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BLUETOOTH WIRELESS TECHNOLOGY: A MILESTONE IN ICT

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ABSTRACT

This article summarizes the Bluetooth technology – a type of Wireless Personal Area Network (WPAN) with emphasis on the pivotal role of Bluetooth enabled devices in ICT. The areas of application of Bluetooth technology, its security, basic design and architecture, and likely future trends in its applications are also discussed with a view to highlighting its major significance. Bluetooth was compared with other wireless communications technologies specifically Infrared Data Association (IrDA) and Wireless Fidelity (Wi-Fi®) showing their dissimilarities and, above all, the advantages of Bluetooth wireless protocol over the other wireless technologies which have made it a topic of discourse in ICT are discussed.

KEY WORDS: Bluetooth Protocol, Bluetooth Wireless Technology, PICONET, Bluejacking, ISM,

INTRODUCTION

Bluetooth takes its name from the 10th century Viking king, Harold Blatand or Harold Bluetooth in English, son of the first king of Denmark. He is said to have got the name from a penchant with blueberries. Harold Bluetooth is reputed to have been responsible for uniting the warring factions in parts of what is now Sweden, Denmark and Norway. Developers of the Bluetooth technology saw in this legend a parallel with what they aimed to do: cause convergence in the telecommunications, computing, automotive and network industries and so bestowed their project with the name Bluetooth (Vworld, 2005). Bluetooth is a standard developed by a group of electronic manufacturers – the Bluetooth Special Interest Group that allows any sort of electronic equipment to make its own connections without wire, cables or any direct action from a user.

The Bluetooth technology is a wireless protocol utilizing short range communications technology facilitating data transmission over short distances from fixed and mobile devices creating Wireless Personal Area Network (WPAN). 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 Local Area Network technology, Bluetooth wireless technology is designed as a cable replacement technology"(Bhagwat, 2001).

The intent behind the development of Bluetooth was the creation of a single digital wireless protocol, capable of connecting multiple devices and overcoming problems arising from synchronization of these devices. Bluetooth uses a radio technology called frequency hoping spread spectrum. It chops up data being sent and transmits chunk of it on up to 79 different frequencies in its basic mode, the modulation is Gaussian Frequency Shift Keying (GFSK). It can achieve a gross data rate of 1mb/s.

The Bluetooth SIG developed Bluetooth as a range radio technology communicating on 2.45GHz, that makes it possible to transmit signals within a 10m range between what is known as your Personal Area Network (PAN) providing data, voice and audio connections. Bluetooth is a standard and communications protocol primarily designed for low power consumption, with a short range (power-class-dependent: 1m, 10m, 100m) based on low-cost transceiver microchips in each device. Bluetooth makes it possible for these devices to communicate with each other when they are in range. Since the communicating devices are using RF communications system they do not need to be in line of sight of each other.

All Bluetooth enabled devices are grouped into various classes using the range of transmission as a criteria, there are three known common classes-class1(100m), class2(10m) and calss3(1m). In most cases the effective range of class 2 or 3 devices is extended if they connect to a class 1 transceiver compared to making connections to a pure class 2 or 3 network. The higher sensitivity and transmissions power of class 1 devices can achieve this.

The 2.4GHz Industrial Scientific and Medical (ISM) is the frequency of interest for WPANs like infrared data association (IrDA- Data) and Bluetooth world wide because of its general availability and suitability for low cost radio solutions.

Although both IrDA and Bluetooth are WPANs they have a number of dissimulation,-IrDA uses direct infrared communication while Bluetooth employs RF communication. The IrDA uses low level security during connection of devices because it requires direct line of flight between the transmitter and receiver.

While synchronizing information between a cell phone and a PC one do not need its take out the phone from ones purse or pocket because of the unidirectional

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capability of Bluetooth that does not require that the phone remain in a fixed position for the IrDA the phone must be placed in the proper location and remain stationary while the synchronization executes. Bluetooth provides authentication and encryption in the base band protocol as means of security. Authentication is based on a challenge repose protocol using secret key (Passwords or Pins).

There is a type of wireless local area network (WLAN) called Wi-Fi that uses the same frequency range as Bluetooth although with different modulation techniques. Wi-Fi differs from Bluetooth in that it provides higher throughput and covers greater distances, but requires more expensive hardware that consumes more power. Wi-Fi is a replacement for cabling for LANS, It is also like a traditional Ethernet network and requires configuration to set up shared resources to transmit files and to set up audio links. Hence Wi-Fi requires more set up, enables faster connection, better range from the base station and better security than Bluetooth.

Bluetooth is a replacement for cabling in a variety of small scale applications. Bluetooth protocols simplify the discovery and setup of services between devices. Bluetooth enabled devices can advertise all of the services they provide. This makes using services easier because more of the security, network address and permission configuration can be automated then with many other WPANS and WLANs.

TECHNOLOGIES

Wireless Area Network

There are presently two types of technologies provided for use in WPANs. These are Bluetooth and IrDA-data. IrDA-Data is based on infrared (IR) communication and provides a simple inexpensive means of short range fast data rate for wireless data communication. Bluetooth is based on radio frequency (RF) communication and provides short – range, low power and high – bandwidth data connections (Infrared Data Association, 1998). The focus of this write-up is on Bluetooth wireless technology.

Bluetooth

Curt Franklyn of How Stuff Works explained the Bluetooth technology in this way 'just a our PCs are connected to a CPU which can connect to a keyboard, scanner and printer and just like a TV can use a remote control device and also connect to a DVD and VCR and also like a CD player can connect with a receiver and speakers by use of wires, cables and infrared devices plugs and protocols, so does the Bluetooth work. Only that it works by means of an intelligent radio chip embedded in the phone and other Bluetooth enabled devices to connect an array of divergent communication equipment thus forming a community of communication devices, but absolutely without wires. With this technology one can enjoy point to point communication between two devices (a "master" and a "slave") or point to multipoint communication with a "master" device communicating with up to seven "slaves". However, note that the total transfer speed will be shared among several slaves because all that traffic will pass through one master device. This means that you can multitask: make a call on your phone surf the net and send data to your printer all at the same time with no interference (Vworld, 2005)(How Stuff Work, 2009).

The Bluetooth technology was developed to provide a wireless interconnection between small mobile devices and their peripherals. Target markets were the mobile computer (portables), the mobile phone, small digital assistants and peripherals. These markets were represented by the companies that created the technology: Intel, 3COM, Ericsson, IBM, Motorola, Nokia and Toshiba, they were further supported by 1600 other early adopter companies. The goals of the technology did not include developing another Wireless Local Area Network (WLAN) technology for which there were already many in the market and many were being developed[Rechard et al 2003]. It is worthy of note here that the WLANs are specifically designed to effectively satisfy a large group of people over a common backbone, while Bluetooth technology was designed to connect mobile devices over a personal and private connection. The Bluetooth technology is designed to actually clone the capabilities, cost effectiveness and security facilities provided by common cables carried by mobile travelers. It is expected that the technology must support the types of data used by mobile users and must have a low power consumption rate and must be compact to support the small and portable devices into which the technology must be integrated. It must also be global as the mobile devices will travel and must work with devices found in other parts of the world (Chine, 2006).

Bluetooth is a Radio Frequency (RF) specification for short-range, point to multipoint voice and data transfer. It can transmit through walls with a link range of up to 10 meters. It is designed to facilitate ad-hoc connections for stationary and mobile communication environments. Bluetooth technology can be used in devices such as phones and pagers, modems, LAN access devices, headsets, notebooks, desktop and hand held computers (BSIG, 1999).

GENERAL FEATURES OF BLUETOOTH

Major features of the Bluetooth are the following:

1. Operates in the 2.4 GHz Industrial, Scientific and Medical (ISM) band.
2. Has major support for both synchronous and asynchronous data.
3. Transmissions are capable of penetrating walls.
4. Has built-in security at the link level.
5. Uses frequency hopping.
6. Omni-directional transmission.
7. Can support up to eight devices in a Piconet.

BLUETOOTH BASIC DESIGN/ARCHITECTURE

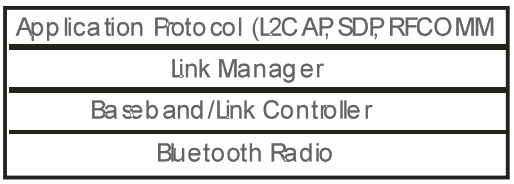

Figure 1: Bluetooth Basic Design/Architecture

Using figure 1 above the Bluetooth design can be divided into the following:

Application Protocols: This allows interfacing with upper layer applications.

Link Manager: The Link Manager coordinates how data is transmitted.

Base band/Link controller: This takes care of processing the transmitted data.

Bluetooth Radio: It carries out the receiving and transmission of data and voice.

For a Bluetooth device to operate it must meet the ISM band of between 2.4 to 2.5 GHz worldwide and 2.44 to 2.4835 GHz for Europe and USA. This band is open to any radio system cordless telephones, garage doors and microwave ovens (Chatschik, 1999). The hardware that converts incoming radio signals into a digital form for further processing by the host application is called a Baseband. While the link controller acts as a watchdog in sending and receiving data, identification of the sending device and final authentication of the link, it also coordinates the way devices listen to transmission from other devices. The Bluetooth technology accepts two link types: the Synchronous Connection Oriented (SCO) which supports symmetrical circuit switched point to point connections used specifically for voice communications. The Asynchronous Connectionless (ACL) link is the second link type and supports symmetrical and asymmetrical packet-switched point to multipoint connections used for packet data. The data rate used for SCO links is 64 kbits/s. ACL links can reach maximum of 721 bits/s in one direction and 57.6 kbits/s in the other direction if no error connection mechanism is used.

Management of the entire communication between Bluetooth enabled devices is done by the link manager. Bluetooth units connect to each other forming a Piconet which consists of up to eight active devices. The link manager tries discovering other remote Bluetooth link managers to achieve a link and also setup security and configuration (Bluetooth White Paper, 2000).

Application Level Protocols (Bluetooth Protocol Stack). Bluetooth Protocol Stack is defined as a layer protocol architecture consisting of core protocols, cable replacement protocol, telephony control protocols, and adopted protocols. The mandatory protocols for all Bluetooth stacks are L2CAP and SDP while HCI and RFCOMM are additionally universally supported protocols.

- **L2CAP** – The Logical Link Control and Adaptation Protocol is used to multiplex multiple logical connections between two devices using different level protocols. It provides segmentation and reassembly of on-air packets. L2CAP packet payload can be configured to about 64 kb, but the minimum mandatory supported size is 672 bytes [Wikipedia, 2009].

- **SDP (Service Discovery Protocol)** – checks for the availability of some specific services and finally determines the characteristics of those available services. It allows devices discover what services each other support, and what parameters can be used in connecting them. SDP can be used to determine which Bluetooth profiles are supported by the headset and the protocol multiplexor settings needed to connect to each of them while connecting a mobile phone to a Bluetooth headset. Each service is identified by a Universally Unique Identifier (UUID).

- **RFCOMM (Cable Replacement Protocol)** – Radio Frequency Communications (RFCOMM) is the cable replacement protocol used to create a virtual serial port used to make replacement of cable technologies transparent through minimal modification of existing devices (Wikipedia, 2009). RFCOMM is a transport protocol formulating EIA-232 (formerly RS-232) serial ports over L2CAP protocol (Chine, 2006).

- **LMP (Link Management Protocol)** – controls the radio link between two devices. It is implemented on the controller.

- **HCI (Host/Controller Interface)** – Achieves an efficient communication between the Host stack (e.g. a mobile phone OS or PC) and the controller (the Bluetooth I.C.). It enables the host stack or controller I.C to be swapped with minimal adaptation. HCI has several standards, each uses different hardware interface to transfer the same command, event and data packets. The most commonly used hardware interfaces are USB (in PC) and UART (in mobile phones and PDAs). For devices that having simple functionality such as headsets the host stack and controller are implemented on the same microprocessor.

There are other protocols in the Bluetooth stack such as BNEP (Bluetooth Network Encapsulation Protocol), AVCTP (Audio/Visual Control Transport Protocol) and Adapted Protocol from the internet such as UDP/TCP/IP, PPP and WAE/WAP which are not of much importance to this discussion.

NETWORKING VIA BLUETOOTH ENABLED DEVICES

For communication to take place between Bluetooth units, one must be the master and the others act as slaves. Interference is avoided by using a Frequency – Hop (FH) spread spectrum technology which is very efficient for low – power, low – cost radio

implementation. The Bluetooth main advantage is the high hop-rate due to the choice of parameter of 1600 hops per second with a shorter packet length. Bluetooth devices avoid attenuation. Every frequency band in FH system has hop channels which are merely fractions in the frequency band. In Bluetooth one channel is used in 625μs (one slot) followed by a hop in a pseudo random order to another channel from another 625μs transmission repeated constantly. This enables the Bluetooth traffic achieve a wider hopping spread which allow the traffic cover the entire ISM band, thus achieving a system with good interference protection (Chine, 2006).

The master unit's identity and system clock are pivotal elements in the frequency hop technology. The hop sequence and its phases are used to determine the hop channel, the identity of the master determines the sequence and the master unit's system clock determines its phase. The slave unit uses an offset in its system clock to create a copy of the master's clock. This is the way every unit in the Bluetooth connection hold synchronized clocks and the master identity that uniquely identifies the connection. Figure 2 shows how synchronized hops with the master can be achieved.

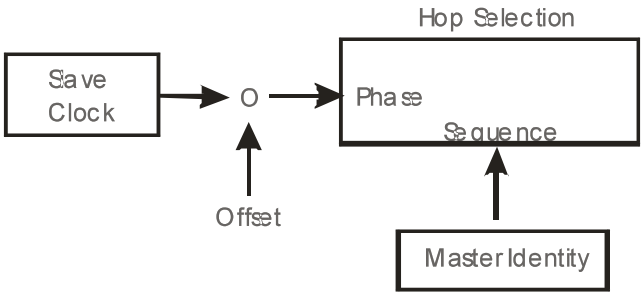

Figure 2: The Hop Selection

Since Bluetooth packets have fixed format, the master's identity and master's system clock are combined to achieve a 72 bit access code which comes first in the packet. This provides a means for synchronization. This code is unique for the channel and must be used by all packets transmitting on a specific channel. Immediately after the access code is a 54 bit header which contains error correction, retransmission and flow control information. The last in the sequence is the payload and the header.

Remember as discussed earlier that Bluetooth units operate on the ISM band at 2.45 GHz. The transmitting power is between 1 and 100 MW. This low power consumption makes Bluetooth units operate from power supplied by small battery for a long time (12 months). Facts have shown that Bluetooth has a maximum range of 10m with a great possibility of extending it to 100m. While the maximum bit rate is 1Mbit/s. But due to the different protocol layers which act as inhibition to the data payload, the maximum effective payload is placed at about 721 kbits/s. Due to the frequency hopping scenario where the link types may be changed during a session, the SCO and ACL are the link types in the Bluetooth technology. When two Bluetooth devices come together and form an ad-hoc connection called a Piconet, the number of devices allowed in a Piconet is unlimited even though only eight devices can be active at a particular point in time. There is no difference between the hardware or software in a master or slave. The first unit that makes the connection is the master unit. The roles in a Piconet can change but there can never be more than one master. The master unit controls all traffic in the Piconet by allocating capacity for SCO links and handling a polling scheme for ACL links.

APPLICATIONS, FUTURE TREND AND SECURITY OF THE BLUETOOTH TECHNOLOGY.

Applications of Bluetooth

The use of Bluetooth wireless technology is the way the world will likely go in the nearest future. Since its first release in 1998, Bluetooth SIG attests that over 3400 companies in the year 2005 already signed up with the pro-Bluetooth group (Vworld, 2005). The number has been increasing yearly till date. Virtually all phone hardware and software companies are members, including networking, computing and medical industries. In the same year, 2005, the Bluetooth SIG in its press release puts Bluetooth shipment figures at about five million per week (Vworld, 2005). Since the year 2003 Fedex has streamlined its package and logistics operations by the use of Bluetooth enabled handheld computers and barcode scanners. And in far Australia the Cocacola company has equipped its field sales and marketing personnel with Bluetooth enabled ThinkPad's and phones which allow them log on to the internet for updating client information, e-mail and to also have access to company network with ease (Vworld, 2005). Bluetooth exists in many products, such as telephones, play stations 3, and recently, in some high definition watches, modems and headsets.

Future Trends

Some anticipated future developments in the Bluetooth wireless technology (with some currently in use) are listed below.

- Integrated Broadcast Channel
- Automatic topology management
- Alternate MAC and PHY transportation
- Quality of service improvement

The integrated Broadcast Channel will be based around ability of users to pull information from information points which brings about an enhancement in Bluetooth units for carrying out advertisement. Automatic topology management brings about the automatic configuration of the Piconet topologies when Bluetooth units are connected. The Alternate MAC and PHY's method for transporting Bluetooth profile data when lot of data is to be sent. This means that the high speed MAC, PHY's transportation will only be used to transport data using its low power per bit radios when a large amount of data is to be transmitted. However, the Bluetooth radio will still be used for device discovery, initial connection and profile discovery. The quality of service of Bluetooth devices are intended to be further improved to enable audio and video data transmission of a higher quality, especially when several Bluetooth units using their best effort to transmit within a Piconet traffic.

Security

In September 2008, the National Institute of Standards and Technology (NIST) in UK published a guide to Bluetooth security that will serve as reference to organizations on the capabilities of Bluetooth and steps for securing Bluetooth technologies effectively. While Bluetooth has its benefits, it is susceptible to denial of service attacks, eavesdropping, man-in-the-middle attacks, message modification and resource misappropriation. Users/organizations must evaluate their acceptable level of risks included in the NIST document as security checklists with guidelines and recommendations for creating and maintaining secure Bluetooth Piconets headsets and smartcard readers (Wikipedia, 2009).

Bluetooth units are always paired before there can be any communication between them in order to avoid others listening in. Bluetooth implements confidentiality, authentication and key derivation with custom algorithms. Bluetooth key generation is generally based on Bluetooth PIN which must be entered into devices willing to communicate. Using this PIN safeguards against others with wireless Bluetooth headset from being able to hear your phone conversations or retrieve your data on another pocket PC. Another security measure used in Bluetooth electronic equipment is the ability to hop between 79 frequencies 1600 times per second, which makes it virtually impossible for anyone to listen in. The encryption of data sent between two units could as well stop eavesdropping. There is presently a security concern called Bluejacking, whereby an impostor sends a picture or a message from one user to an unsuspecting user through Bluetooth wireless technology. Most common messages are advertisement and short messages that means no harm. Bluejacking does not involve the removal or alteration of any data from the device.

FIGURES OF MERIT OF BLUETOOTH TECHNOLOGY

1. Innovation in the Bluetooth technology A responsibility of the SIG. the Bluetooth wireless technology is set to revolutionize the personal connectivity market by providing freedom from wired connections for portable handheld devices. The Bluetooth SIG is driving development of the technology and bringing it to the market (Chine, 2006).

2. Bluetooth uses low energy
   On june12, 2007, Nokia and Bluetooth SIG announced that Wibree will be a part of the Bluetooth specification, as an ultra low power Bluetooth technology. Battery life for devices using Bluetooth low energy is designed to last up to one year (Wikipedia, 2009).

3. Bluetooth technology has versatile applications more prevalent applications for Bluetooth includes wireless control of communication between a mobile phone and hands-free headset, transfer of contact details, calendar appointments and reminders between devices with OBEX (Vworld, 2005).

4. Bluetooth is a replacement for cabling Bluetooth is a replacement for cabling in a variety of small scale applications (Chine, 2006).

5. The Bluetooth protocol stack eases connections and enhances security Bluetooth is defined as a layer protocol architecture consisting of core protocols, cable replacement protocols, telephony control protocols and adopted protocols. This protocol when combined together allows seamless communication between portable devices with enhanced security (Chine, 2006).

6. Bluetooth uses the advanced ISN band Bluetooth operates in the ISN band, the ISN band is open to any radio system, cordless telephones, garage doors openers and microwave ovens operates in this band. To meet the requirement for the interface on frequency band between 24.00 and 2.500GHz must be selected.

Generally, it is expected that Bluetooth wireless technology will bring about a high level of innovation in the area of wireless communication because of its comparative advantage in power consumption which pretends a great potential for its continuous use application for years to come.

The intent behind the development of Bluetooth technology by SIG is creation of single digital wireless protocol capable which can also overcome problems and from the synchronization of such Bluetooth enabled devices. The enormous advantages of Bluetooth over IrDA in line higher data throughput, low power disruption and higher level security of data are observed as some of the major strengths of the Bluetooth wireless technology as WPAN

CONCLUSION

Wireless communication is the transfer of information over a distance without the use of electrical conductors or wires. Based on the criteria and

requirements for WPAN, Bluetooth is the most appropriate for short range networking. Its further use in WPANs implementations will greatly benefit consumers, organizations, businesses and researchers because of it ability to be powered by batteries for months and its frequency hopping capability which makes it more secure than other PANs. The most spectacular feature of Bluetooth is that it does not require you to do anything special to make it work. No synchronization of cables. Devices find one another and begin a conversation without any user input at all. The Bluetooth wireless technology has come to stay since its cheap and provides a bridge for existing data networks.

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