Wireless Personal Area Networks (WPANs)

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The market for wireless personal area networks is expanding rapidly. As people use more electronic devices at home and in the office, and with the proliferation of peripherals, a clear need for wireless connectivity between these devices has emerged. Examples of the devices that need to be networked are desktop computers, handheld computers, printers, microphones, speakers, pagers, mobile phones, bar code readers, and sensors. Using cables to connect these devices with a PC and with each other can be a difficult task in a stationary location. When you add mobility into the mix, the challenge becomes daunting. If the setup and administration of a WPAN becomes simple and intuitive in the future for the end user, then the most concrete scenario for WPAN technology is cable replacement. This provides a compelling reason to use WPAN technology, and will open the door for more advanced applications in the future. Here are the main characteristics of a WPAN:

- Short-range communication
- Low power consumption
- Low cost
- Small personal networks
- Communication of devices within a personal space

While providing these features, a WPAN has to achieve two main goals: broad market applicability and device interoperability. It is important that the WPAN specification addresses the leading device categories that require wireless connectivity in a way that is both easy to implement and affordable. The price point to make a technology attractive is $5 (U.S.) or less. At this level, device manufacturers are willing to incorporate a technology into a broad range of devices for both the consumer and business markets. Interoperability is also imperative. Wireless capabilities are not very useful if they do not allow a device to communicate with other devices and peripherals.

Three wireless standards are leading the way for WPANs: IrDA, Bluetooth, and IEEE 802.15. Each of these standards enables users to connect a variety of devices without having to buy, carry, or connect cables. They also provide a way to establish ad hoc networks among the abundance of mobile devices on the market. Each of these standards is discussed in the following subsections.

WPAN Standards

Many standards are available for personal area networks. Each standard has strengths and weaknesses, making it suitable for specific application scenarios. In some cases, more than one technology will be able to perform a required task, hence nontechnical factors such as cost and availability will factor into the decision as to which technology is more appropriate. Here we take a look at the leading standards in this space. The information provided will give you a solid understanding about where each standard is being used and for what purposes.

IrDA

IrDA, the acronym for Infrared Data Association, is an international organization that creates and promotes interoperable, low-cost infrared data connection standards. IrDA has a set of protocols to support a broad range of appliances, computing, and communication devices. These protocols are typically aimed at providing high-speed, short-range, line-of-sight, and point-to-point wireless data transfer. IrDA protocols use IrDA DATA as the data delivery mechanism, and IrDA CONTROL as the controlling mechanism.

Chances are that you currently own a device that has support for infrared communication. The Infrared Data Association estimates that more than 300 million IrDA enabled devices have been shipped, making it one of the most pervasive wireless technologies in existence. The original goal of IrDA was to provide a cable replacement technology, much like the other PAN standards. The idea was that two computers could communicate simply by pointing them at each other. For example, to print a document, you would simply point the infrared (IR) port at the printer and be able to send the data. No cables would be required.

Technically, infrared technology is well suited for such tasks. The following are some of infrared's features:

- Communication range of up to 1 meter, although a distance of 2 meters can often be reached.
- A low-power option for communication up to 20 centimeters. This requires 10 times less power than the full-power implementation.
- Bidirectional communication.
- Data transmission from 9600 bps to a maximum speed of 4 Mbps.

In theory, using IR for data transfer is a great idea. Unfortunately, even with such ubiquity it is rarely used for its original intent. This may be due to technical challenges in many early implementations, or more plausibly, to the line-of-sight restriction. For IR to work, the communicating devices have to maintain line of sight. This means that they have to situated within the operating range (typically up to 2 meters apart), point at each other, and have no physical impediments. In most office environments, this limitation is not practical for many peripherals such as printers or scanners. Using infrared to transfer data between two devices is more realistic. Two device users can use infrared to transfer information, such as electronic business cards, between one another. Users with Palm devices call this type of transfer *beaming*, as in, "Can you beam me your contact information?" Beyond user-to-user data transfer, infrared is not commonly used for information transfer, since most users do not use two devices with IR ports. While nearly all portable devices have one, the majority of desktops do not. Once again, this limits the effectiveness of IR as a mass-market data transfer protocol.

That said, there are some areas where infrared is frequently used. The IrDA CONTROL standard allows wireless peripherals such as keyboards, mice, game pads, joysticks, and pointing units to interact wirelessly with a host device, very often a desktop PC or gaming unit. A host device can communicate with up to eight peripherals simultaneously. The data transmission rate for IrDA CONTROL typically reaches a maximum at 75 Kbps, which is easily fast enough for the type of data being transferred by these types of devices.

One of the major advantages of IrDA from a device manufacturer's perspective is cost. IR ports can be incorporated into a device for as low as $1 (U.S.). This is a very low cost for implementing wireless communication into a device compared to other WPAN standards.

Bluetooth

Bluetooth is a standard for enabling wireless communication between mobile computers, mobile phones, and portable handheld devices. Unlike IR, Bluetooth does not require a line of sight between devices to be effective. It is able to communicate through physical barriers, typically with a range of 10 meters, although with power amplifiers, 100 meters is possible. Bluetooth uses the unlicensed 2.4-GHz spectrum for communication, with a peak throughput of 720 Kbps. It is expected that this throughput will increase to around 10 Mbps with future Bluetooth specifications.

The origins of Bluetooth date back to 1994 when Ericsson was researching ways to enable mobile phones to communicate with peripherals. Four years later, in 1998, Ericsson, along with Nokia, Intel, Toshiba, and IBM, formed the Bluetooth Special Interest Group (SIG) to define a specification for small form-factor, low-cost wireless communication. Since then, 3COM, Lucent, Microsoft, and Motorola have joined the Bluetooth SIG as Bluetooth promoters. In addition, well over 2,000 companies have joined the SIG as Bluetooth Adopter/Associate members. This all happened before a single Bluetooth product was commercially available, leading to unprecedented market excitement.

People were excited about the futuristic products that would soon be available, expecting that every device, from portable computers to home appliances, would soon incorporate Bluetooth technology. These devices would then interact with one another, transferring data files, contact information, security credentials, and even perform financial transactions. All of this would happen seamlessly without any technical knowledge required from the user.

Needless to say, the hype once again surpassed the technology. While Bluetooth will indeed enable those scenarios someday, right now it is most effective as a cable replacement technology. Since a line of sight is not required for communication, getting Bluetooth devices to interact with one another is trivial. Bluetooth provides an autodiscovery mode, whereby Bluetooth devices will automatically discover other devices that are within range. Once they are detected, they can start communicating. There is some concern that this will overload the 2.4-GHz spectrum as more Bluetooth devices become available. To address this issue, the Bluetooth specification defines three device modes:

- **Generally discoverable mode.** This allows a Bluetooth device to be detected by any other Bluetooth device within its proximity.
- **Limited discoverable mode.** Only well-defined devices will be able to detect a device in this mode. This mode will be used when a user has many Bluetooth devices and wants them to discover each other automatically.
- **Nondiscoverable mode.** This makes the device invisible to other devices so it cannot be detected.

When two or more devices connect, they form a piconet, an ad hoc network that can consist of a maximum of eight devices. Every device in a piconet can communicate directly with the other devices. It is also possible to have networks with more than eight devices. In this case, several piconets can be combined together into a scatternet. In a scatternet configuration, not all devices can see each other; only the devices within each piconet are able to communicate. Figure 3.1 helps to illustrate how this works. In this figure there is one scatternet consisting of five piconets; the hands-free mobile phone is a member of three different piconets and is able to communicate directly with the headset, the Bluetooth pen, and the access point, but is not able to communicate directly with the laptops, printer, or fax machine.

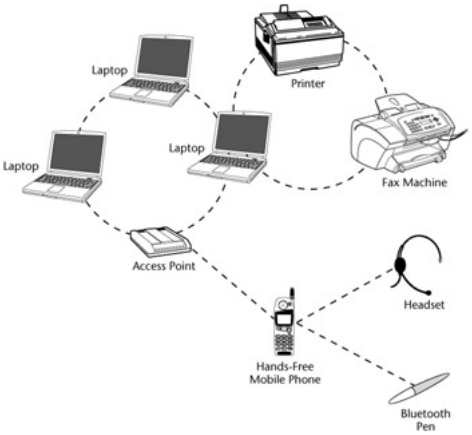

Figure 3.1: Bluetooth scatternet with five piconets.

The number of Bluetooth devices on the market is growing every day. It is common for mobile phones, PDAs, laptops, and peripherals to come equipped with Bluetooth chips. This has been made possible by the lowered cost of Bluetooth chipsets [currently around $20 (U.S.), with a targeted range of $5 to $10 (U.S.)] in conjunction with increased market demand. Users are now aware of the many compelling features that Bluetooth offers. The leading ones include:

- Cable replacement
- Mobile device networking
- Global ad hoc networking
- Support for both voice and data communication
- Worldwide vendor and product support

Bluetooth Profiles

In order for Bluetooth to realize true ubiquity, interoperability is a key. Bluetooth devices from different vendors have to be able to communicate seamlessly. In order to promote this level of interoperability, the Bluetooth SIG has defined 13 profiles that device manufacturers can use when implementing their products. These profiles help ensure that Bluetooth products are built on a single foundation, allowing for true interoperability.

The entire second volume of the Bluetooth v1.1 specification is dedicated to profile definitions. Each profile is designed for a specific task. Four profiles are foundation profiles, providing the building blocks upon which other profiles are constructed. The other nine profiles are usage profiles. These describe actual usage cases where Bluetooth technology excels. Bluetooth profiles are not meant to be the definitive way to use Bluetooth technology but rather are aimed at providing standards for implementers to build upon. Device manufacturers will base their Bluetooth offerings on these profiles, ensuring that all Bluetooth devices will be able to communicate with one another.

Detailed summaries of each profile are provided in the Bluetooth profile definition book, which is over 450 pages long. If you are interested in obtaining this information, visit the Bluetooth Web site at www.bluetooth.com.

Bluetooth Security

Because cable replacement is one of Bluetooth's primary uses, the overall goal of Bluetooth security is to make the wireless connection at least as secure as cables would be. The Bluetooth specification defines security at the link level. Application-level security is not specified, leaving the developer to choose the security mechanism that is most appropriate for each particular application.

The Bluetooth specification defines several security measures that can be employed in various situations. Additionally, each profile definition outlines when security should be implemented for particular usage scenarios. Bluetooth communication can be encrypted for over-the-air communication and has built-in device authentication. The level of encryption is user-defined and can have a key size between 8 and 128 bits. This allows the user to determine what level of security is required. Note that a tradeoff exists between speed and security: Greater key lengths lead to slow communication. For authentication, each Bluetooth device has a unique address so the user can have some faith in the device with which they are communicating. (For an overview of mobile and wireless security, see Chapter 6, "Mobile and Wireless Security.")

HELPFUL REFERENCE	The Bluetooth SIG is aware of the importance of security, and has put together a concise Bluetooth security white paper that can be downloaded from the whitepapers section of the official Bluetooth Web site: www.bluetooth.com/dev/wpapers.asp.

802.15

802.15 is a specification driven by the Institute of Electrical and Electronics Engineers (IEEE) to develop consensus standards for short-range wireless networks or wireless personal area networks. It has similar goals to Bluetooth in that it looks to address wireless networking of portable and mobile computing devices such as PCs, PDAs, mobile phones, peripherals, and consumer electronics. The 802.15 WPAN Working Group was established in 1999 as part of the Local and Metropolitan Area Networks Standards Committee of the IEEE.

At the time of establishment, the 802.15 WPAN Working Group was aware of the Bluetooth specification and used parts of it as the foundation for the 802.15 standard. The 802.15 WPAN specification is aimed at standardizing the Media Access Control (MAC) and Physical (PHY) layers of Bluetooth, in the attempt to accommodate wider adoption of short-range wireless technology. 802.15 also deals with issues such as coexistence and interoperability within the networks. To accomplish this goal, four task groups have been established, each working on specific components of the 802.15 specification. They are:

- **802.15 WPAN Task Group 1: WPAN/Bluetooth.** The WPAN Task Group 1 (TG1) has created the WPAN 802.15.1 standard based on the Bluetooth v1.1 specification. To accomplish this, the IEEE licensed technology from the Bluetooth SIG. Specifically, 802.15.1 defines the MAC and PHY specifications for wireless connectivity of devices that are either fixed or portable within the personal computing space. The spec also takes into consideration coexistence requirements with 802.11 wireless local area network (WLAN) devices.
- **802.15 WPAN Task Group 2: Coexistence Mechanisms.** The 802.15 WPAN Task Group 2 (TG2) is developing the recommended practices to facilitate the coexistence of WPAN (802.15) and WLAN (802.11) technologies. Part of this task involves developing a coexistence model to quantify the mutual interference of a WPAN and a WLAN. Once approved, this outcome of TG2's work will become the IEEE 802.15.2 specification.
- **802.15 WPAN Task Group 3: High Rate WPAN.** The 802.15 WPAN Task Group 3 (TG3) is chartered to publish a new standard for high-rate (20 Mbps or higher) WPANs. In addition to high data rates, 802.15.3 also has to provide a means for low-power and low-cost solutions to address the needs of portable consumer electronics, digital imaging, and multimedia applications.
- **802.15 WPAN Task Group 4: Low Rate-Long Battery Life.** The 802.15 WPAN Task Group 4 (TG4) is chartered to establish a low-data-rate (200 Kbps maximum) solution with long battery life (many months to many years) and low complexity. It is intended to operate in an unlicensed international frequency band and is targeted at sensors, interactive toys, smart badges, home automation, and remote controls.

The 802.15 specification is still a work in progress as each of the task groups is at different stages in the specification process. TG1 has completed the 802.15.1 specification and has gotten approval from the IEEE Standards Association (IEEE-SA), while the other groups are still working toward that level. Once completed, the 802.15 WPAN specification will cover all of the current issues surrounding WPAN technology, including Bluetooth compatibility, coexistence with 802.11, high-data transfer rates, and low-power consumption solutions. The combination of all of these will make the IEEE 802.15 specification very attractive for WPAN infrastructure providers.

WPAN Comparison

Of the three WPAN standards, IrDA, Bluetooth, and 802.15, IrDA has been around the longest, and has the highest market penetration, with more than 300 million enabled devices shipped. At the same time, infrared also is the most limiting, as the range is up to 2 meters, and it requires a line of site between communicating devices. The Bluetooth specification addresses these issues by using unlicensed 2.4-GHz spectrum for communication. This allows for communication through physical barriers, as well as larger ranges, typically up to about 10 meters. Bluetooth has also garnered a lot of industry attention, with more than 2,000 companies joining the Bluetooth SIG. In order to provide further standardization for WPAN technology, the IEEE 802.15 specification was developed. The 802.15 specification uses Bluetooth v1.1 as a foundation for providing standardized short-range wireless communication between portable and mobile computing devices. Table 3.2 provides a summary of the leading WPAN technologies.

Table 3.2: Comparison of WPAN Technologies

STANDARD	FREQUENCY	BANDWIDTH	OPTIMUM OPERATING RANGE	POINTS OF INTEREST
IrDA	875nm wavelength	9600 bps to 4 Mbps. Future of 15 Mbps	1-2 meters (3–6 feet)	Requires line of site for communication.
Bluetooth	2.4 GHz	v1.1: 720 Kbps; v2.0: 10 Mbps	10 meters (30 feet) to 100 meters (300 feet)	Automatic device discovery; communicates through physical barriers.
IEEE 802.15	2.4 GHz	802.15.1: 1 Mbps 802.15.3: 20-plus Mbps	10 meters (30 feet) to 100 meters (300 feet)	Uses Bluetooth as the foundation; coexistence with 802.11 devices.

There is no clear leader, as we are still in the early stages of WPAN technology development. Bluetooth has generated the most industry attention so far, but 802.15 is just as exciting. Since 802.15 is interoperable with both Bluetooth and 802.11, it will have a solid future in the WPAN space. In many ways, IR is not a competing technology to either Bluetooth or 802.15 since it addresses a separate market need. IrDA is included in nearly all mobile devices, providing a quick and easy way for reliable short-range data transfer. With its low implementation costs, many low-end devices will continue to support IrDA, while more advanced devices with more robust wireless needs will implement Bluetooth or 802.15.

Another area of interest is the increasing range that these technologies can address. Initially, Bluetooth was aimed at a personal operating space of 10 meters. Now, with power-amplified Bluetooth access points, the range has extended to 100 meters. 802.15 is in the same situation. The increased range for these technologies blurs the line between wireless personal area networks and wireless local area networks.