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Enhanced VGDRA for Dynamic WSN

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Abstract— Sensor Nodes are fundamental blocks of Wireless Sensor Networks. The focus of researchers is still on reducing the energy dissipation by the sensor nodes over time. Sensor nodes once deployed have a fixed amount of energy available to them. In order to use the energy efficiently the sensor nodes are grouped together based on the tasks performed by them. These groups of sensor nodes are known as clusters. Each cluster is headed by a cluster head connecting the cluster with the base station. Energy consumption is directly proportional to the distance from the base station. The concept of network lifetime is closely related to the energy consumption and area coverage in wireless sensor network. The main aim of the proposed technique is to select cluster heads in such a way that they extend the network lifetime and increase throughput of the network. The efficiency of the proposed cluster head selection technique is that it covers energy consumption and routes selection for data delivery from sensor node to the base station. In this paper an Enhanced Virtual Grid-based Dynamic Routes Adjustment Scheme is proposed presenting a set of rules for the selection of cluster heads in such a way that the energy consumption by the cluster heads is balanced throughout the network and it does not get over exploited.

Keywords*-component; Energy consumption, Cluster Head, Mobile Base Station, Sensor nodes, Wireless sensor networks*

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I. INTRODUCTION

The recent advances in the field of Wireless Sensor Networks (WSN) has brought the focus on its possible future applications. WSN is a network with a number of sensor networks (SN's) deployed over an area [1]. WSN consists of SN's, radio modules and batteries as integral components of its architecture. Prima facie, WSN has a large area of application from day to day scenario to dangerous and unattended environments. WSN nodes need battery power in order to facilitate the functions of data sensing, processing and communicating it to the base station i.e. sink for further operations. In WSN's with a static base station, nodes have many to one connection and send sensed data to a fixed point leading to an energy hole in the network. This phenomenon lead to the rise of mobile base stations [2]. The mobility of base station slows down the energy dissipation in the SN and maintains connection with the remote and hostile regions inside the WSN [3]. Moreover, situations like a natural hazard requires the base station i.e. rescuer equipped with life saving kit to be mobile [4] so that survivors get help irrespective of their location. In war situation, where getting information regarding enemy intrusion is crucial, having mobility of base station is very useful.

Balancing the energy dissipation of SN with the help of mobile base stations stabilizes the energy-hole problem; though brings in other challenges that needs to get tackled. With the introduction of mobile base station the WSN becomes dynamic unlike the traditional static networks [5]. Awareness regarding the current location of mobile sink by SN is necessary to get an efficient data delivery in dynamic environment. In recent time various researchers have worked hard to find solution of energy hole problem by introducing the concept of mobile base stations. But every solution provided in the literature have their own drawbacks.

Directed Diffusion protocol [6] broadcasts the coordinates of base station periodically to the entire network. The rapid broadcast brings in more collision resulting to an increased number of retransmission of data. The flooding of location updates periodically leads to an increased overhead on the limited energy of the SN. Avoiding the frequent location updates is achieved by enabling the SN to maintain a working route to the base station without using excess energy in communication by inducing a virtual backbone structure to overlay the network [7]. In WSN's comprising of a virtual infrastructure only few selected nodes are responsible for maintaining the track of current mobile sink location in the network. The selected nodes collect the data periodically from all the SN inside its coverage area and later transmits the sensed data to the base station. In Virtual Grid based Dynamic Routes Adjustment [8] the network is divided in a grid structure. Each cell has a cluster head(CH) responsible for collecting data from the SN and keeping mobile base station location update. Routes to the base station are adjusted periodically improving the energy dissipation and data delivery in the WSN using a single mobile sink.

In this paper an Enhanced Virtual Grid-based Dynamic Routes Adjustment (EVGDRA) Scheme for mobile base station based dynamic network is proposed. EVGDRA aims to improve the network performance by avoiding the over exploitation of nodes heading the clusters. The proposed method takes the advantage of reduction in the energy used by SN in data transmission from source to CH and eventually to the base station. Inside each cluster, a node does not becomes leader for the second time until all the other SN head the cluster once. The rotation of CH inside the clusters reduces the chance of over exhaustion of few nodes getting elected frequently leading to an extended life of the network. CH is responsible for collecting sensed data from each SN inside the cell and transferring it to the mobile base station.

The rest of this paper is organized in the following manner: Section 2 gives an overview of the background study done on the different cluster head selection methods in WSN's. Section 3 presents a novel scheme EVGDRA for the selection of CH in mobile base station base dynamic WSN's. Section 4 gives an elaborate explanation of the simulation and results of the proposed EVGDRA scheme. Section 5 summarizes and concludes the paper.

II. BACKGROUND STUDY

In past few decades many data collection and dissemination schemes have been introduced for dynamic environment in WSN. Depending upon the pattern of changing coordinates of the mobile base station the schemes are said to have controlled and uncontrolled mobility of the base station. Schemes with controlled movement of base station [9-12] change its location depending upon some external controller or according to the dynamic environment of the network. In schemes with uncontrolled mobility of base station the magnitude of parameters regarding the sink movement is decided independently. A literature review of related work is discussed regarding the techniques used and the relative pros and cons.

Khan et al. [8] proposed a scheme Virtual Grid based Dynamic Routes Adjustment (VGDRA) Scheme for Mobile Sink based WSN. The SN nearest to the midpoint of the cell within a certain threshold distance is selected as the CH. The current header elects the next after its energy goes below a certain preset value. The selection of CH from within a certain threshold distance leads to an energy-hole problem near the centre of the cell reducing the network life.

Virtual Circle Combined Straight Routing scheme (VCCSR) [12] constructs a virtual infrastructure including lines and circles. Selection of CH is done at rendezvous points. A rendezvous point in the virtual network is at the intersection of virtual circle and straight lines. The CH in VCCSR works in accordance with a set of communication rules to transmit data to the mobile base station. The mobile base station rotates around the virtual structure and collects data from the border CH. In VCCSR header at the centre of the virtual structure loses its energy very soon creating an energy hole.

Erman et al. [13] proposed Hexagonal cell-based Data Dissemination (HexDD) scheme which creates a virtual hexagonal structure containing numerous mobile base stations inside the network. The SN send their data to the border line nodes. Data is eventually transferred to the central cell. The base stations collect the data from the central cell. The HexDD leads to a higher energy dissipation at border SN and at the centre cell.

Backbone-based Virtual Infrastructure [14] tries to reduce the number of CH to as low as possible in order to minimize the energy consumption in propagating location updates of base station. The scheme uses HEED [15] for selecting the CH and elects the header depending upon the energy available to the SN. One of the headers is elected as root of tree and each time a base station enters the cluster it connects with the nearest leader. Whenever the base station changes its cluster the location update is sent to the root of the tree. The problem with this method is that root node being the central of the network loses its energy much earlier.

Two-Tier Data Dissemination scheme proposed by Luo et al. [16] creates a virtual infrastructure for each base station covering the whole network. The base station selects a dissemination node locally within a fixed area each time it has a query. The dissemination nodes are selected till the query reaches the source and a reverse path is also established along with it. The process reduces the energy consumption in location update at the cost of network life.

Chen et al. [17] proposed a Geographical Cellular-like architecture that constructs a hexagonal cell based backbone infrastructure. Initially a Control Node from outside the network selects few base points. Base points become the initial CH and construct the architecture through control packets. The CHs calculate the standard coordinate of neighbor headers and the nearest point to each of them. The nearest point to each neighbor header is informed to become header and act as the base station located at the standard coordinate. Later the new headers return acknowledgement packets received from different headers. The need of frequent selection and communication leads to an increased level of energy consumption and reduced network life.

A priority based CH selecting technique proposed by Wu et al. [18] selects headers based on the priority attached to them. The priority could be static like node id or position as well as dynamic like residual energy or node degree. The scheme aims for load balancing by transferring load optimally from overloaded clusters to under loaded clusters.

Heinzelman et al. [19] proposed Low Energy Adaptive Clustering Hierarchy (LEACH) protocol that lets SN elect themselves to be the cluster head for the next round. The election of cluster head is done at two levels. Each node decides its cluster head for itself. The local cluster heads collect data and send it to the cluster head at the higher levels. The cluster heads at the higher level send the monitored data to the base station.

Power Efficient Gathering in Sensor Information Systems (Pegasis) proposed by Lindsey et al. [20] presents a technique of data dissipation where each node transmits and receives information from its neighbor SN. Each sensor node takes turn to be the header for transmitting data to the base station. SN together create a chain like structure to reach the base station. Each SN aggregates the data received from the previous SN consuming a higher amount of energy.

After the critical review of literature it is observed that electing the header in cluster based networks is crucial. The CH election largely impacts the network life, throughput, energy dissipation, data routing and many other aspects of the network. The proposed work focuses on improving the CH selection technique in the existing system of VGDRA with the objective of increasing the life and throughput of the network and reduce the energy consumption in the data collection and dissemination. The proposed EVGDRA leads the existing scheme to work more efficiently in the dynamic evironment of WSN in civil and military areas like vicinity monitoring, security etc. [21].

III. METHODOLOGY

VGDRA divides the network in a grid like structure. Each cell in the grid is considered a cluster with randomly deployed nodes. CH selection is done based on threshold distance from midpoint of the cell and a threshold residual energy level. The CH nodes are connected with each other forming a virtual backbone structure. SN inside each cell transmit data to its header. CH communicate with adjacent leader to reach the mobile base station. Base station updates its location to the nearest CH from where it gets propagated in the network.

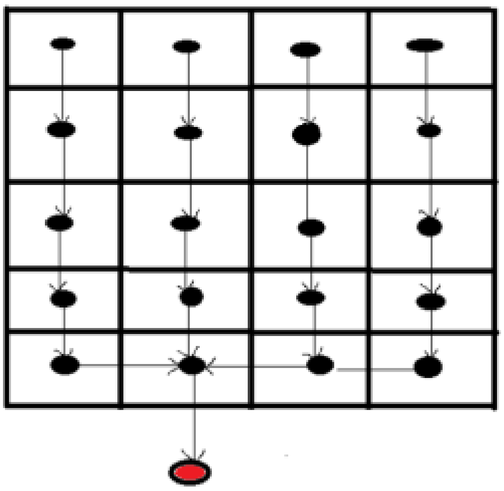


Figure 1. Virtual Backbone Structure

The CH are appointed within a minimum threshold distance from the midpoint initially. With the degradation in energy level of the CH, a new header is selected from inside the threshold distance as soon its energy reaches a threshold level. This leads to an early energy depletion in the SN within the threshold distance in each cell consequently reducing the network life. An energy hole gets induced in the network with time degrading performance of the scheme.

The proposed work suggests a technique namely EVGDRA for electing CH with the focus on extending the life and throughput of the network by reducing the energy consumption compared to VGDRA scheme. The network is considered as dynamic with the presence of mobile base station. Nodes are deployed randomly inside the network environment and are kept static. CH selection is performed based on the normalized distance from the midpoint and the residual energy of the nodes. Normalized distance of a SN is calculated by dividing difference of distance of the node from midpoint and the SN closest to the centre of the cell with the difference of distance of the farthest and closest node from midpoint. Normalized distance is summed with the energy of respective nodes and then sorted for each cell, CH for the cell is selected from the top of the list and is rotated throughout for each session of data delivery. The SN elected as the header waits for all the other nodes inside the cell to become CH once to get its turn to lead again.

Terminology used: energy is remaining energy of each SN, SN's are elected as CH only when its G==0, Dnode of a SN is sum of its normalized distance from midpoint of cell and residual energy.

The pseudocode for EVGDRA scheme is present as below:

```
1. START
2. Deploy SN's randomly in WSN
3. FOR (all SN's inside each cell)
        {
         G=0
         energy=1
        }
4. END FOR
5. Calculate Midpoint of each cell
6.  FOR (All SN's inside each cell)
7.      Determine and normalize distance from midpoint of the respective cell
8. END FOR
9. FOR (Each SN)
10.    IF energy(SN)=0
11.         Go to step 27
12. else
13.   FOR (Each SN)
14.         Dnode(SN) = normalized distance(SN) + energy(SN)
15.   END FOR
16. FOR (each cell)
17.        Sort Dnode in ascending order
18. END FOR
19. SN at the top of Dnode is checked
20. IF G(SN) ==0
21.        SN is elected as CH
22.        G(CH)=(number of nodes in cell) - 1;
23. else
24.        next SN in Dnode is checked
25. END IF
26. END IF
27. END FOR
28. STOP
```

The most important attribute of the proposed EVGDRA scheme is rotation of the role of CH among the SN's inside each cell. A SN elected as the CH for any single round of data transmission to the mobile base station has to wait for its next chance to head the cluster. It gets elected as CH again only after all the other SN's inside the cell have been elected as CH once maintaining the balance of the energy consumption in heading the cell.

IV. SIMULATION AND RESULTS

This section of the paper includes performance analysis of the proposed scheme using MATLAB as the platform. Table 1 shows the different scenarios created for establishing the proposed EVGDRA scheme. A mobile base station moves inside the network randomly. Initial energy of all the SN is taken as 1 Joule. Energy consumption in transmission (Tx) and receiving (Rx) the data is calculated using equation 1 and 2 respectively.

Table 1 Network Parameters

Area	No. of Nodes
100	100, 150,200
200	100, 150,200
300	100, 150,200

$$Tx=(Eelect\times K)+(Eamp\times K\times d^2) \quad (1)$$

$$Rx=(Eelect\times K)+(Eag\times K) \quad (2)$$

where K is the packet size

Eelect is energy consumed in running radio module

Eamp is energy required for noise purging in channel

Eag is power required for data aggregation

The values of different parameters used in the simulation are listed in table 2.

ISSN: 2321-8169
399 – 406

Table 2 Values used in calculation of energy consumption

Parameters	Values
Eelect	50 nJ
Eag	10 pJ/bit/m^2
Eamp	10 nJ/bit/m^2
K	6400

To establish the effectiveness of EVGDRA a comprehensive comparison has been made with existing VGDRA and pegasis protocol in terms of average residual energy in each SN after transmitting data to the base station i.e. after each round, total energy used by the network in every round, network life until the first node dies and the throughput of the network.

A. The average residual energy of each node after transmitting data once-

The average residual energy of each node after a round is the energy remaining with each node after they have sent data from SN to CH and eventually to the base station. Figure 2 shows the graphs for average energy available per node per round for the existing VGDRA, Pegasis and the proposed EVGDRA. It can be observed that EVGDRA has more average energy available per node as compared to traditional VGDRA and Pegasis protocol after each time data is sent. The average residual energy of SN's in smaller network dimensions is equal in our proposed scheme and the traditional approach. The graph shows that the performance of VGDRA degrades with the increasing dimensions and density of the network. The comparison indicates that EVGRA is better than both the VGDRA and Pegasis protocols. It is evident from the graphs that with the increase in network dimension and node density EVGDRA works significantly longer than the VGDRA and Pegasis consuming less amount of energy.

B. Total Energy used by the network-

Total energy used by the network is sum total of energy consumed by all the SN's inside the network. Figure 3 includes various graphs demonstrating the sum of energy used by all the nodes inside a network in each round. EVGDRA gives an improved performance with the increase in network dimension and density. It is evident from the graphs, EVGDRA uses the least amount of energy as compared with the existing VGDRA technique and Pegasis protocol. As the size and the node density of the network is increased the amount. Energy dissipation in EVGDRA is lower than the VGDRA and Pegasis protocol which lead to an extended lifetime.

C. Network Life-

Network life refers to the time span for which the system is taken to be operating properly. In simulation work the network is assumed to be alive till the first node dies. A demonstration of comparison of network life of existing VGDRA, Pegasis and EVGDRA is shown in Figure 4. The analysis shows that EVGRA has a longer life span as compared to the traditional VGDRA and Pegasis scheme. Moreover as the size of the network becomes large, EVGDRA has a life time that is longer than the Pegasis protocol and almost double than the existing VGDRA scheme.

D. Throughput-

The total number of packets delivered to the destination successfully in the network life time is called the throughput of the network. Table 3 presents a comparative chart for the throughput of the of Pegasis, VGDRA and EVGDRA in an area of 100×100, 200×200 and 300×300 with 100, 150 and 200 nodes deployed randomly. It is observed that EVGDRA performs better than VGDRA and Pegasis. The higher the throughput of a network the more data reaches to the destination.

The above mentioned performance results for VGDRA, Pegasis and EVGDRA shows that the average residual energy available to SN's in EVGDRA is greater than VGDRA and Pegasis leading to lesser amount of total energy consumption. In EVGDRA the availability of energy to the SN's enable them to work longer and hence increasing the network life and the amount of data transmitted in its life span. The overall study of the results obtained shows that EVGDRA has a significant improvement over VGDRA and Pegasis when network is expanded over large area and has a high SN density. The results obtained proves the proposed EVGDRA gives better results in large geographical regions that need to be monitored frequently and for long time span as it has a longer network life as compared to the VGDRA and Pegasis.

V. CONCLUSION AND FUTURE SCOPE

An Enhanced Virtual Grid-based Dynamic Route Adjustment scheme that improves the performance of the VGDRA is proposed. EVGDRA balances the energy consumption of CH throughout the network. The balanced energy dissipation diminishes the energy hole problem present in the VGDRA scheme. It is observed that the EVGDRA technique has an increased life span and throughput in comparison to the traditional VGDRA and Pegasis scheme. Moreover it extends the scope of VGDRA protocol to larger and denser networks. EVGDRA promises an improved performance as compared with the existing VGDRA and Pegasis protocol.

In future improvement can be done in the area of data routing between the source SN and the mobile base station by using an optimal data routing algorithm in the scheme.

ISSN: 2321-8169
399 – 406

Table 3. Comparison of Throughput in the network/10^4 life

Area / Protocol	100×100			200×200			300×300		
	100 nodes	150 nodes	200 nodes	100 nodes	150 nodes	200 nodes	100 nodes	150 nodes	200 nodes
Pegasis	5.505	14.625	19.465	6.29	6.3850	7.46	3.39	4.5312	5.40
VGDRA	11.5025	19.515	21.35	6.94	7.2975	8.02	3.71	4.3162	3.44
EVGDRA	11.5175	21.135	22.065	6.9925	9.0525	12.09	3.755	4.8450	7.06

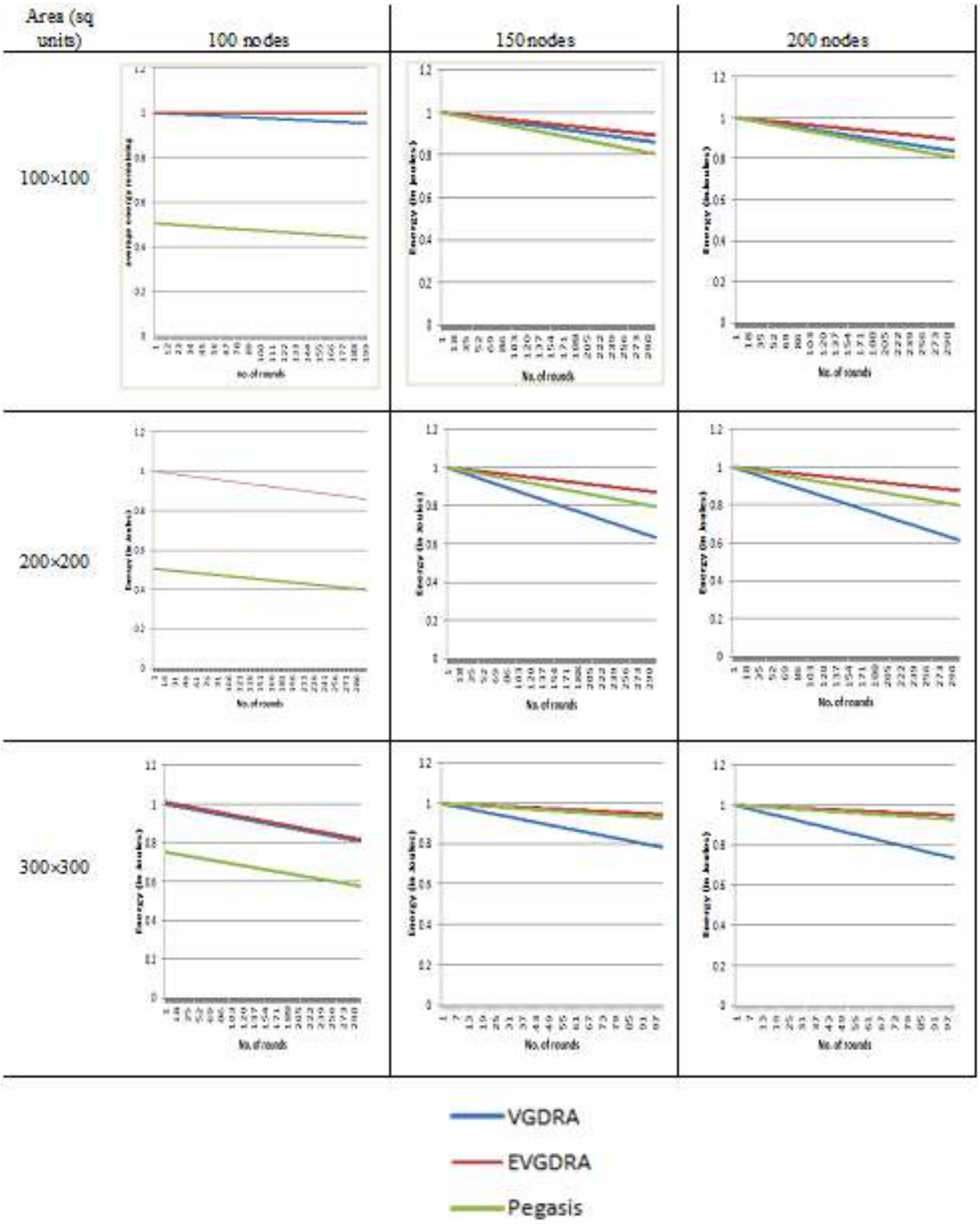


Figure 2 Comparison of Average Residual Energy

ISSN: 2321-8169
399 – 406

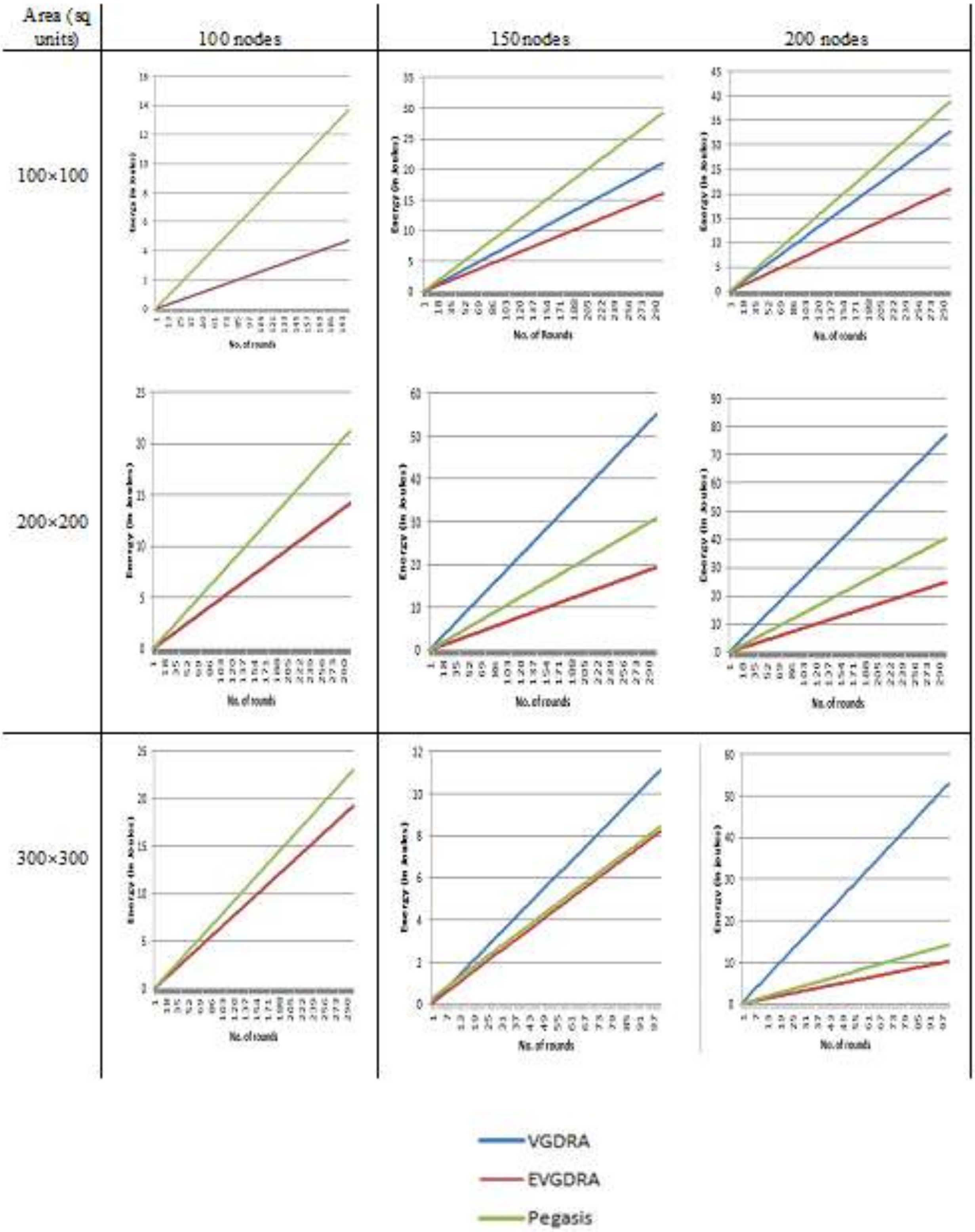


Figure 3 Comparison of Total Energy Used

ISSN: 2321-8169
399 – 406

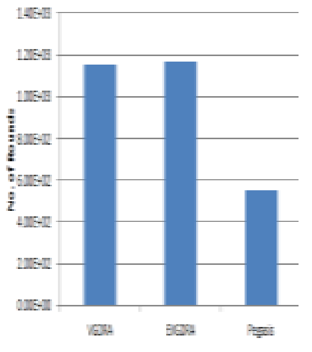
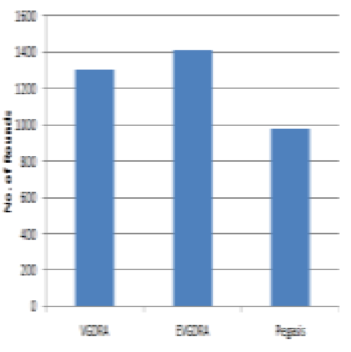
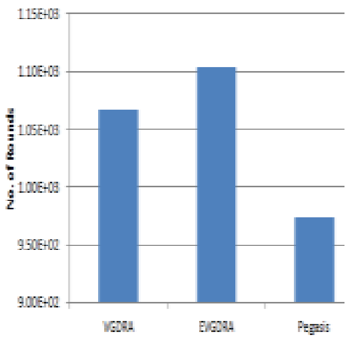
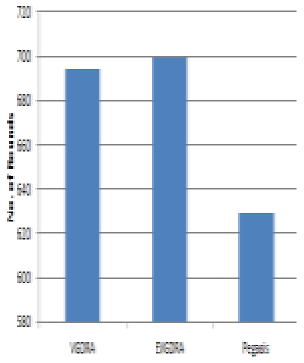
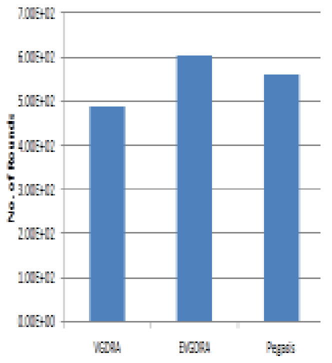
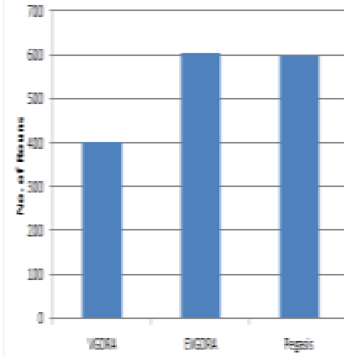
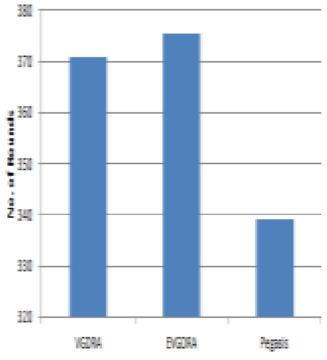
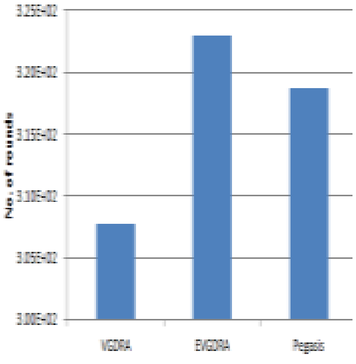
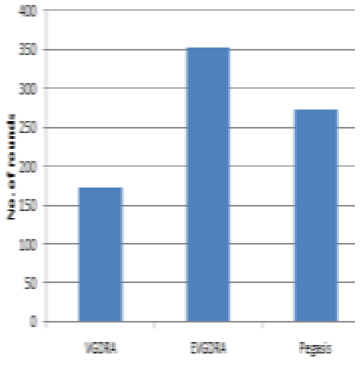
Area (sq units)	100 nodes	150 nodes	200 nodes
100×100			
200×200			
300×300			

Figure 4 Comparison of Total Energy Used

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