Qos Measurement of Zigbee Home Automation Network using Various Routing Protocols

Gurjit Kaur
Faculty ECE Deptt.
Rayat Polytechnic College
Distt. SBS Nagar, Punjab

Kiran Ahuja
Faculty ECE Deptt
DAVIET
Distt. Jalandhar, Punjab

ABSTRACT
In recent years, the home environment has seen a rapid increase in usage of network enabled digital technologies that offer new and exciting opportunities to increase the connectivity of devices within the home environment for the purpose of home automation. One of such digital technologies is known as ZigBee which is a recent wireless standard based on IEEE 802.15.4 used for Personal Area Networks. ZigBee is a low-cost, low-power, wireless mesh networking standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking provides high reliability and larger range. This paper provides the performance analysis of different wireless mobile ad hoc routing protocols like OLSR INRIA, OLSRv2 NAGATA, ZRP, AODV and DYMO based on their effect on the quality of service by using CBR application in Zigbee home automation network using static IEEE 802.15.4. The QOS parameters such as data packet delivery ratio, average end-to-end delay, jitter, and throughput are investigated as the performance metrics. The results show that even though AODV gives the highest throughput of 95% and receive 25 packets which is highest amongst all five protocols but still overall OLSR INRIA is the best suited routing protocol for CBR application of Zigbee home automation since it produced lowest jitter value of 0.04 and lowest average end-to-end delay value of 0.23 which are both favorable conditions for better performance of CBR application of Zigbee home automation network.

General Terms
IEEE802.15.4 (Zigbee) , WSN et al.

Keywords
OLSR, INRIA, OSLRv2NAGATA, AODV, DYMO, CBR.

1. INTRODUCTION
Wireless Sensor Networks (WSNs) are fully autonomous self-configuring ad-hoc networks. Its new emerging applications are related to monitoring and control in home, office, industrial, and outdoor environments. WSNs may consist of thousands of tiny and enormously energy-constrained nodes, which communicate wirelessly with each other, sense their environment, and share collaborative tasks. Due to the large number of nodes, frequent battery replacements are difficult; hence, the network lifetime should be in years requiring a very careful design of communication protocols, algorithms, and hardware platforms.

The growth of mobile computing devices including laptops, personal digital assistants (PDAs), and wearable computers have created a demand for wireless personal area networks (WPANs). To meet these challenges, IEEE 802.15.4 [1] low rate wireless personal area network (LR-WPAN) standard has been introduced. The goal of the IEEE 802.15.4 standard is to provide a low-power, low-cost, and highly reliable protocol for wireless connectivity among inexpensive, fixed and portable devices [2] [3]. These devices can form a sensor network or a Wireless Personal Area Network (WPAN). Thus it suits wireless sensor network applications where a large number of tiny smart sensors having the low power, low range, and low bandwidth are deployed in an ad hoc manner for the purpose of automation.

ZigBee [4] is an open specification built on the IEEE 802.15.4 Physical and MAC layer standard for low-power wireless networking, which complements the LR-WPAN standard with network and security layers and application profiles. For security and reliability, ZigBee supports access control lists, packet freshness timers, and 128-bit Advanced Encryption Standard (AES). Different stack profiles are defined for home control, building automation, and plant control applications. The first version of ZigBee specification was announced in December 2004.

This paper provides the performance analysis of different wireless mobile ad hoc routing protocols like OLSR INRIA, OLSRv2 NAGATA, ZRP, AODV and DYMO by measuring parameters such as packet delivery, average end-to-end delay, jitter and throughput on the zigbee home automation using static IEEE 802.15.4 star topology.

The organization of the paper is as follows. Section 2 discusses related works for performance evaluation of IEEE 802.15.4 topology in various simulation environments. The overview of zigbee and IEEE 802.15.4 protocol is discussed briefly in Section 3. Simulation set up has been discussed in Section 4. Simulation results have been discussed in Section 5. Finally, we conclude our work in Section 6.

2. RELATED WORK
According to our best knowledge, there exist only few articles [5] that analyze mathematically or simulate the performance of IEEE 802.15.4. The performance of IEEE 802.15.4 in a star network with 100 nodes was analyzed in [6]. The paper contains a compact mathematical analysis of average power consumption and transmission failure rate. The analysis was complemented with real measurements of steady state powers and transient energy, and switch times from a standard compliant evaluation board. A special contribution was bit error rate measurements with two evaluation boards connected through a set of calibrated attenuators. The operational analysis considered mainly the effect of path loss and packet size on energy consumption.

J. Zheng and M.J. Lee [7] implemented the IEEE 802.15.4 standard on NS2 simulator and provided the comprehensive performance evaluation on 802.15.4. The literature comprehensively defined the 802.15.4 protocol as well as simulations on various aspects of the standard. It mainly confined to performance of IEEE 802.15.4 MAC.

The authors provided performance evaluations of IEEE 802.15.4 MAC in becon-enabled mode for a star topology [8]. The performance evaluation study revealed some of the key throughput-energy-delay tradeoff inherent in IEEE 802.15.4 MAC.The performance of IEEE 802.15.4 was analyzed for medical sensor body area networking [9]. The analysis considered quite extensively a very low data rate star network with 10 body implanted sensors transmitting data 1 to 40 times per hour. The analysis focused on the effect of crystal tolerance, frame size, and the usage of IEEE 802.15.4 Guaranteed Time Slots (GTS) on a node lifetime. For analyzing the standard performance in WSN applications, further analysis with larger and more complex network topologies and other IEEE 802.15.4 MAC parameters would be required.

The authors presented a novel mechanism intended to provide Quality of Service (QoS) for IEEE 802.15.4 based Wireless Body Sensor Networks (WBSN) used for pervasive healthcare applications [10]. The mechanism was implemented and validated on the AquisGrain WBSN platform.

The performance simulations of IEEE 802.15.4 in a star network were presented [11]. The network consisted of 49 nodes configured to IEEE 802.15.4 beacon-enabled mode. The evaluation considered latency and energy with different amounts of background traffic. Also, the performance of IEEE 802.15.4 GTS and beacon tracking were simulated. Still, the applicability of the results for WSN applications was insufficient, since larger network sizes with cluster tree network topologies were required.

3. ZIGBEE WIRELESS NETWORK

It is based on IEEE 802.15.4 standards, which is aimed for Low Rate Wireless Personal Area networks (LR-WPAN). IEEE 802.15.4 standard focuses on the lower two layers of the protocol stack for defining the basic communication methods for instrument networks but requires much more additional work to produce marketable product. On top of IEEE 802.15.4 radio communication standards, the ZigBee Alliance (an industry consortium of semiconductor manufacturers), other providers, and manufacturing companies provide this additional work. The ZigBee specification is designed to utilize the features supported by IEEE 802.15.4, particularly the low data transmission rate and energy consumption features. It targets control and monitoring applications where low-power consumption is a key requirement. The candidate applications are wireless sensors, lighting controls, and surveillance. It also targets market areas like residential home control, commercial building control, and industrial plant management.
The ZigBee protocol stack is given below in Figure 1. The Physical layer, which is referred to as IEEE 802.15.4 PHY, is concerned with the interface to the physical transmission medium and exchanging data bits with the layer above. It consists of two PHY layers which operate in two separate frequency ranges: 868/915 MHz and 2.4GHz.

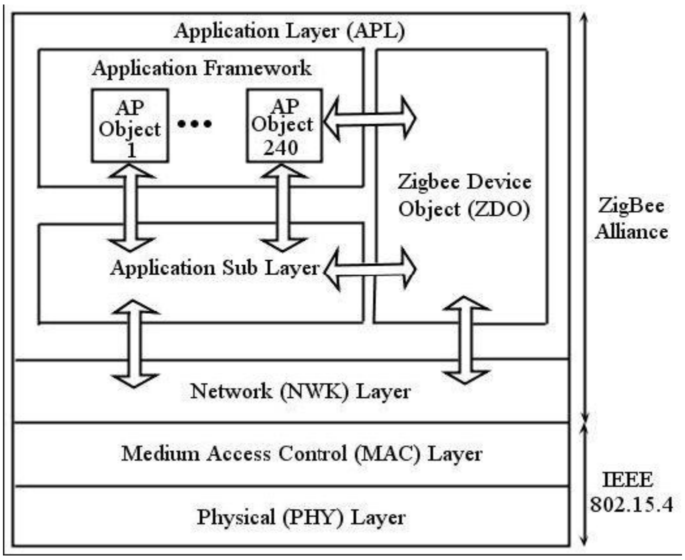

Figure 1: ZigBee functional layer architecture and protocol stack [12]

The Medium Access Control (MAC) layer is also known as the Data Link Layer. This layer is concerned with the addressing. It determines where the data is going for outgoing data and where the data is coming for incoming data. It is also responsible for assembling data packets or frames to be transmitted and decomposing received frames.

The Network (NWK) layer is right above MAC which is specified by IEEE 802.15.4 and is defined by the ZigBee Alliance. It allows devices to communicate with each other. It is involved in the initialization of the device, network self-organization, and routing of data and network discovery within the network. Routing protocols are important as they dynamically share information between routers, automatically update routing table when topology changes, and determine best path to the destination. So it is required to do their performance evaluation.

4. SIMULATION SETUP

The main objective of this simulation study was to analyse the effect of different wireless mobile ad hoc routing protocols like OLSR INRIA, OLSRv2 NAGATA, ZRP, AODV [13] and DYMO [14] on the performance of zigbee home automation using static IEEE 802.15.4 star topology for varying parameters. The simulations have been carried out using QualNet version 5.0, software which provides scalable simulations of wireless networks.

In the simulation model, a star topology with one PAN co-ordinator, one PDA (personal digital assistants), and 10 devices are uniformly deployed in an area of 1500m x1500m. PAN is static mains powered device placed at the centre of the simulation area. Only the uplink traffic i.e. devices to PAN co-ordinator are considered in the simulations which suits WSN application like automation industry where a large number of devices communicates to a single sink server for data delivery and processing. The transmission range of devices is one hop away from PAN Coordinator in star topology. The fact that BO (Beacon order) = SO (super frame order) assures that no inactive part of the super frame is present [15]. A low value of this parameter implies a great probability of collisions of beacon frames as these would be transmitted very frequently by coordinators. On the contrary, a high value of the BO (beacon order) introduces a significant delay in the time required to perform the MAC association procedure since channel duration which is a part of association procedure is proportional to BO (beacon order). In our simulation model, function for acknowledging the receipt of packets is disabled. It is due to the fact that overhead mechanism is too expensive for low data rate WSN application for which 802.15.4 is designed.

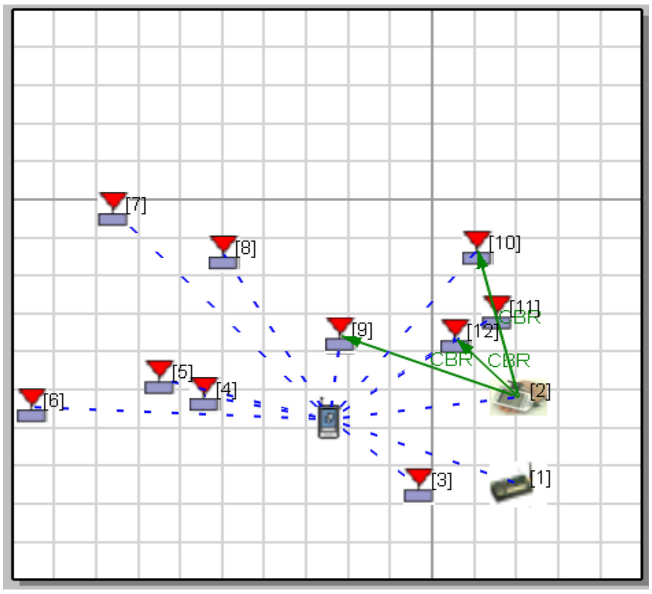

Figure2: Simulation setup of zig-bee home automation network

Following QoS performance metrics were used to evaluate QoS parameters for IEEE 802.15.4 star topology using different routing protocols:

Jitter is often known as a measure of the variability over time of the packet latency across a network. A network with constant latency has no variation (or jitter). Packet jitter is expressed as an average of the deviation from the network mean latency. Jitter refers to a variation in packet delay, resulting in differing packet inter-arrival times or out-of-sequence packets or both

Average End-to-End delay indicates the length of time taken for a packet to travel from the CBR (Constant Bit Rate) source to the destination. It represents the average data delay an application experiences during transmission of data. The end-to-end delay is the time taken for a data packet to reach the destination node. The delay for a packet is the time taken for it to reach the destination. And the average delay is calculated by taking the average of delays for every data packet transmitted. The parameter comes into play only when the data transmission has been successful.

$$P_D=T_r-T_t$$

Where

P_D =Packet Delay

T_r = Receive Time at Destination

T_t= Transmit Time at Source

$$\square=\Sigma P_D/N_r \qquad (16)$$

Where

□ =Average Delay

ΣP_D = Sum of all Packet Delays

N_r=Total Number of Received Pkts

Throughput is the number of bits passed through a network in one second. It measures how fast data can pass through an entity (such as a point or a network). The throughput of a node is measured by first counting the total number of data packets successfully received at the node and computing the number of bits received, which is finally divided by the total simulation runtime. The throughput of the network is finally defined as the average of the throughput of all nodes involved in data transmission. Therefore, throughput can be stated as:

$$Tn=Tbr/Sr$$

Where

Tn = Throughput of a Node

Tbr = Total Data Bits Received

Sr = Simulation Runtime

Similarly the throughput for the network can be defined as:

$$Tnn=\sum Tn/Nn$$

Where

Tnn=Network Throughput

∑Tn= Sum of Throughput of Nodes Involved in Data Trans.

Nn=Number of Nodes

5. PERFORMANCE ANALYSIS

This section presents the simulation results to show the impact of various QOS metrics on different wireless mobile ad hoc routing protocols like OLSR INRIA, OLSRv2 NAGATA, ZRP, AODV and DYMO by using CBR application on zigbee home automation network having static IEEE 802.15.4 star topology.

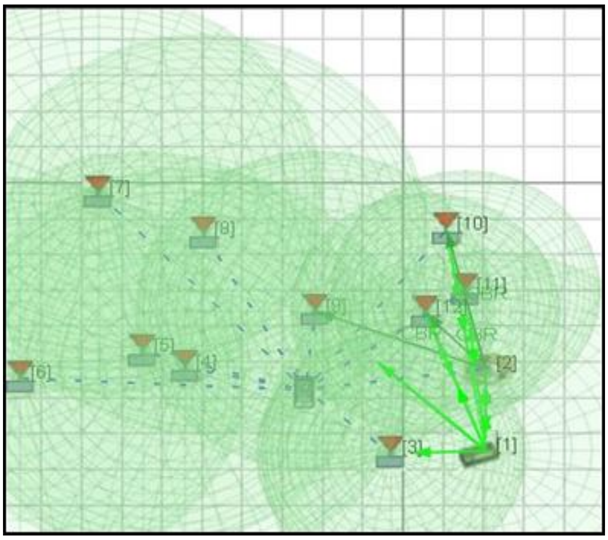

Figure3: QualNet animation during simulation execution

The following table depicts comparison of routing protocols based on CBR applications on the application layer.

Table I: Comparison of different routing protocols using CBR application in zigbee home automation network

ROUTING PROTOCOL	TOTAL PACKET RECIEVED	THROUGHPUT	AVG END TO END DELAY	JITTER
OLSR INRIA	24	94	0.23	0.04
OLSRv2 NAGATA	23	90	0.23	0.04
ZRP	24	91	0.74	0.10
AODV	25	95	3.32	0.43
DYMO	24	92	3.03	1.27

Figure 4 shows the value of jitter for different routing protocols. OLSR INRIA and OLSRv2 NAGATA produced the lowest value of 0.04, DYMO produced highest value of 1.27, and AODV and ZRP produced a value of 0.43 and 0.10 respectively. So, in terms of jitter OLSR INRIA and OLSRv2 NAGATA performs better than other protocols since low jitter corresponds to high efficiency.

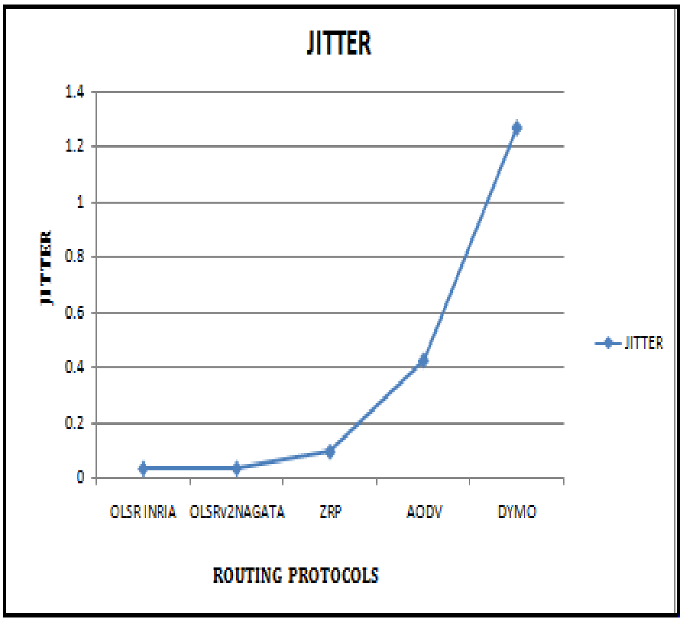

Figure 4: Impact of Jitter on various routing protocol using CBR application

Figure 5 shows the performance of average end-to-end delay for different routing protocols. The average end-to-end delay of a packet depends on delay at each hop comprising of queuing, channel access and transmission delays as well as route discovery latency. ZRP produced average end-to-end delay value of 0.7, OLSR INRIA and OLSRv2 NAGATA produced a significantly low value of 0.04 whereas DYMO and AODV produced higher values of 3 and 3.5 respectively. So, in terms of average end-to-end delay OLSR INRIA and OLSRv2 NAGATA performs best since low average end-to-end delay would lead to faster performance.

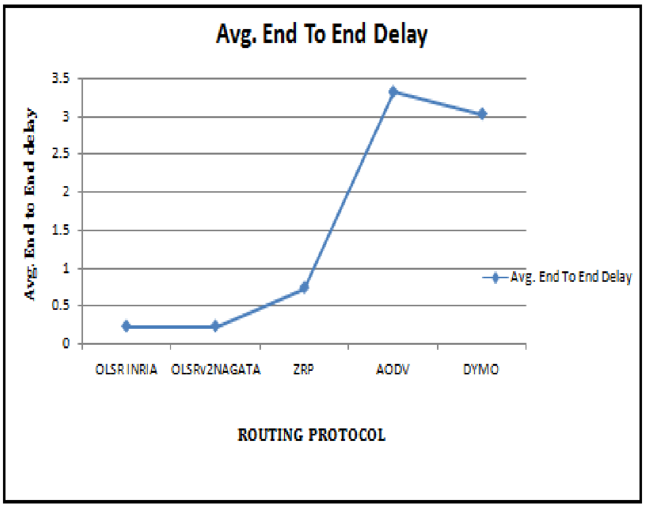

Figure5: Impact of Average end to end delay on various routing protocol using CBR application

Figure 6 presents the performance of throughput for different routing protocols. According to our findings, ZRP produced a throughput value of 91%, DYMO 92%, OSLR INRIA 94%, and AODV 95%. According to throughput results, AODV performs best since it produces more output as compared to other protocols.

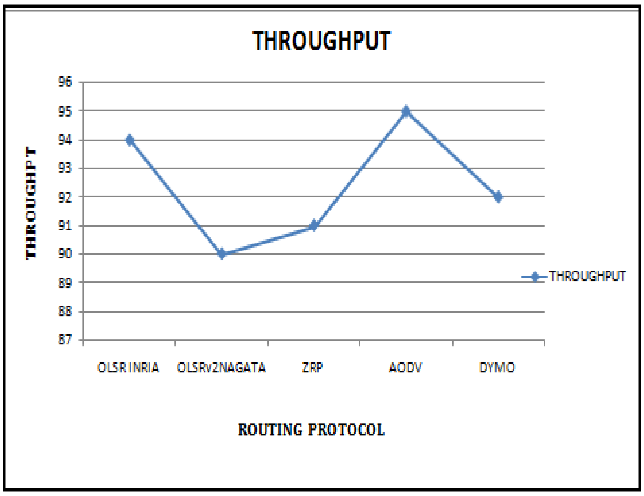

Figure 6: Impact of throughput on various routing protocol using CBR application

Zigzag pattern of total packets received by zigbee authome network are presented in Figure 7 according to which OLSR INRIA, ZRP, and DYMO received 24 packets each, AODV received 25 packets whereas OLSRv2 NAGATA received 23 packets. Since higher number of packets produce faster response time; therefore, AODV has an edge over all other protocols.

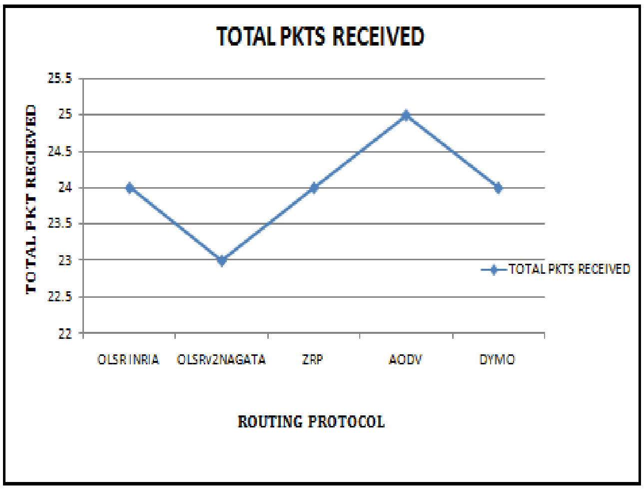

Figure 7: Impact of total packet received on various routing protocol using CBR application

6. CONCLUSION

This paper investigate the effects on QOS by using different wireless mobile ad hoc routing protocols like OLSR INRIA, OLSRv2 NAGATA, ZRP, AODV and DYMO by using CBR application in zigbee home automation network having static IEEE 802.15.4 star topology. Quality of service metrics (average end-to-end delay, throughput, jitter, and data packet delivery ratio) are used to compare to ad hoc routing protocols. The findings suggest that although AODV produce a little higher throughput and receive slightly more number of packets than all other protocols which makes it a suitable choice for zigbee home automation network but still OLSR INRIA is the best suited protocol for CBR application of zigbee home automation network because of the fact that AODV's throughput value and number of packets received is not significantly higher than OSLR INRIA. Also, OSLR INRIA performs better overall and produce less jitter and average end to end delay as compared to all other protocols.

7. REFERENCES

[1] IEEE Std 802.15.4 2006 Part 15.4, "Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)," 2006.

[2] E. Callaway et al., "Home Networking with IEE802.15.4: A developing Standard for Low-Rate Wireless Personal Area Networks," *IEEE Communications Magazine*, Vol. 40 No. 8, pp 70-77, Aug. 2002.

[3] J. Zheng and M. J. Lee "Will IEEE 802.15.4 make Ubiquitous networking a reality?A discussion on a potential low power, low bit rate standard," *IEEE Communications Magazine,* Vol. 42, No. 6, Jun 2004, pp. 140 – 146.

[4] ZigBee Alliance Document 053474r06, "ZigBee Specification, Version 1.0," Dec 2004.

[5] Mikko Kohvakka, Mauri Kuorilehto, "Performance Analysis of IEEE 802.15.4 and ZigBee for Large-Scale Wireless Sensor Network Applications", *PE-WASUN'06*, October 6, 2006, Torremolinos, Malaga, Spain

[6] J. Zheng and Myung J. Lee, "A comprehensive performance study of IEEE 802.15.4," Sensor Network Operations Book, IEEE Press, Wiley Interscience, Chapter 4, pp. 218-237, 2006.

[7] Bougard, B., Catthoor, F., Daly, D.C., Chandrakasan, A.,Dehaene, W., "Energy efficiency of IEEE 802.15.4 standard in dense wireless microsensor networks: modeling and improvement perspectives", in *Proceedings of Design, automation and test in Europe (DATE'05)* (Munich, Germany, March 7-11, 2005). IEEE, 2005, Vol. 1, 196-201.

[8] G. Lu, B. Krishnamachari, and C.S. Raghavendra, "Performance evaluation of the IEEE 802.15.4 MAC for low-rate low power wireless networks," in Proceedings of the 23rd IEEE International Performance Computing and Communications Conference (IPCCC '04), Pages 701-706, Phoenix, Ariz, USA, April 2004.

[9] Timmons, N.F., Scanlon, W.G., "Analysis of the performance of IEEE 802.15.4 for medical sensor body area networking", in *Proceedings of the 1st IEEE international conference. On Sensor and ad hoc communications and networks (SECON'04)* (Santa Clara, CA, USA, 4-7. October, 2004). IEEE, 2004, 16-24.

[10] Jose Javier Garcia, Thomas Falck, "Quality of Service for IEEE 802.15.4 based Wireless Body Sensor Networks," 3rd *International Conference on Pervasive Computing Technologies for Healthcare*, Pages 1-6, 1-3 April 2009

[11] Lu, G., Krishnamachari, B., Raghavendra, C.S., "Performance evaluation of the IEEE 802.15.4 MAC for low-rate low-power wireless networks, in *Proceedings of the 23rd IEEE international Performance computing and communications conference (IPCCC'04)",* (Phoenix, AZ, USA, April 15-17, 2004). IEEE, 2004, 701-706.

[12] *Sanatan Mohanty, "*Energy Efficient Routing Algorithms for Wireless Sensor Networks and Performance Evaluation of Quality of Service for IEEE 802.15.4 Networks ", M. Tech thesis, NIT Rourkela, 2010.

[13] C. E. Perkins, E. M. Royer and S. Das "Ad Hoc On-demand Distance Vector Routing (AODV)," IETF RFC 3561, July 2008

[14] I. Chakeres , C. Perkins, " Dynamic MANET On-demand routing Protocols for Mobile Ad Hoc Networks (DYMO)," draft-ietf-manet-dymo-09,Novenmber 2007.

[15] Sanatan Mohanty, Sarat Kumar Patra, "Performance Analysis of Quality of Service Parameters for IEEE 802.15.4 Star Topology using MANET routing", *ICWET '10, February 26-27, 2010, Mumbai, Maharashtra , India*.

[16] Vaddina Prakash Rao, "The Simulative Investigation of Zigbee/IEEE 802.15.4", Master Thesis, Dresden University of Technology, 2005.