double the download speeds of today's 128-kbps system. Also, Metricom has successfully completed laboratory trials of an additional 10-times-speed-improved third-generation MCDN. This scenario requires both modem-and network-infrastructure upgrades: modem-to-MicroCell links would move to the 2.4-GHz unlicensed band, and MicroCell-to-MicroCell and MicroCell-to-WAP links would use the 5.75- to 5.875-GHz band.

I don't have the space here to cover topics such as the interaction between MCDN and other broadcast technologies in the 900-MHz and 2.4-GHz bands, MCDN's packet-header specifications, its encapsulation of other protocols' packets and encryp-

Figure 5



Of static users, 80% will experience 128 kbps or higher download speeds on the second-generation Ricochet network (a), and predicted speeds while in motion (b) agree with measured data (c), albeit with wide variance among users (courtesy Metricom).

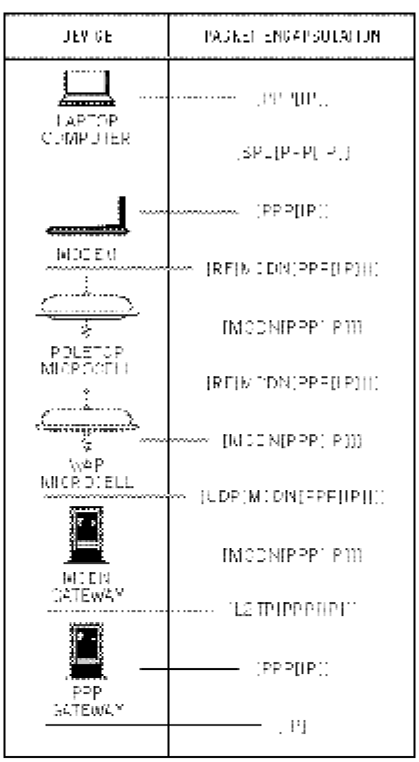


Figure 6

Metricom's layer-encapsulation approach comprehends numerous other network protocols, as well as data-security schemes, such as virtual private networks (courtesy Metricom).

tion schemes, and network-entity discovery, registration, and frequency-hopping synchronization (Figure 6). For more information on those topics, as well as other predicated and measured data on network performance as a function of distance, speed, topology, interference, and user load, see references 1 to 5.□

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Author's biography

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WEB ONLY

HANDS-ON HAPPY MEMORIES

While traveling on business in Silicon Valley, my often-rustic overnight accommodations don't enable me to access the Internet over an analog modem. En route to and from the Valley, I also favor the traffic-avoiding and environment-embracing Amtrak (www.amtrak.com). You can probably see, then, why high-speed wireless-Internet access is one of my long-time interests. The first technology I tried, GSM (Global System for Mobile communications) data services over my Pacific Bell (www.pacbell.com) cellular phone, was fraught with negatives: high connect charges, unreliable service, and best-case downloading speeds of 9600 bps and typical speeds of 4800 bps or less.

Until Metricom's recent demise, I used a combination of CDPD (cellular digital-packet data) via a Sierra Wireless (www.sierrawireless.com) PC Card modem and GoAmerica's (www.goamerica.net) service and Ricochet, through Wireless WebConnect's (www.wwc.com) service. CDPD's primary advantage is coverage; I can access the Internet the entire time I'm on the train between Sacramento and San Jose. CDPD downloading speed is also consistent even when the train is moving at high velocity, and the Sierra Wireless card looks like a LAN adapter to my notebook PC. But, with download speeds only approximately two times faster than those of GSM, I still grit my teeth whenever I get an e-mail with a large file attachment or access a graphics-intensive Web site.

Once I moved within the MCDN coverage area, just north of Berkeley, CA, I switched to my Ricochet modem. With the train at full speed, my network bandwidth was only about twice as fast as CDPD. It was fascinating to see downloads dramatically accelerate when the train pulled into a station and came to rest. And, once I reached my destination, as long as I was static and had access to a strong network signal, I could easily double the advertised 128-kbps download speeds. If I lived in the San Francisco Bay area, I would have probably used Ricochet and Wireless WebConnect as my exclusive Internet-service provider, both at home and on the road. My $50 DSL (digital-subscriber-line) service, albeit roughly four times faster (when the server on the other end of the connection isn't the bottleneck), would have been redundant and hard to justify.

I've successfully used both the Novatel (www.novatelwireless.com) Wireless Merlin and Sierra Wireless AirCard 400 modems for Ricochet. The Novatel device employs AT modem-command strings and Windows 98's Dialup Networking, and the Sierra device, like its CDPD equivalent, acts as a LAN card. If I had to pick a favorite, it would be the Sierra AirCard 400, mostly because my notebook PC has faulty power management and crashes Dialup Networking after I put it into sleep mode until I reboot. As long as I keep the AirCard 400 installed when I put the notebook PC in standby mode, it continues to work after I reawaken the PC. The AirCard also has a convenient detachable antenna.

Enfora (www.enfora.com) makes a PocketSpider CDPD modem for my Compact Flash slot-equipped Casio E-125 Pocket PC, but I've had no luck finding a Ricochet equivalent (see "Pick Pocket," *CommVerge*, April 2001, pg 58). Despite sampling multiple null-modem adapters, I couldn't successfully log onto the Ricochet network using the GS USB/serial modem (www.wwc.com/techsupport/install-CE20-serial.htm). And, although Novatel Wireless makes a Windows CE driver for my Casio's MIPS (www.mips.com) CPU, and the Casio "saw" the modem through the CompactFlash-to-PC Card adapter, the system locked up whenever the modem powered up to look for a valid network connection. Novatel Wireless suspects excessive current drain; they've been able to make it work with Compaq (www.compaq.com) iPaq Pocket PCs, whose PC Card module has its own power supply. I guess I'll have to wait not only for the Metricom network resurrection, but also for National Semiconductor's low-power, highly integrated chip set to appear.