Experimental evaluation of a Routing Protocol for MWSNs: HRGC protocol under Study

Shahzana Memon[1], Irfana Memon [1], Rafia Naz Memon[2], Baby Marina[3], Pardeep Kumar[2] M. Sulleman Memon[1]
[1]Department of Computer Systems Engineering, QUEST, Nawabshah, Sindh, Pakistan
[2]Department of Software Engineering, QUEST, Nawabshah, Sindh, Pakistan
[3]Department of Information Technology, SBBUSBA, Nawabshah, Sindh, Pakistan

Abstract- Routing protocol in MWSNs is spinal column for data communication. To the best of our knowledge, very little work has been done in this area. Recently, *S. Kim et. Al proposes scheme named* HRGC scheme [1] for data communication in MWSNs. However, HRGC scheme has many limitations.

This paper gives experimental evaluation of HRGC scheme to highlight the limitations. The HRGC scheme is analyzed in terms of communication overhead, packet delivery ratio, packet loss ratio. The experimental results are achieved through different experiments carry out on MWSNs with varying size of network. The paper highlights the critical issues of HRGC scheme. To the best of our knowledge, it is the first study of HRGC scheme for analyzing the scheme with different parameter. Our research work will be good guidance for new researcher in this field.

Index Terms- WSNS, MWSNs, HRGC, Communication Overhead, Energy consumption, Packet loss, data delivery ratio

I. Introduction

Currently, there is vast growing in sensor network based real time applications with mobility. Hence, enhanced version of sensor network has appeared that is called Mobile Wireless Sensor Networks (MWSNs). In MWSNs, sensors are attached on the mobile objects such as animals, humans, etc [2-4]. MWSNs have different advantages over static sensor network including, supports mobility, reduced energy consumption. However, due to mobility, MWSNs have various issues such as connectivity, high packet loss, and low packet delivery ratio. An efficient routing scheme is required for MWSNs considering the above issues [5-6]. To the best of our knowledge, very little amount of research is done in this field. This paper will give the detailed information about existing work for MWSNs. Also, we highlight the limitation of very recent scheme through experimental analysis.

Section 2 discuss the state of art of MWSNs. Section 3 explains the work procedure of the recent work HRGC scheme. Section 4 shows the experimental results of HRGC scheme. Section 5 presents the discussion on the results. Section 6 concludes the paper and describes our future work.

II. Literature Review

S. R. G et. al propose Flow Based Routing Protocol [7]. In this work, author consider network with multiple base stations (BS). BS can move in the network field. In this way sensor node can send data to nearest BS. However, this scheme gives satisfactory results only in small network field and is not efficient for large network.

T. et. al proposed routing scheme for MWSNs [8]. In this scheme, the concept of redundant tree was used to save energy of some nodes. This tree is generated through the sink node. The sink node can move in the network field while all other source nodes will be stationary. However, the scheme is not efficient in dense network due to single mobile sink.

W.W. et. al proposed a scheme to analyse the routing scheme with stationary node and routing schemes with mobile nodes [9].

Q. H. et. al propose protocol, in which author used sleep scheduling method for save the energy of nodes. However, their work supports one mobile sink and all other stationary nodes [10].

A. Z. et. al proposed scheme assigns the task of spanning tree management to sink.

They assume that, sink node have more energy as compare to source nodes and forwarding nodes. They have divided the nodes into two categories.(i) The initiator node (the sink) works as root of the tree (ii) The non-initiator nodes works as the intermediate and leaf nodes of the tree. Sink node starts, process and terminates the execution of algorithm by processing five types of massages [11].

Abdulai et. al propose mDBEA scheme for MWSNs [12]. In this scheme authors consider the network with two types of nodes: sink node and source nodes. The sink node is stationary while source nodes can move in the network field. They use the concept of varying sensor transmission range for saving energy of nodes. However, this scheme increases channel contention and communication overhead.

Rishiwal V et. al propose ECMR scheme [13]. In this scheme authors consider the network with two types of nodes: sink node and source nodes. The sink node is stationary while source nodes can move in the network field. In this scheme, source nodes broadcast information till it arrives at the sink node. However this scheme results different issues: high communication overhead, high packet loss, high energy consumption.

S. Kim et. al propose HRGC scheme for MWSNs [14]. This scheme is explained in detailed with working procedure and experimental results in next section.

III. WORKING PROCEDURE OF HRGC SCHEME

Hierarchical Routing Graph Construction (HRGC) scheme [1] was designed to support mobile devices to solve route dis-connectivity issue cause by node mobility. HRGC scheme works in two phases.

A. Skeleton Graph Construction

The authors have considered Wireless HART standard to perform graph construction in network. This standard does not provide any specific routing scheme but it completes the requirements for static network construction by exploiting the join process. The authors have modified the join massage by exploiting 6-bit of Data Link Protocol Data Unit (DLPDU) specifier to distinguish between static and mobile nodes as shown in figure 1. When a node wishes to participate in Wireless HART network, it sends join massage by setting bit-6 as "0" for static node and bit-6 as "1" for mobile nodes. The network manager determines the mobility status of each device through modified join massage.

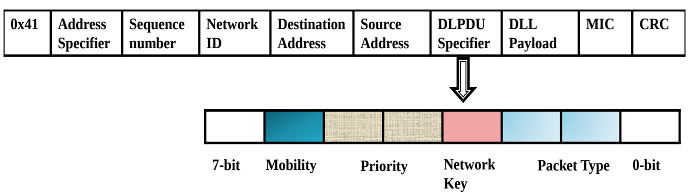

Figure 1. A modified data link protocol data unit (DLPDU)

The authors have constructed uplink graph and broadcast graph based on the set of static nodes only. Their connection could not be damaged from mobile node movement because they create connection between gateway and static nodes irrespective of the mobile nodes.

(i) Broadcast Graph Construction: To construct Broadcast graph, the Network Manager considered static nodes only and creates graph to satisfying (2,0) reliability. Firstly, it selects a node that must have at least two edges from gateway. If its candidates are more than two then, it selects node with lower average hop count h from gateway. After inserting all nodes with two edges in to broadcast graph, the Network Manager inserts node with one edge to the graph. Once all static nodes are connected to broadcast graph the network manager terminates the process.

(ii) Up-link Graph Construction: To construct the uplink graph with HRGC, the network manager firstly reverses the direction of edges in original network topology then it follows same steps of broadcast graph construction to the reversed edges and nodes. Once all nodes are inserted in uplink graph with reverse edges, network manager terminates its process.

Figure 2 shows original topology considered for graph construction through HRGC and Figure 3 shows skeleton uplink graph and skeleton broadcast graph construction those are created after applying HRGC on original topology. They assumed that Node D is mobile node and all other are static nodes. When Node D moves around node S5, any of the routes of static nodes are not affected due to node D movement because skeleton graph construction process works without considering mobile nodes.

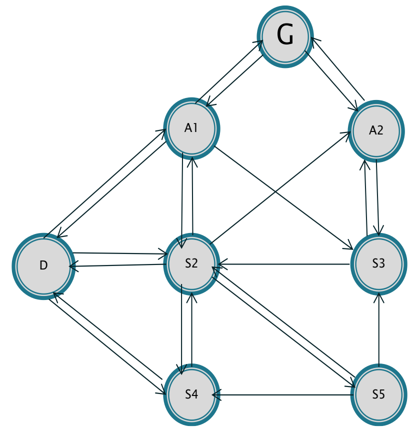

Figure 2. Original Network Topology

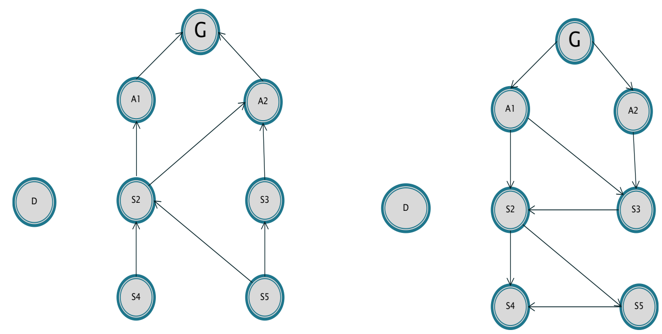

Figure 3. Uplink graph & Broadcast graph construction

B. Grafting mobile nodes in to skeleton Graph

To prevent the route disconnection issue, the authors have grafted mobile nodes into skeleton graph. Due to movement of mobile nodes communication routes of mobile nodes changes constantly so if each time they construct a new graph according to changes in network, mobile nodes will face packet omission issue during graph construction process. To resolve this issue, they have constructed a graph for each mobile node on all static nodes in advance by assuming that mobile node exists near all static nodes.

(i) Mobile nodes grafting in Skeleton Broadcast Graph: Initially network manager separates no: of static and mobile nodes and generates skeleton broadcast graph for all static nodes. For each mobile device NM creates connection between each mobile node and all static nodes. Once all mobile nodes are connected, Broadcast graph with mobile nodes is returned and the process is terminated. Mobile node is now able to receive broadcast massages from gateway at any location.

(ii) Mobile nodes grafting in Skeleton uplink graph: The process of grafting mobile nodes in skeleton uplink graph is similar as mobile node grafting in skeleton broadcast graph but the edges will be reversed in upward direction.

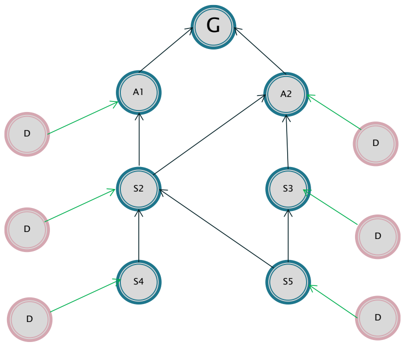

Figure 4 (a) . Grafting mobile nodes in Uplink Graph Construction

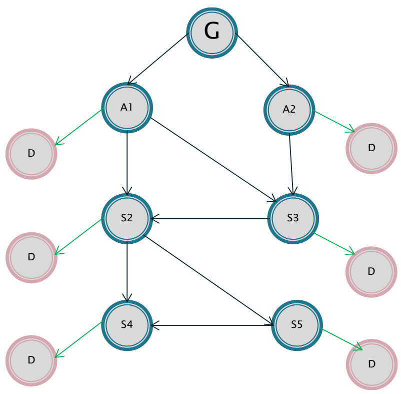

Figure 4 (b) . Grafting mobile nodes in Broadcast Graph Construction

Figure 4 (a & b) shows the example of mobile node grafting in skeleton broadcast graph and skeleton uplink graph. Based on the assumption that mobile node D is near all static nodes and is connected with them, it can send and receive packet at any location to and from gateway. For example, mobile node D is near static node s4, it can receive packet from gateway through path G→A1→S2 →S4→D. Similarly, if mobile node D is near static node S4 it can sent packet to the gateway through route S4→S2→ A1→G.

IV. EXPERIMENTAL EVALUATION OF HRGC SCHEME

A. Network Structure

The performance of HRGC scheme is evaluated in this section. We have implemented HRGC scheme with random and lattice deployment in OMNET++ network simulator. We have compared the results of HRGC scheme by varying its network deployment as random and in lattice structure. Table 1 shows the network settings for experimental evaluation of HRGC.

Table 1. Experimental Parameters

Parameters	Values
Simulation Area	500m* 500m
No. of nodes	100 (80 Static, 20 Mobile)
Node Distribution	Random, Lattice
Packet sending interval	4 sec
Packet header size	32 bit
Data Packet size	2 bytes
Control Packet size	24 bit
Mobility Model	Random Way Point Mobility model
Mobile Node Speed	1 m/s
Transmission range of each node	150m
Simulation time	1,2…5 hrs

B. Performance metrics

In this section, we define performance metrics, which will be used to analyze the HRGC scheme.

i. **Communication Overhead:** It is defined as total no. of control packets and data packets transmitted over the network.

ii. **Packet Delivery Ratio:** It is the ratio between the received packets by the destination and the generated packets by the source.

iii. **Packet loss:** Packet loss is the failure of one or more transmitted packets to arrive at their destination.

iv. Packet loss minimizes the Packet Delivery Ratio

v. **Average Residual Energy (ARE):** It is the average of remaining energy of all the nodes when packet transmission is completed.

V. EXPERIMENTAL RESULTS AND DISCUSSION

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. We have compared the results by varying mobile node speed and simulation time as mentioned in the Table 1 to measure the efficiency of HRGC scheme by deploying network randomly and in lattice structure. The results are measured in terms of communication overhead, packet delivery ratio, packet loss ratio and average residual energy.

A. Communication Overhead

Figure 5 shows the communication overhead with random and lattice deployment by varying simulation time from 1 to 5 hrs. HRGC generates high communication overhead with random network deployment as compare to lattice structure because in random structure network creates huge connections in between nodes to make them connected after the execution of phase 1 and phase 2 in HRGC. According to its working process mobile nodes receive packets from all the available connections/routes in network that is causing huge communication overhead whereas, in lattice structure nodes are placed on defined locations, network creates less number of connections between nodes that causes less amount of packet transfer within network. In both network designs communication overhead rises as simulation time increases.

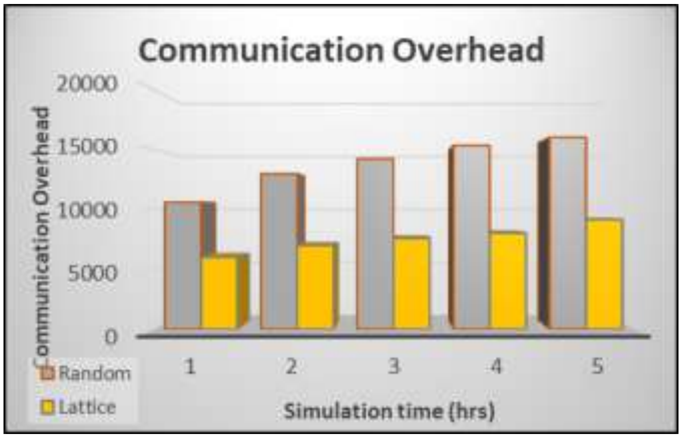

Figure 5. Grafting mobile nodes in Broadcast Graph Construction

B. Packet delivery ratio

Figure 6 shows the Packet delivery ratio with random and lattice deployment by varying simulation time from 1 to 5 hrs. In case of lattice network structure HRGC generates good packet delivery ratio as it generates less communication overhead during skeleton network construction and mobile node grafting. With random network structure HRGC do not generate good Packet delivery ratio due to the huge communication overhead in network. According to working mechanism of HRGC it creates the routes for mobile nodes on all static nodes in advance that is not an effective way in case of mobility because mobile nodes do not stay at one location, they keep moving after some interval. The network remains in grafting process all the time and nodes are keep sending control packets to keep network connected that causes packet interference and route disconnections due to mobility.

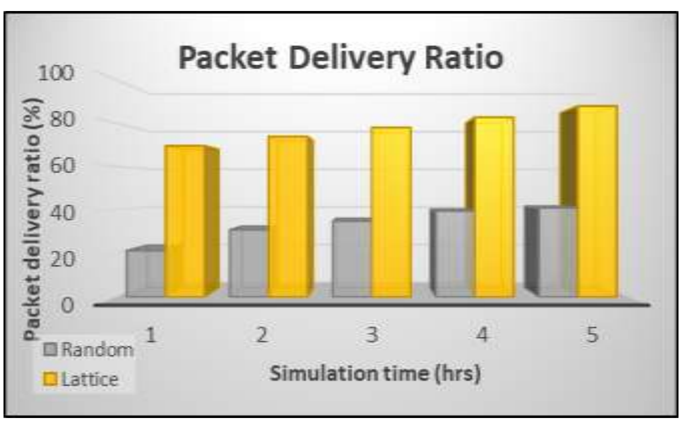

Figure 6. Packet Delivery Ratio

C. Packet loss ratio

Figure 7 shows Packet loss ratio with random and lattice network deployment by varying simulation time from 1 to 5 hrs. In case of lattice structure HRGC has less packet loss ratio and in random network structure HRGC has high packet loss in network during data transfer. Packet loss occurs due to multiple reasons such as, Huge amount of data transfer through all routes within network causes packet interference that degrades packet delivery ratio and it rises packet loss in network.

In HRGC nodes are consistently in grafting process that causes energy exhaustion of nodes. If any node dies due to high energy consumption or accidental damage it causes huge route disconnections in network and HRGC have not defined any route reconstruction scheme in case of route breakages.

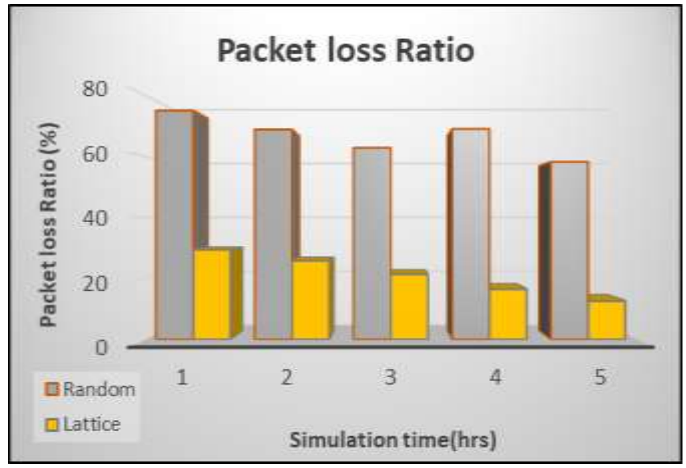

Figure 7. Packet loss ratio

D. Average Residual Energy

Figure 8 shows Average Residual Energy of network with 1 m/s mobile nodes speed for running simulation for 5 hours. With random network deployment HRGC scheme consumes huge energy because of high amount of packet transfer within network during skeleton network construction and mobile node grafting. Whereas, with lattice network deployment energy consumption is less because of low communication overhead.

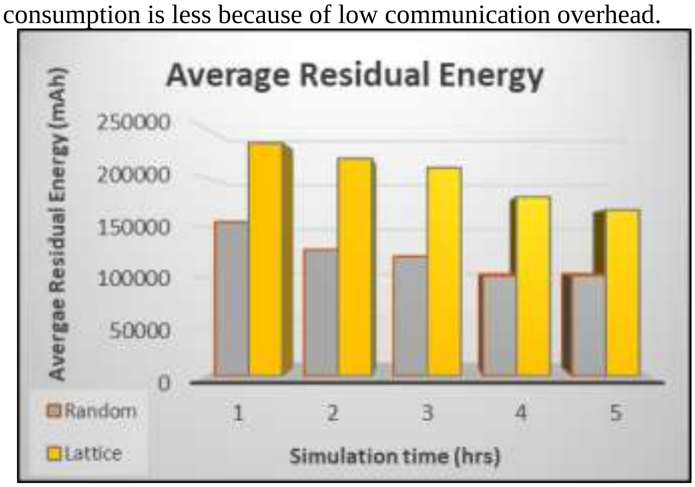

Figure 8. Average Residual Energy

VI. CONCLUSIONS AND FUTURE WORK

A. Conclusions

In MWSNs, routing schemes are the backbone for data communication. However, most of the existing real time applications are purely mobile applications where route disconnections is the main challenge that effects packet transmission within network. In this paper, we have analyzed Hierarchical Routing Graph Construction (HRGC) scheme [1] with experimental evaluation of in terms of communication overhead, packet delivery ratio, packet loss ratio and average Residual energy of nodes by deploying network as random and in lattice structure. Most of the real time MWSNs applications cannot be deployed with lattice structure. So, routing protocol must support the random deployment of network. Therefore, in this research work, we analyze the existing HRGC scheme with lattice and random deployment. The simulation results show that performance of HRGC scheme decreases with random network deployment due to high communication overhead. HRGC have some major limitations that effects the performance of HRGC with random network structure specially as compare to lattice network structure.

- HRGC faces high communication overhead issue because mobile nodes send control packets at every 4 sec through all available routes to and from gateway that causes high communication overhead in network that affects the packet delivery ratio, increases packet loss ratio and raises energy consumption within network.
- As in the working process of HRGC, they construct the graph for mobile nodes on all static nodes in advance. It is impossible to define routes for mobile nodes in advance because node can take move any time at any location randomly so, network will be in grafting process all the time that causes high energy consumption within network.
- The authors have not considered route or node failure issue after skeleton network construction as well as mobile node grafting in network. If any node dies due to energy exhaustion after skeleton graph construction or mobile node grafting, there is no any route reconstruction scheme defined in HRGC.

B. Future work

Our ongoing work is proposing an improved routing scheme for MWSNs that overcomes the limitation HRGC scheme. We also propose route reconstruction scheme to maintain the connectivity. We will compare our proposed scheme with HRGC scheme for with both random and lattice network.

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Correspondence Author – Dr. Irfana Memon
Department of Computer Systems Engineering, QUEST, Nawabshah,Sindh,Pakistan