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Gary F. Templeton
Mississippi State University

Mark B. Schmidt
St. Cloud State University

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Gary F. Templeton
Mississippi State University

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ABSTRACT

Ultra-wideband (UWB) is a promising class of high-speed wireless communications applications that is projected to significantly change local and wide area network architectures. This article describes the technology, its probable application areas, the environmental forces that are constraining and enabling commercialization, and the prospects for short-term growth for UWB services. Commercial sale and distribution of UWB products has been approved, and widespread sale is expected by 2007.

INTRODUCTION

PulsON™, invented by Larry Fullerton in 1987, is an ultra-wide band (UWB) data transmission method that promises to dramatically change the face of wireless communications (IEEE, 2003). The innovation is so significant that industry observers have hailed Fullerton as a modern-day Thomas Edison (Maney, 1999). The future of UWB (bandwidths contained in the 650 MHz to 5 GHz frequency range) depends almost exclusively on his company, Time Domain Corporation (http://www.time-domain.com/) in Huntsville, AL.

UWB allows for highly efficient use of the entire frequency spectrum by simultaneously transmitting signals on multiple frequencies: each half nanosecond (a billionth of a second) pulse contains many frequencies at once. Figure 1 depicts traditional continuous sine waves transmit information through the modulation of the wave's amplitude or frequency. Sine waves are physically limited in information capacity and number of users.

Figure 1: Wireless Transmission Using Traditional Continuous Sine Waves.

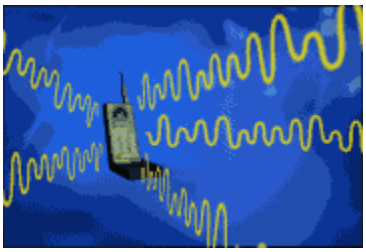

Figure 2 illustrates how 40 million coded pulses per second are used in UWB, which transmits more data and supports essentially unlimited users. Since UWB pulses are so brief and are sent at unset time intervals, normal radio receivers treat them as noise and filter them out. Most importantly to its users, UWB transmissions are received without interference from conventional transmissions. Thus, it can share spectrum with other applications. For an in-depth description of this technology, see Siwiak and Withington (Siwiak, 2001).

Figure 2: Wireless Transmission Using Coded Pulses.

PulsON™ promises new forthcoming patents, methods, and applications, but more significantly informs us on how to use the spectrum of available communications frequencies. In applications, it does not require an assigned frequency or a power amplifier and requires a very low-power signal ($1/500^{th}$ of the energy currently needed for cellular communications). The result is a potential paradigm shift in wireless communications for local or wide area applications. A handful of strategically significant issues have threatened to undermine the commercial evolution of PulsON™ and although Fullerton and Time Domain have made significant progress, several barriers remain (Aiello and Rogerson, 2003).

UWB APPLICATIONS

For short distance transmissions, PulsON™ is superior because it is very effective at penetrating doors, walls, and other obstacles over a distance of up to 230 feet. For wide areas, PulsON™ has the potential to supplant existing GPS protocols because it is far more precise. To put it into perspective, PulsON™ not only can easily see the famous Stealth fighter, it can tell if its wing flaps are up or down.

Several prototypes have been built using UWB, although no applications are currently on the market. The short-term future of UWB depends on what applications into which it initially gets built. Approximately 95% of UWB applications will be indoors, underground, and in noisy environments, as it will set free multiple tens of megabits in bandwidth in small areas. The advantage of UWB in small spaces is that it can leverage off multi-path (where the signal bounces off local objects during propagation) environments. There are four primary application areas for UWB:

Radar

UWB signals allow users to better observe objects behind coverings, including brick, concrete, and metal walls. One application of UWB is underground radar to find gold that has previously been undetectable. Zircon (http://www.zircon.com/) has plans for building high-precision stud-finders used in industrial construction. UWB can be used to create a 'radar bubble' to be used in intrusion tracking. Existing prototypes can detect gunfire orientation and the orientation of laser pointers used on rifles. Other applications are medical imaging and ground-penetrating radar.

Data Transmission

The low power required by the PulsON™ architecture allows for the digital transmission of information at extremely high rates at low cost. Example applications are a refrigerator that can communicate to a local repair shop that it needs service and wireless tracking of children, golf carts, consumer goods, and materials in production. Once the UWB standard has been approved, the market for PAN (personal area networks) applications will just begin. One implication of UWB-based PAN is cable (i.e., USB or Firewire) replacement.

Motion Detection

Time Domain's RadarVision™ helps the user locate moving objects by tracking precise real-time directional information.

Location

Since prevailing GPS cannot function indoors (the receivers don't have line-of-sight views of the GPS satellites), one promising application area for UWB is local positioning. This approach can help rescue workers find people in the rubble of earthquakes or help parents find their missing child in malls. Another concept under development is an automotive collision-detection system.

The following sections describe the constraining and enabling factors associated with PulsON™ and the future of UWB.

CONSTRAINTS TO COMMERCIALIZATION

Five factors stand out as possible inhibitors of UWB commercialization:

Technical

A technical barrier has been the required information processing power needed, which are just now becoming commercially available. IBM has developed a cost-effective chip named "PulsON™," which have only been simulated in prototypes. This aspect will continue to hamper development of a mobile market for UWB.

Competing technologies

UWB differs from Code Division Multiple Access and Time Division Multiple Access in that it does not use a continuous sine wave signal. UWB is often compared to Bluetooth, another short-distance wireless technology that connects mobile wireless devices and PCs. There are at least two major advantages of UWB over Bluetooth: 1) transmission rate of 480 Mbps at 2 meters and 110 Mbps at 10 meters (Palenchar, 2004) and 2) number of practical connections within a small space. UWB is 10 times faster than Wireless Fidelity ("Wi-Fi"), a growing alternative to wired LAN.

U.S. Government

The primary barrier to the commercialization of UWB is the Federal Communications Commission (FCC), who is concerned that UWB might interfere with GPS and public safety broadcasting. The company argued that since UWB promises to work better inside than outside, it will actually complement GPS, which is used outdoors in large spaces. The FCC approved the commercial use of UWB on February 14, 2002. FCC regulations permitting widespread sale of UWB products were approved on October 1, 2003. The first UWB product focus is expected to be in home wireless networks. The growth of UWB products should rapidly accelerate by 2005.

Patent Progress

On February 14, 2002, the 74th patent was granted to Time Domain by the U.S. Patent and Trademark Office (another 155 remain pending). Patent 6,304,623 is a landmark achievement for the company and the evolution of UWB, because it contains methods allowing consumer electronics products (cameras, PCs, DVD players, phones, etc.) to efficiently send and receive digital video, audio, and data.

Standardization

Since it doesn't make sense to create commercial applications with no industry standard in place, IEEE is developing UWB standards (reference IEEE 802.11x). It is anticipated that the initial protocols will be available in 2005. Once approved, there will be an instant market for UWB products.

CAUSES OF COMMERCIALIZATION

There are three primary factors that are currently fueling the commercialization of UWB technology.

Governments

The U.S. Government is interested in positioning, location, and tracking applications. At present, it is legal to sell UWB technology to public safety and health organizations and consistently gets inquiries regarding physical security applications. For a variety of reasons, government entities interested in UWB include the Federal Emergency Management Agency, the U.S. Department of Health Services, the Office of Emergency Preparedness, Metro New York Disaster Medical Assistance Team, and NASA. The aim in such systems is to prevent natural and technical disasters, transportation problems, terrorism, and parts inventory control.

Strategic Alliances

Time Domain has taken a distinctly R&D oriented culture, as it has been a 'startup' company for almost 20 years. Its management has smartly aligned the company with established global technology leaders in order to better leverage its promising intellectual capital. Time Domain's strategic allies include Sony (Japan), Siemens AG (Germany), MCI WorldCom (US), Kolon Group (Korea), Marconi Ventures (US), and Qwest (formerly US West) (US). There are three ways in which Time Domain allows external interests to mutually gain from its UWB technology: as investors, as application providers, and contracting. First, Time Domain has been dependent upon investor funding since its inception. Privately held, the company has judiciously selected its investors, who are allowed to invest in the company based on prospects for assisting in development and future commercialization. Rather than accepting all interested parties, the company sets strategic partnerships with investors that can benefit the company most. The estimated market value of Time Domain is currently well over $250,000,000. Second, instead of striving to create a portfolio of far-reaching applications, it focuses on the competent delivery of chipsets (following the Intel model) that are useful to application providers. For instance, Time Domain has contracted with Lincom Wireless to help develop PulsON^{TM} chipset into a commercial system. Third, the company is very prudent in its selection of contract opportunities. Strategic contracting is based on whether or not it can help Time Domain in technological development. The company limits its participation in contracts that deviate from the goal of technological development.

The UWB Community

Ultra Wideband Working Group (http://www.uwb.org/) was formed in 1998 to allow companies, individuals, and government officials to support the development and use of UWB applications. The group continuously tracks news and facilitates the dissemination of knowledge throughout its membership of over 1,200. The most prominent conference on UWB is the IEEE Conference on Ultra Wideband Systems and Technologies (http://www.uwbst2003.com/), held in May each year.

WHEN WILL UWB HAPPEN?

Whether and when UWB will reach a mature commercialization stage has significant implications for providers of computer applications. UWB has followed a developmental path that has required a level of corporate patience (there are currently no existing applications and only a few dozen prototypes existing to date) similar to Bell Labs' investment in the transistor and fiber optic cable. Several UWB product demos were displayed at the (January) 2003 Consumer Electronics Show in Las Vegas. Several UWB products are currently available for use in many industries (Gifford, 2004). UWB should begin having a meaningful effect in the home market shortly after the IEEE standards are approved in 2005. In-Stat/MDR (http://www.instat.com/) estimates that the total UWB market will not exceed 5% by 2006. Allied Business Intelligence (http://www.alliedworld.com/), a technology market research company, estimates that 45 million UWB chips will be sold in 2007. However, with the marketplace strong hold of IEEE 802.11a, 802.11b, 802.11g, and the 100 Mbps possibilities of the upcoming 802.11n it remains to be seen if UWB changes the wireless paradigm (Rupley, 2004).

MANAGERIAL IMPLICATIONS FOR UWB

UWB has the potential to effect great change in the manner in which many radar, data transmission, motion detection, and location applications are implemented. Much of the current interest in UWB stems from its ability to offer network managers a high speed alternative for wireless networks. In fact, UWB offers two key advantages

over IEEE 802.11a, 802.11b, 802.11g and Bluetooth technologies. The first advantage is that UWB provides considerably higher data throughput. The second advantage is that UWB broadcasts in half nanosecond pulses with many different frequencies and does not consume power between the broadcasts and as such, consumes less power while offering a higher throughput than both IEEE 802.11 and Bluetooth technologies. In fact, UWB offers throughput of up to 480 Mbps (Discrete Time Communications, 2003).

Increasing Managerial Effectiveness

Many types of businesses stand to benefit from the further development and implementation of UWB. A host of businesses will gain by developing, marketing, and selling both hardware and software devices that enable UWB. Those who adopt UWB could enjoy greatly improved throughput for wireless networks. Organizations are becoming more dependent on the effective and efficient transmission of data in more realms then ever before. For instance, many companies are now participating in Business-to-Business online reverse actions (Schoenherr, 2004). Whether on the supplier or consumer side of an online action, it is critical to have the throughput to effectively and efficiently transmit data to the other party. On the application front, any business that can benefit from increased throughput and mobility will stand to gain from UWB. The increased throughput of UWB will increase both the efficiency and effectiveness of wireless networks by allowing managers to share more information in a shorter time period. The simultaneous real-time monitoring of several production lines by a manager serves as but one example. The use of UWB would allow work stations to communicate wirelessly with the mouse, monitor, printer and other peripheral devices. This connectivity allows an increased level of mobility for the user and offers to increase the ability to deliver high quality wireless video (Whittaker, 2005).

Competitive Advantage

UWB offers several advantages over competing technologies. One paramount advantage is that of security. Signals are transmitted around a 2 GHz band in a seemingly random manner (Babyak, 2001). A high level of security can be achieved since a matched synchronized receiver that knows where and when to look for pulses and how to decode them is required to interpret a message. Because organizations are now exceedingly dependent on interorganizational information systems to support inter-firm activities such as supply chain activities (Fedorowicz, Gogan, and Ray, 2004), security is of paramount importance.

Because UWB signals are sent using picoseconds (one billionth of a second) time increments, receivers are afforded the opportunity to focus on the primary signal and can ignore echoes there is no multipath distortion (Babyak, 2001). Due to the lack of multipath distortion, UWB technologies offer an ideal solution for indoor wireless networks. Due to the potential for increased throughput, lack of multipath distortion, and relatively secure nature of the technology the future of wireless data transmission may lie in UWB. As a result of the increased throughput, increased security, and lack of multipath distortion, companies adopting UWB may achieve competitive advantage over competitors that do not. Any organization with an immediate need to share a great deal of data in an efficient and secure manner, such as banks, brokerages, and the military will stand to benefit from the characteristics of UWB.

CONCLUSION

The wireless arena possesses many formative competitors. Each of these competing technologies offers advantages over their competitors. Market forces will eventually choose the best technologies to meet current demands. Prognosticative efforts by some offer that shipments of UWB chips will enjoy a year over year 4 fold increase from 2005 – 2008 (Reynolds, 2004). However, the question of managerial adoption and acceptance of UWB remains.

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