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A Comparative Study of Wireless Communication Protocols: Zigbee vs Bluetooth

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Abstract:
Bluetooth (IEEE 802.15.1) and ZigBee (IEEE 802.15.4) are protocol standards for short range wireless communications. Both standards consume less power and operate in the unlicensed 2.4 GHZ spectrum, while ZigBee can also operate at reduced speeds at 915MHz and 868 MHZ. Bluetooth replace the cable connections between hand phones, PDAs and other portable devices. ZigBee is designed for reliable wirelessly networked monitoring and control networks. In this paper, we provide a comparative study of these two wireless communication standards, evaluating their main features and behaviors in terms of various parameters, including the transmission time, network size, range, security and power consumption. This paper would help engineers in selecting an appropriate protocol while designing applications.

Keywords: ZigBee, Bluetooth, wireless communication protocols.

INTRODUCTION

A number of different wireless technologies have been developed for very short distances. These are referred to as short range wireless communications. Signals in this range travels from a few centimeters to several meters. In contrast, signals in medium range wireless communication travels up to a hundred meters or so, while signals in wide Area wireless communication can travel from several kilometers to several thousand kilometers. Examples of short range wireless communication include Bluetooth, Infrared, near- field communication, ZigBee, Ultra Wide Band (UWB) etc.

The emergence of the above wireless technologies suggests that the expensive wiring can be reduced or eliminated. Many technologies have emerged and provide communication differently. This difference lies in the quality of service and in some constraints related on the application and it environment. The main constraints to be overcome in choosing a wireless technology revolve around the following conditions [1], [2]

- Cost
- Energy consumption
- Range
- Reliability
- Bandwidth
- Conformity (standards)
- Security
- Network architecture (topology)

Bluetooth is a low cost, low power, short-range radio technologies intended to replace the cable connections between hand phones, PDAs and other portable devices. ZigBee is a specification for low-rate wireless personal area networks. ZigBee is widely used in much wireless Monitoring and control application domains due to its low cost, low power and implementation simplicity [3]. For ZigBee and Bluetooth, Baker [4] studied their strengths and weaknesses for industrial applications, and claimed that ZigBee over 802.15.4 protocol can meet a wider variety of real Industrial needs than Bluetooth due to its long-term battery operation, greater useful range, flexibility in a number of dimensions, and reliability of the mesh networking architecture [5].

WIRELESS PROTOCOLS

A. BLUETOOTH (IEEE 802.15.1)

Bluetooth is a type of wireless communication used to transmit voice and data at high speed using radio waves. It is a standard protocol for short range radio communication between many types of devices including mobile phones, computers, entertainment systems and other electronics. Bluetooth is a replacement for cables between these devices to communicate with each other, establishing a personal area network. Devices needs to be approximately within 10 meters to each other and the typical data rate is around 2 Mbps. The technology is named after Danish king "Harald Bluetooth". Bluetooth signals operate in the 2.4 GHz frequency band. Every device using Bluetooth has a small microchip that can send both voice and data signals.

In a typical set up, one device operate as the master and one or more other devices operate as slaves. The master device uses link manager software to identify other Bluetooth devices to create link with them to be able to send and receive data.

Bluetooth uses spread spectrum frequency hopping technology (SSFH), i.e. it uses multiple frequencies at the same time to limit interference when using multiple devices. While Bluetooth does not need a direct line of sight, the signals do not travel very far and need to be within

approximately 10 meters. Bluetooth works great in making phone calls using audio systems of a car or to play music through a wireless speaker.

B. ZIGBEE (IEEE 802.15.4)

Zigbee is a wireless communication technology for short – range, low – power digital radio communications. Relative to bluetooth, Zigbee uses a very little power and a low data transfer rate. ZigBee provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime [5] The IEEE 802.15.4 protocol includes a PHY layer and MAC sub-layer for the Low-Rate
Wireless Personal Area Networks (LR-WPAN).The PHY layer offers three operational frequency bands; there are 27 channels allocated in the 802.15.4 range, with 16 channels in the 2.4 GHz band, 10 channels in the 915 MHz band, and 1 channel in 868 MHz band [6]. The MAC sub-layer handles all access to the physical radio channel. It provides an interface between the service specific convergence sub-layer (SSCS) and the PHY layer [6]. Zigbee is widely used in remote controls, home entertainment systems, energy management and building automation

COMPARATIVE STUDY

Table I summarizes the main differences among these two protocols. Each protocol is based on an IEEE standard. Obviously, Bluetooth and ZigBee give a lower one. In general, the Bluetooth and ZigBee are intended for WPAN communication (about 10m). However, ZigBee can also reach 100m in some applications.

TABLE I - COMPARISON OF BLUETOOTH AND ZIGBEE PROTOCOLS

Standard	Bluetooth	ZigBee
IEEE Spec.	802.15.1	802.15.4
Frequency band	2.4 GHz	866/915 MHz, 2.4 GHz
Max. signal rate	1 Mbps	250 kbps
Nominal range	10m	10 – 100m
Channel bandwidth	1 MHz	0.3/0.6 MHz, 2 MHz
Modulation type	GFSK	BPSK, (+ ASK), OPQSK
Spreading	FHSS	DSSS
Max no. of cell nodes	8	>65000
Extension of basic cell	Scannet	Cluster tree, Mesh

❖ **Transmission Time**

The transmission time depends on the data rate, the message size, and the distance between two nodes. The formula of transmission time in (µs) can be described as follows:

$$T_{tx} = \left(N_{data} + \left(\frac{N_{data}}{N_{maxpld}}\right) \times N_{ovhd}\right) \times T_{bit} + T_{prop}$$

The typical parameters of the two wireless protocols used to evaluate the time of transmission are given in the table below.

Table II - Typical parameters of wireless protocols

Protocol	Max data rate (Mb/s)	Bit time (µs)	Max data payload (bytes)	Max overhead (byte)	Coding efficiency (%)
Bluetooth	0.72	1.39	399 (DH5)	158/8	94.1
Zigbee	0.25	4	102	31	76.52

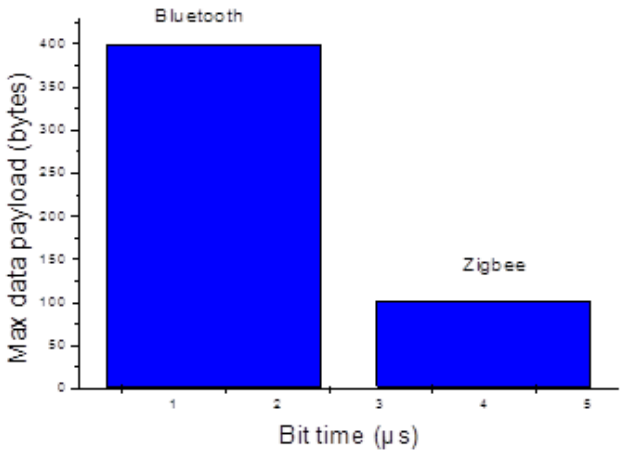

Figure 1: Comparison of transmission time relative to the data size

From the figure above, it clearly shows that the required transmission time is proportional to the data payload size N_{data} and it is not proportional to the maximum data rate

❖ **Chipset power consumption**

To compare the power consumption, table III presents detailed characteristics of particular chipset for each protocol. Figure 2 shows the consumption power in (mW) for each protocol. Obviously we note that Bluetooth and ZigBee consume less power

Table III Power Consumption Characteristics of Chipsets

Protocols	Chipset	V_{DD} (volt)	I_{TX} (mA)	I_{RX}	Bit Rate (Mb/s)
Bluetooth	BlueCore2	1.8	57	47	0.72
Zigbee	CC2430	3.0	24.7	27	0.25

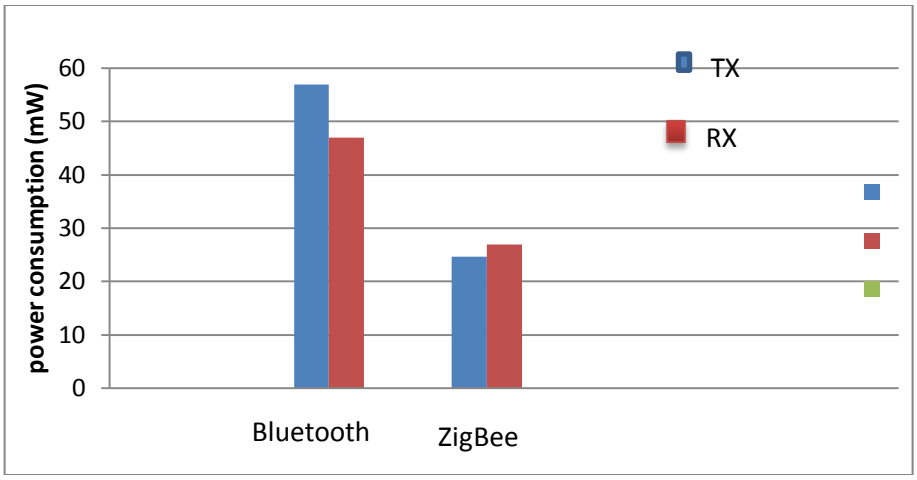

Fig 2: Comparison of chipset power consumption

❖ **Protocol Complexity**

The complexity of each protocol is compared based on the numbers of primitives and events. Table IV shows the number of primitives and Host controller interface (HCI) events for Bluetooth, and the numbers of MAC/PHY primitives for UWB, ZigBee, and Wi-Fi protocols. In the MAC/PHY layers, the Bluetooth primitives include client Service Access Point (SAP), HCI SAP, Synchronous Connection-Oriented (SCO) SAP, and logical link control and adaptation protocol (L2CAP) primitives. As shown in Fig 3, the Bluetooth is the most complicated protocol with 188 primitives and events in total. On the other hand, ZigBee is the simplest one with only 48 primitives defined in 802.15.4. This total number of primitives is only about one fourth the number of primitives and events defined in Bluetooth. As compared with the Bluetooth, the simplicity makes ZigBee very suitable for sensor networking applications due to their limited memory and computational capacity.

Table IV Number of Primitives and Events for different Protocol

Standard	Bluetooth	Zigbee
IEEE spec.	802.15.1	802.15.4
Primitives	151	35
HCL events	37	13

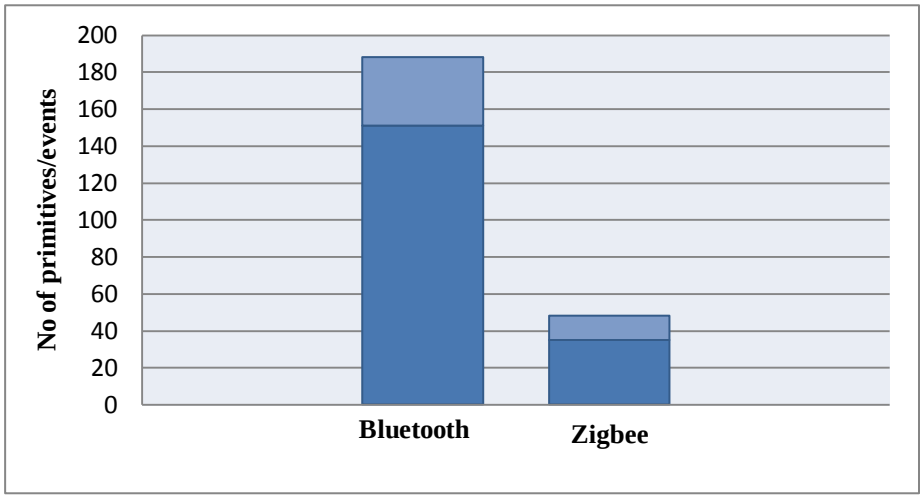

Figure 3: Comparison of the complexity for each protocol

❖ **Range**

Bluetooth is designed to operate within a 10m range, though Bluetooth 2.1 now states a maximum range of 30m [6]. ZigBee, being designed to enable "home and industry automation" [7], allows a range of 10 – 100m.

❖ **Data Rate**

Bluetooth's original data rate was 1Mbps [8], but has proceeded to reach maximum rates of 3Mbps. ZigBee intentionally lags far behind these numbers, sacrificing data rates for power savings, and so transmits only 20-250Kbps.

CONCLUSION

This paper has presented a broad overview of two wireless standards, Bluetooth and ZigBee, with a quantitative evaluation in terms of the transmission time, protocol complexity, and power consumption. Furthermore, network size, range and security are also preliminary compared. This comparison is not to draw any conclusion regarding which one is the best since the suitability of network protocols is greatly influenced by practical applications, of which many other factors such as the network reliability, roaming capability, recovery, chipset price, and installation cost. One can make intelligent decisions about which to use in particular applications. Industrial automation task requires the resilience of mesh networking, making ZigBee a strong choice. For applications requiring high bit rates over short distances, like wireless stereo headphones, Bluetooth remains the best technology.

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