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A Comparative Analysis of Short Range Wireless Protocols For Wireless Sensor Network

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Abstract— Wireless sensor networks are becoming very popular recently due to their performances, functions and intelligence. Intelligent sensor nodes form a network which can be used to transmit and receive real-time traffic for remote monitoring, automation, diagnostics etc. Short range wireless communication is the best suited protocol for deploying such network. Wi-Fi (IEEE 802.11), Bluetooth (IEEE 802.15.1) and ZigBee (IEEE 802.15.4) are three protocol standards for short-range wireless communications with low power consumption. This paper has focused a comparative analysis between those protocol standards in order to evaluate their main features and behaviors. Several performance metrics such as Transmission time, Bit Error Rate, Received power, Packet Delivery Ratio and Power consumption has been used in this paper.

Index Terms— Wireless Sensor networks, Tranmission time, Power consumptoion, Efficiency, Zigbee, Bluetooth

1 Introduction

Wireless sensor networks (WSN), sometimes called wireless sensor and actuator networks [2][3] are spatially distributed autonomous sensors to monitor various physical and environmental conditions. Today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine monitoring, health-care patient monitoring and so on. Different types of technologies are being used to provide communication based on wireless environments and its applications. The QoS of such networks several parameters are directly involved with several parameters such as [4]:
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- Standard
- Bandwidth
- Coverage
- Reliability
- Transmission rate
- Power consumption
- Network topology
- Environment etc.

This paper has focused on a comparative study between three short range wireless protocols such as Bluetooth, ZigBee and WiFi for deploying an intelligent wireless sensor network. In this paper we have attempted the comparison based on transmission time, power consumption, BER, packet delivery ratio etc. which influenced the performance and quality of a short range wireless intelligent sensor network taking into our consideration the cost and the application requirements.

2 Intelligent Wireless Sensor Network

An ideal intelligent wireless sensor network is a smart network capable of fast data processing and consume small amount of power. It is also reliable and accurate in long usage and cheap to purchase. Intelligent wireless sensor network devices are like plug and play that requires no real maintenance.
A Wireless Sensor Network (WSN) generally consists of sensor nodes that can communicate through each other through radio line with a gateway often called an Access Point (AP). The working method of a WSN is very simple. First, data is collected by wireless sensor nodes, compressed, and finally transmitted to the gateway directly or if required, uses other wireless sensor nodes to forward data to the gateway. Secondly, the transmitted data is sent to the monitoring or controlling unit for further process. The further process involves with several responsibilities such as data storage in database or presenting to any related monitoring system.

2.1 WSN Node Architecture

A wireless sensor node consists of a Sensor, MCU, Power Supply, RF Transceiver and an Antenna. Figure 1 shows typical wireless sensor node architecture.

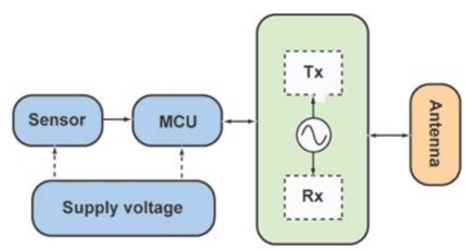

Figure 1: Wireless sensor Node Architecture

Sensor is used for sensing the environment along with a Micro Controller Unit (MCU) for controlling and processing signals form the sensor. The RF transceiver transmits (Tx) and receives (Rx) RF signal by an Antenna that interfaces with the transceiver with the physical environment.

A significant feature of any wireless sensing node is to minimize the power consumption of the network. So it is important for the sensor devices to minimize the power consumed by themselves. Thus, the hardware should be designed in such manner to let the microcontroller unit to control power to the radio, sensor, and sensor signal transceiver.

2.2 Wireless Sensor Network Architecture

There are different types of topologies available in wireless sensor networks. The two most commonly used network topologies that are applied to deploy wireless sensor networks are stated below.

a. Star Topology based WSN

A star network is a topology where a single access point can send or receive a message to or from remote sensor nodes [5]. Sensor nodes cannot send or receive message between themselves directly. They can only send or receive a message from the access point in order to send messages to each other. Star topology is Single hop communication. The benefit of this type of network for wireless sensor networks is in its simplicity and the ability to keep the remote node's power consumption to a minimum level [5]. Figure 2 shows a star topology based WSN architecture. This type of network also allows low latency communications between the remote node and the access point. The main limitation of such network is scalability. The nodes at greater distance may have poor quality connection with the access point.

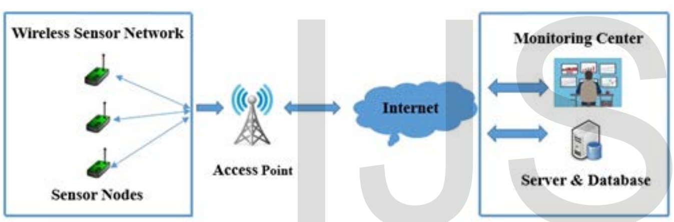

Fig 2: Star topology based wireless sensor network

b. Mesh Topology based WSN

In mesh topology all sensor nodes are connected to each other. It allows multi hop communications between nodes. The signal goes from one sensor to the other until it reaches the destination which can be generalized as Ad hoc network. If a node

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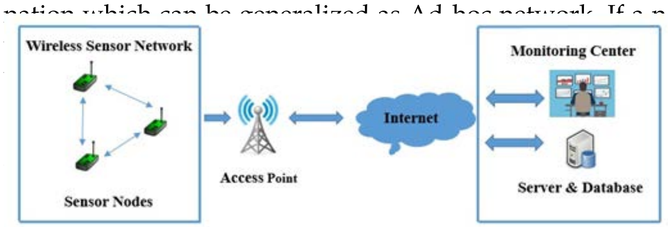

Fig3: Mesh topology based wireless sensor network

An additional type of network can be designed which is a combination of star and mesh network topologies. This type of network is known as hybrid network. A hybrid topology offers a robust and versatile communication network, while maintaining the ability to keep the wireless sensor nodes power consumption to a minimum level [5].

3 Short Range Wireless Protocols

A number of different wireless technologies have been developed for very short distances. The term 'short range wireless communication' is referred to a network protocol where remote nodes are connected in a very short distance say for few meters. In contrast, signals in medium-range wireless communication travel up to 100 meters or so, while signals in wide-area wireless communication can travel from several kilometers to several thousand kilometers. Short range wireless communication has very exiting features. Examples of short-range wireless communications are Bluetooth, Infrared, Near Field Communication, Ultra- Wide Band, WiFi and ZigBee. In our paper we have considered three protocols among them which are WiFi (IEEE 802.11a/b/g/n), Bluetooth (IEEE 802.15.1) and ZigBee (IEEE 802.15.4).

3.1 WiFi (IEEE 802.11 a/b/g/n)

Wireless fidelity (Wi-Fi), IEEE 802.11x is a standard for describing wireless local area networks (WLAN) which allows users to connectivity to the Internet at broadband speeds when connected to an access point (AP) or in ad hoc mode. The data transfer rate. IEEE 802.11a operates at 5GHz with a maximum data rate 54 mbps. IEEE 802.11b and IEEE 802.11g have the operating frequency of 2.4 GHz with maximum data rate of 11 mbps and 54 mbps respectively [6]. For modulation FHSS and DSSS schemes are being used in Wi-Fi.

3.2 Bluetooth (IEEE 802.15.1)

Bluetooth is an IEEE 802.5.1 standard based on wireless radio system designed for short-range communication that uses lower power than WiFi. Bluetooth was originally specified to serve applications such as data transfer from personal computers to peripheral devices such as mouse, key board, printers, cell phone, earphone, personal digital assistants etc. Bluetooth is known as WPAN (Wireless personal area network) for these types of applications. Bluetooth uses a star network topology that supports up to seven remote nodes communicating with a single Access Point.

In Bluetooth Two topologies of connectivity can be defined in Bluetooth: Piconet and Scatternet. A Piconet is a WPAN formed by a Bluetooth device serving as a master in the Piconet and one or more Bluetooth devices serving as slaves [7].

3.3 ZigBee (IEEE 802.15.4)

ZigBee is an IEEE 802.15.4 based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios. ZigBee is less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that require short-range low-rate wireless data transfer [8].

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4 Comparative Analysis

In this paper a comparative analysis has been carried out with several metrics such as transmission time, Received signal power, Bit Error Rate, Power Consumption and Packet Delivery ratio etc.

Transmission Time:
The transmission time, is the amount of time from the beginning until the end of a message transmission. The transmission time depends on the data rate, the message size, and the distance between two nodes.

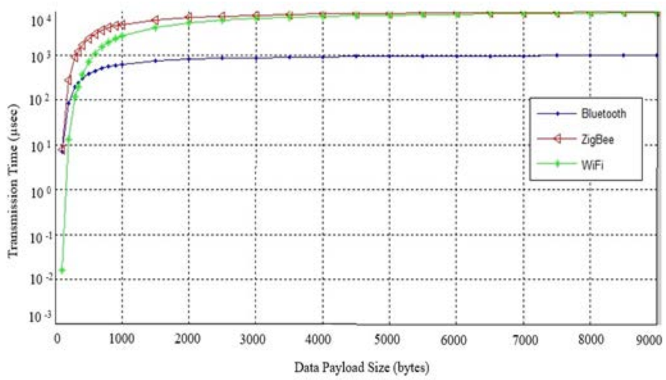

Fig 4: Comparison of transmission time

Figure 4 shows the transmission time comparison for different short range wireless protocols. We have kept payload size 10 Kbytes maximum bit rate 54 mbps for WiFi, 720 kbps for Bluetooth and 250 kbps for ZigBee. It is clearly shown that the required transmission time is proportional to the data payload size and it is not proportional to the maximum data rate.

Received Signal Strength:

RSSI is the relative received signal strength in a wireless environment, in arbitrary units. RSSI is an indication of the power level being received by the receive radio after the antenna and possible cable loss. Therefore, the higher the RSSI number, the stronger the signal.

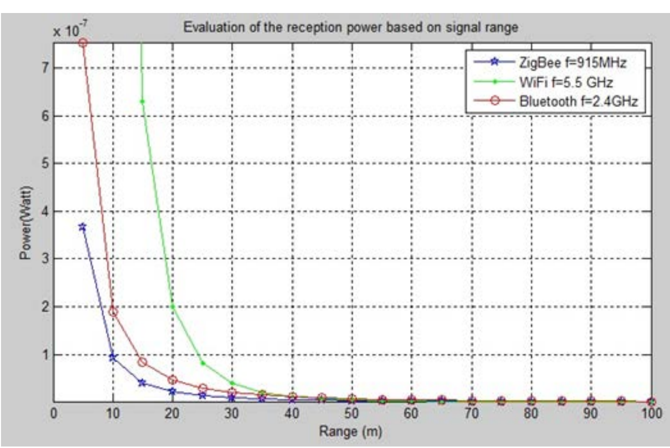

Figure 5: Received Signal Strength

Figure 5 indicates the received signal strength between WiFi, Bluetooth and ZigBee based on the signal range. Here WiFi consumes more power where ZigBee consumes less power.

Bit Error Rate (BER):
The bit error rate is a very efficient way to determine the performance of the modulation used by a communication system and therefore helps to improve its robustness. Figure 6 shows the BER of the different modulations used in WiFi, Bluetooth and ZigBee according on signal to noise ratio E_b/N_0.

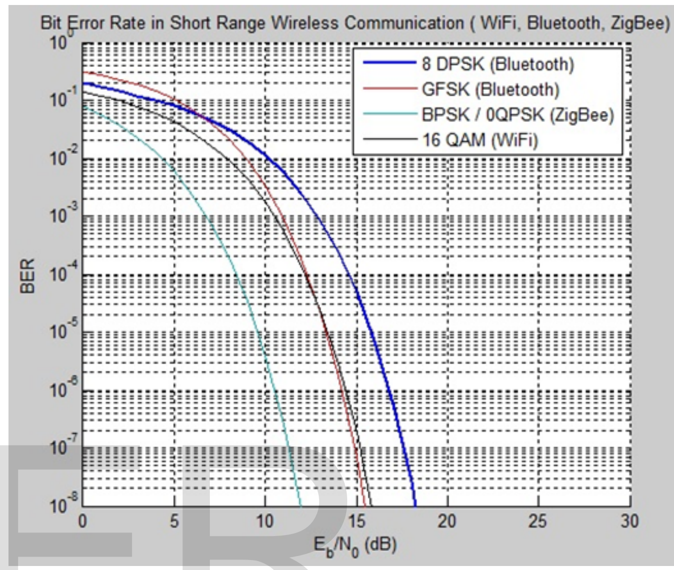

Fig: 6 Bit Error Rate (BER)

In figure 6 it is clearly seen that The BER for all schemes decrease with increasing values of Eb/N0, the curves defining a shape similar to the shape of a waterfall. The exact value of Eb/N_0 (dB) which cancels BER is shown in table 1.

TABLE 1
E_B/N_0 That Cancel BER in Different Protocols

Modulation Scheme	Usage Protocol	BER	E_b/N_0(dB)
16 QAM	WiFi	10^{-8}	16.1
GFSK	Bluetooth	10^{-8}	15.4
8DPSK	Bluetooth	10^{-8}	17.7
BPSK/ 0QPSK	ZigBee	10^{-8}	12.4

The BER for 0QPSK and OQPSK is the same as for BPSK. QPSK seem the best compromise between spectral efficiency and BER followed by other modulations. This modulation scheme is used in ZigBee.

Packet Delivery Ratio (PDR):
PDR indicates the ratio between the number of packet sent and the number of packets received. It is one of the most important metric for packet forwarding.

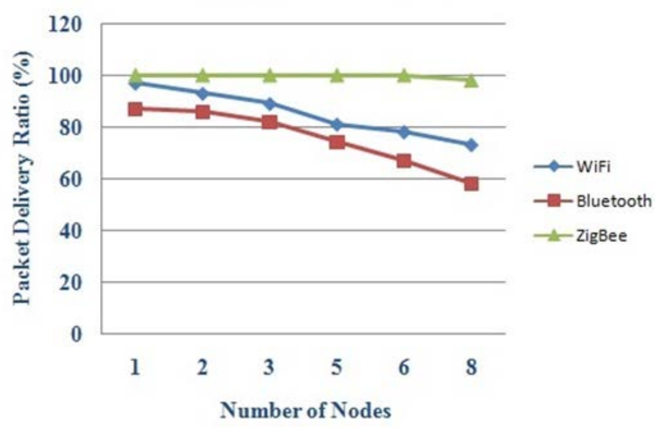

Fig 6: Packet Delivery Ratio

Figure 6 shows the comparison of Packet Delivery Ratio (PDR) between 3 protocols. Here the mobility was kept as stationary. It is seen that Bluetooth has the worst PDR as number of nodes are increasing (87% to 58%). In WiFi the PDR decreases from 96% to 73% as number of nodes increases up to 8. On the other hand ZigBee nodes show almost 100% PDR constantly. This is because as ZigBee operates with a predefined schedule, so nodes don't affect each other.

Power Consumption:
While the data rates are increasing high for wireless sensor applications, the power requirements generally goes higher that makes difficult its use in wireless sensor network applications. So power consumption is a very important metric for this analysis. To compare practically the power consumption, standard values taken from particular chipset for each protocol [9-11]. Figure 8 shows the consumption power in (mW) for each protocol. ZigBee consume relatively less power compared to Wi-Fi and Bluetooth.

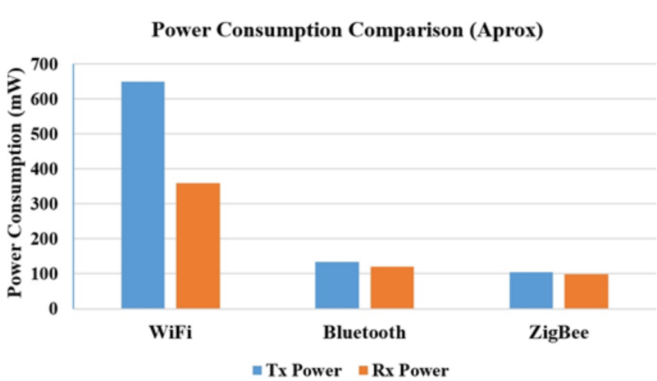

Fig 8: Power consumption power in (mW) for each protocol.

5 Conclusion

In this paper we have tried to make a comparative study between 3 most popular short range wireless protocols in order to deploy a Wireless Sensor Network. The intension of this paper is not to draw any conclusion regarding which one is superior to others. The main intension is to find the most appropriate protocol applicable for wireless sensor networks. In our work we have analyzed 3 protocols based on transmission time, received signal strength, bit error rate, packet delivery ration and power consumption. According to our analysis we can conclude that ZigBee is the best protocol among those 3 as it has stable transmission time, better spectral efficiency, lowest power consumption and highest packet delivery ratio.

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