

Real-Time and Non-Real Time Packet Scheduling Schemes of Wireless Sensor Networks

Shawkat K. Guirguis¹, Mohamed A. Baky², Amany Morsey Ahmed³

Professor, Dept. of IT, Computer Science and Informatics, Institute of Graduate Studies and Research, Alexandria, Egypt¹
Lecturer, Dept. of Mathematics, Computer Science, Faculty of Science, Fayoum University, Fayoum, Egypt²
Demonstrator, Dept. of Mathematics, Computer Science, Faculty of Science, Fayoum University, Fayoum, Egypt³

Abstract: Typical wireless sensor networks (WSNs) comprise a lot of small, lightweight sensor nodes to cover an area to collect data. These sensor nodes are work on the power source Therefore the battery energy of sensor nodes has to be very carefully and cleverly utilized. Additionally, it is also very important to balance the energy consumption of the nodes so that the network stay connected and functional for a long time. Wireless communications have become very pervasive over the time period. WSNs have wide range of application such as traffic analysis, environmental monitoring, industrial process monitoring, and tactical simulations. In WSN, the data packets are transmitted from source node to destination through several intermediate nodes which forward data packets towards the next one hop neighbor. However, each node participates simultaneously in several data transmissions. Each technique of packet scheduling is used for improving the efficiency of the network based on certain performance metrics and scheduling factor and every technique having some limitations.

Keywords: Scheduling, Wireless Sensor Network, Deployment Strategy, Quality of service, Energy Consumption, FCFS, Real-Time, Non-Real Time Non-preemptive priority scheduling, preemptive priority scheduling.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of dense, small and low-cost wireless sensors and memory sensor nodes, which are of two types: sensor node, and sink node or base station (BS) [1]. A sensor node by itself has severe resource constraints, such as limited battery energy supply, transmission radius and sensing capability. However, when a set of sensor nodes co-operate with each other, they can efficiently perform a much bigger task.

The classification of the data packets scheduling should be based on set of factors: the data delivery deadline, data priority, data type, and the no. of queues. A sensor node may need to operate for long time depending on a small battery [2]. So, optimizing the energy efficiency is very important for all sensor operations, which include sensing, computation, and communication. The sensed data may be real time or non-real time. The real-time data sense by the node should have higher priority as compared to non-real time data packet. In order to minimize the consumed energy, dropping packets should not be only according to the deadline but also according to the packet energy consumption. So, the scheduling needs to consider the queuing delay and packet energy consumption, in order to achieve better network Quality of service (QoS) and improve the WSN lifetime [3]. This reduces the sensor node energy consumption. In FCFS scheduling scheme the data packets are processed in order of their arrival time and therefore the data packet which is entering at the last will require a long time to reach to a base station.

II. RELATED WORK

The classification of packet scheduling techniques is based on several factors such as: data delivery, packet type, packet priority and number of queues as shown in Figure 1[2] [4].

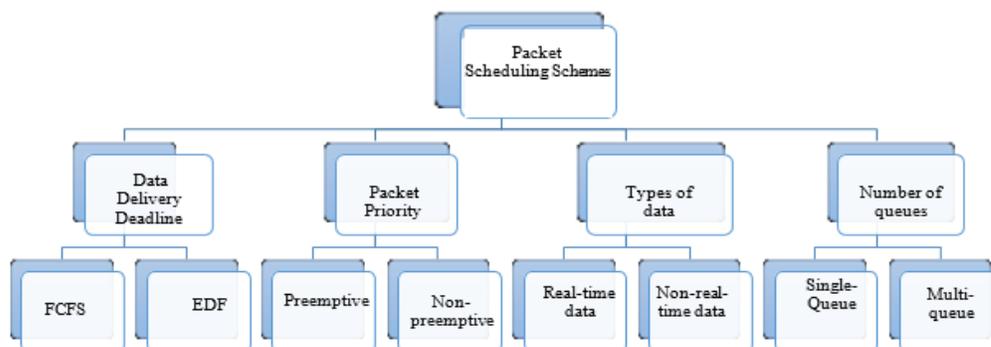


Figure 1: The classification of packet scheduling techniques

The packet scheduling techniques determines how the packets are forwarded at the intermediate nodes between a source and a destination. Before the packets are forwarded, each incoming packet is put into a queue. This insertion happens according to a certain scheduling algorithm, e.g. first in first out. The packet scheduling is also affected by the packet priority [4][5].

a) Data Delivery

Packet scheduling schemes can be classifier based on the deadline of arrival of data packets to the base station, which are as follows [6].

FCFS scheduling: First come first serve is a scheme that is based on the arrival time of the packet. If the packet comes first so it should be served firstly. For real time communication, this requires more time to reach to the destination. The First Come First Serve is the simplest method but it is time consuming scheme for packets that comes late [5]. The Execution of the FCFS policy is simply managed with a First In First Out (FIFO) queue. When the process is ready it enters the ready queue, its process control block is linked on the tail of the queue.

EDF scheduling: It schedules the data packet according to the deadlines of the data packets. Data packets those have short deadline assign highest priority and data packets which have long deadline assign minimum priority [7]. Server is mainly used to serve the real-time data packet which is scheduled by the scheduler to the destination. It decides whether to serve or drop a packet based on the packets remaining time till expiration.

b) Priority

Packet scheduling schemes can be classified based on the priority of data packets that are sensed at different sensor nodes.

Pre-emptive scheduling: The Pre-emptive scheduling technique is one in which the packets that are having higher priority that should be scheduled or processed first. During this preventative priority packet scheduling, higher priority packets area unit processed initial and so it'll preempt lower priority packets by saving the context of lower priority packets if they're already running [8].

Non-Pre-emptive scheduling: In non-pre-emptive priority packet scheduling, once a packet p1 starts execution, task p1 carries on although a better priority packet p2 than the presently running packet p1 arrives at the prepared queue. So p2 needs to wait within the prepared queue till the execution of p1 is complete.

c) Packet Type

Data packets generated at the sensor nodes are classified into two types namely real-time and non-real-time data packets. The schedulers at the sensor nodes identify the types of data packets and schedule them accordingly.

Real-time data packet scheduling: These type of data packets is of highest priority and need to be delivered very quickly, Real-time data packets are processed and delivered to the Base Station with a minimum possible end-to-end delay, otherwise if the delivery of these data packets take a longer time then the data will be of no use. So, in-time delivery of the Real-time data packets is very important [9].

Non-real-time data packet scheduling: Non-real-time data packets are of lower priority than real-time data packets. These packets are usually the data packets from the lower level nodes which have been sent to the Base Station through hand-shaking. The Real-time data generated at the sensor nodes locally is of least priority [10]. These data packets need not be processed quickly and also should not be kept to waiting forever in ready queue. So, these packets are scheduled using a FCFS/SJF algorithm among all the Non-real-time data packets are present in ready queue. The processing of these packets will be interrupted by arrival of real-time data packets.

d) Number of Queue

Packet scheduling schemes can also be classified based on the number of levels in the ready queue of a sensor node. These are as follows [11].

Single Queue: Each sensor node has a single ready queue. All types of data packets enter the ready queue and are scheduled based on different criteria: type, priority, size, etc. Single queue scheduling has a high starvation rate.

Multi-level Queue scheduling: Each node has two or more queues. Data packets are placed into the different queues according to their priorities and types. Thus, scheduling has two phases: (i) allocating tasks among different queues, (ii) scheduling packets in each queue. The number of queues at a node depends on the level of the node in the network.

III. PROPOSED ALGORITHM

This section presents the proposed simulation for comparative performance analysis of data delivery and packet priority scheduling schemes of wireless sensor network. Therefore, there is no need to modify all of the transactions in packet scheduling schemes. Methodology of the proposed simulation requires the following steps:

1) Network Initialization

In the network design, the number of nodes ‘n’ is deployed either sequential or randomly in the networks. The node which is in the centre of the network is chosen as the base station. And the communication range of the node is set to the area of $10 \times 10 \text{ m}^2$, where the nodes are divided into number of clusters with a cluster head ‘ch’.

All data packets at nodes should have limited lifetime, which are controlled by TTL (time-to-live) information carried in the packet header or message format. Each packet has time to live (TTL) which means basically the number of hops that a packet travels to reach destination nodes where a hop is one portion of the path between source and destination. In our proposed simulation, base station (sink node) take the initiative to find dead node in the Wireless Sensor Network. We assume that every node has a unique Node id, every node has a neighbour table which store of its 1-hop neighbour nodes id. Sink node send a Node_health_status_query(NHSQ) message to one of its neighbour node choose randomly from neighbour table. If the node to which the Node_health_status_query message is sent is alive it stores the message id and sender id in a query list table. Otherwise, the sender node waits for a certain time for reply (ACK) message (Acknowledgment message) if it does not receive a reply within that period it assumes that the selected neighbour is dead and it send that info to the sink by selecting next hop of the path to sink from query list table. Figure 3.1 show NHSQ message format and figure 3.2 ACK message format.

Message Id	Message Type	Destination	Message	SenderNodeId	TTL
------------	--------------	-------------	---------	--------------	-----

Figure 2: NHSQ message format

Message Id	Message Type	Destination	Message	SenderNodeId
------------	--------------	-------------	---------	--------------

Figure 3: ACK message format

2) Routing Protocol

In our proposed simulation, we use LEACH protocol for clustering. LEACH is hierarchical protocol which allows the nodes to transmit data to the cluster heads of the cluster to which they belong. The cluster heads aggregate the data received from the non-cluster head nodes & forward it to the Base Station (Sink). It is a cluster-based routing protocol whose main aim is to increase the lifetime of the wireless sensor network. It is a very good example of self-adaptive & self-organized protocol. Its overall operation is based on rounds & each round consists of two stages- set up stage & steady state stage [12]. The core idea of LEACH protocol lies in dividing the whole network into various clusters. In each cluster, a cluster head is selected in hierarchical manner & this role is rotated among the nodes in the cluster in order to homogeneously distribute the power load in every round. This protocol allows scalability & robustness in the network & also helps in compressing the size of information to be sent to the Base Station. The basic architecture is depicted in figure 2. The nodes are selected based on selecting a random number between 0 & 1. The node becomes a CH for the current round if the number is lesser than the following threshold [13]:

$$T(n) = \begin{cases} \frac{P}{1 - P * (r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{if } n \notin G \end{cases} \quad (1)$$

In equation (1), n is a random number between 0 and 1, P is the desired percentage of CHs, r is the current round and G is the set of nodes that have not been chosen as CHs in the last 1/P rounds. Cluster head rotation is performed to distribute the load among CHs.

3) Packet Scheduling

It is based on scheduling factor you need in certain Experiment such that you can choose the scheme based on deadline or priority then the packets generated at source node will be scheduled to being sent and delivered to destination based on chosen scheduling scheme.

4) Performance Evaluation

Performance Evaluation is providing positive results on low Packet delay (end-to-end delay), low energy consumption and high throughput during transmission. Comparison of results obtained from these packet scheduling schemes will provide performance evaluation. The calculations of packet delay, energy consumption, throughput and packet delivery ratio are made using following equations based on WSN performance evaluation benchmark in [14].

a) Average packet delay (APD)

Packet delay refers to average the time taken for a packet to be transmitted across a network from source to destination. Only the data packets that successfully delivered to destinations that counted. It is time metric expressed as total time needed for all packets delivery (*TpackD*) per number of successfully delivered packets (*packSD*), as shown in equation (2):

$$APD = \frac{\sum TpackD}{packSD} \quad (2)$$

b) Total energy consumption (ET)

It is defined as average of nodes energy consumptions in observed time interval (Network lifetime), as shown in equation (3):

$$ET = \frac{\sum_{i=1}^{Nnodes} Ei}{Nnodes} \quad (3)$$

Where *Nnodes* is total number of nodes in network and *Ei* is the energy consumption of node *i*

c) Average Throughput (v)

Average throughput is average number of total packets successfully received packR by destination per observed time interval t as shown in equation (4). It reduces as the time increases.

$$v = \frac{N(packR)}{t}, t = 1 \text{ sec.} \quad (4)$$

d) Packet Delivery Ratio (PDR)

It is defined as number of total packets successfully received (PackR) per number of total packets sent (PackS), as shown in equation (5):

$$PDR = \frac{PackR}{PackS} \quad (5)$$

IV. PSEUDO CODE

The proposed Performance analysis simulation of packet scheduling schemes of wireless sensor network that consists of following steps:

- 1) Input network area of wireless sensor network, number of wireless sensor nodes, type of deployment, number of sink nodes or clusters, packet scheduling factor and packet scheduling scheme based on previous factor.
- 2) Build the wireless sensor network.
- 3) Record the position of each node using its x-axis and y- axis in network area.
- 4) Determine the neighbors of each node.
- 5) Apply clustering using LEACH protocol to determine cluster head (CH) nodes.
- 6) Generate random number of messages using set of source nodes chosen by random selection.
- 7) Send messages to destination nodes randomly chosen.
- 8) Record the messages transactions for each node make sending or receiving process including details of message such as source (sender), destination (receiver), message id, message type, and number of messages sent and received by each node included in transaction.
- 9) Calculate performance metrics using equation 2, 3,4.

V. SIMULATION RESULTS

Simulation is the most deployed method to evaluate algorithms and protocols for WSNs. It enables the researcher to deal with complex topologies, network scalability, and repeating of experiments. Simulations are also carried out at low cost, for these reasons simulation gains a lot of popularity as evaluation method. In the simulation, J-sim was used as the network simulator. The schemes would be compared according to some network metrics.

The simulation is performed on Microsoft Windows 10 Professional 64 bit running on a machine has the following configurations: Intel® Core™ i7-2670QM CPU @ 2.20 GHz, 6 GB of RAM and programmed using Java programming language the WSN java library IDE (Net Beans IDE 8.0.2).

There are parameters play an important role in rule scheduling process are total number of nodes, and packet scheduling scheme. Therefore, if the values of these parameters are changed then the result will be changed. Moreover, we conducted several experiments on each set of parameters to show the influence of these parameters on the suggested simulation. In order to understand the effect of varying packet scheduling schemes, number of nodes and type of deployment on the various efficiency parameters, especially packet delivery ratio and throughput. The following assumptions are made to design and implement packet scheduling schemes. Some of them are mentioned in [9] [10]:

- Sensors are time synchronized.
- Each node has its unique Identifier (ID).
- Data packets (real-time and non-real-time) have variable size.
- The length of data queues is variable. For instance, the length of real-time data queue (pr1) is assumed to be smaller than that of that of non-real-time data queues (pr2 and pr3). However, the length of the non-real-time pr2 and pr3 queues are same.

The experiments were carried out to show the results of comparative analysis between data delivery and packet priority scheduling schemes in WSN.

Table 1 presents simulation environment parameters, and their various values.

Parameters	Values
Routing protocols	LEACH
MAC type	802.11
Buffer Size	50 Packet
Initial node energy (J)	100
Connection Type	CBR
Simulation area	100 x 100 m

In our Simulation, we have two types of deployment for wireless sensor nodes sequential deployment and random deployment. The sensor nodes are deployed on network area 100m x100m. The number of sensor nodes varies from 10 to 100. The number of clusters varies from 3 or 9 cluster. Nodes are distributed uniformly over the Clusters. The ready queue of each node can hold a maximum of 50 packet. Each packet has a Type ID that identifies its type. For instance, type 0 is considered to be a real-time task. Data packets are placed into the ready queue based on the processing time of the packet. Moreover, each packet has a hop count number that is assigned randomly, and the packet with the highest hop count number is placed into the highest-priority queue. Simulation results are presented for both real time data and all types of data traffic.

The comparison is made in terms of average packet delay (end-to-end delay), energy consumption, throughput all these parameters have been investigated against number of nodes. The packet scheduling schemes are evaluated for both sequential deployment and random deployment so the name of each packet scheduling scheme is followed by “-R” which stands for “Random” and “-S” which stands for “Sequential” to indicate the type of deployment in results and graphs.

The following figure shows the average packet delay of Real time and Non-Real packet scheduling scheme for both random and sequential deployment over different number of nodes.

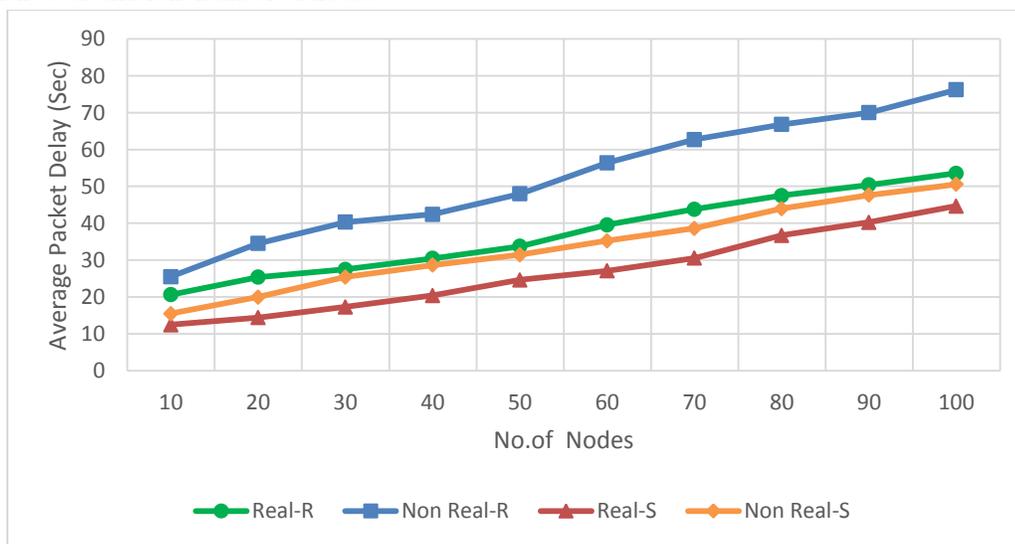


Figure 4 Average Packet delay of Real time and Non-Real Time Packets

From figure 4, we get that in Non-Real-R, Non-Real-S, Real-R and Real-S, the average packet delay increases with less difference smoothly with respect to number of nodes increase. Real-S perform higher as compare to Non-Real-R, Non-Real-S, Real-R such that the average packet delay of Non-Real-R, Real-R, Non-Real-S, Real-S measured by seconds are 52.291, 37.27, 33.722 and 26.868. In random deployment, average packet delay Real-R is higher than that of Non-Real-R by 15 %.

deployment, average packet delay Real-S is higher than that of Non-Real-S by 7 %. In EDF-S, the average packet delay increases when the number of node increases, but not at all network size as it is the same at network size 40 and 50.

The following figure shows the energy consumption of Real time and Non-Real packet scheduling scheme for both random and sequential deployment over different number of nodes.

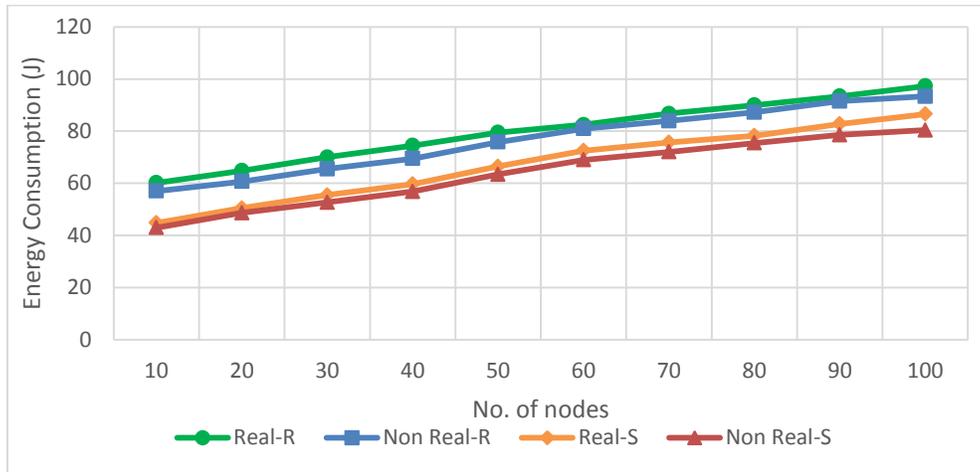


Figure 5 Energy Consumption of Real time and Non-Real Time Packets

From figure 5, we get that energy consumption of the network increase as the number of network nodes increases Such that the average energy consumption of Real-R, Non-Real-R, Real-S and Non-Real-S measured in joules are 153, 139, 118 and 115 respectively. In random deployment, the energy consumption of Real-R is lower than that of that of Non-Real-R by average 15 joules over different network size except at 60 nodes they are close to each other. In the energy consumption of sequential deployment, Real-S is lower than that of that of Non-Real-S by average 3 joules over different network size except at 10 and 20 nodes they are close to each other.

The following figure shows the throughput of Real time and Non-Real packet scheduling scheme for both random and sequential deployment over different number of nodes.

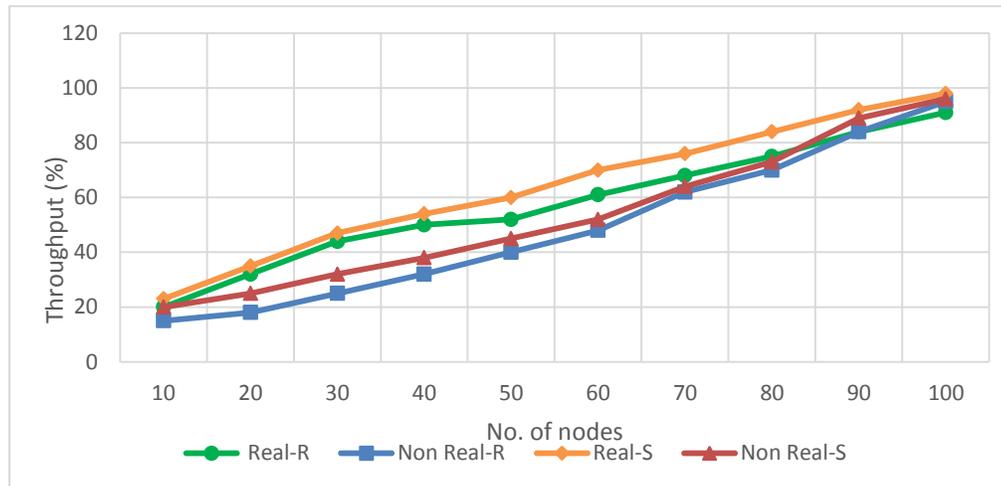


Figure 6 Throughput of Real time and Non-Real Time Packets

From figure 6, We get that throughput increases as the node density increases where the throughput of Real-R, Non-Real-R, Real-S and Non-Real-S increases by average 8.4 packet in total simulation time. In random deployment, the throughput of Real-R outperforms Non-Real-R such that average throughput of Real-R and Non-Real-R are 57.7 and 48.9 respectively. In sequential deployment, Real-S outperforms Non-Real-S such that average throughput of Non-Real-S and Real-S are 63.9 and 53.4 respectively

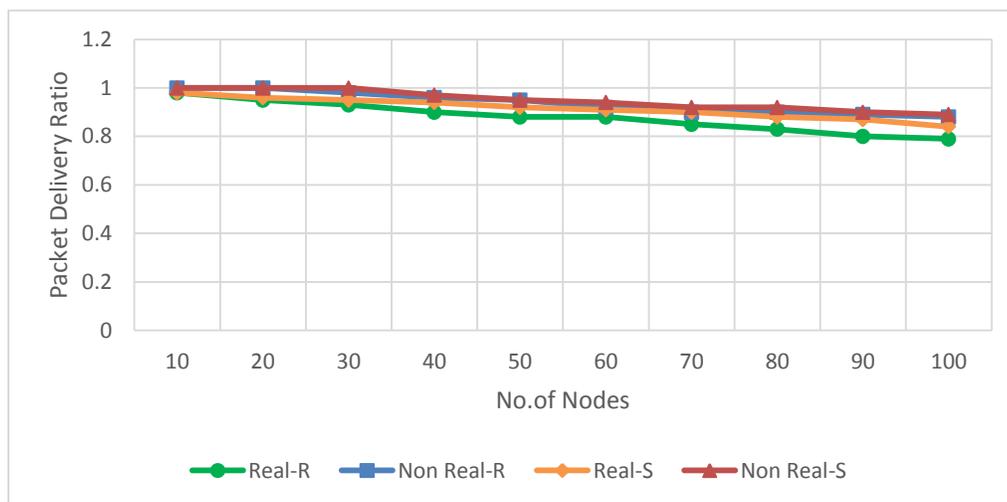


Figure 7 Packet Delivery Ratio of Real Time and Non-Real Time Packet

From figure 4.7, We get that packet delivery ratio (PDR) of packet type schemes Real-R, Non-Real-R, Real-S and Non-Real-S decreases smoothly with very small difference as number of nodes increases. As well as Real-R gives high PDR as compared to Non-Real-R, Real-S, Non-Real-S such that the average packet delivery ratio of Real-R, Non-Real-R, Real-S and Non-Real-S decreases by 2.1%, 1.3%, 1.5% and 1.2% respectively. In random deployment, the PDR of Real-R is higher than that of Non-Real-R by average 6%. In Sequential deployment, the PDR of Real-S is higher than that of Non-Real-S by average 3.4%.

VI. CONCLUSION AND FUTURE WORK

The simulation results showed that the proposed algorithm performs better with the total transmission energy metric than the maximum number of hops metric. The proposed algorithm provides energy efficient path for data transmission and maximizes the lifetime of entire network. As the performance of the proposed algorithm is analyzed between two metrics in future with some modifications in design considerations the performance of the proposed algorithm can be compared with other energy efficient algorithm. We have used very small network of 5 nodes, as number of nodes increases the complexity will increase. We can increase the number of nodes and analyze the performance.

REFERENCES

- [1] M. Bokare and A. Ralegaonkar, "Wireless Sensor Network: A Promising Approach For Distributed Sensing Tasks," Excel Journal Of Engineering Technology And Management Science, Vol. 1, No. 1, Pp. 1–9, Jan. 2012.
- [2] K. Kaur, P. Kaur, and E. S. Singh, "Wireless Sensor Network: Architecture, Design Issues And Applications," International Journal Of Scientific Engineering And Research (Ijser), Vol. 2, No. 11, Pp. 6–10, Nov. 2011.
- [3] M. Bisht and S. Chhetri, "A Survey On The Coverage Of Wsns," International Journal Of Advanced Research In Computer Science And Software Engineering, Vol. 3, No. 3, Pp. 295–300, Mar. 2013.
- [4] S. Ahmed and H. Nishat, "An Enhanced Dynamic Multilevel Priority Packet Scheduling Scheme For Wireless Sensor Networks," International Journal Of Science Technology & Engineering (Ijste), Vol. 1, No. 1, Pp. 469–477, May 2015.
- [5] C. Vijayakumaran and K. Janaky, "An Efficient Multilevel Priority Packet Scheduling For Wireless Sensor Network," International Journal Of Engineering And Computer Science, Vol. 3, No. 5, Pp. 5930–5936, May 2014.
- [6] N. Nasser, L. Karim, and T. Taleb, "Dynamic Multilevel Priority Packet Scheduling Scheme For Wireless Sensor Network," Ieee Transactions On Wireless Communications, Vol. 12, No. 4, Pp. 1448–1459, Apr. 2013.
- [7] S. S. Bansode and S. Sambare, "A Survey On Packet Scheduling Schemes In Wireless Sensor Networks (Wsns)," International Journal Of Innovations & Advancement In Computer Science (Ijiacs), Vol. 4, No. 1, Pp. 54–58, Jan. 2015.
- [8] D. Skariah and E. George, "Priority and Lifetime Based Packet Scheduling Scheme in Wireless Sensor Networks," International Journal of Engineering Research and General Science, Vol. 3, No. 4, Pp. 437–445, Aug. 2015.

- [9] S. Bandos and S. Honale, "Review on Enhanced Multi-Queue Packet Scheduler Scheme for Wireless Sensor Network," *Int J Adv Eng Nano Technol*, Vol. 2, No. 5, Pp. 22–24, Aug. 2015.
- [10] M. R and J. C. A.P, "An Efficient Collision Free Dynamic Multilevel Priority Packet Scheduling in Wsn," *International Journal of Innovative Research in Computer and Communication Engineering*, Vol. 3, No. 5, Pp. 1448–1459, 2013.
- [11] M. K. Indumathi and M. M. Santhi, "Efficient Dynamic Multilevel Priority Task Scheduling for Wireless Sensor Networks," *International Journal of Computer Science and Mobile Computing (Ijcsmc)*, Vol. 3, No. 1, Pp. 210–217, Jan. 2014.
- [12] M. Almeer And I. Kostanic, "An Evaluation Study of Leach Protocol Under Different Scenarios," *International Journal of Sensors and Sensor Networks*, Vol. 2, No. 1, Pp. 7–13, Apr. 2014.
- [13] C. Fu, Z. Jiang, W. E. I. Wei, And A. Wei, "An Energy Balanced Algorithm of Leach Protocol in Wsn," *International Journal of Computer Science (Ijcsi)*, Vol. 10, No. 1, Pp. 354–359, Jan. 2013.
- [14] N. Srivastava, "Challenges of Next-Generation Wireless Sensor Networks and Its Impact on Society," *Journal of Telecommunications*, Vol. 1, No. 1, Pp. 128–133, Feb. 2010.

Authors



Shawkat K. Guirguis was born in 25th February, 1958, Alexandria, Egypt. He obtained the B.Sc. and M.Sc. degrees in Computer Science & Automatic Control, Faculty of Engineering, Alexandria University, 1981 and 1984 respectively with Grade: "Distinction with the degree of honor". In 1988, he obtained a Ph.D. in Electronics & Communication, Cairo University, Co-Supervised by Imperial College of Science & Technology, University of London, U.K. Currently he is Professor of Computer Science and Informatics, department of Information Technology, Institute of Graduate Studies & Research (IGSR), Alexandria University, Egypt. His current research interests include network and information security, data mining and cloud computing.



Mohamed A. Abd El-Baky was born in 3rd February, 1969, Cairo, Egypt. He obtained the B.Sc. and M.Sc. degrees in Computer Science, Faculty of Science, Cairo University, 1992 and 1996 respectively. In 2001, he obtained a Ph.D. in Computer Science. Currently he is Lecturer of Computer Science, department of Mathematics, Faculty of Science, Fayoum University, Egypt. His current research interests include Parallel processing, Message-passing systems, Multiprocessors Scheduling, Multicast communication, Interconnection Network Routing.



Amany M. Ahmed was born in 2nd January, 1993, Alexandria. She obtained the B.SC degrees in Computer Science, Faculty of Science, Alexandria University with Grade: "Distinction with the degree of honor". Currently she is Teaching Assistant for Computer Science, department of Mathematics, Faculty of Science, Fayoum University, Egypt. Her current research interests include Wireless Sensor Networks, Internet of Things, Human Computer Interaction Data Mining and Big Data.