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Virtual Infrastructure based Routing Algorithm for IoT enabled Wireless Sensor Networks with Mobile Gateway

Mr. Dilip Kumar Jang Bahadur
[1]Research Scholar, Department of Computer Science & Engineering,
Sathyabama Institute of Science and Technology, Chennai
e-mail: dilipsaini@gmail.com

Dr. L. Lakshmanan
Professor and HOD Department of Computer Science & Engineering,
Sathyabama Institute of Science and Technology, Chennai
e-mail: lakshmanan.cse@sathyabama.ac.in

Abstract— The IoT technology is seeking the attention of industry and researcher day by day due to its large number of applications and is off monitoring and controlling the object from the remote location. The very basic and important element of IoT is wireless sensor network where sensor nodes are attached with the object and generates the sensory data related to the object an actuator can provide the movement to the object. To make it a success reliable and efficient communication model is the main requirement. To fulfil the objective related to IoT application success in this paper a communication protocol called virtual infrastructure based routing algorithm is proposed. In this proposal a virtual cross region structure is formed in the central of the sensor network, which is called meeting region. In this meeting region the sensor nodes send their generated data and the gateway node receives those data. The problem of energy hole, the mobile gateway node is considered in this proposal. The proposed algorithm is implemented using the standard wireless sensor network simulator tool and compared the performance of the proposed algorithm with the existing algorithm based on some standard performance metrics. The simulation outcome exhibits that the proposed algorithm outperformed the existing algorithms in different performance metrics.

Keywords*:* - Optimal Routing Alogorithm , Wireless sensor Network , IOT,VIRA

1. Introduction

In the IoT infrastructure the wireless sensor network place a vital role in data generation and collection [1-4]. As we have known the sensor nodes are low power computing device which consist of many constraintsSuch as limited battery power and communication range , low processing capacityand storage[22]. In this paperwe focused onhow to reduce energy consumption and increase the lifetime of the wireless sensor network. We also addressed the problem of hotspot or energy hole [11] or crowded center affect faced by the wireless sensor network with static gateway.In the energy whole problem the sensor nodes which resides near to the gateway node forward more data than other node in the network. As a result they deplete they're battery power and die soon. This may result a hole or the partition in the network. The solution to this problem can be the usage of mobile gateway node but at the same time the algorithm become complex to handle the mobile nature of the gateway node [10]. The mobile gateway node need to give its current position information whenever it is ready for the data collection [9]. It makes the whole network topology as well as the routing path the dynamic in nature. Hence the routing algorithm proposed for the wireless sensor network with mobile Gateway comes into the category of reactive routing algorithm. For any application where the freshness of the data is paramount means the data latency cannot be tolerated, the reactive routing algorithm would not be suitable [5-8]. In this paper we address the latency issue related to the data packets while proposing the routing algorithm Along with the efficient management off mobile gateway node.

Many virtual infrastructure-based routing schemes have been proposed [12 - 15]. For the sake of comparing the proposed protocol two existing protocols have been used. The first algorithm is a virtual grid based protocol (VGDRA)[17] and Line based Data Dissemination protocol [LBDD] [16].

In this paper, a Virtual Infrastructure based Routing Algorithm (VIRA) is presented for mitigating the issues of energy consumption and data packet latency. In VIRA, virtual infrastructure with the cross region is constructed in the center of the sensor network. This area is called meeting region and the sensor nodes which resides inside this meeting region is called backbone nodes. Inside the meeting region a tree infrastructure is created to make the communication link for all the backbone nodes. The sensor nodes, who generates the data packet can send the data directly to the meeting region without looking for the gateway's current location.

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2. Related Work

There are many routing algorithm based on virtual infrastructure are proposed by many researchers. Whereas the Baranidharan et al. [18] proposed a virtual infrastructure based routing algorithm which is energy efficient nature. It uses Geo nested routing technique in which a virtual multi ring structure is created for forwarding the data packet generated by the source sensor node. This algorithm has two parts: in the first part the Geo nested virtual infrastructure which is the multi ring infrastructure is created for the affective routing. This will help the sensor node with minimal number of hop-count. In the second part the mobility of the gateway node is managed by using the energy efficient algorithm.

A T Erman et al. [19] proposed the technique for virtual infrastructure creation and the algorithm for data dissemination. the Internet of Vehicle (IoV) scenario is considered Where the sensor nodes are attached with the vehicle and moving around as well as the gateway node also moving to collect the data. the virtual structure is like a honeycomb and taken the scenario of highways. in this algorithm the Highways are considered as the rendezvous region for the data collection and query transmission.

E Hamida et al.[16] proposed A virtual infrastructure based routing algorithm called line based data dissemination algorithm (LBDD). In this a virtual line is created in the middle of the network with the width w. The node which are inside the virtual line are responsible for storing and transmitting the packet to the gateway node. The source sensor generates the data and transmitted to the virtual line. The gateway node sends the query to the virtual line once it is willing to collect the data.

A. W. Khan et al.[17] presented a virtual grid based algorithm called (VGDRA). It creates the virtual grids of similar size and partition the whole sensor network into cells the sensor nodes which are close to the center of the cell would be selected as the Header. These are harder used to collect the data from the other sensor node in the same cell and transmit the data towards the gateway node through other cell headers. The loss of this algorithm is that it took a longer routing path for some of the cell header.

J Shin et al. [20] presented a data dissemination protocol, in which a virtual infrastructure is created in the network horizontally. Rail road type infrastructure is created and in the virtual station the data are stored and transmitted to the gateway node. It can handle the mobility of the gateway node very efficiently but the end to end delay is more in this algorithm.

C Tunca et al. [21] proposed a ring shaped virtual infrastructure which is made inside the sensor network without any width. The sensor nodes coming in the line of this ring are used to store and transmit the packet to the gateway node. For balancing the load of the ring node an algorithm is proposed in this the next ring node will be the sensor node towards the center of the network.

Most of the research are focusing on energy consumption aspect of the sensor network. Some of the research concentrated on data latency and data delivery ratio. But for the all aspect of data communication and its performance parameter are not been covered by a single routing algorithm. In this paper, we focus on energy efficiency, network lifetime, data latency, and delivery ratio and energy whole problem. As well as we provided the algorithm for managing the mobility of the gateway node.

3. Proposed Algorithm

In this section the proposed algorithm please describe using diagram, algorithms, network model with different scenarios and network assumptions.

Network Model

At the time of deployment the sensor network has a number of sensor nodes and one gateway node. All the sensor nodes in the network are static in nature. The gateway node is mobile and it isokinetic within the sensor field using random waypoint method. During the simulation the gateway node is moving with the pace of 5 to 30 meter per second. The gateway node may pause for some duration for data collection, this time duration is called pause time and can be denoted as δ. The sensor node knows there location information and they also calculate their remaining energy. The entire sensor network is divided into virtual region mainly as a cross of width w. This cross region can be found in the middle of the network. The central point of the virtual cross region can be denoted as (u,v) and the entire region is partitioned as vertical up region (vu), vertical bottom region (vb),horizontal left region (hl),horizontal right region (hr). This virtual infrastructure in the network can be seen in the Figure 1. The sensors within the virtual infrastructure (meeting region) are called backbone nodes. The gateway node send its willingness to receive the data packets when it comes to the new position. The backbone node convey the data immediately to the gateway that has been received by the source sensor node.

Mobility Model

In this paper to manifest the mobility of the gateway node the random waypoint mobility method [23] is used. In the simulation the mobility model we have taken as the random waypoint model which represent the gateway node mobility during the simulation. To find out the performance of the routing algorithm High standard mobility model for wireless network is considered called The Random Waypoint model. This model generates the next position of the gateway node randomly but within two points. In the proposed work we consider the two points as the minimum position Pmin and the maximum position Pmax of the gateway. The gateway node moves in the direction of the next position as generated by the mobility model with the pace

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specified in the simulator between 5 to 30 meter per second. At the new position the gateway node should pause for some duration (δ) represents the pause time. The pause time is required for data collection from the source node. The random waypoint method is not calculating the relative location because it is not considering the old position value to calculate the new position value.

Working Principle

As discussed in the network model, the entire sensor network region is divided as a virtual cross infrastructure called meeting region. The sensor nodes belongs to the meeting region are called backbone nodes. Within the meeting region a tree structure is created for making the communication link between the backbone nodes in the meeting region. In tree creation all the backbone nodes are not going to participate, in fact some are reserved for future. Any sensor node which generates the data packet can send the data immediately to its nearest backbone node. The gateway node select any sensor node in its vicinity as an interface node for data gathering. The backbone node make the connection with the interface node to communicate the packet to the gateway node. This entire process is divided into different stages such as Finding the Neighbors, Formation of Virtual Cross Area, Construction of the Tree, Region Discovery by the Sensor Node, Management of the Gateway and Transmission of Data Packet.

Finding the Neighbors

In this stage, every sensor node in the network used to find their neighbors by using the procedure illustrated in Algorithm 1. A sensor node selected by the algorithm broadcast NBR_DET control packet. This NBR_DET control packet consist of current location, the remaining energy and it's node ID. The sensor nodes within the one hop distance can receive the NBR_DET control packet and a table (Nbr) can be maintained for the neighbor list. In the Neighbor table the ID of the neighbor along with its location and remaining energy is stored. Upon receiving the NBR_DET control packet, the receiver node broadcast it 'sown NBR_DET control packet, if the receiver node did not broadcast previously. After the neighbor finding stage all the node in the network has the neighbor list.

Formation of Virtual Cross Area

In the proposed algorithm a virtual cross region is generated in the sensor fieldas shown in Figure1. The sensor node which resides inside the cross region are called backbone node. if we consider the virtual cross area with the width of the w and the total virtual cross area as (xmax, ymax). so we calculate wx and wy, the horizontal and vertical scope of the virtual cross area as shown in Equation 1 and Equation 2.

Wx= (Xmax-w)/2 to (Xmax +w)/2 (1)

Wy= (Xmax-w)/2 to (Xmax +w)/2 (2)

In the equation 1 and 2, w represents the weight off the virtual cross area and xmax, ymaxare the total sensor network area. Any sensor nodes within the scope of wx and wyare called backbone node. The virtual cross area are called meeting region because this reason act as the epicentre of data communication As shown in Figure 1.

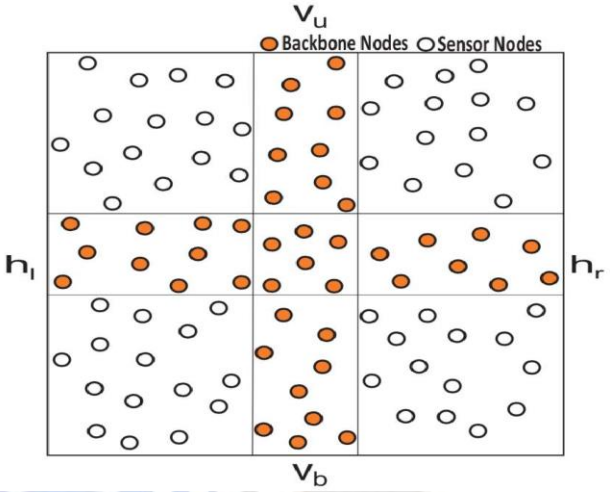

Figure 1: Initial view of the Virtual Cross area formation.

Construction of the Tree

In this stage the tree structure will be formed within the meeting region. In the tree creation some of the backbone node used to take part and some of them are kept reserve for future. For initiating the tree formation the nodes in the boundary (edge) initiates it towards the center of the meeting region. This process can be illustrated in Figure 2. Every sensor has their neighbor list created in the previous stage, which consist of neighbor node ID along with its remaining energy and location.

The boundary (edge) nodes of the meeting region select one of its neighbor based on the criteria shown above. Then the boundary (edge) node send the control packet to the picked neighbor for the tree structure creation. The receiver sensor node, who received the control packet me select the sender sensor node as the parent node and choose one of its neighbors towards the center of the meeting region has next node. Until the tree is constructed up to the center of the meeting region this process will repeat and at last the tree is created as shown in Figure 2.

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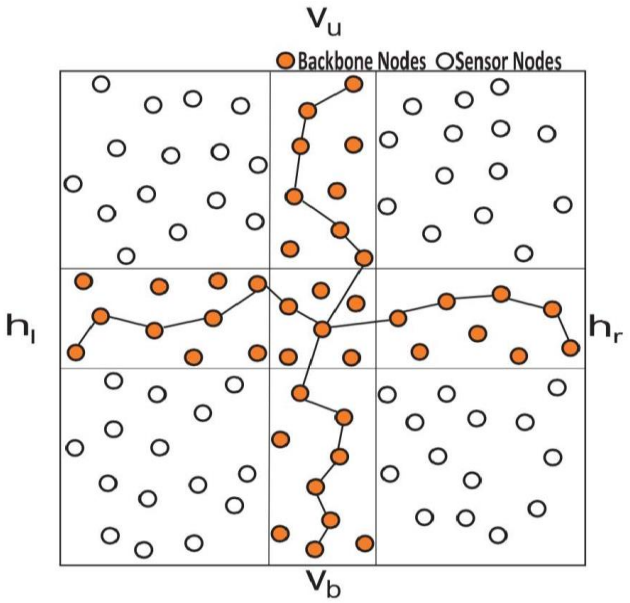
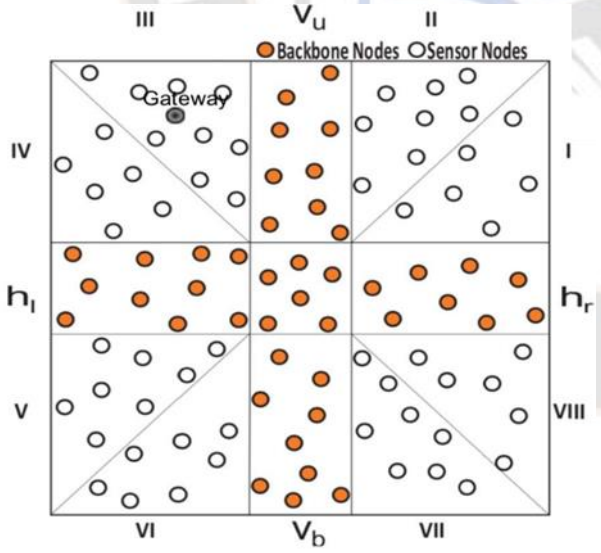


Figure 2: The Tree construction in the Virtual Cross area.

Region Discovery by the Sensor Node

Once the tree construction has been done in the meeting region all the backbone node which are part of the tree are called backbone tree node. All the backbone tree nodes are connected to each other with the communication link and the functionality is to store and convey the packet to the mobile gateway node. When sensor node are generates the data, it convey the packet immediately to the nearest backbone tree node. Here the sensor field is virtually splits into octants as shown in Figure 3.



It will help the sensor to convey their data with shortest path. To know in which Direction the sensor node need to send its data, the sensor node need to know in which region it belongs to. Hence the sensor nodes follow the Algorithm 2 which describes to find out the reason it belongs and after finding the region which is the destination coordinates. Once a sensor node find it's region and destinati Euclidean distance. on coordinates it sends the data packet to the destination by using Euclidean distance.

Management of Mobile Gateway Node

The mobile gateway node are rooming within the sensor network based on the random waypoint mobility method as discussed in the mobility model. The gateway node moves from one point to another point and wait for a particular amount of time in each new place before going to the new position for data collection. The time duration a gateway node waits is called pause time and it's denoted as δ. Once the gateway node arrives to the new point, it chooses one of the sensor node within its range as the interface node for collecting the data. Now it is the responsibility of the interface node to connect with the backbone tree node to create the routing path for the gateway node. The Algorithm 3 describes the process of path creation from the backbone node to the gateway node via the interface n de. All the backbone tree node readjust there communication link to the interface node for the packet communication as shown in Figure 4& Figure 5. The main aim for this algorithm is to manage the mobility of the gateway node by creating the routing path towards the gateway node by using the interface node.

TRANSMISSION OF DATA PACKET

Any sensor node, which generates that data can able to convey their packet to the gateway node via the backbone tree nodes. First of all the sensor need to find out their region and the destination point using the Algorithm 2. After getting the region and the destination point the sensor node will select one of its neighbor as the next node to send the data packet. for that the sensor node will take the help of Equation 3, which calculates the location factor (LF)of its neighbor node based on the remaining energy and the distance with the destination point. The neighbor node with the highest

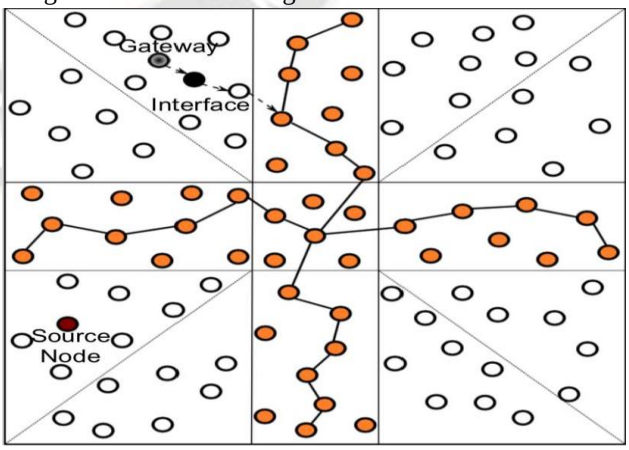


FIGURE 4: INTERFACE NODE SELECTION BY GATEWAY NODE.

location factor is chosen as the next node to forward the data. after receiving the data this neighbor node of the source node use the same procedure to choose its neighbour towards the

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destination point and forwards the data. Once the data reach toany of the backbone tree node, it will forward it to the gateway node by using the tree link and the interface node.

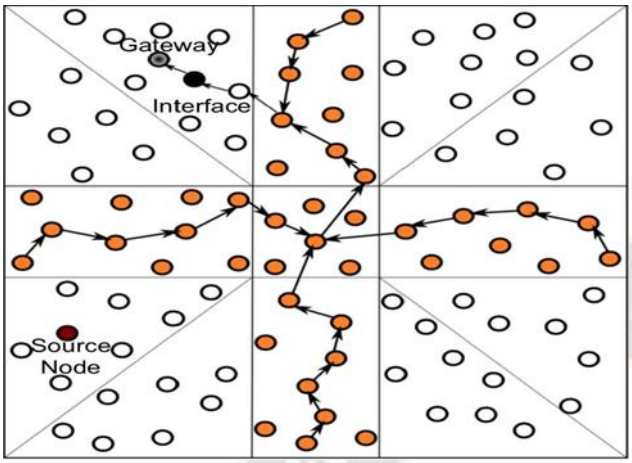

Figure 5: Communication Link creation towards the Gateway Node.

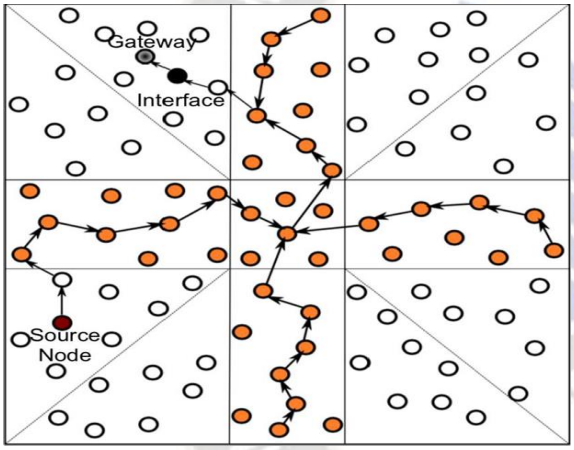

Figure6: Transmission of Data Packet from Source sensor node to the Gateway node.

4. Simulation Result and Discussion

The proposed routing algorithm called virtual infrastructure based routing algorithm called VIRA is simulated and the performance of the proposed algorithm is compared with the existing virtual infrastructure based routing algorithms. The simulation is performed using the network simulation tool called Castalia. here we assume that the gateway node is roming within the sensor field region as par the random waypoint mobility method with the pace of 5 metre per second to 30 metre per second. with different speed and different simulation time the result outcome has been analyzed and compared with some performance metricslike Average Energy Consumption, Average Control Packet Overhead, Packet Latency, Packet Delivery Percentageand Lifetime of the Network. The simulation parameter could be found in Table 1.

Sr No .	Parameter	Values
1	Network Area	500*500 Meter
2	Number of sensor Node	200
3	Data Packet Size	512 bytes
4	Control packet size	32 bytes
5	Delay	5 sec
6	Gateway Node Speed	5,10,15,20,25,30 m/sec
7	Mobility Model	Random Waypoint
8	ETX	50 nj/bit
9	ERX	10 nj/bit
10	E SLEEP	0.2 nj/bit
11	Communication range	87 meter
12	Simulation Time	600 Sec
13	MAC Protocol	TMAC

Table 1: Simulation Parameter

Average Energy Consumption

It is the metric for finding out the performance of the proposed work along with the existing algorithm shows that the

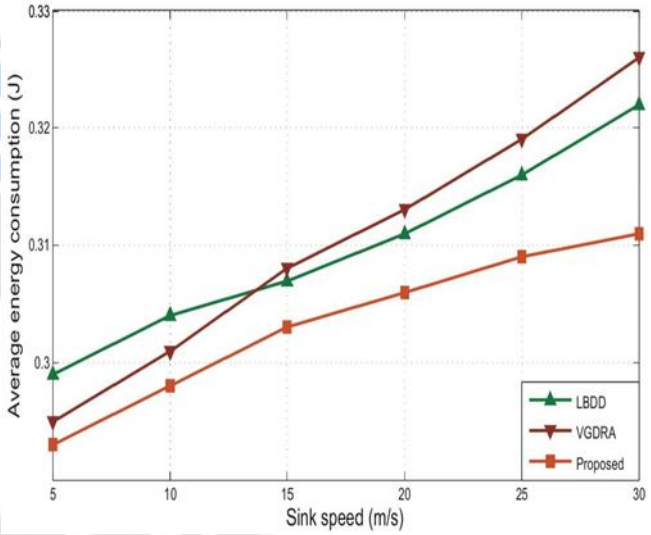

Figure 7: Average Energy Consumption

energy consumption Pernods in the network. We have calculated the average energy consumption by finding out the total energy consumption divided by the total number of sensor nodes in the IoT field. As the result shown in the result in graph the proposed algorithm consumes less energy compared to the existing protocols due to its less overhead for efficiently managing the mobile Gateway Node and less complex algorithm for routing path creation.

Average Control Packet overhead

This parameter signifies that how much control packet has been transmitted and received by the sensor nodes in network. as

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the sensor nodes are divided as the relay node and the non-relay node they used to transmit the control packet for finding the neighbors, construction of the tree, selecting the relay node, managing the mobility of the gateway nodeand for reconstruction of the tree. it is the total energy consumption due to the control packet transmission and reception in the network. it has been calculated as the total energy consumed by the control packet divided by the number of nodes in the network. As we can clearly see from the resulting graph shown in Figure 8 the proposed algorithm consumes less energy in control packet then the existing protocol. It clears that the proposed algorithm is using the energy efficient managing the mobile sink and constructing routing path.

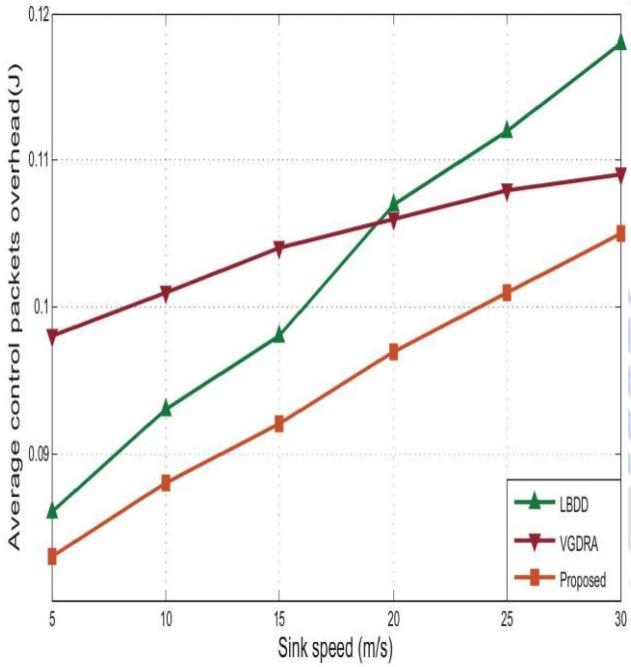

Figure 8: Average Control Packet Overhead

Data Packet Latenc

In the network the main objective is to gather the data packet from the source node and convey it to the cloud for the further processing and storage of data which makes the future decision. To fulfil this objective the data should reach to the gateway node as quick as possible. The parameter named data packetlatency signifies the delay between the data generation and the successful data reception by the gateway node. as the resulting graph shown in the Figure 9, the proposed work quickly communicate the packet to the gateway node as compared to the existing work. It is possible due to availability of the tree in the meeting region and less complex algorithm for data packet transmission

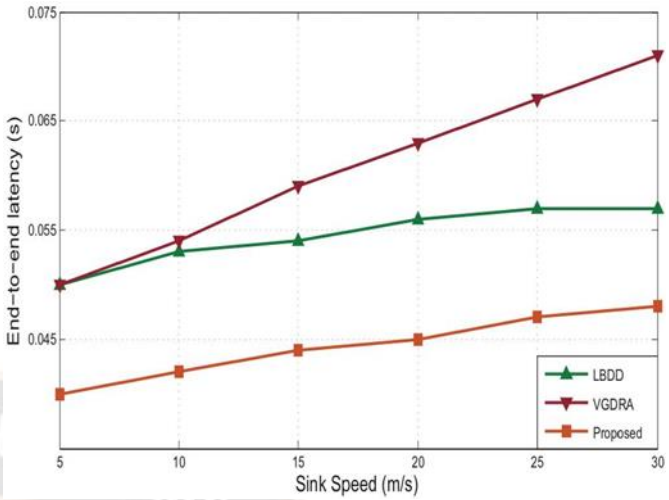

Figure 9: Average Data Packet Latency

Data Packet Delivery Percentage

This performance parameter is very important for any routing algorithm. It signifies how reliable an algorithm can be for different real time application where the data very critical. It shows how much data has been successfully received by the gateway node. It is calculated by the number of data packets received by the gateway node divided by the number of data packet transmitted by the sensor node. As shown in the Figure 10, the result illustrated that the proposed routing protocol have better data packet delivery percentage than the existing algorithm. Because the proposed algorithm able to manage the mobility of the Gateway node efficiently.

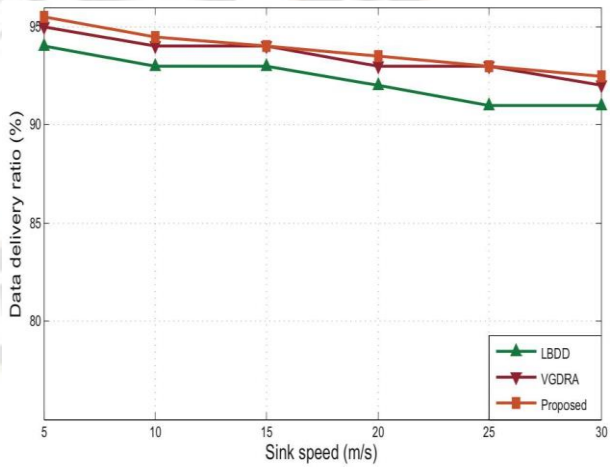

Figure 10: Packet Delivery Percentage

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Lifetime of the Network

The lifetime of the network signifies the time duration of the network when the network is working with the full functionality. In different research the lifetime of the network defines in a different way. In some research it is the time duration at which the first node died in the network and in some research it is the time duration when the network it is partitioned into two part. This parameter is very important to find out the performance of the routing algorithm. As shown in the resulting Figure 11 the number of nodes alive in network for the longer period of time is given by the proposed algorithm. Which signifies that the proposed algorithm is an energy efficient algorithm and consumes less energy.

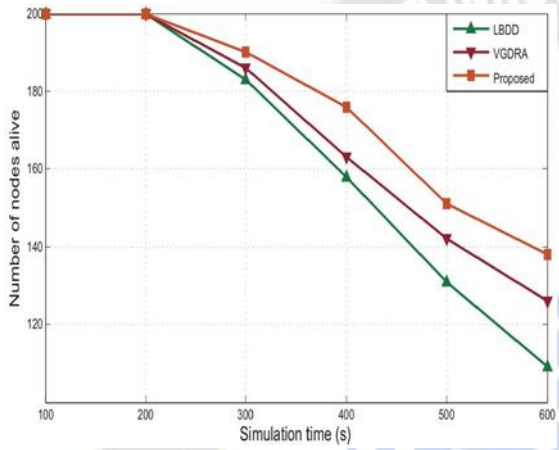

Figure 11: Lifetime of the Network

5. CONCLUSION

In this paper, we have proposed a virtual infrastructure based routing algorithm called VIRA. In this routing algorithm a virtual cross region of width w has been created in the centre of the sensor field. The sensor node belongs to this cross area region is called backbone nodeand this area is called meeting region. In the meeting region a tree structure is created based on some backbone node for data storage and quick transmission of data packet. The whole networkis divided into eight region. The sensor node who generates the data can send its data packet to the backbone known and the backbone node will relay the data to the gateway node. The algorithm is simulated and the result outcome is compared with the existing algorithm and found that the proposed algorithm outperform the existing algorithms based on the energy consumption, delivery ratio,latency and lifetime of the network.

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