Bluetooth Wireless Communication

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***Abstract*- Bluetooth is an open standard for short-range digital radio to interconnect a variety of devices Cell phones, PDA, notebook computers, modems, cordless phones, pagers, laptop computers, printers, cameras by developing a single-chip, low-cost, radio-based wireless network technology. A Bluetooth ad hoc network can be formed by interconnecting piconets into scatternets. The constraints and properties of Bluetooth scatternets present special challenges in forming an ad hoc network efficiently. Bluetooth has client-server architecture; the one that initiates the connection is the client, and the one who receives the connection is the server. Bluetooth is a great protocol for wireless communication because it's capable of transmitting data at nearly 1MB/s, while consuming 1/100th of the power of Wi-Fi. We discuss criteria for different types of scatternets and establish general models of scatternet topologies. This paper highlights the Bluetooth wireless communication.**

***Keywords*: Bluetooth, Scatternet formation, Piconet, Ad hoc network, Hotspot**

I. INTRODUCTION

Bluetooth, the new technology named after the 10th Century Danish King Harold Bluetooth, is a hot topic among wireless developers. This article will provide an introduction to the technology.

Bluetooth was designed to allow low bandwidth wireless connections to become so simple to use that they seamlessly integrate into your daily life. The Bluetooth specification is an open specification that is governed by the Bluetooth Special Interest Group (SIG). The Bluetooth SIG is lead by its five founding companies and four new member companies who were added in late 1999[7]. These nine companies form the Promoter Group of the Bluetooth SIG:

Founding Companies	New Members
Ericsson	3Com Corporation
IBM Corporation	Lucent Technologies
Intel Corporation	Microsoft Corporation
Nokia	Motorola Inc.
Toshiba Corporation	

More than 1200 additional companies are members of the Bluetooth SIG. The magnitude of industry involvement should ensure that Bluetooth becomes a widely adopted technology. The first Bluetooth products should begin to appear this year. The first Bluetooth product from Ericsson is a wireless cellular phone headset to be available in Europe in mid-2000.

A. Characteristics

Bluetooth is specifically designed to provide low-cost, robust, efficient, high capacity, ad hoc voice and data networking with the following characteristics:

1. Mb/sec. transmission/reception rate that exploits maximum available channel bandwidth.
2. Fast frequency hopping to avoid interference.
3. Adaptive output power to minimize interference.
4. Short data packets to maximize capacity during interference.
5. Fast acknowledge, which allows low coding overhead for links.
6. CVSD (Continuous Variable Slope Delta Modulation) voice coding, which enables operation at high bit-error rates.
7. Flexible packet types that support a wide application range.
8. Relaxed link budget that supports low-cost single chip integration.
9. Transmission/reception interface tailored to minimize current consumption.

II. BLUETOOTH ARCHITECTURE

Bluetooth communication occurs between a master radio and a slave radio. Bluetooth radios are symmetric in that the same device may operate as a master and also the slave. Each radio has a 48-bit unique device address (BD_ADDR) that is fixed.

Two or more radio devices together form ad-hoc networks called piconets. All units within a piconet share the same channel. Each piconet has one master device and one or more slaves. There may be up to seven active slaves at a time within a piconet. Thus, each active device within a piconet is identifiable by a 3-bit active device address. Inactive slaves in unconnected modes may continue to reside within the piconet.

A master is the only one that may initiate a Bluetooth communication link. However, once a link is established, the slave may request a master/slave switch to become the master. Slaves are not allowed to talk to each other directly. All communication occurs within the slave and the master. Slaves within a piconet must also synchronize their internal clocks and frequency hops with that of the master. Each piconet uses a different frequency hopping sequence. Radio devices used

Time Division Multiplexing (TDM). A master device in a piconet transmits on even numbered slots and the slaves may transmit on odd numbered slots.

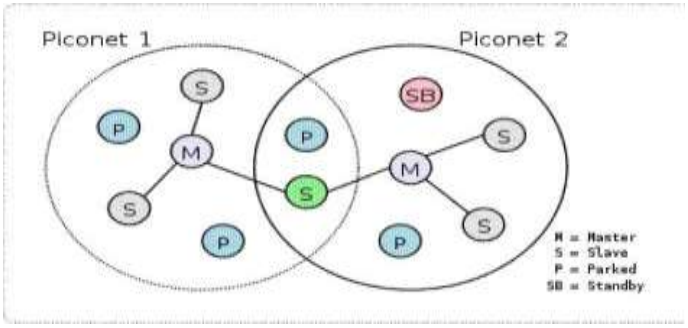

Fig.1: Bluetooth Scatternets and Piconets

Multiple piconets with overlapping coverage areas form a scatternet. Each piconet may have only one master, but slaves may participate in different piconets on a time-division multiplex basis. A device may be a master in one piconet and a slave in another or a slave in more than one piconet.

III. BLUETOOTH PROTOCOL STACK

The protocol stack makes up the core portion of the Bluetooth implementation [3]. As shown in figure 2 the connection devices can exchange data and interact with one another through various applications. The protocol architecture of the bluetooth consists of following in a bluetooth protocol stack:

- Core protocols consisting 5 layer protocols stack viz. radio, baseband, link manager protocol, and logical link control and adaptation protocol, service discovery protocol.
- Cable replacement protocol, RFCOMM.
- Adopted protocols viz. PPP, TCP/UDP/IP, OBEX and WAE/WAP [5].

A. Core Lower Layers

1) Radio:

This layer deals with the conversion of data into radio frequency (RF) signals for transmission through the air [4].Data is broken up into very small packets and transmitted usually one packet per frequency jump or slot [1]. Bluetooth operates in the 2.4 GHz Industrial, Scientific and Medical (ISM) radio-frequency band, which is license-free for low-power transmissions in most of the world [3].

2) Baseband/Link Controller:

Addressing scheme, packet frame format, timing and power control algorithms required for establishing connection between bluetooth devices within piconet defined in this part of protocol specification [3].The baseband layers role is to properly format data for transmission to and from the radio module and perform basic error control[1].The link controller is responsible for encoding and decoding of Bluetooth packets from the data payload and parameters related to the physical channel, logical transport and logical link[4].

3) Link Manager:

The link manager is responsible for the creation, modification, and release of logical links as well as the update of parameters related to physical link between devices [4]. This protocol also includes authentication and encryption specifications [5].

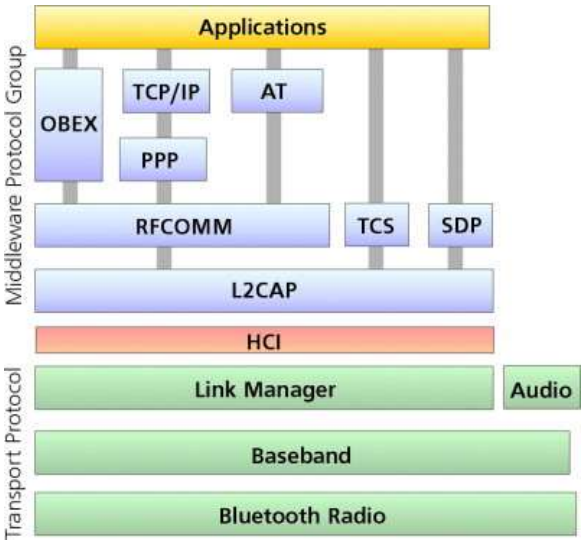

Fig. 2: Bluetooth protocol stack

B. Host Controller Interface(HCI)

The HCI provides a command interface to the baseband link controller and link manager, and access to hardware status and control registers [6].The host controller driver should be independent of the underlying transport technology [4].

C. Core Upper Layers

1) Logical Link Control and Adaptation

The Logical link control and adaptation protocol acts as the middle manager between applications and the bluetooth link controller [3].L2CAP passes packets either to the Host controller Interface(HCI),or in a Host-less system,L2CAP passes packets directly to the Link manager[7].

2) Service Discovery Protocol

Service related queries including device information can be taken care at this protocol so that connection can be established between bluetooth devices [5]. SDP consists of servers and clients components, where the requesting devices are a client and the requested device the server. A single Bluetooth device can perform both roles of a SDP-server and –client [3].

D. Non-Core Upper Layers

1) RFCOMM

The RFCOMM protocol provides emulation of serial ports over the L2CAP protocol. RFCOMM is only concerned with the connection between the devices in the direct connect case, or between the device and a modem in the network case [8].

2) OBEX

Object Exchange (OBEX) is a widely used protocol for simple file transfers between mobile devices. Its main use is in infrared communication, where it is used for generic file transfers between notebooks or PDAs, and for sending business cards or calendar entries between cellular phones and other devices with Personal Information Manager (PIM) application. The OBEX client is used to push and/or pull objects from the OBEX server [8].

3) Bluetooth Network Encapsulation Protocol (BNEP)

The Bluetooth Network Encapsulation Protocol (BNEP) sits on top of L2CAP and allows standard network protocols such as TCP, IPv4 and IPv6 to be transported across Bluetooth links. BNEP provides this encapsulation by replacing the Ethernet header, with a BNEP header and sends this header and the data across the L2CAP layer [3].

E. Audio

Audio transmission can be performed between one or more bluetooth units, using many different usage models. Audio data do not go through the L2CAP layer but go directly, after opening a bluetooth link and a straightforward setup between two bluetooth units [9].

F. Finding a Device

Before a device is able to make a connection to another device, it needs to discover that device. For device discovery, the three states are inquiry, inquiry scan and inquiry response [3].

1) Inquiry State

The inquiry state is entered when a device attempts to discover all other devices within range. In this state the searching device repeatedly transmits inquiry message on a set of different frequencies [3].

2) Inquiry Scan Display

For a Bluetooth device to be discoverable, it has to answer inquiry messages from other devices. This is done by entering an optional inquiry scan state. A device which is discoverable does this periodically (at least every 2.56 seconds) and listens for an extended time compared to the inquiry state. If a device does not want to be located it can be set to be non-discoverable and therefore will not enter the inquiry scan state [3].

3) Inquiry Response State

When a device receives a valid inquiry message it will then enter the inquire response state and respond with a frequency hopping synchronisation (FHS) packet [1].

IV. PACKET TYPE/FORMAT

The data on the piconet channel is conveyed in packets. Each packet consists of 3 entities, the access code (68/72 bits), the header (54 bits), and the payload (0-2745 bits) as follows:

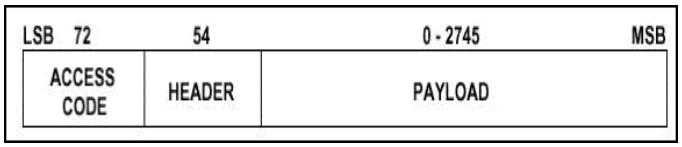

Fig.3: Packet Format

A. Access Code

Access code is used for timing synchronization, offset compensation, paging and inquiry. There are three different types of Access code: Channel Access Code (CAC), Device Access Code (DAC) and Inquiry Access Code (IAC). The channel access code identifies a unique piconet while the DAC is used for paging and its responses. IAC is used for inquiry purpose.

B. Header

The header contains information for packet acknowledgement, packet numbering for out-of-order packet reordering, flow control, slave address and error check for header.

C. Payload

The packet payload can contain voice field, data field or both. It has a data field, the payload will also contain a payload header.

V. BLUETOOTH STATES/MODES

A. Stand-by mode:

Before any connections in a piconet are created, all devices are in STANDBY mode. In this mode, an unconnected unit periodically "listens" for messages every 1.28 seconds.

Each time a device wakes up, it listens on a set of 32 hop frequencies defined for that unit.
The connection procedure is initiated by any of the devices that then becomes master.

B. Page and Inquiry States:

C. A connection is made by a PAGE message if the address is already known, or by an INQUIRY message followed by a subsequent PAGE message if the address is unknown.

In the initial PAGE state, the master unit will send a train of 16 identical page messages on 16 different hop frequencies defined for the device to be paged (slave unit). If no response, the master transmits a train on the remaining 16 hop frequencies in the wake-up sequence.

The INQUIRY message is typically used for finding Bluetooth devices with an unknown address, it is very similar to the page message, but may require one additional train period to collect all the responses.

D. Connection Modes:

Devices synchronized to a piconet can enter power-saving modes in which device activity is lowered. A Bluetooth device in the Connection state can be in any of the four following modes:

1) *Active Mode:*
In the active mode, the Bluetooth unit actively participates on the channel. The master schedules the transmission based on traffic demands to and from the different slaves.
It supports regular transmissions to keep slaves synchronized to the channel.
Active slaves listen in the master-to-slave slots for packets and if an active slave is not addressed, it may sleep until the next new master transmission.

2) *Sniff Mode:*
In the SNIFF mode, a slave device listens to the piconet at reduced rate, thus reducing its duty cycle.
The SNIFF interval is programmable and depends on the application.
It has the highest duty cycle (least power efficient) of all 3 power saving modes (sniff, hold & park).

3) *Hold Mode:*
The master unit can put slave units into HOLD mode, where only an internal timer is running.
Slave units can also demand to be put into HOLD mode.
Data transfer restarts instantly when units transition out of HOLD mode.
It has an intermediate duty cycle (medium power efficient) of the 3 power saving modes (sniff, hold & park).

4) *Park Mode:*
In the PARK mode, a device is still synchronized to the piconet but does not participate in the traffic.
Parked devices have given up their MAC (AM_ADDR) address and occasional listen to the traffic of the master to re-synchronize and check on broadcast messages.
It has the lowest duty cycle (power efficiency) of all 3 power saving modes (sniff, hold & park).

VI. NEED

Today, the majority of people are in possession of a mobile phone. The number of mobile phone users is increasing each year. Mobile phone creates more possibilities for social networking. The deployment of Bluetooth hotspots will widen access to broadband services using mobile phones not only to professionals and mobile workers but more importantly, to other segments of consumers who want to go on-line for non-business related and sociable purposes, and to consumers who do not own PCs[10].

VII. BLUETOOTH PHYSICAL SYSTEM

The Bluetooth system consists of a radio unit, a link control unit and a support unit for link management and host terminal interface functions.

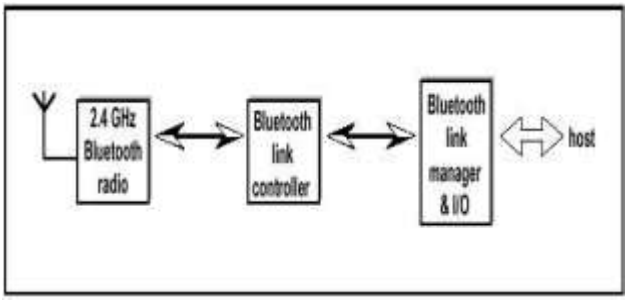

Fig. 4: Bluetooth Physical System

VIII. HOW BLUETOOTH WORKS

Bluetooth sends and receives radio waves in a band of 79 different frequencies (channels) centered on 2.45 GHz, set apart from radio, television, and cell phones, and reserved for use by industrial, scientific, and medical gadgets. Don't worry: you're not going to interfere with someone's life-support machine by using Bluetooth in your home, because the low power of your transmitters won't carry your signals that far! Bluetooth's short-range transmitters are one of its biggest plus points. They use virtually no power and, because they don't travel far, are theoretically more secure than wireless networks that operate over longer ranges, such as Wi-Fi.

Bluetooth devices automatically detect and connect to one another and up to eight of them can communicate at any one time. They don't interfere with one another because each pair of devices uses a different one of the 79 available channels. If two devices want to talk, they pick a channel randomly and, if that's already taken, randomly switch to one of the others (a technique known as spread-spectrum frequency hopping). To minimize the risks of interference from other electrical

appliances (and also to improve security), pairs of devices constantly shift the frequency they're using—thousands of times a second [15]

IX. BLUETOOTH HOTSPOT

The bluetooth hotspot is made up of three separate interlinked components.

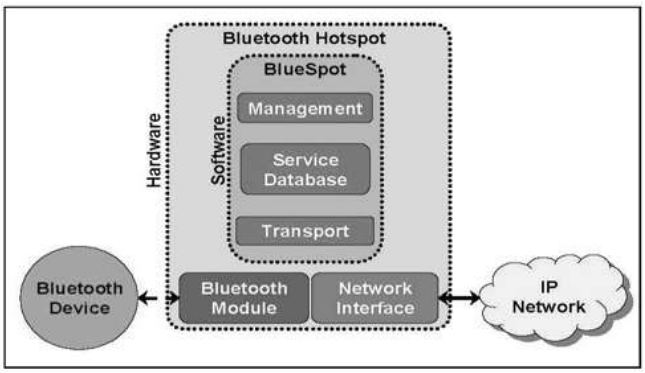

Fig. 5: Bluetooth hotspot components

A. Management Component:

Manages the other software components that make up the hotspot as well as detects when bluetooth devices come within range and leave. The main role of the management component is to supervise such as start and stop the different applications. It periodically scans for the local bluetooth devices that have entered range and detecting as if previously detected device is not communicating and inform to service device component about new device.

B. Service Database Component:

Collects stores and advertises services that are detected by all the Bluetooth hotspots within a network. When it is notified of a new bluetooth device it will acquire a list of all the services that that device is advertising via its SDP server. If the services have transport application available then it can added to an internal database and all the other remote database are notified about the device. Then the local and remote databases will start the transport.

C. Transport Component:

This makes the connection between hotspot and bluetooth devices. It transports the bluetooth communications between the two bluetooth devices via bluetooth hotspots over an IP network.

X. CONNECTION FRAMEWORK

The two jobs that a bluetooth hotspot performs are the advertising of services from remote devices and the facilitating of communication between two devices.

A. Advertising a service:

The steps for advertising a service are:
Bluetooth hotspot X detects bluetooth device A.

1) The management component informs the local service database component(SDC) of the new device within range
2) The SDC queries the SDP server on the bluetooth device and finds out what services it is able to facilitate.
3) The SDC then starts the transport component for services.

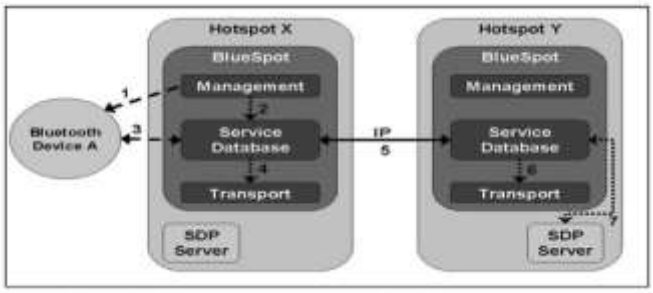

Fig. 6: Advertising a services

B. Using a proxyed service:

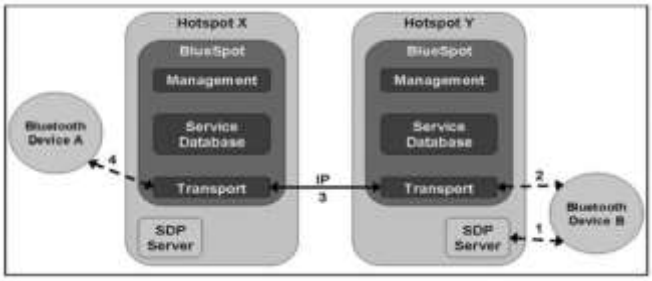

Fig. 7: Using a proxyed service

1) A bluetooth device B browses the SDP server on Hotspot Y.
2) The transport component then connects to its peer and start transmitting the data received from device B1.
3) A bluetooth device B browses the SDP server on Hotspot Y2.

Using the above information it then connect to the transport component and transport component is then connect to its peer and start transmitting the data it receives from device B[1].

XI. APPLICATION EXAMPLES

- A Bluetooth-mouse or a Bluetooth-keyboard could be used at a further distance from a monitor, and while moving about in the room.
- Use e-mail while your portable PC is still in the briefcase! When your portable PC receives an e-mail, you'll get an alert on your mobile phone.
- A travelling businessman could ask his laptop computer to locate a suitable printer as soon as he

enters a hotel lobby, and send a printout to that printer when it has been found, and replied in a positive manner.

- Cable-less connection to printers and faxes, to digital cameras and video projectors. Cordless connection from cell phone to hands free headset.
- Bluetooth interface to office PBX and Dial-up networking and automatic e-mail and use cell phone as office cordless phone. Use of PC or PDA as hands free phone.
- Automatic exchange of files, electronic business cards, calendars etc.

XII. FUTURE

In coming future Bluetooth technology could also be implemented in many public places such as hotels, other heavy traffic locations, airports and train stations,. This will enable people to stay updated with business and personal information. It will allow workers to work at the office, at home, or on the road without any decrease in efficiency because they have all the information they need through their ubiquitous connectivity. Finally Bluetooth is half duplex technology and research is going on in full duplex data, file, image and voice transmission so as to increase the speed of communication [16].

XIII. CONCLUSION

Despite some of the problems, Bluetooth remains a very promising technology, with plenty of medium and long term applications. But the real test will be whether it survives the hype. Promoters are laying on it, with their unrealistic claims.

This technology is probably the only one which has a good chance to become widely available among PDAs and mobile devices. Bluetooth-equipped gadgets can connect to the LAN through the Access Protocols at once.50 kilobytes per second is about all you can expect from Bluetooth.

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