A Survey on Zigbee IEEE 802.15.4 Technology (WPANs)

Aditi Sharma[1], Prof. Pooja Gupta[2], Prof. Soni Changlani[3]

[1]M-Tech Research Scholar, [2]Research Guide, [3]HOD, Department of Electronics & Communication
Engineering

Laxmi Narain College of Technology & Science, Bhopal (M.P.)

Abstract- The low-power IEEE 802.15.4 standard digital radios for the wireless personal area networks in embedded applications requiring low data rates and low power consumption. ZigBee's current focuses to define a universal-purpose, inexpensive, self-organizing, mesh network that can be used for industrial control, embedded sensing, the medical data collection, smoke and the intruder warning, building automation, home automation. The resulting network will use very small amounts of power so individual devices might run for a year or two using the originally installed battery. The radio design has been used by ZigBee has been carefully optimized for low cost in large scale production. It has the few analog stages and uses   digital circuits wherever possible. Even after the radios are cheap, the ZigBee ability Process involves a full validation of the requirements of the physical layer. An uncertified physical layer that malfunctions could cripple the Battery lifespan of other devices on a Zigbee Network. Where other protocols could mask poor sensitivity or other esoteric problems in a fade compensation response, ZigBee radios have very unique engineering constraints: they are both power and bandwidth constrained. In this research paper, we have investigated the advancement and technology of Zigbee.

Keywords - MISO, ZIGBEE, Physical Layer, OQPSK.

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. Th 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 semi-conductor 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.

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. 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:

The major applications of ZigBee are focused on sensor network 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

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]

i. 868–868.6 MHz
ii. 902–928 MHz
iii. 2400–2483.5 MHz
iv. 314–316 MHz, 430–434 MHz, and 779–787 MHz band for LR-WPAN systems in China
v. 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:

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 64-bit 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.
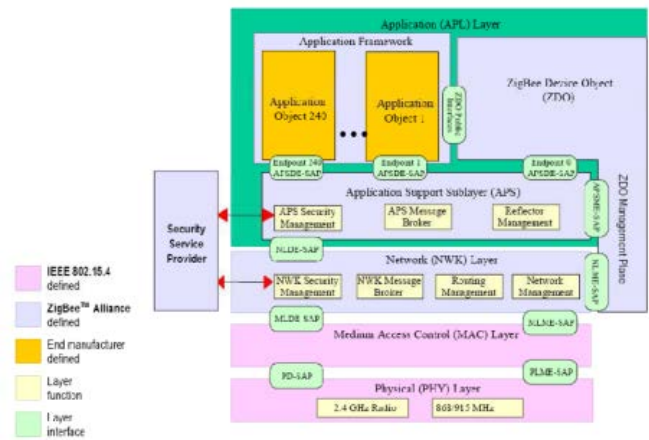

Fig. 1 Zigbee Architecture

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 standardisation 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 low-cost 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]

II. 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.
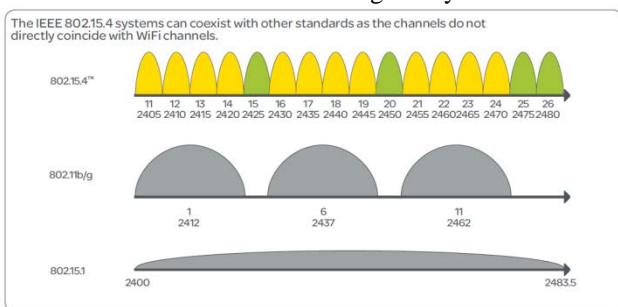

Figure 2: IEEE 802.X Wi-Fi standard comparison

The interfaces between the layers serve to define the logical links that are described in this standard. An LR-WPAN 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.
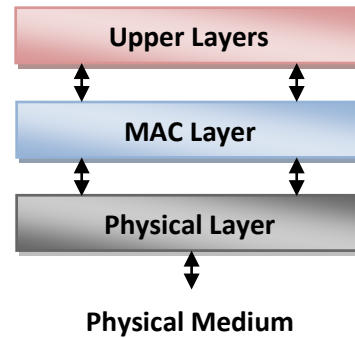

Figure 3: LR-WPAN device architecture

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]

III. RELATED WORK

"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.

Table – 1 Summary of Previous Work

Year	Author	Title	Approach	Result
2012	Singh, D.P.; Agrawal, Y. Soni, and S.K.	Energy optimization in Zigbee using prediction based shortest path routing algorithm	Prediction based shortest path routing algorithm	Significantly save its energy
2012	Siddique, Abdul Hasib; Barkat, Braham; Poshtan, Majid,	Experimental setup of wide area monitoring using Zigbee IEEE 802.15.4 technology and RF FM technique	IEEE 802.15.4 technology and RF FM technique	Better understanding of the problem associated with Zigbee
2010	Nameer N. EL-Emam	Reliability of ZigBee networks under broadband electromagnetic noise interference	Under broadband electromagnetic noise interference	This work also provides a method to predict the minimum number of ZigBee nodes required
2010	Anupam Mondal, Sudipta Sahana, Sainik Kumar Mahata	Platform for teaching of location technologies based on Zigbee Wireless Sensor Networks by learning-through-play theory	Zigbee Wireless Sensor Networks by learning-through-play theory	Both techniques have resulted in positive learning outcomes by enhancing the student role in the learning process
2009	G.Karthigai Seivi, Leon Mariadhasan, K. L. Shunmuganathan	High level modelling of an ultra wide-band baseband transmitter in MATLAB	In this paper and its modelling in MATLAB is discussed in detail	Good for designing its commercial product by optimizing various parameters
2006	Neda Raftari and Amir Masoud Eftekhari Moghadam	Performance Evaluation of IEEE 802.15.4 Physical Layer Using MatLab/Simulink	A brief description of this standard including the physical (PHY) and MAC Layer	Results show how BER is affected with varying data rate and the input signal power to the noise channel

Together techniques have resulted in positive learning outcomes by enhancing the student role in the learning process.
High level modelling of an ultra wide-band baseband transmitter in MATLAB, Oct. 2009

In this study the wireless personal area network (WPAN) system with ranges of 4-10 m become popular in replacing wire system, technologies like Bluetooth and ZigBee used for this purpose but due to its low data rate of 1 Mbps which is not enough for large file transfer and applications like video

streaming there is a need of technology which address all these issue, Ultra Wideband is a emerging wireless technology which support data rates with 0.5 Gbps.

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 0.35mum 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.

IV. 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 we must increase the number of transmitters, which will greatly reduce the error rate of the existing system. Here we can simulate system upto three transmitters but in future with the developments in the antenna technology we can increase more transmitters as our ease. The future of our proposed work will be the lowest power consumption PAN (Personal Area Network) for information sharing and network access.

REFERENCES

[01] J. Stankovic, I. Lee, A. Mok, R. Rajkumar, "Opportunities and Obligations for Physical Computing Systems", in IEEE Computer, Volume 38, Nov, 2005.

[02] The Economist, "When everything connects", April 28th – May 4th, 2007.

[03] N. Aakvaag, M. Mathiesen, and G. Thonet, "Timing and power issues in wireless sensor networks, an industrial test case", In Proceedings of the 2005 International Conference on Parallel Processing Workshops (ICPPW). IEEE, 2005.

[04] S A Bhatti (Student), I A Glover, "Performance Evaluation of IEEE 802.15.4 Receiver in the Presence of Broadband Impulsive Noise" IEEE Student Application Paper 2011.

[05] Minakshmi Roy, H.S. Jamadagni, "Cancellation of Zigbee interference in OFDM based WLAN for multipath channel", ACEEE Int. J. on Network Security, Vol. 02, No. 01, Jan 2011.

[06] Nilesh Shirvoikar, Hassanali Virani, Dr. R.B. Lohani, "Performance Evaluation of Zigbee Using Matlab Simulation", in IJIIT, vol. 1 issue 3 2012-13.