IJCSC Volume 4 • Number 2 September 2013 pp.16-30 ISSN-0973-7391

Bluetooth Technology: Principle, Applications and Current Status

Simranjit Singh Chadha[1], Mandeep Singh [2], Suraj Kumar Pardeshi [3]
[1,2]Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, India
[3] Global R&D Centre, Crompton Greaves Ltd., Mumbai, India
gec2k6@gmail.com, mandy_tiet@yahoo.com, suraj.pardeshi@cgglobal.com

Abstract – This paper explains the Bluetooth wireless technology which is a recently proposed standard for the replacement of cables. Bluetooth is not only wireless cable replacement technology but apart from this it is also used for the creation of adhoc Personal Area Networks (PAN) with good security level. In this paper firstly detailed description of Bluetooth along with its history is given. Description also includes seven protocols of the Bluetooth and three Bluetooth modules from different vendors, their features, specifications and comparison between them. Further applications of the Bluetooth wireless technology and currently used Bluetooth version is described.
Keywords – Personal Area Network (PAN), Personal Computer (PC), Special Interest Group (SIG), Industrial Scientific and Medical (ISM), Frequency Hopping Spread Spectrum (FHSS), Gaussian Frequency Shift Keying (GFSK), Enhanced Data Rate (EDR), Differential Phase Shift Keying (DPSK), Differential Quadrature Phase Shift Keying DQPSK), Basic Rate (BR), Low Pass Filter (LPF), Intersymbol Interference (ISI), Link Management Protocol (LMP), Host Controller Interface (HCI), Logical Link Control and Adaptation Protocol (L2CAP), Radio Frequency Communication (RFCOMM), Service Discovery Protocol (SDP), Synchronous Connection-Oriented (SCO), Asynchronous Connectionless (ACL), Automatic Repeat Request (ARQ), Forward Error Correction (FEC), Protocol Data Unit (PDU), Serial Port Profile (SPP), Universal Asynchronous Receiver/Transmitter (UART), Universal Serial Bus (USB), Restriction of Hazardous Substances (ROHS), Attention (AT), Inter-Integrated Circuit (I2C), PCM (Pulse Code Modulation), Programmed Input/Output (PIO), Bit Error Rate (BER), Electromagnetic Compatibility (EMC), Dial-up Networking (DUN), Dial-up Networking Gateway (DUN GW), Dial-up Networking Data Terminal (DUN DT), Hands-Free Profile (HFP), Headset Profile (HSP), Human Interface Device Profile (HID), Audio/Video Remote Control Profile (AVRCP), Device ID Profile (DIP), Phone Book Access Profile (PBAP),Object Push Profile (OPP), File Transfer Profile (FTP), Health Device Profile (HDP), General Purpose Input/Output (GPIO)

I. INTRODUCTION

Bluetooth which is a recently proposed standard for wireless communication over short range is consuming less power. Initially, it was thought of as a wire replacement technology. Most commonly described application of Bluetooth is its use as a "cordless computer" which consists of several devices that include a Personal Computer (PC) that possibly may be a laptop, mouse, keyboard, printer, joystick, scanner, etc., each of which is equipped with a Bluetooth card. No cable connections are there between these devices and Bluetooth enables seamless wireless communication link between all of them, importantly replacing which is today achieved through use of combination of parallel and serial cables or infrared links. Apart from this Bluetooth has the potential to be used for much more than a technology for wire replacement. Low cost and low power consumption make it an attractive solution typically for the mobile devices [1].

II. HISTORY OF BLUETOOTH WIRELESS TECHNOLOGY

Harald Blatand, who is also known by name as Harald Bluetooth was a Viking and Denmark King. He was known for his extraordinary ability to make people talk to each other and it was during his reign Norway and Denmark were united. So today Bluetooth wireless technology makes it possible for the electronic devices so that they can talk to each other with the help of a short-range and low cost radio communication link. The developers of the Bluetooth wireless technology decided to name this wireless technology after King Harald Bluetooth because they hoped that this technology would unite the world same as Harald Bluetooth united Denmark and Norway.
The idea of Bluetooth wireless technology took place in 1994 when it was decided by Ericsson to check the feasibility of a low-cost, low-power radio interface between the accessories of mobile phones and mobile phones themselves. Basically the idea was to build a small radio into both the laptop and cellular telephone that would

replace the cumbersome cables which are used to connect two devices with the wireless link. Today, Bluetooth Special Interest Group (SIG) supports Bluetooth wireless technology. Main players of this group include Ericsson Technology Licensing AB, 3Com Corporation, Intel Corporation, IBM Corporation, Agere Systems, Inc., Motorola Inc., Microsoft Corporation, Nokia Corporation and Toshiba Corporation. And today there are many companies having Bluetooth Special Interest Group (SIG) membership. Support and backing from these companies makes it sure that in wireless market of world, Bluetooth will gain a chance and acceptance and so it is doing also [2].

III. BRIEF DESCRIPTION OF BLUETOOTH TECHNOLOGY

Bluetooth works in the Industrial, Scientific and Medical (ISM) band from 2400-2483.5 MHz (including guard bands) from mobile as well as fixed devices by creation of PANs with high security level. Several devices can be connected by using this technology, overcoming synchronization problems. Bluetooth uses technology called Frequency-Hopping Spread Spectrum (FHSS) which is a radio technology. The data to be transmitted is first divided into packets and then each packet is made to transmit on one among the designated 79 Bluetooth channels. Bandwidth of each channel is 1 MHz. The very first channel starts at frequency of 2402 MHz and goes up to 2480 MHz in steps of 1 MHz. Usually it performs 1600 hops per second. Originally modulation method used was Gaussian Frequency-Shift Keying (GFSK) scheme which was the only scheme of modulation available; by the time, since with introduction of Bluetooth 2.0+EDR where EDR means Enhanced Data Rate, modulations such as 8 Differential Phase Shift Keying (DPSK) and π/4-Differential Quadrature Phase Shift Keying (DQPSK) can also be used between devices that are compatible. Devices that are functioning with GFSK are operating in Basic Rate (BR) mode in which an instantaneous 1 Mbit/s data rate is possible. The term EDR describes 8DPSK and π/4-DQPSK schemes where each is giving 2 Mbit/s and 3 Mbit/s respectively. In Bluetooth radio technology, combination of BR and EDR modes is classified as "BR/EDR radio"[3].

Piconet - A collection of a number of devices that are connected via Bluetooth radio technology in an ad hoc fashion. To start a piconet requirement is two connected devices, like laptop and cellular phone which may grow to eight connected devices and all other Bluetooth devices are peer units and they also have implementations which are identical. However, at the time of piconet establishment, one unit will be acting as a master and the other units as slaves for connection duration of the piconet [2]. As shown in figure 1.

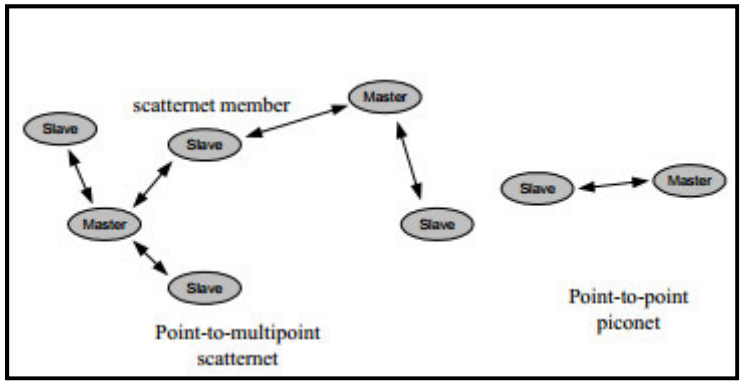

Figure 1: Various topologies in Bluetooth

Bluetooth is a packet-based protocol which is having a master-slave structure. In a piconet up to 7 slaves can be communicated by one master [3]. Timing on the network can be controlled by Bluetooth by designating one device as a slave and the other as a master. The unit which initiates communication link is master and the other participants are slaves. After breakdown of link, the designations of master/slave no longer apply. Fact is that, every Bluetooth device is having both master and slave hardware. The network is called as piconet, which means a small network. When number of slaves is only one, then link is called as point-to-point. In a point-to-multipoint configuration up to seven active slaves can be controlled by a master. Slaves never communicate directly with each other but instead communicate with the master only. Because of timing piconet members cannot transmit simultaneously, hence jam problem is not there between these devices. Finally, realization of communication process across the piconets is

done if the Bluetooth radio device is a slave in one and master in other or slave in more than one piconet. Configurations of piconet in this manner are called scatternets. The depiction of these various arrangements is in figure 1. [4].

Master's clock is shared by all devices. Basic clock which is defined by the master, ticks at intervals of 312.5 µs. Base of packet exchange is basic clock. A slot of 625 µs is made up of two clock ticks; a slot pair of 1250 µs is made up two slots. Considering a very simple case of packets which are single-slot, the transmission of master is in even slots and reception is in odd slots; for the case of slaves, conversely, its transmission is in odd slots and reception is in even slots. Packet length can be 1, 3 or 5 slots but considering all cases, the transmission of slave is in odd slots and master's transmission will begin in even slots [3].

At powering on of a Bluetooth device, its operation may be as a slave device whose master device already running. After this it starts listening for a master's inquiry as if done for the new devices and gives response to it. In the phase of inquiry the master knows the slave's address; there is no necessity for this phase for the case of very simple paired devices that are given permission to know address of each other. Once slave's address is known to a master, a connection towards it may be opened, but the condition is that slave is listening for paging requests. If the case this is like this, master's page request is responded by the slave and the synchronization between two devices is done over the frequency hopping sequence and this sequence is decided by the master and is unique to each piconet. Several types of connections are predefined by Bluetooth, each of which is having a different combination of available error protection, quality of service and bandwidth. Once after establishment of connection, the devices can then start communicating by first optionally authenticating each other. Devices that are not transmission engaged can enter one of several bandwidths and power-saving modes or the connection is teared down. Switching of roles can be done by master and slave, which becomes a necessity when more than one piconet is participated by a device.

Format of Modulation

The format of modulation is GFSK having bandwidth × bit time product (BT) equal to 0.5. The index of modulation is having value between 0.28 and 0.35. For the data rate of 1Mbps in Bluetooth technology, frequency deviation value can be from ±140 to ±175kHz. The generation of GFSK signal is as follows:

First of all the stream of data d(t) is filtered by using a Gaussian filter with impulse and frequency responses h(t) and H(ω) as follows in equations (1) and (2) -

$$h(t) = e^{-\frac{1}{2}\left(\frac{t}{\tau}\right)^2} \qquad \ldots\ldots(1)$$

$$H(\omega) = \tau \cdot \sqrt{2\pi}\, e^{-\frac{1}{2}(\tau\omega)^2} \qquad \ldots\ldots(2)$$

This is having similarity with the e^{-x^2} shape of that of Gaussian, or normal, probability density function. As given in equation, τ is a constant and ω is frequency in rad/sec.

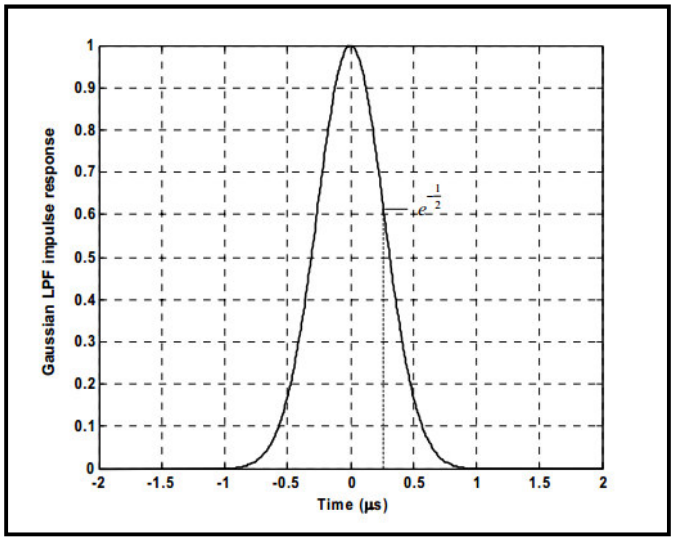

Figure 2: Impulse response of Gaussian LPF

Frequency and impulse responses of a Gaussian filter are Gaussian and it is its peculiar property. Frequency and impulse responses of a Gaussian Low Pass Filter (LPF) are shown in figures 3 and 2 respectively. Bandwidth of the filter from equation (2), can be written given by equation (3)

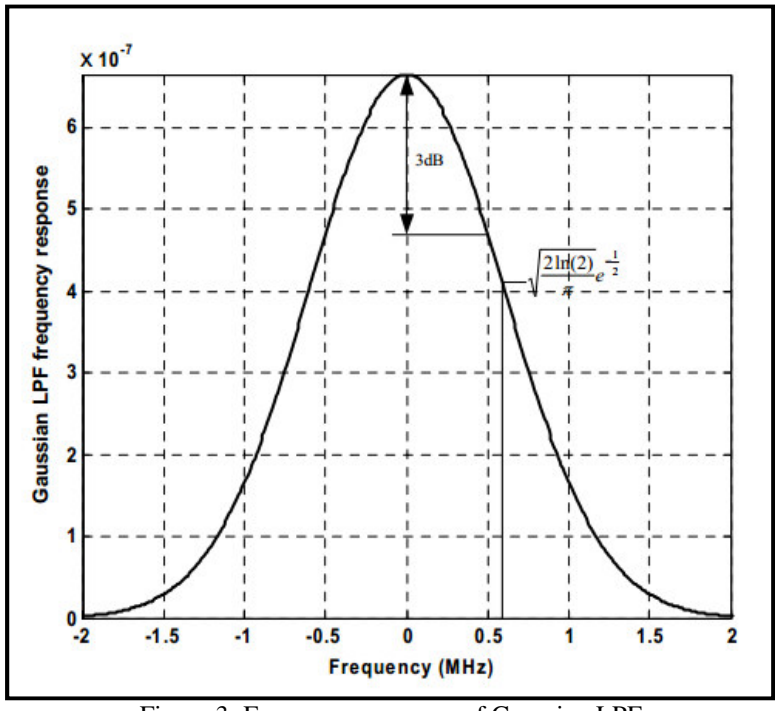

Figure 3: Frequency response of Gaussian LPF

$$B = \frac{\sqrt{\ln(2)}}{2\pi}\frac{1}{\tau} \qquad \ldots\ldots(3)$$

The specification of Gaussian filter is as follows given by equation (4) -

$$BT = (\text{Filter Bandwidth}) \,.\, (\text{Bit Period}) = \frac{\text{Filter Bandwidth}}{\text{Bit Rate}} = \frac{T_b}{\tau}\frac{\sqrt{\ln(2)}}{2\pi} \qquad \ldots\ldots(4)$$

Higher BT means higher bandwidth but less Intersymbol Interference (ISI). Taken a good compromise value, BT = 0.5 value is specified in the Bluetooth standard. Hence the bandwidth is 500 kHz. Therefore, the Gaussian filter output value is as under given by equation (5) -

$$gf(t) = d(t) * e^{-\frac{1}{2}\left(\frac{\pi \quad t}{\sqrt{\ln(2)}\,T_b}\right)^2} \qquad \ldots\ldots(5)$$

The value of` d(t) and gf(t) both have a minimum and maximum of -1 and 1 which represents 0 and 1 bits, respectively. Carrier is frequency modulated by the Gaussian filtered data gf(t). The GFSK signal output is expressed as given by equation (6) -

$$gfsk(t) = \sin(2\pi(f_c + f_d.gf(t)) \qquad \ldots\ldots(6)$$

Where f_d is the frequency deviation and f_c is the center frequency. Hence the transition of instantaneous frequency of the GFSK signal is between a frequency $f_c + f_d$, representing binary 1 and $f_c - f_d$, representing binary 0. According to Bluetooth standard, the modulation index of frequency is specified between 0.28 and 0.35. Index of modulation or modulation index signifies ratio between the deviation of frequency $2f_d$ and the bit rate. Thus corresponding f_d value must be between range of 140 and 175 kHz. As shown in figure 4, representative examples of the unfiltered, GFSK signal and Gaussian filtered. For the purposes of illustration, the center frequency of GFSK signal in figure 4 is 1 MHz [4].

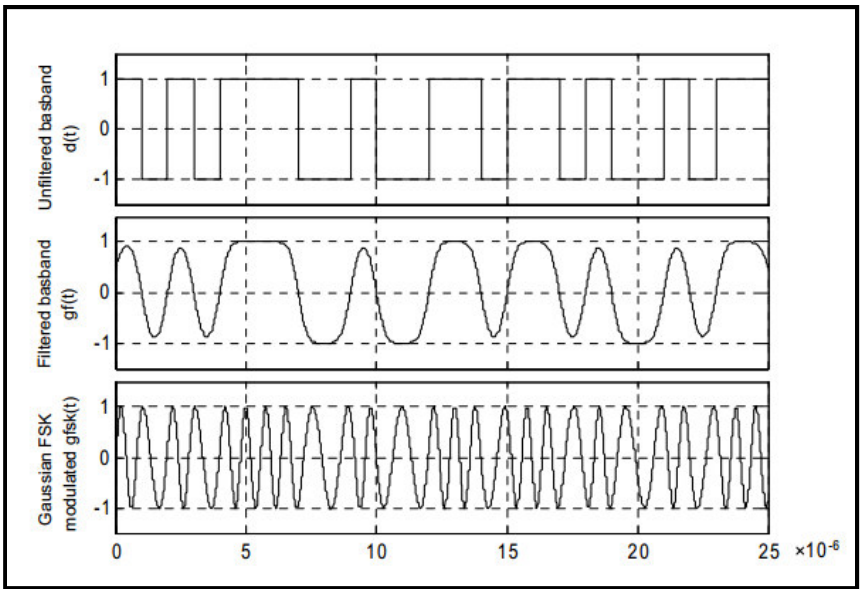

Figure 4: Modulation steps of GFSK

IV. WORKING OF BLUETOOTH DEVICES

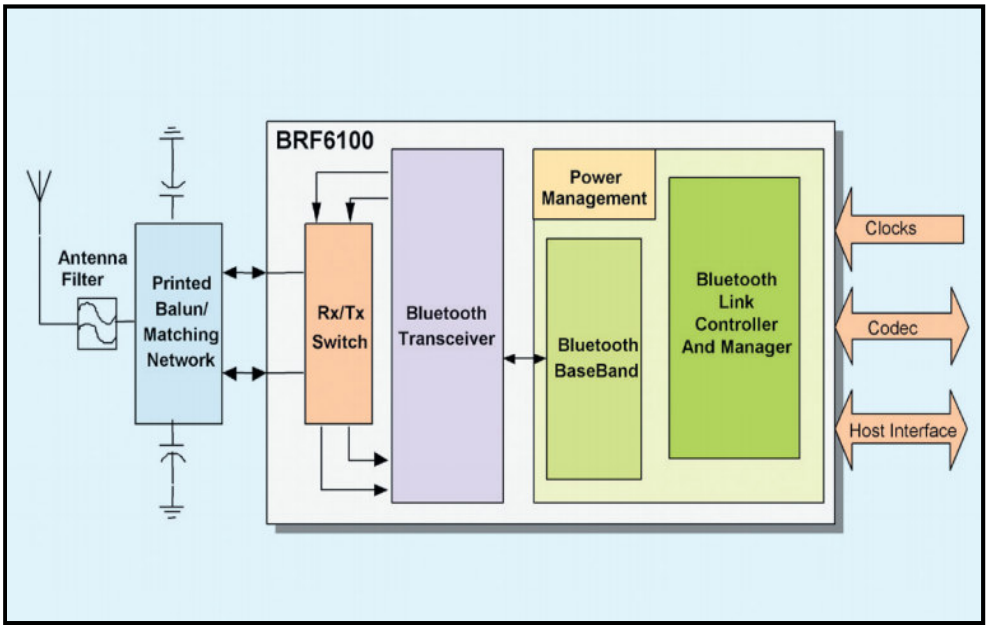

Figure 5: Block diagram of Bluetooth [15]

All the devices that are involved in an electronic discussion are required to know about the meaning of bits being received and transmitted and integrity of the received message whether it is same as the sent message. Meaning of this is the development of a large collection of commands and responses which is known as a protocol. Some types of products are having a protocol which is standard protocol which is used virtually by all companies so commands of one product will tend to cause the same effect on other product. [2]. Block diagram of Bluetooth is shown in figure 5.

Protocols of the Bluetooth

Exactly four parts are needed by any Bluetooth device for proper operation. These include -

1.) A module with a baseband microprocessor
2.) A radio frequency for receiving and transmitting data,
3.) An interface to the host device and
4.) Memory

For making up of these parts, SIG of Bluetooth has given, seven different protocols. For the qualification of any device as a Bluetooth device, these seven protocols must be satisfied. These seven protocols include -

1.) The radio protocol
2.) The baseband protocol
3.) The Link Management Protocol (LMP) protocol
4.) The Host Controller Interface (HCI) protocol
5.) The Logical Link Control and Adaptation Layer Protocol (L2CAP) protocol
6.) The Radio Frequency Communication (RFCOMM) protocol and
7.) Service Discovery Protocol (SDP) protocol

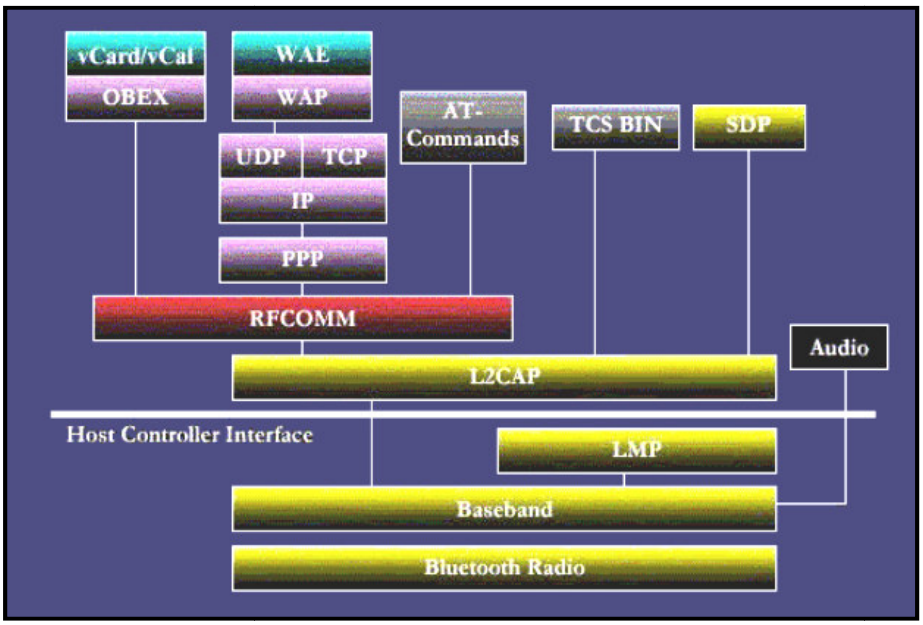

Figure 6: Protocol stack of the Bluetooth

Figure 6. shows these seven protocols. Description of these protocols is given as under –

1.) The Radio protocol - Basically the radio protocol by serving as digital signal-processing component makes Bluetooth a wireless device. Data is transmitted by Bluetooth devices which is in the form of bits (ones and zeros), over a radio frequency. GFSK is used by Bluetooth devices. Another Bluetooth device's receiver will pick up the bits sent through air. This is how the reception and transmission of data takes place. Bluetooth devices use ISM band from [2] 2400-2483.5 MHz (including guard bands) [3] as described earlier. This whole range is cut down into 79 channels of one MHz each. Each of the channels is broken into 625 microsecond time slots. This is shown in figure 7. That comes out to be 1,600 different slots per second. Bluetooth transmits data through these slots and channels.

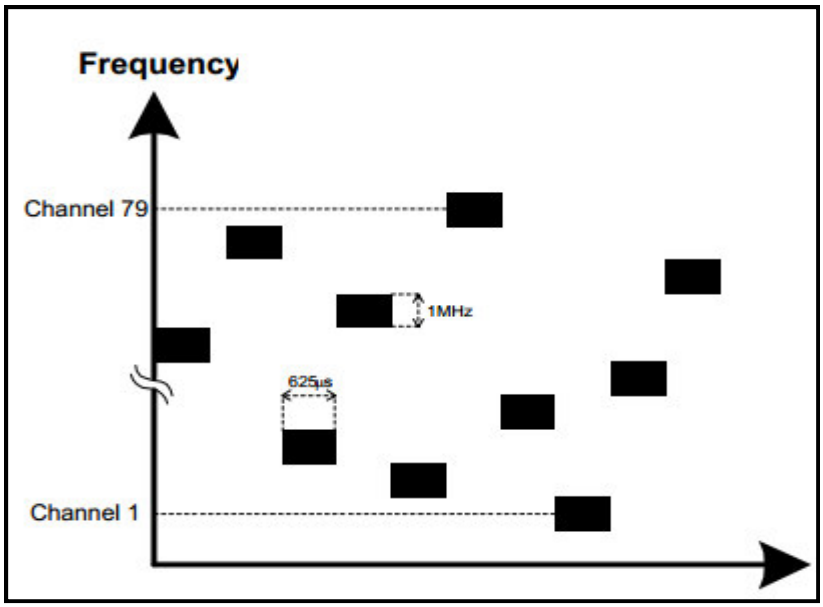

Figure 7: Frequency Hopping Technique

2.) **The Baseband protocol –** The baseband protocol processes the signals that are transmitted and received by the radio. Control of the error correction, links, packets, flow control and channels is also done by this protocol.

a) Links - The Bluetooth devices are capable of making following two different types of links that are –
SCO (Synchronous Connection-Oriented) and ACL (Asynchronous Connectionless)
ACL is used for data packets primarily and primarily SCO is used for voice packets [2].

ACL links primarily are defined for data transmission. They support asymmetrical, symmetrical and packet-switched connections. ACL link type is used by multi-slot packets and they can achieve the maximum of 723 kbps data rate in one direction and 57.6 kbps data rate in the other direction. ACL link bandwidth is controlled by the master and decision of how much of the bandwidth a slave can use in a piconet is taken by it. ACL link supports broadcast messages i.e., to all slaves in the piconet from the master.

Symmetrical, point-to-point, circuit-switched connections are supported by the SCO links, and therefore they primarily are used for voice traffic. For a SCO link, reservation of two consecutive time slots which are at fixed intervals is done. Every sixth slot is reserved for a transmitting channel and reservation of subsequent slot is done for receiving channel by the SCO link, so at most there can be maximum up to three simultaneous SCO links. The data rate of 64kbps is for SCO links [6]. The SCO link allows simultaneous downloads and uploads of data between devices because they are symmetric and typically time-bounded voice traffic is also supported. Reserved intervals are used for transmission of SCO packets. Once after the establishment of connection, SCO packets are sent by both master and slave units at will. Both voice and data transmission is allowed by one SCO packet type with retransmission of data portion only when corrupted [2].

b) Packets - There are thirteen different packet types of Bluetooth in order to handle different tasks. Standard packet format of Bluetooth consists of 0-2745 bits for the payload, 54 bits for the header, 72 bits for the access code. Figure 8 shows standard packet format.

ACCESS CODE	HEADER	PAYLOAD
72 Bits	54 Bits	0-2745 Bits

Figure 8: Format of standard packet

The use of access code is for offset compensation, paging and inquiry, timing synchronization. Three different types of Access codes are there: Channel Access Code, Inquiry Access Code and Device Access Code. Device Access Code is used for paging and its responses while the Channel Access Code identifies a unique piconet. For inquiry purpose inquiry Access Code is used.

The information contained in header is for packet numbering, packet acknowledgement, error checks for header, flow control, and slave address. The packet payload can contain a data field, a voice field, or both. If the packet payload is having a data field, then it also will contain a payload header.

Nine categories of packets are there that contain an access code, payload, and header and same as in the standard packet format. All the nine types of packets have their own special purpose. Some packets are specifically made for voice communication, on the other hand others packets are made for data transfer at high-speed. Data rate of each of the packets is different which depends on the traffic type being sent [2]. Table 1 shows these statistics.

Table 1.: List of all packet types along with their rates of data [2].

Packet Type	Max Payload (Bytes)	Symmetric Rate (Kbps)	Asymmetric Rate (Kbps) Forward	Asymmetric Rate (Kbps) Reverse
DM1	17	108.8	108.8	108.8
DH1	27	172.8	172.8	172.8
DM3	121	258.1	387.2	54.4
DH3	183	390.4	585.6	86.4
DM5	224	286.7	477.8	36.3
DH5	339	433.9	723.2	57.6
HV1	10	64	n/a	N/a
HV2	20	64	n/a	N/a
HV3	30	64	n/a	N/a

c) Connection States - Connection states that are used by the devices are also controlled by the baseband. The two states are Connection state and Standby state. The default low power state is the Standby state in the Bluetooth unit. Only the native clock is running. Bluetooth is ideal for its use in laptops and cell phones which are having limited battery power [2].

d) Error Correction - Baseband's last task is error correction, which baseband protocol also handles. Three kinds of error correction schemes that are used in the baseband protocol are Automatic Repeat Request scheme or ARQ in short, 1/3 rate Forward Error Correction (FEC), 2/3 rate FEC [2].

3.) Link Management Protocol (LMP) - The Link Manager manages or controls setup of link, link configuration, authentication and other low level protocols. It communicates with other remote link managers via the LMP by

discovering them. With the help of the Baseband, for all Bluetooth devices establishment of all the connections take place [2].

3.) **Host Controller Interface (HCI)-** Baseband controller and link manager are provided a command interface by the HCI. Access to control registers and hardware status are also provided by the HCI. The existence of HCI is across three sections, the host, host controller, transport layer. Figure 9 shows the manner of working of this communication between host controller interfaces [2].

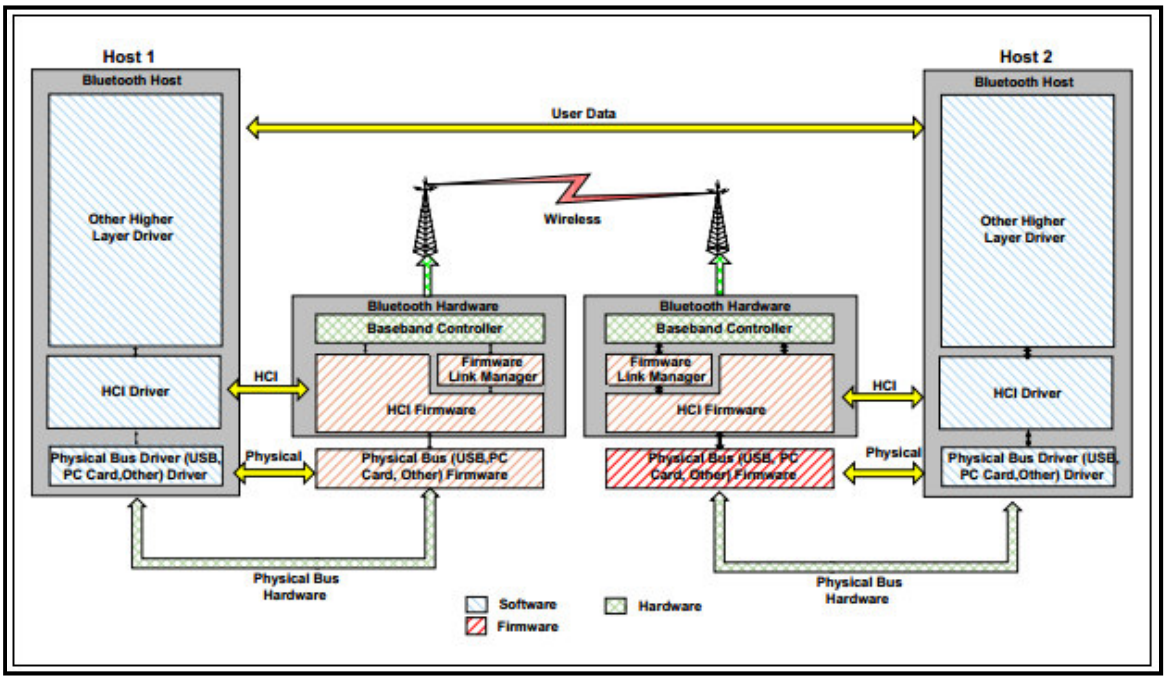

Figure 9: Host Controller Communication example

5.) Logical Link Control and Adaptation Layer Protocol (L2CAP) - Layered over the baseband protocol is the L2CAP as it resides in the data link layer, as can be seen in figure 6. Basically the L2CAP is a processor. Connectionless data services and connection oriented data services are provided to upper layer protocols with segmentation and reassembly operation, protocol multiplexing capability and group abstractions. L2CAP breaks the packets down for Bluetooth transmission into the correct size and when the packet passes through L2CAP of another Bluetooth device, its original form is put back. The specification of L2CAP is defined only for ACL links and there is no support for SCO links which is planned [2].

6.) Radio Frequency Communication (RFCOMM) - RFCOMM is a simple transport protocol. It provides RS232 serial port emulation over the L2CAP protocol. 60 simultaneous connections are supported between two Bluetooth devices by RFCOMM protocol. In a Bluetooth device number of connections which can be simultaneously used depends upon the implementation, means what is that profile which is being used [2].

7.) Service Discovery Protocol (SDP) – SDP is having minimal requirements on the underlying transport. SDP uses a response/request model in which each transaction is having one response Protocol Data Unit (PDU) and one request PDU. Before issuing another request a client on the same L2CAP connection must receive response to each request [2].

V. STUDY OF VARIOUS BLUETOOTH MODULES

Parani - BCD110

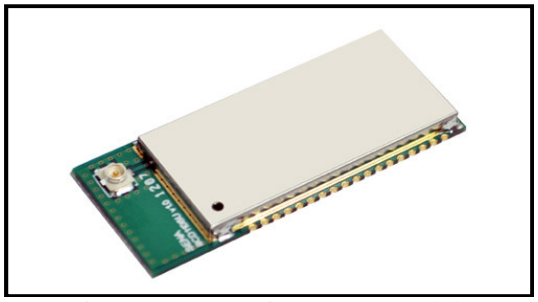

Figure 2.13: Parani-BCD 110 module

BCD110 has Bluetooth v2.0 compatible firmware which runs for SPP based applications by default [17].

BCD 110 features [7] -

- Bluetooth Class 1
- Supports Serial Port Profile (SPP)
- Transmit Power: +18dBm Typical
- Bluetooth v2.0+EDR specification
- Working distance (In an open field): Nom.200m, up to 1000m
- Receive sensitivity: -90dBm (0.1% BER)
- Integrated 8Mbit Flash Memory
- Standard HCI over Universal Asynchronous Receiver/Transmitter (UART) or Universal Serial Bus (USB)
- Supports built-in chip, stub and dipole antennas
- Field-proven SPP (Serial Port Profile) firmware supporting up to 4 simultaneous multiple connections
- 802.11 co-existence
- Firmware upgrade via windows-based software (Parani Updater)
- Restriction of Hazardous Substances (ROHS) compliant
- Easy to use Windows configuration tool available.

Specifications of BCD 110 [7] -

Bluetooth Specifications	Bluetooth v2.0 + EDR, Class1 Supports up to 1000m (0.62 mile) Profile: SPP(Serial Port Profile)
Physical properties	Weight : Parani-BCD110SU: 2g
Environmental	Operating temperature: -40°C ~ 80°C Storage temperature: -40°C ~ 85°C Humidity: 90% (Non-condensing)
Power	Nominal : 70mA@3.3Vdc Maximum : 150mA@3.3Vdc (200mA@3.3Vdc in Test Mode)
Firmware Update	Parani Updater
Configuration	Parani WIN, Parani Wizard, Modem Attention (AT) command set
USB Interface	V2.0
Interfaces	UART, USB, Inter-Integrated Circuit (I2C), Pulse Code Modulation (PCM), Programmed Input / Output (PIO)
Serial Interface	Serial UART speed up to 921.6kbps
Tx Output Spectrum-Frequency range	2402 MHz - 2480 MHz
Receive Sensitivity	-90dBm (0.1% Bit Error Rate short for BER)
Transmit Power	+18dBm Typical

Connect blue: CB−OBS410x−04

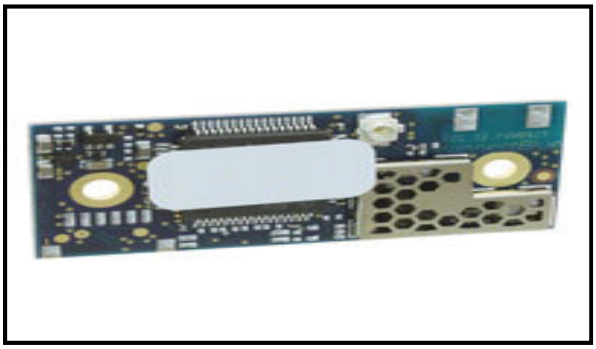

Figure 2.14: Connect blue: CB-OBS410x-04 module

Connect blue: CB−OBS410x−04 features [8] -

- Bluetooth v2.1 Qualified as End Product
- Embedded Bluetooth stack (SPP, Dial-up Networking (DUN))
- High throughput and low latency
- UART interface
- Compliant with Electromagnetic Compatibility (EMC), Safety and Medical standards
- Android support
- Connect Blue Low Emission Mode™
- Easy configuration by AT commands
- External antenna
- Possible to load customer specific configuration in production
- Industrial and Automotive temperature range -30°C to +85°C
- Original Equipment Manufacturer (OEM) Serial Port Adapter 410 with u.fl. connector for external antenna, board-to-board and solder pads and application)
- ConnectBlue Low Emission Mode™ for not disrupting other 2.4GHz radios
- Supports SPP Bluetooth connection to Google Android Operating System (OS) devices
- Configurable via AT commands (via Bluetooth or serial port)
- Maximum number of slaves: 1 (point-to-point)

Specifications of Connect blue: CB−OBS410x−04 [9] -

Wireless Standard	Classic Bluetooth technology
Bluetooth Specifications	Bluetooth v2.1 (Qualified and Listed as Product) Supported Bluetooth Profiles: Serial Port Profile (SPP), Dial-up networking Profile (DUN GW, DUN DT) GW- Gateway, DT- Data Terminal
Radio, Chipset and Stack	External antenna (range & max output power incl. antenna): 150m & 6dBm 2.4 GHz channels: 1-79 Radio: ST-Ericsson STLC2500DB Microprocessor: ST STM32F10x Stack: connectBlue Embedded Bluetooth Stack
Interface	UART Logic-level Via external transceiver, RS232 and RS422/485 option Max baud rate: 460.8 kbit/s Support for non-standard baud rates Flow control: hardware or none 9 digital I/O pins
Throughput	350 kbps

Power	Power supply voltage: 3.0 - 6.0 VDC Current consumption (minimum): 14 mA @3.0V Current consumption (average Tx): 25 mA @3.0V
Mechanical	Operating temperature: -30°C to +85°C Machine mountable Mounting holes Dimensions: 16x36x3 mm (2 mm height on request) Weight: 2 g

Bluegiga WT41 Bluetooth Module

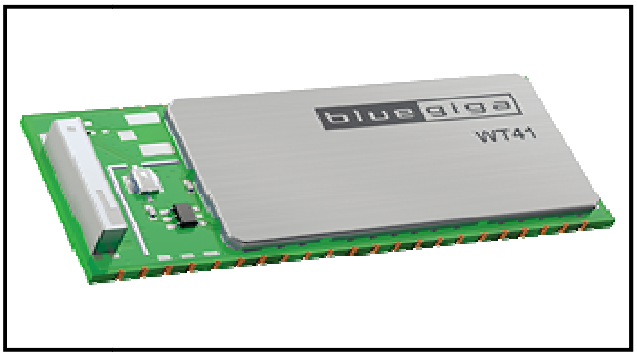

Figure 2.15: Bluegiga WT41 module

Bluegiga WT41 features [10] -

- Bluetooth 2.1+ EDR
- Exceptional radio performance having Transmit power : +20dBm and Receiver sensitivity: -90dBm
- Available with high efficiency chip antenna or u.fl connector
- Integrates a Bluetooth radio, Bluetooth stack and profiles
- Supported Bluetooth profiles: SPP, DUN, Hands-Free Profile (HFP), Headset Profile (HSP), Human Interface Device Profile (HID), Audio/Video Remote Control Profile (AVRCP), Device ID Profile (DIP), Phone Book Access Profile (PBAP), Object Push Profile (OPP), File Transfer Profile (FTP) and Health Device Profile (HDP)
- Standard HCI over UART or USB
- Industrial temperature range -40°C to +85°C

Specifications of BluegigaWT41 [11] -

Class	1
Bluetooth Specification	Bluetooth 2.1+ EDR
Frequency Band	2.4 GHz
Sensitivity	- 90 dBm
Data Rate	2.1 Mbps
Operating Supply Voltage	3.3 V
Output Power	20 dBm
Interface Type	General Purpose Input/ Output (GPIO), UART, USB
Antenna Connector Type	u.fl
Maximum Operating Temperature	+ 85 C
Dimensions	35 mm x 14 mm x 3.5 mm
Minimum Operating Temperature	- 40 C
Mounting Style	Surface-Mount Device (SMD)/ Surface-Mount Technology (SMT)

VI. COMPARISON OF SPECIFICATIONS OF DIFFERENT BLUETOOTH MODULES. [7-14]

Sr. No	Specification	Parani-BCD110	CONNECT BLUE: cB-OBS410x-04	Bluegiga WT41
1.	**Bluetooth Specifications**	Bluetooth v2.0 + EDR	Bluetooth v2.1	Bluetooth 2.1+ EDR
2.	**Operating Supply Voltage**	3.3Vdc	3.0 - 6.0V dc	3.3 V dc
3.	**Interface**	UART, USB, I2C, PCM, PIO	UART Logic-level	GPIO, UART, USB
4.	**Operating Temperature**	-40°C to 80°C	-30°C to +85°C	- 40 °C to 85 °C
5.	**Dimensions**	DIP type: 34.6 x 16.8 x 7.5 mm (0.661 in x 1.362 in x 0.295 in) SMD type: 34.6 x 14.8 x 3.0 mm	16x36x3 mm (2 mm height on request)	35 mm x 14 mm x 3.5 mm
6.	**Frequency Band**	2.4 GHz	2.4 GHz	2.4 GHz
7.	**Receive Sensitivity**	-90dBm	-84dBm	-90 dBm
8.	**RF output power**	+18dBm Typical	max 4dBm	+20 dBm
9.	**Supported Bluetooth profiles**	SPP (Serial Port Profile)	Generic Access Profile (GAP) Serial Port Profile (SPP) Dial-up Networking Profile (DUN GW, DUN DT)	SPP, DUN, HFP, HSP, HID, AVRCP, DI, PBAP, OPP, FTP and HDP
10.	**Cost**	30.00 USD	39.6 USD	35.0 USD

VII. APPLICATIONS OF BLUETOOTH

1.) Control and communication wirelessly of a handsfree headset and mobile phone.
2.) Wireless communication between computer and its peripherals like keyboard, mouse, printer.
3.) Intercom and wireless Bluetooth headset.
4.) Transferring files, reminders, calendar appointments, details of contacts with Object Exchange (OBEX).
5.) Networking of PCs wirelessly in a very confined space where the requirement of bandwidth is less.
6.) Two industrial Ethernet are bridged wirelessly.

7.) Transmission over short range of the data from the health sensor of the medical devices to set-top-box, mobile phone or dedicated telehealth devices.
8.) Replacement of place where infrared was used earlier.
9.) Places where low bandwidth and cable-free connection is desired.
10.) Sending small advertisements to discoverable Bluetooth devices from the advertisement hoardings which are Bluetooth enabled.
11.) Wireless replacement of RS-232 serial cable used in variety of applications e.g. bar code scanners, traffic control devices, medical equipment.
12.) Dial-up internet access using mobile phone (data capable) as wireless modem.
13.) Real time identification of the location of objects by the use of tags and nodes embedded in the objects to be tracked or attached to them.
14.) Use in wireless controllers of game consoles like Sony's Playstation3, Nintendo's Wii, PS vita and PSP Go.
15.) Control and communication between a Bluetooth compatible car stereo system and a mobile phone wirelessly.
16.) For the prevention of loss of the items or their theft, security application on mobile phones makes use of Bluetooth. The items that are protected are having a Bluetooth marker (e.g. tag) which is having communication constantly with the phone and when marker is out of phone's range an alarm goes on.
17.) On behalf of nearby mobile phone, allowing Digital Enhanced Cordless Telecommunication (DECT) phone to answer and ring calls.
18.) Canada, Alberta, Calgary's Roads Traffic division makes use of collected data from the Bluetooth devices of the travelers for the prediction of congestion of roads for the motorists and travel times [3].
19.) Bluetooth can be used in pole mounted Remote terminal units as given in [5] for the configuration and software updation purposes**.**
20.) A new wireless-type physiological signal measuring system using a Personal Digital Assistant (PDA) and the Bluetooth Technology [16].

VIII. RECENT VERSIONS HISTORY AND CURRENT STATUS

Version	Data Rate
Version 1.2	1 Mbit/s
Version 2.0 + EDR	3 Mbit/s
Version 3.0 + HS	24 Mbit/s
Version 4.0	

Bluetooth Core Specification version 4.0 was adopted as of 30 June 2010. It includes Bluetooth high speed, Classic Bluetooth, and Bluetooth low energy protocols. Base of Bluetooth high speed is Wi-Fi, and for the case of Classic Bluetooth, it consists of legacy Bluetooth protocols.
Bluetooth low energy (BLE), which was known previously as WiBree which is a subset of Bluetooth v4.0 but it is having an entirely new protocol stack in order to build up simple links rapidly. It is an alternative to the Bluetooth v1.0 to v3.0 standard protocols and is aimed for the applications requiring very low power consumption running off a coin cell. Design of the Chip allows two types of implementation, single-mode, dual-mode and enhanced past versions. Provisional names Bluetooth ULP (Ultra Low Power) and Wibree were abandoned and for a while the BLE name was used for a while. In late 2011, new logos "Bluetooth Smart" for sensors and "Bluetooth Smart Ready" for hosts were introduced [3].

IX. CONCLUSION

Popularity of Bluetooth can be seen easily in the market from a range of products incorporating this wireless technology. Security of Bluetooth makes it an attractive solution to be incorporated in the products. In this paper, principle of working of the Bluetooth is explained along with protocols of the Bluetooth. Apart from this three different Bluetooth modules have been specified for their features and specifications and also comparison between the three is done on the basis of many parameters such as Bluetooth specification, operating voltage, receiver sensitivity, RF output power, supported Bluetooth profiles and last but not the least is cost which is a very significant parameter for selection of Bluetooth module.

References

[1] Guérin, Roch, Enyoung Kim, and Saswati Sarkar. "Bluetooth technology key challenges and initial research." In Proc. SCS Comm. Networks and Distributed Systems Modeling and Simulation CNDS, pp. 157-163. 2002.

[2] Blasdel Justin, and Kian Pokorny. "The Future of Bluetooth Technology." (2004).

Available at - http://monde-diplomatique.si/test/sale/FAX/Angle%9A%E8ina/Bluetooth.pdf

[3] Bluetooth Article

Available at - http://en.wikipedia.org/wiki/Bluetooth

[4] Emira, Ahmed Ahmed Eladawy. "Bluetooth/WLAN receiver design methodology and IC implementations." PhD diss., Texas A&M University, 2003.

[5] Simranjit Singh Chadha, Mandeep Singh & Rohit Kumar Arora, "A Review of Bluetooth and Wi-Fi Based upon Coexistence Opportunities and Challenges in 2.4 Ghz Band ", Proceedings, International Conference on Electronics and Communication Engineering, 7th April, 2013,Bengaluru, India, pp 76-81.

[6] Bluetooth Technology Overview - F O R U M N O K I A, Version 1.0; April 4, 2003

Available at - http://lms.uni-mb.si/~meolic/ptk-seminarske/bluetooth2.pdf

[7] Parani BCD110, Online product catalog of SENA Technologies

Available at - http://www.sena.com/products/industrial_bluetooth/bcd110.php

[8] OEM Bluetooth Serial Port Module OBS410, Online product catalog of connectBlue

Available at - http://www.connectblue.com/products/classic-bluetooth-products/classic-bluetooth-modules/bluetooth-serial-port-module-obs410/

[9] connectBlue, Product Brief OEM Bluetooth Serial Port Module OBS410

Available at - http://www.connectblue.com/nc/products/classic-bluetooth-products/classic-bluetooth-modules/bluetooth-serial-port-module-obs410/?pdf=1&format=LETTER&pageId=1189

[10] WT41 Long Range Bluetooth Module, Online product catalogue of Bluegiga Technologies

Available at - http://www.bluegiga.com/WT41_Long_Range_Bluetooth_Module

[11] Bluegiga Technologies WT41-E-HCI3, Online price catalogue of Mouser Electronics

Available at - http://in.mouser.com/ProductDetail/Bluegiga-Technologies/WT41-E-HCI3/?qs=%2fha2pyFadugxuV1o%2fw7lyyid6XpN0tY2VKm1o4h3viv3V%2fJ5D26P%252bw%3d%3d

[12] Bluegiga Technologies WT41-E-AI4, Online price catalogue of Mouser Electronics

Available at - http://in.mouser.com/ProductDetail/Bluegiga-Technologies/WT41-E-AI4/?qs=R6JvMBAljWcxHe3vRdkh2w==

[13] Parani-BCD110 Bluetooth embedded OEM module DIP type, Class 1 with U.FL connector, HCI Firmware, Online product price catalogue of SENA Technologies

Available at - http://www.buysena.com/catalogsearch/result/?q=bcd+110

[14] CB-OBS410X-04-0, SERIAL PORT ADAPTER, Online product price catalogue of Digi-Key Corporation

Available at - http://www.digikey.com/product-detail/en/CB-OBS410X-04-0/809-1037-ND/2617077

[15] Matthew B. Shoemake, "Bluetooth, Wi-Fi and Coexistence Mastered in Handheld Devices",
Wireless Electronics

Available at - http://focus.ti.com/pdfs/bcg/epn_03_03.pdf

[16] Jia-Ren Chang Chien; Cheng-Chi Tai, "A New Wireless-Type Physiological Signal Measuring System Using a PDA and the Bluetooth Technology," Industrial Technology, 2006. ICIT 2006. IEEE International Conference on, vol., no., pp.3026, 3031, 15-17 Dec. 2006doi: 10.1109/ICIT.2006.372690

[17] Simranjit Singh Chadha, Mandeep Singh, Suraj Kumar Pardeshi, "Bluetooth for managing Pole Mounted Remote Terminal Unit", International Journal of Computer Science & Communication, Vol.4, No. 2, Sept 2013 (in press).