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Austin's Wireless Future

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Austin's Wireless Future

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EXECUTIVE SUMMARY

The Wireless Future project is an economic development initiative led by the IC² Institute, University of Texas of Austin. The goals of the project are to:

- Elevate the profile of Austin's wireless industry by clearly identifying regional assets;
- Understand better the nature of the wireless sector in Austin in the context of broader technological and market developments;
- Educate stakeholders about the role of wireless technology and services in regional economic and social development; and
- Lay the groundwork for a vision of Austin's success in the wireless sector.

Our Approach

For the purposes of this report we focus on three categories of wireless services and products: existing cellular and PCS services and products; licensed radio spectrum wireless services and products, such as fixed broadband wireless; and unlicensed services and products, such as WiFi hotspots in cafes and airports.

In Section 1 we define what we mean by wireless technologies and provide an overview of market trends, opportunities and challenges, particularly as they relate to cellular and unlicensed technologies.

In Section 2 we explore the near-term future of wireless-- ubiquitous mobile voice and data communication facilitated by the presence of an available wireless connection at all times. We discuss different technological approaches to making ubiquitous mobile communication a reality and the early efforts of companies and communities to derive value from wireless data networks. We also discuss the policy developments that are critical to the continued innovation of wireless technologies and services and the movement toward open spectrum.

Austin's Wireless Sector

The analysis presented in this report is based on interviews with industry and community representatives, monthly stakeholder meetings, a survey of local wireless companies, and a review of existing literature.

Companies

The most startling finding of this study regarding Austin's wireless business sector is that it is significantly larger and more robust than even wireless insiders had thought. At this writing Austin has over 91 companies that are involved with wireless in some way, and more than half are pure wireless ventures.

Over half of Austin wireless companies are working with 802.11 technology. Networking (43% of companies) and cellular/PCS (24%) are important focuses.

Most companies surveyed are small. 55% of them have 10 or fewer employees. 80% have 50 or fewer employees. Only five survey respondents employ more than 100

people. Regarding future employment, almost all companies are very positive. Eighty percent expect to hire more people over the next year.

Consistent with the small size and youth of Austin wireless companies, revenues are also relatively low. Seventy percent of respondents reported revenues of $1 million or less in the most recent fiscal year and over half the ventures are financed through personal savings or personal debt. However, despite the slow economy, a large majority of companies anticipate stable or increased revenue for FY2003.

In the local wireless industry there are approximately 3,400 people employed in companies with 100 or fewer employees. At some of the region's largest employers, such as Motorola, the number of employees is much greater. However, because most new job growth originates in smaller companies, our analysis focuses on this group of startup, small, and growth companies. In 2004, this number will grow to 4,215, a 25.7% increase. In the next four years, the number of workers will grow at an average 18.93% annual compound rate to reach 7,978 by the year 2008.[1] We estimate that last year, the total payroll for wireless employees in Austin MSA was approximately $125 million,[2] and that this payroll generates $85 million in consumption.[3]

Infrastructure

Although Austin is fortunate to have a wide variety of wireless companies, the success of these companies is largely dependent upon access to and the quality of a number of resources. Foremost among company concerns are investment capital, a talented labor pool, and a supportive civic and community infrastructure, particularly for relatively new entrepreneurial companies.

Investment Capital

Some findings based on public information:

- Thirteen top-500 venture capital companies and private equity firms are located in Texas, six of which have invested in the wireless industry. Austin Ventures, Sevin Rosen Funds, and Dali, Hook Partners have invested in more than five wireless companies.
- Of the 17 venture arms of multinational companies studied, ten have invested in wireless. Five of them have more than ten wireless portfolio companies.
- Intel Capital is the leader in wireless venture capital. It invests heavily in the WiFi sub-sector, as it fits Intel's overall company strategy. Motorola Ventures, Nokia Venture Partners, Siemens Venture Capital, and Qualcomm Ventures are the other big stakeholders in wireless.
- There are 15 regional venture capital companies located in central Texas and focused on Austin. All but one of them have invested in the wireless sector. Due to their relatively smaller capital, most invest in only one to three wireless companies. But their investment is important to Austin-based wireless companies such as Wayport, SoloMio, and Motive.

Intellectual Capital

The University of Texas' world-class wireless research program, the Wireless Networking and Communications Group, has attracted the attention of wireless companies and developers worldwide. While WNCG is the region's most visible university-based research endeavor, many of Austin's research assets reside in the private sector. Several of Austin's larger employers have well established research units, such as SBC Laboratories and IBM, and much of this research, as the SBC Laboratories case study in section 3 shows, is in wireless. However, wireless research is not confined to Austin's marquee companies; 30 percent of the companies responding to the Wireless Future survey reported wireless research as a key component of their business.

Human Capital

Austin is known as a city that attracts creative people who do innovative work and the labor pool is a key reason companies choose to locate in Austin. However, 50% of survey respondents reported having to go outside of the region to recruit employees and many identified labor force needs as a critical concern.

42% of the survey respondents said they would hire one to five people in the next year. But in the next five years, almost 60% of the companies expect to hire 20 or more employees locally.

Among the top needs are technical professionals (engineers, scientists, computer scientists) and support professionals (marketing, accounting, business development). Technicians with two-year degrees were needed by 54% of the companies.

Austin's Peers

Dallas, unlike most other cities dependent on knowledge-based jobs, lacks a well-established research university. The city relies instead on its ability to attract young talent from elsewhere.[4] To produce qualified locally trained engineers, Ericsson is aiding the University of Texas at Dallas in developing a curriculum in wireless telecommunications in the school's Department of Computer Science and Electrical Engineering.[5]

The Boston area ranks first nationwide in software engineer workforce and electrical engineers, third in computer hardware engineers, and fifth in computer programmers.[6] However, the city is graying: From 1990 to 2000 Boston experienced an 18.5% decrease in its population aged 18-24, while also seeing an increase in adults aged 45-59.[7] This suggests problems with attracting and retaining talent.

San Diego claims 200 wireless firms, which employ over 15,000 workers and has the most concentrated population of wireless employees coupled with the largest growth.[8] Qualcomm anchors the industry, with Nokia, Samsung, and Ericsson maintaining significant facilities in the area.[9] Despite the presence of these corporations, 80% of the area's wireless companies have fewer than 50 employees, a statistic similar to Austin.[10]

The San Francisco Bay Area/Silicon Valley hosts a significant wireless industry. Six hundred wireless companies reside in the region, employing over 25,000.[11] For

professional support, the Valley's wireless companies networking, educate, and exchange information through the Wireless Communications Alliance.[12] In addition to numerous well-known research universities, the region offers two explicitly wireless university programs, the Stanford University Wireless Communication Research Group and University of California at Berkeley Wireless Research Center.[13]

Seattle--best known as the home of Boeing and Microsoft-- claims 138,000 information technology employees and over 10,000 related businesses.[14] There are 50 wireless companies in the region boasts high crossover between high technology and complementary industries: biotechnology (because of established health research facilities in the Puget Sound area) and digital gaming (due to the presence of Sierra Entertainment and Nintendo). Both sectors have powerful potential relationships with wireless technology. Several institutions of higher learning have programs for wireless communications.

Next Steps

Our recommended next steps for Austin and its wireless industry emerge from a vision of a mobile networked society where access to wireless broadband will be—must be—pervasive. The immense economic and social potential inherent in mobile wireless data communication notwithstanding, the industry overall still faces significant challenges; however, their existence, while daunting, may also point to new business opportunities, e.g. in standards integration and the development of security strategies.

We conclude our study with recommendations for Austin's wireless industry and other stakeholders, based on our analysis of the efforts needed to build and sustain a wireless cluster that will be a significant contributor to Austin's economic future.

Build a Better Network

There is a need for cohesion within the local wireless industry. There have been several critical first steps such as the foundation of the Austin Wireless Alliance and Austin Wireless City. These organizations are new and require the active engagement of

Support Entrepreneurs and Growth of Local Business

This report is but a first step in a necessary ongoing process of identifying industry requirements and building structures for its support. Our survey and stakeholder meetings show a significant number of entrepreneurial startups. This caught the attention of IC²'s Austin Technology Incubator, which as a result is taking a closer look at the wireless sector and prospects for incubation. We recommend that wireless stakeholder groups develop a forum and method for identifying specific business needs.

Capitalize on Austin's Recognized Strengths in Semiconductors, Software, and Digital Media

The synergy seems evident; the semiconductor, software, and digital gaming sectors in Austin are critical resources for local wireless companies, and Austin's already strong position in these three sectors is a key to Austin's potential as a wireless hub. IC² identified a need to disseminate information about application and digital media

development practices and tools for 2.5G and 3G environments, which will be covered by the conference and in other workshops thereafter. Representatives of Austin's key technology verticals should pursue similar knowledge sharing and development activities.

Maintain and Grow Austin's Most Important Asset—People

Austin area educational institutions still need to develop two-year degree programs and vocational programs for wireless technology. The wireless companies need to work more closely with local professional education institutions, such as the Capital Area Training Foundation (CATF) and Austin Community College (ACC), to train qualified technical and professional .

The city should support, as a public service, pervasive availability of broadband wireless access (possibly through its own network) in underserved areas and in zones where pervasive wireless will help economic development. We feel that this ensures pervasive access, which is essential infrastructure for wireless innovation.

Demonstrate Austin's Wireless Savvy

Austin is therefore a perfect test market for new wireless technologies. The city is relatively small. It already has very good infrastructure. Austin is a forward-looking city open to innovation, and as such can host new products and product innovations in a citywide wireless quilt, and evaluate and improve upon them before national and global distribution.

INTRODUCTION

The Wireless Future project is an economic development initiative led by the IC² Institute, University of Texas of Austin. The goals of the project are to:

- Elevate the profile of Austin's wireless industry by clearly identifying regional assets;
- Understand better the nature of the wireless sector in Austin in the context of broader technological and market developments;
- Educate stakeholders about the role of wireless technology and services in regional economic and social development; and
- Lay the groundwork for a vision of Austin's success in the wireless sector.

To date, Austin's wireless sector of over 91 companies has emerged organically, with little attention paid to cluster development. When the Wireless Future project began, these companies as well as other local wireless initiatives had not communicated or coordinated efforts, nor had they been acknowledged by local institutions as a significant sector for economic development within the Austin Metropolitan Statistical Area. But, as this report will show, there is now a great deal of activity around wireless.

In cooperation with business and other stakeholders, this report analyzes the region's wireless assets and the challenges in evolving a wireless cluster. The analysis is based on interviews, monthly stakeholder meetings, a survey of all local wireless companies, and a review of existing literature.

We define the wireless sector broadly, including access providers, developers and manufacturers of devices, software developers, and service providers. Our report targets multiple stakeholders: wireless developers and entrepreneurs, city government, and community groups with limited technical knowledge but a significant interest in the impact of wireless. For readers who lack familiarity with the technology, the report's first section includes a high-level overview.

Though this report focuses on the Austin Metropolitan Statistical Area, the pervasive impact of wireless means our research and findings are applicable to other communities. The IC² Institute is organizing a spring 2004 conference that will highlight the national and global impact of wireless innovation.

Wireless Future Scenarios

The Futures Lab, a local futures-based consultancy, hosted a front-line panel in August 2003 featuring forward-thinking Austin professionals, including wireless entrepreneurs and researchers as well as thoughtful potential stakeholders. We asked Futures Lab to develop a set of scenarios based on the panel discussion that would represent their thinking about the wireless future. We showcase these scenarios throughout the report, beginning with "Seamless Service."

In **Section 1** we define what is meant by wireless technology and provide an overview of market trends, opportunities, and challenges, particularly as they relate to cellular and unlicensed technologies.

Section 2 discusses the emergence of ubiquitous mobile communication, the technologies under development to bring about always-on wireless networks, and early uses of these technologies by companies and communities. Also discussed are policy developments required to facilitate the emergence of new products and services.

Section 3 discusses different technological approaches to making ubiquitous mobile communication a reality and the early efforts of companies and communities to derive value from wireless networks. We also discuss the policy developments that are critical to the continued emergence of wireless technologies and services.

Section 4 The success of Austin's wireless companies is largely dependent upon access to and the quality of a number of resources. Foremost among company concerns are investment capital, a talented labor pool, and a supportive civic and community infrastructure, particularly for young, entrepreneurial companies. In this section we analyze Austin's assets with respect to these important resources and conclude by briefly examining some of Austin's peers.

In **Section 5** we present our conclusions and recommendations.

WIRELESS FUTURE SCENARIO 1: SEAMLESS SERVICE

(*Wired,* May 2006)

Imagine a world where you could have access to your e-mail, address book, video channels, bookmarks, home control system, etc. any time, anyplace, anywhere, and on any device.

You're in paradise, right?

OK—now wake up and get yourself a Nucleus™ account.

The Nucleus Account, available from Austin, Texas-based Dynamic Network Applications (DNA), is a customized suite of data services available to members via any communication device, wireless or wired. In other words, now you can have the convenience of portable services as well as portable devices.

The idea behind the Nucleus account is simple, says DNA president Darby Russell. "People don't really want cellphones—or any other wireless device for that matter. What they want is the freedom and convenience to be connected—anyplace, any time! Once we understood that, it became very clear to us that we needed a seamless connection to all of the services that the typical 'unwired' individual uses on a day-to-day basis."

Steven Silvagni, a Corporate Diversity Trainer from Battle Creek, Michigan, is sitting on a bench in New York City's Central Park. A Nucleus account holder for five months, he has just received a calendar update on his cellphone. "Got to love Friday staff meetings," he says with a smirk. After adding the details of a new acquaintance to his centralized address book, he talks to the Nucleus concierge to arrange a delivery of flowers to his mother in Ohio.

Later that day in his hotel room, Silvagni dials up his package of TV stations on the hotel television. Tonight he chooses an Italian masterpiece from the Sundance Movie channel. "Just like home," he says, beaming.

Like Silvagni, Nucleus member Tina Bernstein also appreciates having her "essentials" available whenever she needs them. A postgrad student at the University of Washington, Bernstein is conducting research for her thesis. Sidling up to one of the library's computers, Tina accesses her extensive collection of Internet bookmarks via Nucleus. Adding a few noteworthy sites (Nucleus automatically updates her list); she vacates the hushed library for a much-needed café latte.

Users gain access to their "nucleus" by keying in an encrypted reference code or, when appropriate, swiping a smartcard. DNA is investigating other means of identification such as retinal scanning, but until such infrastructure becomes more commonplace, they're sticking with more traditional logins.

Members have not only the efficiency and convenience of centralized services but also the ease of consolidated billing. Although most services that DNA offers are provided by third party companies, Nucleus account holders would never know. "I never get the dreaded 'no service' message," says Bernstein. "And having everything itemized on the one statement is an added bonus."

When asked about the ongoing convergence of devices, Russell says, "We're very interested in the ongoing development of technologies like software-defined radio and 'chameleon chips'" (chips that reconfigure themselves on the fly to perform multiple tasks). "I'm all about having one device that does it all."

Maybe one day we'll have a single little black box that does everything we need to live in our increasingly connected world. On that day the wireless world will rejoice—and when the commotion dies down and the last streamer is thrown, there waiting for our new box will be DNA's Nucleus account.

SECTION 1—WIRELESS TECHNOLOGY, TRENDS, AND OPPORTUNITIES

The appeal of wireless is clear. Wireless has been with us over a century, but the personal wireless revolution we're seeing is about one thing: mobility. People want to take their access to the world-as-data wherever they go—to be always on, always connected, even in motion. Wireless is a fluid, mobile, invisible, inexpensive way to sustain unlimited links between people. With the cellphone, those links were originally about verbal communication, but as the technology evolves we can link more than conversation—we can link *experience.* Soon we'll be able to play games with other participants everywhere in the world. We'll be sharing images and sounds, art and culture, even—potentially—touch.

Wireless is a network technology, and its social and economic value is governed by three assumptions, referred to as "laws" of networks:

- **Sarnoff's Law** says the value of a network is proportionate to the *number of subscribers*.
- **Metcalfe's Law** says the value of a network is proportionate to the *square of the number of users.*
- **Reed's Law** says the value of a network is proportionate to the *number of groups.*[15] The utility of large networks, particularly social networks, can scale exponentially with the network's growth.

Network value or utility relates to the promise of wireless: Wireless networks are potentially always on and accessible anywhere. By extending networks, wireless extends network value. Many opportunities will test the social and economic value of wireless networks:

- Extended infrastructure for sales force automation and value chain management.
- Increased opportunities for business-to-consumer and business-to-business messaging.
- Complex challenges (for example, security or bandwidth management) inviting innovative new commercial technologies.
- Expanded channels for distribution and use of digital media.
- Extended opportunities for workforce development.
- Wireless infrastructure for data accumulation supporting scientific studies.
- Robust platforms for community collaboration.
- Emergent democratic systems based on evolving network technologies.

For the purposes of this report we focus on three categories of wireless services and products: existing cellular and PCS services and products; licensed radio spectrum wireless services and products, such as fixed broadband wireless; and unlicensed services and products, such as WiFi hotspots in cafes and airports.

In this section we define what we mean by wireless technologies and provide and overview of market trends, opportunities and challenges, particularly as they relate to cellular and unlicensed technologies.

Cellular Telecommunications Technologies

Evolutionary stages of cellular telecommunications development are described as generations. Begun in the late 1970s, the first generation (1G) provided basic voice telephony using an analog circuit-switched network. This type of network resulted in low capacity, relatively poor voice quality, and limited coverage.

2G Technology

In the early 1990s second-generation (2G) technology took the center stage. The 2G cell phone features digital voice encoding. Digital encoding resulted in added voice efficiencies; however, data transmission was possible only at very low speeds (typically 9.6kbps or 14kbps depending on the system) and required a long time for connection and latency. Since its inception, 2G has improved considerably, with increased bandwidth, packet routing, and the introduction of multimedia.

One of the main problems of 2G technology is that it represented a number of incompatible systems:

- **CDMA (Code Division Multiple Access):** A complex mathematical system created by Qualcomm that allows for multiple calls to be transmitted in the same spectrum simultaneously.
- **GSM (Global System for Mobile Communications):** A technology developed in by an independent organization in Europe with the goal of establishing a global standard based on one system. This goal has been only partially achieved: today most of Europe and Asia use GSM technology, but GSM coverage in North America is spotty. Worse, the bands allocated to GSM vary from region to region, so that a "multi-band" or "tri-band" phone is needed if one is to use the same GSM handset in Europe, Asia and the US.

  According to the GSM Association, GSM represents over 70% of today's digital wireless market.
- **TDMA (Time Division Multiple Access):** A technology that is being phased out. Because TDMA is a dying standard, today's mobile world is divided between the CDMA and GSM technologies.

Briefly, these technologies work as follows:

- *CDMA* multiplies a signal with a unique identifier associated with each handset. It is up to the receiver to take the entire spectrum of signals and divide it by the same unique identifier to isolate the calls.
- *TDMA* and *GSM* take a narrow slice of the available spectrum and chop it into three (TDMA) or eight (GSM) time segments. Each segment can transmit a voice conversation or a data transaction.

With third-generation (3G) technology on the horizon, telecom companies and international standards bodies crafted a new interim standard known as 2.5G, represented by GPRS (General Packet Radio Service) and CDMA 2000 1x networks. These systems provide enhanced data transmission speeds (an average of 50Kbps) that are acceptable for use cases such as downloading a game to a cell phone or sending a low-resolution picture.

3G

The global wireless industry coined the term 3G to define the future generation of high-speed networks that would provide additional capacity and enhanced functionalities. The International Telecommunications Union, through the International Mobile Telecommunications 2000 initiative (ITU IMT-2000), defined the globally coordinated standards for these third-generation wireless networks. The ITU vision defines a worldwide standard that lets users enjoy access anywhere in the world to voice, data, paging, multimedia, and other forms of communication.

ITU identifies a number of bands in the 800-960MHz range as well as four bands in the 1700-2700MHz frequencies. In 2000, the standard was opened to new frequencies, and in some countries 3G is now available over a 450MHz frequency. According to ITU, 3G networks must have the following features:

- High speed data rates: 144Kbps in high-mobility conditions (for example, in a vehicle) and 384Kbps in low-mobility conditions (for instance, walking), up to 2Mbps.
- Packed-switched services (for example, IP traffic) and real-time video.
- Voice quality comparable to landline.
- Greater capacity and improved spectrum efficiency.

The specific radio interfaces covered under IMT-2000 include UMTS (Universal Mobile Telecommunications System) implemented using Wideband CDMA (W-CDMA) air interface, as the evolution of the GSM standard; and CDMA2000, the evolution of cdmaOne technology developed by Qualcomm.

Technically, EDGE is a 3G technology; however, because it is an interim step between GPRS (2G) and W-CDMA (3G), many in the industry are labeling it "2.75G."

Table 1. Generations of Cellular Voice and Data Services

Generation	Transmission technology	Current location
1G	AMPS (Advanced Mobile Phone Service)	US, but declining usage in metro areas
2G	CDMA (Code Division Multiple Access)	Mostly metro areas
	TDMA (Time Division Multiple Access)	Being phased out
	GSM (Global System for Mobile Communications)	Most of the world except US
2.5G	GPRS (General Packet Radio Service) and CDMA 2000 1x	Current changes in the US and some other areas
2.75G	EDGE (Enhanced Data rated for Global Evolution)	In deployment phase in the US
3G	CDMA2000 (Broadband CDMA)	Current push for use in the US
	W-CDMA (Wideband CDMA)	Standard in Japan and Europe

Because voice is transmitted digitally, higher data rates let a single base station handle a larger number of calls. This results in large-scale efficiencies. For example, EDGE provides three times the capacity of GPRS while W-CDMA is 10 times as efficient.

A practical example of the competitive advantages of a 3G network is "3" (formerly Hutchison 3G) in Europe. Since launching its 3G service, this carrier has offered the lowest-priced voice plans in the region. It has been signing up customers as fast as it can. Today, the biggest problem this operator faces, given the unexpected demand, is the shortage of 3G phones from its main suppliers, NEC and Motorola.

Beyond 3G

Next-generation networks require incredibly large investments in new equipment, frequency licensing from governments and implementation costs. Operators have invested billions in frequency allocations alone. Even at these costs, however, these new wireless technologies are highly attractive for operators globally, promising increased efficiency, added call capacity, and the creation of new revenue streams. Downsides of competitive auctions and high spectrum cost are the high barrier to entry and the inability to factor public interest into the awarding of allocations.

If implemented, the projected 4G technology may facilitate a true IP cellular network. 4G mobile phone technology supports Internet Protocol version 6 (IPv6) and promises faster communication speeds (100 megabits per second), capacity and diverse usage formats. These formats would provide richer content and support for other public networks such as optical fiber and wireless local area networks.[16]

4G is currently only an ideal. Still, some companies are incorporating new technological advances into cellular technology, something that some companies are calling "3.5G." 3.5G technology, the convergence of cellular and wireless LAN technologies, has led to a handset that makes calls using Voice over Internet Protocol (VoIP) when a 802.11 network is available (for example, when at home or at the office), then switches to a 3G cellular network when mobile.

Someday 4G networks may replace all existing 2.5G and 3G networks, perhaps even before a full deployment of 3G. Multiple 3G standards are springing up that would make it difficult for 3G devices to be truly global. A strong need exists to combine both the wireless (LAN) concept and cell or base-station wide area network design. 4G is seen as the solution that will bridge that gap and thereby provide a much more robust network.

Table 2. Differences Between 3G and 4G

Major requirement driving architecture	3G (Including 2.5G, Sub3G)	4G
	Predominantly voice driven; data was always add-on	Converged data and voice over IP
Network Architecture	Wide area cell-based	Hybrid: Integration of wireless LAN (WiFi, Bluetooth) and wide area
Speeds	384 Kbps to 2 Mbps	20 to 100 Mbps in mobile mode
Frequency Band	Dependent on country or continent (1800-2400 MHz)	Higher frequency bands (2-8 GHz)
Bandwidth	5-20 MHz	100 MHz (or more)
Switching Design Basis	Circuit and Packet	All digital with packetized voice
Access Technologies	W-CDMA, 1xRTT, Edge	OFDM and MC-CDMA (Multi Carrier CDMA)
Forward Error Correction	Convolutional rate 1/2, 1/3	Concatenated coding scheme
Component Design	Optimized antenna design, multi-band adapters	Smarter Antennas, software multiband and wideband radios
IP	A number of air link protocols, including IP 5.0	All IP (IPv6)

Source www.mobileinfo.com

Competitive Circumstances in Telecom

The current economic downturn has severely affected the telecommunications industry as a whole. The S&P Integrated Telecommunications Services stock price index dropped by 32.6% in 2002, underperforming the overall 22.5% fall in the S&P 1500 Index.[17] The reasons for poor telecom performance are many:

Excessive investment: In the late 1990s, when Internet traffic was growing at breakneck speed, many wholesale interexchange carriers (IXCs) built excessive and expensive fiber optic networks. Today, less than 3% of this network capacity is being used.[18] This excessive investment has created serious cash flow problems and put many wholesale IXCs out of business.

High capital costs: The accounting frauds uncovered in 2002 not only led to the bankruptcy of WorldCom and a 64% drop in Qwest stock[19], but also had an impact on the whole industry. Investors became more cautious, perceiving aggressive accounting practices as the telecom companies' best revenue booster. These worries have upped the cost of capital for telecom companies. Moreover, the WorldCom bankruptcy has affected all the players across the industry that have reciprocal agreements with WorldCom. Many companies are writing off huge accounts receivable from WorldCom.

Wired data services: As the voice service market matures, all major telecom companies regard data service as the new growth point. The data services include enterprise data and packet service, dial-up, household broadband service, and wireless data service.

Traditionally, interexchange carriers have close relationships with business customers. With the Telecommunications Act of 1996, the Regional Bell Operating Companies (RBOCs) also entered the long distance market and began to compete for the enterprise service market. Most of the telecom companies see rising revenue from data and packet services, while voice service revenue is declining.

Telecom companies are currently struggling against cable companies in the household broadband market. Although DSL is the leading broadband technology globally, it is lagging far behind cable in the US. As of June 2002, there were 9.2 million cable Internet subscribers in the US, compared to 5.1 million DSL subscribers.[20] However, telecom companies are taking steps to narrow the gap. On the technology side, DSL providers now have extended-reach DSL, which expands the distance limitation from central office to customer. On the customer side, DSL providers like Verizon and SBC try to attract more subscribers by offering services at 30% to 40% less than cable companies.[21]

Wired versus wireless: Besides the increasing rivalry among the local service companies, telecom companies are now facing challenges from wireless and cable companies, which provide competing services. This is already occurring with cellular customers who choose to "cut the cord" and discontinue landline service in favor of cellular alone. By the end of year 2002, 10 million land access lines had been displaced by wireless, and IDC anticipates that another 14 million access lines will be displaced from 2002 to 2006.

Although most wireline carriers also offer cellular service, this trend concerns them because wireless phone customers generate less revenue for companies, and Regional Bell Operating Company customers can go elsewhere for their wireless services.

According to Merrill Lynch, RBOCs lose about $15 a month when a customer opts to go solely wireless.[22]

Enticements of free long-distance minutes by cellular carriers have also eroded the long distance market. WiFi, with its potential for voice relay, is another possible threat to RBOCs, even if they do succeed in recouping substantial revenue from cellular endeavors. WiMAX, an emerging upgrade to WiFi, could make this even more extreme because of the potential for stronger, better quality voice and data transmission.

Though the cable companies' position in the voice market is still very weak, they have their unique advantages: a direct local link to customers in a wider area, and a reputable brand name. In addition to circuit-switched telephony, Time Warner Cable launched the first VoIP residential service, Digital Phone, in May 2003. With this new service, Time Warner Cable can offer a bundle of choices including video, broadband data, and phone services.[23]

Wireless Telecom Market Directions and Drivers

In 1981 the Federal Communications Commission awarded spectrum licenses[24] for cellular service in Metropolitan Statistical Areas (MSAs) rather than nationally or for larger regions, on the assumption that cellular telephony would have limited use as a complement to local landline service. Each metro area had two licensees: an incumbent local phone company and a newly licensed third party. This system not only failed to provide enough competition to encourage low prices in any area, but it localized coverage so that most carriers had to enter into roaming arrangements to provide coast-to-coast coverage.[25]

Despite the roaming constraint, efforts in the industry to provide lower-cost national service have helped foster significant cellular subscriber growth:

Table 3. Year-to-Year US Cellular Subscriber Growth[26]

Year	Subscribers
1984	91,600
1986	681,300
1988	2,069,000
1990	5,283,000
1992	11,033,000
1994	24,134,000
1996	44,043,000
1998	69,209,000
2000	109,478,000
June 2002	134,561,000
February 2003	137,458,000

Source: CTIA

3G cellular adds non-voice data (for example, software, text messages, e-mail) to cellular wireless offerings. As a result, the cellular carriers' access model for collecting revenues can be enhanced (or replaced) by a model where subscribers are charged for network and content services in addition to, or instead of, access.

Local Number Portability

Part of the 1996 Act is local number portability (LNP).[27] Implemented in November 2003, this policy lets mobile customers keep their phone number should they decide to change carriers; the FCC sees the proposal as a way to enhance competition. Implementation has been slow because of intense delay tactics from cellular lobbyists. The Cellular Telecommunications Industry Association and several wireless carriers filed petitions at the FCC in hopes of overturning FCC authority or delaying the transition.[28] Cellular companies claim that LNP is outside of the regulators' authority. The FCC issued a letter in response to their inquiries, indicating that LNP would go forward as planned later this year.[29] By November 24, 2003, carriers in the top 100 markets had to implement measures for LNP.[30]

LNP will inevitably cause churn, or customer loss to a carrier, to increase as inconvenience barriers dissolve that once made consumers hesitate before changing to a competitor. Where it has been introduced in other markets overseas. number portability has driven churn rates as much as 25% to 50% higher.[31] According to research by Paul Kagan Associates, more than 30% of North American cellular customers change providers each year.[32] Cost and network quality were the top reasons cited for change.[33]

Increased Competition: Competitive situations are different in the wireless, long distance wireline, and local area wireline markets. The wireless market is still growing, although growth slowed in 2002. The market potential is relatively large, with only 51.6% penetration rate in 2001, which could grow to as high as 63.4% in 2004[34]. The wireless market is much less regulated than the landline market. In this growing market, although competition is intense, it is mostly focused on keeping existing customers, tapping the potential users, providing new services, and increasing Average Revenue Per User (ARPU). There are eight major competitors, including six national wireless carriers and two regional carriers. In 95% of the United States, there are three or more different cellular operators.[35]

Wireless Data Services: Wireless data market growth has been slower than expected. A successful deployment of 3G networks is one possible way for traditional telecom companies to rebound via wireless, but so far such endeavors have met with disappointment. Still, the Yankee Group anticipates that wireless data revenue in the US will grow from $0.54 billion in 2002 (less than 1% of total wireless revenue) to $12 billion in 2006 (over 10% of total wireless revenue).[36] So far, between $8 and $10 billion has been spent by wireless companies on 3G upgrades, but networks are plagued by delayed rollouts and low consumer uptake.[37] Reasons for slow adoption by users include disappointment in speed, high-priced handsets, and problems passing calls off to parts of the network owned by other carriers. Because of costs, questionable consumer interests, and the subsequent deployment delays, analysts

predict that 3G will not be widespread until 2005.[38] High-speed data may not be the sole use for 3G; many users may eventually sign up for the enhanced voice quality.[39] For now, companies hope that consumers will be sufficiently attracted to 2.5G networks to entice them to the higher speeds awaiting them in 3G. However 3G will more likely be only one of a set of technologies that will converge in a future of hybrid wireless solutions.[40]

The combination of high-speed data rates and enhanced handset capabilities opens up a number of possibilities of enhanced services, multimedia, and new uses for cell phones. Videoconferencing, enterprise applications, mobile gaming, and multimedia messaging are some examples of successful applications of this new technology that result in added traffic (increased network revenues) and new income opportunities. On average, industry analysts expect data to represent 30% to 35% of operators' revenues as early as 2005. In the US alone, operator data revenue will represent $26 billion dollars by 2007, according to Gartner Group research.

Bundled Services

Cellular services were successfully promoted through a flat fee for a bundled plan, which offers consumers the advantage of predictability and less time devoted to review of monthly bills.[41] The telecom companies are considering a similar tactic to maintain customer loyalty and increase average revenue per user. Because regulators erased the boundaries among local, long distance, wireless, and data services, major telecom companies can now bundle services for a flat fee. By offering a bundle of local, long distance, and Internet services, AT&T successfully increased customer satisfaction. Encouraged by the success, AT&T is now planning with AT&T Wireless to add wireless services to the bundle.[42] Similarly, BellSouth's "Complete Choice" plan bundles local phone service with either cellular or broadband.[43]

Cellular companies see the value in integrating WiFi into their service plans. This is partially motivated by fear of being left behind should WiFi swallow any dreams of a 3G-dominated mobile data market, and partially because many see the potential for the two technologies to complement one another. T-Mobile is the most visible in this arena after they announced in May 2003 offers to bundle cellular service with WiFi access at a substantial discount compared to their WiFi only plans and those of competitors.[44] AT&T Wireless offers service with Wayport hotspots, although at much higher costs, and Sprint is expected to follow its predecessors with its own answer to WiFi.[45]

Alliances: In the wireless market, carriers are forming alliances to share network upgrade and extension costs. In January 2002, AT&T Wireless and Cingular, each of which runs a GSM network, announced a joint venture for the construction and management of a network along 3,000 miles of interstate highway in the western and midwestern regions of the country. Network sharing in smaller markets was regarded as the first step toward a deeper relationship.[46] Although the current capital market is not ideal for mergers and acquisitions, wireless carriers with the same platform (either GSM or CDMA) may join forces when the capital market recovers.

Fixed Broadband Wireless Technologies

Fixed broadband wireless (FBW) technologies provide high-speed Internet (data, voice, and video) services to business and residential subscribers. FBW technology uses wireless transmissions to provide voice and broadband data services to end users. FBW is used mainly for access applications that establish the link between the end user and the network.

FBW deployment architecture is very similar to a standard cellular/mobile telephony deployment, in which antenna sites are like the base stations, and the end-user equipment is like the cellular phone. FBW technology differs from cellular/mobile telephony in that its end-user terminals are in a fixed location (affixed to a building), and it does not support mobility because the terminals require a power connection. So unlike mobile networks, fixed networks do not have to deal with transmission problems caused by terminal movement. Problems like Doppler effect, handover to adjacent cell problems, power management, and control problems do not exist in fixed wireless networks. In essence, FBW can achieve much higher data rates and better voice connectivity than cellular telephony.

A fixed broadband wireless network comprises these parts:

- A digital base station site.
- A radio transmitter/receiver, located outdoors on the end user's premises.
- An indoor unit containing a modem and additional digital functions.
- Interfaces to end-user devices, such as a telephone, Ethernet for a PC/LAN, or an E1/T1 for enterprise telephony.

Fixed broadband wireless standards include Local Multipoint Distribution Services (LMDS) and Multichannel Multipoint Distribution Services (MMDS). Both use the licensed spectrum and are line-of-sight services, meaning there must be no physical disruption of the signal from the provider's antennae to the customer's base station.

Table 3. Differences between LMDS and MMDS

	Type of connection	Data rates	Range	Frequencies
LMDS	Point-to-point wireless applications include connections between cell phone towers and central offices, or trunk connections between metropolitan buildings	Between 150 Mbps and 620 Mbps	2 km	24 GHz, 28 GHz, and 39 GHz
	Point-to-multipoint products can transmit packets omnidirectionally	At 150 Mbps	1 to 3 km	
MMDS	Multichannel multipoint distribution service	128 Kbps to 10 Mbps	50-km range	2.1GHz to 2.7GHz

At the system level, too, fixed wireless networks are less complex than mobile systems, requiring minimal initial capital outlay. Because there is no requirement for mobility, there is no need for ubiquitous coverage; the service provider decides where to deploy the network and which regions to cover. In a mobile wireless network, multiple base stations must be deployed in areas with an unknown number of users, whereas in a fixed scenario a base station serves a known universe of users in a specific location.

FBW Market Directions and Drivers

Fixed broadband wireless has, however, been slow to deploy and develop, and remains a distant third to cable modem access and DSL in total number of broadband subscribers. Deployment challenges include technology standardization, developing a broader base of hardware manufacturers, and continuing the trend toward consolidation among fixed wireless service providers. The fixed wireless provider's antennae and the customer's base station, in most cases, have to be in line of sight, making deployment in urban or mountainous environments difficult and undermining reliability. Also, reliability is severely affected by inclement weather; in foggy or stormy conditions the signal is distorted, forcing vendors in wet climates to locate transmitters closer together.

Fixed wireless applications using the licensed spectrum do not possess the market share necessary to influence standards bodies. The cost of gaining access to the spectrum remains an issue.

The market in the US and western Europe remains small. However, in regions that have poor or no wired infrastructure, fixed wireless broadband remains a viable alternative and may play an important role in providing broadband access to rural and remote regions of the US.

In addition, FBW offers a higher Average Revenue per User (ARPU) compared to most high-speed data solutions on the market, because it is an access technology that allows the service provider to capture end users' local and long-distance voice revenue as well as their high-speed data service revenue.

Analysts have largely written off licensing spectrum for wireless broadband. However, emerging reliable non-line-of-sight technologies that take advantage of unlicensed spectrum (for example, WiMAX, discussed below) have been gaining considerable momentum.

License-Exempt Technologies

Devices and technologies operating in unlicensed spectrum space share the same frequency slots, which are also shared with other radio-frequency devices—everything from cordless phones to microwave ovens.

Many license-exempt technologies exist, though the focus here is on wireless local area networks, known as WiFi. Found, among other places, in handheld devices,

these networks provide data exchange capabilities (for example, exchange of contact information) between PDAs or point-of-sale transactions.

The most common wireless license-exempt technologies include:

Infrared technology: A technology that links two infrared devices held close together and pointing at each other. Infrared communication is slow by today's standards, providing very limited bandwidth. Applications typically involve transmitting text and low resolution graphics.

Bluetooth wireless: The low-power, short-range radio technology that lets electronic devices such as mobile phones, headsets, PDAs, and notebook PCs communicate without wires. Bluetooth is for device-to-device communication only, and provides three connection types: data-only, voice-only, and data and voice transfers.

Bluetooth lets devices form fluid connections for communicating one-to-one or for creating a wireless personal area network (PAN). A PAN is often described as a 10-meter-radius bubble, inside which all of your devices equipped with Bluetooth technology can interact and communicate without physical connections.

Radio Frequency Identification tags (RFID): A new technology that is inexpensive to implement and ideal for identification applications. Commercially, RFID can replace plastic credit cards (customers just get close to the cash register and their credit card information is transmitted securely). For industrial applications such as inventory control, an inexpensive RFID tag can track a product in a warehouse or in a production line. This method replaces precise manual scanning of barcode labels using readers.

ZigBee: Like Bluetooth, a technology that uses the 2.4GHz radio spectrum, although in specific countries ZigBee also uses the 868MHz and 915MHz operating frequency bands. Its data transmission rate is only 128Kbps on average.

ZigBee was designed to serve purposes very different from Bluetooth (which handles relatively infrequent communication of primarily static devices). Applications for ZigBee include home automation, remote controls, toys, health care monitoring, asset management, and access control. For these applications ZigBee provides a much smaller protocol stack than Bluetooth, connection speeds (latency) in the milliseconds (rather than ten seconds with Bluetooth), and a significantly more battery-efficient radio technology; ZigBee devices might use batteries that are not recharged (for example, your TV remote control or a light switch).

WiFi: Wireless Fidelity, also known as the wireless Ethernet, 802.11b, 802.11g, and 802.11a, has emerged as the dominant standard for wireless LANs (WLANS) worldwide. WiFi networks are easy to set up and have coverage of typically 100 to 500 feet, with broadband access hundreds of times faster than a modem connection. Unlike other wireless technologies such as CDMA and GSM, WiFi technology has a wider global acceptance. It has become the "TCP/IP of wireless," a single networking

standard for all developers of wireless technology, equipment manufacturers, service providers, and users.[47]

WiMAX: Also known as 802.16, World Interoperability for Microwave Access technology is an emerging standard for wireless broadband. WiMAX technologies, proposed as a last-mile solution for wireless networks, are expected to enable voice, data, and multimedia applications with a connection range of up to 30 miles.

Bluetooth and WiFi

Like WiFi, Bluetooth technology is a wireless standard that operates in the unlicensed 2.4 GHz radio spectrum. Both standards allow for wireless connection to the Internet, but that's where the similarity ends. WiFi technology is embedded in PCs and connects to the Internet through a network; Bluetooth is embedded in a wide range of consumer and corporate products and connects them with each other. Though WiFi's speed and bandwidth makes it more attractive for connecting to the Internet, Bluetooth's low cost and low power consumption could make it a natural technology for connecting everything else.

From its inception, Bluetooth was designed to be a small-form factor, low-cost, low-power technology. Power consumption is critical, as it directly affects battery life—crucial for devices such as PDAs and mobile phones. To achieve Ethernet-level data rates, WiFi uses much more battery power. In fact, in a typical PDA with both technologies in full power, a WiFi PDA could expect little more than an hour of operation, but a PDA using Bluetooth technology could operate for five to ten hours.

WiMAX and WiFi

WiMAX (802.16) seems to be the next logical step after WiFi (802.11). More robust for high-speed broadband delivery, it is expected to see increased usage within the next few years, similar to the growing popularity of WiFi in late 1990s. WiMAX and WiFi are complementary, as the two technologies address different segments of the market and are optimized for different tasks (local versus metropolitan area networking). The table below highlights the differences between 802.11 and 802.16.

Table 4. Differences between WiFi and WiMAX

	WiFi (802.11)	WiMAX (802.16)	Technical difference
Range	Sub ~300 feet (add access points for greater coverage)	Up to 30 miles Typical cell size of 4 to 6 miles	802.16 MAC tolerates greater multipath delay spread (reflections)
Coverage	Optimized for indoor performance	Outdoor NLOS Performance Standard support for advanced antenna techniques	802.16: 256 OFDM (versus 64 OFDM) Adaptive modulation
Scalability	Channel bandwidth is wide (20 MHz) and fixed; cell planning is constrained	Flexible use of available spectrum	3 non-overlapping 802.11b channels 5 non-overlapping 802.11a channels 802.16: limited by available spectrum
Bit rate	2.7 bps/Hz peak Up to 54 Mbps in 20 MHz channel	5 bps/Hz peak Up to 100 Mbps in a 20 MHz channel	802.16: MAC efficiency constant with PHY rate increase
QoS	No QoS support; 802.11e working to standardize	QoS built into MAC; voice/ video and differentiated service levels	802.11: contention-based MAC (CSMA) 802.16: grant request MAC

3G and WiFi

Are cellular and WiFi competitive or complementary? The two types of service currently have distinctly different emphases.

Cellular remains focused on voice communication. With broader 3G adoption there will be data services, but they may have to transcend the limitations of the handset; for instance, a telephone is not the ideal device for digital media.

WiFi is limited by range, and is therefore less mobile. Thus far there is no clear business model for WiFi service, and there are open questions about authentication and accounting, roaming, and the business requirements for pervasive WiFi. The current 802.11b protocol is clearly just a first step, an implementation that opened awareness of the potential for wireless broadband networking to evolve as an important platform for many applications and devices.

The future will bring a convergence of wireless technologies that support more stable, sustainable business models based on innovation around the real killer apps: mobility and ubiquity of network access. In fact, WiFi and 3G might be complementary, as 3.5G technology defines their convergence.

WiFi Market Drivers and Directions

Wireless LANs provide access in a defined geographic area—in industry terms, a *hotspot*. A hotspot can be an office, home, or coffee shop.

Typically the devices using a WLAN are notebooks or high-end PDAs. When wireless network cards for laptops dropped in price, more users began to carry them, having discovered an increasing number of wireless access points that were either accidentally or intentionally free. Many wireless network points were open by default and therefore unsecured. An informal community of WiFi users propagated the concept of "war-chalking," marking sites with symbols indicating the presence and status of a wireless network. Operators of coffee shops, restaurants, hotels, and other venues began to offer free wireless access as an amenity.

Hundreds of equipment manufacturers are now entering the market with millions of WiFi and wireless Ethernet cards and access points ("APs"—wireless hubs). A single WiFi standard ensures interoperability with other devices. As prices have dropped, demand for WiFi and other wireless equipment has risen, resulting in millions of privately run and deployed wireless networks. In addition, these wireless networks have also begun appearing in public spaces also called hotspots.

Table 5. Number of Hotspots in the US, 2002-07

Year	Number of hotspots
2002	3,020
2003	12,080
2004	21,140
2005	36,240
2006	54,360
2007	72,480

Source: Yankee Group, July 2003

Table 6. WiFi Forecasts

	2002	2003	2004
Expected service revenue	$8.4 million	$34.3 million	$204.7 million
WiFi enabled devices	9.5 million	22.3 million	38.7 million

Source: World Trade, May 2003[48]

In the past two years, dozens of new companies have added WiFi access points in cafes, hotels, airports, book stores, and other public spaces. These *hotspot operators* (HSOs) install WiFi access points, then sell high-speed wireless Internet access or offer it free as part of value-added services.

Hotspot operators enjoy a very low barrier to entry—as little as $25 for an access point and $29 per month for a DSL line. Larger hotspots require additional equipment, antennae, and faster connections such as T1 lines. Still, the cost of a hotspot is far lower than a cellular node—WiFi uses unlicensed spectrum (vs. licensed spectrum), and the equipment necessary to set up a hotspot costs hundreds of dollars (versus hundreds of thousands or millions in cellular).

Nonetheless, WiFi faces significant challenges:

Lack of ubiquity: Despite the growing popularity of WiFi networks in homes, offices, and public places, commercial public US hotspots today are concentrated in hotels, airports, and a few national retail and café chains. According to wireless provider Boingo's own market research, there are nearly two million potential hotspots in the US alone. Clearly, hotspot deployment is in its infancy. However, so long as uncertainties linger about the economics and characteristics of the hotspot industry, significant investment capital will remain on the sidelines. On the other hand, many hotspots are appearing that are operated for free to the end-user as an amenity, and community wireless hotspots may prove a good alternative for providing broadband to traditionally underserved areas.

Fragmentation: One poorly understood characteristic of the hotspot industry is fragmentation. WiFi's relatively short range of approximately 100 to 500 feet increases the likelihood of multiple hotspots in a given area.

As in the early days of cellular and ATMs, the lack of unified roaming capability in commercial WiFi constrains the industry's development. Far fewer people used ATM cards when they were only accepted at the issuing banks' locations. Similarly, cellular only took off when people could roam from area to area and were not required to change phones and providers. WiFi users today are forced to either maintain accounts with each of the hotspot operators they encounter in their travels or enter their credit card number each time they want to connect. As commercial hotspots increase in number, so will fragmentation, making the problem even more widespread. Support for unified roaming across all commercial hotspots will create an expanded market for wireless access providers.

However if the free public WiFi model predominates, roaming will not be a significant issue.

Difficult user experience: WiFi is a transparent amenity, and the industry to date has done little to advertise hotspot locations. Though this is rapidly changing, it is still sometimes difficult for users to find hotspots, and that uncertain availability, along with inconsistent quality of service, has brought some users a negative WiFi experience. Even if a user is aware that WiFi is present, getting connected has been a complex ritual. Users were expected to know things like "SSIDs" ("Service Set Identifiers"—the identifying names given to WiFi networks), how to turn on and off

security settings, and how to program often clunky configuration software on their laptops. These shortcomings have largely been addressed by improvements in hardware and related software, automating configuration and service identification.

Lack of focus: Like WiFi, the WISP (Wireless ISP) industry is built upon an unlicensed foundation, allowing literally thousands of competitors to enter the market. In the cellular industry there is a government-mandated limit on competition. Only a set number of licensees hold spectrum licenses. This allows the cellular industry to be vertically integrated—the same company that owns the spectrum can afford to build and operate required physical networks, and market to, support, and bill end-user customers.

In WiFi, no such spectrum protection exists, and as in the ISP space, anyone with a bit of capital and entrepreneurial ingenuity can compete in the service provider value chain.

Given this, vertical integration in WiFi will be very difficult, if not impossible. Thus it is critical to understand how the distinct layers of the industry fit together so that WiFi-related companies can focus their capital effectively.

Security issues: These may appear to be inherent in all wireless networks because radio signals are accessible to anyone with a receiver. However the Internet itself is a public switched network with no expectation of security except through encryption, and WiFi is no less secure. Wireless data networks (specifically WiFi) do pose different problems from cellular. Where WiFi is used to extend a LAN, security measures (firewalls) will attempt to limit access to trusted users. The Wireless Encryption Protocol (WEP) used to provide this security is less than robust. Where WiFi is used to provide access to the Internet (hotspots), there may be less concern for internal data, which may be minimal or nonexistent, or hidden behind a firewall.

Interference: This is a potential problem for wireless devices in the industrial 2.4 GHz frequency range of unlicensed spectrum. Sources of interfering signals may include microwave ovens and other wireless devices operating within this range. However, there is very little field experience of fatal contention from other 2.4GHz devices. Packet rates become slower, but they don't die completely.

Wire to wireless: Wireless connections to the Internet are ultimately connected to some kind of wired infrastructure, and are generally limited to areas where a connection is available. The maximum range of 802.11 (WiFi) is 150 feet, and the effective range is as little as 50 feet; the emerging 802.16 (WiMAX) standard extends that range to 30 miles. Range may be further extended by repeaters. It is also possible for rural or remote wireless to connect via satellite to the global network. The network at Mt. Everest's base camp is an example of a wireless network with satellite connectivity.

Although there are other forms of wireless access to data, WiFi emerged as a de facto standard for public access to the Internet and for residential extension of access. However, because of its signal strength and distance limitations, and its weak security, the 802.11b standard is unlikely to persist as a permanent solution.

WIRELESS FUTURE SCENARIO 2: BRIDGE COLLAPSE AVOIDED

August 20, 2009 (New York, NY)—The East River span of the Triborough Bridge was closed yesterday following alerts from its newly installed network of wireless stress sensors.

According to Metropolitan Transportation Authority (MTA) spokesperson Paula Pritchard, the seismic sensors detected fissures in newly poured concrete panels that severely weakened the structural integrity of the bridge. The entire Triborough Bridge complex carries approximately 250,000 vehicles per day between Queens, Manhattan and the Bronx. Ms Pritchard said, "Many lives have potentially been saved, thanks to the new sensing technologies employed by the MTA."

The bridge, opened in 1936, has been the subject of a long-term rehabilitation project completed earlier this year. The $550 million program included the replacement of 1.6 million square feet of deck as well as the installation of the sensor network and other significant upgrades—money well spent, according to Pritchard.

The sensor network was supplied by an Austin, Texas company, The Sensor Farm. Said Steve McDonald, CEO of The Sensor Farm, "We as an organization are sincerely thankful that we have played a part in averting this potential tragedy."

Speaking of the virtues of his company's products, McDonald said that wireless sensors can be installed almost anywhere. "The sensors are part of a self-organizing network that provides users with real-time usable information." Because of their relatively low price, many wireless sensors can be employed together, generating an extremely accurate picture of prevailing conditions.

In addition to stress-checking applications such as the Triborough Bridge installation, wireless sensors monitor situations such as air quality, traffic movements, and many specific uses in agriculture, security and manufacturing. Dozens of cities are now using wireless sensors as the backbone of their Intelligent Transportation Systems (ITS) that optimize road usage and traffic flow.

According to McDonald, as the sensors get smaller, the number of potential uses continues to grow. "You may not know they're there, but they sure make a difference to your safety and quality of life," he declared proudly.

The MTA is making funds available to equip all of Manhattan's bridges and major arterial roads with wireless sensor networks. Following repairs, the East River span is scheduled to reopen in late October.

WIRELESS FUTURE SCENARIO 3: BLASTRO BLASTS OFF!

Billboard, June 2007

Complete entertainment anywhere, anytime—that's what Blastro aims to provide its subscribers.

Originally an Internet-based streaming music and video content provider, Blastro (www.blastro.com) now offers comprehensive content that can be accessed via any wireless communication device. Now with seven million users and counting, the ubiquitous media provider is definitely in orbit.

PLEASING MORE PEOPLE MORE OF THE TIME

Speaking from Blastro headquarters in Austin, Texas, founding partner Casey Charvet praises the company's never-ending pursuit to connect people with their chosen entertainment. "We're always looking to please more people more of the time!"

Blastro, and a handful of other providers offering similar services, have provided broad opportunities for hardware manufacturers, software designers, advertisers, and artists alike. "Our services leverage advances in bandwidth and compression technologies, as well as breakthroughs in displays such as the new FOLEDs [flexible organic light emitting devices]," explained Charvet. "The net result is a challenge to programmers and artists to fully use the medium."

BEYOND AUSTIN CITY LIMITS

Blastro's subscriber base is truly international, with users spanning the globe from Tuscaloosa to Taipei. Because Blastro uses 'Omni Roam®' technology, users can always have their preferred entertainment on tap anywhere.

According to programming director Nick Harcourt, whose inbox is routinely filled with new material from content developers from around the world, "I want to put you in the audience for any performance in the world. As long as the images and sounds are captured, I can find a way to get it to you."

Because of this massive reach, advertisers have been beating down the company's doors. Presented in the same 'made for wireless' style as the other content, the ads on Blastro seem like part of the regular programming.

FASHIONABLY FREE

Blastro recently teamed up with Charmed Technology (www.charmed.com) to launch a range of wireless enabled fashion essentials. Dubbed Blastware, the range includes bags, jewelry, and eyewear that are as stylish as they are functional.

The company is also negotiating with several well-known filmmakers to

boost its stock of made-for-wireless movies. Says Charvet, "With the gradualdecentralization of the film industry that we have seen over the past ten years, many creative people now pursue new careers without being subjected to the iron fist of an executive sitting in a Hollywood office."

Now free of the captivity of cinemas, televisions, and DVD players, many Blastro users are putting themselves close to the action. Picture yourself watching the seventies classic "Jaws" from the deck of a fishing boat. What about joining Jody Foster in her claustrophobic confines to watch "Panic Room" (2002)? "We used to think surround-sound was pretty cool, but now you can surround yourself with just about anything," Harcourt observes.

Blastro continues to push both the technological and geographical boundaries of entertainment, taking the humble wireless device to new places in the time–space continuum. My parents wanted their MTV, but I need my Blastro!

DISCLAIMER: *The preceding scenario is fictional and used for illustrative purposes only. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply the endorsement, recommendation, or favor of Blastro. The views and opinions of authors expressed herein do not necessarily state or reflect those of Blastro.*

SECTION 2—UBIQUITOUS MOBILE COMMUNICATION

The preceding two Wireless Future Scenarios illustrate two very different examples of how wireless networks would be used but the underlying principle is the same--ubiquitous mobile communication facilitated by the presence of an available wireless connection at all times.

In this section we discuss different technological approaches to making ubiquitous mobile communication a reality and the early efforts of companies and communities to derive value from wireless networks. We also discuss the policy developments that are critical to the continued emergence of wireless technologies and services.

Wireless Quilts

"Wireless Quilt" is a term suggested by Marc Smith of Microsoft's Collaborative and Multimedia Systems Group, and used in Howard Rheingold's book *Smart Mobs*. Others have used the term *wireless blanket*, but the word *quilt* suggests the patchwork aspect of wireless coverage, as opposed to a blanket or canopy analogy, which suggests a single operator or technical base.

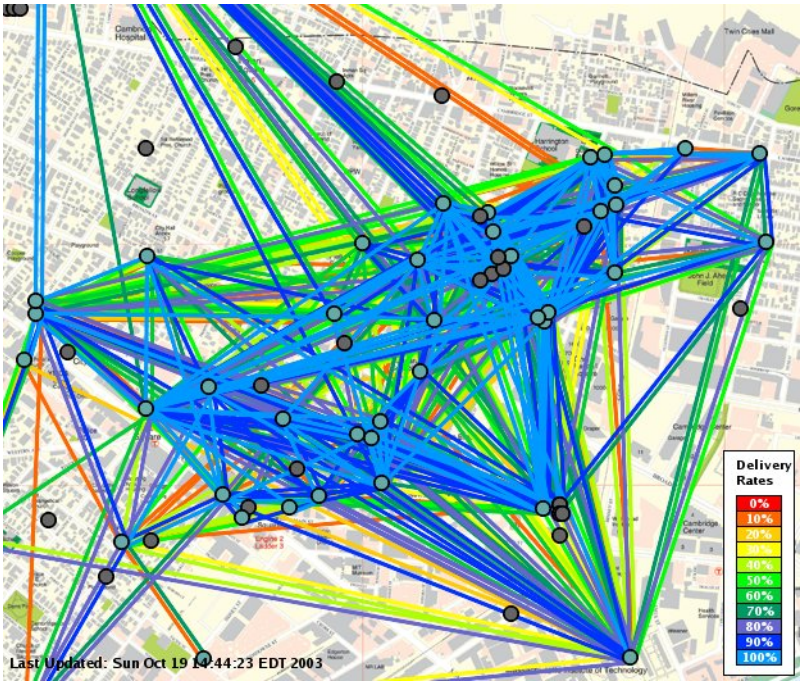
Rheingold is referring to the quilt-like patching together of diverse, open WiFi access points established and maintained by many operators to create a pervasive wireless network for public access. Through wireless quilts, users of wireless devices can make network connections without disruption via access points strategically located throughout a given area. As access points appear and become pervasive, we expect that wireless networks will evolve toward increasingly sophisticated ubiquitous computing systems. Through these, private and public service providers will collaborate to ensure broadband access for a growing number of wireless devices.

The WiFi "grassroots" movement is driven by recent advances in wireless technology as well as regulatory actions that have made it possible for users to share wireless Internet access at higher speeds, comparable to 3G technology being offered through cellular communication operators. Now communities of wireless users can create their own networks using 802.x technologies within designated unlicensed spectrum.

The "Social Impact of Wireless" section of this chapter discusses Rheingold's *Smart Mobs* in greater detail.

Mesh Networks

One example of a wireless quilt is MIT Roofnet[49]. Its goal is to build a production-quality self-organizing network capable of providing Internet service while researching scalable routing protocols. The Roofnet design requires no configuration or planning beyond installing the hardware.



Roofnet is a *mesh network*, which means that each node in the network of about 50 computers connects via 802.11b wireless to every other node, a few of which are Internet gateways. This structure is supported by a sophisticated routing protocol, SrcRR, designed to find optimal routes for data.

Roofnet is a single mesh providing broad coverage, but pervasive wireless is less apt to be a single network than multiple access points that are only loosely interconnected (insofar as they are all linked to the Internet). Other community mesh networks in the US exist (Seattle, the Bay Area), but they use more traditional, less sophisticated routing protocols such as OSPF to form a backbone of reliable links, rather than connecting every computer to all others.

Currently urban wireless coverage is more likely provided through a patchwork of hotspots with diverse entities providing connectivity to the Internet. The various approaches to coverage have different characteristics:

- *Point-to-point networks* can provide reliability, but they do not scale to handle more than one pair of end points.
- *Point-to-multipoint networks* can handle more end points, but their reliability is determined by the placement of the access point and end points. You can drop ad hoc networks or multihop systems into place with minimal preparation, and they provide a reliable, flexible system that can be extended to thousands of devices.
- The wireless mesh network topology developed at MIT for industrial control and sensing is a point-to-point-to-point, or peer-to-peer, system called an *ad hoc multihop network*. A node can send and receive messages, and in a mesh network, a node also functions as a router and can relay messages for its neighbors. Through the relaying process, a packet of wireless data will find

its way to its destination, passing through intermediate nodes with reliable communication links.

Wireless mesh networks like the MIT Roofnet are multihop systems in which devices assist each other in transmitting packets through the network. Of the different topologies for wireless networks (point-to-point, point-to-multipoint, and mesh), mesh networks have the highest scalability, reliability, and adaptability. These are the most important attributes of a wireless network for industrial control and sensing applications.

Like the Internet and other peer-to-peer router-based networks, a mesh network offers multiple redundant communications paths throughout the network. If one link fails for any reason, the network automatically routes messages through alternate paths.

A mesh network is self-organizing and does not require manual configuration. Adding new gear or relocating existing gear is as simple as plugging it in and turning it on. The network discovers the new node and automatically incorporates it into the existing system.

Canopy Networks

Motorola has developed a broadband wireless platform, called Canopy, over which Internet service providers can deliver wireless Internet access to specific points. Canopy is a proprietary system distributed by licensed installers and retailers. The Canopy system includes three elements:

- A small subscriber module attached to the home or building
- Community-sized access points, mounted on utility poles or water towers to distribute service to the surrounding community
- The backhaul[50] unit, which can provide bulk connectivity from a remote network to the access point site

Canopy is a controlled form of wireless network similar to the wireless quilt, but more centralized. Canopy is a point-to-multipoint network operating on radio frequencies; like WiFi, the system operates in the Unlicensed National Information Infrastructure (UNII) spectrum of 5.25 to 5.35 GHz and 5.725 to 5.825 GHz. Canopy differs from WiFi and other types of unlicensed wireless in the ability it gives service providers to control and monitor the network and its users, and the presence of a technology that eliminates interference from other systems and controls freeloading on the network. It is deployed at a fixed location and transmits over a network of multiple access points located throughout a given area. Once Canopy is set up, the provider organizes the network similar to a traditional Internet service provider. The initial connection delivered to the subscriber module is based on the location of the canopy's desired deployment and accessible high speed connections. That is, the provider can choose satellite access or any other means of broadband access to provide backhaul for the last-mile connection.

The Canopy system uses point-to-point and point-to-multipoint networks that can span distances ranging from two to 10 miles in a multipoint configuration, to as many as 20 miles in a point-to-point configuration.

The Canopy components are small, unobtrusive, easy to install, and can serve a wide range of network purposes. A Canopy system can be deployed as a standalone system, or the Canopy elements can extend the reach of wired IP distribution systems such as cable and DSL. Canopy elements also can serve as redundant IP backhaul for organizations and service providers.

Sophisticated base-band processing and directional antennae enable the Canopy technology to virtually eliminate interference from other systems operating on the same frequency bands. To maintain privacy and security, the system comes equipped with an advanced over-the-air data encryption system (DES) providing cryptographically encoded communications. 128-bit authentication allows only authorized subscribers to gain service onto the Canopy network.

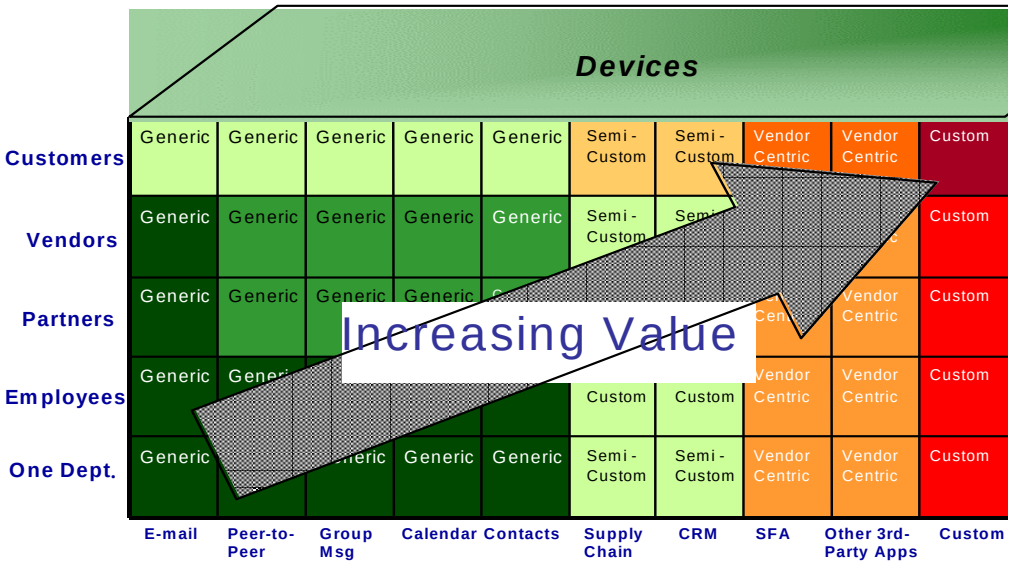
An alternative to the wireless networking of localized access points, Canopy provides reliable and secure access based upon a subscriber or authorized access. The transmission of data as secure packets permits a more secure wireless network. This networking alternative is beneficial in terms of security for subscribers and service providers who are concerned about interference and data interception, and who need sophisticated backhaul support.

Business Applications of Wireless Technologies

Business applications strongly drive wireless technology development and the industry's overall direction. Wireless companies have recently begun to focus on enterprise applications.

Business applications can be summarized in a matrix developed by Austin-based wireless market research firm iGillott Research:

Figure 1. Business Applications Matrix



Source: iGillott Research

The matrix describes the usage and functions of wireless apps. The left axis indicates scope of usage, ranging from internal use by a single company department (bottom) to the entire market (top). The bottom axis indicates breadth and sophistication of function, from simple e-mail (left) to very broad or unique value-added applications (right). Currently most wireless applications are found on the bottom left corner: internal e-mail, messaging, calendar, and contact management.

There are two trends here. One is upward, toward the integration of outside users. The other trend is to the right: more business functions with wireless connections, such as supply chain management, sales force automation, work force automation, and totally customized banking applications. As the applications move toward the right, wireless technology adds more value, but it is also more difficult to manage and bears higher risks.

Disagreements exist about whether the upward trend will continue, as huge support expenses have slowed it down. However, a trend toward value-added applications is definitely taking place, particularly in two domains: supply chain management and sales force automation.

Wireless in Supply Chain Management

Of these areas, supply chain management (SCM) has the most applications of wireless technology. Wireless has proven efficient and reliable in SCM applications, as the cases of UPS and Texas Instruments reveal.

UPS DIAD IV

Since wireless technology became available, United Parcel Service (UPS) has pioneered applications in supply chain management. Its goal: to efficiently track every package, and thereby shorten delivery time to satisfy customers. The challenge is the mobility of its delivery drivers, who must use wireless devices to scan package delivery data and send it instantly to the enterprise data processing center. UPS aims to track the exact location of any package in real time. To date UPS has been very successful in applying the latest wireless technology to meet its specific supply chain management needs.

Since the introduction of its first-generation wireless network, UPS has been cooperating with Symbol Technologies, Inc. to provide wireless solutions. In 1996, even before the 802.11 specifications were ratified, UPS started using a wireless scanner/terminal system. Across two fingers the delivery driver wore a scanner, which connected to a terminal device on the forearm. The terminal linked to the company network through a proprietary Direct Sequence Spread Spectrum (DSSS) wireless network. DSSS operated at 900 MHz and 56Kbps.

For the next generation of its wireless technology, UPS made several changes to the data transmission process. UPS announced its fourth-generation wireless handheld computer, the Delivery Information Acquisition Device (DIAD IV) in April 2003. DIAD IV's new features comprise Bluetooth as the connection between the scanner and the terminal, and standards-based LAN and WAN technologies instead of

proprietary DSSS. With this new device UPS is integrating almost all the wireless technologies on the market, from the Personal Area Network (Bluetooth), to the Local Area Network (WiFi), to the Wide Area Network (CDMA, GPRS, GPS). DIAD IV also has a dial-up modem for fixed-line connections.

With DIAD IV, the ring scanner is no longer wired to the terminal. It transmits data using Bluetooth to the terminal on the driver's belt. The terminal is then connected to the UPS network through CDMA or GPRS, depending on the standard supported in that region. Inside a UPS center, the DIAD IV transmits data through a WiFi network. Also, DIAD IV is GPS-enabled, allowing UPS to track packages even when they are en route.

The DIAD IV integration resolved several additional problems:

- **Bluetooth/WiFi interference:** Interference between Bluetooth and WiFi was a major problem. The UPS solution uses Time Division Multiple Access (TDMA) to divide the airwaves into "time slices": 80 milliseconds for 802.11 data, then 20 milliseconds for Bluetooth.
- **Free roaming required:** Symbol's latest Spectrum24 access point model lets users roam freely between access points without authentication delays.
- **Battery life:** Symbol also developed a "power save" mode for the device, which turns off the power when not in use. With an appropriate battery, DIAD IV can stay alive for more than six hours, longer than any UPS driver's shift.

For a full rollout UPS must deploy the DIAD IV to 70,000 drivers worldwide at an estimated cost of $127 million. Although UPS has not disclosed a specific cost savings, the company expects the fourth generation to increase customer satisfaction as well as logistical efficiency. With the third-generation device in 1999, UPS anticipated a cost savings of $150 million a year. Similarly, FedEx, by upgrading its PowerPad palmtops at a cost of $150 million, expects to save $20 million annually.

Although to date UPS has not partnered with WAN carriers to provide wireless services, that may be the next step. To achieve greater mobility, UPS will inevitably rely more on WAN to transmit data. Set to select its WAN carriers from domestic and international markets, UPS has sent out a request for proposals to both CDMA and GPRS service providers. Unlike other business users, UPS is less interested in network bandwidth than in reliable coverage and connectivity countrywide.

Texas Instruments RFID

Texas Instruments manufactures RFID tags, which can automatically provide detailed information about an item within a certain range without scanning. RFID is one of many Automatic Identification (Auto-ID) systems, which have played a crucial role in supply chain management, just-in-time inventory control, and point-of-sale product identification.[51]

Currently the most common application for RFID is in automotive immobility: Entering the wrong key causes RFID-enabled vehicles to immobilize themselves as a

theft deterrent. Almost half the RFID tags Texas Instruments ships are used in the automotive industry. RFID is also widely used in access control.

The biggest RFID potential lies in supply chain management, currently dominated by barcode technology. Considering the potential use on pallets, cases, and individual items, RFID proponents say the sales of RFID tags could easily reach tens or hundreds of billions of units annually. Texas Instruments' challenge is to tap this SCM market, while simultaneously offsetting materials and production costs and contributing to the establishment of a reliable industry-wide standard for Auto-ID systems.

An RFID system consists of a transponder (also called the tag), which has a small coiled antenna, and a reader with an antenna. RFID systems can be categorized in two ways: by frequency and by power supply.

- **Frequency:** RFID systems are made in low-frequency (125 to 134 KHz), high-frequency (13.56 MHz), and ultrahigh-frequency (300 MHz to 1 GHz) categories. Low-frequency systems have a shorter reading range (within one foot), but are also much less expensive. High-frequency tags can be read within three feet; ultrahigh-frequency tags have a reading range of over 20 feet.

  Texas Instruments manufactures RFID products only in the low-frequency and high-frequency ranges, although it is testing ultrahigh-frequency products. Its automotive immobility tags, which account for almost half the company's RFID sales, operate at 134 KHz, low-frequency. For supply chain management, TI ships 13.56 MHz high-frequency tags, a proven technology with satisfactory reliability and accuracy.
- **Power supply:** RFID tags can also be classified as passive or active. Passive tags do not contain an innate power supply, but are activated by radio waves from the reader. Passive tags are lighter, less expensive, and have a virtually unlimited operating life. However, they have a much shorter reading range and are often read-only tags.
- Active tags have an integrated battery with a two to ten-year life span. Active tags are typically read/write, meaning the reader can modify information in the tags.

Marks and Spencer, a British retailer, has used RFID technology to increase operating efficiency and cut costs. Marks and Spencer uses 3.5 million 13.5 MHz RFID tags on plastic food trays for which a short time to market is crucial. RFID technology helps the company reduce costs in several ways:

- RFID boosts the average availability time of food in the store by six to eight hours. This results in major cost savings, as the food stays fresh for only two to three days.
- RFID eliminates the labor cost related to old barcode technology. With barcodes, Marks and Spencer workers spent time peeling off the used barcodes and putting on new ones. The company calculates that the RFID has reduced the touch labor cost by 80%.

- Although priced at 35 cents, the RFID tags are not as expensive as they seem: rewritable and recycleable, the tags can be used for the entire ten-year life of the plastic trays, making the amortized lifetime cost of the tags only one penny.

The primary issue for RFID technology is cost. Currently, each tag costs between 35 cents and a couple of dollars. The cost must drop to five cents per tag, the threshold price for mass applications in supply chain management, before RFID use becomes widespread. The future will bring a continuous decline in price.

The industry also requires a single standard for Auto-ID technology. MIT's defunct Auto-ID Center, a partnership among roughly 100 companies and several major universities, promoted the Electronic Product Code (EPC) standard to manage RFID coding. However, certain large RFID manufacturers, among them Texas Instruments, support the Universal Code Council (UCC), asserting that as a business organization, UCC has the experience to effectively manage Universal Product Code.

Privacy advocates also note a concern with RFID tags, especially if they remain active beyond point of sale.[52]

Wireless in Sales Force Automation

For manufacturers the number-one wireless application is sales force automation (SFA).[53] According to an August 2002 Datamonitor survey, 59% of surveyed companies identified their sales force as the section of their company most likely to benefit from mobile technologies.[54] Another survey published by *Managing Automation* in July 2002 showed that 67% of manufacturers that built a wireless infrastructure have some form of SFA application.

With such market potential, it is therefore not surprising that SFA solution providers differ on which technologies, platforms, and devices to offer end users. Competing SFA solution providers can be classified in three categories:

- Traditional enterprise software vendors.
- Mobile application specialists.
- Web-only applications providers.

Despite these differences, most mobile solution providers agree that SFA solutions should be customized to meet specific needs in a certain industry. Major vendors have all adapted their SFA solutions to various vertical industries, such as the pharmaceutical and automotive trades.

Traditional Enterprise Software Vendors

Traditional large enterprise software vendors regard sales force automation as a logical extension of their complex enterprise systems. Their mobile solutions emphasize integration with central database and enterprise resource planning (ERP) systems. Traditionally they support mobility only for data from the vendor's system.

A good example is the Siebel Pharma, a companywide Customer Relationship Management (CRM) solution for pharmaceutical firms that integrates sales, marketing, service, and R&D information. Siebel, the leader in the CRM market, adds the capability of exchanging data with the mobile sales force through real-time wireless PDAs. In July 2003 Bayer Yakuhin, one of Bayer's subsidies in Japan, announced it would deploy the Siebel Pharma, which will connect its 600 field sales and marketing representatives to the enterprise system by wireless.[55]

However, to compete with the specialist mobile solution providers, some big software vendors are trying to make their mobile system compatible with third-party data sources. SAP is testing this idea through its newly launched mySAP solution.

Specialist Mobile Solution Providers

Specialist mobile solution providers, such as AvantGo and Everypath, hold that mobile applications should be based on an understanding of how mobile workers prefer to use and interact with wireless devices before reaching the backend system. A more flexible, end-user-oriented approach differentiates them from traditional enterprise system vendors.

Specialist providers of mobile solutions usually support all major ERP and CRM systems. For instance, the AvantGo Mobile Sales solution offers adapters for Siebel, other ERP and legacy systems, and even Web-based data.[56] Moreover, AvantGo devices integrate access to corporate e-mail and to its long-established Internet service, My AvantGo.

In the long run, however, specialist mobile solution providers will face increasing pressure from giant enterprise-wide solution vendors, as these vendors bundle more wireless and mobile packages with their applications.[57]

Web-only Applications Providers

In Web SFA applications the legendary success story is Salesforce.com, Inc. Despite the economic downturn, Salesforce.com doubled its sales in 2002, reaching $52 million, and its sales figures are expected to double again in 2003, reaching $100 million.[58] The idea of applying proven and widely accepted Web-based technologies without proprietary software is attracting more customers who want to take advantage of sales force automation. And with a browser-based interface, even the 2G wireless networks can provide access via Web-enabled mobile devices. In its latest product, the Salesforce.com S3, Salesforce.com cooperated with TIBCO to enable real-time integration between S3 and the most popular software packages including Siebel, SAP, Oracle, and PeopleSoft.

Unlike other solution providers, Salesforce.com has recommended the use of notebook computers for a full application of its on-demand solution. However, the Salesforce.com S3 is also available in the Wireless Edition, which is targeted at small mobile device users with real-time connectivity.

The success of Web-based applications will affect the overall landscape of the SFA market. Some software solution providers like AvantGo have already partnered with Salesforce.com by providing seamless and immediate access to Salesforce.com S3 on their devices[59].

Wireless Scientific Applications

Wireless technology is being used in a variety of scientific projects, mostly related to environmental and biological field science. The characteristics of radios and attached devices—individual sensors and data loggers, computers, and networks—offer promise for these fields.

Current commercial satellite systems and services can connect, readily and affordably, to digital wireless devices radiating from a base station, making wireless data collection possible from virtually everywhere on Earth. In particular, radios operating in the unlicensed 902 MHz to 928 MHz range have proven superior to radios using the 2.4 GHz or 5.8 GHz frequencies for fetching field data through vegetation and trees.

Current Trend

The present move toward standardization makes it relatively inexpensive and easy for technicians supporting science data networks to assemble, interface, configure, and deploy wireless data networks from off-the-shelf equipment. They can readily deploy data loggers, relay radios, sensors, power sources, and data bases to researchers via the Internet.

As the technology becomes better understood and easier to use, and as equipment expenses fall with volume, informed users without particular expertise will assume more responsibility for technical setup. Wireless field deployments will become commonplace.

Obstacles

One of the chief problems in field deployment of wireless technology is delivery of sustained power to radios. Many data loggers are placed in valleys, woods, and low terrain—precisely where solar panels deliver the least efficient power to storage batteries. In cold regions it can cost more for solar or wind power generation and battery storage than for complete radio systems. Possible solutions include fuel cell technologies and power harvested in the field, but much work remains to be done on the problem.

Transferring data costs more energy than processing collected data. Therefore, field sensors require not only smaller, short-range networking radios, but also very small processors to connect them. Small, low-power processors can parse and perhaps reduce the data strem to the least amount of significant data, then economically communicate only that amount.

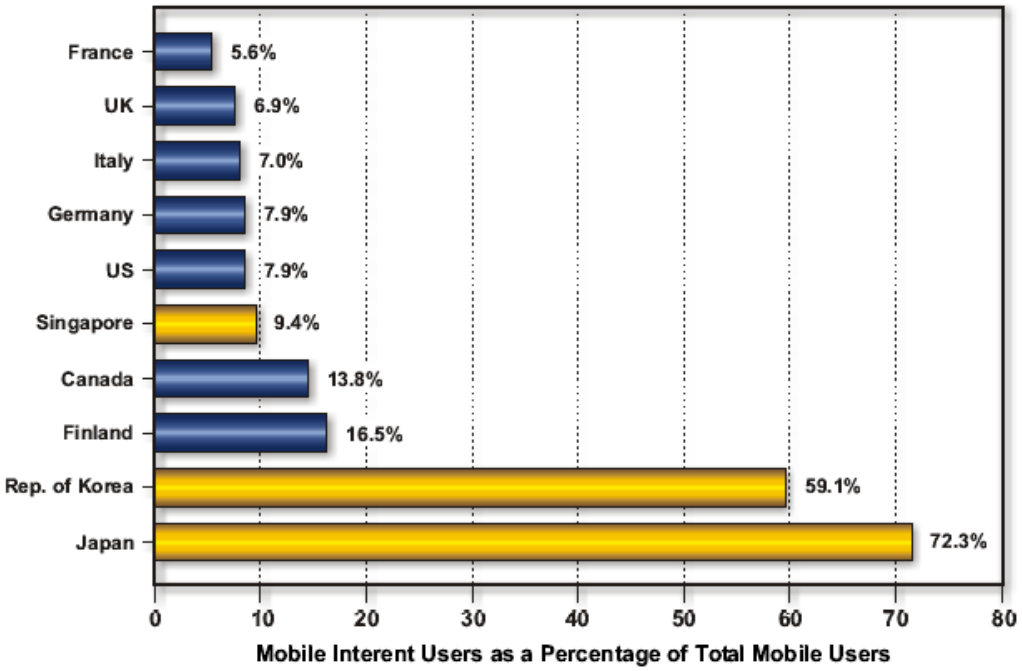
Yet though the rate of development in wireless data radios is accelerating, for field science the industry has stagnated. Field environmental sensors generally require low data rates to communicate efficiently. Therefore high-bandwidth radios—such as 802.11b 11Mbps (half duplex) devices—have limited utility for field data collection. Moreover, such radios, which operate at 2.4 GHz or 5.8 GHz, do not penetrate vegetation as well as slower, frequency-hopping 902 MHz to 928 MHz radios. But because manufacturers do not consider field science a worthwhile market, pricing and development of radios operating in optimal frequency ranges (902 MHz to 928 MHz) lag other applications.

Wireless Entertainment

Wireless gaming in the US today is, in effect, at the same stage as the Internet in 1992—characterized by slow data rates and low-fidelity content. The combination of low-cost, high-performance mobile devices, and high-speed wideband wireless will seed the growth of wireless gaming here and worldwide.

Currently Japan, South Korea, Finland, and Canada are global leaders in wideband mobile connectivity and gaming (3G, 2003). The wireless game market in the US is nascent—only 39% of Americans who play computer or console games also play games on mobile devices (ESA, 2003). But Datamonitor forecasts that 200 million people in the US and Europe will be playing mobile games by 2005 (Consumer Electronics Association, 2002).

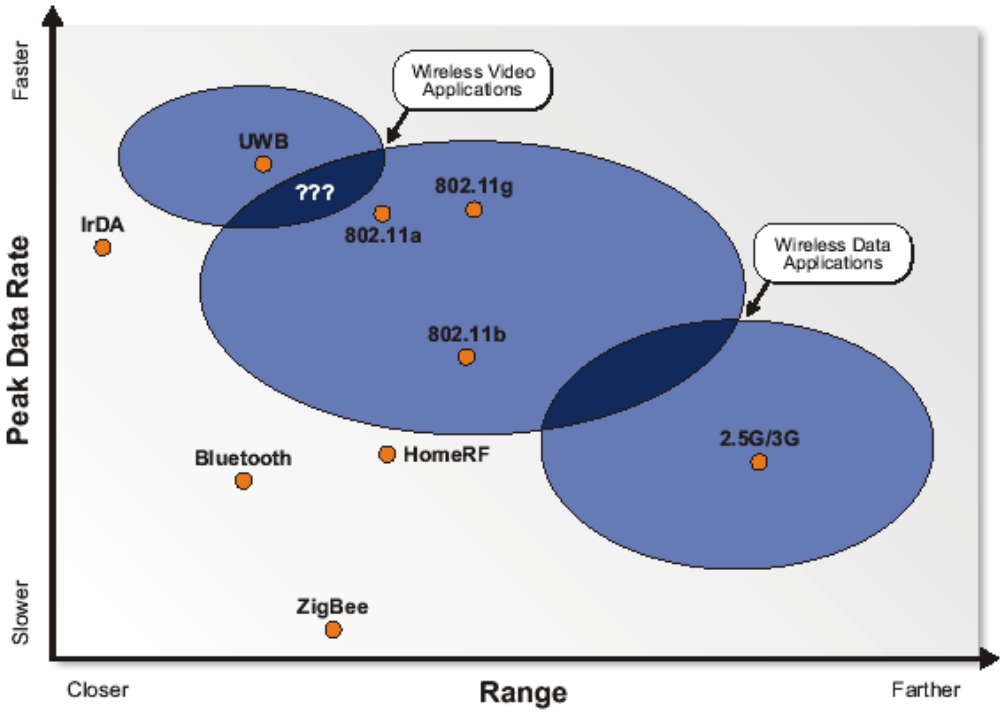
Figure 2. Mobile Internet Penetration



Wireless access speeds range from 54Kbps to 100Mbps. Wireless networks include cellular networks (see Figure 3), homeRF, Bluetooth, ultrawideband (UWB), and

802.*x* (Wireless LAN and WiMAX). 802.*x* is important because of high speeds and synergies with other mobile networks technology. The 802.*x* device market doubled in 2002 to $1.8B (Synergy Research Group, 2003).

Figure 3. Wideband Platform Rate and Range



Source: W.R. Hambrecht & Co., 2003

Vendors such as ipUnplugged AB, Padcom Inc., PCTel Inc., Intec Telecom Systems plc., and Intellinet Technologies Inc. are releasing technologies that connect mobile PCs, cellular phones, and MIAs seamlessly across multiple networks—from LAN (local area network) to 802.*x* to 2.5 and 3G (Nobel, 2003). This type of multi-network connectivity, or hopping across networks, is called *intelligent roaming*.

Network delivery methods will most likely combine satellite, fixed-line, and wide-area and local-area wireless, leading to ubiquitous wideband communication using common transport. Internet protocol (TCP/IP) is now the common thread across all communications networks. Innovation is required to drive the "last-100-yards connectivity problem"; 802.*x* is emerging to fill this gap, though by no means does it replace other technologies. The transformational impact will be felt as more spectrum is set aside for public use in peer-to-peer configurations (Ghanbari, 2003). Thus, peer-to-peer computing and 802.*x* networking are important trends.

Cellular wireless technologies can be broadly grouped in generations, with each generation providing higher data rates and additional services. Second-generation (2G) and third-generation (3G) technologies are the most widely available, although deployment of 3G has met with challenges in the US. In the transition from 2G to 3G networks, interim (2.5G) technologies are providing better services while the

challenges of implementing 3G are met. On the horizon are fourth-generation technologies (4G) currently in the planning and research stages.

Wireless, particularly 802.*x*, is a disruptive technology fundamental to competitive positioning in the global economy. The world now has more wireless mobile phone users than fixed line subscribers. We have passed through the "Negroponte Switch," where content that used to be carried over wires (phone lines) is wireless, and TV is now dependent on wires (cable). Wireless may reverse the Negroponte Switch, enabling all digital communications, including TV, to go wireless rather than fixed-line.

Community Wireless

The last-mile problem—bringing connections directly to homes and businesses from the Internet backbone—typically leaves rural and low-income urban areas without broadband access. Telecom companies are reluctant to invest in infrastructure that they believe will yield small returns. Wireless is emerging as a solution to the last-mile problem. Community uses of wireless Internet include distance learning, health care, telecommuting, and enhanced local communication.

For communities using wireless for the last mile, service typically comes in two forms: satellite and WiFi. Satellite service generally involves higher startup and monthly costs than other broadband options, and offers lower speeds and higher latency. In addition to requiring line of sight with a satellite dish, service is adversely affected by inclement weather.

Local Multipoint Distribution Service (LMDS) was at one time considered a licensed spectrum alternative for wireless Internet access. Originally designed to serve high-rise buildings, LMDS receives high frequency signals from roof antennae and connects to interior wires.[60] After two rounds of spectrum auctions, LMDS failed to deliver services because of high costs, and many endeavors went bankrupt.[61]

To date, wireless ISPs (WISPs) are the most successful at delivering wireless broadband, and in many cases are a community's only broadband option. Unlike hotspots, which cover only a limited range and require wired connections, WISPs use fixed wireless to send a directed signal up to 40 miles from the wired connection. Currently WISPs serve more than 600,000 customers in America, and in upcoming years WISPs are expected to generate $1 billion in annual revenue.[62,63]

Further evidence of the growth of WISPs appeared earlier this year in Congress with the introduction of the Jumpstart Broadband Act. The Senate version, introduced by Sen. Barbara Boxer (D-CA) and Sen. George Allen (R-VA), would require the allocation of additional spectrum for unlicensed use, with provisions of interference management.[64] The bill, still in committee in both the House and Senate, received endorsements from many in the WiFi sector, including the WiFi Alliance.[65]

"Smart Mobs"

Extending his work on social networks in cyberspace, Howard Rheingold introduces emerging realities evoked by wireless technologies in *Smart Mobs: The Next Social*

Revolution.[66] For Rheingold, the social aspect of technology is not an obscure afterthought, but a vital factor in the uses and adoptions of various innovations. In his words, "Tomorrow's fortunes will be made by the businesses that find a way to profit from these [social] changes, and yesterday's fortunes are already being lost by businesses that don't understand them."[67]

A "smart mob" comprises individuals connected through mobile wireless technologies and using their connections for collaborative efforts—either good or bad. These alliances, distinct from those made possible by wire-based Internet, put a new face on traditional ideas of trust and cooperation.[68] Rheingold highlights examples of the role of text messaging in coordinating demonstrations, both during the 2001 unseating of Philippines President Estrada and the 1999 World Trade Organization protests in Seattle.[69]

On a smaller scale in Finland, "swarming" refers to the assembly of teens prompted by text messaging via mobile phones.[70] Examples of this have cropped up in this country, including Austin, with the spread of "flash mobs," informal groups called to a central location to perform an often wacky and lighthearted task. Such groups, of all sizes and acquaintance levels, are inspired to collective action by their mobile devices. They interact in ways previously not imagined, or at least not feasible.

Through discussions with wireless executives, creators, and users across the globe, Rheingold highlights the social consequences of wireless. Existing social relationships are enhanced and new ones facilitated. For example, people can find potential dates via cellular matching services, or they can scan a person's mobile device listings to find common interests. The casual greetings allowed by text messaging enhance phone users' social networks.

Some other examples of social changes Rheingold discusses:[71]

- Wireless capabilities alter perceptions of time and space in ways different from landline precursors. People can make decisions on the go. We have new definitions of "absence" and "presence," as those reachable via cellular phone are considered present.
- Teens using text messages have a new sense of privacy, allowing for conversations that extend beyond the reach of parents. As attention splits between a silent, virtual text world and physical realities, existing norms are being violated and new ones created.

Rheingold also discusses upcoming widespread ubiquitous computing, or computation and communication capabilities built into everyday objects and places. Rheingold draws from a speech by the president of Bell Labs who likens this phenomenon to a layer of "communication skin."[72] Several key questions about impending constant surveillance are posed: Who will control the technology, and what it is used for? Will we become different people as a result of using such technologies?[73]

Finally, just like any technology, wireless and emerging technologies can be used for questionable or malevolent purposes. Opportunities for increased surveillance and the loss of personal privacy are two such threats.[74] Others include the use of text messages

by terrorists or violent individuals. But on the flip side, people also have increased opportunities via wireless to combat such trespasses and potential atrocities.

FCC Spectrum Policy

The Radio Act of 1927 established the Federal Radio Commission (FRC) to oversee the licensing of radio frequencies. The goal was to prevent a chaos of multiple competing signals on the same frequencies. In 1934 the FRC became the Federal Communications Commission (FCC), and in 1938 the FCC allowed the operation of certain license-exempt radio devices, with these conditions:

- Operators of these devices have no vested rights to continued operation.
- Operators may not cause harmful interference.
- Operators must accept any interference received.
- Operators must cease operation if notified by FCC that device is causing harmful interference.

There were few types of license-exempt devices at first (for example, wireless record players, carrier current communication systems, and control devices). However, in the 1960s and '70s new devices appeared, such as wireless microphones, telemetry systems, garage door openers, television remotes, cordless telephones, and so forth. In the 1990s wireless Ethernet extended the reach of local area networks (LANs), and more recently the same technology was widely adopted for public wireless access to the Internet. 802.11b WiFi's increasing popularity has led to innovative thinking about potential uses of license-exempt spectrum.[75]

Significant reforms for today's wireless industry began ten years ago when Congress started adopting policies with a more market-based outlook. 1993's Omnibus Budget Reconciliation Act allows for spectrum allocation based on auction bidding rather than by lottery.[76] The FCC, which allocates spectrum for the private sector, considered spectrum auctions a success four years later.[77] As a result, the Balanced Budget Act of 1997 extended the auction system until 2007, with possibility for renewal.[78]

Recognizing the need to update spectrum policies and under intense pressure from the wireless industry and government, Chairman Michael Powell created the Spectrum Policy Task Force in June 2002. The Task Force advises the Commission on "market-oriented approaches" and ways to employ "minimal regulatory intervention."[79] A November 2002 report from the Task Force made the following conclusions and recommendations:[80]

- Portions of spectrum remain unused at various times of day and in locations near spectrum borders. The time of spectrum use should be added as a consideration for licenses to allow time-sharing of spectrum.
- In modern wireless devices interference is a lesser issue, and devices are smart enough to operate on a time basis.
- Closer measurement of interference is needed to increase reliability and to identify portions of unused spectrum that could go unlicensed.
- Increased unlicensed spectrum is necessary.

Perhaps the most significant recommendation of the report calls for adoption of a hybrid of prevailing spectrum-use models. The methods to be used include the command-and-control, exclusive use, and commons models.

- **Command and Control:** The government allocates specific frequencies for government-defined uses.
- **Exclusive Use:** The licensee has exclusive and transferable flexible-use rights for a specific spectrum within a defined geographic area. This comes with flexible use rights that are governed primarily by technical rules to protect spectrum users against interference.
- **Commons:** Unlimited numbers of unlicensed users are allowed to share frequencies, with usage rights that are governed by technical standards or etiquettes but with no right to protection from interference.[81]

The Task Force calls for a transition from the Command and Control model to the other two models.

Open Spectrum

Open Spectrum is a new way of thinking about spectrum policy. The existing regulatory perspective treats radio frequencies as property, or as constrained resources, because multiple users of the same frequency create interference. Advocates of Open Spectrum note that interference is not an inherent problem but can be overcome by technological advances such as spread spectrum. This approach lets multiple signals coexist by increasing spectrum efficiency.

There are two ways to implement open-spectrum technologies:

- **Designate specific bands for unlicensed devices:** The first method is to designate specific bands for unlicensed devices, with general rules to foster coexistence among users. This is the approach that allowed WiFi to flourish in the 2.4 GHz and 5 GHz bands.
- **Underlay unlicensed technologies:** The second mechanism is to "underlay" unlicensed technologies in existing bands without disturbing licensed uses. This approach, epitomized by the ultra-wideband technology the FCC authorized in early 2003, effectively manufactures new capacity by increasing spectrum efficiency. Underlay uses either an extremely weak signal or "agile" radios able to identify and move around competing transmissions.[82]

Changes in the Air

Spectrum policy is gaining momentum in political circles, as evidenced by several key decisions made in 2002 and 2003. In November 2002 the FCC announced that 90 MHz of additional spectrum for "new advanced wireless services," including 3G, will be available for auction.[83] Shortly thereafter the Commission opened another 30 MHz for the same purpose.[84]

Exhibiting its preference for more flexible spectrum, the Commission eased spectrum cap rules, opening the door for consolidation deals in the industry.[85] Under the ruling, effective January 1, 2003, the amount of spectrum that commercial mobile radio services can use is no longer limited. The previous limit on urban carriers was 45 MHz.[86] Democratic Commissioner Michael Copps dissented from the decision, citing imminent industry consolidation and decreased competition.[87]

Beginning May 13, spectrum licensees were now able to lease unused bandwidth.[88] This change in policy reflects the Commission's trend toward letting the market allocate spectrum. According to the Commission, allowing secondary markets to use spectrum will boost innovation, create competition, help spread online services, and continue the tradition of public interest.[89] Licensees are responsible for the leasing agreements and must maintain legal control of their portion of spectrum. Once again, Copps dissented, claiming that spectrum sharing is illegal, and fearing impact on rural access.[90]

Also in May, the Commission made a partial commitment to the Commons method of spectrum allocation when it proposed the addition of 255 MHz of spectrum for unlicensed use.[91] Commissioners recognized the commercial success of previously unlicensed bands and agreed about the updated allocations.[92]

On Oct.16, 2003, the Commission opened spectrum in the 70, 80, and 90 GHz range specifically for broadband Internet.[93] In this range signals are thin but concentrated, allowing them to function without interference within a concentrated area of other signals. This change also introduces a non-exclusive licensing approach which is designed to invite innovation and has already brought the attention of wireless startup companies hoping to capitalize on the freed-up spectrum. Also in October, 3G vendors learned that the Commission is releasing 90MHz of spectrum for auction in 2004.

Increasing the intensity of the issue, President Bush on June 5, 2003 released a Presidential Memo on Spectrum Policy.[94] Bush created a Spectrum Policy Initiative headed by the Secretary of Commerce, to make recommendations on spectrum allocation. Members of state and local government, the wireless industry, consumer groups, economists, and others will play key roles in public meetings to address the issue. The process culminates in a recommendation report due in 2004.

The conclusion of the FCC's "Unlicensed and Unshackled" paper is that a largely unanticipated "explosion of services and providers" using unlicensed technology points to a promise of ongoing innovation that will benefit consumers as "an enabler of important business and personal communication needs." The report suggests clear but flexible rules to facilitate continuing innovation in the unlicensed realm.[95]

SECTION 3—AUSTIN'S WIRELESS BUSINESS SECTOR

The most startling finding of this study regarding Austin's wireless business sector is that there is one, one much larger and more robust than even wireless insiders had thought. In this section we provide an overview of the 91 wireless companies operating in Central Texas, discuss results of a survey of the needs, direction, and focus of these companies, and conclude by showcasing a small sample of companies in brief case studies.

Wireless Business Inventory

This section offers an overview of Austin's wireless companies, explains category breakdowns, and gives a snapshot of the Austin wireless industry as of Fall 2003. Note that the status and goals of these companies change frequently, and new companies are constantly entering the field.

In the Austin Metropolitan Statistical Area (MSA), the IC² Institute identified 91 companies as part of the local wireless industry. This includes companies that are not exclusively wireless but offer wireless products or services as part of their larger business.

Companies are categorized here in four ways:

- Company type—exclusively wireless or blended wireless.
- Office type—local headquarters or branch.
- Types of products and services.
- Types of wireless technologies.

Company Type

- **Exclusively wireless:** Company's products/services are completely wireless.
- **Blended:** Company's products/services consist of other technologies, but include wireless.

Of the 91 companies currently identified, 47 are exclusively wireless and the remaining 44 are blended. As wireless grows, more companies will introduce wireless products and services as part of blended business offerings, and some blended companies could move to exclusively wireless.

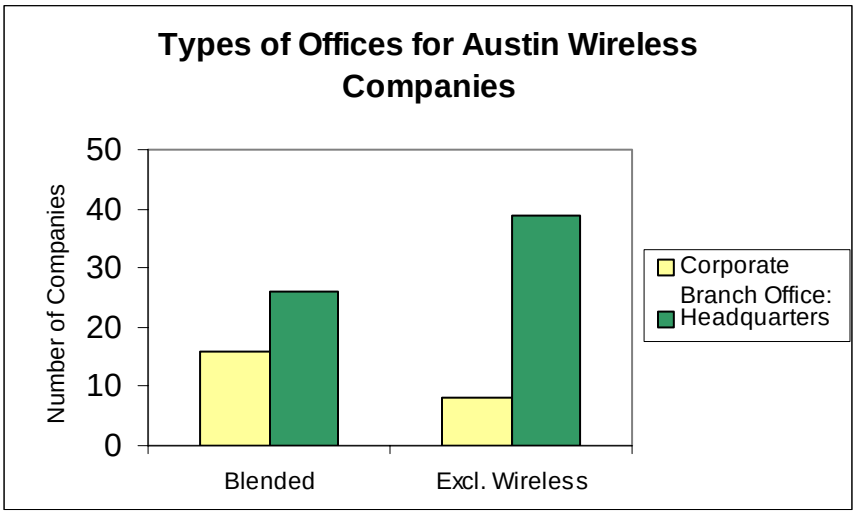
Office Type

- **Headquarters:** Austin location is a corporate headquarters, the sole office, or the sole US office.
- **Corporate branch office:** Austin location is a branch office of an international or national company.

The following graph shows that a higher percentage of wireless companies use Austin as their headquarters or sole office than as a branch office. This is a potential

asset because as these companies develop, chances are that the majority of their expansion will occur locally.

Figure 4. Types of Offices for Austin Wireless Companies



Products and Services

Although some companies have multiple offerings, this report classifies each company by its primary output. The report doesn't use the Standard Industrial Classification (SIC) system or North American Industry Classification System (NAICS) because the codes fail to isolate wireless companies specifically. Instead, this report uses the following categories:

- **Hardware**: Manufacturing or development of handsets, antennae, towers, infrastructure equipment, semiconductors, and other components.
- **Software**: Design and/or development of application for specific use on wireless devices. Includes games and billing software.
- **Hardware and Software**: Emphasis on related hardware and software. Companies in this category create products that work in tandem and complement one another in a system.
- **Access**: ISPs and WISPs.
- **Services**: Market research, equipment installation or maintenance, consulting, engineering and design services. Companies that primarily create custom hardware or software designs are considered service companies because they provide design services for a specific client.

The figures below show the outputs for exclusively wireless companies and for blended companies.

Figure 5. Distribution of Austin Wireless Companies by Product/Service—Exclusively Wireless

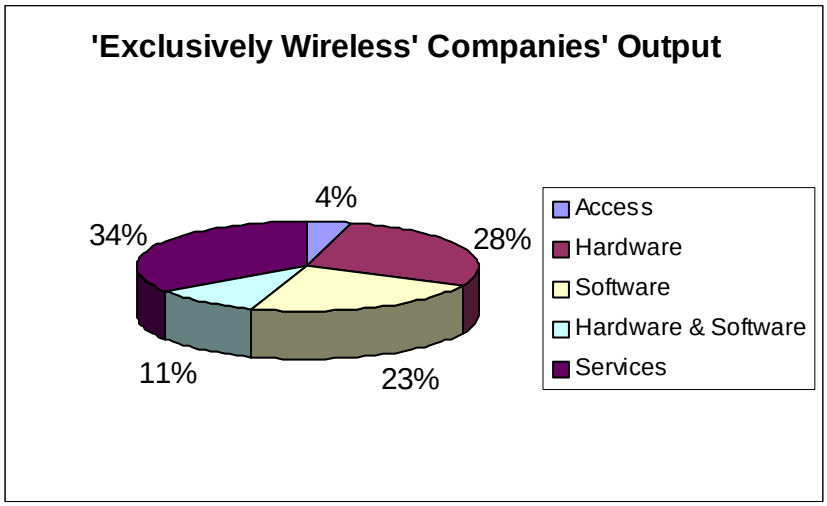
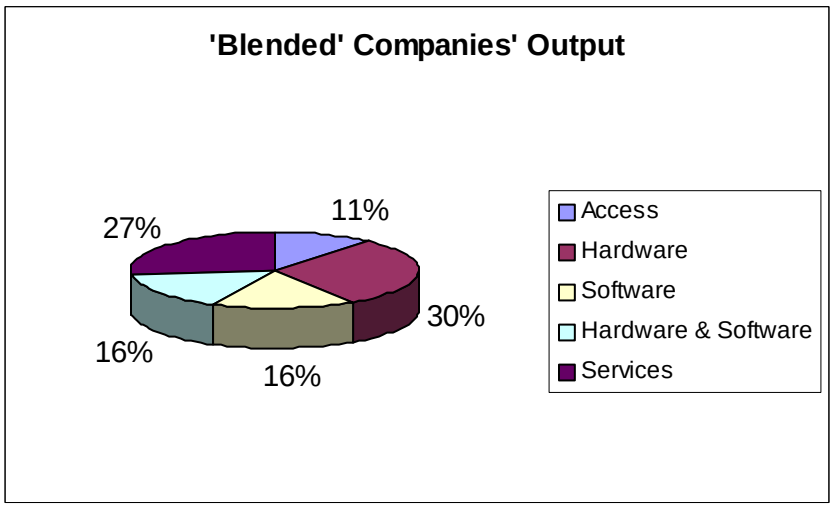


Figure 6. Distribution of Austin Wireless Companies by Product/Service—Blended Wireless



Exclusively wireless companies focus more tightly on software than blended companies. This report highlights software and content development as potential strengths and areas for growth in the Austin wireless industry.

Services are the largest chunk of the local wireless industry for both blended and exclusively wireless companies. Blended companies show a slightly bigger stake in hardware because many belong to the local semiconductor industry, which includes many companies creating chips for wireless devices.

Technology Type

This report analyzes and categorizes Austin wireless companies based on the technologies or equipment they currently target. These areas are highly subject to change as new standards and platforms are introduced. The 16 categories were identified as entirely wireless or as areas where wireless significantly enhances existing technologies.

Because these groupings are not mutually exclusive and most of the 90 companies fit into multiple categories, this analysis only indicates the number of Austin companies doing work in each of these areas. Therefore, percentages in the following table add to more than 100%.

Table 7. Technology Focus of Austin Wireless Companies

Technology type	# exclusively wireless	# blended	Total	Percent
802.11	21	34	55	**60%**
Antennas/towers	4	2	6	**7%**
Bluetooth	5	0	5	**5%**
Cellular/PCS	15	9	24	**26%**
Games	3	1	4	**4%**
GPS	5	0	5	**5%**
Microwave	3	1	4	**4%**
Networking	18	22	40	**44%**
Remote monitoring/sensors	3	1	4	**4%**
RF	8	4	12	**13%**
Sales force automation/inventory control	4	0	4	**4%**
Satellite (not GPS)	4	1	5	**5%**
Security	2	5	7	**8%**
Semiconductors/chips	3	10	13	**14%**
Ultrawideband	1	0	1	**1%**

Over half of Austin wireless companies are working with 802.11 technology. Networking (43% of companies) and cellular/PCS (24%) are the next biggest areas. The 12% of local companies working in semiconductors are mainly secondary companies devoting a portion of their business to the development of semiconductors for the wireless industry.

Economic Impact

In the local wireless industry there are approximately 3,400 people employed in companies with 100 or fewer employees. At some of the region's largest employers, such as Motorola, the number of employees is much greater. However, because most new job growth originates in smaller companies, our analysis focuses on this group of startup, small, and growth companies.

In 2004, this number will grow to 4,215, a 25.7% increase. In the next four years, the number of workers will grow at an average 18.93% annual compound rate to reach 7,978 by the year 2008.[96] We estimate that last year, the total payroll for wireless employees in Austin MSA was approximately $125 million,[97] and that this payroll generates $85 million in consumption.[98]

Wireless in Austin will benefit the semiconductor, software, and digital gaming industries already here. Austin already has a strong position in all three.

The semiconductor industry is the upstream supplier for the wireless sector. Motorola and AMD are two world-class chip manufacturers. As they release smaller, faster, cheaper, and less power-hungry chips, the wireless companies will be among the first beneficiaries. Conversely, the proliferation of wireless technology will increase demand for innovative semiconductor products. Though the biggest chip buyers are currently the computer and automotive industries, the next growth area could come from wireless. Motorola's Semiconductor Product Sector recently chose wireless communications as one of its three focus markets.

The software and digital gaming industries provide complementary wireless applications. They will definitely enjoy a better strategic position in the presence of a strong local wireless industry.

The wireless industry is so closely related to all three of these fields that some wireless companies spring directly from them, straddling two or more industries. For instance, Codetoys is both a wireless and a digital gaming company.

Wireless Company Survey

Wireless Future project conducted an online survey of Austin's 91 wireless companies in the last half of 2003. Companies were asked about their line of business, employment and revenue figures, funding sources, and plans for the future. This report analyzes 39 complete responses received.

The 39 respondents represent different company types, with a history ranging from less than a year to well over ten years. However, the sector is overwhelmingly young. 26 of the 39 companies that responded to the survey were established in 1999 or later.

Most are privately held, LLCs, or other for-profit companies; only 16% are public.

Employees

Most companies surveyed are small. 55% of them have 10 or fewer employees. 80% have 50 or fewer employees. Only five employ more than 100 people. Regarding future employment, almost all companies are very positive. Eighty percent expect to hire more people over the next year. Only two companies don't have new hiring plans over the next five years.

Almost half the respondents agreed that the availability of qualified professionals is the most important workforce issue. The most desirable professionals over the next two years are technical (engineers, scientists, computer scientists) and support (marketing, accounting, business development).

Revenue

Consistent with the small size and youth of Austin wireless companies, revenues are also relatively low. However, despite the slow economy, a large majority of companies anticipate stable or increased revenue for FY2003.

Table 8. Distribution of Austin Wireless Companies by Revenue

Most recent fiscal year revenue	Number of Companies (n=34)
Over $100M	4
$10-100M	3
$1M-10M	3
$501K-1M	7
$101-500K	3
$0-100K	11
Negative	3

Funding Sources

Most respondents are privately held. Their top sources of funding are product/service revenue (52%), personal savings (47%), private venture capital (32%), and angel investors (29%). About 37% of the companies wish to seek seed/venture/expansion capital in the next 12 months. 20% are not sure about it. The firms seeking capital would mostly need it for service/product/application development.

Table 9. Funding Sources

	Response percent	Response total
Personal Savings	47%	16
Personal Debt	14%	5
Federal Government	0%	0
State/Local Government	0%	0
University internal funds	0%	0
Private venture capital	32%	11
Corporate venture capital	17%	6
Private investor(s) (i.e., angel investors)	29%	10
Product/service revenue	53%	18
Other (please specify)	3%	1
Total Respondents		34

Attractiveness of Austin and Central Texas

31 of the 39 surveyed companies originated in Austin, indicating that Austin it's growing its own wireless sector. Four of the companies relocated to Austin and four are branch offices. The two reasons most crucial to decisions to locate or remain in Austin are personal/family reason and access to educated workforce. Also important are proximity to research universities, proximity to similar businesses, and culture and entertainment. Interestingly these three items were given equal importance by respondents.

Based on the responses, four main benefits the central Texas region should offer to lure suppliers and other similar businesses into the area are tax incentives (48%), cluster development (attract other similar business developments, 48%), sector development events (networking events, 45%), and facility incentives (office space and warehouse space, 42%). Technology incubation services are also seen as important; 39% of respondents marked it as the most important benefit a region could offer. Six respondents have been approached by other regions to relocate. Of the incentives offered, five of the companies were offered incubation and related services.

Finally, the wireless companies would like to see the following issues addressed in a wireless technology symposium in Central Texas:

- Technical issues and the future of wireless (68%)
- Commercialization of goods/product to market (51%)
- Telecom and wireless (45%)
- FCC regulations (37%)
- Industrial alliances (34%)
- Social and cultural impact (34%)

Implications

Most surveyed companies are optimistic about the future. Over the next five years they expect higher revenue and plan to hire more people.

Given that most the companies originated in the central Texas area, Austin's best course lies in encouraging local entrepreneurial startups. The city could perhaps tap into a whole new segment by attracting existing companies to set up shop. But either way, efforts should focus on access to an educated technical workforce, tax incentives, sector development events (networking events), facility incentives, and cluster development (attracting other similar business developments).

As there is a greater need for technical professionals (engineers, scientists, computer scientists etc) and support professionals (marketing, accounting, business development etc) the wireless industry should form ties with the University of Texas at Austin. There is already some movement in this direction; the Wireless Networking and Communications Group in UT's College of Electrical Engineering takes active part in the industry's developments. (The WNCG is discussed later in this report.)

Wireless companies list two critical areas where they most desire support: fundraising and marketing/sales services.

Wireless Adoption and Business Development in Austin

Hotspots

Schlotzky's

1971: Schlotzsky's opened its first shop on South Congress Avenue in Austin, Texas. Today Schlotzsky's has 650 restaurants in 38 states and seven countries.[99]

When it began providing Internet access for customers, Schlotzsky's featured Cool Deli Stations ("Cyber-delis"): iMacs, strategically placed within the restaurants, using a wired T1 connection. After placing these stations, Schlotzky's developed new ideas to improve efficiency and the customer experience, but the requirements of the wired connection hindered implemention This gave the company a compelling reason to migrate to wireless.

The objectives of the move to wireless:

- Improve the customer experience and demonstrate the benefits of a wireless network.
- Generate goodwill and a "popular buzz" in the media and surrounding community.
- Increase the number of patrons and the length of their visits, eventually increasing the loyal customer base.

Schlotzsky's promoted its free wireless access by using warchalking. Inspired by the Depression-era hobo practice of marking friendly territory, warchalking became the wireless culture's roadmap for hotspots around towns. Schlotzsky's surrounded its locations with these markings to rouse interest.

Each store's WiFi connection costs approximately $2,000, including the antenna. The high-speed Internet connection costs $300-500 per month. Total cost for the first year runs about $8,000 per store. A recent in-store survey concluded that six percent of customers go to Schlotzsky's for the wireless connection (excluding Cool Deli Stations). This is roughly 15,000 customers per store per year. Based on an average cost per meal of $7 (a sandwich and drink), this adds up to about $100,000 in sales per year.

Austin Public Library

At the Austin Public Library's main branch, the John Henry Faulk Central Library, 12 technical staff programmers started a small wireless network on the 4th floor. "The equipment was cheap, [so] we could buy stuff and experiment with the network," says Joe Faulk, manager of library information systems.[100] The staff created a simple, free wireless network that lets patrons log on without registration, user IDs, or passwords.

The staff expanded the wireless network to a nearby park, then made plans to install wireless at all Austin Public Library (APL) branches. The project grew to become almost unmanageable, until WiFi-Texas, a local company, stepped in and offered to help. WiFi-Texas provides high-speed wireless Internet access to high-density multi-family dwellings in Austin and nationwide.[101] WiFi-Texas provided the hardware that helped APL go wireless, and Schlotzsky's Deli offered access points and routers that tied in with the library's existing infrastructure.[102]

Currently the main library, the adjacent Austin History Center, and five branch libraries have wireless access. At present the response has not been overwhelming. One reason may be that the APL's audience is not an underserved community.

University of Texas

The University of Texas at Austin (UT) is the largest single-campus university in the United States. In wireless coverage UT is ahead of most universities. Its case is unusual in three ways:

- The wireless network is much bigger than common enterprise networks, serving all 14 schools/colleges and 78 academic departments, a total population of 70,000—the equivalent of a middle-sized town.
- UT has a flexible information management system. A centralized computer service department supports the wireless network, but affiliated schools make their own decisions regarding wireless in their buildings.
- Due to high decentralization, the service levels in different schools and departments vary greatly. The Law School, the computer science department, and the Business School have the largest wireless population.

The Information Technology Services Department—Telecommunications and Networking (ITS) runs all information and communication systems on campus. The ITS installed its first official wireless network in fall 2001. Initially the coverage was only minimal. But as the number of students who bring a laptop to school increased, some schools found that a wireless network is a cheaper and simpler way to meet Internet access needs. For instance, the Law School has the whole building covered by wireless, and all students are required to use a laptop. There is no need to install expensive cables and ports in every classroom.

Though the wireless network is much more flexible than fixed lines, it is also less controllable. William Green, manager of the ITS, says that though he can control the speed and quality of Ethernet ports, he cannot guarantee the service level of a wireless network.[103] Also, it is impossible to contain the spillover of the signals. Green doesn't like to compare wireless and wired networks: "It all depends on what you want. For casual use, casual Web browsing, e-mail—[wireless is] fine. For production work I need to do high-bandwidth transfers, and I need to guarantee service. We're not there yet."

In the near term, the foreseeable development will be a dramatic increase in the number of wireless users. Green said the number doubled from 200 simultaneous users at peak hours in fall 2002 to 400 simultaneous users in spring 2003, with about 4,000 people regularly using the service. This fall, he said, the number could grow to somewhere between 8,000 and 10,000 regular users. The demand will drive the affiliated schools to ask for more wireless capacity.

Mozart's

In July 2002, the coffee shop Mozart's decided to set up a free wireless network. Although management questioned the overall effect of wireless on revenue, they went ahead with the plan in order to enhance the shop's image, remain competitive, and appear ahead of the times.

Though increasing revenue was not one of the main reasons for going wireless, Mozart's did benefit from the venture. Much (approximately 80%) of the shop's revenue comes during evenings and nights, and it has always been a challenge to fill mornings and afternoons. Wireless helps change this. Having a wireless connection brings in customers during these lulls.

AMD, in collaboration with Insignia, is starting a program that lets visitors to a city quickly identify local hotspots through a Web search. Mozart's plans to take part in this program in Austin.

iGillott Research

Based in Austin, iGillott Research is a market strategy consulting company for the wireless and mobile communications industry. iGillott Research does not focus on wireless carriers, but instead consults primarily for the equipment and service vendors, software solution providers, mobile device vendors, and content providers who sell to these carriers.

iGillott provides two types of services: wireless market research subscription and strategy consulting. Through its Flexible Subscription Services (FSS), iGillott provides its customers a quarterly list of research topics and lets them choose the most interesting topics. The different types of clients usually develop interest in a given topic at about the same time. Current hot topics: WLAN, mobile device management, and enterprise implementation.

Iain Gillott, principal and founder of iGillott, observes that it's now technically feasible to run businesses wirelessly. He believes that business owners will be more willing to cut budgets on other expenses before mobile communications, because it makes business more efficient and productive.

Austin's weakness, Gillott says, is the lack of a big player in the wireless industry. A big wireless company would attract talented researchers, just as Qualcomm did and continues to do for San Diego. Gillott believes that Austin will not become a wireless manufacturing center. Instead, Austin will host a mix of software, wireless gaming, and multimedia companies. Being relatively small, Austin could become a completely wireless city.

Raak Technologies

Raak Technologies (www.raaktechnologies.com), established in 2002 in Austin, provides security products and services for Wireless LAN networks. Raak's products and services include smart cards for strong authentication, 802.1*x* client software, and a turnkey personalization and deployment service. The company's solutions include wireless LAN security, web site authentication, digital certificates, email security, and VPN and dial-up authentication. Raak Technologies also provides professional services, and, as a founding member of the WLAN smart card consortium, has contributed to the development of the EAP-SIM/WLAN-SIM specifications. Raak Technologies' products include the Raak T8 USB Smart Tokens, the Raak C7 Smart Card, and the Raak Smart Card Reader.

Raak deployment services improve the security and lower the costs of deploying smart cards and tokens to employees, customers, and business partners. Raak markets card personalization, printing, certificate generation, customer fulfillment, and management services. Raak also offers enrollment and customer support options on a dedicated Web site. Raak's customers can set enrollment policies, pre-register

users, or handle enrollment on a case by case basis. Raak's Card Deployment services focus broadly on corporate intranets and extranets, WLAN and VPN authentication applications, as well as secure access to BtoB sites and ASPs. The Raak Card Deployment and Management service targets corporations and online service providers with programs ranging from 50 to 5,000 users. Raak's professional services team helps clients analyze, design and implement authentication and smart card projects for their personal needs.

Headquartering in Austin

When the co-founders of Raak launched the company in early 2002, one co-founder was located in Austin, the other out of state. The deciding factors for locating the headquarters in Austin were UT's commitment to the wireless industry and the quality of life in Austin. As of mid-2003, both co-founders were located in Austin.

Raak's initial decision to locate in Austin has in recent months been reinforced by the formation of the Austin Wireless Alliance (AWA). AWA provides a networking and support group for the wireless industry in Austin. In addition, AWA raises the awareness of the wireless industry in Austin with professional organizations (e.g., venture capital firms), which will facilitate local wireless firms' interactions with the professional groups.

The cost of doing business in Austin is lower than in Silicon Valley or the Washington DC area, which were alternatives that have a good pool of software and hardware engineers and a network of experienced startup professionals.

With regard to disadvantages, Austin's labor pool of security engineers is limited, though growing. Another disadvantage is that for firms that have a requirement to travel extensively, especially internationally, Austin's airport has fewer options that an airport such as DFW. But for Raak, Austin's advantages far outweigh the disadvantages.[104]

Future Initiatives

Raak plans to build on its initial installations by expanding its WLAN security solution and moving into the health care, government, and financial sectors

Like most self-funded early-stage companies, Raak faces the challenge of generating revenue with limited resources. However, the company expresses confidence that Raak's WLAN security solutions, coupled with strategic channel partners, will generate the growth necessary to take Raak to the next level.[105]

Rocksteady Networks, Inc.

Rocksteady Networks, Inc., founded in Austin in December of 2000, provides software solutions that deliver security and premium broadband services to users at the edge of the network. Examples include corporations with high-value users in remote offices, and multi-resident units such as large apartment complexes.

The RocksteadyNSA Network Sharing Application authenticates each user entering the network environment and then selectively provides access to specific resources and bandwidth based on the specific user's relationship to the organization. Customers benefit from improved network security, as well as enhanced usability and sharing. Rocksteady Networks is a founding member of the Austin Wireless Alliance and is involved with several research initiatives.

Rocksteady works primarily through corporate partnerships in the enterprise space, as well as partners associated with wireless, cable, and wired technologies. Rocksteady software is currently deployed in ten different countries around the world through a partnership with a major Fortune 500 company, and has undisclosed partnerships with other national technology companies. One current major relationship involves a wireless initiative that will use Rocksteady's platform.

Rocksteady Networks plans to remain in Austin because of the technology resources available locally. These resources are specific to Rocksteady's business initiatives. Rocksteady takes advantage of local software engineering resources, especially those familiar with the wireless base networking space. Rocksteady's primary challenge is in getting visibility outside of Austin. However, with the significant presence of major companies such as IBM, SBC Labs, Time Warner, and a focus on silicon chip manufacturing and network management, the location becomes less challenging due to valuable relationship opportunities.[106]

Wayport

Given the company's growth since its inception in 1996, Wayport has the potential to serve as a local wireless industry anchor and to attract other wireless companies to the Austin area. Wayport provides broadband access and services, primarily for business travelers, through commercial-grade hotspots in hotels, airports, and restaurants. Wireless connectivity in these locations lets mobile businesspeople and travelers access Virtual Private Networks (VPNs), centralized corporate information, and office resources.

WiFi diffusion in the late 1990s was slower than expected, but Wayport now has a lucrative business. As of November 2003, the company had deployed WiFi in 700 hotels and six airports, and is currently staging a pilot program with McDonald's. These hotspots attract 250,000 users a month, with a 10 to 15 percent growth rate each month. Wayport is broadening its customer base from business travelers to families and other travelers.

The company's business model emphasizes customers' online experience and careful selection of hotspot venues, according to Dan Lowden, vice president of marketing.[107] Anticipating the introduction of new technological standards, Lowden said they can readily adapt their business model to such changes. The company already made the successful transition from Ethernet to WiFi, and he expects that Wayport will embrace upcoming wireless standards.

The benefits of Austin

Austin provides access to a large pool of local talent with diverse skills. Over the past year Wayport hired around 80 new employees. Wayport has found that University of Texas students make good call center employees because of their availability in the evenings and on weekends. The company also benefits from Austin's creative atmosphere. Wayport launched its first hotspot in Austin's Four Seasons Hotel; Lowden said this took advantage of the city's innovative early-adopter mentality.

Wayport has relationships with some of Austin's large technology companies, including Dell, IBM, and Intel. For example, Dell notebook computer customers receive a free card allowing them trial access to Wayport's network. Also, the companies have many clients in common, making visits to Austin advantageous for out of town businesspeople.

Wayport's niche in the wireless future

Some observers contend that the real moneymaking potential in wireless is not in access, but in content, services, and innovative products. This raises questions about paid models like Wayport's versus local grassroots movements to provide free, public WiFi access. Lowden believes that free and paid wireless will coexist. Wayport differentiates itself from free providers through its substantial security provisions and the reliability of its network. The company's emphasis on customer service, strategic locations, and reliable, consistent online experiences cannot be matched by most amateur networks, Lowden said.

Wayport looks forward to the near future when WiFi will be integrated into all new notebook computers and, eventually, into most computer and communication devices. The company plans to provide content as well as access. Lowden predicts that content services will become an increasingly important supplement to broadband services. Currently users get a free online subscription to *Business Week* magazine, and Wayport wants to extend offerings, adding movies and other entertainment to enhance its service.

Tuanis Technology

Tuanis Technology (www.tuanistechnology.com), an Austin consulting firm, specializes in Microwave Data Networking (MDN) using unlicensed spectrum. Technical services include site surveys, network design, engineering, and network installation, all based on Tuanis' position as an MDN equipment reseller. Tuanis also offers marketing services, financial planning, and assistance in developing wireless business plans.[108]

Randall Baker, president and founder of Tuanis, said clients want firms that explain technology as well as install it. Tuanis does both. According to Baker, only a few other wireless consulting firms operate under this model. For Tuanis, technology does not matter as much as the client they are serving. The challenge is use the technology effectively to solve client problems. Although technical standards and

players in the wireless industry are expected to be somewhat volatile in the near future, in the long run this will not affect customers, according to Baker.

In 2001 Baker moved from Atlanta to Austin to start the company. He cited as primary reasons for relocation Austin's tech savvy and reputation for nurturing young companies. Baker describes Austin as a hotbed for entrepreneurial activities, of which wireless is a growing part. Austin provides high-quality technical talent without the high business and living expenses of California. Although Austin has many positive qualities for Tuanis, Baker said he would like to see increased collaboration between the city government and local companies, along with more opportunities to take advantage of resources at the University of Texas.

Access to capital has been a challenge. Recent difficult economic conditions have adversely affected the technology industry, and those with capital do not always understand wireless or new company models. Baker's advice to others wishing to launch a startup is to focus on customers and revenues, and the rest will take care of itself.

SBC Laboratories

SBC Laboratories is a wholly-owned subsidiary of SBC Communications. Formerly known as SBC Technology Resources Inc. (TRI), it was established in 1988 as a research and development arm to support all the SBC affiliates. In June 2003, in an effort to enhance a consistent SBC brand name, TRI was renamed SBC Laboratories. SBC Labs has about 150 technical and professional staff in Austin and another 50 staff in Pleasanton, California. Some 14 of the Austin technical staff is focused on wireless technology.

SBC Labs is a separate entity under SBC Communications, working exclusively on internal R&D projects for other SBC units, including joint ventures like Cingular Wireless. SBC Labs prepares project proposals annually for SBC's profit-and-loss business units. Projects are funded by these business units, assuring that R&D work is targeted to specific market needs. Currently SBC Labs focuses on four technology areas: broadband Internet, wireless, network services, and enterprise IT.

SBC Labs is not a R&D manufacturing unit that develops its own products. It is, rather, an R&D arm that identifies the best technologies and applications in the market, performs systems integration, and tests systems for scalability and performance. SBC Labs provides a strategic technology vision for its SBC business units to ensure competitive products and services.

Wireless Technologies

In wireless, SBC Labs is working on technologies such as WiFi, free space optical systems, UWB, GPRS/EDGE, WCDMA, and 802.16. In August 2003, SBC announced an ambitious plan to deploy more than 20,000 WiFi hot spots in 6,000 venues over the next three years. Partnering with Cingular, SBC also plans a service that integrates WiFi and 3G. SBC Labs has been working with vendors like Wayport in laying out the WiFi networks based on DSL technology. SBC is the first company to use DSL for

WiFi hotspots. The lab believes DSL has an advantage over T1, as it can leverage the existing infrastructure and requires much less capital expenditure.

Future Vision and Challenges

SBC Labs believes that the trend for future wireless technology applications will focus on the integration and convergence of different wireless and landline technologies. The bundled service of WiFi and 3G (EDGE) is a good example. To stay ahead of competition, the biggest challenge for SBC Labs remains the attraction and retention of high-quality technical personnel. SBC Labs needs people who not only have a strong technical background, but also have the strategic mindset, and seek to work in a stimulating and challenging environment.

Choice of Austin

The most important reason for SBC Communications to set up its R&D arm in Austin is that SBC can find talents from a large pool of high-tech professionals. Austin has been regarded as a technology center with hundreds of high tech companies. The engineers in these companies, as well as researchers and graduates of the University of Texas at Austin, have become a good source of labor. Second, SBC Labs values the presence of a major university with strong research capabilities. As an industrial affiliate, SBC Labs has enjoyed a good working relationship with UT's Wireless Networking & Communications Group (WNCG) led by Professor Ted Rappaport. Third, Austin offers a high quality of life that is attractive to engineers and technical professionals, as suggested by the fact that many of SBC Labs' retired engineers choose to stay in Austin, even though most of them come from the Midwest.

Motorola's iDEN Subscriber Group

Motorola's iDEN Subscriber Group is based in Florida but has several employees in the Austin area. iDEN technology, which stands for Integrated Digital Enhanced Network, combines digital two way radio, digital wireless phone, alphanumeric messaging and data capabilities. There are more than 15 million iDEN users worldwide.[109]

A variety of enterprise and consumer applications have emerged based on iDEN technology.

What's important about iDEN technology?

There are some features about iDEN that have important applications for consumer and business users.

Walkie-talkie service. A Motorola iDEN phone can serve as a "push-to-talk" two-way radio, which can be especially useful for mobile workforce management. The advantage of a walkie-talkie is that it can keep mobile work forces in constant contact. In addition, it can be much more cost efficient than cellular telephone service.

Location-based services. Motorola is a market leader in integrating GPS technology for mobile phone users. Going well beyond basic E911 capabilities, iDEN technology provides a platform for location-based services such as commercial fleet management solutions.

Java™ platform. Another important feature of iDEN technology is Java 2 Micro Edition (J2ME™), a development platform that leverages the vast Java developer community to enable a range of applications and services that can run on Motorola's J2ME technology-enabled mobile phones. J2ME technology enables users with the ability to download applications to their mobile phones.

A variety of applications. For consumers, some of the most popular applications include games and downloadable ring tones. There is also a very large variety of business solutions that have been developed for Motorola iDEN handsets, including asset tracking, mobile workforce management, secure wireless payment, and fleet management.

iDEN in Austin

Motorola works with a handful of companies in the Austin area that are committed to developing best-in-class wireless data solutions for Motorola iDEN handsets. This network of Austin-based application developers includes HillCast Technologies, a financial service application developer; Manning Navcomp, a vehicle tracking solutions provider; and a number of other wireless software developers and service providers.

WIRELESS FUTURE SCENARIO 4: UNWIRED SMART FRIDGE

Smart Refrigerator V5.0 is now a wireless, self-powered, modularized (optional) network appliance!

Thursday, March 8, 2012—Samsung, creator of the world's first Smart Refrigerator and leader in home networking technologies, today announces the release of Version 5.0 of its Smart Refrigerator series.

New Features in Version 5.0 include:

- **Revolutionary self-contained power supply:** Using fuel cell technology, Samsung liberates you from the grid. This not only saves you money but alleviates the inconvenience and waste associated with increasingly common power outages. Appliances will never be the same again!
- **Complete home control:** Using your fridge as a wireless base station, you can preset the operation times of your washing machine, video hard drive recorder (VHDR), microwave oven, etc. The schedules of appliances can also be set and controlled remotely via a wireless device. A suite of software can be downloaded (at additional cost) to expand your home control capabilities.
- **Energy savings:** A record of your energy consumption can be tracked using the fridge's control pad. You can check the energy consumption of each household device and save power consumption if and when needed.
- **Real-time video feed:** Want to know just how much soda is left in the bottle when you're standing at the store? Get a visual check on your wireless device thanks to the Smart Fridge's interior cameras.
- **Portable module (*optional*):** Whether you are going to the supermarket, on a camping trip or spending an afternoon outdoors with friends, the Uni-Fridge® portable module can come with you. The module's micro fuel cell even lets you power other appliances.
- **OLED panel doors (*optional*):** Turn your fridge into a large-format media screen. Watch your favorite shows, control your home network, or just videochat with your friends and family from the Smart Fridge's 26-inch paper-thin OLED (organic light emitting device) display.
- **Trim kit:** Choose from 18 colors to fit your kitchen or, for the latest in customization, select the OLED upgrade and change the image or color whenever you like!

Other features that you've come to expect of the Samsung Smart Fridge:

- **Convenience:** You can easily control your home appliances, such as a networked refrigerator, washing machine or microwave oven, by using the web pad or accessing your home system via a wireless device or other Internet access point.

- **Intelligence:** The Smart Refrigerator detects the shelf life of your food and automatically displays a list of items stored in the fridge. It will even order pre-assigned essentials when they run low so that they're delivered to your door. Never run out of milk again!
- **Beverage station:** By only opening the mini-door, you have instant access to your favorite drinks, while keeping cold air inside the refrigerator.
- **User-friendly interior:** A great exterior is only the beginning. When you open the doors to your refrigerator, you'll be amazed. You'll say, "How organized!"

The Smart Fridge Version 5.0 is the flagship of Samsung's Networked Life® range. For the over a decade, we have been at the cutting edge of appliance integration and convergence. Now with our advanced fuel cell technologies, we provide you and your family with more control, independence, and security.

Whether you're entertaining, sending data, or protecting your home, Samsung Electronics' Networked Life® solutions will transform your home into a digital hive of active appliances.

The Standard version of the Samsung Smart Fridge will retail for $4,599. Samsung's Modular model will have a retail price of $5,599 and includes an easy-to-lift carry case. A 'wired' version of the fridge is also available for use with home-based fuel cell generation and traditional energy delivery installations. Contact Samsung for pricing details. All models are available for purchase at www.samsung.com or at your local electronic distributor.

DISCLAIMER: *The preceding scenario is fictional and used for illustrative purposes only. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply the endorsement, recommendation, or favor of the Samsung Corporation. The views and opinions of authors expressed herein do not necessarily state or reflect those of the Samsung Corporation.*

SECTION 4—AUSTIN'S WIRELESS ECOLOGY

Although Austin is fortunate to have a wide variety of wireless companies, the success of these companies is largely dependent upon access to and the quality of a number of resources. Foremost among company concerns are investment capital, a talented labor pool, and a supportive civic and community infrastructure, particularly for young, entrepreneurial companies.

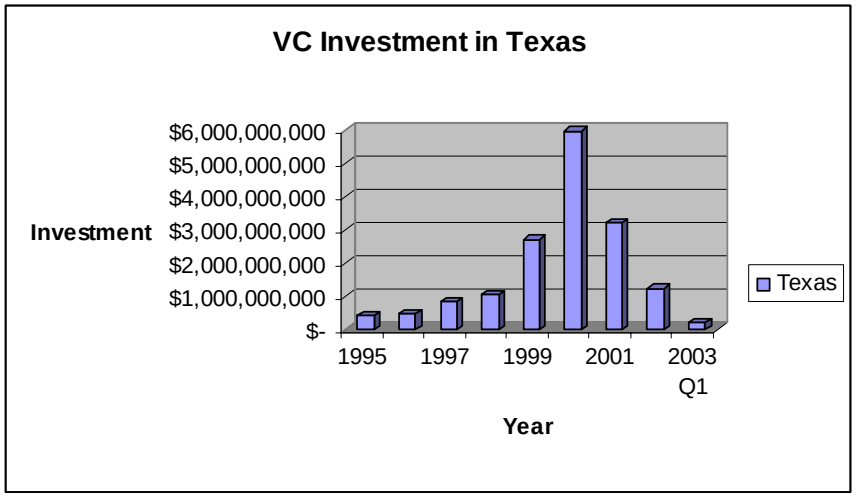
In this section we analyze Austin's assets with respect to these important resources and conclude by briefly examining Austin's peers.

Investment Infrastructure

The overall investment trend in the venture capital (VC) industry is shown in the figures below. After the explosive growth of VC investment from mid-1999 to the end of 2000, investing activities have plummeted for two and a half years. Although many experts predicted that the VC investment had bottomed in the fourth quarter of 2002, and would flatten out in 2003, it actually continued to drop by another 10% in Q1 of 2003.

VC investment in Texas is more or less in line with the national trends. This report concentrates on Texas venture capital companies and venture capital arms of multinational companies.

Figure 7. Venture Capital Investment in Texas 1995-Q1 2003



A growing portion of venture capital is going to later-stage rather than early-stage companies. The portion of investment in early-stage companies has decreased from 25.6% in 1998 to only 17% in the first quarter of 2003.[110] In the current market, later-stage companies are often valued as low as startups, making them more attractive to investors.[111] Of course, later-stage companies also face challenges; many that received early-stage funding in 2000 will come back for money in 2003 and 2004.

Venture Capital Investment in the Wireless Industry

Wireless was among the sectors most affected when the high-tech bubble burst in 2001. The percentage of venture capital that the wireless industry received dropped from 22% in 2000 to only 9% in 2001. Now a bright spot in high-tech investment, the wireless industry, both in equipment and services, is once again strong.

Although total VC investment declined in Q1 of 2003, VC investment in the wireless industry worldwide increased by an impressive 64% from $658 million in the last quarter of 2002 to $1.077 billion. The investment level in wireless has been consistent for the past seven quarters at an average of $918 million per quarter.[112] It is estimated that the wireless industry now garners 13% to 19% of all venture capital investment.[113] Five percent of wireless investment has gone to early-stage companies, 38% to middle-stage, and 57% to later-stage.[114]

Venture capital interests reflect the future directions of the wireless sector. Currently, most VC investment in wireless goes to satellite communications, WiFi, mobile data acceleration (MDA), RF semiconductor, directory assistance software (DA), Ultra Wideband (UWB), ZigBee, and protocol software. Some details:

Satellite: Satellite technology received the largest investment in the wireless industry in the first quarter. However, of the $157 million investment, $156 million went to one company, Denver-based Wildblue Communications, which provides satellite high-speed Internet access.

WiFi: In the past three years WiFi has received more than $1.6 billion in VC investment worldwide. In the first quarter of 2003 alone, 22 WiFi companies received $70 million.[115] Although this is the area where venture capitalists see huge potential, there is a growing consensus in the VC industry that the WiFi subsector has now been overfunded.

VC targets in this space have been WiFi semiconductor developers, providers of platforms for managing WiFi access, system technology developers, and network operations companies. In the past two years, WiFi venture capital has shifted focus from semiconductor companies to systems and operations companies.[116] Network operations companies, including roaming-billing, administration, efficiency, and security, have received 34% of total VC funding in WiFi, compared with 31% for chipset companies.

RF semiconductor: RF semiconductor companies remain attractive to venture capital. They meet the ongoing demand for higher frequency, multi-frequency, and wideband frequency. Also, a balanced ecosystem is developing, where small RF semiconductor startups are cooperating with big chip manufacturers like Texas Instruments and Motorola.[117]

Mobile Data Acceleration: Another area where VC investment is growing. Four companies received a total investment of $22 million in the first quarter of 2003. MDA gained popularity because the technology increases data transmission abilities and provides visible economic returns. The delay in 3G cellular also benefits MDA, as companies seek higher performance level with existing infrastructure.[118]

New areas for venture capital: Some other areas in wireless have also caught attention of venture capitalists, including fixed wireless broadband, network management software, power management chips, directory assistance software, and protocol software.

Investment and Sustainability

The success of the wireless sector (and prevention of another "bubble") depends not only on the success of companies in attracting investment, but also on the sustainability of their business models. The dot-com bubble was driven by the most exuberant IPO market in history, from the beginning of 1997 through Q3 1999. Technology companies and dot-coms had easy access to inexpensive capital in the IPO market. The average time for VC development, management, and financing of a portfolio company before going public was shortened to only six months to three years, compared with an average of four to eight years before 1997.[119]

But the dot-com boom became a pyramid scheme when some investors realized they could get an exponential return by cashing out after an IPO was launched, because stock market investors were rushing to buy dot-com stocks and pushing market values to unrealistic levels. VCs were lured to pay less attention to sustainable business, because the market accepted immature business models.

When the IPO money was gone, many companies fell apart. Could this happen again with wireless?

In the era of easy IPO money, the valuation of portfolio companies in pre-IPO rounds increased dramatically. The percentage increase of the pre-IPO rounds was significantly higher than in previous financing rounds, implying that most of the "bubble" in investment valuation came from the pre-IPO rounds financing.[120] To avoid another bubble, the IPO market needs to be watched closely.

Currently, the IPO market is one of the worst for venture-backed companies in two decades. *Entrepreneur* magazine stated that in 2002 venture capital investing fell to its lowest level in five years ($21.2 billion). There are only about 50 venture-backed IPOs per year, and later-stage companies are usually significantly undervalued. On the other hand, the merger and acquisition (M&A) market for venture-backed companies has remained strong since 2001. Unlike the IPO market, the typical buyers in M&A transactions are usually large companies seeking expansion or entering a new market. They are more knowledgeable in the specific field and much more cautious about sustainability.

Given the current situations in the capital market, another bubble in technology companies is unlikely, at least in the short run. However, with the economy recovering, and the capital market rebounding, the venture-backed technology companies may once again have easy access to cheap capital. Past lessons are a key to noticing danger.

Venture Capital in Austin

From Q2 2002 to Q1 2003 venture capital investment in Austin held at a low level of $50-100 million per quarter. In Q2 2003 there was a jump of 85% to $142.2 million, a

positive signal for Austin's technology industry. Austin seems to be outperforming the market, as nationwide VC investment has remained at $4-4.5 billion per quarter for the past year. It is premature to call this the start of an increasing trend. We still must watch VC investment for the next two quarters.

The biggest contribution to the Q2 increase came from investments in semiconductor industry and media and entertainment. A big increase in early-stage investment in the quarter represented 56% of all seed and early-stage investments in the past 12 months.

Figure 8. Venture Capital Investment in Austin Q1 2001-Q2 2003

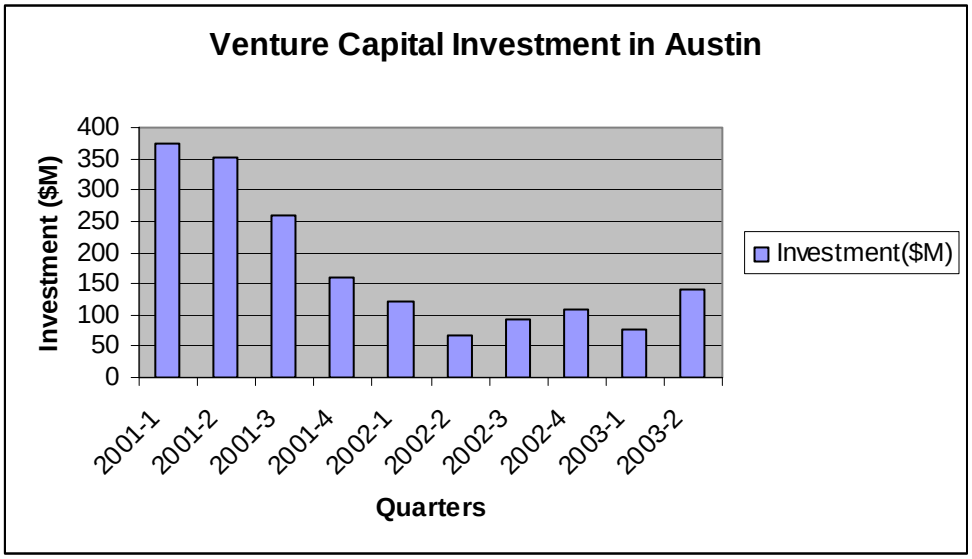


Table 10. Venture Capital Investment in Austin MSA, Q2 2003

Sector	Companies	Deals	Investment ($M)
Software	11	11	37.8
Networking and Equipment	2	2	11.9
Medical Devices and Equipment	2	2	4
Business Products and Services	2	2	13.8
Semiconductors	2	2	35.2
Telecommunications	1	1	6.5
Media and Entertainment	1	1	18
Computers and Peripherals	1	1	4.2
Industrial/Energy	1	1	0.2
Biotechnology	1	1	10.5
Total	24	24	142.2

Source: PWCMoneyTree

Table 11. Venture Capital Investment in Austin Metro Region Q3 2002-Q2 2003

Sector	Companies	Deals	Investment ($M)	Qtr avg. investment
Software	30	30	113.3	28.325
Semiconductors	5	5	72.7	18.175
Computers and Peripherals	8	8	59.6	14.9
Telecommunications	5	5	40.4	10.1
Media and Entertainment	4	4	32.5	8.125
Networking and Equipment	4	4	30.5	7.625

Source: PWCMoneyTree

The following research is based on three categories of venture capital companies from which the wireless industry in Austin seeks investment:

- Top-500 venture capital companies located in Texas.
- Venture capital arms of large corporations.
- Local venture capital firms in Austin.

Our research is focused on their targeted industries and past investment in wireless companies.

Some findings based on public information:

- Thirteen top-500 venture capital companies and private equity firms are located in Texas, six of which have invested in the wireless industry. Austin Ventures, Sevin Rosen Funds, and Dali, Hook Partners have invested in more than five wireless companies.
- Of the 17 venture arms of multinational companies studied, ten have invested in wireless. Five of them have more than ten wireless portfolio companies.
- Intel Capital is the leader in wireless venture capital. It invests heavily in the WiFi sub-sector, as it fits Intel's overall company strategy. Motorola Ventures, Nokia Venture Partners, Siemens Venture Capital, and Qualcomm Ventures are the other big stakeholders in wireless.
- Also listed are 15 regional venture capital companies located in central Texas and focused on Austin. All but one of them have invested in the wireless sector. Due to their relatively smaller capital, most invest in only one to three wireless companies. But their investment is important to Austin-based wireless companies such as Wayport, SoloMio, and Motive.

For details on these venture capital firms and their investment in the wireless sector, see the appendix.

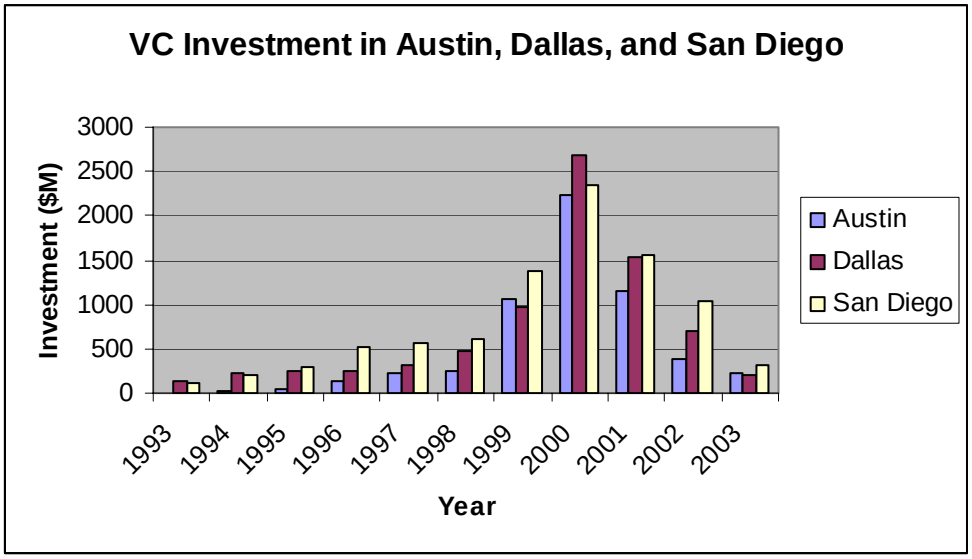
Comparison: VC Investment in Austin, Dallas, and San Diego

This section compares venture capital investment in three metropolitan areas: San Diego, Dallas, and Austin. San Diego and Dallas both have a recognized telecom industry and have seen recent innovation in the growing wireless industry.

Targeted areas of VC investment are more significant than the VC firms' actual location. However, VC activity benefits local economic growth. In July 2003, *Entrepreneur* magazine listed the top 100 venture capital firms, based on the firms' activity and investments. The top 100 VC firms include Austin-based firms Austin Ventures, Agave Capital, G 51 Capital, and Gefinor Ventures. StarTech in Richardson, TX represents the Dallas area, and Forward Ventures, Mission Ventures, and Windamere Venture Partners represent the San Diego area.

Figure 9 tracks aggregate VC investment in the three cities for the year ending June 30, 2003.

Figure 9. VC Investment in Austin, Dallas, and San Diego



Source: PricewaterhouseCooper/Venture Economics/NVCA MoneyTree Survey

For much of the last decade, San Diego has been most attractive to VCs, except during the telecom heyday in 2000 when Dallas took the lead. In total VC investment Austin lags behind the other cities, attracting only about two-thirds as much as San Diego. But investments in the three cities are closely correlated. Generally VC investment in Dallas is more sensitive to economic changes, probably because it is less diversified, with almost half of all VC investment in the past year going to telecommunications.

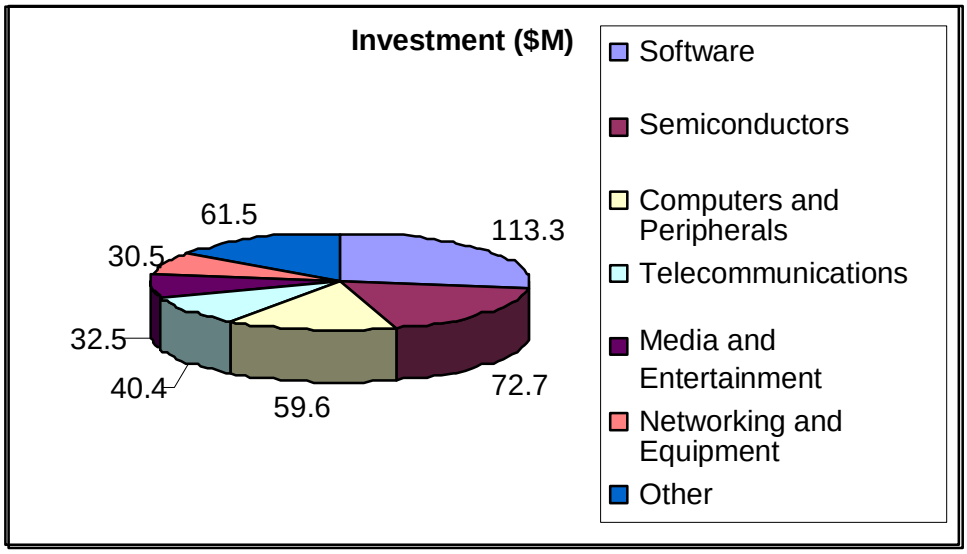
From the industries that top the list of VC investments in these cities, the patterns of their strengths and strategic focuses are clear.

- **Austin** attracted most of its venture capital to software, semiconductors, computers and peripherals, and telecommunications. The only area where Austin leads is software.

- **Dallas** is strongest in telecom, networking equipment, and software.
- **San Diego** has shifted investment from IT industry; biotechnology garnered almost 30% of total venture capital. Still, the telecom, semiconductor, and software sectors received big investments, keeping San Diego as the national leader. San Diego receives more investment in telecom and semiconductors than Austin, but Austin's investment structure resembles San Diego's, except for the biotech industry.

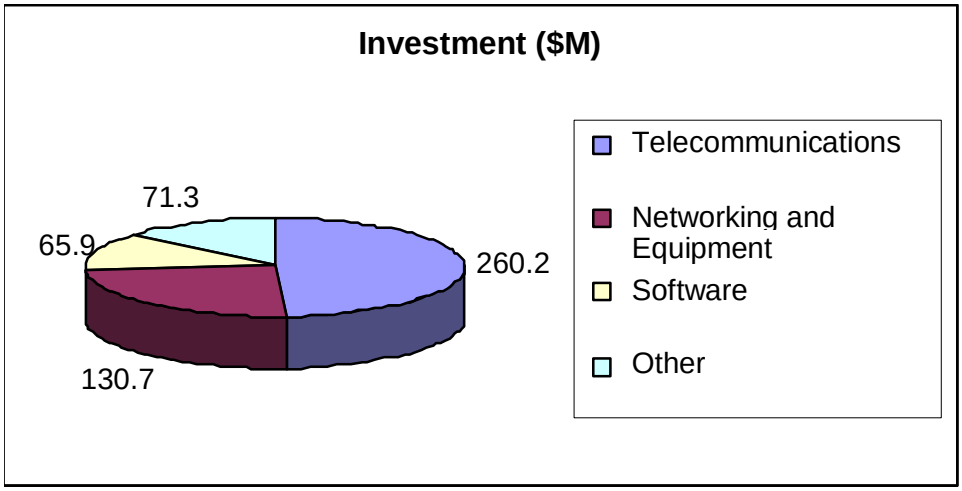
Wireless industry data is not broken out, because the wireless industry has a large crossover among other industries. A keyword search for "wireless" within the results lists industries including telecommunications, software, business products and services, computers and peripherals, industrial/energy, networking and equipment, and semiconductors.

Figure 10. VC Investment in Austin, Q3 2002-Q2 2003



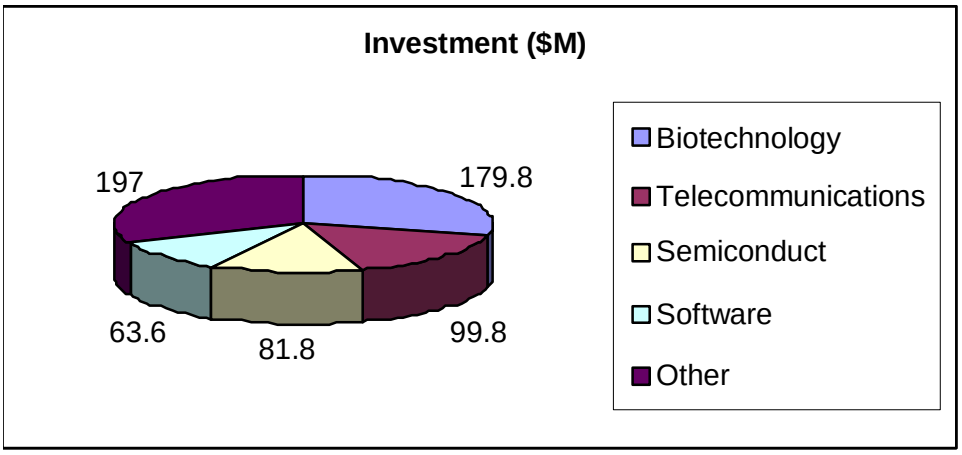
Source: PricewaterhouseCooper/Venture Economics/NVCA MoneyTree Survey

Figure 11. VC investment in Dallas from Q3 2002 to Q2 2003



Source: PricewaterhouseCooper/Venture Economics/NVCA MoneyTree Survey

Figure 12. VC Investment in San Diego, Q3 2002-Q2 2003



Source: PricewaterhouseCooper/Venture Economics/NVCA MoneyTree Survey

Special Funds

In addition to tax incentives and bonds, Texas offers several funds that can potentially help wireless companies wishing to relocate to or start business in the state.

Telecommunication Infrastructure Fund Board

In 1995, with the establishment of the Telecommunication Infrastructure Fund Board (TIF), the Texas legislature set aside $1.5 billion to distribute through community grant programs for technology infrastructure, equipment and training.[121] Specific target areas for TIF funding included public schools, institutions of higher learning, libraries, and nonprofit healthcare facilities.

Although TIF grants were exclusively for nonprofit entities, the large scale of the programs attracted interest from technology vendors. Each sponsored project allowed local companies to contract out to technology companies, including wireless.

The 78th legislature did not renew funding for TIF, forcing still-active grants to enter a phase-out period to be administered by the Texas Workforce Commission.[122]

Texas Capital Access Fund

Qualified businesses in Texas can benefit from a state-sponsored reserve account designated to make them more attractive borrowers. The Texas Capital Access Fund reduces uncertainty for lenders making loans to eligible businesses—nonprofits and businesses that would otherwise have trouble obtaining loans.[123] Businesses with less than 500 employees are eligible to receive funds, as long as they are based in Texas or have at least 51% of their employees in the state.

Texas Enterprise Fund

In its 78th session, the Texas legislature authorized a $295 million economic development fund to attract and maintain business activity in Texas.[124] The Texas Enterprise Fund, created to help sustain the state economy, includes $55 million earmarked for technology and biotechnology companies. Days after the fund's enactment, Texas Instruments received $50 million for its decision to build its next chip plant in Richardson.[125] In August, after the consortium Sematech was courted by New York's economic development fund, the Enterprise Fund granted Sematech $40 million to secure its presence in Austin.[126]

Human and Intellectual Capital

Workforce

The last three years have sent many technology workers looking for jobs. During 2001 and 2002, high tech employment shrank 10%, with electronics manufacturing taking the biggest loss.[127] However, the software services industry managed to add jobs.[128]

Workers in the wireless industry were also hard hit, and their skills are becoming more mainstream. As Grant Jay, who recruits wireless workers for Goldbeck Recruiting in Vancouver, told *Wireless Week*:[129]

> "The standard wireless candidate is going away, where you're strictly wireless. Wireless is just a piece of the puzzle. You need the full IT background, wireline, hardware, network, security. [Wireless] is just a medium, you need to know what goes on that medium and if there's an application for it."

As wireless devices and applications proliferate, skills acquired in other technology areas grow more adaptable to wireless.[130] This is particularly true in programming—for example, Java programming skills map to Java 2 Micro Edition.[131] However, programmers wishing to cross over to the wireless world must adapt to smaller, more limited interfaces, as well as differing needs of users on the go.

Professional Standards

As the field matures, more workers will define themselves as wireless workers. To cater to these workers, professional and industry groups are emerging. Nationally, the Cellular Telecommunications and Internet Association (CTIA), established in 1984, provides space for online job and resume postings, as well as education, lobbying, research, and investment materials for the entire wireless industry.[132]

Focused more on wireless as a career, the Folsom, CA based Association of Wireless Professionals (AWP) is a national umbrella organization for workers of all skill levels in the wireless industry. To bring national recognition and standards to the field, AWP is developing education and certification programs for sales and customer service representatives working in wireless.[133] Industry professionals select course material and topics based on needs they identify in the field. Students who complete

courses will gain certifications in wireless professional sales and wireless professional management.

Another group, the Global Wireless Education Consortium (GWEC) brings companies and institutions of higher education together to develop curricula for a strong wireless industry workforce.[134] GWEC has developed 22 "points of knowledge" for inclusion in curricula at two- and four-year institutions.[135] The points range from basic skills such as communication and teamwork, to switching expertise, microwave knowledge, software development, and health/safety issues in wireless.

In 2001, in conjunction with Seattle area community colleges, GWEC released "Skill Standards for Wireless Telecommunications."[136] The report emphasizes the need for consistent standards for skills for technicians in the industry. Two concentrations are identified:

- **Deployment and Implementation**: workers who install, monitor, troubleshoot and test equipment
- **Maintenance and Operations**: workers who repair, troubleshoot, and maintain systems

For each concentration, the report articulates associated activities, skills and performance indicators. Report authors hope the standards will serve as benchmarks for entry-level employment and a basis for curricula for the wireless industry.

Austin's Wireless Workforce

Texas, and especially Austin, has the technological expertise for wireless jobs. As seen in this table provided by the Texas Workforce Commission, seven out of the top ten projected occupations for Texas are directly computer-related:

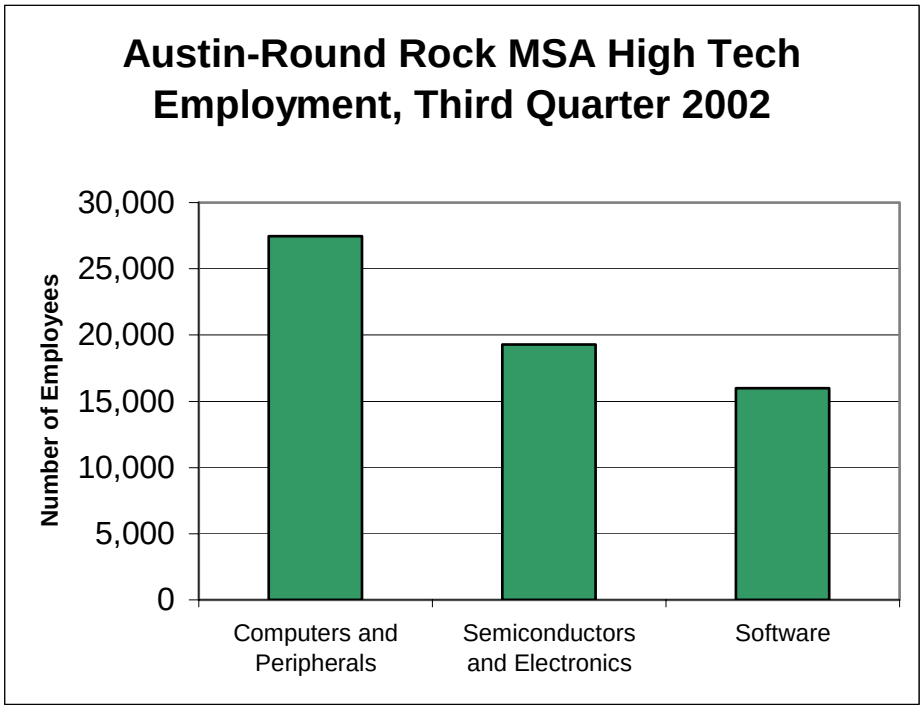
Table 12. Top Texas Occupations for 2000-2010

1	Computer Support Specialists
2	Computer Software Engineers, Applications
3	Network & Computer Systems Administrators
4	Desktop Publishers
5	Computer Software Engineers, Systems Software
6	Network Systems & Data Communications Analysts
7	Database Administrators
8	Medical Records & Health Information Technicians
9	Social & Human Service Assistants
10	Special Education Teachers, Preschool, Kindergarten, & Elementary School

Source: Texas Workforce Commission[137]

According to the Bureau of Business Research at UT's McCombs School of Business, the high-tech sector employed 94,880 people in the Austin MSA in the third quarter of 2002.[138] These industries provide talent pools for local wireless companies. The breakdown is as follows:[139]

Figure 13. Austin-Round Rock MSA High-Tech Employment, Q3 2002



Source: Bureau of Business Research

Although Austin has a relatively strong public school system, the city is outdone by cities with more options for two-year degrees, such as the wireless curriculum at Seattle Central Community College.

Acknowledging the need for additional two-year education programs in the area, the 78th Legislature funded a building for the Southwest Texas State University Multi-Institution Teaching Center, which currently operates at night in classrooms borrowed from Round Rock high schools.[140] The facility, to open in 2005, will hold classes for ACC and Texas State University-San Marcos (formerly Southwest Texas State University) and will focus on engineering.

Creative Class

Austin's strong film, music, and artistic communities, and its overall creative atmosphere, may help foster the content-creation side of technology

Richard Florida, professor of regional economic development at Carnegie Mellon University, uses the term "creative class" to describe people who design, problem-solve, and compose for a living and consequently enjoy a 40% higher pay than their

non-creative counterparts.[141] The creative class includes engineers, actors, writers, musicians, artists, architects, scientists, and programmers. Kevin Stolarick, also a Carnegie Mellon professor, analyzed growth in American cities and came to the conclusion that creativity is a stronger predictor of urban growth than education.[142] Florida and Stolarick claim that creative workers are the fastest-growing economic class in the nation, and that over one third of Austin's jobs are among that group.[143] (By the third quarter of 2002, the film and music industries employed 2,859.[144])

During the past decade, Austin's creative class prompted an influx of talent and income potential. Families moving to Austin from another Texas city had higher incomes than those leaving Austin, giving the city a $2.15 billion net income gain from other Texas cities.[145] In 1993, Austin had the seventh-highest average family income levels for the state; by the end of the decade Austin was first.[146] Austin is attracting entrepreneurial immigrants and Californians in search of an easier lifestyle.[147][148] Los Angeles, San Jose, Chicago, Phoenix, Washington DC, and San Diego, as well as older manufacturing economies, are the top areas from which Austin pulls talent.[149]

Opportunities in Higher Education

Austin lacks two-year degree programs focusing on wireless. However, students can pursue more general studies in related technology fields. Students at Austin high schools, Austin Community College (ACC), and area universities have curricula focusing on information technology. Specifically, ACC and high school students can take classes in networking and computer repairs that can help them gain certification as technicians.[150] Opportunities at these levels will expand in 2005 when the Southwest Texas State University Multi-Institution Teaching Center in Round Rock moves into its own building (see "Austin's Wireless Workforce" above).[151] The suburban Austin facility hosts classes from ACC and Texas State University- San Marcos (formerly Southwest Texas State University).

At UT, the recently established Wireless Networking and Communications Group (WNCG) in the department of Electrical and Computer Engineering will serve as a major local talent source. The WNCG develops research and educational materials in six areas fundamental to wireless networks: propagation and antennae; modulation and coding; signal processing techniques and implementation; sensor and ad-hoc networks; network security; and network architectures, software, and protocol performance.

The WNCG was founded by Professor Theodore S. Rappaport, P.E., Ph.D. He joined UT in 2002, holding the William and Bettye Nowlin Chair in Engineering. Dr. Rappaport has 30 patents issued or pending and has authored, co-authored, and co-edited numerous books in the wireless field, including the textbooks *Wireless Communications: Principles & Practice* and *Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications*. He received the 1999 Stephen O. Rice Prize Paper Award from the IEEE Communications Society.

The WNCG program operates under the Communications, Networks, and Systems (CommNetS) curriculum. Within the past year the WNCG has recruited over 60

graduate students. The program is advised by 14 faculty members, and six major companies have joined as stakeholders in WNCG's new Industrial Affiliates program. The WNCG has spurred competition for admission to the Electrical and Computer Engineering graduate program.

As the WCNG case demonstrates, industry stakeholders often help shape education institutions course offerings and programs. Texas Instruments is particularly aggressive in developing Texas curricula to suit its need for engineers with experience with digital systems processors (DSP). In addition to working with colleges and universities, TI developed DSP curricula for 58 high schools nationwide and wants to do the same for middle schools.[152]

In addition to the technical degree programs, MBA programs at UT's McCombs School of Business and St. Edward's University produce management talent and students with investment, management, and marketing knowledge. Local universities also give students experience in programming, digital media, and the arts, all valuable in content-creation areas of technology.

Training

The Capital Area Training Foundation (CATF) is a workforce and education development nonprofit that partners with the Greater Austin Chamber of Commerce. CATF hosts industry conferences ("clusters"), notably for the semiconductor industry, that bring together executives and educators to address workforce needs.[153] According to David Nunez, cluster director for IT and high tech manufacturing, the local wireless industry is emerging as a target for workforce development. Because of increasing interest from the Chamber of Commerce, CATF will mediate between companies and educators to develop key workforce skills that support wireless in Austin.

Nunez sees an increasing need for network technicians, who remain important because networks need constant maintenance and because maintenance cannot be outsourced to other regions, unlike programming jobs.

The survey of wireless companies conducted for this report shows that workforce availability is a salient concern for local companies. Fewer than half the companies surveyed have workers who trained in the Central Texas region. Reflecting the general small size of Austin wireless companies, 42% of the survey respondents said they would hire one to five people in the next year. But in the next five years, almost 60% of the companies expect to hire 20 or more employees locally. Among the top needs are technical professionals (engineers, scientists, computer scientists) and support professionals (marketing, accounting, business development). Technicians with two-year degrees were needed by 54% of the companies.

Research

Dr. Theodore Rappaport's Wireless Networking and Communications Group (WNCG) in UT's College of Engineering has positioned itself as a major research center in the wireless industry. The WNCG serves the worldwide

telecommunications industry by researching wireless technology and its uses, and by providing a meeting place for wireless research and business leaders.

As a focus for the wireless industry, the WNCG will bring attention to the Austin area and specifically to UT. Through work with major wireless and telecom corporations, WNCG is helping to bring research talent to Austin from all over the world.

Government initiatives on the local, state, and federal levels will directly affect Austin's wireless sector. Dr. Rappaport commented, "The wireless industry is closely tied to spectrum regulation, and the necessity of being connected to Washington, and more importantly international policymakers, is critical to the success of Austin positioning itself as a wireless hub."[154]

The WNCG is currently looking at partnering with promising university research centers in Asia and worldwide. This partnership would cultivate new talent and foster growth globally. For Austin and its businesses, this means an increase in exposure, direct connections to successful research centers, and possibilities for expansion into overseas markets.

While WNCG is the most visible university-based research endeavor, many of Austin's research assets reside in the private sector. Due to the proprietary nature of this research much of Austin's promise as a wireless leader remains hidden. Several of Austin's larger employers have well established research units, such as SBC Laboratories and IBM, and much of this research, as the SBC Laboratories case study in section 3 shows, is in wireless. However, wireless research is not confined to Austin's marquee companies; 30 percent of the companies responding to the Wireless Future survey reported wireless research as a key component of their business.

Civic Infrastructure

Opportunity Austin

In September 2003 the Greater Austin Chamber of Commerce (GACC) released its latest economic development plan, "Opportunity Austin," using demographic and economic data analyzed by Market Street Services.

Opportunity Austin specifically targets the wireless industry for support. Specifically, the project suggests the establishment of a wireless research consortium. The GACC also highlights three other areas—software, semiconductors, and digital media—with clear connections to wireless.

Broad goals of Opportunity Austin include bolstering local companies and the recruitment of corporate headquarters and regional offices with incentive packages. The GACC plan calls for reform of the city's permit system and development of a formal tax incentive policy.

The plan cites a survey done by the city's Small Business and Entrepreneurship Subcommittee, reporting that 76% of small business respondents said that "doing

business" with the city is complex and difficult.[155] Due to concerns for environmental quality, the city has more restrictive development policies and a more burdensome permit process than other Texas cities. The GACC submitted these recommendations:

- Development of a small business resource center and Web site, to be implemented in about 18 months
- Easing of requirements for site planning and construction
- Assistance and special consideration for small businesses and entrepreneurs going through the permit process
- More flexibility and incentives for innovative landscaping and preservation

Those proposals that require rule or code changes go before the City Council for approval in October 2003, and city staff have already begun plans for implementation.

City of Austin

The Austin City Council created a Taskforce on the Economy to study current procedures and make recommendations for a policy to be authorized by the City Council.[156] The Taskforce has three subcommittees: Traditional Industries, Small Business and Entrepreneurship, and Cultural Vitality. The subcommittees released their findings in a report in April 2003. Two sets of recommendations affect wireless companies.

To attract anchor companies from the wireless industry, and to maintain growing companies, the Traditional Industries subcommittee recommended tax and other incentives.[157] These policies, now in place, implement performance-based initiatives under Local Government Chapter 380. Under this plan, companies receive refunds on sales and property tax if they meet certain preset performance goals, such as job creation, community contributions, and public services. According to Sue Edwards, director of the Economic Growth and Redevelopment Services Office, this approach creates no risk to Austin because it requires no upfront investment, and companies only reap benefits if they perform.[158] The incentives are part of a package that GACC recruiters present to companies on recruiting trips.

In addition, the subcommittee recommended a systematic way to target and recruit industries and firms to the region. They identified the characteristics of industries targeted for recruitment:

- Long-term and solid in nature
- Good performance forecast
- Complements regional resources and competitors
- A valuable cluster or fills supply gaps
- Consistent with local values and vision

Austin Technology Incubator

The Austin Technology Incubator (ATI) brings together business, government, and academic resources to catalyze technology business development. ATI was founded in 1989 by Dr. George Kozmetsky. It currently operates as a nonprofit incubator and is a program of the IC² Institute of The University of Texas at Austin. ATI's mission is to provide business resources and professional services that assist technology startups in the global market.

ATI supports promising high-growth companies in technology-based industries through a targeted services package: strategic advice, access to financing, marketing and PR support, a benefits program, mentoring, and turnkey infrastructure (low-cost Internet access, shared conference rooms, shared copy and fax equipment, etc.). Supported by the University of Texas, the City of Austin, and the Austin community, ATI works with investors, professional service providers, outside industry experts, and others for the benefit of its member companies.

New Initiatives in the Wireless Sector

The University of Texas and the Austin business community, together with state and local government, seek to drive new economic activity in the wireless sector. ATI is well positioned to improve their efforts, for these reasons:

- ATI has established itself as a key element in commercializing technologies and know-how emerging from UT research. ATI works with the Office of Technology Commercialization and the Wireless Networking and Communications Group at UT to capitalize on the University's wireless research.
- ATI plays a decision-making role on the Steering Committee of the Austin Wireless Alliance, an organization supporting the wireless industry in Austin.
- In an industry where even young companies need foreign markets, ATI lets wireless companies "go global on day one." Its global network of sister incubators and business contacts offers international sales channels and partnerships for companies seeking to establish a global footprint.

The ATI is working to create a new "wireless business incubator" fostering the creation of businesses involving wireless technology, applications, and services. Currently ATI is hiring experienced staff, creating a board of advisors, and formulating a funding strategy. The incubator seeks to put sponsor companies in touch with early-stage startups to establish investment, partnership, customer-supplier relationships, etc.

Austin Wireless Alliance

The Austin Wireless Alliance serves as a forum for local industry professionals. The group brings entrepreneurs, business leaders, educators, and technologists together to share ideas and promote the local wireless industry.[159] AWA is set to align with GACC, IC², UT, investors, and Austin Technology Council to collaborate to achieve

these goals. In addition to bringing these stakeholders together, AWA will help support wireless startups and leverage local research resources.

Community Networking

Around the world, community networks—local technology access and education programs—use wireless technologies to bring Internet access to areas that otherwise might have to wait years for service. Texas became a leader in this area in 1995 with the establishment of the Telecommunications Infrastructure Fund Board (TIFB).[160] The agency, which was cut from the state budget this year, aimed to ensure equitable telecommunications access in the state. TIFB grant programs covered education, libraries, and health care. TIFB funded three rounds of community networking grants, enabling 188 communities to establish local computer access and services.[161]

Recognizing the advantages in WiFi, many Texas community networks chose to use wireless as all or part of their network strategy. TIFB aided them by defining standards for grantees installing wireless networks.[162] The standards serve as a guide on issues such as security, equipment, antennae, wireless bridges, and site surveys.

Rural communities are particularly active in community networks because they need to bring broadband access to both residents and local businesses. Although most communities have dial-up access, poorly maintained phone lines often keep rural users' connection speeds well below the standard 56Kbps. WiFi is a lower-cost and higher-speed wireless option for rural communities, usually delivered via a WISP using fixed wireless.

This trend is particularly evident in West Texas where the flat, treeless terrain permits exceptional line of sight that keeps wireless signals strong and predictable. AMA Wireless has a 20,000-square-mile wireless network in the Texas Panhandle and eastern edge of New Mexico, one of the largest wireless backbones in the country.[163] The company has collaborated with eight local community networks. AMA Wireless' sister company, Attebury Grain, contributes its grain elevators as antenna platforms. This model is seen throughout rural areas in the Austin MSA and Hill Country; antennae are mounted on water towers and grain elevators because of their height and central location.

For these community networks, the biggest challenge is weather. Lightning and wind often put antennae out of commission, requiring immediate attention to the equipment during intense storms.

Lockhart is a town of almost 12,000 located about 30 miles outside of Austin, with a high number of commuters to the city.[164] Lockhart Community Network, a first-round TIFB grant recipient, brought broadband access to the town with WiFi delivered by antennae mounted on water towers. Michele Schalin, city training coordinator for the project, said wireless permits broad access across town at low costs.[165] "[Wireless has] shown a lot of people, in this particularly small town, the benefits of high-speed Internet," she said. Twelve computer access sites are open in the community, and sites are also used for a wide variety of training courses.

Dick Wieland, professor of business at St. Edward's University in Austin and volunteer at Lockhart Community Network, is working with his MBA students to produce a business plan for a nonprofit hybrid WISP to provide access to residents and small businesses.[166] Wieland said that as people retire and move to Lockhart and as more Austin commuters move to town, the demand for urban services like broadband rises.

Lockhart's network is an example of how the relatively low cost and quick deployment times of wireless allow small communities to sidestep costly installations from telecom companies who have yet to provide infrastructure in their area. Wireless networks can be locally run to suit the needs of the community and potentially bring profits to local providers rather than to large telecom companies.

Community Wireless in Austin

Although Austin does not face many challenges of its rural suburbs, the city still uses wireless for cost-saving Internet access.

According to Ana Sisnett, executive director of Austin's community network, Austin Free-Net (AFN), many people who need free Internet access don't own laptops, and therefore cannot take advantage of access that relies on personal portable devices.[167] AFN seeks indirect ways to bring wireless access to underserved communities.

As discussed in the "Hotspots" chapter of this report, the Austin Public Library is deploying WiFi access to various branches around the city. As a library's current desktop workstations reach capacity, wireless access could permit more flexible equipment use. Stephanie Neely, managing librarian at the Little Walnut Creek branch, does not have wireless access at her branch yet, but she has already envisioned several uses for the technology.[168] GED and ESL classes with wireless laptops could sidestep space constraints and move into the building's auditorium. "I think laptops open up interesting possibilities for more flexible seating arrangements for students and different ways of positioning instructors," Neely said.

Another possibility is to make laptops available for patron use inside the building. But securing funding for the laptops and additional equipment is a challenge.

Wireless can also help facilitate home Internet access for those not in broadband service areas and those who cannot afford access at all. In Texas, many community networks have begun a laptop checkout program; even if wireless access is not yet available, residents can use the equipment from the privacy of their homes. WiFi can assure high-speed connections for these users. A community like Prairie Lea, a small rural town on the outskirts of the Austin MSA, could take advantage of something like this. Currently citizens can borrow laptops through their community network, but access is limited to dial-up service.

Austin Free-Net

AFN provides 40 public access points throughout the city, in addition to digital literacy classes and technology work with nonprofits. AFN's most ambitious wireless

project involves several branches of the Austin Public Library. AFN funds access to the libraries, which in turn provide hotspot access to patrons. By going through AFN, the library system bypasses city government bureaucracy and offers online access almost immediately.[169]

Internet access is essential to nonprofit organizations, which can benefit from fast and relatively inexpensive wireless networks. To meet these needs, AFN began Fix-Net, which provides low-cost network and equipment installation, training, technical support, and consulting for nonprofits. Sisnett said these services aim to close the "organizational divide" hampering nonprofits that cannot effectively take advantage of technology. Depending on the location and the organization's needs, Fix-Net staff recommend wired or wireless networks, and advise organizations on the related technical standards. Since May 2003 Fix-Net has deployed two wireless networks to nonprofit organizations.

Austin Wireless City

At the heart of the grassroots WiFi movement in Austin is the Austin Wireless City (AWC) project, a nonprofit organization providing equipment and software expertise to venues wishing to offer free public wireless access. The idea is based on the pervasive wireless access models already seen in many US cities.

Richard MacKinnon, founder of AWC, compares the organization's goals with those of the "Web-raising" movement of the 1990s. This was inspired by barn raisings in rural America, where volunteers cooperated with a common goal.[170] In this case the goal is to deploy free wireless access. Current venues on the AWC network include coffee houses, restaurants/bars, bakeries, and bookstores. In order to invite innovation, the only criteria for the inclusion of a public venue on the network is that it offers access free of charge, so hotspots offering free access may appear in any number of contexts.

Since the organization formed in October 2002, AWC volunteers have started the AWC hotspot "recipe" by evaluating hardware and software options. As of November 2003, AWC volunteers have deployed 13 hotspots based on the set specifications, and 59 more venues are interested in receiving wireless access.[171] Volunteers also help take care of deployed access points. In the first two months of operation, the number of users registered to use AWC's hotspots grew from 150 to around 900.

Users of an AWC hotspot log in using open-source software provided by Less Networks, a start-up company also run by MacKinnon. A user accessing an AWC hotspot is greeted with a log-in screen branded with the name and logo of the venue. Once logged in, users can access network chat rooms, bulletin boards, and user profiles. Eventually, users will see advertising targeted to their location. MacKinnon emphasizes that the portal and community features differentiate AWC hotspots from the social isolation of commercial hotspots.

Just as the AWC log-in software is open-source, MacKinnon wants to keep the organization's hotspot recipe open for other cities to duplicate and adapt. Process

and documentation are important to this potential blueprint. For now, the focus of the organization is recruiting, retaining, and training volunteers, and documenting the process. AWC's 20 volunteers include "walkers," people who evaluate potential venues and do site surveys; "hotspotters," who install the access point; and the caretakers who monitor connections.

AWC does not charge venues for hotspot deployment and provides some equipment at no cost; venues pay ISP connection fees. In the future, AWC would like to strike deals with local ISPs and offer cheaper rates as part of their deployment package. To reduce equipment costs, the organization has teamed with Image Microsystems, a computer recycler, which has offered to donate computer hardware. The company is based in California but has an office and recycling facility in Austin.

The donation agreement has brought major progress for AWC. The first Image Microsystems shipment provided servers for 13 hotspots. Although the machines are a little outdated for commercial users, they still meet the minimum requirement for a hotspot server. Furthermore, MacKinnon believes that the environmental conservation efforts put forth by AWC will give their hotspots additional leverage, in contrast to commercial carriers using completely new equipment.

The company has shown great interest in supporting the cause of a free wireless Austin. In the upcoming year, MacKinnon plans to travel to other cities with active wireless groups to present the accomplishments of AWC and to introduce the organization's model in hopes of potential expansion.

A Quick Look at Austin's Peers

Boston

With almost half of Massachusetts' population located in the greater Boston area, the region is the economic keystone of the state. Financial services are the top industry cluster in the area, with software and communication services close behind.[172] In 2001 Massachusetts spent over $5 million in R&D spending for software and communication services and almost $3.5 million for computer and communications hardware.[173] No specific data on the wireless industry could be located.

Over half the state's colleges and universities are in the Boston area. The obvious technological leader is the Massachusetts Institute of Technology (MIT). MIT graduates create approximately 150 companies per year related to the school.[174] The workforce reflects the talent from MIT as well as workers relocating to the region.

Nationwide, Massachusetts ranks first in software engineer workforce and electrical engineers, third in computer hardware engineers, and fifth in computer programmers.[175] However, the city is graying: From 1990 to 2000 Boston experienced an 18.5% decrease in its population aged 18-24, while also seeing an increase in adults aged 45-59.[176] This suggests problems with attracting and retaining talent, as well as possible future gaps in the workforce as older workers retire.

Dallas

Within Texas, the Dallas/Fort-Worth Metropolitan Statistical Area leads in technology and wireless development. The region claims half the state's workforce, including 230,000 technology workers—thus the nickname "Silicon Prairie."[177] Texas Instruments remains an innovator in chip design, including RFID tags.[178] Alcatel Network Systems is another Dallas native, and corporate giants such as Motorola, SBC Mobile Systems, Lucent Technologies, Ericsson, and Nokia have offices in the city.

The Dallas MSA has well-established infrastructure for technology companies located just north of Dallas in Richardson's "Telecom Corridor." The area hosts 70,000 high tech workers and has 250 million square feet of office space.[179]

Unlike most other cities dependent on knowledge-based jobs, Dallas lacks a well-established research university. The city relies instead on its ability to attract young talent from elsewhere.[180] To produce qualified locally trained engineers, Ericsson is aiding the University of Texas at Dallas in developing a curriculum in wireless telecommunications in the school's Department of Computer Science and Electrical Engineering.[181] In addition, the Greater Dallas Chamber of Commerce's Technology Business Council is targeting wireless as a key emerging industry for the region.

San Diego

Silicon Valley earned fame for its role in the Internet and personal computer revolution, and now San Diego is attracting equivalent buzz for wireless.

The roots of the city's wireless industry lie in defense research and the 1968 formation of Linkabit, the brainchild of two University of California San Diego professors.[182] Linkabit spawned numerous spinoff companies, including Qualcomm, and served as a focal point for wireless employment.

San Diego claims 200 wireless firms, which employ over 15,000 workers.[183] Though other cities may surpass the region in number of wireless firms, San Diego has the most concentrated population of wireless employees coupled with the largest growth.[184] Since 1993 wireless employment has skyrocketed 257%.[185] Qualcomm, spearhead of CDMA technology, anchors the industry, with Nokia, Samsung, and Ericsson maintaining significant facilities in the area.[186] Despite the presence of these corporations, 80% of the area's wireless companies have fewer than 50 employees, a statistic similar to Austin.[187] The majority of the region's wireless workforce consists of engineers, technicians, salespersons, and skilled assembly workers as well as high concentrations of workers with CDMA and RF chip expertise.[188]

San Diego has the educational and professional support system to feed their wireless industry. The California Institute of Telecommunication and Information Technology and the University of California at San Diego Center for Wireless Communication give students specific expertise in the industry. The San Diego Regional Technology Alliance and the San Diego Telecom Council (SDTC) serve as information clearing houses and professional focal points for technology and wireless companies. To cater specifically to the wireless sector, SDTC hosts 11 different special interest groups for

wireless members, ranging from Bluetooth, sensors, and CDMA to fixed wireless and satellite.[189] Marco Thompson, president of SDTC, describes the culture:[190]

San Diego still has a small-town business community flavor with respect to the wireless business, to the point where competitors attend events, speak on the same panels and talk openly about their plans, products, financing. That flavor in San Diego is unique.

San Francisco Bay Area/Silicon Valley

Given the region's role in the Internet and personal computer industries, it is natural that Silicon Valley hosts a significant wireless industry. Six hundred wireless companies reside in the region, employing over 25,000.[191] Sun hardware and Java-based software, Cisco's LAN technologies, and Intel's Centrino chip are a few examples of wireless products originating from Silicon Valley companies. For professional support, the Valley's wireless companies networking, educate, and exchange information through the Wireless Communications Alliance.[192]

In addition to numerous well-known research universities, the region offers two explicitly wireless university programs, the Stanford University Wireless Communication Research Group and University of California at Berkeley Wireless Research Center.[193]

Seattle

Best known as the home of Boeing and Microsoft, Washington state claims 138,000 information technology employees and over 10,000 related businesses.[194] According to the WSA, Washington's technology trade association, around 50 of these companies are wireless.[195] The Seattle area hosts T-Mobile and AT&T Wireless—and even Boeing is dabbling in wireless.[196] The region also boasts high crossover between high technology and complementary industries: biotechnology (because of established health research facilities in the Puget Sound area) and digital gaming (due to the presence of Sierra Entertainment and Nintendo). Both sectors have powerful potential relationships with wireless technology.

Reflecting the number of wireless companies in the state, several institutions of higher learning have programs for wireless communications. The University of Washington, with its top engineering and computer science programs, offers a wireless communications technology certification at its Bellevue campus.[197] Seattle Central Community College offers an applied science degree in wireless telecommunications, preparing students for jobs in wireless networking and customer services or as technicians.[198]

Outside Seattle, Washington State University's Electrical Engineering department in Pullman offers an emphasis in Radio Frequency and Wireless Communications and collaborates with wireless companies through its Radiowave Communication Consortium.[199]

SECTION 5—AUSTIN'S WIRELESS FUTURE: NEXT STEPS

Our recommended next steps for Austin and its wireless industry emerge from a vision of a mobile networked society where access to wireless broadband will be—must be—pervasive. We believe that wireless advances will focus on innovative content (digital media), devices, and services. The access provider model will evolve to emphasize value-added services to ensure profits, whereas basic access will be priced as a commodity, and will often be available free in public places.

The immense economic and social potential inherent in mobile wireless data communication notwithstanding, the industry overall still faces significant challenges:

- Business models for emerging wireless companies are unclear.
- Immature industry standards result in solutions that are not quite ready for the mass market.
- Security of wireless systems is not yet sufficiently robust for broad adoption by business users.
- Some industry observers see wireless as a potential source of the next "bubble."

These are legitimate, immediate concerns for the wireless industry as a whole; resolving them does not put the region at a specific competitive disadvantage within the industry. However, enthusiasm for the industry must be tempered by a consideration of these challenges. On the other hand, their existence, while daunting, may also point to new business opportunities, e.g. in standards integration and the development of security strategies.

One wireless content developer used a frontier metaphor for his business: it's like being in the Wild West, unsettled but filled with opportunities for those who persevere.

We conclude our study with these recommendations for Austin's wireless industry and other stakeholders, based on our conclusions about the efforts needed to build and sustain a wireless cluster which will be a significant contributor to Austin's economic future.

Build a Better Network

First, there is a need for cohesion within the local wireless industry. The success of our meetings with stakeholders through summer and fall 2003 suggested that wireless industry professionals were eager to participate in such networking events. Attendance grew from 30 people to around 70 enthusiastic participants. Other organizations have emerged to contribute to industry cohesion. The Austin Wireless Alliance (AWA) was formed in October 2003 by local companies in partnership with the Wireless Networking and Communications Group and IC2 Institute at the University of Texas, the Austin Chamber of Commerce, and the Austin Technology Council to provide a forum for the local wireless industry. At the same time,

community wireless activists formed Austin Wireless City, a nonprofit organization dedicated to the proliferation and support of free public wireless access points in venues throughout Austin. The stakeholder meetings also drew technology representatives from city and state government.

Support Entrepreneurs and Growth of Local Business

This report is but a first step in a necessary ongoing process of identifying industry requirements and building structures for its support. Our survey and stakeholder meetings show a significant number of entrepreneurial startups. This caught the attention of IC2's Austin Technology Incubator, which as a result is taking a closer look at the wireless sector and prospects for incubation. We also recommend that the AWA and its partner, the Austin Technology Council survey business needs in more detail and work with the City of Austin, the University of Texas, Austin Community College, Capital Area Training Foundation, the local semiconductor industry and other interested groups and institutions to determine how those needs may be met, and what incentives may be create for business development in, and relocation to, Austin.

Capitalize on Austin's Recognized Strengths in Semiconductors, Software, and Digital Media

Will the effort to encourage the investment of resources in the promotion and development of the wireless sector create unwanted conflict with other Austin technology sub-sectors? This doesn't appear to be the case. In fact, the growth of the wireless industry may enable growth within other sectors, e.g. semiconductors required for wireless hardware, digital media and software required for wireless devices. The synergy seems evident; the semiconductor, software, and digital gaming sectors in Austin are critical resources for local wireless companies, and Austin's already strong position in these three sectors is a key to Austin's potential as a wireless hub. The IC² Institute will follow up, specifically in the area of digital media convergence with wireless technology, during the Wireless Future Conference in March 2004. In conversations with Metrowerks, which produces development tools for creating wireless applications, IC² identified a need to disseminate information about application and digital media development practices and tools for 2.5G and 3G environments, which will be covered by the conference and in other workshops thereafter. Representatives of Austin's key technology verticals should pursue similar knowledge sharing and development activities, as well. It is also important to open channels of communication with local manufacturers of semiconductors and other essential hardware.

Maintain and Grow Austin's Most Important Asset—People

The wireless companies need to work more closely with local professional education institutions, such as the Capital Area Training Foundation (CATF) and Austin Community College (ACC), to train qualified technical and professional workforce. Wireless Networking and Communications Group will be a source of exceptionally strong undergraduate and graduate wireless talent, as well as research and development activities. However, Austin area educational institutions still need to develop two-year degree programs and vocational programs for wireless technology. The city government of Austin should work with the University of Texas, the Capital

Area Training Foundation, Capital IDEA, the workforce development staff of Austin Community College, and wireless companies to ensure that these institutions can train students in the skills the wireless industry needs

The city should support, as a public service, pervasive availability of broadband wireless access (possibly through its own network) in underserved areas and in zones where pervasive wireless will help economic development. We feel that this ensures pervasive access, which is essential infrastructure for wireless innovation.

Demonstrate Austin's Wireless Savvy

Austin is a forward-looking city open to innovation, and as such can host new products and product innovations in a citywide wireless quilt, and evaluate and improve upon them before national and global distribution. Smaller companies that work to increase the productivity and usage of wireless networks will locate in Austin for the opportunity to be a part of the pre-mass distribution of wireless hardware and software.

Austin is therefore a perfect test market for new wireless technologies. The city is relatively small. It already has very good infrastructure. The residents have a higher income level, and are more high-tech and network oriented. The test market image can be a good promotional point for Austin's wireless industry, which should approach the leadership of wireless industry associations, like CTIA, Wi-Fi Alliance and WiMAX Forum, and build the substantive business case for Austin suitability for market trials. This is a proven developmental strategy. For instance, Seoul, Korea is a test market for WiMAX technology trials, because the wireless business community (and local government) promoted itself to these associations. They've also set-up a support network of local public/private sector groups to actively enable this process.

Improve Visibility

Austin's wireless companies need to develop outreach to local, national, and global audiences: Austin is The Wireless City.

The Chamber of Commerce and other pillars of the Austin business community will need an understanding of the social, economic, and cultural impacts of wireless, and an understanding how Austin can become a vital part of the Wireless Future. This will require educational efforts by Austin's wireless companies and proponents. All parts of Austin's economy will benefit from the success of the wireless sector, and if Austin is to be perceived as a wireless city, it is important to have broad understanding and buy-in.

A number of Wireless Future stakeholders commented on the general lack of understanding of wireless technology, including the business and social opportunities, and the challenges to pursuing those opportunities. Although this problem is not exclusive to Austin, the local industry can work to correct it locally and can make some effort to extend that work globally to ensure an educated consumer base. We see this report as an important early step in establishing that work.

Austin also needs a higher international profile for the enhancement of all industry, not just wireless. However the goal of establishing Austin as a hub within the

wireless industry will contribute significantly to Austin's global visibility. Austin has many of the elements a hub would require: a major University with a significant wireless research program, local availability of raw materials and workforce, highly-developed Internet presence, high degree of cultural creativity, etc. Austin does lack on significant element, a major wireless company of sufficient size and attraction to serve as an anchor for the local industry. Attracting or creating such a company is one of the greatest challenges we face.

APPENDIX A: AUSTIN WIRELESS COMPANY DIRECTORY

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
@ Hand	8501 N. MoPac Expwy. 4th Floor	Austin	78759	www.hand.com	@Hand's Mobile Work Management product line provides software for automating and improving the mobile business process. The company was established in 1998 in Austin.	sales force, monitoring	Corporate HQ
Advanced Micro Devices	5901 E. Ben White Blvd.	Austin	78741	www.amd.com	Advanced Micro Devices (AMD) designs and manufactures integrated circuits, flash memory, and networking products. Although AMD's headquarters are in California, Austin is home to one of the company's production facilities.	semiconductors, WiFi	Corporate Branch Office
Affinegy	1214 W. Sixth Street Suite 209	Austin	78703	www.affinegy.com	Affinegy provides software solutions and consulting services for the broadband and wireless Internet market. The company's solutions let users configure and manage LAN/WAN networks.	WiFi, networking, security	Corporate HQ
Airchalk Wireless	9600 Great Hills Trail, Suite 150W-1555	Austin	78759	www.airchalk.com	AirChalk operates a network that enables wireless service providers to buy and sell branded, secure roaming access. The newly established company is in its funding phase	WiFi, networking	Corporate HQ
Alcatel	9430 Research Blvd.	Austin	78759	www.alcatel.com	Alcatel creates products for a wide range of sub-sectors in the telecommunications industry, including carriers, service providers and enterprises. Alcatel offers a line of GSM/GPRS products and software for wireless carriers. The company is headquartered in France.	WiFi, networking	Corporate Branch Office (with other TX offices)
Alereon Inc.	7600 North Capital of Texas Highway Building C, Suite 200	Austin	78731	www.alereon.com	Headquartered in Austin, Alereon, Inc. is a new fabless semiconductor company focused on developing and deploying UWB chipsets for personal area networking applications that comply with the emerging IEEE standard (802.15.3a).	semiconductors, UWB	Corporate HQ
AnyTime Communications	P.O. Box 866	Cedar Park	78630	www.anytimecommunications.com	Established in 2001, AnyTime Communications offers networking services for both residential and business customers. Services include: connectivity, networking, upgrades and maintenance for wireless, wired broadband and dial-up Internet access.	networking, WiFi	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Applied Materials	9700 E. Hwy. 290	Austin		www.appliedmaterials.com	Headquartered in Santa Clara, CA, Applied Materials Inc. supplies products for use in semiconductor manufacturing. Chips made using Applied Materials' equipment are seen in PCs, PDAs, gaming equipment cellular phones and GPS devices. The company's Austin office works in R&D as well as manufacturing.	semiconductors, WiFi	Corporate Branch Office
Artemis Wireless Werks	#126 6001 W. Parmer Ln. Suite 370	Austin	78727	www.artemiswerks.com	Artemis Wireless Werks provides software solutions, training, marketing and technical writing services for technology companies.	cell, WiFi, Bluetooth, networking	Corporate HQ
AZAR Computer Software Services	1200 Regal Row	Austin	78748	www.azarinc.com	Azar Computer Software Services Inc. provides billing software to the cable and satellite television industry. The Austin based company has been in business since 1979.	satellite	Corporate HQ
Bandspeed	7000 West William Cannon Dr. Suite 2.199	Austin	78735	www.bandspeed.com	Software and antennas from Bandspeed allow access point manufacturers to increase their coverage and capacity. The company also offers a switch-based architecture for WLAN deployment.	WiFi, networking	Corporate HQ
Caci	8329 N. MoPac Expwy.	Austin	78759	www.caci.com	Focusing on government networking infrastructure needs, CACI International Inc.'s solutions are applied to federal electronic government, intelligence and defense programs. The U.S. Department of Defense is CACI's largest customer. The company was established in 1962 and is headquartered in Arlington, VA.	networking, WiFi	Corporate Branch Office
Canyon Semiconductor	3925 W. Braker Ln.	Austin	78735	www.canyonsemiconductor.com	Canyon Semiconductor, located in the Austin Technology Incubator, was formed to address wireless infrastructure applications using wide bandgap semiconductors. The company, formed in 2002, focuses on analog semiconductors in high speed communications markets.	semiconductors, cell, RF	Corporate HQ
Carcomm International	1700 W. Koenig Ln.	Austin	78736	www.carcomm.nl	Headquartered in Netherlands, Carcomm provides car cradles for wireless devices. In addition, Carcomm offers antennas and wireless accessories.	antennas, cell	Corporate Branch Office

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
CAZITech Consulting	10773 Yorktown Trail	Austin	78726	www.CAZITech.com	Clients of CAZITech Consulting can receive business development assistance, strategic planning services and marketing and competitive analyses. CAZITech helps support universal Internet access, open standards and competition in telecommunications.	WiFi, networking,	Corporate HQ
CFX Engineering	2700 Via Fortuna, 2nd Floor	Austin	78746	www.cfxamerica.com	CFX, LP and CFX Construction, LP provide engineering, construction and surveying services. For the wireless industry, CFX provides services for telecommunications infrastructure deployment. CFX was established in 1996.	cellular	Corporate HQ
Cirrus Logic	2901 Via Fortuna	Austin	78746	www.cirrus.com	Established in 1984, Cirrus Logic supplies high-performance analog, digital signal processing and mixed-signal chip solutions for consumer electronics. Cirrus Logic provides WiFi technology to Motorola.	semiconductors, WiFi	US HQ
Cisco Systems Inc.	12515 Research Blvd.	Austin	78759	www.cisco.com	Cisco Systems Inc. provides networking solutions based on the Internet Protocol. Established in 1984, the company has developed advanced routers, switches, and VoIP for use in broadband and wireless networks.	WiFi, networking	Corporate Branch Office
Communication Solutions	5510 North IH-35	Austin	78751	www.rockwellcollins.com/comsol/	Communication Solutions designs and manufactures high performance SIGINT electronic instruments and subsystems using microwave, RF and digital signal processing technologies.	microwave, RF	Corporate Branch Office
Computer and Internet Resources	1915 S. Austin Ave. Suite 108	George-town	78626	http://www.igg-tx.net/wireless.htm	Located in Georgetown, an Austin suburb, Computer and Internet Resources Inc. is an ISP serving Central Texas and the Hill Country. Users can choose from dial-up, ISDN or wireless Internet connectivity for their home or business.	WiFi, networking	Corporate HQ
Connectione	3925 Braker Ln. Suite 324	Austin	78759	www.connectione.com	Connectione provides nationwide multi-carrier wireless and mobility solutions, helping mobile professionals stay connected with their clients and associates. The company was established in 2001.	WiFi, cell, networking	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Constant.com	1106 Clayton Ln.	Austin	78723	www.constant.com	Constant.com provides wireless, DSL, ISDN, T1, Dialup Internet access, web hosting nationwide. NABI Networks, Constant.com's parent company, was one of the first independent ISPs in Austin.	WiFi, networking	Corporate HQ
DBI Plus	802 Siebert Dr.	Kyle	78746	www.dbiplus.com	DBI Plus Inc. serves as the U.S. representative for Poynting Antennas.Antennas sold through the company are used for Bluetooth, military, spectrum monitoring, and LPDA.	antennas, Bluetooth, WiFi, cell	Corporate Branch Office
Dell	One Dell Way	Round Rock	78682	www.dell.com	Headquartered in Round Rock, an Austin suburb, Dell Computer designs and manufactures desktop and notebook computers and peripherals. The company was established in 1984.	WiFi	Corporate HQ
Diarcy Technologies	3804 Tamarack Trail	Austin	78727	www.diarcy.com	Engineering services related to electronics, RF, microwave, and antennas are the specialty of Diarcy Technologies. The native Austin company was established in 1990.	WiFi, RF, antenna, microwave	Corporate HQ
Druma	6633 Highway 290 E. 301	Austin	78723	www.druma.com	Druma Inc. provides custom programming and integration solutions businesses who use HP 200LX Palmtops.	sales force, monitoring	Corporate HQ
ETS Lindgren/EMC Test Systems	1301 Arrow Point Drive	Cedar Park	78613	www.emctest.com	ETS-Lindgren creates components and systems that measure, shield and control electromagnetic energy. The company's products include diagnostic tools and turnkey facilities.	antennas, microwave, RF	US HQ
Fly Technology	108 Wild Basin Road, Suite 120	Austin	78746	www.flytechnology.com	Established in 2000, Fly Technology provides the services layer for wireless technology companies. Specifically, they offer portal software which can be personalized and branded.	networking, WiFi	Corporate HQ
Frog Design	804 Congress Ave.	Austin	78701	www.frogdesign.com	Software user-interface design, e-commerce solutions and electronics design are the services offered by Frog Design. Headquartered in Silicon Valley, Frog was founded in 1969.	WiFi, cell	Corporate Branch Office
Grande Communications	13505 Burnet Rd. 401 Carlson Circle	Austin San Marcos	78727 78666	www.grandecom.com	Grande Communications delivers high-speed Internet, local and long-distance telephone and digital cable television services over its own advanced broadband network to communities in Texas. Headquartered in San Marcos, the company will offer wireless home access in early 2004.	WiFi, networking	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Hewlett Packard	12401 Research Blvd.	Austin	78759	www.hp.com	HP is a technology solutions provider to consumers, businesses and institutions globally.HP's Wireless & Mobility solutions seek to remove obstacles to successful wireless, mobile deployment.	WiFi	Corporate Branch Office (with other Texas offices)
Hillcast Technologies	906 E. 5th St., Suite 210	Austin	78702	www.hillcast.com	HillCast Technologies is an Austin based developer of mobile applications for the financial services industry. Users can receive market data, graphs on their wireless devices via the company's software.	cell, WiFi, Bluetooth	Corporate HQ
IBM		Austin		www.ibm.com	Personal computer pioneer, IBM, creates notebook computers and caters to the wireless workforce through their e-business segment.	WiFi	Corporate Branch Office
iGillott Research	7070 W.Hwy 71, Suite 340 PMB 386	Austin	78735	www.igillottresearch.com	iGillott Research is a market strategy consulting company focused on the wireless and mobile communications industry. Areas of expertise include 2G, 3G, SMS, and mobile commerce.		Corporate HQ
Intag Communications	5104 Jacobs Creek	Austin	78749	www.intag.com	Intag Communications, Inc., designs, installs and services Structured Cabling Systems and WLANs. Intag was established in 1979 and is headquartered in St. Louis.	WiFi, networking	Corporate Branch Office
Integral Signals Processing	P.O. Box 27661	Austin	78755	www.integralsignal.com	Integral Signals Processing makes satellite weather stations.	satellite	Corporate HQ
Intel	1501 N. MoPac Expwy., Suite 400	Austin	78746	www.intel.com	Since 1968, Intel has manufactured computer, networking and communications chips and components. Intel developed the Centrino technology for connecting notebooks to WLANs.	semiconductors, WiFi	Corporate Branch Office
Isochron Data Corp.	110 Wild Basin Rd. Building 1, Suite 320	Austin	78746	www.isochron.com	Isochron Data Corp. provides products for wirelessly monitoring and controlling vendor products and inventory. The company is also developing Bluetooth applications.	sales force, Bluetooth	Corporate HQ
Knockabout Games	701 Brazos St. Suite 700	Austin	78701	www.knockaboutgames.com	Entertainment and gaming software for wireless devices are what Knockabout Games creates. Software designers at Knockabout also offer custom designed applications for mobile devices	cell, games	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Less Networks	P.O Box 4721	Austin	78765	www.lessnetworks.com	Less Networks works with open source software to create access portal to providers of free WiFi access. It's a partner with the Austin Wireless City Project.	WiFi, networking	Corporate HQ
Metrowerks	9801 Metric Blvd.	Austin	78758	www.metrowerks.com	Metrowerks was established in 1985, and in 1999 became a Motorola subsidiary. The company offers development tools and services focusing on popular wireless platforms.	cell, WiFi	Corporate HQ
Motion Computing	9433 Bee Caves Rd. Building 1, Suite 250	Austin	78733	www.motioncomputing.com	Using Windows platform and Intel's Centrino technology, Motion Computing offers made-to-order Tablet PCs and related equipment. The company was established in 2001.	WiFi	Corporate HQ
Motive	12515 Research Blvd. Building 5	Austin	78759	www.motive.com	Founded in 1997, Motive Communications provides technology solutions for ISPs. Motive helps manage "technology ecosystems" so that businesses can take advantages of technology and pass along their savings and success to their own customers.	Motive	12515 Research Blvd. Building 5
Motorola	7700 W. Parmer Ln. (sales & eng.) 3501 Ed Bluestein Blvd. (semicond) 6501 W. William Cannon Dr. (semicond)	Austin	78729 78721 78735	www.motorola.com	Motorola supplies wireless infrastructure equipment such as cellular transmission base stations, amplifiers, and network switching systems. Motorola's semiconductor unit is a leader in embedded chips used in wireless, networking, automotive, and consumer products.	semiconductors, WiFi, satellite, cell	Corporate Branch Office
National Instruments	15000 N. MoPac Expwy.	Austin	78759	www.ni.com	National Instruments was established in 1975 and is headquartered in Austin with more than 3,000 employees and direct operations in 40 countries. National Instruments creates hardware and software to enhance PC's, including measurement and automation software.	RF, cell	Corporate HQ
Netbotz	11044 Research Blvd. Building C, Suite 100	Austin	78759	www.netbotz.com	Netbotz, established in 1999, makes wireless monitoring base stations and accompanying software. Products from Netbotz provide security against human break-ins and physical problems.	monitoring, security, WiFi	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
OTM Engineering	248 Addie Roy Rd. Suite B-200	Austin	78746	www.otmengineering.com	OTM Engineering designs communication projects for numerous local, national, and international companies. Services include network design, wireless, cabling, infrastructure, voice systems.	networking, WiFi	Corporate HQ
Qwest Communications	8303 N. MoPac Expwy	Austin	78759	www.qwest.com	Quest provides voice, video and data services through broadband, wireless, and cellular networks for residential and businesses. Quest focuses on networking, WiFi, cellular technologies. The company is headquartered in Colorado.	networking, cell, WiFi	Corporate Branch Office
Raak Technologies	608 E. 42nd St.	Austin	78751	www.raaktechnologies.com	Network security for LANs and WLANs is the goal of Raak technologies. Raak's Wireless LAN security solution combines smart cards with an integrated client application.	security, WiFi, networking	Corporate HQ
RasTrac	13706 Research Blvd., Suite 211	Austin	78750	www.navcomp.com	Manning NavComp is an application developer of vehicle tracking solutions. Its RASTRAC software helps tracking commercial vehicles over commercial radio, cellular telephone, Cellular Digital Packet Data or satellite communications.	GPS, sales force, cell	Corporate HQ
Raven Industries	500 Center Ridge Dr. #600	Austin	78753	www.ranvenind.com	Raven Industries provides electronics, reinforced plastic, and flow control devices. Raven also designs and manufactures antennas for nearly all GPS needs and applications.	GPS, satellite	Corporate Branch Office
Reunion Wireless	3800 Country Rd. 268	Leander	78641	www.reunionwireless.com		WiFi, networking	Corporate HQ
Rich Finney & Associates	104 Crest View Drive	Lakeway	78734	www.richfinney.com	Rich Finney & Associates focuses on network design and engineering services. They also focus on technology assessments and Internet service in the underserved communities, including the Lockhart Community Network.	WiFi, networking	Corporate HQ
Rocksteady Networks	3410 Fair West Blvd., Suite 210	Austin	78731	www.rocksteady.com	Rocksteady Networks, Inc. provides software solutions that deliver security and premium broadband services to users at the edge of the network. Rocksteady Networks is a founding member of the Austin Wireless Alliance.	networking, security, WiFi	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
SBC Laboratories	9505 Arboretum Blvd.	Austin	78759	www.labs.sbc.com	SBC Laboratories is the R&D subsidiary for SBC Communications Inc. SBC Labs develops solutions for markets, technology, and security through hardware and software working with WiFi, networking, and fixed wireless.	WiFi, networking, fixed wireless	Corporate Branch Office
Schlumberger-Sema	8311 Ranch Road 620 N	Austin	78726	www.slb.com	SchlumbergerSema is the Information Technology (IT) business segment of Schlumberger Limited and located in Austin. SchlumbergerSema supplies IT consulting, systems integration, and network and infrastructure services, including WLAN networking, to the energy industry, as well as to the public sector, telecommunications and finance markets.	cell, security, WiFi, networking	Corporate Branch Office
Sematech	2706 Montopolis Dr.	Austin	78741	www.sematech.com	Sematech is an international R&D consortium that focuses on semiconductors and is headquartered in Austin. Members cooperatively develop solutions to critical industry challenges outlined in the International Technology Roadmap for Semiconductors (ITRS).	semiconductors	Corporate HQ
Sierra Microwave Technology	1 Sierra Way	George-town	78626	www.sierramicrowave.com	Founded in 1985, Sierra Microwave Technology produces high reliable parts for the military and space industries. The company is headquartered in Georgetown, an Austin suburb.	microwave	Corporate HQ
Sigma Tel	3815 S. Capital of Texas Hwy., Suite 300	Austin	78704	www.sigmatel.com	SigmaTel, Inc. a semiconductor company headquartered in Austin. SigmaTel designs, develops, and markets proprietary, analog intensive, mixed-signal ICs for a variety of products in the consumer electronics and computing markets, including MP3 players, notebook and desktop PCs, DVD players, and digital televisions.	semiconductors	Corporate HQ
Silicon Laboratories	7000 W. William Cannon Dr. Building 1& 2	Austin	78735	www.silabs.com	Established in 1996, Silicon Laboratories designs and integrated circuits. For the wireless industry, the company produces single chip RF synthesizers, cellular handset transreceivers, integrated circuits, and other wireless equipment.	semiconductors, RF, cell	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
SoloMio	1011 San Jacinto Blvd., 5th Floor	Austin	78701	www.solomio.com	Spun off from Vignette in 2000, SoloMio Corporation is a global telecom software company. Specifically, the company creates call management software for the cellular industry.	cell	Corporate HQ
Sony Online Entertainment	11940 Jollyville Rd.	Austin	78759	www.sonyonline.com	Sony Online Entertainment Inc. is located in San Diego and has development studios in Austin. The company's wireless products include role-playing games for cellular phones, and wireless versions of their popular console games.	games	Corporate Branch Office
Starlink Inc.	500 Center Ridge Dr., Suite 600	Austin	78753	www.starlinkdgps.com	Starlink Inc. provides engineering services and products focusing on electronics and radionavigation, particularly GPS tracking systems. The company was established in 1993 and is part of Raven Industries.	RF, GPS	Corporate HQ
Survivor Soft	5109 McIntyre Cir.	Austin	78734	www.survivorsoft.com	Survivor Soft creates games for use on cellular phones. The Austin-based company is a development studio making use of the Java 2 Micro Edition platform.	games, cell	Corporate HQ
TDK RF Solutions	1101 Cypress Creek Rd.	Cedar Park	78613	www.tdkrfsolutions.com	TDK RF Solutions Inc. creates automated test systems, software, antennas for use in electromagnetic compatibility test applications. TDK RF designs and manufactures its products. The company is headquartered in Cedar Park.	RF, antenna	US wireless HQ
Team Smarty Pants	1705 Guadalupe St.	Austin	78701	www.teamsmarty.com	Team Smarty Pants! Inc., established in 1994, creates digital media and game content for mobile devices. The company is currently working on an entertainment and communication platform bridging portable and deskbound devices.	games, cell	Corporate HQ
TechWorks/Buffalo Technology	4030 W. Braker Lane #120	Austin	78759	www.techworks.com www.buffalotech.com	TechWorks/Buffalo Technology (USA) Inc., subsidiaries of Japan's MELCO Group, develops and manufactures computer memory, storage and networking products. Buffalo's AirStation line for WLAN deployment features routers, bridges, antennas, converters and access points.	antennas, WiFi	Corporate HQ
Telcordia Technologies	106 E. Sixth St. Littlefield Building #415	Austin	78701	www.telcordia.com	Telcordia Technologies is a provider of telecommunications software and services for IP, wireline, wireless, WiFi, and cable networks. The company is headquartered in New Jersey and is a subsidiary of SAIC.	networking, WiFi	Corporate Branch Office

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Tengo Internet	?????	Austin	????	www.tengointernet.com	Austin-based WISP TengoInternet Inc. deploys hotspots creating “TengoZones” at hotels and camping/ recreation vehicle sites. Established in 2001, Tengo’s network reaches 25 cities throughout Texas, New Mexico, Arizona, Nevada, California and Florida.	WiFi, networking	Corporate HQ
Teravicta Technologies	2535 Brockton Dr., Suite 500	Austin	78758	www.teravicta.com	For over two years, Teravicta Technologies has manufactured and designed RF switches and relay products. Products from the company are used in WLANs, cellular base stations, RADAR, and satellite with specific uses in both industrial and military contexts. Teravicta’s manufacturing and development processes, including packaging and testing, occur in Austin.	RF, WiFi, satellite, cell	Corporate HQ
Time Warner	12012 N. MoPac Expwy	Austin	78758	www.timewarneraustin.com	Time Warner Cable of Austin is a cable operator and ISP offering Roadrunner, AOL Broadband, and wireless services.	networking, cell	Corporate HQ
T-Manage	2111 W. Braker Lane	Austin	78758	www.tmanage.com	Recognizing increasing trends toward mobile and dispersed corporate structures, TManage offers solutions to connect disparate employees and offices to centralized corporate hubs. The company was established in 1988 and was recently acquired by California-based MegaPath Networks.	security, networking	Corporate HQ
Tokyo Electron, Texas	2500 Montopolis	Austin	78741	www.telusa.com	Tokyo Electron was established in 1963 and has its United States headquarters and research and development office in Austin. Tokyo Electron was the first company to introduce American semiconductor production equipment and integrated circuit (IC) testers to Japan.	semiconductors	US HQ
Traq Wireless	8300 N. MoPac Expwy, Suite 310	Austin	78759	www.traq.com	Traq-Wireless brings wireless management solutions to businesses relying on cellular phones, PDAs and other mobile communication devices. Currently the company is working with clients to take advantage of wireless local number portability. Traq was established in 1999.	cell	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Triact Associates Inc.	11121 Calavar Drive	Austin	78726	www.triactassociates.com	Triact Associates Inc. provides wireless networking services to businesses. Specifically, the company does site surveys, web and wireless enablement, remote network management, deployment of wireless bridges, project management, and technology consultation.	networking, WiFi	Corporate HQ
Trillion Partners	9802 Waterford Centre Blvd., Suite 150	Austin	78750	www.trillionpartners.com	Trillion Partners help bridge the last mile broadband gap by bringing connectivity to schools, government offices, medical facilities, and institutes of higher education. Trillion currently serves over 750 schools and works with the federal E-Rate Program.	networking, WiFi, 80	Corporate HQ
Trimble Navigation	2105 Donley Dr.	Austin	78758	www.trimble.com	Trimble Navigation provides GPS software and equipment, along with laser and optical technology. Applications of the company's technology are seen in asset tracking, vehicle navigation, machine guidance, and mapping. Established in 1978, the company has its headquarters in California.	GPS, software	Corporate Branch Office
Tstar Internet	PO Box 667	Marble Falls	78646	www.tstar.net	TSTAR Internet is headquartered in Marble Falls, TX, within the Austin MSA. TSTAR installs and provides wireless services via Ethernet connections and wire-based ISDN, including WiFi technology.	WiFi, networking	Corporate HQ
Tuanis Technology	815A Brazos St. Ste. 210	Austin	78701	www.tuanistechnology.com	Combining business and technical expertise is the strength of consulting firm, Tuanis Technology. The company specializes in Microwave Data Networking (MDN) utilizing unlicensed spectrum and is an equipment reseller. Tuanis was established in 2001.	WiFi, networking	Corporate HQ
Uplink Corporation	9508 Jollyville Rd. Suite 200	Austin	78759	www.uplinkgolf.com	UpLink brings the convenience of GPS technology to the golf industry. Courses using UpLink's Golf Course Management System can track golf carts, and measure distances on greens, with the aid of colorful display units installed on each cart.	GPS	Corporate HQ
Vytek	One Congress Plaza, 4th floor	Austin	78701	www.vytek.com	Vytek solutions include infrastructure creation, including wireless infrastructure, applications and connection equipment for messaging, broadband, telemetry, paging, networking, and monitoring. Vytek's headquarters are in San Diego.	networking, monitoring, RF, WiFi	Corporate Branch Office

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
Wayport	8303 N. MoPac Expwy, Suite A-300	Austin	78759	www.wayport.com	Hotspot access for business travelers is the primary goal of Wayport's Wi-Fi network. Located in over 700 hotels and six airports nationwide, the company's wireless networks gives travelers and mobile workers a quality and consistent Wi-Fi access experience. Wayport was established in 1996.	WiFi, networking	Corporate HQ
WiFi Alliance	N/A	Austin		www.wifialliance.org	Wi-Fi Alliance is a non-profit trade association with the goal of setting industry standards for WLAN interoperability. Since the alliance formed in 1999, over 200 companies, including leaders in the personal computer industry, have joined the alliance. Over 915 wireless products are currently certified.	WiFi, networking	Corporate HQ
WiFiTexas.com Inc.	815-A Brazos #326	Austin	78701	www.wifi-texas.com	"Amenity networks, " or commercial grade broadband networks in public spaces, are the output of Wi-Fi Texas.com. The company has deployed hotspots in RV parks, apartment/ condominium complexes, restaurants, and special events.	WiFi, networking	Corporate HQ
Wintegra	7200 N. MoPac Expwy, Suite 270	Austin	78731	www.wintegra.com	Wintegra was founded in 2000 and has its corporate headquarters in Austin. Wintegra, Inc. is a semiconductor company that enables communications infrastructure equipment providers to upgrade their product lines toward the next generation of access networks with single chip solutions. Applications for their chips include wireless technology and capabilities.	semiconductors, WiFi	Corporate HQ
Wireless Computing	14101 W Highway 290, Building 700	Austin	78737	www.wireless-computing.com	Using RF technology, Wireless Computing Inc. creates computer peripherals that free users from the burden of cords and wires. Products include wireless keyboards, wireless mice, and a wireless presentation remote.	RF	Corporate HQ
Wireless Valley	2404 Rutland Dr., Suite 700	Austin	78758	www.wirelessvalley.com	Wireless Valley provides software and measurement solutions for use in wireless network management. Wireless Valley provides software and measurement solutions for use in wireless network management. The company moved in Austin in 2002.	networking, cell, Bluetooth	Corporate HQ

Company	Address	City	Zip	Web site	Line of business	Technology	Office type
WISP Gear	1202 FM 685 Suite C5	Pfluger-ville	78660	www.wispgear.com	WISP Gear Inc. provides WISPs, businesses and hospitality sites with the hardware, software and expertise needed to deploy wireless networks. The present-day company was established in 2002 after the reorganization of CCMF Wireless and CCMF Computers. WISP Gear is headquartered in Pflugerville, an Austin suburb.	WiFi, RF, networking	Corporate Branch Office
Wi-Speed Communications	1506 North Street Suite 400	Austin	78756	www.wi-speed.com	Wi-Speed Communications offers an alternative to teleco Internet connectivity by bringing fixed wireless to Central Texas. Earlier this year, Wi-Speed introduced its services to Austin by offering services to business that otherwise would have no feasible way to receive broadband connectivity.	WiFi, networking	Corporate HQ
Xilinx	500 N. Capital of Texas Hwy. Building #3	Austin	78746	www.xilinx.com	Xilinx was established in 1984 and is headquartered in San Jose, with a corporate sales office in Austin and a partnership with IBM. Xilinx is a semiconductor company that also produces software design tools, including software design tools for wireless applications	semiconductors	Corporate Sales Office
Zeecon Wireless Internet	3415 North Us Hwy 281	Marble Falls	78654	www.zeecon.com	Zeecon Wireless Internet L.L.C provides wireless broadband access to the Texas Hill Country. Zeecon connects Internet users to their fiber optic lines via wireless technology.	WiFi, networking	Corporate HQ

APPENDIX B: LOCAL VENTURE CAPITAL

Company	Strategic focus	Investment in wireless	Remarks	Types of Companies Invested in wireless	Typical Investment in Wireless	Offices
Access Venture Partners		3 companies	seed and early stage; investment between $250,000 and $2,000,000	ASP, Radio Frequency IC, Microwave radio solutions	RFMD	Silicon Valley, Denver, Austin
G-51 Capital Management	software, hardware, and business services	1 company	Gap Keeper in early stage. Gap between early stage private and institution investment; gap of funding in syndication investment	Tablet PC	Motion Computing	Austin
Hunt Ventures, LP	info tech and life science	2 companies	early stage		Airspan, Antenna Software	Dallas, Austin
Trellis Partners	networking, telecom, application software	1 company	early stage	WiFi	Wayport	Austin
Murphree Venture Partners	Internet infrastructure, software, life science, telecom, optical/semi-conductors, energy	1 company (others not shown on website)	seed and early stage technology co.	business applications & networking	BT	Austin, Houston, Albuquerque, Colorado Springs, Boulder
Sentient Ventures	information tech, life sciences, intellectual property commercialization	No direct investments	Texas early stage companies. No wireless yet, but invests in Murphee Venture Partners, Austin Technology Incubator, Emergent Technologies	N/A	N/A	Austin, San Antonio, Dallas
Eyes of Texas Partners	Computing tech, wireless, Internet & enterprise applications, telecom, semi-conductors, energy, life science	1+ company	Texas early stage companies.	supply chain management		Austin
Gefinor Ventures	Software, Wireless Communications, Nano and MEMS, Internet/services	1 company	asset management, private equity investment, and real estate; Early stage; Colorado and Texas	Wireless infrastructure software	Idetic	Austin, New York, Colorado

Company	Strategic focus	Investment in wireless	Remarks	Types of Companies Invested in wireless	Typical Investment in Wireless	Offices
JatoTech Ventures	networking, wireless, semiconductor	2 companies	early stage, be the first investor, service-oriented, more attention to limited portfolio companies, $0.5 to 3 m initially, $5 to 8 m over life	Wi-Fi solutions, wireless processor and software	Bandspeed, Ubicom	Austin
Techxas Ventures	software, communications, electronics, semiconductor, life science and molecular science driven IT	2 companies	early stage, $100k to $3m in one round, $1m to $8m in a company, Texas only	Wireless software, services,	BroadJump, SoloMio	Austin
Triton Ventures	business software, B2B online companies, communications technology, technology-enabled services.	2 companies	Especially interested in spin-out opportunities.	supply chain management, software for handheld	ClearOrbit, Gallerywatch.com	Austin
Verity Ventures	business applications, data/telecommunications enterprise soft-ware, infrastructure enablers	3 companies	For early-stage Texas technology companies, with emphasis on Dallas and Austin.	supply chain management, infrastructure software, remote monitoring.	Motive, Chordus, Netbotz	Austin
First Capital Group of Texas	communications/ electronics technology, media products, manufacturing	4+ companies	For early-stage, expansion stage, and management buyouts in the Southwest.	security monitoring, semi-conductors, infrastructure.	Certicom Security, CCI Telecom, Mimix Broadband, Shockwatch	Austin, San Antonio, Dallas
Adams Capital Management	Information tech, supply chain software, telecommunication, semiconductor	1 company	emerging growth companies, market-centric, driven by economics	wireless infrastructure,	AirNet Communications,	Austin, Boston, Palo Alto, Pittsburgh
Koch Ventures	IT services, Nanotech, enterprise software, communications	1 company	early stage companies in Texas and Southwest	Mobile operator solution	SoloMio	Dallas

APPENDIX C: IEEE WIRELESS STANDARDS

The Institute of Electrical and Electronics Engineers (www.ieee.org) leads the way in developing open, innovative standards for Wireless Local Area Networks (Wireless LANs), Wireless Personal Area Networks (Wireless PANs), and Wireless Metropolitan Area Networks (Wireless MANs). IEEE Wireless standards development covers the following areas critical to industry today.

802.11™ Working Group for Wireless Local Area Networks

The IEEE 802.11 specifications are wireless standards that specify an over-the-air interface between a wireless client and a base station or access point, as well as among wireless clients. The 802.11 standards can be compared to the IEEE 802.3™ standard for Ethernet for wired LANs. The IEEE 802.11 specifications address both the Physical (PHY) and Media Access Control (MAC) layers and are tailored to resolve compatibility issues between manufacturers of Wireless LAN equipment.

802.15™ Working Group for Wireless Personal Area Networks

The IEEE 802.15 Working Group provides, in the IEEE 802 family, standards for low-complexity and low-power consumption wireless connectivity.

Today, there are currently four IEEE 802.15 standards projects (including one with two variants) in development:

- IEEE Std 802.15.1™-2002—1Mb/s WPAN/Bluetooth v1.x derivative work
- P802.15.2™—Recommended Practice for Coexistence in Unlicensed Bands
- P802.15.3™—20+ Mb/s High Rate WPAN for Multimedia and Digital Imaging
- P802.15.3a™—110+ Mb/s Higher Rate Alternative PHY for 802.15.3
- P802.15.4™—200 kb/s max for interactive toys, sensor and automation

802.16™ Working Group for Broadband Wireless Access Standards

IEEE 802.16 specifications support the development of fixed broadband wireless access systems to enable rapid worldwide deployment of innovative, cost-effective and interoperable multi-vendor broadband wireless access products.

P1451.5™ Working Group for Wireless Sensor Standards

Many companies are developing various wireless communication interfaces and protocols for sensors. An openly defined wireless transducer communication standard, that can accommodate various existing wireless technologies, will reduce risk for users, transducer manufacturers, and system integrators. It will enhance the acceptance of the wireless technology for transducers connectivity.

The standard will define Transducer Electronic Data Sheets (TEDS) based on the IEEE 1451™ concept, and protocols to access TEDS and transducer data. It will adopt necessary wireless interfaces and protocols to facilitate the use of technically differentiated, existing wireless technology solutions. It will not specify transducer design, signal conditioning, wireless system physical design or use, or use of TEDS.

The IEEE Standards Association

The IEEE Standards Association (IEEE-SA), a worldwide standards-setting body, develops consensus standards through an open process that brings diverse parts of an industry together. It has a portfolio of more than 870 completed standards and more than 400 in development. IEEE-SA promotes the engineering process by creating, developing, integrating, sharing, and applying knowledge about electro- and information technologies and sciences for the benefit of humanity and the profession.

Recent Developments

New IEEE 802.11g™ Standard Extends Data Rate of IEEE 802.11b™ WLANs to 54 Mbps from 11 Mbps [200]

Recently the most widely used IEEE 802.11b™ technology got a much-awaited speed increase through a new amendment to the IEEE 802.11™ standard ratified by the Standards Board of the Institute of Electrical and Electronics Engineers. The added transmission speed gives wireless networks based on IEEE 802.11b (often called WiFi) the ability to serve up to four to five times more users than they now do. It also opens the possibility for using IEEE 802.11 networks in more demanding applications, such as wireless multimedia video transmission and broadcast MPEG. The new amendment allows IEEE 802.11g units to fall back to speeds of 11 Mbps, so IEEE 802.11b and IEEE 802.11g devices can coexist in the same network. The two standards apply to the 2.4 GHz frequency band. IEEE 802.11g creates data-rate parity at 2.4 GHz with the IEEE 802.11a standard, which has a 54 Mbps rate at 5 GHz. (IEEE 802.11a has other differences from IEEE 802.11b or g, such as offering more channels.)

"The WiFi Alliance applauds the IEEE for passing the IEEE 802.11g amendment to the IEEE 802.11 standard," said Frank Hanzlik, Managing Director of the WiFi Alliance. "This very exciting achievement continues the evolution of wireless LAN technology." In response to the amendment's approval, the WiFi Alliance will be announcing the first round of WiFi CERTIFIED™ 802.11g products in the near future. "With over 700 WiFi CERTIFIED products already available around the world, we expect that the approval of this amendment will increase product certifications and industry growth."

IEEE Approves Two Amendments to Wireless Local and Municipal Area Network Standards[201]

Of the two approved amendments, one, IEEE 802.11F™, sets specifications so access point devices from different vendors in IEEE 802.11™ wireless local area networks (WLAN) can interoperate. The other, IEEE 802.16™/Conformance01, allows end users to evaluate how well a product designed for IEEE 802.16 wireless metropolitan area networks conforms to the standard.

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