Optimum Retransmission based Energy-Efficient Multipath Routing Protocol (OREMRP) in WSN

Laveena Mahajan[1], Avani Chopra[2]
[1]Research Scholar, Computer Science and Engineering, DAVIET Jalandhar, India
[2]Assistant Professor, Information Technology, DAVIET Jalandhar, India
(E-mail:mahajanlaveena05@gmail.com, bhatia_avani@yahoo.com)

Abstract**—**With recent advances in Wireless Sensor networks, routing in WSN has been considered an important field of research over the past decade. Currently, multipath routing approach is widely used in wireless sensor networks to increase network lifetime and to improve the performance of the network. It uses multiple paths for routing data between the source and sink node, specifying benefits such as fault tolerance, load balancing, bandwidth aggregation, and improves Quality of service (QoS) of the network. In this paper, the multipath routing protocol based on optimum retransmission is proposed to improve the energy-efficiency of the multipath wireless network. The performance of proposed multipath routing protocol is compared with Interference-Minimized Multipath Routing protocol (IM2PR) by using OMNET++ network simulator and MIXIM framework. The proposed multipath protocol shows the better result in terms of packet reception ratio, latency, energy consumption, and packet delivery overhead as compared to IM2PR.

Keywords— Energy-Efficiency, MIXIM, Multipath Routing Protocol, OMNET++, Optimum Retransmission, Wireless Sensor Networks

I. INTRODUCTION

In recent years, Wireless sensor network (WSN) is fascinating much attention of researchers. WSN is a large network consisting of thousands of low-power devices known as sensor nodes which are capable of processing, communicating and sensing the data [2] [3]. Due to the ubiquitous and flexible nature of WSN, they have been utilized in many applications such as health care, traffic control, military, environment monitoring, and information gathering in battlefields.

Routing is one of the challenging issues in the wireless sensor network. Thus, various routing protocols have been proposed for WSNs. Some protocols use a single path to transmit data to the sink node while other distributes the packets to be sent into the multiple paths between the source and sink node. Although the single-path routing is simple and scalable and the optimal path is selected on the basis of metrics, such as the gradient of information, the distance to the destination, or the node residual energy level. But, network lifetime can't be increased by selecting an optimal path and sending the data through that single path [5]. On the other hand, multipath routing technique is an efficient routing mechanism providing efficient network resource utilization and data transmission in different networks. Multipath routing technique either uses an alternate path or concurrent paths for transmitting the data. Alternate path routing uses primary path for data transmission and makes the other alternative path to be as a backup path which is to be used in case of any node failure or in the case when primary path consumes more energy than other paths. On the other hand, concurrent path routing protocol uses multiple concurrent paths for data transmission and evenly distributes the traffic load over the network, thus extending the network lifetime [3].

In alternative path routing, the source node first discovers the multiple paths during the route discovery phase but then, chooses a single path to route data towards the sink node. Meanwhile, the other discovered multiple paths are not discarded; they are kept as backup paths [3] in the case when the primary path fails. It includes Braided Multipath Routing which first constructs the primary path and then, for each node on the primary path, the best path is determined which doesn't include that node and also includes Reliable and Energy-Aware Multipath Routing which is designed to construct energy-efficient wireless sensor networks, while provides reliable data transmission through maintaining a backup path from each source node towards the sink node [4] and increases the lifetime of the network.

On the other hand, concurrent multipath routing technique uses several multiple paths simultaneously to route data from the source towards the sink node. It distributes the load across the network and reduces the number of transmission delays [3]. It includes Reliable Data-Transmission Routing which supports a reliable communication over unreliable low-power wireless links and introduces data redundancy while transmitting data towards sink node and involves Energy-Efficient Routing to balance network traffic and resource utilization throughout the network.

Thus, multipath routing techniques are designed for efficient network resource utilization and improving the network lifetime which overcomes conventional single path routing schemes that may not be optimal to maximize the network lifetime and connectivity. In this paper, we propose an optimum retransmission based multipath routing protocol that uses alternate multipath routing technique to transmit the data between the sink and the source node.

The primary objective of the proposed work is to improve the Quality of Service (QoS) and energy-efficiency of the wireless network by using the concept of optimum retransmission. This shows that only the number of packets dropped can be easily retransmitted to the sink node instead of sending all packets again to the sink node. The rest of paper is organized as follows: section II shows the related work. The proposed multipath routing protocol i.e. OREMRP is discussed in section III. Section IV describes Performance analysis and Results with different parameters including Packet Reception ratio, Latency, Energy Consumption, Packet delivery overhead. The conclusion is provided in section V.

II. RELATED WORK

Multipath routing techniques provide reliability, higher throughput, lower delay, improved load balancing, and Quality of service (QoS). The authors in [2] [3], proposed Wireless Sensor Network scenario aiming at energy management provides acquired data access in order to increase sensor node energy autonomy. The optimization of energy consumption of each WSN node is achieved by using the different modulation techniques in order to maximize the lifetime of the network. A comprehensive analysis of various multi-path routing techniques in Wireless sensor network has been discussed in [4] [5]. It explains taxonomy of different multipath routing techniques, detailed operational characteristics of existing multipath routing techniques on basis of different categories and its benefits over single path routing protocols. The open issues for further research have been discussed and challenges related to the designing of multipath routing protocols have been identified.

In paper [6], authors illustrate that multipath routing is considered to be as an efficient method to improve network capacity and makes effective resource utilization under heavy traffic conditions. With advancement in the development of multipath routing protocol, the author in [7] presents an Interference-Minimized Multipath Routing protocol (IM2PR) due to the drawbacks of an existing multipath protocol. This protocol provides event-driven packet forwarding and discovers minimum interfering paths in WSN to improve transmission quality between an event and sink area. The protocol is proposed by using different mechanisms and highlights the main advantages of using multipath routing to meet performance requirements of different applications discussed in [6].

Multipath routing protocols also use load balancing algorithm to distribute the traffic over the multiple paths [9]. Based on this algorithm, an Energy-aware node-disjoint multipath routing protocol (EANDMRP) [8] and Low-Interface Energy-Efficient Multipath Routing Protocol (LIEMRO) [10] are proposed to maximize the network lifetime and improving QoS of the network by distributing the traffic load over the multiple paths. LIEMRO discovers interference minimized node-disjoint paths and provides better reliability, improves end to end delay, packet delivery fraction and enhances the energy efficiency.

It has been identified that the multipath routing can be fundamentally more efficient than the traditional approach of single path routing. In contrast to the single-path routing approach, the concept of multipath routing focused on heuristic methods. The author in [11], investigates multipath routing scheme as a rigorous approach and demonstrates the significant advantage of optimal solutions. Energy-Efficient data Routing Protocol for wireless sensor networks (EERP) keeps a set of good paths and chooses one path on the basis of the node state and the cost function of this path. In EERP, each node has a number of neighbors through which it can route packets to the base station. A node bases its routing decision on two metrics: state and cost function [14]. Robust and energy efficient multipath routing protocol (REER) is energy-efficient routing protocol discussed in [17] that uses a single path among the discovered paths to transfer the data message when this path cost falls below a certain threshold, it then switches to the next alternative path.

The paper [12] [16], emphasis on OMNET++4.5 network Simulator and MIXIM 2.3 framework [21] for modeling the multipath routing protocols and design the multi-hop wireless network and explained the realistic behavior using this simulator. It provides detailed models of the wireless channel (fading, etc.), wireless connectivity, mobility models, models for obstacles and many communication protocols especially at the Medium Access Control (MAC) level [12]. The simulation is based on the proper selection of wireless sensor node, routing protocol and other important parameters [13]. The critical issues in any WSN are QoS and energy. To overcome this issue, MIXIM framework simulates WSN with QoS in the real-time environment [18]. Long hops of transmission maintain the QoS with more energy consumption which results in a reduction of network lifetime.

The overview of the network simulators for designing the multipath wireless environment is shown in [20] [22] and optimum retransmission multipath routing algorithm is proposed by using OMNET++ simulator.

III. OPTIMUM RETRANSMISSION BASED ENERGY-EFFICIENT MULTIPATH ROUTING PROTOCOL

The Proposed protocol is based on optimum retransmission in which only dropped packets have been retransmitted from the node where packets have been dropped in order to increase the Quality of Service (QoS) of the multipath environment. The lifetime of the sensor nodes directly depends on the efficient use of energy stored in the on-board battery of sensor node. All the processes performed by the sensor node such as sensing, processing, coordination, communication requires energy.

The proposed multipath protocol i.e. OREMRP uses an alternate path routing technique in which primary path is constructed for data transmission which other path is taken as the backup path to improve the energy efficiency of multipath routing protocols discussed in [1]. The proposed protocol consists of three phases: (1) Initialization phase, (2) Path establishment phase, and (3) Data transmission and path maintenance phase. The following sections describe these phases in detail. All the notations used in this paper are presented in Table 1.

A. Initialization Phase

At the initialization phase, every node approximates data transmission quality of its links to its neighbors. Moreover, all nodes calculate its distance to an intermediate neighbor node to transmit data towards the sink. Every node uses this information for selecting its best next-hop node on the basis of minimum hop count.

B. *Data Establishment Phase*

During path establishment, the source node along with its neighboring nodes discovers the primary route by calculating the shortest distance of each intermediate node. In other words, P_i is constructed by the nodes on basis of minimum hop count.

$$\text{Hopsize} = \sum \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2} \qquad (1)$$

where (X_i, Y_i), (X_j, Y_j) are the coordinates of sensor node i and sensor node j.

At the time of primary path P_i creation, every intermediate node which is selected for path establishment is checked before transmitting the data towards the sink node.

C. *Data Transmission and Maintenance Phase*

In Data Transmission phase, data is transmitted from source to the sink node. During P_i is construction, each node is checked. In case of any node, n_i failure, an alternate intermediate node is selected from the previous node on the basis of the shortest distance to transmit data to the sink node [1].

But, if no node fails in constructing P_i, then, data is directly transmitted to the sink node through P_i. At the sink node, the data is received and it is checked that whether all the frames are received by the sink node or not. If no frames dropped during data transmission, i.e. whole data packets are transmitted to sink, then, the transmission, T_x gets completed. But if the number of frames dropped, then, the counter counts the number of times the frames dropped. If it is only the first time the frames dropped, then, retransmission, R_x of the dropped frames is required.

ROUTING ALGORITHM

Select S_o, S_i
Construct P_i by *min_hopcount*
If (n_i fails=True)
Select a_i
Else
Transmit Data to S_i
Similarly, make alternate path, A_i
If (*dropped_frames* = False)
T_x Completed
Else
  If (count<=1)
  R_x is done from n_{fd}
  Else If
  L_i Fails
  Select P_j from S_i

TABLE I. ALGORITHM DEFINITIONS

Symbol	Description
S_o	Source Node
S_i	Sink Node
P_i	Creating path P_i
n_i	Node in the path P_i
a_i	Alternate intermediate node
T_x	Transmission of packets
R_x	Retransmission of packets
L_i	Link
P_j	Creating another path P_j

In that case, only the dropped frames are retransmitted from the node where there is a loss of frames instead of retransmitting the whole data from the source to the sink. This lead to an optimum retransmission of the data [1]. If the value of a counter is greater than one i.e. frames dropped more than once, then it leads to the link, L_i failure during the data transmission process. It will forward an error message towards the source node. Upon reception of an error message by the sink node, source node disables the failed path and leads to the creation of another path P_j. Thus, path maintenance phase handles the path failure and selects another backup path.

IV. PERFORMANCE ANALYSIS AND RESULTS

A. *Simulation Setup*

We have performed our performance evaluations in the OMNET++4.5 network simulator with MIXIM 2.3 framework. We demonstrate multipath wireless environment consisting of a total of 100 sensor nodes as shown in figure 1.

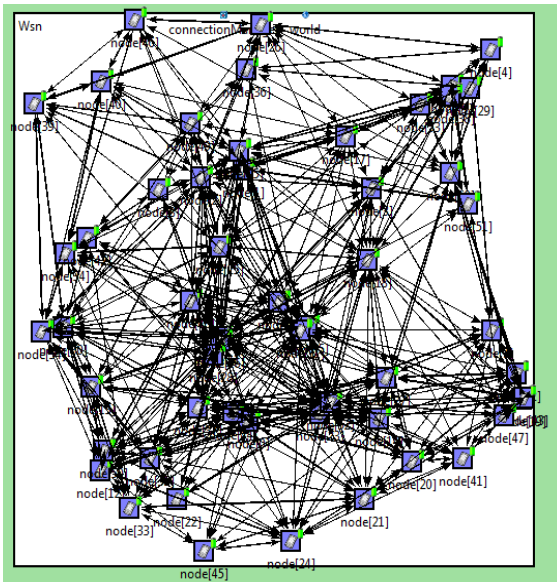

Figure 1: Multi node WSN

The simulation parameters are demonstrated in Table 2. In order to precisely simulate the characteristics of a wireless sensor network and to improve the accuracy of the simulation results, we have developed a multipath WSN environment.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
Network Size	30m×30m
Node Deployment	Uniform Node Distribution
No. of nodes	100
Carrier Frequency	2.4Ghz
Simulation Time	20ms
Bit rate	256 Kbps
Application layer Header Length	50 bytes
Network Layer Header Length	24 bits
Sink Node Address	Node 0
Mobility type	Static
Medium Access Control Layer	CSMA

B. *Performance Evaluation*

This section analyzes and compares the performance of proposed multipath routing protocol based on optimum retransmission i.e. OREMRP and IM2PR. For each analysis, there are 20 simulation runs. The analysis is based on the parameters like packet reception ratio, latency, energy consumption and packet delivery overhead.

1) *Packet Reception Ratio*

Packet reception ratio is defined as the ratio of a number of packets received by the sink node to the total number of packets sent from the source node.

$$PRR = \frac{R_p}{N_p} \quad (2)$$

In the equation (2), R_p is the number of Received packets p, at the sink node and N_p is the total number of packets send by the source node. The PRR achieved at the sink node through IM2PR and proposed multipath protocol in the network with 100 nodes is presented in Figure 2.

Based on Figure 2, with an increase in the packet generation rate, there is a more chance of packets collision over the network which degrades the packet reception ratio. Moreover, during the data transmission process, by increasing the number of the packets to be transmitted decreases the packets to be received by the sink node.

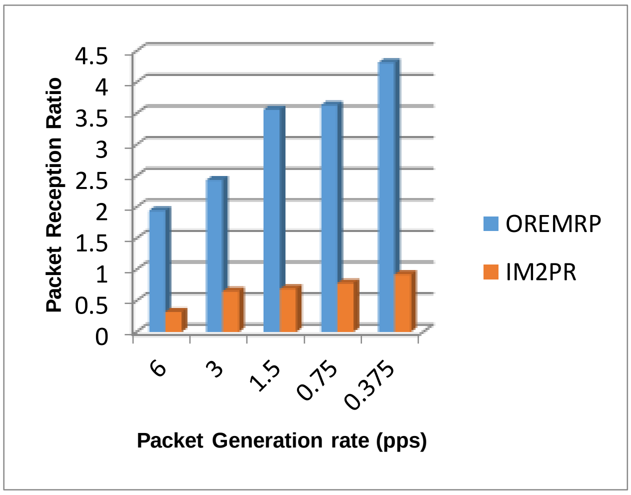

Figure 2: Packet reception ratios achieved by OREMRP and IM2PR versus packet generation rate

2) *Latency*

This metric is defined as the average elapsed time for sending data packets from source node to the sink node. The average packet delivery latency of IM2PR and proposed multipath routing protocol with 100 nodes in the network is depicted in Figure 3.

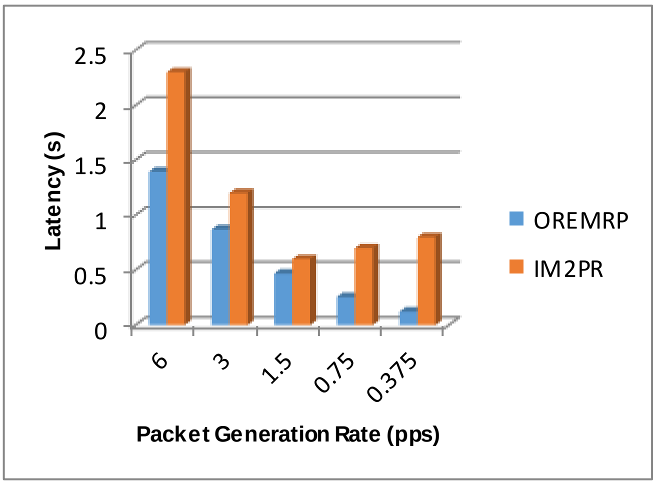

Figure 3: Latency achieved by OREMRP and IM2PR versus packet generation rate

It is observed from above figure 3 that the average packet latency reduces as the packet generation rate decreases. Thus, with a decrease in the number of transmitted packets, less time will be taken for transmitting the packets to the sink node due to which average latency decreases. Moreover, as the network traffic load increases, there will be more packet collisions and wireless interferences which increases the packet delivery latency.

3) *Energy Consumption*

This metric presents the average energy consumed by the individual node to transmit data packets to the sink node through proposed multipath routing protocol and IM2PR. Hence, this metric compares the energy consumption of these multipath routing protocols in the network with 100 nodes.

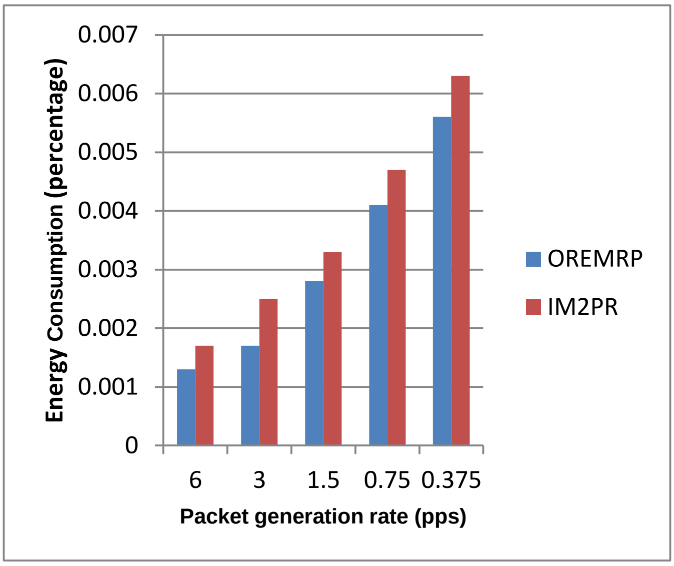

Figure 4: Energy consumption achieved by OREMRP and IM2PR versus packet generation rate

It is shown in figure 4 that the proposed multipath routing protocol OREMRP consumes less energy in comparison to the existing protocol IM2PR. This is due the fact that OREMRP uses alternate multipath routing technique to transmit the data and based on the concept of retransmission in which only dropped frames are retransmitted instead of retransmission of whole data packets.

4) *Packet Delivery Overhead*

It is the ratio of the number of data and control packets transmitted during the path establishment and data transmission processes to the number of data packets received by the sink node.

$$\text{Packet Delivery Overhead} = \frac{\sum_{p=N} (D_p + C_p)}{R_p} \qquad (3)$$

where $\sum (D_p + C_p)$ is the total number of data packets, D_p and control packets, C_p transmitted during path establishment and transmission phase and R_p is the received packets at the sink node.

Based on the figure 5, it is shown that the packet delivery overhead achieved by OREMRP is less as at packet generation rate 6, more packets received at the sink node due to which its packet delivery overhead decreases in comparison to the existing protocol i.e. IM2PR.

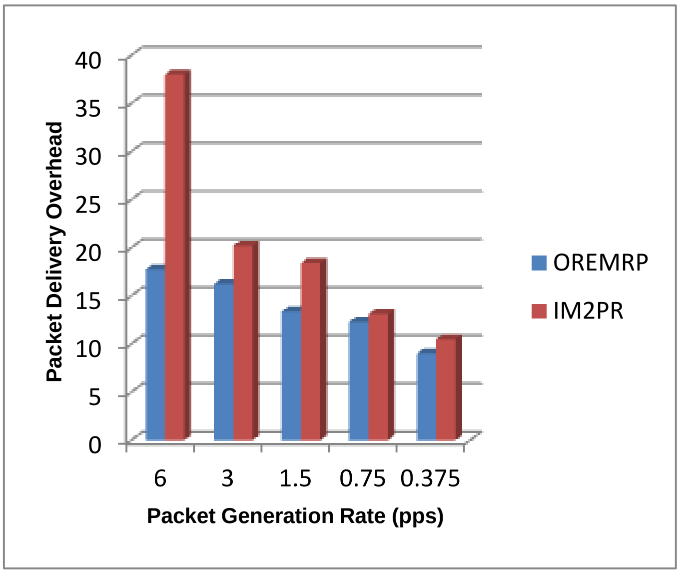

Figure 5: Packet Delivery Overhead achieved by OREMRP and IM2PR versus packet generation rate

V. CONCLUSION

This paper proposed Multipath routing protocol i.e. OREMRP based on optimum retransmission to improve the energy-efficiency of multipath protocols in a wireless sensor network. The total energy consumption of the network during communication depends on the energy consumed in the transmission of packets and the amount of energy required during retransmission of packets, in case of a collision.

As with increase in the number of the transmitted packets, the energy requirement as well as the collision rate of packets also increases which leads to frequent retransmissions. So, to increase the lifetime of the network, this multipath routing protocol is proposed.

The proposed multipath protocol uses alternative path routing where the primary path is computed first and an alternative path is taken as the backup in case the primary path fails. It follows the concept of optimum retransmission in which only dropped packets is retransmitted from the node where the packets have been dropped in order to improve the energy-efficiency and Quality of Service (QoS) of the network.

The Optimum retransmission based multipath protocol OREMRP is compared with IM2PR (Interference-Minimized Multipath Routing protocol) in terms of PRR, latency, energy consumption and packet delivery overhead. The achieved results reveal that it improves the energy efficiency with high packet transmission quality of packet delivery in the multipath WSN environment.

REFERENCES

[1] Laveena Mahajan, Avani Chopra, Robin Chadha," Performance analysis of Optimum-Retransmission based Multipath Routing Protocol in WSN using OMNET++

Simulator", International Journal of Latest Engineering and Management Research, 2018.

[2] Ricardo Godai Vierira and Adilson Marques da cunha, “A WSN Energy Management Architecture”, IEEE -978-0-7695-3984-3, 2010. pp. 1159-1164.

[3] Himanshu Sharma and Vibhav Kumar Sachan” Energy Efficiency of the IEEE 802.15.4 Standard in Wireless Sensor Networks: Modeling and Improvement Perspectives “, International Journal of Computer Applications (0975 – 8887) Volume 58– No.9, November 2012.

[4] Mohammad Masdari and Maryam Tanabi, “Multipath Routing protocols in Wireless Sensor Networks: A Survey and Analysis”, International Journal of Future Generation Communication and Networking Vol.6, No.6 (2013), pp.181-192.

[5] R. Marjan, D. Behnam, A. B. Kamalrulnizam and M. Lee, “Multipath Routing in Wireless Sensor Networks: Survey and Research Challenges”, IEEE (2012).

[6] M. T. Tarique, K. E. Adibi and S. Erfani, “Survey of Multipath Routing Protocols for Mobile Ad Hoc Networks”, J. Netw. Comput. 2009, pp. 1125-1143.

[7] Marjan Radi, Behnam Dezfouli, K. A. Bakar, S. A. Razak, Tan Hwee-Pink “IM2PR: Interference-Minimized Multipath Routing protocol for Wireless Sensor Networks”, Wireless Networks, October 2014, Volume 20, Issue 7, PP 1807-1823.

[8] Priya Gopi, “Energy-Aware Node Disjoint Multipath Routing Protocol for Wireless Sensor Networks”, International Journal of Computer Trends and Technology (IJCTT) – volume 13 number 3 – Jul 2014.

[9] Ye Ming Lu and Vincent W.S. Wong “An Energy-Efficient Multipath Routing Protocol for Wireless Sensor Networks”, International journal of communication systems, 2007, pp. 747-766.

[10] Marjan Radi, Behnam Dezfouli, S.A.Razak, K.A.Bakar, “LIEMRO: A Low Interference Energy-Efficient Multipath Routing Protocol for Improving QoS in Event-Based Wireless Sensor Networks”, 2010 Fourth International Conference on Sensor Technologies and Applications (SENSORCOMM).

[11] R. Banner and A. Orda, “Multipath Routing Algorithms for Congestion Minimization”, IEEE/ACM transactions on networking, (2007).

[12] A. Köpke, M. Swigulski, P.T. Klein Haneveld, H.S. Lichte, S. Valentin, ” Simulating Wireless and Mobile Networks in OMNET++ The MiXiM Vision”, IEEE, 2010.

[13] Haafizah Rameeza Shaukat, Fazirulhisyam Hashim, “MWSN Modeling Using OMNET++ Simulator”, 2014 Fifth International Conference on Intelligent Systems, Modelling and Simulation.

[14] Boulfekhar S, Benmohammed M, ’A Novel Energy Efficient and Lifetime Maximization Routing Protocol in Wireless Sensor Networks." Wireless Personal Communications 72(2):1333–1349, (2013).

[15] Huang X, Fang Y ,"Multiconstrained QoS Multipath Routing in Wireless Sensor Network" Wireless Networks 14(4):465–478, 2007.

[16] Arslan Musaddiq, Fazirulhisyam Hashim, “Multi-hop Wireless Network Modelling Using OMNET++ Simulator” IEEE 2015, International Conference on Computer, Communication and Control Technology, April 21-23 in Malaysia.

[17] Bashir Yahya and Jalel Ben-Othman, " REER: Robust and Energy Efficient Multipath Routing Protocol for Wireless Sensor Networks ", IEEE, 978-1-4244-4148-8/09, 2009.

[18] Ravi Kishore Kodali, Vijay Kumar Malothu, “MIXIM Framework Simulation of WSN with QoS”, 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT).

[19] Qiang Ni, Lamia Romdhani, Thierry Turletti, "A Survey of QoS Enhancements for IEEE 802.11 Wireless LAN", Journal of Wireless Communications and Mobile Computing, Vol 4(5), 2004, pp.547-566.

[20] J. Zhang, J. Chen, J. Fan, W. Xu, and Y. Sun, “OMNET++ based simulation for topology control in wireless sensor network: a case study,” in Wireless Communications and Mobile Computing Conference, 2008.

[21] K. Wessel, M. Swigulski, A. Kopke, and D. Willkomm, “Mixim: the physical layer an architecture overview,” in Proceedings of the 2nd International Conference on Simulation Tools and Techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2009, p. 78.

[22] A. Varga and R. Hornig, “An overview of the OMNET++ simulation environment,” in Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops. ICST, 2008, p. 60.