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WIRELESS COMMUNICATIONS TECHNOLOGY LANDSCAPE

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Wireless networks are becoming more pervasive, accelerated by new wireless communications technologies, inexpensive wireless equipment, and broader Internet access availability. These networks are transforming the way people use computers and other personal electronics devices at work, home, and when traveling.

There are many wireless communications technologies that can be differentiated by frequency, bandwidth, range, and applications. In this white paper, we survey these technologies, which can be broadly organized into the four categories depicted in Figure 1. These categories range from wireless wide area networks (WWANs), which cover the widest geographic area, to wireless personal area networks (WPANs), which cover less than 10 meters.

Wireless Personal Area Networks (WPANs)

WPANs are very small ad hoc networks that typically extend to 10 meters or less. Because of their limited range, WPANs are used mainly as cable replacement technologies for data synchronization and connectivity for devices that are close to each other.

Bluetooth® wireless technology is the prevalent WPAN technology today. It operates in the 2.4-GHz unlicensed frequency band. Figure 2 shows its evolution from version 1.1 at a data rate of 1 Mbps to version 1.2, which improves the signaling and frequency band coexistence mechanisms. The 3-Mbps Bluetooth 2.0+ Enhanced Data Rate (EDR) was ratified in November 2004 and products are beginning to appear on the market.

Over the next three years, WPAN applications that require higher data rates may adopt the emerging high-bandwidth Ultrawideband (UWB) technology. UWB provides high bandwidth by transmitting at very low power across a broad frequency spectrum. The UWB physical interface (or "PHY") specification—802.15.3a— is under development in the IEEE, and a competing specification is under development by an industry working group called the MultiBand Orthogonal Frequency Division Multiplexing (OFDM) Alliance (MBOA). Initial UWB products with data rates of 100-480 Mbps are anticipated in early 2006. Future versions are expected to have data rates of up to 1 Gbps. Failure to resolve the issue

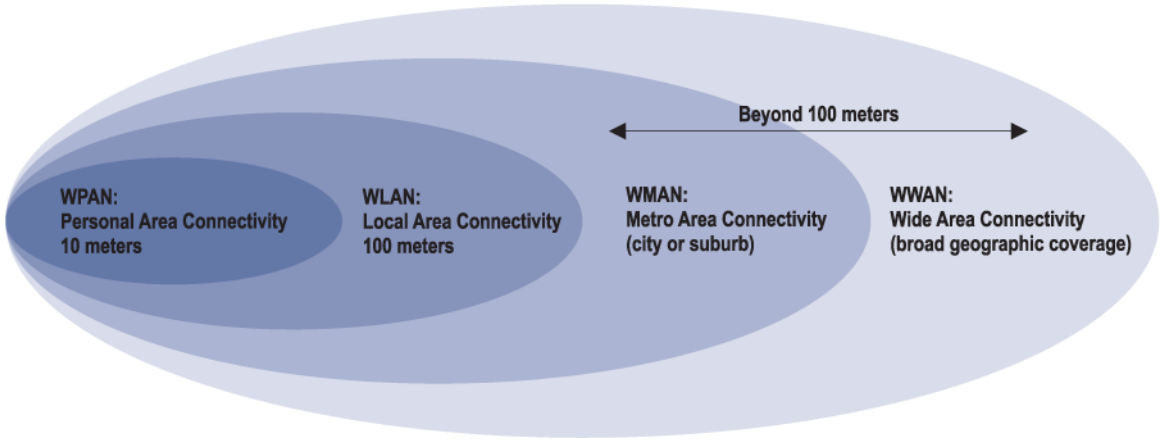
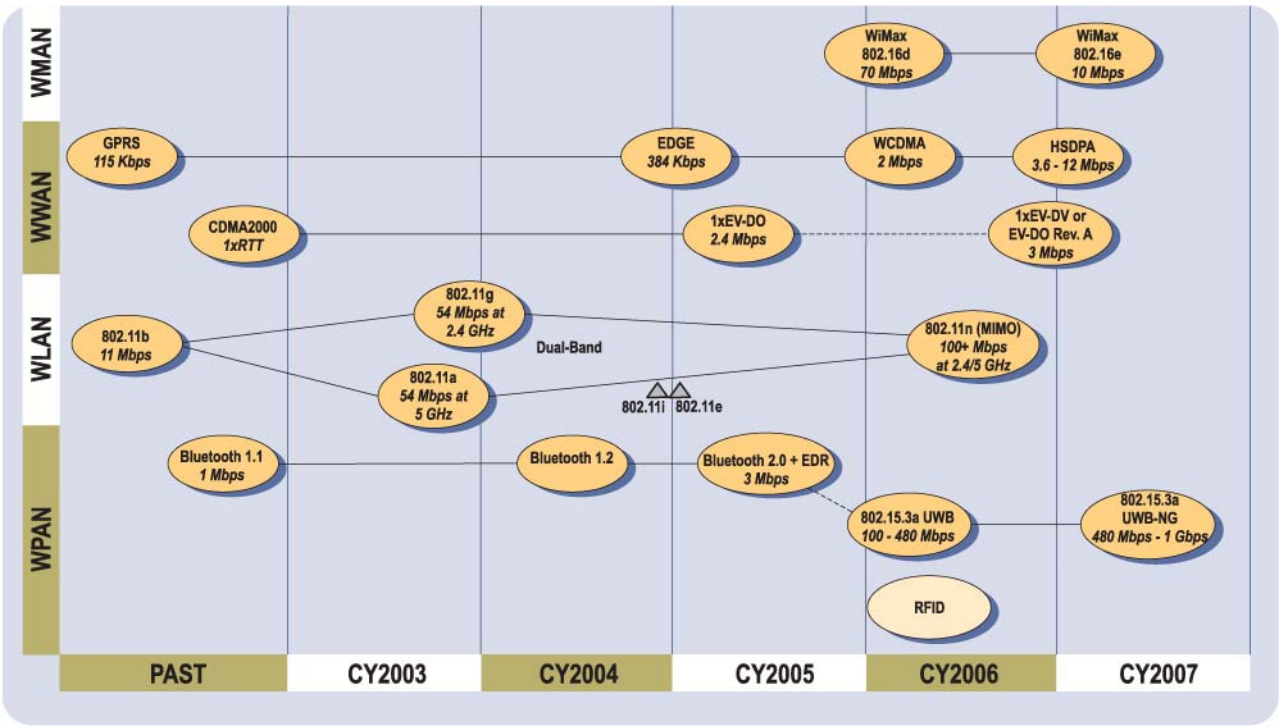


Figure 1. Wireless Technologies Categorized by Range



Note: The data rates in this paper are commonly cited peak channel data rates. Actual end-user throughput, which is dependent on the device radio, signal conditions, distance, and protocol efficiencies, will be lower.

Figure 2. Wireless Communications Technology Landscape

of competing standards may stall the market opportunity for UWB technology. In addition, although the U.S. Federal Communications Commission (FCC) has approved a large amount of spectrum for UWB in the U.S., there are regulatory and regional policy issues outside the U.S.

An additional wireless technology that fits roughly in the WPAN category—ZigBee (802.15.4)—is optimized for low-bandwidth niche applications such as instrumentation and home automation. Zigbee is not depicted in Figure 2 because it is unlikely that it will be deployed outside these specialized applications.

Wireless Local Area Networks (WLANs)

In contrast to WPANs, WLANs provide robust wireless network connectivity over a local area of approximately 100 meters between the access point and associated clients. Today's WLANs are based on the IEEE 802.11 standard and are referred to as Wi-Fi networks. 802.11b was the first commercially successful WLAN technology. It operates in the 2.4-GHz frequency band at 11 Mbps. By implementing a different data transmission method, data rates were increased to 54 Mbps in 2003 with 802.11g in the 2.4-GHz band and 802.11a in the 5-Ghz band. Today, "dual-band" Wi-Fi access points and client network adapters that support various combinations of 802.11a, b, and g are common. Highly integrated, single-chip solutions that are smaller and require less power have enabled new designs and applications.

In addition, new standards address Wi-Fi network security. Wi-Fi Protected Access (WPA) and 802.11i (or WPA2) focus on user authentication and encryption. WPA2 employs next-generation Advanced Encryption Security (AES) encryption. A component of WPA and WPA2—the IEEE 802.1X standard—provides a port-level authentication framework. Finally, the upcoming 802.11e standard addresses quality of service (QoS). QoS enables the prioritization of latency-sensitive applications such as voice and multimedia. The Wi-Fi Alliance, an industry group responsible for certification and interoperability testing, has developed the Wi-Fi Multimedia (WMM) test specification to certify product compliance with the 802.11e standard.

The next-generation WLAN standard is IEEE 802.11n, which is currently being defined. 802.11n will be back-

ward-compatible with 802.11a, b, and g, and will provide data rates in excess of 100 Mbps. The 802.11n performance increases stem from new Multiple-Input, Multiple-Output (MIMO) radio technology, wider radio frequency (RF) channels, and improvements to the protocol stack. MIMO enables higher data rates by increasing the number of radios and antennas in a wireless device. 802.11n is scheduled for IEEE ratification in mid-2006. Dell is leading an initiative in the Wi-Fi Alliance to launch a product certification program concurrent with ratification of the IEEE 802.11n standard.

Wireless Metro Area Networks (WMANs)

A WMAN is a wireless communications network that covers a large geographic area such as a city or suburb. Traditionally, long-distance wireless technologies providing T1 or T3[1] data rates have been proprietary—owned and operated by major telephone companies, independent local exchange carriers (ILECs), and other providers to link remote sites or large campuses. The IEEE has standardized a new set of WMAN technologies that operate in licensed and license-exempt frequency bands. The best-known of these technologies—IEEE 802.16d or "WiMax"—will operate in the 2- to 11-GHz frequency range. (In the U.S., it will operate in the 2.5-, 3.5-, and 5.8-GHz frequency bands.) Its maximum data rate when operated within line of sight and under ideal conditions is 70 Mbps over 50 kilometers. Initial deployments will require an external antenna at the customer premises. A mobile version—802.16e—is planned in 2007. It is not yet clear when (or whether) telecommunications and Internet service providers will broadly deploy the required infrastructure to support either the fixed or mobile versions of Wi-Max. However, it is widely expected that WiMax deployments will leverage existing and emerging "tower" infrastructures and installations.

Wireless Wide Area Networks (WWANs)

WWANs are digital cellular networks used for mobile phone and data service and operated by carriers such as Cingular Wireless, Vodafone, and Verizon Wireless. WWANs provide connectivity over a wide geographical area, but, until recently, data rates have been relatively low—115 Kbps—compared to other more localized wireless technologies. Two WWAN technologies—Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA)—dominate WWAN deployments worldwide. These two technologies are expected to evolve on parallel paths for the foreseeable future.

Europe standardized early on GSM. Today, GSM and its associated wireless data capability, General Packet Radio Service (GPRS) and next-generation Enhanced Data GSM Evolution (EDGE), have about two-thirds of the worldwide market. These technologies have been deployed in North America, Europe, and Asia. Next-generation EDGE boosts GPRS data rates by 3–4 times. Other GSM operators, especially those that have acquired new 3G frequency spectrum, are commercializing Wideband CDMA (WCDMA), which is expected to have data rates of 2 Mbps. An extension called High-Speed Downlink Packet Access (HSDPA) is expected to be deployed starting in 2006. HSDPA will further increase these data rates to 3.6 Mbps and beyond.

CDMA technology dominates in the U.S. The CDMA2000 WWAN technology has seen strong deployments in North America, Japan, Korea, and China. The CDMA2000 single-carrier radio transmission technology (1xRTT) version has been widely deployed. The next-generation 1xEvolution-Data Optimized (1xEV-DO) is currently being aggressively deployed by Verizon Wireless and Sprint PCS in the U.S. and will support a data rate of 2.4 Mbps. Carriers will build on EV-DO with version A of the specification, which will support even higher data rates and Voice over Internet Protocol (VoIP) calls.

Emerging RFID Technologies

Dell is monitoring a new wireless category—radio frequency identification (RFID)—that is beginning to be piloted by large retailers and other companies to replace the bar codes used for asset management and inventory tracking. In RFID systems, an RFID tag is affixed to an asset or inventory item. The tag stores unique informa-

1. T1 and T3 lines are high-bandwidth wired communications lines that provide dedicated point-to-point connections.

tion about the item, including a unique ID number, that can be read by a separate RFID reader. The reader is tied into back-end database applications that use the information to track, monitor, report, and manage each item as it is moved from one location to another.

Another emerging application of RFID technology is referred to as Near Field Communication (NFC). The NFC initiative addresses close-range—approximately 7 centimeters—consumer applications that require robust security. For example, NFC technology might be used for secure payments and transactions that use smart cards equipped with RFID chips.

Global Wireless Spectrum "Harmonization"

A challenge for Dell and the industry is dealing with variations in frequency spectrum allocation from country to country. Because of these variations, for instance, a PDA or mobile phone that uses a GSM-based WWAN link may work in some parts of the world, but not others where the appropriate frequency spectrum may not be available for the service. In addition, each country has its own unique requirements when allocating spectrum for various wireless communications technologies. For example, the frequency bands allocated in Europe for GSM include 900 MHz and 1800 MHz. In contrast, the U.S. allocates 800 MHz and 1900 MHz for GSM. This variation in spectrum allocation presents challenges when developing wireless devices that can support GSM service in more than one region of the world. Mobile devices must support multiple bands, which increases product complexity and cost. The industry continues to work through standards groups and government regulatory agencies to drive efficiencies in global spectrum harmonization.

Conclusion

The vision of ubiquitous access to information, anywhere, anyplace, and anytime, is beginning to become a reality, enabled by rapidly emerging wireless communications technologies with coverages that range from a few inches to many miles. These technologies have the potential to dramatically change society as people "untether" their devices from information sources and communications mechanisms.

Dell recognizes the importance of these wireless technologies to its enterprise, small business, and consumer customers. Dell also recognizes the importance of industry standards to widespread adoption. In the same way that early competing WLAN technologies gave way to the IEEE 801.11b standard, it is important that the industry drive toward worldwide standardization in other wireless technologies. Dell has taken a leadership role in this effort, actively engaging in the development of strategic standards, regulatory and spectrum policy, and interoperability certification programs so that Dell customers benefit from these technologies.