



## Literature Survey on ZigBee / IEEE 802.15.4 System Implementation

**Kumari Pooja<sup>1</sup>, Shailesh Khaparkar<sup>2</sup>, Pankaj Sahu<sup>3</sup>**

<sup>1</sup>Research Scholar, <sup>2</sup>Associate Professor, <sup>3</sup>Assistant Professor,

<sup>1,2,3</sup>Department of Electronics & Communication,

Gyan Ganga Institute of Technology and Science, Jabalpur, Madhya Pradesh, India

### ABSTRACT

ZigBee is a low-cost, low-power consumption, wireless mesh networking standard. Firstly, the low cost allows the technology to be widely deployed in wireless control and monitoring applications. Secondly, the low power-usage allows longer life with smaller batteries. Thirdly, the mesh networking provides high reliability and more wide range. ZigBee is a standard which defines a set of communication protocols for low data rate short range wireless networking. ZigBee based on wireless devices operate in 868MHz, 915MHz and 2.4GHz frequency bands for operation. ZigBee is targeted mainly for battery power uses where small 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 called as sleep mode.

**Keywords:** ZigBee, Physical Layer, OQPSK, low-cost, low-power.

### I. INTRODUCTION

Wireless personal area network (WPAN) and wireless local area network (WLAN) technologies are growing fast with the new emerging standards being developed. For sometime, Bluetooth was most widely used for short range communications. Now, ZigBee is becoming as an alternative to Bluetooth for devices with low power consumption and for low data rate applications. The Bluetooth standard is a specification for WPAN.

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wireless control and monitoring applications. Secondly, the low power-usage allows longer life with smaller batteries. Thirdly, the mesh networking provides high reliability and more wide range. ZigBee is a standard which defines a set of communication protocols for low data rate short range wireless networking. ZigBee based on wireless devices operate in 868MHz, 915MHz and 2.4GHz frequency bands for operation. ZigBee is targeted mainly for battery power uses where small 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 called as sleep mode. Consequently, ZigBee enabled devices are capable of being operational for several years before their batteries needs to be replaced [3].

ZigBee standard is specifically developed to address the need for very low cost implementation of low data rate wireless networks with ultra low power consumption. The ZigBee Standard reduced the implementation cost by simplifying the communication protocols and reducing the data rate. The minimum requirements to meet ZigBee and IEEE 802.15.4 specifications are relatively relaxed compared to other standards such as IEEE 802.11, which reduces the complexity and cost of implementing ZigBee compliant transceivers.

### Applications:

Although products based on the Bluetooth standards are often capable of operating at greater distances, the targeted operating area is the one around the individual i.e., within a 10m diameter. Bluetooth

utilizes a short range radio link that works in 2.4GHz industrial scientific and medical (ISM) band similar to WLAN. On the other hand, the radio link in Bluetooth is based on the frequency hop spread spectrum. We know that Bluetooth occupies only 1MHz, the signal changes the centre frequency or hops at the rate of 1600Hz. Bluetooth hops over 79 centre frequencies, so over time the Bluetooth signal actually occupies 79MHz.

ZigBee standard is developed by ZigBee Alliance, this has several member companies, from the semiconductor industry and software developers to original equipment manufacturers and installers. The ZigBee alliance was formed in 2002 as a non profit organization open to everyone who wanted to join. The ZigBee standard has adopted IEEE 802.15.4 as its Physical Layer (PHY) and Medium Access Control (MAC) protocols. Therefore, a ZigBee compliant device is compliant with the IEEE 802.15.4 protocol.

The major applications of ZigBee are focused on sensornetwork and automatic control, such as personal medical assistance, industrial control, home automation, remote control and monitoring [6].

One of the intended application of ZigBee is in-home patient monitoring. A patient's essential body parameters, for example blood pressure and heart rate can be measured by wearable devices. The patient wears a ZigBee device that interfaces with a sensor that gathers health related information such as blood pressure on a periodic basis. Then the data is wirelessly transmitted to a local server, for instance a personal computer inside the patients home, where initial examination is performed. Finally the vital information is sent to the patients nurse or physician via the internet for further analysis.

Another example of a ZigBee application is monitoring the structural health of large scale building and structures. In this application, several ZigBee enabled wireless sensors like accelerometers can be installed in a building and all these sensors can form a single wireless network to gather the information that will be used to evaluate the building structural health and detects the signs of possible damage. After an earthquake, for example, a building could require before it reopens to the public. The data gathered by the sensors could help further and reduce the cost of inspection. Home automation is one of the major application areas for ZigBee wireless networking. The

typical data rate in home automation is only 10Kbps. Some of the possible ZigBee applications in a typical residential building are light control systems, security systems, meter reading systems, irrigation systems, multizone Heating, Ventilation, and Air Conditioning (HVAC) systems.

## II. RELATED WORK

“Design Optimization of LMS-Based Adaptive Equalizer for ZigBee Systems with Fading Channels”, IEEE 2018 [1].

This paper investigates the influence of fading channels on the performance of ZigBee using IEEE 802.15.4 PHY layer with direct sequence spread spectrum (DSSS) technique and offset quadrature phase shift keying (OQPSK) modulation. Least mean square adaptive linear equalizer (LMS ALE) is combined to the system to minimize the channel effects. Performance and design analysis are presented in details. In addition, two design optimization procedures for the adaptive equalizer based on genetic algorithm (GA) and particle swarm optimization (PSO) are proposed. The multi-objective optimizations aim to choose the equalizer design parameters that achieve the optimum ZigBee transceiver steady-state and transient performance. For verification purposes, the proposed design is simulated and tested in MATLAB environment at different network scenarios. The results certify the ability of the proposed technique to extract the original transmitted signal at the receiver with minimum bit error rate (BER) and maximum speed of adaptation. ZigBee is considered as one of the most commonly used standards in wireless sensor networks (WSNs). Minimizing the effect of multipath fading channels is crucial for any network performance.

“Performance Evaluation and Delay-Power Trade-off Analysis of ZigBee Protocol”, IEEE 2018 [2]. In this paper, authors analyze the superframe structure of the Medium Access Control (MAC) sublayer of IEEE 802.15.4 protocol (ZigBee), designed for Low-Rate Wireless Personal Area Networks (LR-WPANs), and evaluate the effects of the inactive portion of a superframe on average delay, and average power consumption. The four-dimensional Markov chain-based analysis of the slotted Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) algorithm presented in this work considers backoff freezing and acknowledged packet transmission that are not studied in the existing works. The analytical

results prove that the performance of LR-WPANs depends significantly on the length of a superframe's active portion. We introduce a variable – Superframe duration-Beacon interval Ratio (SBR), which is utilized by tuning a few MAC parameters to achieve 35% reduced delay, on an average, compared to the existing state of the art. The results show that the proposed model also yields improved performance in terms of power consumption, for short and medium contention windows. In addition to the proposed analysis, this work provides optimized superframe order values that achieve trade-offs between delay and power consumption as demanded by user-provided QoS requirements corresponding to different contexts.

“Zigbee Baseband Hardware Modeling for Internet of Things IEEE 802.15.4 Compliance”, IEEE 2017 [3]. This paper is modeling the hardware for baseband communication in Internet of things (IoT) Chip with processor 32 bit RISCx. Based on IEEE 802.15.4 about Wireless Personal Area Networks (WPANs), for zigbee with frequency 2450 MHz we have to use Direct Sequence Spreading Spectrum (DSSS) and for the communication modulation we have to use Offset Quadrature Phase Shift Keying (O-QPSK). In this hardware modeling we used the AWGN (Additive White Gaussian Noise) and Rayleigh fading as part of non ideal system in the channel. In receiver we used costas loop to recover the carrier. as it is a hardware modeling, we compare Bit Error Rate (BER) between 6 bit and 8 bit. There is a big BER difference between the 6 bit system and the 8 bit system. 8 bit system has a better bit error rate but the chip area that it used is bigger. Contrary for the 6 bit, the chip area used is smaller but the bit error rate is worse than the 8 bit.

“Superregenerative Reception of Narrowband FSK Modulations”, IEEE 2015. In this paper we investigate the possibilities of narrowband FSK detection using a super regenerative (SR) receiver. Previous SR FM demodulation techniques rely on detecting the amplitude variations caused by the different frequencies involved in FSK modulation. However, this requires relatively high frequency deviations because the frequency response of SR receivers is not very selective. In this paper different approaches were taken for, exploiting the distinct phase trajectories of FSK modulations resulting from the transmitted data. The well-known fact that the SR oscillator response preserves the phase information of

the received signal is successfully exploited to allow the detection of several FSK modulations.

“Energy optimization in Zigbee using prediction based shortest path routing algorithm, March 2012.

In this paper, Zigbee is a wireless standard that allows small amount of data transfer to comparatively tiny range. It needs to confirm 802.15.4, Low-Rate Wireless Personal Area Network (WPAN) standard. Zigbee module along with shortest path routing algorithm is defined. It helps to minimize number of transmissions. Along with the energy optimization is used. That helps sink node to significantly save its energy.

Experimental setup of wide area monitoring using Zigbee IEEE 802.15.4 technology and RF FM technique, Nov. 2012 In this, it is important for a modern power grid to be smarter in order to provide reliable and sustainable supply of electricity. The system was also tested with RF transmitters and receivers for better understanding of the problem associated with Zigbee and also finding potential ways to solve that problem faced during the lab practical. LABVIEW software has been used to control and monitor the received data. The proposed system for Distributed Generation (DG), a MATLAB based program is proposed.

Reliability of ZigBee networks under broadband electromagnetic noise interference," The goal of this paper is to determine the robustness of the ZigBee wireless networking technology under the influence of interference caused by broadband electromagnetic noise from the operating environment of sensing, monitoring, and control systems. In addition to answering the research question of how will ZigBee survives under broadband electromagnetic noise, this work provides a method to predict the minimum number of ZigBee nodes required for reliable operation within a given space.

Platform for teaching of location technologies based on Zigbee Wireless Sensor Networks by learning-through-play theory, April 2010. In this study an experimental Wireless Sensor Network (WSN) platform is introduced as an aid in teaching location techniques based on RSSI (Received Signal Strength Indicator) in the frame of a an radiolocation. The platform is implemented using low-cost commercial modules and one easy-to-use software program. The teaching techniques tries to develop the learning by

doing theory and it is completed with a final practice that implements the knowledge through play theory. Performance Evaluation of IEEE 802.15.4 (Research Paper) Physical Layer Using MatLab/Simulink, IEEE 802.15.4 (Zigbee) is the new standard that has been developed for the low cost, low data rate and very low power consumption wireless network. This research paper provides a brief description of this standard including the physical (PHY) and medium access control (MAC) layer. It focuses on developing the Zigbee protocol and the performance evaluation of these models. Simulation has been run using the results have been analyzed. The result shows how the relationship between the signal bit error rate (BER) and signal to noise ratio (SNR) is affected when varying the data rate and the input signal power to the noise channel.

Comprehensive design of a high frequency PLL synthesizer for ZigBee application, April 2006. Time-to-market demands shorter design period of applied semiconductor devices. For that reason the iteration steps, the simulation time duration and repetitions have to be minimized along the design flow. In this study a new design method of a phase locked loop (PLL) frequency synthesizer and its complete design flow is introduced. This analogue system will have to be realized on 0.35µm CMOS technology, so that the complete layout has to be designed. The work has been focused on the main critical element of the PLL circuit, therefore two types of a voltage controlled oscillator (VCO) blocks were obtained. The carrier frequency is 2.4 GHz during transmission according to the ZigBee standard, therefore the VCOs were designed for operating on this frequency. In this work, the mixed-signal simulation results of the entire system discussed.

### III. OPERATING FREQUENCIES and DATA RATES:

There are three frequency bands used for IEEE 802.15.4.

Protocol

These are:

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

The 868MHz band is used in Europe for a number of applications, such as short range wireless networking.

The 915MHz and 2.4GHz bands are part of industrial, scientific and medical (ISM) frequency bands. The 915MHz frequency band has been used mainly in North America, where as the 2.4GHz band is used worldwide. Multiple PHYs are defined to support various frequency bands including [1]

1. 868–868.6 MHz
2. 902–928 MHz
3. 2400–2483.5 MHz
4. 314–316 MHz, 430–434 MHz, and 779–787 MHz band for LR-WPAN systems in China
5. 950–956 MHz in Japan.

The major standardization bodies in the WSN area are the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF) and the HART communication foundation. Notable standards and specifications are:

### IV. IEEE 802.15.4 Standard

This standard [4] specifies the PHY and MAC layer for low-rate WPANs. Various platforms are based on this standard and other specifications, such as Zigbee and wireless HART provision, are built on top of the standard covering the upper layers to provide a complete networking solution. Some of the main characteristics of the IEEE 802.15.4 are given below:

- 250 kbps, 40 kbps and 20 kbps high data rates.
- Two addressing modes, which are 16-bit short and 64bit IEEE addressing.
- CSMA-CA channel access.
- Automatic network start by the coordinator of the network.
- Power management control.
- 16 channels in the 2.4 GHz ISM band, 10 channels in 915 MHz ISM band and one channel in the 868 MHz band.

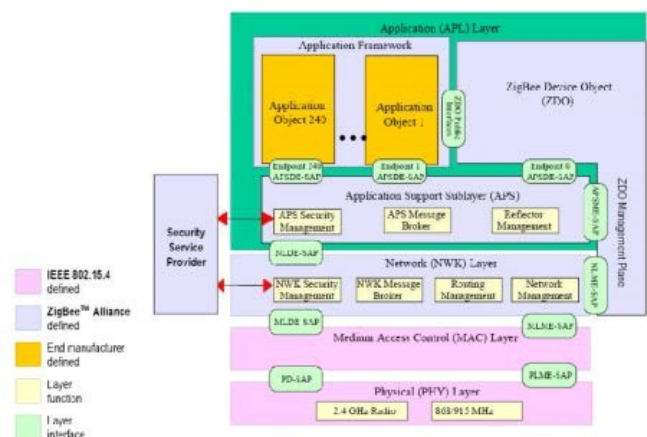


Fig. 1 Zigbee Architecture

**Wi-Fi Compatibility:**

The 2.4 GHz band, which ranges from 2400 MHz to 2483.5 MHz, is a worldwide band allocated to wireless LAN devices governed by IEEE 802 standards:

- IEEE 802.11 – WiFi standard •
- 802.15.1 – Bluetooth
- 802.15.4 – ZigBee.

The above standards cover LAN and MAN carrying variably sized packets. They find the no. of channels that devices can use in the 2.4GHz band and together they appear to coexist happily. ZigBee devices uses up to 16 separate 5MHz channels (nos. 11-26) in the 2.4 GHz band, almost all the channels do not overlap with channels occupied by 802.11 and Wi-Fi network. What's more, as considered above, ZigBee automatically retransmits data end-to-end in the event of interference. And even after, very little data is retransmitted. With its special focus on sensors and controls, ZigBee should not be affected by similar wireless technologies with different purposes. Yet concerns have been voiced that despite efforts made by standardization bodies to ensure smooth coexistence, communication technologies transmitting at very different power levels could interfere with each other. Questions have in particular been raised over how Wi-Fi might affect ZigBee when both are transmitting in the same channel with Wi-Fi transmissions taking place at a much higher power rating.

Low cost for users is not only about lower power consumption. Other factors are low retail cost and low maintenance and installation costs. The 802.15.4 PHY layer was designed precisely to ensure low cost and high levels of integration. On the other hand ZigBee's radio design principally uses digital circuitry it does include analog stages. On the other hand, make use of of direct sequence CDMA results in very simple analog circuit that lends itself to lowcost implementation.

As observed above, 802.15.4's MAC enables multiple topologies that are not complex and have only two basic modes of operations. The result is low or no maintenance (particularly in residential fit-and-forget applications), while networks' self-healing capability and node redundancy further dispenses with maintenance. The extensive use of RFDs – cheap to manufacture and maintain thanks to their inherent low

functionality, low ROM and RAM – helps keeps cost down.

Further controlling cost is the ZigBee application layer. It was designed to let networks grow physically without the need for more powerful power transmitters, even when networks have large numbers of nodes with low latency requirements.

In addition to low power consumption, the key factor in ZigBee's low cost is, perhaps, its simplicity. By way of comparison, the number of layers in ZigBee's protocol stack is four times less than in Bluetooth's. Indeed, further comparison with Bluetooth can be a convenient way of highlighting some other ZigBee strong points.

**Major Parts of the IEEE 802.15.4 WPAN:**

A system meeting the requirements to this standard consists of several components. The most basic is the device. Two or more devices communicating on the same physical channel constitute a WPAN. All though, this WPAN includes at least one FFD, which operates as the PAN coordinator.[1]

**V. LR-WPAN DEVICE ARCHITECTURE**

The IEEE 802.15.4 design is defined in terms of a number of blocks in order to simplify the standard. These blocks are known layers. Each layer is responsible for one part of the standard and offers services to the higher layers.

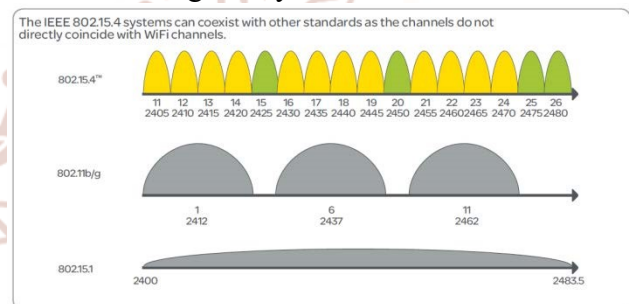


Figure 2: IEEE 802.X Wi-Fi standard comparison

The interfaces between the layers serve to define the logical links that are described in this standard. An LRWPAN device comprises as a minimum one PHY, which consists of the radio frequency (RF) transceiver along with its low-level control mechanism and MAC sub layer that provides access to the physical channel for all types of transfer. Figure 2 shows these blocks in a graphical representation, which are discussed in more detail in next paragraphs.

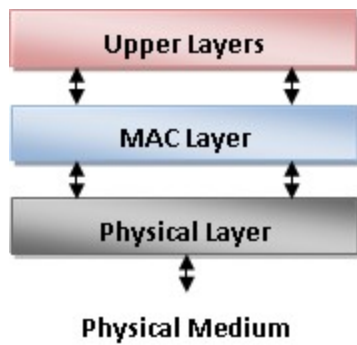


Figure 3: LR-WPAN device architecture

The upper layers, shown in Figure 3, consists of a network layer, which provides network configuration, manipulation, message routing, and an application layer, that provides the intended function of the device. The description of these upper layers is outside the scope of this standard [1].

#### **Physical layer (PHY):**

The PHY provides two services: the PHY data service and the PHY management service. The PHY data service enables the transmission and reception of PHY protocol data units (PPDUs) across the physical radio channel. The description of the PHY are activation and deactivation of the radio transceiver, ED, channel selection, clear channel assessment (CCA), and transmitting as well as receiving packets across the physical medium. The UWB PHY also has the feature of precision ranging [1].

#### **Power consumption considerations:**

In many applications that use these standard, devices will be battery powered, and battery substitute or recharging in relatively short intervals is impractical. The power consumption is of significant concern. Battery-powered devices will require duty-cycling to reduce power. These devices will spend most of their operational life in a sleep state; though, each device periodically listens to the RF channel in order to determine whether a message is pending.

In addition to the power saving features of the LR-WPAN system, the UWB PHY also provides a hybrid modulation that enables very simple, non coherent receiver architectures to further minimize power consumption and implementation complexity. [2]

## **VI. CONCLUSIONS**

From the survey, the existing with 2.4 GHz band and with O-QPSK modulation works significantly with low power operations but there is always a need some improvement in the system, so here we have tried to reduce the Bit Error Rate and also the Power

Requirements of the system which will be the revolution in the field of 802.15.4. Here to improve BER we can implement different modulation techniques like MSK or PSK, but it should be in accordance with the protocol. The future of our proposed work will be the lowest power consumption PAN (Personal Area Network) for information sharing and network access.

## **REFERENCES**

1. Asmaa M. Romia et al, "Design Optimization of LMS-Based Adaptive Equalizer for ZigBee Systems with Fading Channels", IEEE International Conference on Computing, Mathematics and Engineering Technologies – iCoMET 2018.
2. Soumen Moulik et al, "Performance Evaluation and Delay-Power Trade-off Analysis of ZigBee Protocol", IEEE Transactions on Mobile Computing, 2018.
3. Trio Adiono et al, "Zigbee Baseband Hardware Modeling for Internet of Things IEEE 802.15.4 Compliance", IEEE 6th International Conference on Electrical Engineering and Informatics (ICEEI), 2017.
4. Pere Pala et al, "Superregenerative Reception of Narrowband FSK Modulations", IEEE Transactions on Circuits & Systems-I: Regular Papers, Vol. 62, No. 3, March 2015.
5. Varshney et al., "Comparative Analysis of OQPSK and MSK Based ZigBee Transceiver Using MATLAB", International Journal of Advanced Research in Computer Science and Software Engineering 3(6), Pp. 948-956, June - 2013.
6. Irfan Ali et al, "Bit-Error-Rate (BER) Simulation Using MATLAB", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 3, Issue 1, Pp.706-711, February 2013.
7. Kapil Dev Jha et al, "Design & Simulation of ZigBee Transceiver System Based on MSK and QPSK Using MATLAB", International Journal of New Trends in Electronics and Communication (IJNTEC) ,Vol.1, Issue. 4, Nov. 2013.
8. Wei Yuan et al, "Coexistence Performance of IEEE 802.15.4 Wireless Sensor Networks Under IEEE 802.11b/g Interference",

- International Journal Distributed Sensor Networks volume 2010(2010),Article ID581081,Pp -6,2010.
9. G. M. Tamilselvan and Dr. A. Shanmugam, "Probability Analysis of channel collision between IEEE 802.15.4 and IEEE 802.11b using Qualnet Simulation for various Topologies" International Journal of Computer Theory and Engineering, Vol. 1, No. 1, April 2009.
  10. Nazif Cihan Tas et-al, "IEEE 802.15.4 Throughput Analysis under IEEE 802.11 Interference" International Symposium on Innovations and Real Time Applications of Distributed Sensor Networks, 2007.
  11. Yuan, W., Linnartz, J. P. M. G., & Niemegeers, "Adaptive CCA for IEEE 802.15.4 wireless sensor networks to mitigate interference" IEEE wireless communications and networking conference Sydney, pp.1-5,2010.
  12. Z. Alliance, "ZigBee Alliance," WPAN industry group, the industry group responsible for the ZigBee standard and certification, 2010.
  13. C. V. Berta, D. P. A. Rodolfo, R. Susan, and P. Dirk, "Experimental evaluation of beacon scheduling mechanisms for multihop IEEE 802.15.4 wireless sensor networks," in Proceedings of the 4th International Conference on Sensor Technologies and Applications (Sensor Comm '10), pp. 226-231, July 2010
  14. S. Ahmed, "The Role of ZigBee Technology in Future Data Communication System," Journal of Applied Information Technology, vol. 5, no. 2, pp. 129 - 135, 2009.
  15. IEEE Standard for Local and Metropolitan Area Networks-Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs), IEEE Computer Society Std. IEEE 802.11b: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4GHz Band, 1999.
  16. K. Shuaib and I. Jawhar M. Alnuaimi, "Performance Evaluation of IEEE 802.15.4 Physical Layer Using Matlab/Simulink" in Innovations in information technology, Pp. 1-5 November 2006.
  17. Maryam Alnuaimi, Mohamed Boulmalf, Farag Sallabi and Abderrahmane Lakas Khaled Shuaib, "Performance Evaluation of IEEE 802.15.4: Experimental and simulation Results," Journal of Communications, vol. 2, pp. 29-37, June 2007.
  18. IEEE Std.802-15.4, "IEEE Standard for Wireless Medium Access Control(MAC) and Physical Layer(PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)," 2003.
  19. Ramanathan. P, Pradip Manjrekar, "Wireless Sensor Network For Monitoring Accidents Continuously Using Zigbee" in International Journal of New Trends in Electronics and Communication (IJNTEC) Vol.1, Issue. 4, Nov. 2013.
  20. Sohraby, K Jana, R. Chonggang Wang, Lusheng Ji, and M. Daneshmand, "Voice communications over ZigBee networks," IEEE communications magazine, vol. 46, pp. 121 -127, January 2008.