IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Performance Analysis of Quality of Service Evaluation in IEEE 802.15.4 Wireless Sensor Networks

Surendra Kumar Kurmi[*1], Navdeep Kour Saluja[2], Sunil Patel[3]
[*1,2] Infinity Engineering College, Sagar, India
[3]Oriental University, Indore, India
Surendrakumarkurmi@gmail.com

Abstract

The popularity of Wireless Sensor Networks (WSN) have increased tremendously in recent time due to growth in Micro-Electro-Mechanical Systems (MEMS) technology. WSN has the potentiality to connect the physical world with the virtual world by forming a network of sensor nodes. IEEE 802.15.4 is the emerging next generation standard designed for low-rate wireless personal area networks (LR-WPAN). The work reported in this paper provides performance evaluation of quality of service parameters for WSN based on IEEE 802.15.4 star topology. The performance studies have been evaluated for varying traffic loads using MANET routing protocol in QualNet . The data packet delivery ratio, average end-to-end delay, total energy consumption, network lifetime and percentage of time in sleep mode have been used as performance metrics. Simulation results show that DSR (Dynamic Source Routing) performs better than DYMO (Dynamic MANET On-demand) and AODV (Ad–hoc On demand Distance Vector) routing protocol for varying traffic loads rates.

Keywords: Wireless Sensor Networks (WSN), Ad-hoc On Demand Distant Vector (AODV), Dynamic Source Routing (DSR), Dynamic MANET on demand (DYMO), Quality of Service (QoS).

Introduction

The term ―QoS is used in different meanings, ranging from the user‘s perception of the service to a set of connection parameters necessary to achieve particular service quality. ITU-T (Recommendation E.800 [ITU-TE.800]) and ETSI [ETSI-ETR003] basically defines Quality of Service (QoS) [14] as ―the collective effect of service performance which determines the degree of satisfaction of a user of the servic. The goal of QoS provisioning is to achieve a more deterministic network behaviour so that information carried by the network can be better delivered and network resources can be better utilized. Moreover, certain service properties such as the delay, reliability, network lifetime, and quality of data may conflict by nature. For example, multi-path routing can improve the reliability. However, it can increase the energy consumption and delay due to duplicate transmissions. The high resolution sensor readings may also incur more energy consumptions and delays. Modeling such relationships, measuring the provided quality and providing means to control the balance is essential for QoS support in WSN [15].

The rest of the paper is organized as follows. In Section II, we present the Challenges for QoS Support in WSNs and Parameters Defining WSN QoS. Section III presents a survey on various MANET reactive routing protocols. Section IV presents the related work. We present simulation setup and performance metrics in section V. In section VI we present simulation result using Qualnet network simulator. Finally section VII concludes the paper.

Challenges for QoS Support in WSNs and Parameters Defining WSN QoS

WSNs inherit most of the QoS challenges from general wireless networks, their particular characteristics pose unique challenges as follows [**16**].

Severe resource constraints*:* The constraints on resources involve energy, bandwidth, memory, buffer size, processing capability, and limited transmission power.

Data redundancy*:* WSNs are characterized by high redundancy in the sensor data.

Scalability*:* A wireless sensor network usually consisting of hundreds or thousands of sensor nodes densely distributed in phenomena

Network dynamics*:* Network dynamics may arise from node failures, wireless link failures, node mobility, and node state transitions due to the use of power

Packet criticality: The content of data or high-level description reflects the criticality of the real physical phenomena with respect to the quality of the applications.

The QoS service parameters used in traditional wired networks are throughput, reliability, delay and jitter. Security and mobility are essential in any wireless network, while data accuracy is especially relevant to the WSNs. The Network lifetime is usually shortened by decreasing latency or increasing any of the other parameters which affects energy consumption of WSN nodes in terms of processing, transmission and reception of data packets. The QoS parameters for WSN as given in [**4**] are Data accuracy, Energy usage, Reliability Latency, Security, Mobility, Throughput ect.

MANET Reactive Routing Protocols

Ad-hoc On-demand Distance Vector Routing (AODV)

Ad–hoc on demand distance vector routing (AODV) is a stateless on-demand routing protocol [**17**]. It establishes routes on as desired by a source node, using route request (RREQ) and route reply (RREP) messages. When the source node needs a route to another node, it broadcasts a RREQ message with a unique RREQ identification number. The message will reach the neighbouring nodes, which will update the sequence number for this source node. At same time, each neighbour node can also set up a reverse route to the source node in the routing table. Under the following two conditions, the neighbour node that receives a RREQ will send back a RREP to the requesting source node: (1) The neighbour node is the destination node. (2) The node has a route to the destination node that meets the freshness requirement specified in the RREQ message.
Figure 1 shows the process of signals with AODV from node 1 to node 8.

Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [**19**] is an on demand reactive routing protocol based on the concept of source routing . That is, the sender knows the complete hop-by-hop route to the destination for data packets to be transverse in the whole network. These routes are stored in a route cache. The data packets carry the source route in the packet header. The nodes can dynamically discover a source route across multiple network hops to any destination in the network. This makes the network completely self-organizing and self-configuring without the need for a network infrastructure or administration. DSR protocol is composed of two mechanisms: route discovery and route maintenance.

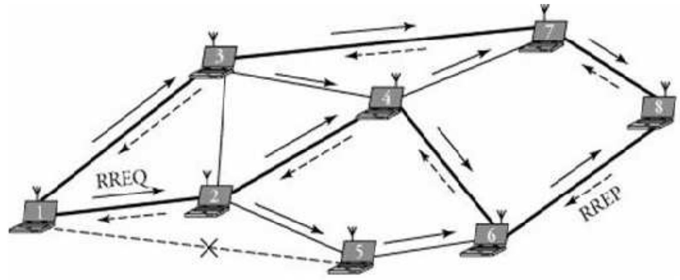


Figure 1: AODV Communication signaling from node 1 to node 8 [18]

Figure 2 shows an ad-hoc wireless network with eight nodes and a broken link (3-7). Node 1 wants to send a message to the destination, node 8 using DSR routing protocol.

The Dynamic MANET On-demand (DYMO) routing protocol

The Dynamic MANET On-demand (DYMO) routing protocol [**90**] is a unicast reactive routing protocol which is intended for used by mobile nodes in wireless multi-hop networks. DYMO is a reactive routing protocol. In this routing message (control packet) is generated only when the node receives a data packet and it does not have any routing information. The basic operation of DYMO protocol is route discovery and route management.

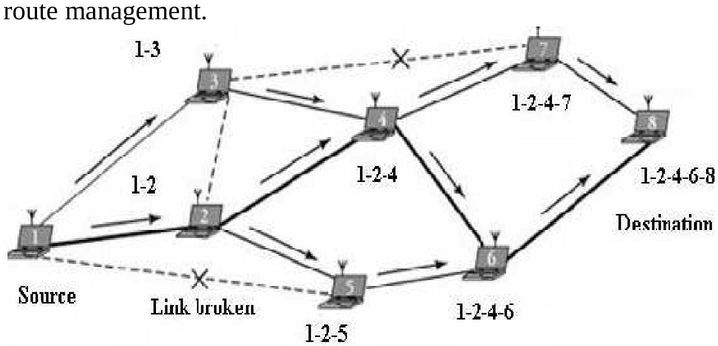


Figure 2: DSR Communication signaling from node 1 to node 8 [18]

Related Work

J. Zheng and M.J. Lee [**2**] implemented the IEEE 802.15.4 standard on NS2 simulator and subsequently produced the comprehensive performance evaluation on 802.15.4. Similarly in [**91**], the authors provided performance evaluations of IEEE 802.15.4 MAC in beacon-enabled mode for a star topology. J.S.Lee [**22**] attempted to make a preliminary performance study via several sets of practical experiments. T.H.Woon and T.C. Wan [**23**] extended existing efforts but focuses on evaluating the performance of peer-to-peer networks on a small scale basis using NS2 simulator. A Mathematical Model for performance analysis of IEEE 802.15. 4 non-beacon enabled mode has been presented in [**24**]. In [**25**], 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.

Simulations set up and Performance metrics Figures and Tables

TABLE 1: IEEE 802.15.4 Star topology simulation parameters

Parameter	Value
Area	50m *50m
Transmission range	30meter
Simulation Time	170M,85M,18M,5Mand 3M
Channel Frequency	2.4GHz
Data rate	250Kbps
TX-Power	0dBm
Path Loss Model	Two Ray Model
Phyand MAC Model	IEEE 802.15.4
Energy Model	MICAZ Mote
Battery Model	Simple Linear,1200mAhr
Payload Size	1000 and 50 bytes
BO and SO	5

The main Objective of this simulation study is to evaluate the performance of IEEE 8021.5.4 star topology on different popular reactive wireless mobile ad hoc routing protocols like AODV, DSR and DYMO with varying traffic load. The simulations was carried out using QualNet network simulator [**96**. For simulation, a star topology with one PAN Coordinator and 100 devices , uniformly deployed in an area of 50mx50m as shown in Figure 5.3 was considered. The simulation parameters are listed in Table 1. Following performance metrics are considered to evaluate the QoS in IEEE 802.15.4 networks.

Packet delivery ratio (PDR): It is the ratio of number of data packets successfully received by the PAN Coordinator to the total number of data packets sent by RFD.

Average End-to-End delay: It indicates the time taken for a packet to travel from the CBR source to the destination.

Throughput: It is the number of bits passed through a network in one second. It is the measurement of how fast data can pass through an entity (such as a point or a network).

Energy Consumption: This is amount of energy consumed by MICAZ Mote devices during the periods of transmitting, receiving, idle and sleep. The unit of energy consumption used in the simulations is mJoule.

Energy per goodput bit: It is the ratio of total energy consumed to total bits received.

Network Lifetime: This is defined as the minimum time at which maximum numbers of sensor nodes are dead or shut down during a long run of simulations.

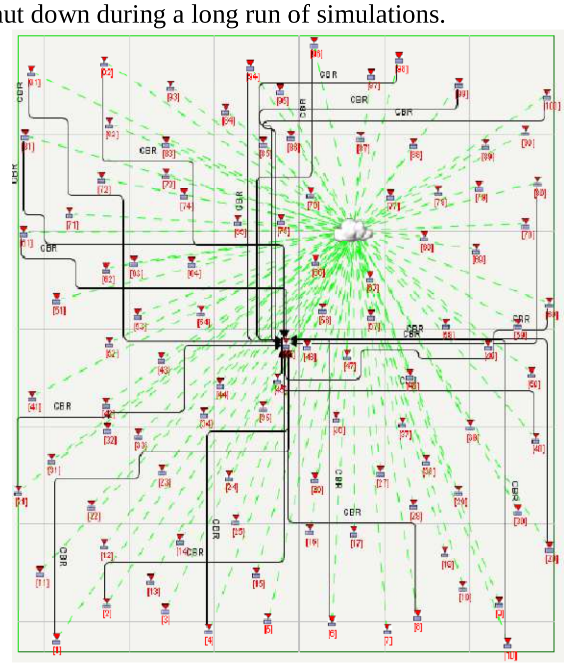


Figure 3: Simulation set up for Star Topology

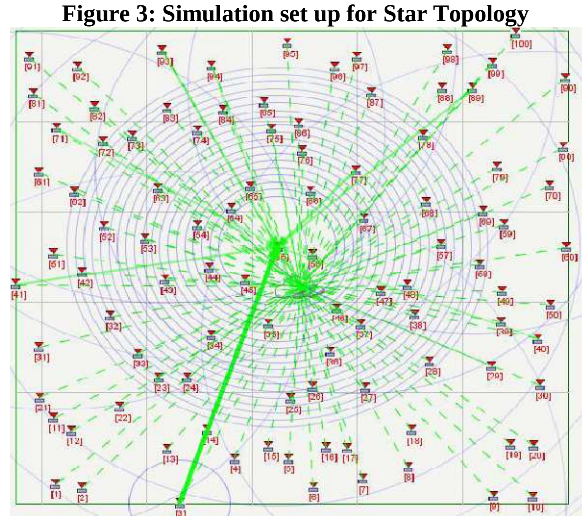
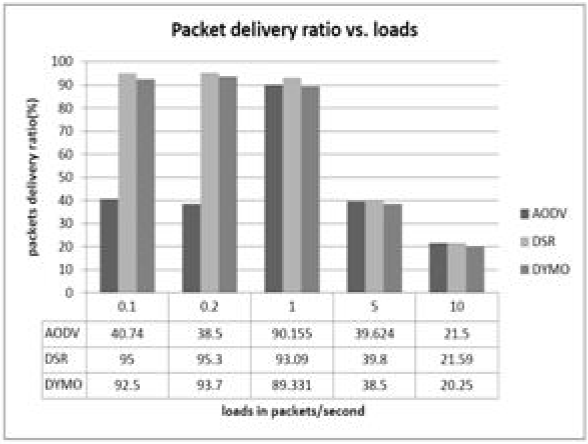


Figure 4: QualNet animator during simulation execution

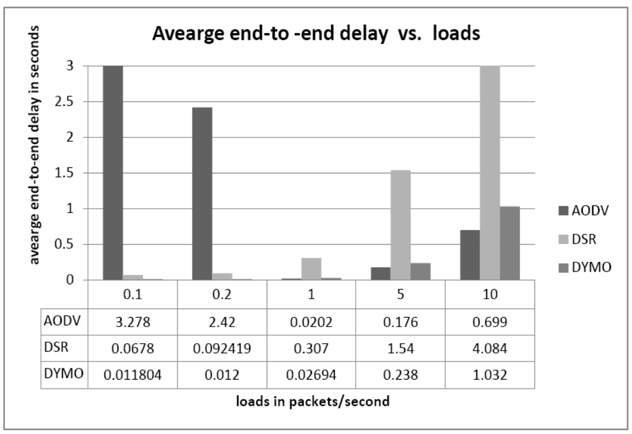
Simulation Results Discussion

The **Packet delivery ratio (PDR)**: The performance of PDR vs. load for varying traffic is shown in Figure 5. It is observed from the figure that DSR performs better than AODV and DYMO. The better performance of DSR is due to its source routing based aggressive caching approach.



	0.1	0.2	1	5	10
AODV	40.74	38.5	90.155	39.624	21.5
DSR	95	95.3	93.09	39.8	21.59
DYMO	92.5	93.7	89.331	38.5	20.25

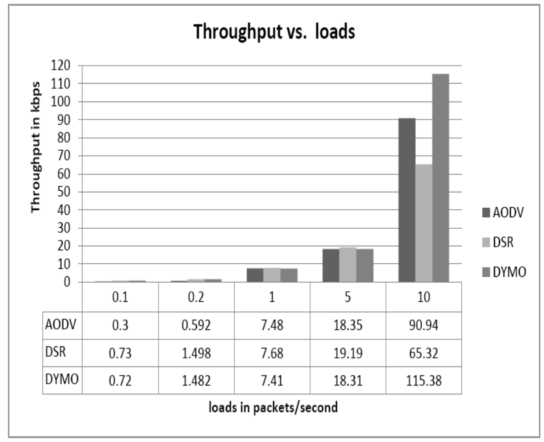
Figure 5: Packet delivery ratio vs. loads (packets/second)



	0.1	0.2	1	5	10
AODV	3.278	2.42	0.0202	0.176	0.699
DSR	0.0678	0.092419	0.307	1.54	4.084
DYMO	0.011804	0.012	0.02694	0.238	1.032

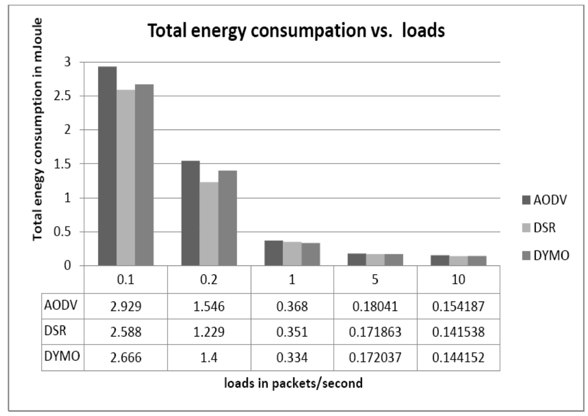
Figure 6: Average delay vs. loads (pkts/sec)

Average end to end delay: The plot for average end-to-end delay for varying traffic loads is shown in Figure 6. The average end- to- end delay of a packet depends on route discovery latency, besides delays at each hop and the number of hops. At low loads, queuing and channel access delays do not contribute much to the overall delay. From the figure 6, it is observed that DYMO, AODV and DSR is lower for a load of one packet per second. Lesser delay is attributed to its source routing mechanism.



	0.1	0.2	1	5	10
AODV	0.3	0.592	7.48	18.35	90.94
DSR	0.73	1.498	7.68	19.19	65.32
DYMO	0.72	1.482	7.41	18.31	115.38

Figure 7: Throughput vs. loads (packets/second)



	0.1	0.2	1	5	10
AODV	2.929	1.546	0.368	0.18041	0.154187
DSR	2.588	1.229	0.351	0.171863	0.141538
DYMO	2.666	1.4	0.334	0.172037	0.144152

Figure 8: Total energy consumption vs. loads (pkts/sec)

Throughput: Figure 7 shows performance of throughput (in kbps) vs. loads in packets per second. From the graph, it is observed that maximum throughput is achieved when the load is at 10 packets per second. DYMO shows better throughput in comparison to AODV and DSR. Better throughput is due to lower average end to end delay.

Total energy consumption: The plot for total energy consumption vs. load of three routing protocols is shown in Figure 8. The total energy consumption includes energy consumption in transmission, reception, idle and sleep modes of operation The total energy consumption of three routing protocols decreases exponentially when it transferred packets from low traffic loads to high traffic loads.

Percentage of time in sleep mode: The performance of the percentage of time in sleep mode vs. loads is shown in Figure 11. From the figure, it can be noticed that less than 1 mAhr is required to send data at different traffic loads. The IEEE 802.15.4 supports a Battery Life Extension (BLE) mode, in which the back-off exponent is limited to the range 0- 2. This greatly reduces the receiver duty cycle in low traffic rate applications.

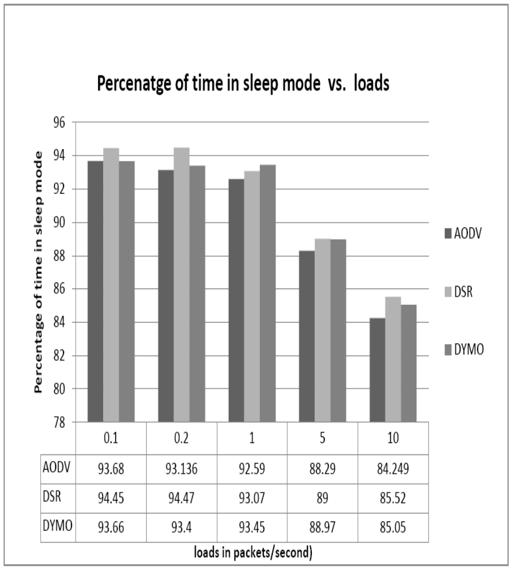


Figure 11: % of time in sleep mode vs loads (pkts/sec)

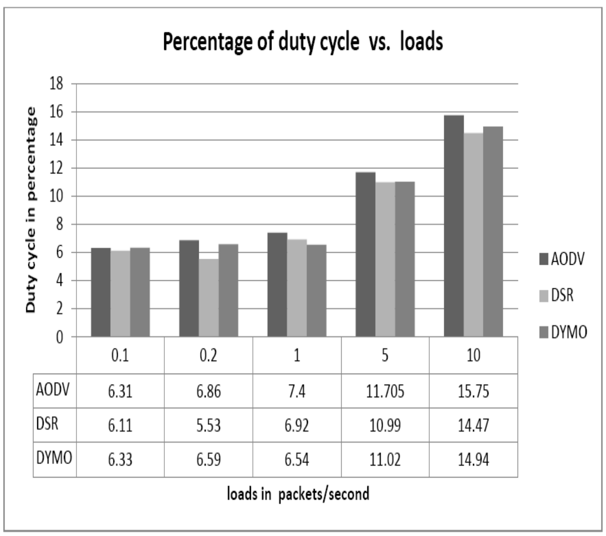


Figure 12: % of duty cycle vs loads (packets/second)

However, in dense networks, this mode results into excessive collision rates. It is due to energy efficient IEEE 802.15.4 MAC which minimizes low duty cycle on RFD to send data packets. It clearly shows that DSR performs better than other two routing protocols. The lower duty cycle of DSR as shown in Figure 12 indicates that nodes in

DSR remain in sleep mode for longer period.

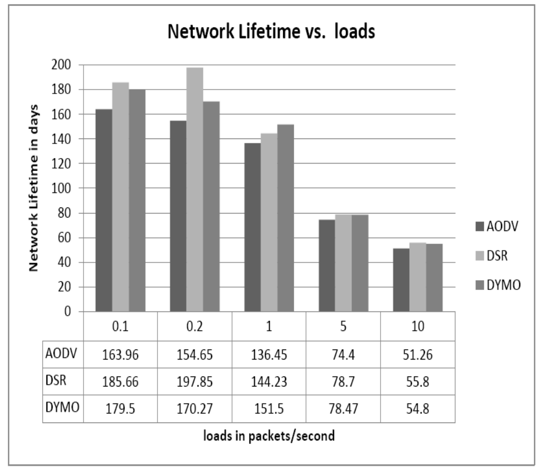


Figure 13: Network lifetime vs. loads (pkts/second)

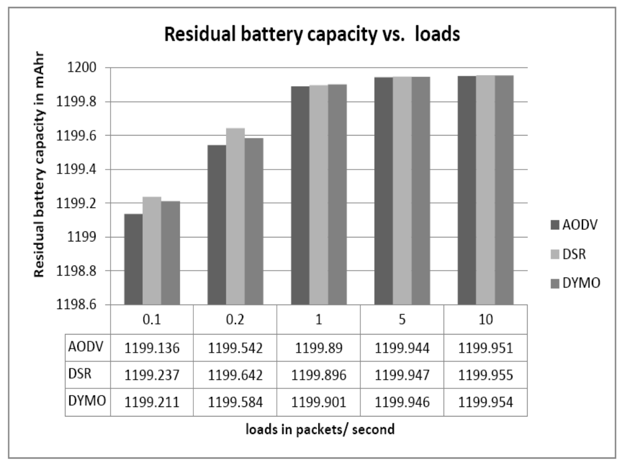


Figure 14: Residual battery capacity vs. loads (pkt/sec)

Network Lifetime: The Figure 13 describes performance of the network lifetime verses the traffic loads. The network lifetime calculation in our simulation based on residual battery capacity as shown in Figure 5.14 after running it full battery capacity 1200mAHr to the respective simulation time for varying traffic loads. The DSR routing protocol has higher lifetime in comparison to ADOV and DYMO. This is due to low control packet overhead and higher percentage of time nodes are in sleep mode. DSR also minimizes the overall network bandwidth as it does not use periodic routing messages. By doing so, DSR also tries to conserve battery power as well as avoidance of routing updates that are large enough.

Conclusion

The Wireless Sensor Networks Quality of service is significantly different from traditional wired and wireless networks. This chapter discussed the challenges for quality of service support and parameters for defining QoS in WSNs. It also discussed support and design choices of different layers like application layer, network layer, transport layer, data link layer and physical layer. To support QoS, cooperation between layers is essential. Otherwise, each layer may try to maximize different QoS metrics, which will have unpredictable and possibly undesirable results. The QoS is more challenging in heterogeneous wireless sensors networks where a diverse mixture of sensors for monitoring temperature, pressure, and humidity are deployed to monitor the phenomena, thereby introducing different reading rates at these sensors.

This section evaluated the performance analysis of Quality of Service parameters of WSN based on IEEE 802.15.4 star beacon enabled mode topology. Simulations have been performed using reactive MANET routing like AODV, DSR and DYMO in QualNet for varying loads**.** From the simulation results, it can be concluded that on an average DSR performs better than DYMO and AODV for different rates of traffic loads. The simulations are performed for 200 nodes and 20 application per sessions. If the payload size goes beyond standard IEEE 802.15.4 *MaxMACFrameSize* which is equal to 102 bytes, then it simply drop the packet. So, the overall performance of the three protocols on IEEE 802.15.4 for standardizing for WSNs is not promising. The major reason behind the performance degradation is all these protocols are designed mainly for mobile ad-hoc network where topology changes frequently. To meet these challenges of performance degradations, new routing protocols should be designed for IEEE 802.15.4 networks keeping in view of above routing protocols key features

References

[1] K. Sohraby, D. Minoli, T. Znati, WIRELESS SENSOR NETWORKS-Technology, Protocols, and Applications.: Wiley-interscience, 2007.

[2] J. Zheng and M.J. Lee, "A Comprehensive Performance Study of 802.15.4," in Sensor Network Operations.: IEEE Press, 2006, ch. 4, pp. 218-237.

[3] H. Karl, A. Willig, Protocols and Architectures for Wireless Sensor Networks. New York: John-Wiley, 2007.

[4] Mauri Kuorilehto, Mikko Kohvakka, Ultra-Low Energy Wireless Sensor Networks in Practice Theory, Realization and Deployment. England: John-Wiley, 2007. www.scalablenetworks.com/QualNet/documentation.

[5] Vijay K. Garg, Wireless Communications and Networking. USA: Elsevier, 2008.

[6] Shahin Farahani, ZigBee Wireless Networks and Transceivers.: Elsevier, 2008.

[7] Nitaigour P. Mahalik, Sensor Networks and Configuration Fundamentals, Standards, Platforms, and Applications.: Springer, 2007.

[8] S. Dagtas, "Multi-stage Real Time Health Monitoring via ZigBee in Smart Homes," in proceedings of IEEE International Conference on Advanced Information Networking and Applications (AINAW), 2007, pp. 82-86. http://www.geatbx.com/docu/algindex-01.html.

[9] K. M. Passino, "Biomimicry of bacterial foraging for distributed optimization and control," Control System Magazine,IEEE, vol. 22, pp. 52-67, June 2002.

[10] S. Mishra, "A Hybrid Least Square-Fuzzy Bacterial Foraging Strategy for Harmonic Estimation," IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, vol. 9, no. 1, pp. 61-73, February 2005.

[11] Babita Majhi and G. Panda and A. Choubey, "On the Development of a New Adaptive Channel Equalizer using Bacterial Foraging Optimization Technique," in Annual IEEE india conference, 2006, pp. 1-6.

[12] Mario Marchese, QoS over heterogeneous networks.: John &Wiley sons Limited, 2007.

[13] S. Misra, S. C. Misra, I. Woungang, Guide to Wireless Sensor Networks.: Springer, 2009.

[14] Dazhi Chen, Pramod K. Varshney, "QoS Support in Wireless Sensor Networks: A 111 Survey," in Proceedings of the International Conference on Wireless Networks, vol. 1, Las Vegas, Nevada, USA, 2004, pp. 227-233.

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

[16] Nader F. Mir, Computer and Communication Networks.: Prentice Hall, November 02, 2006.

[17] D.B.Johnson, D.A. Maltz, Y. Hu, and J. G. Jetcheva, "The Dynamic Source routing protocol for Mobile Ad Hoc Networks (DSR)," IETF RFC 4728, February 2007.

[18] I.Chakeres, C.Perkins, "Dynamic MANET On-demand (DYMO) Routing protocols for Mobile Ad Hoc Networks(DYMO)," draft- ietf-manet-dymo-09 November 2007.

[19] 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, Phoenix, Ariz, USA, April 2004, pp. 701-706.

ISSN: 2277-9655
Impact Factor: 1.852

[20] J.S. Lee, "Performance evaluation of IEEE 802.15.4 for low-rate wireless personal area networks," IEEE Transactions on Consumer Electronics, vol. 52, no. 3, pp. 742- 749, August 2006.

[21] W.T.H Woon, T.C. Wan, "Performance Evaluation of IEEE 802.15.4 Ad Hoc Wireless Sensor Networks: Simulation Approach," in IEEE International Conference on Systems, Man and Cybernetics, vol. 2, october 2006, pp. 1443-1448.

[22] C. Buratti and R.Verdone, "A Mathematical Model for Performance Analysis of IEEE 802.15. 4 Non-Beacon Enabled mode," in European Wireless Conference , June 2009, pp. 1- 7.

[23] Jose Javier Garcia, Thomas Falck, "Quality of Service for IEEE 802.15.4-based Wireless Body Sensor Networks," in Proceedings of 3rd International Conference on Pervasive Computing Technologies for Healthcare, UK,London, April 2009, pp. 1-6. www.scalable-networls.com/QualNet.