GILDER
TECHNOLOGY
REPORT

December 2006 / Vol. XI No. 12

The Suits and the Cowboys

Wi-Fi builds for volume and WiMAX builds for performance. We have seen this before in the battle between PCs and workstations. Volume wins.

Inside:

It's the Suits versus the Cowboys in the battle for your wireless future.

The Suits are the cellular carriers; the Cowboys are entrepreneurs implementing the IEEE's (Institute of Electrical and Electronics Engineers) 802.xx protocols. The Suits bring zillions of dollars in wireless infrastructure, a long operating history, a huge base of captive customers, thousands of roaming agreements, and vertical integration of systems, software, and services. The Cowboys bring…uh, they bring…uh…well, they'll improvise. My money is on the Cowboys. The battle replays minicomputers and PCs. The minicomputers were the Suits. The PCs were the Cowboys. PCs won handily. Here's the story for wireless.

My office and my house are in the middle of nowhere. I'm at the end of 1.7 miles of pavement, on a ridge that sticks out between a couple of taller ridges. There are good views from my property, but there's no clear view to geosynchronous satellites, to heavily populated areas, or to ridges with repeaters. There's no cable TV and no phone company central office within five miles. Around here, fiber is a word on cereal boxes.

This is not a good situation for a technology analyst in Silicon Valley, so I have been

(CONTINUED ON PAGE 3)

FEATURED COMPANY: Power-One (PWER)

What's Impeding Digital Power?

Rallying the beleaguered faithful at the Gilder/Forbes Telecosm Conference in October, Power-One chairman, Steve Goldman, reminded us why digital power is inevitable and why his company—a middling 30-year-old supplier of power conversion products to the communications industry—should reap a goodly portion of the coming windfall.

His trump card is the rule of Moore's law in digital silicon—as line widths shrink, chip currents rise and voltages fall. Systems houses, in turn, are putting more and more chips on each circuit board, which now require not only more voltages, but also lower voltages, higher currents, and better efficiencies. Regulating and managing power on these complex boards is becoming problematic for traditional analog solutions, which typically require one hard wire per function; if you have 30 power-related functions, you often have 30 wires, a lot of interface, a lot of complex circuitry.

Fortunately, Moore's law solves the problem it is creating. In analog, where Moore's law doesn't apply, die size shrinks about 30% every four to eight years. On the digital side, die size shrinks 100% every eighteen months, creating huge economies as chips get smaller and denser and include more functions at lower costs. Using rapidly shrinking digital technology, engineers can design power modules in 10% of the time with 90% fewer components compared to analog. And changes can be made on the fly using a graphic interface, avoiding the costly reengineering and re-layout mandated by fixed analog.

Power-One understood the advantages of digital early on and remains the only company with a complete digital-power solution. Using his Z-One technology, Goldman is already giving his rivals heartburn. For instance, a power unit he developed for a large server company improved efficiency from 89% to 93%, thereby reducing electrical costs per server by $1,400 every three years, rendering the power supply essentially free compared to a competing solution.

So, where's the mullah?

That's what we asked Goldman. If digital power is so paradigmatic, why are sales for the first nine months of this year up only 12% over the same period last year and an even smaller 6% over the same period in 2004? (And why were frustrated investors, many eyeing Goldman at Telecosm, wondering if their shares would ever return to the $10 price of two year ago or the $14 peak hit a distant three years ago.)

Goldman gave them three reasons for the digital delay, beginning with the bane of protracted product lifecycles that afflicts many of our telecosm innovators looking to break into the big systems houses. Consider, for example, that a multi-gigabit switch may take three to five years to develop and may last five-years in the field. If the manufacturer introduces a major new technology that requires him to completely redesign his boards, and it doesn't work, he could lose a generation of sales. Due to their complexity and cost, high-end systems are most in need of digital power, and vendors of these products are most able to justify the expense and pay the price. Yet they are resisting the technology, as they do all paradigm shifts.

Adding to this inertia are the gatekeepers who approve new power management technologies. They are all analog engineers, steeped in the ways of linear technology over their long careers and unchallenged by junior colleagues trained as they were. (According the Goldman, digital power has yet to be discovered at the at the world's universities, a remarkable lag that may last until systems vendors begin asking for digital graduates and start funneling grant money into the new field.) Power conversion has been analog since Adam and these authorities will be the last to bring down a generation of products with a novelty destined to make them look like novices.

Once Goldman picks up a hard-fought contract, he must completely redesign his customer's board-level power architecture and wait the cycle before revenues roll in—assuming the system sells. Of course, the bane of the product cycle becomes a bounty for Goldman once Z-One is designed into a system, erecting a lofty barrier to entry for digital latecomers who must now endure the same competitive process.

Goldman blames himself for the third impediment to digital power. Seems he jumped so far ahead of his competitors that potential customers can't find second sources or standardized products, increasing yet further their insecurity as they lack the muscle to drive down prices through competition or the assurance that their products will interoperate with future power architectures.

We believe this final "hurdle" is ultimately good news and a sign of Goldman's triumph—unless someone can point us to a disruptive revolution that has been supported by all the established companies and that began with many potential, standardized sources. Goldman, not lately in the habit of fostering competition, obviously agrees with us. Last year, when rival Artesyn introduced a digital point-of-load (POL) regulator, he promptly sued and the product never emerged. Artesyn has since been acquired by **Emerson** (EMR), against whom Goldman continues his litigation.

Several months ago, **Silicon Labs** (SLAB) capitulated in its own lawsuit with Power-One by recognizing some of Power's broad patent claims. Joining **Atmel** (ATML) and **C&D Technologies** (CHP), Silicon also signed onto Power's Z-Alliance after disembarking from the competing digital power group, the PM-Bus Alliance. Goldman expects that Z-One will ultimately prevail as the industry standard over the PM-Bus protocol, which has yet to claim a product.

The *real* risk

We add to Goldman's list a possible fourth holdup for Power-One—its recent acquisition of Magnetek's power electronics group with products ranging from digital microcontrollers for motors to 50 kilowatt (kW) converters and including a custom ac-to-dc business which will enable Power to compete head-on with the big three—**Tyco** (TYC), Emerson, **Delta Electronics**. The custom market is more than twice as large as the standard ac/dc market and is growing twice as fast. Lately, Power has been turning down big custom jobs in the $5m range because it lacks both the facilities and engineers needed for this work.

The acquisition solves both of these problems; with Magnetek's power group comes a cast of top custom engineers supported by a low-cost custom-manufacturing facility in China. Since only a third of the Chinese plant is equipped, room to grow is substantial. Goldman has already ordered more equipment, needed "immediately" to service Power's existing customers, including **Cisco** (CSCO) and large storage vendors, as well as new customers added through Magnetek, such as **IBM** (IBM), **Google** (GOOG), **Siemens** (SI), **Motorola** (MOT), and **Alcatel** (ALA).

The purchase, which will raise Power's revenue by more than half and catapult it to the sixth largest power supply company in the world from sixteenth, is the potential snag that really concerns us. Major acquisitions are hard for the best companies, and Power-One has left a trail of operational missteps and missed goals, such as the recent earnings shortfall caused by a fumbling contract manufacturer. Power spent most of the second quarter identifying and solving the problem, only to follow with a significant slip in gross margin during the third quarter, coming up short at 32.7% compared to the 34% management had expected.

Now management must restructure and integrate big time while ramping challenging new technologies and products. Power-One paid Magnetek $88m for the division, reversing its balance sheet fortunes from $78m of net cash in the third quarter to some $16m of net debt in the current quarter. Our guesstimate excludes the impact of cash drain for restructuring, which is expected to depress gross margin to the upper 20s and kick operating expenses north of the lower 20s as a percent of revenue. Long term, gross margin is expected to gradually recover to the low 30s and operating expenses to the low 20s of sales.

Based on the foregoing estimates, operating margin is unlikely to exceed 5% next year, when Power is projecting revenue to hit $540m. The resulting earnings of 30 cents per share yields a forward price-to-earnings multiple of 24 at the recent stock price of $7.20—a full valuation for many well-run companies. However, if Power achieves its long-term goals by 2008, operating margin would hit 10% that year and sales would grow by 18% to $637m for earnings of 72 cents at today's share count. Based on a growth PE of 30, the stock would triple to $21.60.

Hold on. Before you grab more shares of Power-One, remember that the company has often fallen short of its goals and that skeptical investors have tended to depress its market valuation. Thus, think of this growth scenario as the high-end upside in the two-year timeframe.

Patience should pay off

But that's only the beginning. Power-One is a long-term play on a fundamental innovation that will not pay off until the end of the decade and beyond. That's been our rallying cry for two years and we're sticking by it. Goldman's ruminations on speed bumps and dinosaurs were nothing new to long-time GTR subscribers still waiting for **EZchip** (LNOP) to hollow out the router and for **Altera** (ALTR) and **Xilinx** (XLNX) to out flex ASICs.

Meanwhile, we will closely monitor the Magnetek mega acquisition for signs that it is becoming a serious distraction. Ultimately, the purchase may prove very positive for Power's digital products by creating a larger, more influential, more credible company. Digital power can apply to any industry, and Power now reports over 70 design wins, some with tier-1 vendors, spanning applications from wireless, networking, telecom, and test equipment to aerospace, aviation, and computing. Some of the newfound digital customers are bringing additional business to Power's traditional product lines, including high-volume wins with the likes of large server and storage companies.

Now, look for Magnetek's customers to do the same for Power's digital products.

Indeed, they may have nowhere else to turn. By developing a complete digital power architecture, only Power-One has the mastered all the skills needed to launch digital power down a new learning curve, benefiting from Moore's law. As an early leader, Power-One will relentlessly push performance and volume up and costs down, forming circles of collaborative design and development with customers, smartchip manufacturers, and board-level designers while rivals run like Achilles to catch up.

That's a race Zeno would love, and we think you will too.

— Charlie Burger, November 27, 2006

(CONTINUED FROM PAGE 1)

looking for anything that might improve things. Several years ago, I got a WebRamp box. One interface to the WebRamp is three modem connections and the other is Ethernet. I could attach one to three 56 kilobits per second (Kbps) modems to separate phone lines, plug them into the WebRamp, and share the aggregate bandwidth on my home network over Ethernet. The WebRamp managed the connection sharing to the Internet service provider (ISP).

I limped along like this for several years. WebRamp, which had been a startup, went public, was bought, and disappeared. That was the end of software updates; performance degraded.

Then **Verizon** (VZ) announced EV-DO (Qualcomm's—QCOM—Evolutionary Data Only system) and began turning it on in California. With EV-DO, one purchased a PC card from Verizon that provided data service over the cellular network at promised download speeds of 400 to 700 Kbps. Hey, these rates qualify as broadband in the U.S. and in third-world countries, and they are wireless and mobile. In any case, they're way better than the 26Kbps of my analog phone line. At that time, the price for Verizon's "unlimited broadband access" was $90 a month, but it has since dropped to $60. The cost was high compared to the phone line, but it offered about twenty times the data rate.

Visiting a Verizon store, I had three questions: 1. Is there EV-DO coverage in my area? 2. Will the PC card and its software allow me to share the connection on my home network? And 3. Does the service agreement allow me to share the connection on my home network?

Verizon's in-store representative had detailed maps to answer the first question. According to the company's coverage maps, there was no service in my area. But based on the one bar of power on my Verizon handset, I believed the company might well be wrong.

I tried asking my second question about six different ways, but it didn't work. I knew that by using a Windows operating system program called Internet Connection Sharing the laptop could share its connection with the rest of my home network—that is, unless Verizon's software interfered with Windows. For each phrasing of the question I got a puzzled look and the same answer: the EV-DO card plugs into the PC-card slot, so it can't be plugged into a desktop at the same time. OK, no answer to the second question either.

The answer to my third question was also not known in Verizon's outpost. I was zero for three, but desperate, so I signed the two-year contract and took the experiment home. I would have fifteen days to answer the questions myself before the contract became binding.

The experiment

I installed the Verizon software on my laptop computer and plugged in the EV-DO card. The software recognized the card, configured it, and established a connection to the cellular network flawlessly and quickly. Impressive. With a single bar of coverage, I could access the Internet through the cellular network from my home! The coverage maps were wrong; as I had suspected, the connection-mapping explorers hadn't been to my neighborhood. The answer to question one is yes; there is EV-DO coverage in my neighborhood; one down and two to go.

My home network has a server, a PC-based PBX (private business exchange), two desktops, two laptops, three wireless access points, and several experimental computers attached to a common Ethernet network.

I installed the Verizon software on three laptops and tried the EV-DO card in each of them. Nothing worked. Verizon's software isolates the laptop that has the card. It's not even possible to access files stored on other computers while the Internet connection is active; the Verizon software offers only a black-and-white choice: connection to the cellular network or connection to the local network.

That's the end of the experiment. I cannot use the EV-DO card as my home network's Internet connection. Even the expensive route of using one card for each computer

- Advanced Micro Devices (AMD)
- Altera (ALTR)
- Anadigics (ANAD)
- Analog Devices (ADI)
- Broadcom (BRCM)
- Cepheid (CPHD)
- Corning (GLW)
- Energy Conversion Devices (ENER)
- Equinix (EQIX)
- EZchip (LNOP)
- Finisar (FNSR)
- Flextronics (FLEX)
- Ikanos (IKAN)
- Intel (INTC)
- Microvision (MVIS)
- National Semiconductor (NSM)
- NetLogic (NETL)
- PMC-Sierra (PMCS)
- Power-One (PWER)
- Qualcomm (QCOM)
- Semiconductor Manufacturing International (SMI)
- Sigma Designs (SIGM)
- Semitool (SMTL)
- Sprint Nextel (S)
- Synaptics (SYNA)
- Taiwan Semiconductor (TSM)
- Texas Instruments (TXN)
- Xilinx (XLNX)
- Zoran (ZRAN)

Note: The Telecosm Technologies list featured in the Gilder Technology Report is not a model portfolio. It is a list of technologies that lead in their respective application. Companies appear on this list based on technical leadership, without consideration of current share price or investment timing. The presence of a company on the list is not a recommendation to buy shares at the current price. George Gilder and Gilder Technology Report staff may hold positions in some or all of the stocks listed.

Semitool (SMTL)

PARADIGM PLAY: WET ELECTROPLATING TECHNOLOGY

NOVEMBER 27: 13.73; 52-WEEK RANGE: 7.81 – 14.10; MARKET CAP: 438.09M

As semiconductor geometries drop toward 32 nanometers and below, the fields of materials science, physics, chemistry, mechanics, software, simulation, and robotics are set to converge, and vertically-integrated Semitool is there to create the convergent cluster tools using its versatile Raider platform with its 14 chambers that can accommodate and coordinate a variety of processes, including its forte—wet chemistry. Semitool is a master of the messy fluids and sulphurs, solvents and slurries increasingly coursing through wafer fabs, cleaning, stripping, flattening, photo-resist removing and surface prepping silicon for copper interconnects.

The surprise is that for next generation devices, the industry is actually coming back to wet techniques. The use of high-energy plasmas in physical vapor deposition or cleaning and photo-resist stripping turns out to inflict damage on increasingly intricate patterns and ever more delicate device structures. Moreover, these dry processes tend to get too hot and cause damage that requires further cleaning. It's not the humidity but the heat, and Semitool's mastery of wet processes enables them to beat both.

Semitool has been aggressively discounting Raider platforms for first-time buyers and investing in tools that will lead to new processes and long-term customer relationships, thereby sacrificing near-term margins for long-term success. The strategy is working. Raider is now used in each of Asia's four major foundries and has become a critical component in many of the world's leading fabs. And as a result of a recent joint development effort with Taiwan Semiconductor, Semitool is now qualified for the giant fab's new process for lead-free electroplating.

During the September quarter, Semitool took two Raider orders for new back-end cleaning applications from customers here and in China, and received a first-time order from a Japanese flash memory manufacturer which will use Raider for copper plating applications. CEO Ray Thompson is seeing growing demand in the memory market for his copper plating tools as the space switches rapidly from aluminum to copper interconnects. Thompson, who recently installed his first front-end cleaning tool at a new DRAM manufacturer, sees "compelling" long-term growth opportunities in memory. Meanwhile, copper interconnect is rapidly ascending in all microchip starts, and Semitool has been taking share through its alliance with AMD.

Momentum is building. During the September quarter, revenue advanced 36% over the year-ago quarter to $65m, while net income surged to $3.9m or $0.12 per share from $1.1m or $0.04 per share. For the fiscal year ending September, revenue increased 28% to $243m from $190m in fiscal 2005, and net income increased to $9.8m or $0.31 per share from $7.2m or $0.28 per share (excluding $0.07 from the patent infringement settlement with Novellus).

Follow-on orders from existing customers are also increasing (90% of fourth-quarter bookings were repeat Raider orders), sending gross margin back up to 47.6% from the low of 43.4% last December when Thompson began to push Raider. Though gross margin may fluctuate a bit as he continues his push, it is clearly trending toward his goal of 50%. Also benefiting earnings has been the transition to a direct sales force in Asia, leading to a meaningful decline in commission costs and the reduction of Sarbox compliance expenses, which fell $1.8m during the year.

Based on trends and management projections, Semitool could well boost earnings 87% to $0.58 per share during the coming fiscal year, giving the stock a forward price-to-earnings multiple of 24 at the recent 52-week high of $14.10. Though almost double the low of $7.81 in July and a bit above the semiconductor equipment industry's typical multiple of 22, it's still a reasonable value for investors buckling up for a decade or longer ride into the sub–20 nm future in an industry facing a major crisis of transition, from aluminum interconnects to copper interconnects, from doped polysilicon gates to metal gates, from silicon dioxide to new "high-K" dielectrics, from amorphous silicon links to super-porous low K interconnects. ("K" relates conductance and temperature in materials.) Enter gently, however, as the stock could well ease back toward the industry mean over the near-term.

Semitool is ready for all these transitions with an array of key technologies, from "powerwave" acoustical tools for new electroplating effects to computational fluid dynamic (CFD) simulation software that enables real-time fine-tuning of wafer-fab processes. For the next steps into the nanoworld with its exquisitely fragile structures, the company has been developing supercritical CO2 with superfluid properties free of viscosity and surface tension. As the industry moves from 2-D structures to 3-D, with deep vias linking one chip to another one below it, back-end packaging increasingly resembles front-end processing. Semitool's electroplating technology works at both ends.

With continued ascendance of its multiprocess platform and wet chemistry technology in a Moore's law world, we expect that Semitool's heyday has yet to arrive. — *Charlie Burger*

Online Bonus Material: For additional analysis on **Altera (ALTR)**, **Synaptics (SYNA)** and **Xilinx (XLNX)** logon with your GTR subscriber ID at *www.Gildertech.com*.

doesn't work because I regularly ship files around the network. The agreement does seem to say something like one computer at a time. Why would Verizon do this?

Verizon has "broadband" coverage in my area that no one else offers. It is priced well above much faster cable services that don't care how many computers are connected to the network. Why does Verizon insist on controlling how I use the card?

A few years ago, it looked as if all the advantages in the competition for wireless Internet access belonged to the cellular networks. They could incrementally upgrade their networks and their services, from basic phone service to data-based services to multimedia. They had great connections to the backbone network. Their already-in-place systems could even support mobile connections. And they had the accounting systems to make billing simple for the customer.

Contrast that position with the state of Wi-Fi. Coverage was sparse and mobile connections weren't even dreamed about. Companies were searching for a business model that would make Wi-Fi services worth offering at all—forget universal coverage or mobile access.

The battle for wireless broadband access looked like a lopsided match between cellular networks, with a host of advantages, and Wi-Fi networks, still searching for a business model.

The answer

My experiment with Verizon's EV-DO slapped me in the face with the answer to who will win: cellular or 802? Successful companies develop a culture that suits the competitive situation. For example, **Intel**'s (INTC) culture of intense focus on next-generation microprocessor design and on leading-edge semiconductor process led it to the top of the highly competitive microprocessor market. Cellular carriers have cultures expressing three primary "genes" in the DNA of telephone companies: a build-out mentality, vertical integration, and complicated pricing. The build-out mentality comes from the legacy of the government's treatment of the electromagnetic spectrum as physical property, encouraging carriers to build out networks to the extent of their spectrum ownership. Telephone companies are vertically integrated in providing the network infrastructure, the services, and the customers' devices. Finally, complicated pricing helps to obscure profits in a highly regulated business that includes price controls.

But the culture that builds momentum for a growing company may paralyze it when things change. Look what happened to phone companies after deregulation. They had cultures suited to regulated-monopoly environments. Similar problems befall government-contracting companies when they move into commercial markets. The wild-west nature of IEEE 802 systems is changing the competitive environment for the cellular networks. As my experiment with Verizon's PC card demonstrates, companies that developed in a regulated environment will find it difficult to adapt. I concluded that the inertia of the cellular networks' culture will prevent them from exploiting their huge initial advantages; they will lose to the 802 zoo.

Verizon integrates the customer device (the network-access hardware and software), the cellular network, and the service. This integration is part of its competitive problem. The market should have competing end user device hardware and software; it should have competing cellular networks; and it should have competing services. Imagine how much better each would be if provided by separate competing companies. You don't have to imagine it; that's what's happening in 802. The 802 world is like the PC world, horizontally fragmented, not vertically integrated.

But before finally giving up on the cellular players, I decided to give them one more chance.

A few months after my experiment with Verizon's EV-DO card, I decided to experiment with a similar card from Cingular. As a prelude to the trip to town to visit a Cingular store, I checked the Internet for the latest options. I found the Kyocera KPC650 PC card and a companion Kyocera KR1 "mobile router." The KPC650 is an EV-DO card that is an option with Verizon's wireless broadband service. The KR1 mobile router is just what it sounds like—and exactly what I needed—it is a wireless access point with four Ethernet ports and a slot for a wireless PC card, such as the KPC650. I headed to Fry's Electronics to buy one. At the store I found D-Link's DIR-450 EV-DO-compatible mobile router. The store had only one; I bought it and headed for a Verizon store. Since I had already experimented with Verizon's wireless broadband, I knew I had reception at the house. (No need to start the experiment over with Cingular's service.) So I was back with Verizon.

I inserted the KPC650 and plugged in D-Link's mobile router. Nothing. I installed Verizon's software in a laptop and initialized the KPC650. It worked perfectly. I popped the card out of the laptop and inserted it in the mobile router; this time it connected flawlessly. I uninstalled the broadband-access software from the laptops. I established a wireless connection between the mobile router and a laptop and configured the router. I connected an Ethernet cable from the mobile router to a newly installed Ethernet card in the server and configured the server to forward packets from the local network to the mobile router. That extended Internet access to the wired home network and to the rest of the wireless access points on the local network through the server's firewall. (The mobile router also has a firewall.)

I'm happy. My Internet connection is at least fifteen times faster. Two weeks later I installed a high-gain antenna to replace the miniature antenna that's on the KPC650. Testing the new antenna I find that although it does not enhance the top data rate, the robustness of the signal improves. I canceled my dial-up service and returned two copper connections to the phone company. With the three cancellations, I'll break about even for the cost of the new service. I have gone from four copper phone lines to one, so I no longer need the PBX to manage options among copper connections—another potential decommissioning ceremony and more savings.

The cellular carriers aren't dead. The mobile router should be popular with emergency services. Installed in a service van, fire truck, or ambulance, it acts as a Wi-Fi access point, providing wireless Internet access for computers, laptops, and handheld devices that are in or are close to the vehicle.

The 802 zoo

In the old days, there was a PC card for 802.11b that looked very much like Verizon's cellular-access card. But the 802.11b (Wi-Fi at 11 megabits per second) card didn't come with a contract that restricted its use and its software didn't enforce use policies on my laptop's operating system. If it had, I'd have bought a card from one of the supplier's numerous competitors instead. Similarly, the Linksys

wireless access points have no use contract and no enforcing software for the client computers. I use the access points as I see fit. If they do the job, I'm happy with the systems and the company is happy with the sales. Everybody wins. If the systems don't have the performance or coverage I want or if they don't do the job, I can buy more of them or I can buy compatible systems from competitors. The supplying company may try to imagine its customers' uses when designing the product, but it's happy to sell systems whose uses don't meet its preconceived uses.

Telecom providers weave their preconceived notions of use into the fabric of their offerings in ways that can create a virtual straitjacket. Their culture prevents them from splitting into competitive segments in services, in infrastructure, and in devices and it prevents them from offering services that compete as if they came from an independent company. In this example, Verizon is unable to deliver the access card independently; it offers the card bound with the service offering. It is a losing strategy because its restrictions inevitably bar the imaginative uses customers find. Verizon is bound to this losing strategy by a corporate culture that developed before entrepreneurial broadband.

In the environment of the 802 zoo, a similar freewheeling situation holds for the network providers (they pay for the equipment) and for service providers (they provide email and web access). There are network providers and service providers who care about use and about network loading and they may have contracts that limit use and software that enforces policies, but it's a developing and competitive market. Network and service providers are still experimenting with business models. There are many of them in wide-open competition.

This is the 802 zoo. The IEEE is the umbrella organization responsible for the specifications. The wireless protocols of interest fall into three basic market segments: local-area networks (Wi-Fi), wide-area networks (WiMAX), and low-end networks (ZigBee). Wi-Fi, WiMAX, and ZigBee are backed by powerful commercial alliances. There are other members of the 802 zoo, but they are less in competition with the cellular networks.

Wi-Fi (802.11)

Wi-Fi, for Wireless Fidelity, is essentially wireless Ethernet for local-area networks. With an omnidirectional antenna, the transmitter's range is supposed to be 300 feet. However, if you call an equipment provider's help desk, they won't talk to you if the transmitter (access point) is more than 60 feet from your laptop.

Wi-Fi began with 802.11b, which operates in unlicensed spectrum, called the ISM (industrial, scientific, and medical) band, at 2.4 gigahertz (GHz). It supports data rates to 11 megabits per second (Mbps).

Next came 802.11a, which operates in unlicensed spectrum, called the UNII (unlicensed national information infrastructure) band, at 5 GHz. It supports data rates to 54 Mbps. It is incompatible with 802.11b.

Last, there's 802.11g, which operates in the ISM band at 2.4 GHz with data rates to 54 Mbps and is backward compatible with 802.11b.

In addition to these three specifications, there's an alphabet soup of supplementary specifications in various stages of completion. For an idea of just how much is going on, look at the working group project timelines at *http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm* (and that page is just for 802.11). Important projects for Wi-Fi's competition with cellular networks include mobility (802.11p, 802.11r), quality of service (802.11e), security (802.11i), mesh networking (802.11s), and throughput enhancements (802.11n).

IEEE 802.11n includes MIMO (multiple-input, multiple-output) antenna arrangements, such as those supported by **Airgo Networks**, **Atheros** (ATHR), **Broadcom** (BRCM), **Marvell** (MRVL), and **Wavion**, that help raise transfer rates in current systems to 108 Mbps. Airgo Networks uses a proprietary protocol, but the others, who implement pre-approval versions of the 802.11n standard, were dealt a setback when the version 1.0 draft was rejected in a working-group vote earlier this year. MIMO transmitters and receivers send and receive several data streams over the same set of frequencies. Using MIMO, multipath signals (signals that arrive at the antenna at different times by bouncing off buildings and other objects), once viewed as purely harmful interference, can, with today's improved signal processing, be harnessed as additional data streams. Employing more antennas at the transmitter and at the receiver and using more data streams can push data rates to 600 Mbps.

Wi-Fi "hotspots" are proliferating. A recent survey ("Taipei tops hotspot survey," EETimes online 29 June 2006) says there were 115,000 hotspots in 128 countries. Even my hometown of Los Gatos, CA, has free wireless access in its tiny downtown park.

Enterprise-class Wi-Fi systems, such as the AirMasetro from Austin, TX startup **Bandspeed**, incorporate quality-of-service (QOS) features and second-generation encryption. These systems enable secure voice-over-IP (VOIP) calling and data transfer. This market is projected to be $900 million this year and is expected to grow to $2.6 billion by 2010, when unit volumes will reach 13.2 million (EETimes, 5 June 2006, pg 34-42).

WiMAX (802.16)

WiMAX is for wide-area networks, sometimes called wireless MANs (metropolitan-area networks). Various service acronyms, like local multipoint distribution system (LMDS), multichannel multiple point distribution system (MMDS), and wireless Internet service providers (WISPs), have been tried. They have not been successful because each one has been a proprietary standard. Proprietary standards fragment chip production and system production so that unit volumes do not climb the learning curve to make products

cheaper. The 802.16 standardization efforts hope to remedy the situation.

WiMAX is designed to operate in licensed bands as well as in the same unlicensed bands that Wi-Fi operates in. WiMAX is, therefore, a good choice for the traditional wireless carriers such as **Sprint Nextel** (S) or for startups such as **Clearwire** that own spectrum and want to deploy wireless services based on open standards.

WiMAX currently operates in 2.5 GHz, 3.5 GHz, and 5.8 GHz bands in the United States. The U.S. government will open the 1710 megahertz (MHz) and 2110 MHz bands to WiMAX through FCC auctions in 2007. Beginning in 2008, and as analog broadcast TV vacates the 700 MHz channels, this spectrum will be auctioned. According to the FCC: "This spectrum offers potential to deploy new methods of providing high-speed Internet access, and is suitable for new fixed wireless in underserved areas, as well as next-generation, high-speed mobile services." That's a good description of WiMAX. The auctions are not yet scheduled (for more information, see *http://wireless.fcc.gov/auctions*). These lower frequency bands, especially at 700 MHz, have excellent propagation characteristics, including obstacle penetration, for broadband data transfers.

The current WiMAX version, commonly called 802.16d, was derived from 802.16a and was published as 802.16-2004, in 2005. It supports fixed base stations and portable clients, but not mobility. (There is no automatic handoff of mobile clients between base stations.) With an omnidirectional antenna, the base station's range is 3 to 5 miles. The maximum data rate is 75 Mbps.

Wi-Fi and WiMAX lose data rate as transmitter-receiver separation increases.

The next flavor of WiMAX, 802.16e, supports mobile clients. The final specification, approved in December 2005, was published in February 2006 as 802.16e-2005. With an omnidirectional antenna, the base station's range is 1 to 3 miles. The maximum data rate for 802.16e is 15 Mbps.

The only version of WiMAX that's getting into the field, 802.16d, with products from companies such as **Redback Systems** (RBAK), is incompatible with the anticipated version (802.16e) that supports mobility. The result is that the WiMAX market will develop more slowly than it would if 802.16e had backward compatibility with 802.16d.

WiMAX has powerful backers. Intel, which recently invested $600 million in WiMAX provider Clearwire, is one; **Freescale** (FSL), which also invested in Clearwire, is another. South Korea is another, as its WiBro, which is essentially 802.16e, is already being fielded.

Fragmenting a WiMAX market that is already behind the Wi-Fi market in development, however, has the consequence that WiMAX systems will climb the learning curve to cheaper systems more slowly and may, therefore, never be cost-competitive.

ZigBee (802.15.4)

ZigBee is a low-power, self-organizing short-range network for sensors that enable home, office, and factory automation. ZigBee is the low-power complement to Wi-Fi and WiMAX. Wi-Fi provides local-area network connections with reasonable data rates at power costs that can be borne by laptops and hand-held devices. WiMAX provides the metropolitan-area network's wireless backhaul; it spends more power to achieve high data rates over long distances.

With some 200 backers, ZigBee has more than enough participation to ensure a thriving and competitive market.

Networks of ZigBee-based sensors are self-organizing and fault tolerant. Data transfer rates range from 20 Kbps to 256 Kbps over distances of a few feet to a maximum of 300 feet. ZigBee devices operate in unlicensed bands, including the 900 MHz band, the ISM band, and the UNII band (in the U.S.; other bands apply in other countries).

Z-Wave is a proprietary competitor to the IEEE ZigBee standard. **Zensys**, which is backed by Intel Capital, builds Z-Wave devices that are claimed to be smaller, lower power, and cheaper than ZigBee's devices. But when I met with Dr. Bob Heile, chairman of the ZigBee Alliance, he chuckled at the idea and I know why. A look at the backers of ZigBee and a walk around the exhibits at a recent ZigBee open house convinced me that ZigBee has more than enough participation to ensure a thriving and competitive market, with some 200 backers including **Ember**, Freescale, **Hitachi**, **Honeywell** (HON), **Huawei**, **Mitsubishi Electric**, **Motorola** (MOT), **Philips**, **Samsung**, **Siemens** (SI), **STMicroelectronics** (STM), and **Texas Instruments** (TXN) that have sold more than 10,000 development systems. ZigBee and its backers will be winners in this competition.

Others (802.xx)

The Mobile Broadband Wireless Access (MBWA) Working Group, designated 802.20, has been working on global roaming and on vehicular mobility. I say "has been" because its activities were suspended on 8 June 2006 until 1 October. The group was considering two proposals: one from **Navini Networks** and one from Flarion, which has been purchased by Qualcomm. The letter of suspension says that group activity became "highly contentious" and "the group's operation revealed a lack of transparency, possible 'dominance,' and other irregularities..." There is also overlap between the objectives of 802.20 and 802.16e.

The future

In the 802 vision, you wear an earpiece connected by Bluetooth (802.15.3) to a handset that has a secure, mobile Wi-Fi (802.11) local-area connection to an access point and has ZigBee (802.15.4) connections to local-area sensors. The

access point has a WiMAX (802.16) wide-area connection to the "lambda rail." The WiMAX base station supports 802.16e, so the backend of your car's Wi-Fi access point can connect to the WiMAX base station as you cruise the Interstate. If you cannot connect to a free-access network, your gear will connect to a cellular network.

Three developments may change this vision: cheap radios, mesh networking, and smart antennas.

Systems from startup **Mesh Dynamics** contain three or four radios based on Atheros chips. The system is 2x6x8 inches, dissipates 400 milliwatts (mW) per radio, and can be powered from an Ethernet cable (no need for an electrical outlet). One radio, operating 802.11b/g Wi-Fi with an omnidirectional antenna, serves as the access point for local connections. Two radios, operating 802.11a, form backbone link connections. The network organizes itself, establishing connections, routing around failed nodes, and changing link channels as necessary to avoid interference. Radios, at $40, are cheap enough that two radios can be dedicated to the backhaul links.

Besetting mesh radio networks are four major issues: Interference between users' access links and mesh links; traffic jams through nodes close to the backbone link; single-radio scaling, and unacceptable delays through multiple hops. Using cheap radios, multiple-radio nodes, mesh networks, and directional antennas, however, Wi-Fi networks already in the field demonstrate link distances and data rates that are as good as WiMAX will be able to provide—and they do it today at costs below what WiMAX will be able to achieve. Wi-Fi's MIMO systems already exceed the maximum data rates projected for WiMAX systems. I'm sure WiMAX's advocates will be able to point to advantages for WiMAX systems, but time and system cost are on the side of Wi-Fi. When WiMAX radios are cheap enough, it would be a simple thing for Mesh Dynamics to substitute WiMAX radios for the Wi-Fi radios that do the backhaul in its current systems.

Cities and even counties are enveloping their areas in Wi-Fi "clouds." One incentive is financial. It gives city or county employees anywhere, anytime access to information relevant to their jobs. Rather than blanket the city in separate, sparse radio networks for each service (fire, police, utilities, roads, etc.), the government consolidates infrastructure costs and provides better coverage.

For example, using systems from Mesh Dynamics, Sandoval County in New Mexico, an area a little smaller than the state of Connecticut, is providing megabit wireless access throughout the county. Complete, plug-in Wi-Fi radio modules cost only $40 to $100, depending on power output. Couple radios to directional antennas mounted on towers and Wi-Fi can span distances of 20 to 50 miles (in favorable terrain) for backbone communication at data rates of 54 Mbps (below 20 miles) to 24 Mbps (at maximum distance).

It is looking like Wi-Fi has the potential to provide universal access in cities and in rural areas and it can also act as the wireless backhaul network. WiMAX will have an uphill struggle to achieve affordability before being overwhelmed by Wi-Fi deployments. Wi-Fi builds for volume and WiMAX builds for performance. We have seen this before in the battle between PCs and workstations. Volume wins.

The main event, however, is competition between the vertically integrated telcoms owning licensed spectrum and the horizontally fragmented 802 zoo operating in unlicensed spectrum. It comes down to the Suits versus the Cowboys. The Suits have a head start: massive infrastructure, captive customers, exclusively owned spectrum, and vertical integration for soup-to-nuts solutions. Undermining these advances is a monopoly oriented corporate culture, proprietary solutions, and the inertia inherent in vertical integration.

The Cowboys have open standards and a wild-west entrepreneurial environment. The Cowboys suffer from many competitors fragmenting the market and from operating in unlicensed spectrum.

My experience with Verizon's PC card and with a host of Wi-Fi products tells me that the Cowboys have the advantage. The vertically integrated cellular providers are handicapped by a corporate culture that makes them want to control the service as if it were the old switched-circuit voice network—and that will be unacceptable to generations of users that grew up with the wide-open development of the PC.

A key to the outcome will be how fast the Suits can learn from the Cowboys.

– Nick Tredennick, with Brion Shimamoto, November 27, 2006

Got Questions?

Visit our subscriber-only discussion forum, the Telecosm Lounge, with George Gilder and Nick Tredennick, on www.gildertech.com

GILDER TECHNOLOGY REPORT PUBLISHED BY GILDER PUBLISHING, LLC AND FORBES INC. • Copyright ©2006, by Gilder Publishing, LLC

291A MAIN STREET, GREAT BARRINGTON, MA 01230, TEL: (413) 644-2100, FAX: (413) 644-2122 • EMAIL: INFO@GILDER.COM

EDITOR	TECHNOLOGY ANALYST	MANAGING EDITOR	CONTRIBUTING EDITORS	ART DIRECTION	SUBSCRIPTION DIRECTOR	CUSTOMER SERVICE
George Gilder	Charlie Burger	Mary Collins	Brion Shimamoto Nick Tredennick Bret Swanson	Thomas McCarthy	Linda Bentley	Sandy Fleischmann

For subscription information telephone toll free: (877) 733-7876 • WWW.GILDERTECH.COM