

## **PERSONAL AREA CONNECTIVITY WITH BLUETOOTH™ WIRELESS TECHNOLOGY**

Pratik Mehta, Senior Communications Architect  
Clint H. O'Connor, Dell Technology Strategist  
Alan Sicher, Wireless Product Manager



*Imagine the following scenario. You return to your office from a several-day-long regional meeting. On entering your office, you wirelessly synchronize recent appointments and e-mails on your personal digital assistant (PDA) with your docked notebook computer. You sit down, lean back in your chair with a wireless keyboard in your lap, and begin work at your notebook computer. You receive a call on your mobile phone and use a wireless headset to answer the call. When finished, you undock your notebook and head off to a weekly status meeting. At the meeting, you need to share a file with a nearby associate, but there is no network connection. You transfer the file to your associate's notebook computer using a wireless link. You also exchange business cards with another attendee using a wireless link between your PDAs. Later, at a customer site, you use your mobile phone to connect to your corporate office.*

What may someday make this scenario feasible is the emerging Bluetooth wireless personal area network (WPAN) technology. WPANs are very small ad hoc networks that cover only a personal work space, an office, or a meeting room. In contrast to Wi-Fi®, which is a robust LAN technology, Bluetooth wireless technology is designed as a cable replacement technology. Its major advantage is freedom from cables when performing tasks such as synchronizing data between a portable computer and PDA or sharing files in a meeting room or small area.

Dell recently launched Bluetooth WPAN technology in its latest Dell™ Latitude™ and select Inspiron™ portable computers and the Axim™ X5 Pocket PC. With this technology, customers can connect devices such as mobile phones, printers, PDAs, and other computers without having to use physical cables. When connected to a

Bluetooth mobile phone, the portable computer can use the mobile phone as a modem to connect to the Internet. Or, the Bluetooth link can be used to exchange or synchronize data between the portable computer and the mobile phone or a PDA. A user can also print from the portable computer to a local Bluetooth printer without having to use a parallel or Universal Serial Bus (USB) cable.

Originally developed by Ericsson (mobile communications company) as a cable-replacement technology, the emerging Bluetooth wireless technology allows devices to be connected over short-range wireless links. It is beginning to appear in a wide range of devices, including mobile phones, headsets, desktop and portable computers, PDAs and other handheld devices, digital cameras, and printers. The In-Stat/MDR market research firm predicts that Bluetooth wireless technology will experience high growth over the next few years. According to In-Stat/MDR, sales of Bluetooth chip sets that are embedded in Bluetooth devices will increase from 10.4 million units in 2001 to 510 million units in 2006.<sup>1</sup>

In this white paper, we review the emerging Bluetooth wireless technology, describe some of its applications, and identify issues that the industry is addressing. We conclude with a discussion of the Bluetooth solution available on the latest Dell portable computers and Axim X5 Pocket PC.

### **Bluetooth Wireless Technology Overview**

Bluetooth wireless technology is a specification for a low-cost, low-powered radio and associated protocol stack that provides a short-range wireless link between notebook computers, mobile phones, PDAs, and other portable devices. The specification, currently at version 1.1, is developed by the Bluetooth Special Interest Group (SIG).

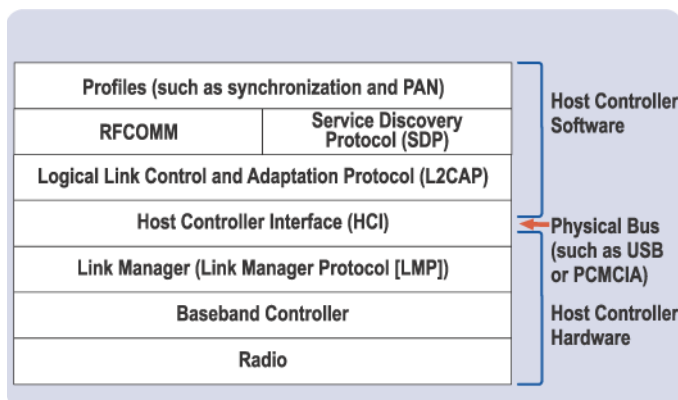
1. "Strong Growth for Bluetooth Chipsets in Spite of Economy," In-Stat/MDR, [www.instat.com/newmk.asp?id=504](http://www.instat.com/newmk.asp?id=504), January 14, 2003.

## Architecture

A simplified view of the Bluetooth protocol stack is presented in Figure 1. It shows the layers that correspond to the hardware and software components of a Bluetooth solution. On a PC or PDA, the interface between the two is a physical PC bus such as a USB, Compact-Flash, or PC Card bus.

The hardware portion of the stack consists of the radio, baseband controller, and Link Manager Protocol (LMP). The LMP is used to set up and control the link and implement the Bluetooth link-level security discussed later in this paper.

The upper layers of the stack consist of the logical link control and adaptation protocol (L2CAP), client protocols, and application profiles. The L2CAP segments and reassembles data into packets for transmission. It also interfaces with client protocols such as the Bluetooth Service Discovery Protocol (SDP), which enables applications to discover which services are available on a Bluetooth device, and RFCOMM, which enables a Bluetooth device to emulate a serial port. Finally, application “profiles” define how particular user scenarios (such as dial-up networking and synchronizing data between two devices) are accomplished. Although shown as an upper application layer in the simplified diagram, a profile can be viewed as a vertical slice through the protocol stack. A profile specifies mandatory options and parameters for each protocol. This approach decreases the risk of interoperability problems between different Bluetooth devices.



Note: In this simplified diagram, the application layer (or profiles) is shown as an upper layer. Some of the profiles interface to lower layers.

**Figure 1. Simplified View of the Bluetooth Protocol Stack**

## Radio

The baseband controller and radio are the heart of the Bluetooth hardware solution. Because of the controller's small size, low cost, and low power requirements, it can be incorporated into many electronic devices or appliances. It is ideal for PDAs with their small form factor and low power requirements. It can also be implemented on a USB device (or “dongle”), PC Card, or PC system board.

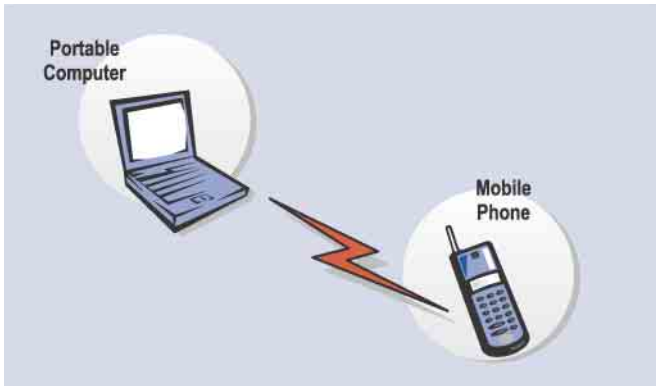
Bluetooth wireless technology operates in the 2.4-gigahertz (GHz) Industrial, Scientific and Medical (ISM) band (from 2.4 to 2.4835 GHz), dividing this frequency range into 79 1-megahertz (MHz) subchannels and hopping from channel to channel 1,600 times per second. Transmitting and receiving devices must synchronize on the same hop sequence to communicate. The technology has a maximum theoretical data rate of 1 Mbps. Actual maximum throughput is approximately 400–700 Kbps, depending on the channel configuration.

Bluetooth links are short range, designed to link personal electronics devices that are fairly close together—typically no more than 10 meters (or approximately 30 feet). Unlike Infrared Data Association (IrDA) devices, a Bluetooth link does not require that the devices be lined up precisely within line-of-sight of each other. For example, it is possible for a PDA and portable computer to link to each other even if they are across the room from each other or the PDA is inside a briefcase or pocket. For this reason, Bluetooth wireless technology may offer more flexibility than the IrDA ports on portable computers, mobile phones, and PDAs.

## “Piconets” and “Scatternets”

In most current Bluetooth usage models, two devices such as the portable computer and mobile phone shown in Figure 2 are connected. However, the specification defines configurations in which up to eight devices can link together in an ad hoc WPAN called a piconet. The specification also defines the methodology for piconets to connect to each other in scatternets. However, most typical usages will be limited to a few devices on a piconet. A key strength of the Bluetooth wireless technology is that a device can handle multiple, simultaneous connections. For example, a portable

computer can be synchronizing with a PDA, while accepting input from a Bluetooth wireless keyboard.



**Figure 2. Bluetooth Piconet of Two Devices**

## Bluetooth and Wi-Fi Technologies

The ability to form a Bluetooth piconet or scatternet does not mean that it can be considered a wireless local area network (LAN) technology along the lines of Wi-Fi networking. Because the Bluetooth networking capabilities, range, and throughput are limited, it is best suited as a cable-replacement technology, rather than as a replacement for the Wi-Fi WLAN technology. Bluetooth wireless technology is complementary to Wi-Fi networks. It is better suited to ad hoc connectivity and usages, while Wi-Fi is the prevalent wireless networking technology.

### Establishing a Bluetooth Connection

A Bluetooth device is equipped with Bluetooth hardware (radio and baseband controller) and software (Bluetooth protocol stack and user interface). The software allows a user to configure options, “discover” and connect to nearby Bluetooth devices, and perform operations over the Bluetooth link.

Typically, a user initiates a Bluetooth connection between two devices (such as a notebook computer and PDA) that are close to one another. The purpose of the link is to perform a specific task such as synchronizing the calendars or transferring a file between the two devices. To initiate the connection, the user opens Bluetooth client software on one of the devices, usually the portable computer, and “discovers” nearby devices—in this case, the PDA—that are configured to be “discoverable.” For security purposes, a device can be

configured to not be discoverable by other Bluetooth devices. The following discovery and pairing processes can be initiated:

- **Name discovery:** The name of the Bluetooth device is detected. The default device names are designed to easily identify the device.
- **Service discovery:** Specific services available from the device are discovered. These services are usually based on profiles defined in the Bluetooth specification. In addition to low-level services associated with establishing connections, there are profiles for services such as cordless telephony, serial port, dial-up networking, faxing, file transfers, and synchronization. If both devices support a particular Bluetooth profile (such as synchronization), the user can proceed with synchronizing data between the devices.
- **“Pairing”:** Also referred to as “bonding,” the two devices form a private connection. Pairing is optional and is not required in all scenarios. For security purposes, a PIN (referred to as a “passkey”) is usually required before the connection is allowed. For example, to control access to a Bluetooth printer, it can be assigned a PIN that users of other devices must enter when pairing with the printer.

Once the devices’ services are discovered and, if required, paired, the user can initiate a specific service such as a serial port connection. Some client software allows each service to be configured with or without encryption (referred to as “Secure Connection” in the current Dell implementation).

### Device Interoperability

In order for two Bluetooth devices to perform a particular service, they must both support the associated Bluetooth profile. If they do not, even though they can discover one another and pair, they cannot perform the service. For example, when a portable computer and a PDA link to each other, the list of services from the PDA may include synchronization and file-transfer services. If the Bluetooth implementation on the portable computer supports these services, the two devices can synchronize data and transfer files.

It is important when connecting Bluetooth devices to determine which services are supported by each de-

vice. At this early stage in the development of Bluetooth wireless technology, device services vary and interoperability problems between devices are not uncommon. In addition, the Bluetooth specifications body has added many profiles that address specific devices and market scenarios. This proliferation could tend to increase interoperability problems. As the technology matures, it is expected that most device types will converge on a common set of Bluetooth services so that these interoperability problems diminish. The profiles presented in Table 1 are emerging as the most commonly used and implemented. Some profiles such as the generic access and object exchange profiles may not be mentioned in Bluetooth products, but the services are implied by the presence of other profiles. For best compatibility, look for products and devices that support the profiles listed in Table 1.

## Security

Bluetooth wireless technology is frequency-hopping. It uses a pseudo-random hopping sequence that is unique to the device to hop 1,600 times per second among 79 channels. This provides a measure of security, because two devices must synchronize on the same hop sequence to communicate. Devices can also be configured so that they cannot be discovered by other Bluetooth devices. In addition, the Bluetooth specification defines security at the link and service level.

### Link-Level Security

Link-level security is handled in the lower layers (L2CAP and below) before the link is established. At the link level, the Bluetooth specification defines one-way or mutual authentication and encryption. These features

Service	User Application	Description
Generic Access Profile	Foundation for all other profiles.	Provides access and security functions to other profiles.
Service Discovery Application Profile	Used to discover other devices and the services on those devices.	Allows a Bluetooth requesting device to discover the services offered by a another device. Included on all Bluetooth devices.
Serial Port Profile	Used with ActiveSync or HotSync software to synchronize a PDA with a portable computer. Also used for other legacy serial applications.	Provides RS-232 serial cable emulation for Bluetooth devices. Legacy applications can use a Bluetooth link without any modification as a serial cable link.
Dial-up Networking Profile	Allows a mobile phone or dial-up modem to be used to access a network.	Connects a computer device to a WAN through a dial-up networking gateway device such as a mobile phone or dial-up modem. The WAN can be a digital mobile network such as GPRS or the Public Switched Telephony Network (PSTN).
Object Push Profile	Used to exchange business cards (vCard), appointments (vCal), or to "push" objects.	Uses the Generic Object Exchange profile to transfer specific objects between devices. Also used to send objects to a Bluetooth printer.
Generic Object Exchange Profile	Used as a foundation for other object-oriented profiles to perform tasks such as printing or file and business card transfers. IrDA replacement.	Used with an application layer to provide a method for file transfer, object push, or synchronization between two devices. Uses a Bluetooth version of the IrDA OBEX layer. (The OBEX layer is above the RFCOMM and L2CAP layers of the Bluetooth protocol stack.)
Human Interface Device (HID) Profile	Provides support for devices such as a Bluetooth mouse, keyboard, joystick, or gamepad.	Uses HID protocol from the USB specification. Provides quality of service for low-latency performance. On the PC, this is a new Bluetooth profile. Microsoft plans to make this profile available in a future version of the Pocket PC operating system.
Hard Copy Cable Replacement (HCRP) Profile	Allows two Bluetooth devices to establish the equivalent of a wired connection (for example, a Windows driver-to-printer connection).	Provides application-layer connectivity. The application and device must handle the protocol. For example, a Microsoft® Windows® driver formats the printer output that is sent over a Bluetooth HCRP connection to the printer, just as if it were a wired connection.
Audio Gateway/Headset Profile	Allows Bluetooth audio headsets to link wirelessly to telephony devices.	Uses a Synchronous Connection Oriented (SCO) channel for full-duplex telephony audio and an Asynchronous Connectionless Link (ACL) for control signaling. Provides telephony-grade audio, rather than high-fidelity stereo sound. May not be directly relevant for portable computer applications.
PAN Profile	Used to connect Bluetooth devices in a personal area network.	While the new PAN profile is not yet widely available, it is a fundamental profile being developed by the Bluetooth SIG that will be supported in future Microsoft operating systems.
File Transfer Profile	Used to transfer files between Bluetooth devices.	Allows files or folders to be browsed, pulled, pushed, and deleted between two devices. Files can also be transferred using the Object Push or PAN profiles. On the PC, the PAN profile may supersede the File Transfer profile over time.

**Table 1. Commonly Used and Implemented Bluetooth Profiles**

are optional. The authentication and encryption features use a 128-bit secret link key that is shared by a pair of devices. The key is generated when the two devices initiate communication. During initialization, a PIN code is entered to both devices and is used to generate an initialization key, which in turn is used to generate the secret link key. The link key is used for authentication and to derive an encryption key.

### **Service-Level Security**

After the Bluetooth link is established, service-level security governs access to the services on Bluetooth devices. This access can be limited at the device and service level. A Bluetooth device can be “trusted” or “untrusted” when attempting to access services on another device. A trusted device has unrestricted access to all services on the other device. In contrast, an untrusted device may have its access to services limited.

Dell recommends that customers configure each device and service with appropriate security measures based on the sensitivity of the data involved, the need to limit access to a particular device such as a printer, and so forth. For further Bluetooth security, Dell recommends that customers:

- Enable encryption of services.
- Avoid storing confidential files in a portable computer's Bluetooth shared folders.
- Avoid pairing devices in a public place where the signal can be easily picked up.
- Manage “discoverability” of your device by other devices.

For in-depth information on Bluetooth security, see the Bluetooth SIG website at [www.bluetooth.org](http://www.bluetooth.org). The SIG is working on updated PC security guidelines.

### **Coexistence with Wi-Fi Networks**

Because the 2.4-GHz radio spectrum is an unlicensed band, Bluetooth wireless technology shares it with other 2.4-GHz technologies, including cordless phones, microwave ovens, and 2.4-GHz Wi-Fi (802.11b and 802.11g) networks. Bluetooth devices must coexist with Wi-Fi networks. In the future, a common scenario will be the portable computer user who connects to a network via a Wi-Fi connection and who synchronizes with a handheld device via a Bluetooth link.

These two wireless technologies may interfere with each other when operating close together. The impact varies, depending on factors such as the distance from the 802.11b access point, the duration and timing of the Bluetooth and Wi-Fi transmissions, and the power of the devices.

These potential interference problems are limited by the “bursty” nature of Bluetooth and Wi-Fi connections. Bluetooth wireless technology is mainly used for short periods of time to perform operations such as synchronizing a mobile device to a PC several times a day. Thus, the opportunity for interference with an 802.11b connection is limited to these short periods of time. However, in a business environment with many active Bluetooth devices, the interference could be noticeable.

The industry has developed solutions to address this issue. The solutions use a variety of approaches, but generally the mechanisms used are either collaborative or noncollaborative. Collaborative mechanisms rely on Wi-Fi and Bluetooth technologies to communicate and collaborate with each other to minimize interference. These solutions require the Wi-Fi and Bluetooth devices be collocated and, thus, are suited to devices with integrated WLAN and Bluetooth capability. In contrast, in noncollaborative approaches, the devices do not communicate. Instead, the Bluetooth devices use various methods to alter their hopping sequence or packet scheduling to avoid channels with substantial interference. Dell systems with built-in Wi-Fi and Bluetooth radios are equipped with a solution that minimizes interference problems between the two technologies.

### **Software Support**

Because Bluetooth wireless technology is an emerging technology, a wide range of Bluetooth protocol stacks and associated software applications are provided by third-party software companies. The Dell solution on Latitude and Inspiron systems enables a portable computer to support a broad set of Bluetooth services and, thus, devices. With this type of solution, users are more likely to find common services between the devices and avoid interoperability issues.

If more than one Bluetooth protocol stack is installed on a portable computer, they are likely to conflict with one

another. For this reason, Dell recommends that customers with Latitude and Inspiron portables equipped with Dell's integrated Bluetooth solution carefully evaluate any software that accompanies new Bluetooth devices before installing it on their systems. The Dell Bluetooth solution supports many devices without the need to install an additional or replacement Bluetooth protocol stack.

Dell is working closely with Microsoft to address the protocol stack conflict issue in future releases of Microsoft Windows operating systems as Bluetooth services become part of the operating system. Because Bluetooth wireless technology is still maturing, the services supported by devices and the operating system may evolve. A good example is the new PAN profile, which is not yet supported by many products or devices. It promises to be a key profile and it will be integrated into Microsoft's future operating systems.

The next version of Microsoft's Pocket PC operating system (Pocket PC 2003) will include native support for the following Bluetooth services: serial port, object push, object exchange, and dial-up networking profiles. For current and future compatibility, Dell recommends that customers select devices and solutions that support the profiles listed in Table 1. Many less common profiles may not be supported by Bluetooth devices.

## Bluetooth Evolution

Dell is an adopter member of the Bluetooth SIG, which is working on new versions of the specification designed to lower the barriers to Bluetooth adoption. Version 1.2, which is expected to be released by early 2004, includes:

- Adaptive frequency hopping to reduce interference problems with other radios in the 2.4-GHz spectrum
- Faster connection time
- Improvements to accommodate streaming data
- Mechanisms to roam between piconets and establish scatternets

## Dell Bluetooth Solutions

Dell offers a Bluetooth solution on the Dell Axim X5 Pocket PC and the new D family of Latitude and select Inspiron portable computers.

### Dell Axim X5 Pocket PC

The Axim X5, which runs Pocket PC 2002, supports Bluetooth wireless technology through the Dell True-Mobile™ 300 CompactFlash adapter and associated software. This Bluetooth solution includes support for object exchange, serial port, synchronization, and dial-up networking, which allows the following services:

- Exchange of business cards, calendar appointments, and documents with other Bluetooth devices
- Accessing the Internet and corporate network using a mobile phone
- Synchronizing data on a computer that is equipped with Bluetooth wireless technology

### Latitude and Inspiron Portable Computers

The Bluetooth solution on the D family of Latitude and on select Inspiron portable computers includes integrated hardware (radio and baseband controller) that coexists with Dell's integrated Wi-Fi hardware. The solution also includes a Bluetooth application and driver stack that supports many of the key services presented in Table 1, including service discovery, serial port, dial-up networking, Generic Object Exchange, audio headset, and HID.

With its support for some of the most common Bluetooth services, this solution supports many Bluetooth devices typically used in conjunction with a portable computer such as PDAs (including the Axim X5 Pocket PC), mobile phones, printers, other portable computers, and the emerging mouse and keyboard devices that use a Bluetooth link instead of cables.

## Conclusion

Designed as a cable-replacement technology, Bluetooth wireless technology is well suited to the connectivity requirements of WPANs composed of portable computers, PDAs, mobile phones, and printers. It is ideally suited to mobile devices (particularly PDAs) because of their small size, low power requirements, and applications (mobile phone wireless WAN connectivity, peer-to-peer business card or calendar exchange, and wireless synchronization). As the technology matures, implementations increase, and native operating system support becomes available, interoperability and

ease-of-use issues should diminish. Dell is committed to providing Bluetooth solutions that meet customer needs, have been thoroughly tested for compliance, and coexist with Wi-Fi networks.

For more information on Bluetooth wireless technology, see [www.bluetooth.com](http://www.bluetooth.com) and [www.bluetooth.org](http://www.bluetooth.org).

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