A New Reliable and Energy Efficient Opportunistic Routing Protocol for Wireless Sensor Networks

Ashish Ohri[1] Ashish Sharma[2]
[1,2]Department of Computer Science & Engineering
[1,2]Bells Institute of Management and Technology, Shimla (HP), India

Abstract— the major research problem in WSN is to save energy in different operations of the network and increase the lifetime. Most of the energy of a node is consumed during routing process. This is because the environment in which the WSN is used is unstable in nature most of the time like in habitat monitoring, defense applications and industrial applications etc. Hence, there is a need of energy efficient routing protocols. Researchers have proposed protocols and algorithms for routing process in WSN. Traditional routing protocols do not work well with WSN because it is a constrained network. The routing protocols for WSN are classified into four different categories, data centric, hierarchical, location based and opportunistic routing protocols. Opportunistic routing protocols are efficient and reliable in the data delivery process because it utilizes the broadcasting nature of WSN. In this paper we have proposed an energy efficient opportunistic routing protocol which is able to increase the reliability and lifetime of the network. The proposed protocol also increase system throughput and system delay, and energy efficiency. The proposed protocol can be applied to static sensor networks to produce high performance.

Key words: WSN, Routing, Communication, Opportunistic Routing, Energy Efficiency

I. INTRODUCTION

Wireless sensor network (WSN) constitute of homogenous, self-organized sensor nodes. The sensor nodes have limited capabilities [1] [3]. Each sensor node perform some network operations like sensing, routing and processing the data. The data will always be sent toward a high capability node called as base station (BS) or sink. The radio frequency channel has been used to transmit data from node to node in WSN. The resources in wireless sensor network are limited like limited storage, energy and short communication ranges. If all the sensors are operating in the network than the lifetime of the network will be very less. To improve the network lifetime energy must be saved in different operations like sensing, communication, aggregation and processing [1]. The energy efficiency of a network depends on the type of application. Some application require continuous data deliveries, some require event based data deliveries and some require time based data deliveries. Some application require critical data delivery like tracking targets in military application. In this type of applications the data must reach the base station immediately after the event occurrence. Hence, if traditional fixed path routing protocols are used and the path is broken than there will be problem of delays in data delivery due to route setup. Also most of the network's energy is consumed in communicating data packets, hence the routing protocols must be energy efficient [2].

Routing protocols for WSN must utilize the broadcasting nature of wireless nodes [3]. This will help in finding multiple paths toward destination. In critical applications multiple paths can help the data to reach destination without having high delays. This multipath routing can be done through opportunistic routing protocols.

In opportunistic routing, the intermediate nodes cooperate with each other on packet forwarding Opportunistic Routing in Wireless Sensor Networks in order to achieve high throughput in the face of lossy links [4]. Opportunistic routing tries to beat the disadvantage of a defective wireless link by taking advantage of the broadcast nature of the wireless sensor network such that one communication can be overheard by more than one node [3] [6]. The numbers of nodes serve as an intermediate node, but only one node will lastly forward the packet. This selection procedure is critical and based on opportunistic rules. Opportunistic routing in WSN can offer enhanced performance in terms of energy consumption and end to end delay.

Opportunistic routing takes benefit of the broadcast nature of the medium and change both the relay node selection and the number of the possible paths to the destination in order to improve the performance of the traditional best path routing [3]. Compared to traditional end-to end, multi-hop routing, the core idea in opportunistic routing is that at each hop, a set of next hop relay candidates receiving the packet successfully compete to act as an intermediate. Instead of choosing a single route ahead of time, the path is determined as the packet moves through the network, based on which sensor receives each transmission.

This paper proposed a new opportunistic routing protocol. The newly proposed protocol improves network lifetime and energy consumption performance we introduce opportunistic routing in the wireless sensor networks. Generally it can be compared to multi-hop communication, which means the nodes within the network can be able to communicate with the help of two or more nodes, which are acting as the relay nodes, between the source and destination node.

II. RELATED WORK

The research work carried out by various researchers will be discussed in this section. This section focuses energy efficient opportunistic routing protocols. Looking back into literature ExOR [4] was the first opportunistic routing protocol designed for wireless networks. ExOR works on the principle of utilizing the abilities of broadcasting of wireless radio. The basic condition of ExOR working is expected transmission count (ETX). ETX [4] metric always return the smallest number of transmissions needed for data transmission from source to destination. Another metric has been defined called as expected any path transmission (EAX) [5], which was more efficient than ETX for wireless networks. LCOR [11] was the protocol proposed on the basis of this metric. LCOR

was energy efficient but reliable in data delivery. Another protocol known as SOAR was defined which was based on ETX. This protocol focuses on the duplicate packet reduction in the network. Another protocol proposed recently was MDOR (Middle position dynamic energy opportunistic routing) [9] was proposed which has designed on the basis of distance between two nodes. This protocol focuses on reducing end-to-end delays and increase the network lifetime of the network. The protocol sort the neighbor list in a node according to distance and chose the middle position node as new forwarder. This process will be repeated until data packet reaches the base station. Another protocol proposed is based on the energy depletion factor (EDF) metric [8]. This metric calculates the impact of each transmission and reception on the forwarder node. If EDF of a node is below certain threshold value than this node will be chosen as the next hop forwarder.

All of these protocols have certain limitations of connectivity, energy efficiency and reliability in data transmission. In this paper a new energy efficient and reliable OR protocol has been presented. This protocol provide data reliability and good throughput in the presence of malicious nodes. The protocol will be briefly discussed in the upcoming section.

III. PROPOSED PROTOCOL

The primary issue considered in this paper is the energy efficiency and data delivery reliability. An OR metric has been designed in which the distance and energy of the forwarder node has been considered to choose the next hop forwarder. The energy efficiency component calculates the energy consumption inside the node for transmitting, receiving and processing data packet. The other component i.e. distance will make sure that the data packet make progress in the network. Using this component the optimal transmission distance node has been selected as next hop forwarder. The algorithm and its components will be explained in upcoming subsections.

A. Forwarder Selection Metric

A forwarder selection metric has been defined in this paper. This metric consist of two constituents: distance and residual energy of each node. The metric will be calculated at each node periodically for all the neighbor nodes. Distance will be used only for checking the packet progress towards destination. The distance between node n_i with coordinates (x_i, y_i) and node n_j (x_j, y_j) is as given in Eq. 1 below [9].

$$D_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (1)$$

The other component i.e. energy is also calculated periodically for each node in the neighbor list of a node. This component ensures that the energy consumption will be distributed to each and every node in the network equally. By this distribution of energy load the fixed path routing disadvantage of energy consumption on same set of nodes again and again will be reduced and always a different node will be selected as next-hop forwarder. This component will be calculated as below in Eq. 2. Total energy consumption will be equal to the sum of energy consumed during transmission, reception and sending acknowledgements.

$$E\_total = E_{recieving} + E_{transmitting} + E_{ack\_sending} \quad (2)$$

Receiving ($E_{receiving}$), transmitting $E_{Transmitting}$ and acknowledgement ($E_{ack\_sending}$) sending energies have been calculated as given in Eq. 3, 4 and 5 below. Total energy (E_{total}) is the amount of energy consumed during different routing operations in sensor node.

Forwarding Energy (forwarding n-bit packet) [8]:

$$E\_trans(n,d) = n*E\_antenna + n*E\_amplification*d\text{^}2 \quad (3)$$

Reception Energy (reception of n-bit packet) [8]:

$$E\_rcv\ (n) = n*E\_antenna \quad (4)$$

Here, E_antenna and E_amplification is dependent on the type of sensors the applications are using for WSN. In this paper the standard values for these energies have been considered for simulation given in simulation parameters table in next section. In the next subsection the proposed algorithm has been described in brief.

B. Forwarder Selection Algorithm

In wireless sensor networks the OR protocol takes the benefits of broadcasting wireless links to send data toward the base station. The OR protocol firstly has to form the neighbor list and decide which node will have the priority to send the data first. If multiple nodes will send the data toward base station then there will be number of duplicate packets at base station. The proposed algorithm reduce the number of duplicate packets at base station by selecting best next-hop nodes as forwarder. The proposed protocol has been compared to MDOR [9] and EEOR [10]. MDOR is based on the dynamic energy consumption in the network, which means that for each transmission and reception the energy consumption will be different. It selects the next-hop forwarder as the middle position node, which is having distance not very low or higher. But this will not be able to cope up with energy efficiency problem. EEOR [10] selects the next-hop on the basis of energy consumption. This OR protocol induces delays in the network. The proposed protocol tries to optimize these two algorithms and give best results.

```
Best_hop_selection(S, BS)
Input: source node S, target node BS.
Output: Successful transmission of data packet from node S to node BS
1. Define S as Source Node
2. Create neighbor list NB(S)
3. Sort NB according to distance
4. if (BS ℰ NB(S))
5. {
6. Send data packets to BS and quit algorithm
7. }
8. else
9. {
10. FL(S) is the subset of NB(S) (FL (S) is the forwarder list)
11. }
12. Select the middle distance node with higher energy (FD) from FL(S).
    (neither near to S nor near to BS having highest energy in all nodes belongs to FL(S)).
13. Start communication with FD
14. If (acknowledgement received)
15. {
16.    Best_hop_Selction(FD,BS)
17. else
18. {
19. Discard FD from FL (S).
20. }
21. Goto step 12
```

Fig. 1: Proposed Best Forwarder Selection Algorithm

For the middle position sensor nodes, the energy value has been calculated by using Eq. 2. The node for which energy value (E_total) is the highest, will be selected as the next hop forwarder. If the acknowledgement is not received within specified time than this forwarder node (FD) will be discarded from the forwarder node list (FL). Than another node with highest energy and middle distance will be selected

as next- hop forwarder. This will be repeated again and again for each node in the path until there will be destination (BS) on the neighbor list of any of forwarder nodes. For every new data transmission the forwarder selection values for energy and distance has been updated by recalculation. Figure 1 shows the proposed best hop selection OR algorithm.

IV. Results and Analysis

MATLAB is used to simulate the results of proposed OR protocol [12]. This section discusses the results obtained after simulating the scenario of wireless sensor network. The simulation results have been compared with the results of the MDOR [9] and EEOR [10] protocols. Table 1 shows the parameter setting of the network.

Simulation Parameter	Value
Area	500 x500 m
Number of Nodes	50, 100, 200
Initial Energy of Each node	0.5 Joule
Electronic Energy (E_{elec})	50 nJ (50*0.000000001 Joule)
Amplification Energy (E_{amp})	100 pJ (10*0.000000000001 Joule)
Packet Size	50 bits
Number of Simulation Rounds	300
Threshold Energy E_{th}	0.2 Joules

Table 1: Simulation Parameters

A. Deployment of Sensor nodes

The nodes are randomly deployed in 500 x 500 m field. The nodes are deployed in such a way that these can approximately cover the whole application area. The base station position is 250 x 250 m in the field. The field area has been considered physical world environment. The proposed OR protocol starts working immediately after the deployment process is complete. Figure 2 below represents the random deployment of the nodes in the area of consideration.

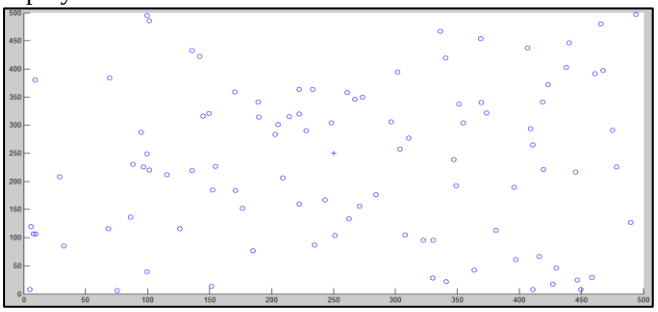

Fig. 2: Deployment of Sensor Nodes

1) Energy Efficiency

Energy efficiency is the main objective of the proposed algorithm. It can be calculated as the total energy consumption in the network for performing different network operations. In MATLAB the simulation works on the basis of simulation rounds. The energy efficiency has been calculated as the total energy consumption after each round in the network. After the operation of network starts the sensor's energy starts decaying. This energy reduction is due to network operations like setting up the network, transmission, reception and acknowledging the data packets, processing of data and sensing of data. As the nodes are decaying their energy the consumption of energy will go on increasing per round as we can see in figure 3 below. It can be seen in the figure that energy consumption for proposed OR protocol is less as compared to other two algorithms. This is because the proposed OR protocol distribute energy consumption equally to all nodes so that every node can survive up to their maximum lifetime. Hence, the proposed OR protocol is more energy efficient than MDOR [9] and EEOR [10].

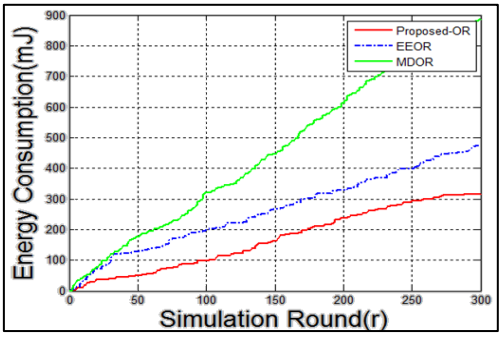

Fig. 3: Total energy consumption

2) Latency (End-to-end Delay)

Latency can be measured as the time elapsed between sending the packet and receiving the same at the base station. This is also called as end-to-end delay for the packets to be reached at destination.

The communication in wireless sensor networks is always from source nodes to base station. In random deployment of nodes some nodes are able to communicate directly with base station. While, some nodes follows multi-hop communication i.e. source nodes has to go through relay nodes to forward the data packet toward base station. Hence, in some cases the network delay can be very low and in the some cases it can be high. Hence in figure 4 values of end-to-end delay after each communication in each round has been plotted. It can be seen that the proposed OR protocol has a good latency as compared to other two protocols.

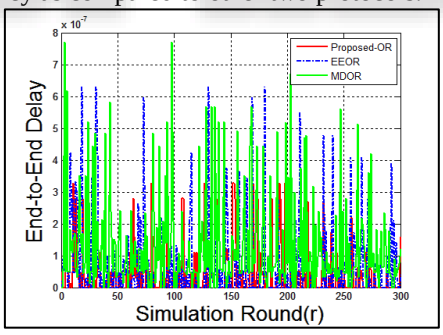

Fig. 4: End-to-end delay

3) Throughput

Throughput of a network can be measured in different ways. Throughput will be calculated as the average number of packets received successfully at base station per second in each round.

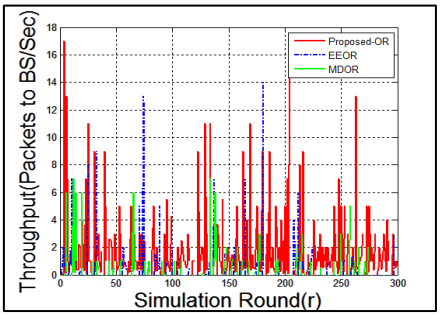

Fig. 5: Packet to BS per Second

Figure 5 represents the throughput for each round. The proposed OR protocol have good throughput as compared to the other two. Because, proposed OR protocol is efficient in energy consumption and that's why the sensor nodes are able to survive and communicate for a long time in the network. As long as the communication goes on the base station will continue to receive the packets.

4) Network Lifetime

Network lifetime for wireless sensor network is dependent upon the energy consumption in the network. When the energy of the network is 100 percent the network lifetime will also be 100 percent. But as the nodes starts operating in the network the network lifetime will be reduced. Figure 6 represents the percentage of lifetime remaining after each round of simulation. Proposed OR protocol has a good network lifetime because of the less energy consumption in the network.

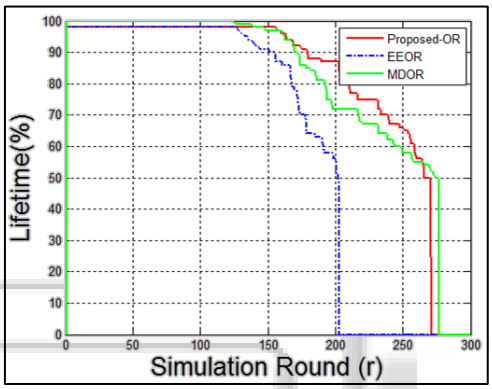

Fig. 6: Network Lifetime

V. Conclusion and Future Scope

Proposed protocol describe an energy-efficient multi-hop routing protocol using opportunistic forwarding via sensor nodes in the network for the purpose of maximization of the life time of wireless sensor network and for the minimize energy consumption of sensor network. It chooses forwarder nodes on the basis of distance and energy. The forwarder nodes selected on the way calculates the metric for each transmission periodically. Opportunistic routing exploits the broadcasting nature of wireless links and due to this the data packets will never got stuck in the path. This is because when the data packets are broadcasted multiple nodes will receive the data packet and there will be a chance for every node to transmit data toward the base station. This may increase duplicity of packets. To avoid duplicity of data packets in the proposed protocol the highest priority node will forward the packet. If the highest priority node fails to forward the packet than second highest priority node will forward the data and there is no need to retransmit data packet. This protocol can further be extended to include more parameters according to sensor network applications. Different applications have different sensitivity factors. Different network designs have different constraints with respect to varying challenges. There are different issues at design level of WSN, like node deployment, heterogeneity, localization and synchronization which needs to be explored further. There are various protocols already developed for WSNs need to be compared with respect to WSNs application classes.

References

[1] Akyildiz, I.F., and Kasimoglu, I.H.: 'Wireless sensor and actor networks: research challenges', Ad hoc networks, 2004, 2, (4), pp. 351-367.

[2] Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor networks. Ad hoc networks, 3(3), 325-349.

[3] Kumar, N., and Singh, Y.: 'Routing Protocols in Wireless Sensor Networks', in Niranjan, K.R., and Ashok Kumar, T. (Eds.): 'Handbook of Research on Advanced Wireless Sensor Network Applications, Protocols, and Architectures' (IGI Global, 2016), pp. 86-128

[4] Biswas, S., and Morris, R.: 'ExOR: opportunistic multi-hop routing for wireless networks', in Proceedings of 35th SIGCOMM Computer Communication Review (ACM, 2005), Philadelphia, Pennsylvania, USA, pp. 133-144

[5] Zhong, Z., Wang, J., Nelakuditi, S., and Lu, G.-H.: 'On selection of candidates for opportunistic anypath forwarding', ACM SIGMOBILE Mobile Computing and Communications Review, 2006, 10, (4), pp. 1-2

[6] Hsu, C.-J., Liu, H.-I., and Seah, W.K.G.: 'Opportunistic routing : A review and the challenges ahead', Computer Networks, 2011, 55, (15), pp. 3592-3603

[7] Rozner, E., Seshadri, J., Mehta, Y.A., and Qiu, L.: 'SOAR: Simple opportunistic adaptive routing protocol for wireless mesh networks', IEEE Transactions on Mobile Computing, 2009, 8, (12), pp. 1622-1635

[8] Kumar, N., and Singh, Y.: 'An Energy Efficient Opportunistic Routing Metric for Wireless Sensor Networks', Indian Journal of Science and Technology, 2016, 9, (32), pp. 1-7

[9] Sharma, M., & Singh, Y. Middle Position Dynamic Energy Opportunistic Routing for Wireless Sensor Networks. In Advances in Computing, Communications and Informatics (ICACCI), 2015 International Conference on (pp. 948-953). IEEE.

[10] X. Mao, S. Tang, X. Xu, X.-Y. Li, and H. Ma, "Energy-efficient opportunistic routing in wireless sensor networks," Parallel Distrib. Syst. IEEE Trans. On, vol. 22, no. 11, pp. 1934–1942, 2011.

[11] Dubois-Ferriare, H., Grossglauser, M., and Vetterli, M.: 'Valuable detours: Least-cost anypath routing', IEEE/ACM Transactions on Networking, 2011, 19, (2), pp. 333-346

[12] http://wislab.cz/our-work/wireless-sensor-network-simulation-tutorial-for-matlab.

