Design and Implementation of a Low Power Consuming Zigbee Technology in Wireless Sensor Network (WSN)

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ABSTRACT

In recent years, Wireless sensor networks (WSN) have achieved an attention on a world level. These consist of small sensors with limited power and limited resources. Wireless sensor standards developed with the special requirement for consuming low power. Some of these standards are Wireless HART, IETF 6LoWPAN, ISA100.11, IEEE 802.15.3, Wibree, IEEE 802.15.4 and ZigBee. IEEE 802.15.4 has been developed to focus on low cost of deployment, low complexity and low power consumption. IEEE devices are designed to support the physical and data link layer protocols and ZigBee defines the higher layer communication protocols built on IEEE 802.15.4 standards. This paper provides a review on ZigBee technology. Firstly it gives an introduction to the ZigBee technology then the characteristics of ZigBee. After that there is an introduction to ZigBee alliance. Then are the access methods, devices and topologies supported by ZigBee. The most important part of this paper consists of the protocol architecture of ZigBee and in the last section there is various application of ZigBee technology in wireless sensor network.

1. INTRODUCTION

ZigBee is a low-cost, low-power, wireless mesh networking standard. First, the low cost allows the technology to be widely deployed in wireless control and monitoring applications. Second, the low power-usage allows longer life with smaller batteries. Third, the mesh networking provides high reliability and more extensive range. ZigBee is a standard that defines a set of communication protocols for low data rate short range wireless networking. ZigBee based wireless devices operate in 868MHz, 915MHz and 2.4GHz frequency bands. ZigBee is targeted mainly for battery power applications where low data rate, low cost and long battery life are main requirements. In many ZigBee applications, the total time the wireless device is engaged in any type of activity is very limited. The device spends most of its time in power saving mode, also known as sleep mode. As a result, ZigBee enabled devices are capable of being operational for several years before their batteries needs to be replaced.

2. IMPLEMENTATION OF ZIGBEE TECHNOLOGY

a) ZigBee Architecture

The network architecture is based on the Open Systems Interconnection (OSI) seven-layer model, where each layer is responsible for one part of the standard and offers services to the higher layers. Different layers in the protocol stack are shown below in figure. Each layer has a definite set of services. The Data Entity (DE) performs the data transmissions and the Management Entity (ME) performs all other services except that. The service entity communication between layers is performed through Service Access Points (SAP) that supports service primitives to perform the required functionality.

Physical (PHY) Layer

Physical layer provides two services: the PHY data service and the PHY management service interfacing to the Physical Layer Management Entity (PLME). The PHY data services enable the transmission and reception of PHY layer Protocol Data Units (PPDUs) across the channel. At a glance IEEE 802.15.4 PHY layer is responsible for:

- Activation and deactivation of the radio transceiver
- Signal Detection, Modulation and Data Encryption
- Link quality indication for received packets
- CCA for CSMA/CA
- Channel frequency selection
- Data transmission and reception

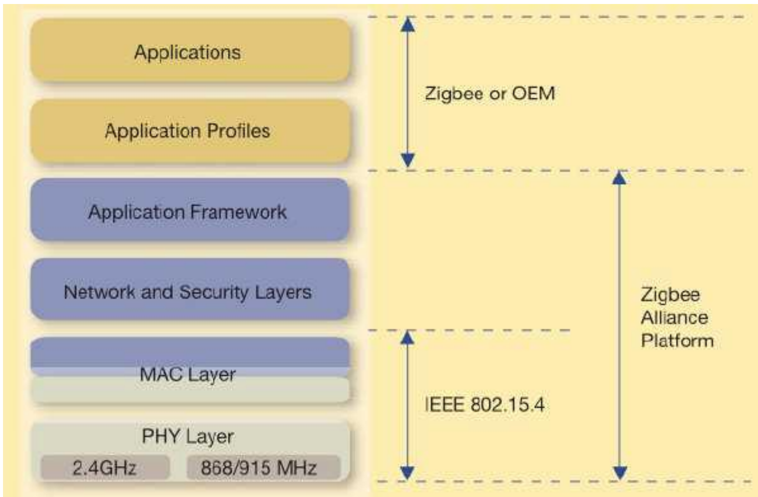

Fig: zigbee Architecture

Medium Access Control (MAC) Layer

MAC sub layer handles all access to the RF channel and is responsible for the following tasks:

- To provide a reliable link between two peer MAC entities
- Coordinator generates network beacons
- Support PAN association and disassociation
- Employ CSMA/CA mechanism for channel access
- Handing and maintain guaranteed time slot mechanism

Network (NWK) Layer

The network layer builds upon the IEEE 802.15.4 MAC's features to allow extended coverage. Additional cluster can be added or removed in this layer. All the network topologies discussed above are defined in this layer.

The ZigBee Network layer mainly performs following tasks:

_ Establish a new network
_ Joining and leaving a network
_ Configure the stack for operation when a new device joins the network
_ Assign address to device which is joining the network, this operation is carried by coordinator.
_ Routing frame to their destinations
_ Enable a device to synchronization with another device either through tracking beacons or by polling
_ Applying security operations

Application layer

The Application Layer (APL) consists of three different blocks which have different functionalities and responsibilities:
The **Application Support sub layer (APS)** is responsible for maintaining a table of devices that are connected to each other. The APS layer provides an interface between the NWK layer and the APL with its set of services.

The **ZigBee Device Object (ZDO)** is responsible for managing ZigBee devices in the network. This can be discovering a new device in the network and define its task in the network. It also determines the services the new device provides. Possible device types are those defined in the ZigBee standard and they are obviously coordinators, routers and end devices.

The **Application Frame (AF)** contains application objects which can be manufacturer defined applications. Each device can contain up to 240 applications objects that are defined through endpoints. An example of an application object is a power switch or an A/D converter.
The Security Service Provider (SSP) provides enhanced security options as encryption with 128 bit key transport.

b) Operating Frequencies and data rates

There are three frequency bands used for IEEE 802.15.4. These are

- 868 – 868.6 MHz (868MHz band)
- 902 – 928 MHz (915MHz)
- 2400 – 2483.5MHz (2.4GHz band)

Data rates of 250 kbps (@2.4 GHz), 40 kbps (@ 915 MHz), and 20 kbps (@868 MHz)

The 868MHz band is used in Europe for a number of applications, including short range wireless networking.
The 915MHz and 2.4GHz bands are part of industrial, scientific and medical (ISM) frequency bands. The 915MHz frequency band is used mainly in North America, where as the 2.4GHz band is used worldwide.

c) Design of ZigBee Transmitter
This section describes the implementation of ZIGBEE transmitter system. The design of ZigBee transmitter using OQPSK modulation with half sine pulse shaping is shown in the Figure given below. Here the input bit stream is having a data rate of 250Kbps.

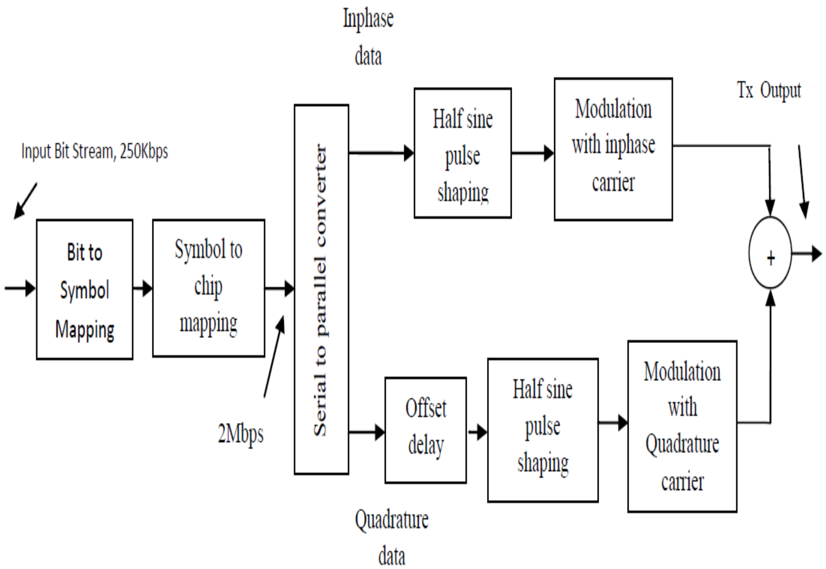

Fig: Block Diagram of Zigbee Transmitter

Now we are mapping 4 input data bits to a symbol having a symbol rate of 62.5Kilo symbols per second. The symbol is then used to select one of 16 nearly orthogonal 32-chip PN sequences to be transmitted and results in a chip rate of two mega chips per second. After that, resultant chip sequence is send to the serial to parallel converter. It is used here to separate the even indexed chips and odd indexed chips.

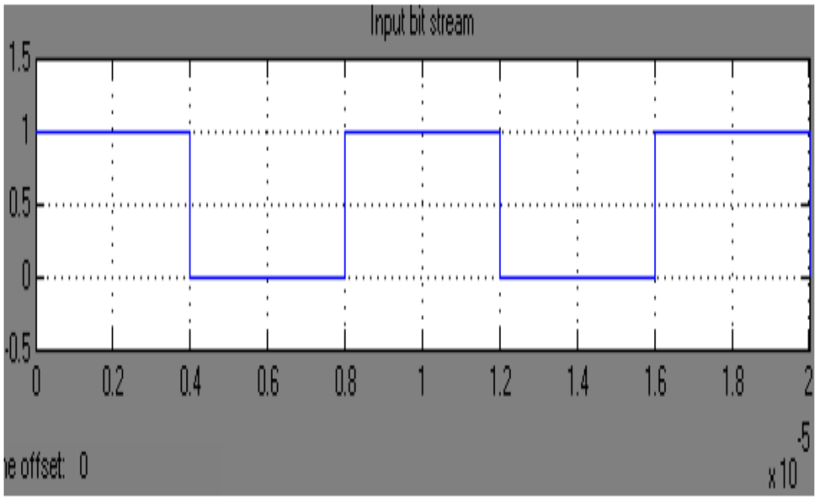

Fig: Input Bit Stream

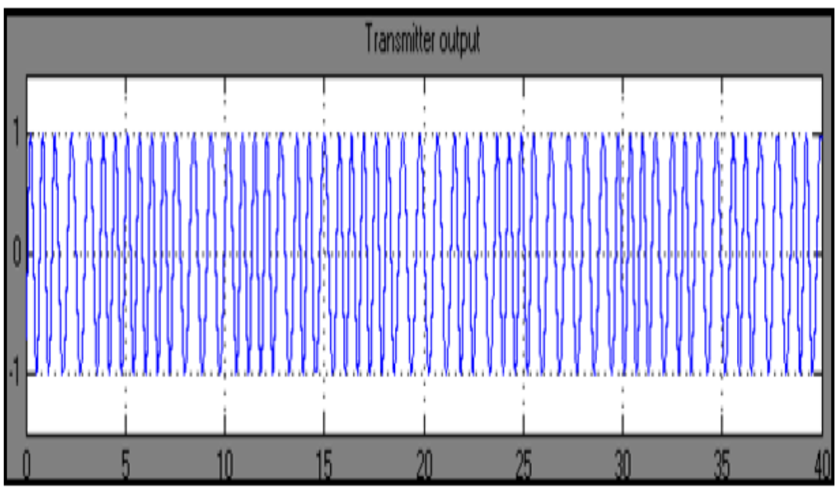

Fig: Output of Zigbee Transmitter

d) Design of ZigBee receiver

There are two type detection schemes available for the detection of original baseband data. They are coherent detection and non-coherent detection. In coherent detection, the phase of carrier that we used in the transmitter and phase of recovered carrier must be same. So proper carrier synchronization is necessary in the coherent demodulation. In case of non-coherent demodulation, there is no need of carrier synchronization. Coherent detection is costlier to implement, that is, the receiver must be equipped with a carrier recovery circuitry, which in turn increases system complexity, and can increase size and power consumption. Additionally, there is no ideal carrier recovery circuit. So, no practical digital communication system works under perfect phase coherence. While Non coherent detection uses previous bit information for extracting the original data and there is no need of using the carrier recovery circuit. Non-coherent detection is simpler, but it suffers from performance degradation as compared to coherent detection, but this difference can be small in practice for some modulation schemes due to the specifics of the modulation and also due to the penalty caused by imperfections in the carrier recovering process.

The block diagram of the ZigBee Receiver is shown in Figure below.

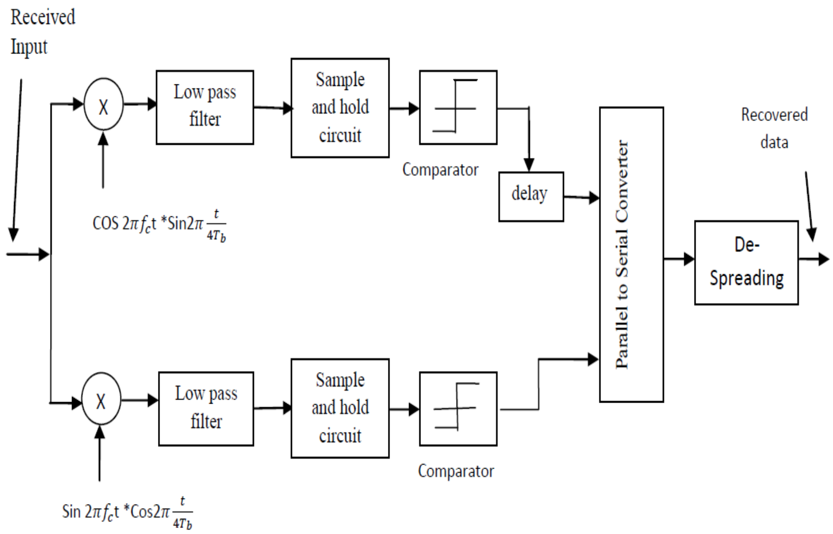

Fig: Block Diagram of Zigbee Receiver

In the receiver configuration of ZigBee, we are using a MSK demodulator and a multiplier for despreading. This multiplier is supplied by a PN sequence data that is an exact replica that used in the transmitter. The data coming from the MSK demodulator (i.e. at the parallel to serial converter) is having a data rate of 2Mbps. From this data, the original data is extracted by multiplying with the PN sequence data. But the 2Mbps data obtained at the output of parallel to serial converter contains some offset delay. This offset delay must introduced in the PN sequence data while multiplying with 2Mbps data, So that output contains original bit stream without any errors. The incoming received signal is applied to two synchronous demodulators, consisting of a multiplier followed by a low pass filter. This sampled data is passed through a decision device. Decision device is a simple comparator which contains a threshold value for making a decision. If the input to the comparator is greater than the threshold value, it decodes the bit as 1 otherwise it decodes as 0.

Output of Receiver

The transmitted signal is passed through a AWGN channel. The outputs of both inphase and Quadrature signals after multiplying with half sine signal. The final output of zigbee receiver is shown below which is same as input at transmitter except a small delay (1.5µs).

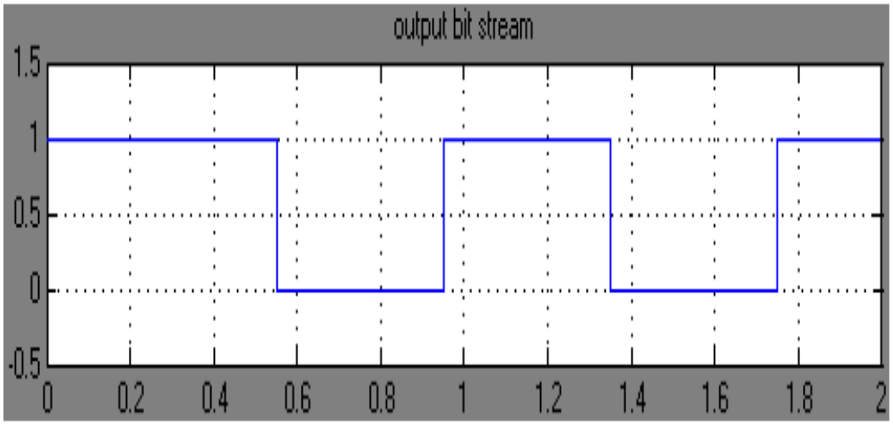

Fig: Output bit Stream

3. Design of Zigbee topology and broadcasting to get Bit Error Rate (BER):

Here we work to simulate and physical level simulation of IEEE 802.15.4 ZigBee protocol. We have simulated the ZigBee system for Mesh topologies for IEEE 802.15.4. In physical Layer Implementation of IEEE 802.15.4 ZigBee for Throughput Calculation we here try to reduce the BER bit error rate by using platform MATLAB SIMULINK.

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BER: Bit error rate

Bit error rate is the number of bit error per unit time. The BER is defined as the number data packets received incorrectly divided by the total number of received packets in the network.

SIMULATION

Now the layer Implementation of IEEE 802.15.4 ZigBee has been done. First with the help of Mesh topological Model we understand the working of IEEE 802.15.4 ZigBee protocol and then various topologies are simulated in MATLAB. BER calculation for ZigBee has been done by using encoding techniques for Throughput Calculation by reduction in the bit error rate.

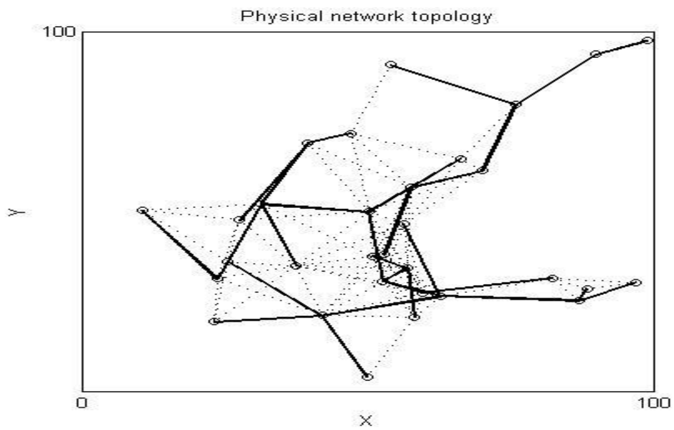

Fig: Physical Network Topology

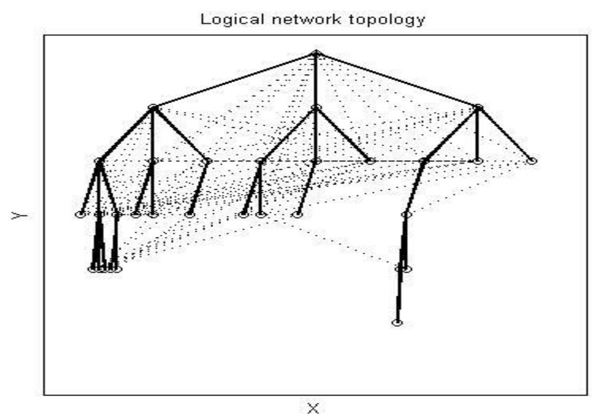

Fig: Logical Network Topology

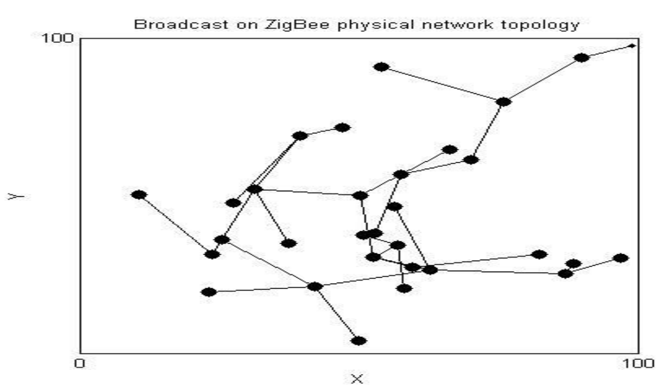

Fig: Broadcast on ZigBee Physical Network Topology

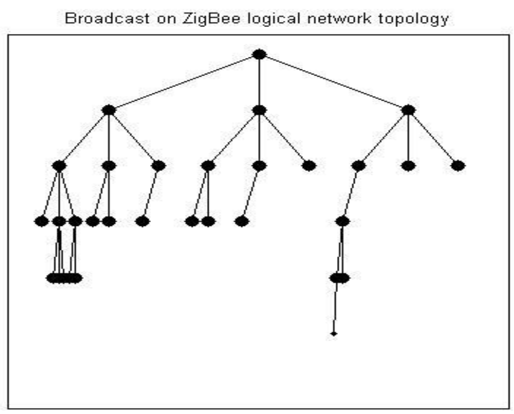

Fig: Broadcast on ZigBee Logical Network Topology

Result of ZigBee Network Topology Generator using matlab:

tranRange=25;
Cm=3; Lm=6;
% bs1=1093;
n=31;
rseed = 1;
rnseed = 1;

Simulation Result in matlab:
numAlreadyforward = 30
numNonforward = 1
numReceive = 215
timeDelay = 0.7743

BER Calculation= (215-214/215)*0.7743=0.0036

Table: BER and Delay using different nodes

Nodes	Delay	BER bit error rate %
35	**0.7807**	**0.0064**
31	**0.7743**	**0.0036**
30	**0.5825**	**0.0027**
28	**0.5820**	**0.0061**
23	**0.5799**	**0.0039**

3. WIRLESS SENSOR NETWORK APPLICATIONS

A wireless sensor network (WSN) (sometimes called a wireless sensor and actor network are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location.

- Area monitoring
- Environmental/Earth sensing
- Health care monitoring
- Chemical agent detection

- Air pollution monitoring
- Landslide detection
- Forest fire detection
- Industrial monitoring
- Design of systems in ships
- Design of systems in Trucks
- Design of systems in airplanes

CONCLUSION

It can be concluded that ZigBee has a lot of features which make it suitable for the wireless sensor networks in different situations like logistic telemetry situations. It is a low cost, low power and low data rate wireless standard. Its support for multi-hop communication and mesh networking adds to its suitability for the WSNs. It supports different kinds of routing protocols which carry out routing in the wireless sensor networks. But it is still a very new technology to rely on and use in these kinds of tracking situations. As it is in the early stages of its development, so a great deal of work relating ZigBee is still have to be done. Thus, it is a growing technology and has all the features to become a globally accepted standard for logistic telemetry applications and many other applications.

Design and simulation of Zigbee transceiver using MSK modulation technique in Simulink is presented here. This shows that this is most promising technology which provide low data rate with low BER & large acquired area. So, this technology can be used for future Personal Area Network in general purpose. ZigBee/IEEE 802.15.4 is a global hardware and software standard designed for WSN requiring high reliability, low cost, low power, scalability, and low data rate. A WSN consists of many inexpensive wireless sensors, which are capable of collecting, storing, processing environmental information, and communicating with neighboring nodes. ZigBee is designed to support low-cost network layer.

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