CS2K707(P) Seminar Report

on

Bluetooth Technology

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by

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Certified that this Seminar Report entitled

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is a bonafide report of the Seminar presented by

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Abstract

Bluetooth is a Radio Frequency specification for short-range, point-to-point and point-to-multi-point voice and data transfer. Bluetooth will enable users to connect to a wide range of computing and telecommunications devices without the need for proprietary cables that often fall short in terms of easy-to-use. The report examines what Bluetooth is, what it is good for and who is promoting it. The specification and profiles show how the technology works and how it is used -are reviewed. Competing and complementary technologies are discussed, as well as specific issues such as co-existence with wireless ethernet. And finally, some early products and some proposed new usage examples are presented.

Contents

1 What is Bluetooth ?

1.1 Overview

Bluetooth has become the de-factor global standard for short-range wireless data communications that allows devices to communicate with each orther using secure radio waves, and is the basis for the IEEE 802.15.1 standard.

Bluetooth was originally conceived as a basic cable replacement technology.Bluetooth operates in the 2.4 GHz Industrial, Scientific, and Medical(ISM)band, which is already crowded,Bluetooth has been designed to operate in a noisy environment.

Bluetooth is designed for use in mobile devices, where size, cost, and battery life are key factors. It nominally operates with a 10-meter range, although higher-powered versions are available yielding a range up to 100 meters. Since it is a radio link, Bluetooth is not limited to line-of-sight and can pass through walls. It uses frequency hopping to change its frequency 1600 times a second in a random pattern, and employs 128-bit encryption at the link layer for added security.

1.2 What's in a Name ?

While many new technologies bear technical names,like RS-232 or IEEE 802.11b, Bluetooth, the wireless technology, is different.
Bluetooth was named after the 10th Centure Viking King, Harald Blatand(A.K.A., Bluetooth)who peacefully united all the tiny island kingdoms of Denmark, southern Sweden, and southern Norway into one country.In keeping with its namesake, Bluetooth eliminates the need for cabling in a wide range of products, including cellular phones, PCs, headphones, audio equipment, printers, and many more. It has huge industry support, with more than 2000 companies in the Bluetooth Special Interest Group(SIG), including leading players in the telecomunication and computing industries.

1.3 What is Bluetooth Good For?

Bluetooth was originally conceived as a basic cable replacement technology. It allows all the various interconnecting wires coming out of the back of a PC to be replaced by a single Bluetooth radio in each device. The cost of adding Bluetooth wireless capability is expected to be less than the cost of the cable it is replacing, especially when considering the additional cost of the connectors at the receiving end in a device that is already space-limited such as a PC, PDA, or cellular phone. Additional saving are realized in devices such as PCs where a single Bluetooth radio can replace several cables. Bluetooth usage model have quickly expanded beyond basic cable replacement into other realms.

Bluetoothh also enables wireless personal ad-hoc networks, known as PANs,or personal area networks. IEEE 802.15.1, which is based on the Bluetooth stand, defines a fixed personal operating space(POS), which is a fixed sphere of 10 meters radius around a person, whether stationary or mobil PANs allow your PDA to be synchronized with your PC automatically when you come within range. PAN also allow PCs to share data in a local peer-to-peer network without requiring the use of a fixed network infrastructure. Ultimately, Bluetooth's ability to inexpensively create wireless PANs will enable the creation of "smart environments" in which virtually any electronic device can be networked.

Bluetooth is also capable of acting as an access point to other networks, allowing, for instance, a PDA to browse the Internet via a cellular phone connection, or through an Internet-connected PC, or by directly connecting to a LAN access point.

1.4 Bluetooth Special Interest Group (SIG)

In 1994, Ericsson Mobile Communications decided to investigate the feasibility of a low-power, low-cost radio interface between mobile phones and their accessories. They quickly realized the true potential of the technology. In February 1998, the Spical Interest Group (SIG) was formed. Today, the Bluetooth SIG includes nine promoter companies, and over 2000 "early adopter" and associate member companies.

The original charter of the SIG was to monitor the technical development of a short-range radio and to create an open global standard, thus preventing the technology from becoming the property of any single company. The work resulted in the first Bluetooth spcification, issued in July 1999. The further development of the specification is still one of the main issues for the SIG.

1.5 Who Are the Bluetooth Promoters?

The most important number in the Bluetooth SIG is not the over 2000 members, it is one of the nine promoter companies. That number expanded in December 1999 with the addition of 3Com, Lucent Technologies, Microsoft and Motorala to the existing core of Ericcson, IBM, Intel, Nokia and Toshiba.

The group includes major hardware manufacturers from what are expected to be the early, dominant markets for Bluetooth phones and portable computers and is one of the reasons for the explosive growth in SIG membership. The inclusion of Microsoft ensures the Bluetooth support will find its way into desktop operating system, as well as handheld computers and other devices. Additionally, 3Com plans to include Bluetooth support in its new Palm OSversion 4.0.

Bluetooth is a trademark of Ericsson and is jointly promoted by the Bluetooth promoter companies. Although Ericsson invented the technology, the intellectual property has been placed in the public domain, and the SIG licenses the use of the technology royalty-free to SIG members.

2 The Bluetooth Specification

The Bluetooth specification, which is controlled by the SIG, defines a short-range radio link capable of voice or data communication with a maximum throughput of 720 kilobits per second, over a distance of roughly 10 to 100 meters. Key features are robustness, low complexity, low power, and low cost.

Radio frequency (RF) operation is in the unlicensed ISM band at 2.4 to 2.48GHz, using a spread spectum, frequency hopping, full-duplex signal at up to 1600 hops per second.The raw bit rate 1 Mbps. The signal hops in a random sequence among 79 slotted frequencies, with 1 MHz-wide channels, providing the link with a high degree of immunity to interference. RF output is specified as 0 dBm in the 1 milliwatt(mW) 10 meter range version, and -30 to +20 dBm in the expected to use short-range, 10 meter, radies.

The Bluetooth protocol uses a combination of circuit and packet switching. Up to three simultaneous 64 kb/s full-duplex voice channels are supported. Alternatively, a channel that simultaneously supports asynchronous data and synchronous voice may be used. The asynchronous data channel can support asymmetric data rates up to 723.2 kb/s with a 57.6 kb/s back channel, or a symmetric channel data rate of 433.9 kb/s in both directions.

When producing the radio specification, high emphasis was placed on developing a design that would enable single-chip CMOS implementations, thereby reducing cost, power consumption, and the chip size required for implementation in mobile devices. The device contains the RF radio, baseband controller and microprocessor on a single CMOS integrated circuit.

2.1 Core Specification

- Radio
- Baseband
- Link Manager Protocol(LMP)
- Host Controller Interface(HCI)
- Logical Link Control and Adaptation Protocol(L2CAP)
- RFCOMM
- Service Discovery Protocol(SDP)

The **Radio layer** defines the requirements for a Bluetooth tranceiver operating in the 2.4 GHz ISM band.

The **Baseband layer** decribes the specification of the Bluetooth Link Controller(LC) that carries out the baseband protocols and other low-level link routines.

The **Link Manager Protocol(LMP)** is used by Link Managers(on either side) for link setup and control.

The **Host Controller Interface(HCI)** provides a common interface to the Baseband Link Controller and Link Manager, and access to hardware status and control registers.

The **Logical Link Control and Application Protocol(L2CAP)** supports higher-level protocol multiplexing, packet segmentation and reassembly, and the conveying of quality of service information.

The **RFCOMM** protocol provides emulation of serial ports over the L2CAP protocol. The protocol is based on the ETSI standard TS 07.10.

The **Service Discovery Protocol(SDP)** provides a means for applications to discover which services are provided by or available through a Bluetooth device.

2.2 Network Topology

Bluetooth units that come within range of each other can set up ad-hoc point-to-point and/or point-to-multipoint connections. Units can dynamically be added to, or disconnected from, the network. When two or more Bluetooth units share a channel, they form a piconet.

- A device can be a master, a slave, or both.
- A master can share an asynchronous channel with up to 7 simultaneously active slaves in a piconet.
- To support more than 7 slaves, or to save power, devices can be "parked" in one of several low-power modes.
- By swapping out active and parked slaves in the piconet, up to 255 slaves can be virtually connected using a park address. In this mode, a device can participate again within 2ms.
- To park even more slaves, a 48-bit device address is used. Practically, an unlimited number of slaves can be parked in this manner.
  Slaves can participate in different piconets, and a master of one piconet can be slave in another -this is know as a scatternet.

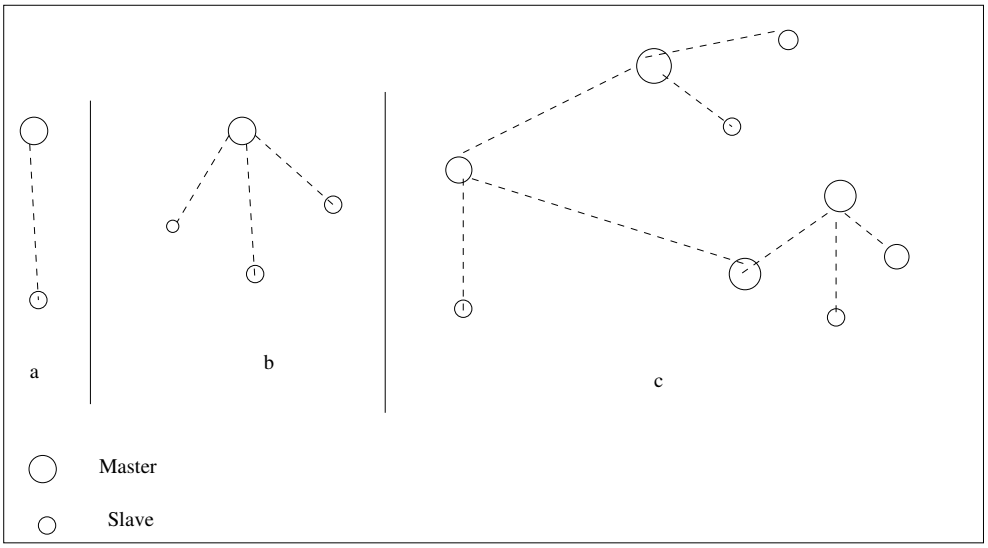

Figure 1: Piconets with single slave (a), multiple slaves (b), and a scatternet (c).

For example, a cellular phone may be a piconet master with a headset as a slave. Additional slaves may be added to the piconet, such as, PADs and PCs. This cellular phone may also be a slave in another piconet to master landline phone base unit.

Several piconets can be established and linked together in ad-hoc scatternets, where each piconet is identified by a different frequency hopping sequence. ALL users participating on the same piconet are synchronized to this hopping sequence. The topology

can be decribed as a multiple piconet structure.

The full-duplex data rate within a multiple piconet structure with 10 fully loaded, independent piconets is more than 6 Mb/s.

2.3 Physical Channel

The Bluetooth radio channel is represented by a pseudo-randam hopping sequence that hops through 79 RF channels. The channel is divided up into time slots, each 625 microseconds in length, yielding a nominal hop rate of 1600 hops per second. Each slot corresponds to an RF hop frequency and is numbered according to the clock of the piconet master. The slot numbering ranges from 0 to 227-1 and is cyclic with a cycle length of 227. The equates to a channel hopping sequence cycle time of approximately 23.3 hours.

To achieve full-duplex operation, a Time Division Duplex (TDD) scheme is used where master and slave alternatively transmit.(fig 2)

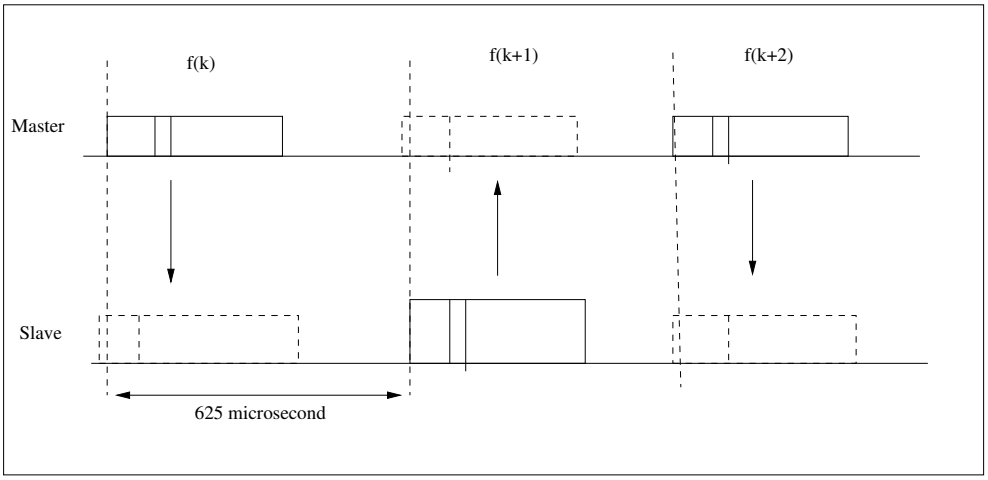

Figure 2: TDD and timing

The master starts its transmission in even-numbered time slots only, and the slave starts its transmission in odd-numbered time slots only. Packets transmitted by the master or the slave may extend over up to five time slots(fig -3). The RF hop frequency remains fixed for the duration of a multi-slot packet. The RF hop frequency of the first slot after a multi-slot packet is determined by current Bluetooth clock value.

3 Functional Overview

The Bluetooth baseband decribes the specifications of the digital signal processing part of the hardware, the Bluetooth link controller, which controls how connections in a piconet are created and maintained. Bluetooth radios transition through the following connection states during normal operation.

* Standby- Waiting to join a piconet
* Inquire- Ask about to connect to
* Page- Connect to a specific radio
* Connecteed- Actively on a piconet(master or slave)

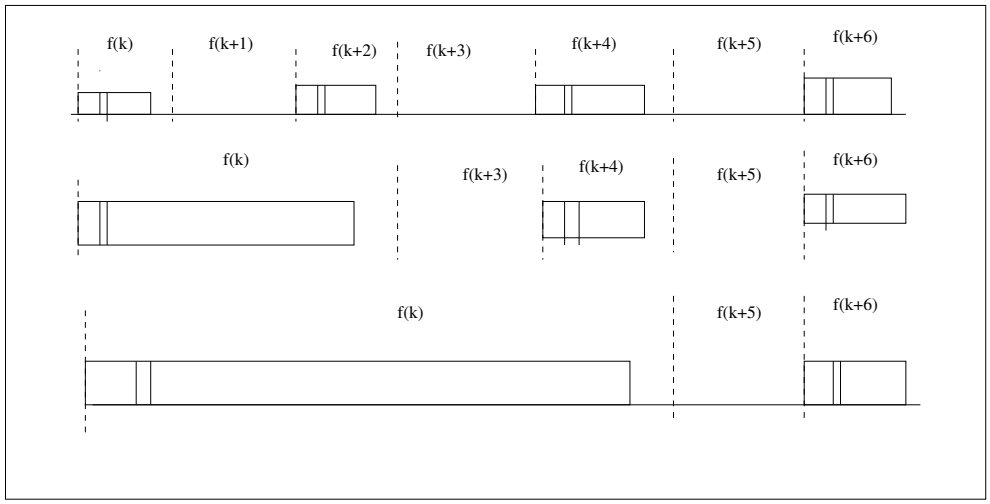

Figure 3: Multi−Slot packets

∗ Park/Hold/Sniff- Low power connected states
Figure 4 illustrates the Bluetooth radio's functional states, along with typical state transition times. Note that the typical time is about 2 seconds but may be as long as 10 seconds, which may preclude using Bluetooth for high-speed "drive by" applications involving moving vehicles and fixed acces point.

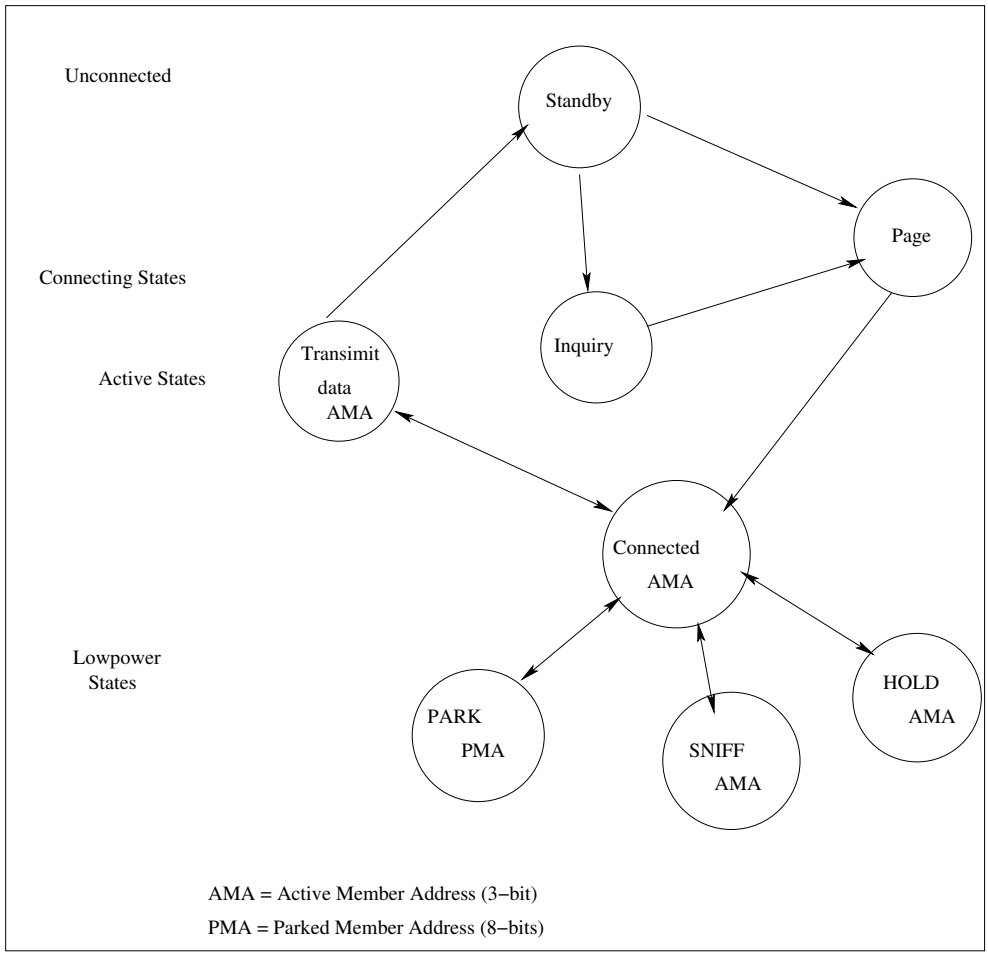

Figure 4: Functional State Diagram

3.1 Protocol Stack

Figure illustrates how the various core components fit together to form the basis foundation of the Bluetooth protocol stack. Some components are Bluetooth spe-

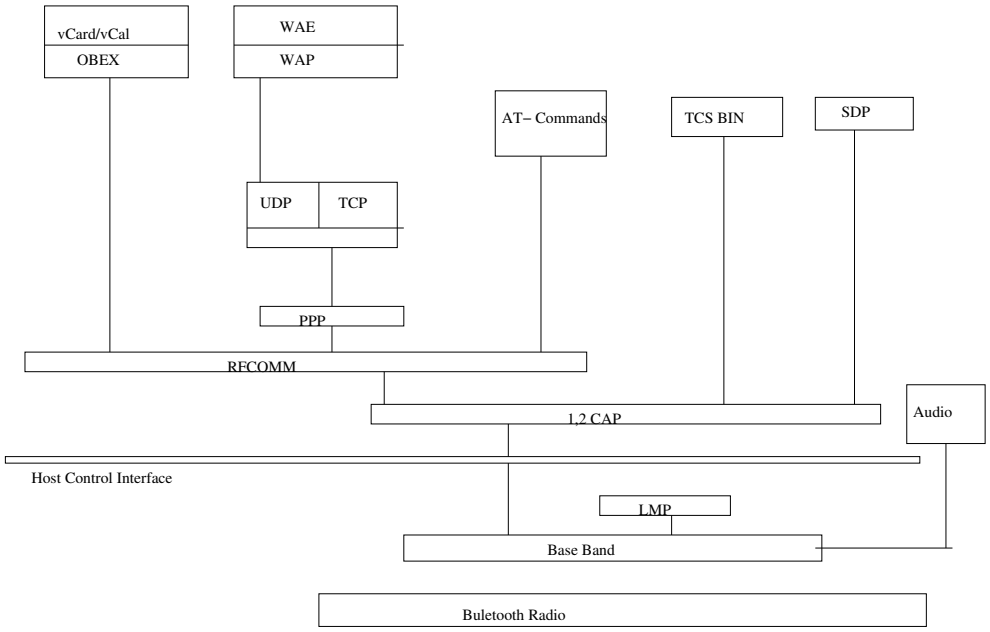

Figure 5: Bluetooth Protocol Stack

cific(the core components), some are reused from other specifications (IP, WAP) and others have been modified for the Bluetooth protocol stack(vCard/vCal, WAE, Audio).

The most interesting core components from the practical application point of view are RFCOMM and Service Discovery Protocol.
It is the Service Discovery Protocol that different Bluetooth from most other wireless technology, enabling the concept of a PAN devices are capable of spontaneously joining into a network as they approach each other, staying only while they are in close proximity, and spontaneously leaving the network when they are not in close proximity.

3.2 Profiles

The profiles describe how different parts of the specification can be used to fulfill a desired function for a Bluetooth device. Profiles represent the default solution for a usage model and form the basis for Bluetooth devices.

Each Bluetooth device must support at least one profile, but may support several profiles. The idea is that if two devices support the same profile, then they should be able to interoperate.

The profiles specification in version 1.1 of the Bluetooth specification are

· Generic Access Profile(GAP)
· Service Discovery Application(SDAP)
· Cordless Telephony Profile (CTP)
· Intercom Profile(IP)

- Serial Port Profile(SPP)
- Headset Profile(HP)
- Fax Profile(FP)
- LAN Access Profile(LAP)
- Generic Object Exchange Profile(GOEP)
- Push Profile(OPP)
- File Transfer Profile (FTP)
- Synchronization Profile(SP)

The **Generic Access Profile** defines the generic procedures related to discovery of Bluetooth devices and link management aspect of connecting to Bluetooth devices. It is the core on which all other Profiles are based.

The **Service Discovery Application Profile** defines the features and procedures for an application in a Bluetooth device to discover services registered in other Bluetooth devices and retrieve any desired available information pertinent to these services.

The **Cordless Telephony Profile** defines the features and procedures that are required for interoperability between different units active in the 3-in-1 phone use case. This profile also shows how the use case can be applied generally for wireless telephony in a residential or small office environment.

The **Intercom Profile** defines the requirements for Bluetooth devices neccessary for the support of the intercom functionality within the 3-in-1 phone use case. This is also referred to as the 'walki-talkie' usage of Bluetooth.

The **Serial Port Profile** defines the requirements for Bluetooth devices necessary for setting up emulated serial cable connections using RFCOMM between two peer devices.

The **Headset Profile** define the requirements that shall be used by devices implementing the usage model called 'Ultimate Headset'.

The **Dial-up Networking Profile** defines the requirements that shall be used by devices(modems, cellular phones) implementing the usage model called 'Internet Bridge'.

The **Fax Profile** defines the requirements for Bluetooth devices necessary to support the fax use case. This allows a Bluetooth cellular phone(or modem) to be used by a computer as a wireless fax modem to send/recive a fax message.

The **LAN Access Profile** defines how bluetooth enabled devices can access the services of LAN. Also, this profile shows how the same mechanisms are used to form a network consisting of two Bluetooth-enabled devices.

The **Object Push Profile** defines the requirements for applications providing the object push usage model. Typical scenarios covered by this profile involve the pushing/pulling of data objects between Bluetooth devices.

The **File Transfer Profile** defines the requirements for applications providing the file transfer usage model. Typical scenarios involve a Bluetooth device browsing, transferring and manipulating objects on/with another Bluetooth device.

The **Synchronization Profile** defines the requirements for applications providing the synchronization usage model. Typical senarios covered by this profile involve manual or automatic synchrinization of data when two Bluetooth devices come within range.

3.3 Profile Structure

The Bluetooth profile structure and dependencies are depicted in figure 6. A profile is dependent upon another profile if it re-uses parts of that profile, by implicitly or explicitly referencing it. Dependency is illustrated in the figure: a profile has dependencies on the profile in which it is contained-directly and indirectly. For example, the Object Push profile is dependent on Generic Object Exchange, Serial Port, and Generic Access profiles.

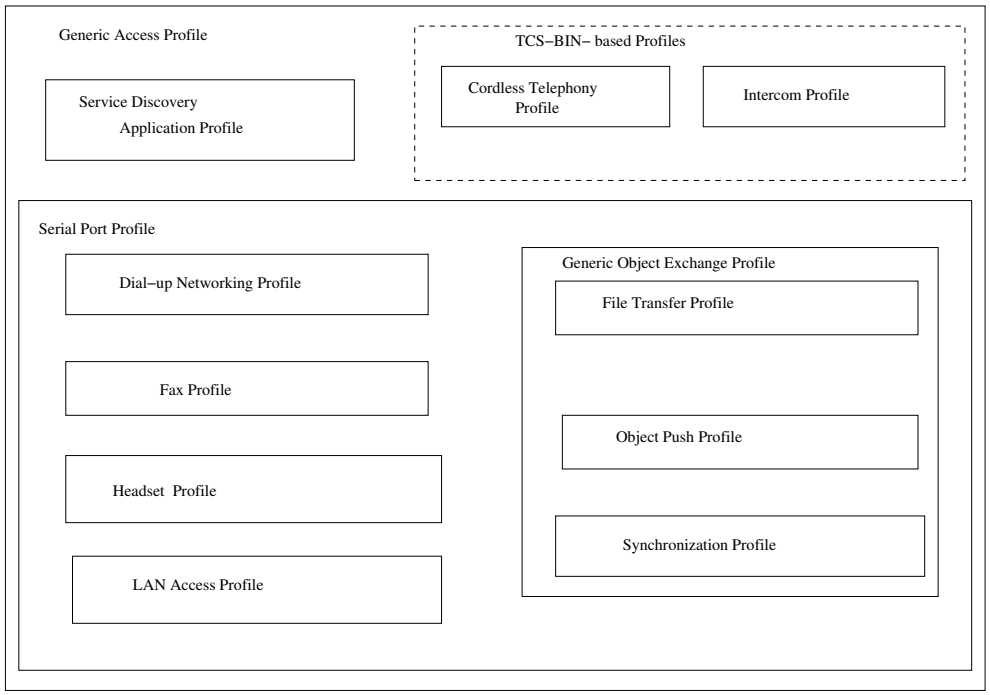

Figure 6: Bluetooth Profile structure

The key challenge and primary reson for the delay in Bluetooth adoption has been getting Bluetooth-enabled products to work in interoperability test with other product.

4 Early Products And Prototypes

4.1 Plug-in models

Initial product consist of plug-in modules to allow to Bluetooth-enable existing devices.

These are basic cable replacement devices that interface through existing ports, and include the following:

- PCMCIA card
- USB dongle
- Memory Stick
- LAN access points
- Cellular phone dongle

4.2 Digital image messaging

Bluetooth-enable Nokia 9110 and FujiFlim digital camera that can communicate with one another using Multimedia Messaging Services (MMS).

4.3 Bluetooth infowear

In what the Bluetooth community calls "unconscious" or "hidden" computing, Bluetooth-enabled products will automatically seek each other out and configure themselves into networks - most often, with just two nodes. Thugh small, such networks can be quite useful.

4.4 Bluetooth Pen

With the Bluetooth pen, e-mails, faxes and e-commerce orders can be sent electronically by simply putting pen to paper. The technology was developed by Ericsson, Anoto and time Manager and is scheduled for introduction in the second half of 2001.

4.5 Xyloc

Ensure Technologies patented Xyloc technology allows a user to wear a key in the form of an ID badge-sized KeyCard or small, pager-sized KeyFob. A Lock attaches to the user's PC through the Keyboard, USB or serial port. The Lock and Key use an encrypted two-way Bluetooth radio link to identify the user to the Xyloc software on the computer.

When a user approaches a Xyloc secured computer, the Key transmits a uniquely encrtpted code to the Lock, which relays the information to a security database for validation. If the user is authorized, the system unlocks the keyboard and screen; if unauthorized the system remains secure. When the user steps away from the computer, Xyloc immediately and automatically secures the computer.

5 Bluetooth And Wireless Ethernet

As enterprises are installing wireless ethernet in the bulidings, Bluetooth is coming and it will be in everything from cellular phones to PCs. Intel currently estimates as many as 80 percent of all notebooks will come equipped with Bluetooth by 2005.

Both Bluetooth and 802.11b operate in the 2.4 GHz unlicensed frequency band, which means that they can be used virtually anywhere in the world. The physical layers are different, since Bluetooth uses the frequency hopping method and 802.11b generally uses direct sequence spread spectum.

There are actually three different variatiants of 802.11b. One version does use frequency hoppping, but because Bluetooth hops 600 times as fast, it is anticipated that when these two collide, Bluetooth will have quickly recovered and continued hopping along, long before 802.11b even detects that there has been a collision. It is for this reson that Bluetooth has the potential to severely disrupt 802.11b in the same environment, despite 802.11b's much higher power output.

Ultimately, at about the same time that the cost of integrating Bluetooth drops to the point that it starts appearing in PCs as standard equipment, 802.11b may be replaced by much speedier 802.11 a-based radios as the preferred means of high-speed LAN access, especically in corporate campus environments. Operating in the 5 GHz band and away from Bluetooth interference, 802.11a is capable of 54 Mbps, or higher, throughput.

6 Application

Hotels are testing, or plan to test, services that allow guest to check in unlock room doors and even control room temperature with handheld devices equipped with Bluetooth Technology.

The Holiday Inn Wall Street in New York allows some travelers to check-in via Bluetooth-enable Ericsson handset phones. When the services is rolled out, guests with Bluetooth-enabled phones will provide credit card and phone numbers when they make reservations. When they enter the hotel, if their phones are on, they will automatically receive a message from the hotel's computer asking if they want to check in. After they enter the PIN they received when they booked, the computer will send back message with their room number. Guests will also be able to unlock their room doors using their phones.

Ericsson and ICA Ahold have conducted trials of e-payment via Bluetooth in retail stores. Using mobile phones with Wireless Application Protocol (WAP) and Bluetooth technologies, customers have been able to pay for goods, check their accounts and find out about current offerings. This method of making payments is both faster and easier than regular purchasing with cash or credit card.

7 Conclusion

Bluetooth is an enabling technology. As such, it is poised to change our world in ways we cannot imagine. New usage will emerge as a result of this new technology.

Bluetooth will enable a technology like WAP to finally achieve widespread acceptance through the use of PDAs as the user interface instead of the current display-limited cellular phones.

In order for Bluetooth to be successful, however, the first user experiences must be pleasurable. Installation, setup and operation must be simple, and it must work the first time out of box. Devices must be able to interoperate as expected, flawlessly.

Bluetooth fits best in low-power mobile devices for use in PANs. It should not try to compete with wireless LAN technologies, but it needs to co-exist with them.

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