

A review on comparative study of Bluetooth and ZigBee

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Abstract—Wireless communication have some short range communication protocols, two are Bluetooth (over IEEE 802.15.1) and ZigBee (over IEEE 802.15.4) with low power consumption. Bluetooth is based on a wireless radio system designed for short range and cheap device to replace cables for computer peripherals. ZigBee provides self-organized multi-hop and reliable mesh networking with long Battery lifetime. This paper is a review paper of comparative study of Bluetooth and ZigBee.

Keywords—Wireless communication, Bluetooth, ZigBee FHSS, piconet, cluster tree.

I. Introduction

Handheld devices are rapidly becoming an integral part of our daily lives, and many road warriors already carry a cell phone, palmtop, and laptop computer with them. In most cases, these devices do not have compatible data communication interfaces, or, if they do, the interface requires cumbersome cable connections and configuration procedures. An obvious solution is to get rid of the cables and use short-range wireless links to facilitate on-demand connectivity among devices. Bluetooth and ZigBee are wireless short range communication protocols.

Bluetooth is generally used for point to point communication, although Bluetooth networks can be established quite easily. Bluetooth can also be used to create small ad-hoc networks, often with one USB to Bluetooth convertor as the master and up to 4 serial to Bluetooth adapters as slaves.

ZigBee supports protocols for defining a type of sensor network that controls applications used in residential and commercial settings such as air conditioning, heating and lighting. It harmonizes the application software layers specified by the ZigBee alliance and the IEEE 802.15 that defines the physical and MAC protocol layers. ZigBee is anticipated to be able to eliminate electrical cabling in houses thereby allowing the freedom of wireless light switches.

II. Bluetooth

A. Overview

Bluetooth is a short-range radio link intended to replace the cable(s) connecting portable and/or fixed electronic devices. Key features are robustness, low complexity, low power and low cost [8].

Founded in February 1998, Bluetooth is a standard developed by the members of the Bluetooth SIG (Ericsson, Intel, Toshiba, Nokia & IBM.) that allows any sort of electronic equipment to make its own connections, without wires, cables or any direct action from an user. Today, more than 1000 companies have joined SIG to work for an open standard for the Bluetooth concept.

Bluetooth is a low-cost, low-power, secure and robust standard for short-range connectivity. The technology has been designed for ease of use, simultaneous voice and data and multi-point communications. It supports a range of 10 m, which can be increased up to 100 m with the use of an amplifier. Any Bluetooth system has four basic parts [2][3][4]: a radio (RF) that receives and transmits data and voice; a baseband or link control unit that processes the transmitted or received data; link management software that manages the transmission; supporting application software. The Bluetooth radio is a short-distance, low-power radio that operates in the unlicensed spectrum of 2.4 GHz. This spectrum is shared by other types of equipment (e.g. microwave ovens)[4].

In order to avoid interference, the Bluetooth specification employs Frequency Hopping Spread Spectrum (FHSS) techniques. Using a nominal antenna power of 0 dB.m, the range is 10 m (33 feet). Optionally, a range of 100 m (328 feet) may be achieved by using an antenna power of 20 dB.m. Data is transmitted at a maximum gross rate of up to 1 Mb/s. Protocol overhead limits the practical data rate to a little over 721 Kb/s. Interference or being out of range may further decrease the achievable data rate. Baseband is the hardware that turns received radio signals into digital form, which can be processed by the host application. It also converts digital or voice data into a form that can be transmitted using a radio

signal. The baseband processor takes care of converting data from one form to another (such as voice to digital data), compressing it, putting it into packets, taking it out from packets, assigning identifiers and error correction information and then reversing the entire process for data that is received. In Bluetooth, the baseband function is called a link controller. The link manager software runs on a microprocessor and manages the communication between Bluetooth devices. Each Bluetooth device has its own link manager, which discovers other remote link managers, and communicates with them to handle link setup, negotiate features, and authenticate QoS and to encrypt and adjust data rate on link, dynamically. The application software is embedded in the device that operates an application over the Bluetooth protocol stack. This software allows the PDA, the mobile phone, or the keyboard do its job. All Bluetooth devices must have compatible sections in their Bluetooth stack, so that all Bluetooth devices will be able to inter-operate with each other. Any two Bluetooth devices that come within a range of each other can set up an ad-hoc connection, which is called a piconet. Every piconet consists of up to eight units[4].

There is always a master unit in a piconet and the rest of the units act as slaves. The unit that establishes the piconet becomes the master unit. The master unit can change later but there can never be more than one master. Several piconets can exist in the same area. This is called a scatternet. Within one scatternet all units share the same frequency range, but each piconet uses different hop sequences and transmits on different 1 MHz hop channels. All piconets share the 80 MHz band, and thus as long as the piconets pick different hop frequencies, no sharing of hop channels occurs[4][1].

B. Characteristic of Bluetooth

The basic characteristics of Bluetooth are [3][4]:

1. Operates in the 2.4 GHz band at a data rate of 720 Kb/s;
2. Uses Frequency Hopping (FH) spread spectrum, which divides the frequency band into a number of channels (2.402-2.480 GHz yielding 79 channels);
3. -Radio transceivers hop from one channel to another in a pseudo-random fashion, determined by the master;
4. -Supports up to 8 devices in a piconet (1 master and 7 slaves);
5. -Piconets can combine to form scatternets.[1,2,4]

C. Bluetooth topology

. There can be only 2 ~ 8 Bluetooth devices talking to each other. This is called a piconet. Among these devices, there can be only one master device, all the rest are slave devices. A device can belong to two piconets meantime, serving as slaves

in both piconet or a master in one and slave in another. This is called a bridging device. Bridging devices connect piconets together to form a scatternet[8]

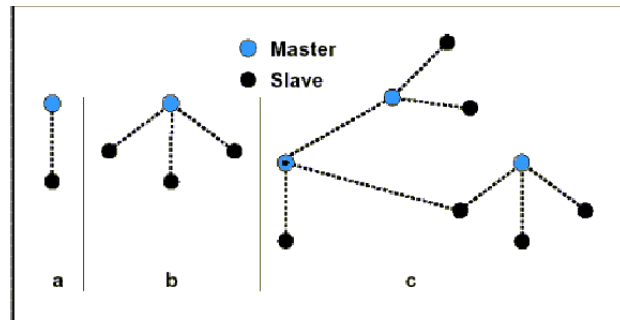


Fig1: Single-slave piconet (a), multiple-slave piconet and scatternet (c)

D. Bluetooth applications

Bluetooth provides support for three general application areas using short-range wireless connectivity [8]:

1. Data and voice access points. Bluetooth facilitates real-time voice and data transmissions by providing effortless wireless connection of portable and stationary communications devices.
2. Cable replacement. Bluetooth eliminates the need for numerous, often proprietary cable attachments for connection of practically any kind of communications device. Connections are instant and are maintained even when devices are not within line of sight. The range of each radio is approximately 10 m, but can be extended to 100 m with an optional amplifier.
3. Ad hoc networking. A device equipped with a Bluetooth radio can establish instant connection to another Bluetooth radio as soon as it comes into range [9].

III. ZigBee

ZigBee technology is a low data rate, low power consumption, low cost, wireless networking protocol targeted towards automation and remote control applications. IEEE 802.15.4 committee started working on a low data rate standard a short while later. Then the ZigBee Alliance and the IEEE decided to join forces and ZigBee is the commercial name for this technology. ZigBee is expected to provide low

cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. In addition, ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. ZigBee compliant wireless devices are expected to transmit 10-75 meters, depending on the RF environment and the power output consumption required for a given application, and will operate in the unlicensed RF worldwide (2.4GHz global, 915MHz Americas or 868 MHz Europe). The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz. IEEE and ZigBee Alliance have been working closely to specify the entire protocol stack. IEEE 802.15.4 focuses on the specification of the lower two layers of the protocol (physical and data link layer). On the other hand, ZigBee Alliance aims to provide the upper layers of the protocol stack (from network to the application layer) for interoperable data networking, security services and a range of wireless home and building control solutions, provide interoperability compliance testing, marketing of the standard, advanced engineering for the evolution of the standard. This will assure consumers to buy products from different manufacturers with confidence that the products will work together. IEEE 802.15.4 is now detailing the specification of PHY and MAC by offering building blocks for different types of networking known as "star, mesh, and cluster tree". Network routing schemes are designed to ensure power conservation, and low latency through guaranteed time slots. A unique feature of ZigBee network layer is communication redundancy eliminating "single point of failure" in mesh networks. Key features of PHY include energy and link quality detection, clear channel assessment for improved coexistence with other wireless networks. A ZigBee system consists of several components. The most basic is the device. A device can be a full-function device (FFD) or reduced-function device (RFD). A network shall include at least one FFD, operating as the PAN coordinator. The FFD can operate in three modes: a personal area network (PAN) coordinator, a coordinator or a device. An RFD is intended for applications that are extremely simple and do not need to send large amounts of data. An FFD can talk to RFDs or FFDs while an RFD can only talk to an FFD.[5]

A. *Characteristics of ZigBee*

ZigBee have the following:

1. *2.4GHz and 868/915 MHz dual PHY modes.* This represents three license-free bands: 2.4-2.4835 GHz, 868-870 MHz and 902-928 MHz. The number of channels allotted to each frequency band is fixed at

sixteen (numbered 11-26), one (numbered 0) and ten (numbered 1-10) respectively. The higher frequency band is applicable worldwide, and the lower band in the areas of North America, Europe, Australia and New Zealand .

2. Low power consumption, with battery life ranging from months to years. Considering the number of devices with remotes in use at present, it is easy to see that more numbers of batteries need to be provisioned every so often, entailing regular (as well as timely), recurring expenditure. In the ZigBee standard, longer battery life is achievable by either of two means: continuous network connection and slow but sure battery drain, or intermittent connection and even slower battery drain.
3. Maximum data rates allowed for each of these frequency bands are fixed as 250 kbps @2.4 GHz, 40 kbps @ 915 MHz, and 20 kbps @868 MHz.
4. High throughput and low latency for low duty-cycle applications (<0.1%)
5. Channel access using Carrier Sense Multiple Access with Collision Avoidance (CSMA - CA)
6. Addressing space of up to 64 bit IEEE address devices, 65,535 networks
7. 50m typical range
8. Fully reliable "hand-shaked" data transfer protocol.

B. *ZigBee topology*

Types of topologies that ZigBee supports: star topology, peer-to-peer topology and cluster tree.

Star Topology:

In the star topology, the communication is established between devices and a single central controller, called the PAN coordinator. The PAN coordinator may be mains powered while the devices will most likely be battery powered. Applications that benefit from this topology include home automation, personal computer (PC) peripherals, toys and games.

After an FFD is activated for the first time, it may establish its own network and become the PAN coordinator. Each start network chooses a PAN identifier, which is not currently used by any other network within the radio sphere of influence. This allows each star network to operate independently.

C. Applications of ZigBee

Peer-to-peer Topology:

In peer-to-peer topology, there is also one PAN coordinator. In contrast to star topology, any device can communicate with any other device as long as they are in range of one another. A peer-to-peer network can be ad hoc, self-organizing and self-healing. Applications such as industrial control and monitoring, wireless sensor networks, asset and inventory tracking would benefit from such a topology. It also allows multiple hops to route messages from any device to any other device in the network. It can provide reliability by multipath routing.

Cluster-tree Topology:

Cluster-tree network is a special case of a peer-to-peer network in which most devices are FFDs and an RFD may connect to a cluster-tree network as a leave node at the end of a branch. Any of the FFD can act as a coordinator and provide synchronization services to other devices and coordinators. Only one of these coordinators however is the PAN coordinator. The PAN coordinator forms the first cluster by establishing itself as the cluster head (CLH) with a cluster identifier (CID) of zero, choosing an unused PAN identifier, and broadcasting beacon frames to neighbouring devices. A candidate device receiving a beacon frame may request to join the network at the CLH. If the PAN coordinator permits the device to join, it will add this new device as a child device in its neighbour list. The newly joined device will add the CLH as its parent in its neighbour list and begin transmitting periodic beacons such that other candidate devices may then join the network at that device. Once application or network requirements are met, the PAN coordinator may instruct a device to become the CLH of a new cluster adjacent to the first one. The advantage of this clustered structure is the increased coverage area at the cost of increased message latency.[5]

1. 1.Home Control: Security, Heating, Ventilation, and Air- Conditioning(HVAC), Lighting control, Access control, Irrigation
2. Personal health care: Patient monitoring, Fitness monitoring,
3. Industrial control: Asset management, Process control, Energy management, Environmental,
4. Building automation: Automatic Meter Reading (AMR), Security, HVAC, Lighting control, Access control,
5. 5.Consumer electronics: Remote control,
6. PC & peripherals: Mouse, keyboard, joystick,
7. Environment: Environment monitoring.[6]

IV. Zigbee and Bluetooth: A Comparison

Both belonging to same Wireless Private Area Network(WPAN)k ie. IEEE 802.15, ZigBee and Bluetooth are a lot in common. Both run in the 2.4 GHz unlicensed frequency band and uses small form factors and low power. Well being part of the same IEEE standard, ZigBee(802.15.4) and Bluetooth(802.15.1) are not at all competing technologies, there are a lot of difference between them in terms of Application and Technicality. The technology used in ZigBee is less expensive and less complex than Bluetooth.

ZigBee protocols are intended for embedded applications requiring low data rates and low power consumption, Typical application where ZigBee are used includes: home entertainment , smart lighting , Wireless Sensor Networks, Industrial Control, Embedded sensing etc. While Bluetooth have many application in day to day life, it came into existence when it was needed to eliminate wired connection between two devices forming Ad Hoc network. Today the applications of Bluetooth can be seen everywhere, like headsets, Intercom, Data Transfer, Medical Equipments, etc.. Table 1 shows the basic defferences between these two technologies.

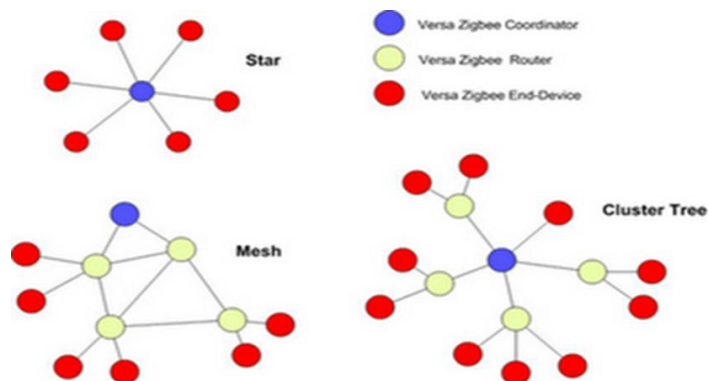


Fig 2: ZigBee Topologies: Star , Mesh, Cluster tree

STANDARD	BLUETOOTH	ZIGBEE
IEEE SPECIFICATION	802.15.1	802.15.4
FREQUENCY BAND	2.4 Ghz	868/915Mhz,2.4 Ghz
MAX SIGNAL RATE	1Mbps	250Kbps
NORMAL RANGE	10M	10-100M
NORMAL TX POWER	0-10 dBm	(-25)-0 dBm
NUMBER OF RF CHANNELS	79	1/10,16
CHANNEL BANDWIDTH	1 MHz	0.3/0.6 MHz,2MHz

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MODULATION TYPE	GFSK	BPSK(+ASK),O-QPSK
SPREADING	FHSS	DSSS
COEXISTANCE MAECHANISM	Adaptive frequency Hopping	Dynamic frequency Selection
BASIC CELL	PICONET	STAR
EXTENSION OF THE BASIC CELL	SCATTENET	CLUSTER TREE,MESH
MAX NUMBER OF CELL NODES	8	>65000
ENCRYPTION	ED stream cipher	AES BLOCK CIPHER (CTR,counter mode)
AUTHENTICATION	SHARED SECRET	CBC-MAC (ext. of CCM)
DATA PROTECTION	16-bit CRC	16-bit CRC

Table 1: differences between Bluetooth & ZigBee[10]

Conclusion

There is a lot in common between Zigbee and Bluetooth, like both operating in the same frequency band of 2.4 GHz and belonging to the same wireless private area network (IEEE 802.15). But even if this is the case, they are not exactly competing technologies. Also, there is a multitude of differences between the two wireless technologies for ‘personal area networks’ both application and technical. As will be explained in the article, both technologies aim towards a different set of devices and applications and different means of designing for those applications.

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