POSITION BASED ROUTING PROTOCOLS
IN
WIRELESS SENSOR NETWORKS

Dissertation submitted to the Jawaharlal Nehru University
in Partial fulfillment of the requirements
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MASTER OF TECHNOLOGY
IN
COMPUTER SCIENCE AND TECHNOLOGY

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CERTIFICATE

This is to certify that the dissertation entitled **"POSITION BASED ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS"**, being submitted **Mr. Vipin Kumar** to the School of Computer and Systems Sciences, **Jawaharlal Nehru University**, New Delhi, India, in partial fulfillment of the requirements for the award of the degree of **Master of Technology** in **Computer Science and Technology**, is a record of bonafide work carried out by him under the supervision of of **Mr. Sushil Kumar, Assistant Professor**.

The matter embodied in this dissertation has not been submitted to any other University or Institution for the award of any other degree or diploma.

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DECLARATION

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Dedicated to my late grandfather,

my grandmother

And dearest family

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VIPIN KUMAR

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List of Acronyms

ADV	ADVertisement
ACQUIRE	ACtive Query Forwarding in Sensor Networks
BS	Base Station
DC	Data Centric
DIR	DIrectional Routing
DREAM	Distance Routing Effect Algorithm for Mobility
GAF	Geographic Adaptive Fidelity routing
GBR	Gradient Based Routing
GEAR	Geographic and Energy Aware Routing
GEDIR	GEographic DIstance Routing
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
IDSQ	Information-Driven Sensor Querying
IEEE	Institute of Electrical and Electronic Engineers
LAR	Location-Aided Routing
LEACH	Low Energy Adaptive Clustering Hierarchy
MANET	Mobile Adhoc NETworks
MCFA	Minimum Cost Forwarding Algorithm
MECN	Minimum Energy Communication Network
MFR	Most Forward within Radius
NFP	Nearest with Forward Progress
OC	Overhead Counts
PDR	Packet Delivery Ratio
PEGASIS	Power-Efficient GAthering in Sensor Information Systems
QoS	Quality of Service
REQ	Request
SPIN	Sensor Protocols for Information via Negotiation
TEEN	Threshold-sensitive Energy Efficient sensor network protocols
WSNs	Wireless Sensor Networks

Abstract

Wireless Sensor Network consists of large number of sensor nodes with self- organizing capability which allows a new node to automatically join the network. In this network, the energy saving and finding an optimal path are the fundamental design issues. DIR greedy forwarding method is used to avoid unnecessary transmissions. In this method each node makes forwarding decisions based on the position of itself, its one-hop neighbor and position of destination.

In this work, we proposed a position based routing algorithm to disseminate information via optimal path with minimal number of the control packets. The proposed routing algorithm uses the greedy forwarding approach to select a greedy node in one direction which results into loop free routing. Network area is divided into number of zones and one special node (VIP node) is selected in each zone except the destination zone. This algorithm identifies an optimal route based on the number of link and distance from destination. The proposed protocol provides guaranteed delivery of packets, because VIP node has multiple links. The proposed routing algorithm is simulated using GlomoSim network simulator. It is analyzed from the simulation results that the control packet overhead in VIP algorithm reduces by 20% to 24% as compare to well-known routing protocol LAR1. Further, it is observed that VIP algorithm attaining lower end-to-end delay and higher packet delivery ratio as compared with LAR1. We believe that algorithms and results are satisfactory and fulfill most of our initial objectives.

Chapter 1

INTRODUCTION

1.1 Wireless Sensor Networks

Wireless Sensor Networks (WSNs) consist of a large number of sensor nodes which are small in size. Each sensor node includes sensing, processing, transmission, position finding system and power units. These small nodes communicate over a wireless link without having a fixed network infrastructure [1]. They contribute to each other to produce high quality information. These sensor nodes measure conditions in the environment and transform these measurements into signals. These signals can be further processed to produce the required information about the event happening around the sensors. WSNs have restricted energy, processing power and memory. WSNs have a deep effect on Military and civil application such as intrusion detection, security and surveillance, weather monitoring, detecting surrounding conditions such as temperature, movement, sound, light or the pressure of objects.

Because of limited transmission range, communication between two sensor nodes requires involvement of intermediate nodes to forward the packets. The routing protocols for WSNs are categorized into geographic and non-geographic. Geographic routing protocols perform routing on the basis of the location of the source node, the location of the next hop and the location of the destination node. Non-geographic routing protocols are based on the tables and these routing tables are built at the cost of control packet overhead [2]. These control packets are exchanged to each other to update the routing tables.

In the geographic routing protocols the location of the nodes may be acquired by using Global Positioning System (GPS), if nodes are equipped with a GPS receiver. Position based routing protocols are highly scalable and show robust behavior in the situations where frequent topological changes. Such protocols can reduce communication and processing overhead that occurs because of neighborhood information exchange. The two main components of position based routing are location services and forwarding strategy. Location services provide the location information of a node and forwarding strategies can be based on minimizing the number of hop count, energy consumption, geographic distance and delay.

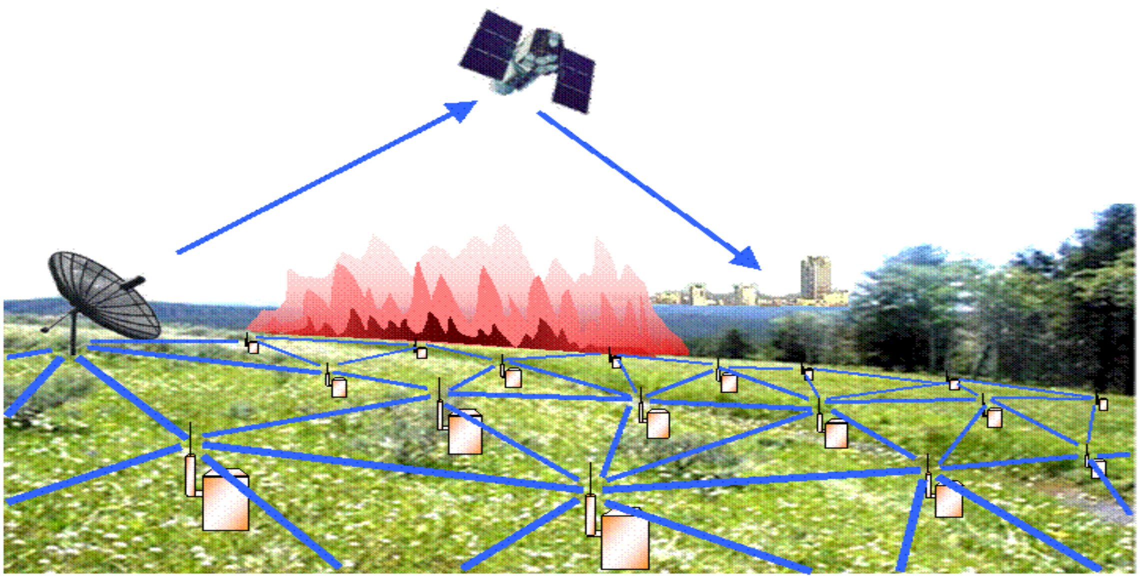

Fig. 1.1 Example of WSNs [3]

1.2 Characteristics of WSNs

The characteristics of sensor networks and application requirements have a crucial impact on the network design objectives in term of network capabilities and network performance [4].

- **Dense sensor node deployment**

  WSNs consist of a large number of sensor nodes that are densely deployed and can be higher in order of numbers than that in a Mobile Adhoc Networks (MANET).

- **Battery-powered sensor nodes**

  Sensor nodes are powered by batteries. These nodes are deployed in such an environment where it is very difficult to recharge or change the batteries.

- **Energy, computation, and storage constraints**

  In WSNs, sensor nodes have limited energy, computation, and storage capabilities.

- **Self-configurable**

  In WSNs, sensor nodes are deployed randomly and these are capable to autonomously configure themselves in a communication network [4].

- **Unreliable sensor nodes**

  Sensor nodes are unreliable because these nodes are deployed in a hostile environments. So these are very prone to physical damages or failures.

- **Data redundancy**

  In most sensor network applications, sensor nodes are deployed in a certain region and collaborate to each other to accomplish a common sensing task. Thus, the data sensed by multiple sensor nodes may have a certain level of data redundancy.

- **Application specific**

  WSNs are usually designed for a specific application. The design of a network changes according to the application's requirement.

- **Many-to-one traffic pattern**

  In WSNs the data sensed by sensor node is forwarded through multiple intermediate nodes to a particular sink. It exhibits a many-to-one traffic pattern.

- **Frequent topology change**

  WSNs consist of a large number of sensor nodes, so due to the node failures, damage, addition of new nodes, energy depletion, there is frequently changing in network topology.

1.3 Application of WSNs

- **Military**

  WSNs can be used by the military for a number of purposes such as monitoring or tracking the enemies and force protection.

  - Battlefield surveillance.
  - Nuclear, biological and chemical attack detection.

- **Area monitoring**

  Area monitoring is a common application of WSNs. In area monitoring, sensor nodes are deployed in a certain region where some phenomenon is to be monitored. When the sensors detect the event being monitored (heat, pressure), the event is reported to one of the base stations, which then takes appropriate action.

- **Air pollution monitoring**

  WSNs have been deployed in several cities to monitor the concentration of dangerous gases for citizens.

- **Forest fires detection**

  A network of sensor nodes can be installed in a forest to control when a fire has started. The area will be deployed with sensors to control temperature, humidity and gases which are produced by fire in the trees.

- **Greenhouse monitoring**

  The sensors are used in green houses [5] to control the temperature and humidity levels. When the temperature and humidity drops below particular levels, it must be notified to the control station.

- **Landslide detection**

- **Commercial Applications**
  - Home automation for smart home environments.
  - sDetecting and monitoring thieving.
  - Vehicle tracking and detection.

1.4 Routing Protocols in WSNs

In this section we survey the existing protocols in wireless sensor networks. In WSNs, routing protocols can be divided based on network structure and protocol operation. The protocols based on network structure are divided into Flat-based routing, Hierarchical based routing and Location based routing.

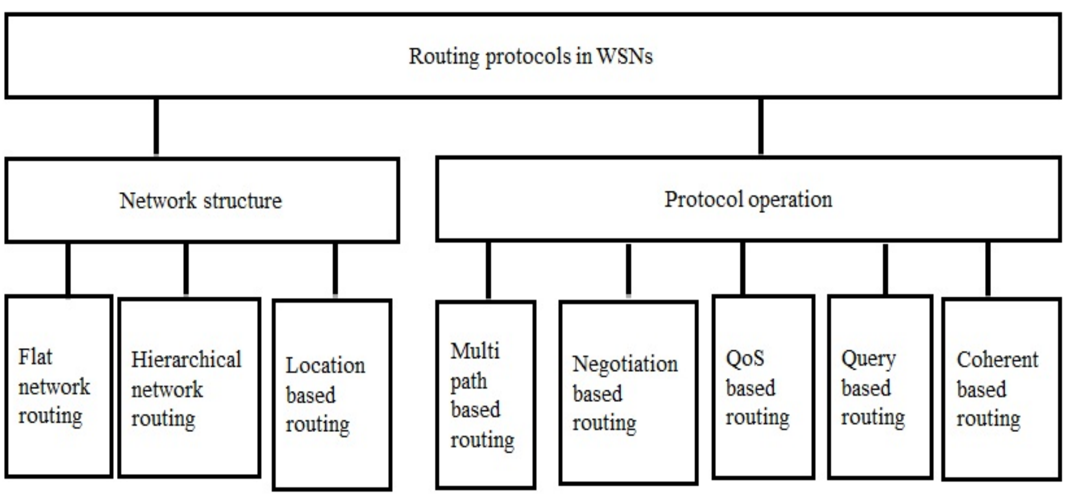

Fig. 1.2 Routing Protocols in WSNs: taxonomy [6]

1.4.1 Network structure

1.4.1.1 Flat network routing

In flat network routing, each node plays the same role. In the networks all nodes work together to perform the sensing task. Because WSNs consist of large number of such sensor nodes, it is not feasible to assign a global identifier to each node [6]. So data centric (DC) routing comes into consideration. In DC, Base Station (BS) sends queries to pre-defined regions and waits for data from the sensor nodes that are located in the selected regions. Two main types of algorithms in flat routing are flooding and data centric routing. In flooding each node forwards data to all its neighbors and due to this, much redundant data occurs. In DC routing there are no global identifiers for nodes. The data is identified using attribute based naming. There are some protocols based on flat network routing.

- **Sensor Protocols for Information via Negotiation (SPIN):** Heinzelman *et al*. in [7, 8] proposed a protocol, called SPIN. It distributes all the information at each node to every node in the network. If a user has any query, it can get the required information immediately. SPIN is a three-stage protocol [6] and the nodes use three types of messages to communicate. These messages are Advertisement (ADV), Request (REQ), and DATA. This protocol starts when SPIN node gathers new data. The node broadcasts an ADV message. If any neighbor is interested in that data, it sends a REQ message. After getting this REQ message the actual DATA is sent to the neighbor node. Operation of SPIN is illustrated in Fig. 1.3.

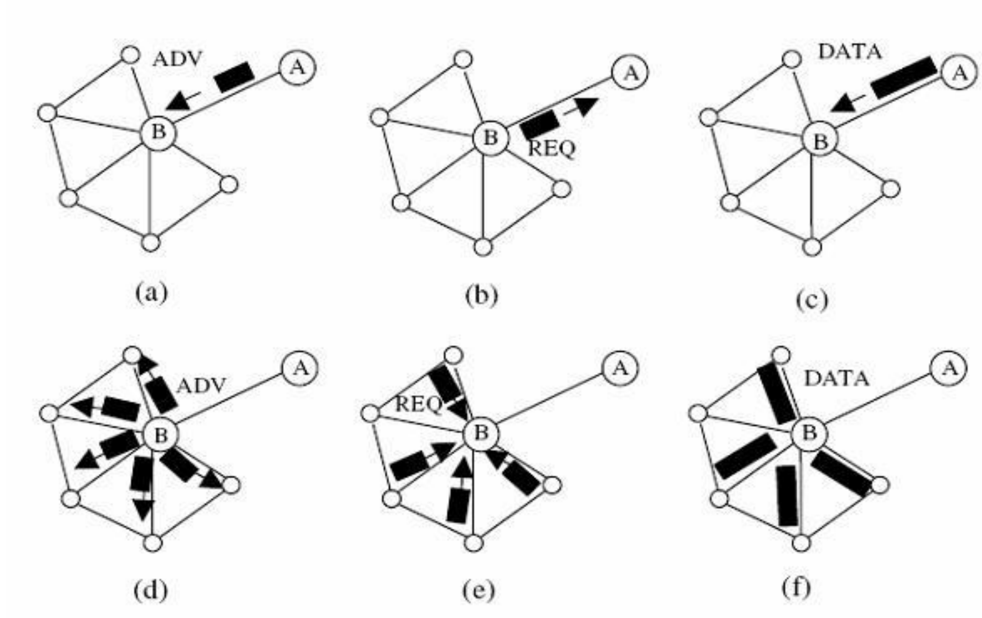

Fig. 1.3 Illustration of SPIN protocol [9]

- **Directed Diffusion:** C. Intanagonwiwat *et al*. in [10] proposed a popular data aggregation technique for WSNs, called directed diffusion. In directed diffusion the BS broadcasts interest which describes a task required to be done by the network. After receiving the interest, each sensor node stores the interest entry in its cache and sets up a gradient toward itself to the nodes from which it receives the interest. If a node has data, it sends data through the interest's gradient. It chooses only best paths to avoid further flooding. Operation of direct diffusion is illustrated in fig. 1.4.

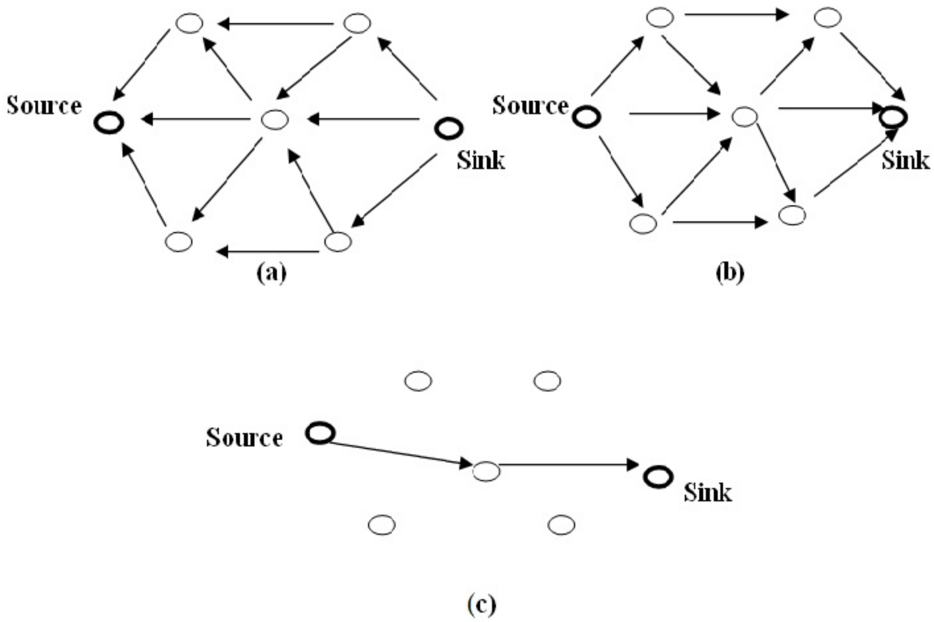

Fig. 1.4 Example of Directed Diffusion (a) Propagate interest (b) Set up gradient and (c) send data [6]

- **Minimum Cost Forwarding Algorithm (MCFA):** In MCFA [11] each node records the estimated least cost from itself to BS. Initially at each node, the least cost is set to infinity (∞). The BS broadcasts a message with the cost set zero. When a node receives this broadcast message, it compares the cost of message with its estimated least cost. If the estimated cost of the message plus the cost of current link is less than the cost of that node, the estimate on the message and the estimate recorded by the node are updated [6] and then the message is broadcasted to neighbors. If this calculated estimate cost is more than the cost of a node, the broadcast message is discarded. The fig 1.5 illustrates steps of this process.

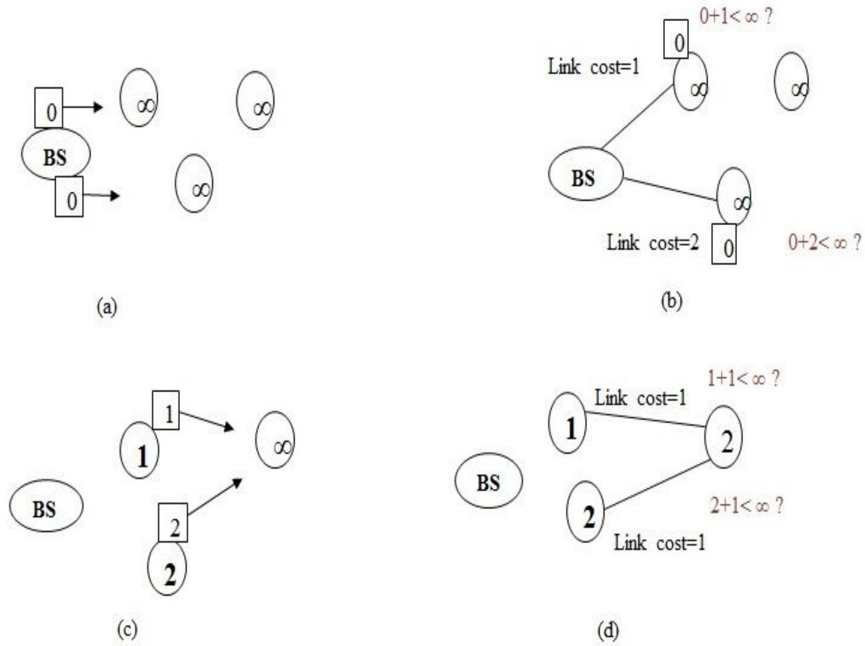

Fig. 1.5 Example of MCFA

Minimum Cost Forwarding Algorithm

i) Each node sets its least cost to BS as ∞.

ii) BS broadcasts a message with least cost set to zero.

iii) If cost of message+link cost < local cost, update local cost and cost on the message, then re-broadcast the message.

iv) If cost of message+link cost >= local cost, discard messages.

- **Gradient Based Routing (GBR):** GBR is the variant of directed diffusion. It is proposed by Schurgers et al. [12]. This routing is based on the calculation of a parameter, called the height of the node. In GBR height is the minimum path between nodes and BS in terms of the number of hops between them. The difference between a node’s height and the height of its neighbor is called gradient of that link [6]. To forward the data, nodes choose the links which have largest gradient.

Other flat routing techniques are

- Rumor routing
- Information-Driven Sensor Querying (IDSQ)
- Energy-Aware Routing

1.4.1.2 Hierarchical routing

In WSNs, hierarchical architecture adopts the concept of clustering [13]. It reduces the communication overhead. In this routing, sensor nodes are grouped into clusters and each cluster contains a cluster head (CH). Some sensor nodes are responsible for sensing a target and some nodes are responsible for transmitting data to the BS. The CH can also perform data aggregation to reduce the amount of data before transmitting it, to the BS. In this routing, the nodes with high-energy can be used to process and send the information and low-energy nodes can be used to perform the sensing task [6].

- **The low-energy adaptive clustering hierarchy (LEACH):** Heinzelman et al. [14] proposed a hierarchical routing protocol, called LEACH protocol. LEACH is a cluster-based protocol. LEACH randomly selects a small number of sensor nodes as CHs and this responsibility is rotated among the sensors to distribute the energy load. In LEACH, nodes send the data to the respective CHs. After compressing the data these CHs send an aggregated packet to the BS.

Other Hierarchical routing techniques are

- Power-Efficient Gathering in Sensor Information Systems (PEGASIS)
- Threshold-Sensitive Energy Efficient Sensor Network Protocols (TEEN)
- Minimum energy communication network (MECN)

1.4.1.3 Location based routing

This kind of routing is based on the location of nodes. The distance between neighboring nodes can be estimated on the basis of incoming signal strengths. The location of nodes may be available by using GPS if nodes are equipped with a small low-power GPS receiver [15]. In location based routing each node knows its own location, its neighbor location and location of the destination node.

1.4.2 Routing protocols based on protocol operation

- **Multipath Routing Protocols:** In this type of routing protocols, it uses multiple paths in order to enhance network performance [16]. If one path is not available it selects other possible path to transmit the packets.

- **Negotiation-Based Routing Protocols:** Flooding produces implosion and overlap [17] between the sent data, due to this reason a node will receive duplicate copies of the same data. The sending of the same data from different nodes consumes more energy and processing. These types of protocols eliminate redundant data transmissions through negotiation.

- **QoS-based Routing:** These kinds of routing protocols are based on the quality of services. In QoS-based routing protocols [6], it has to balance between energy consumption and data quality. When data deliver to the BS, the network has to satisfy certain QoS metrics such as energy, delay and bandwidth.

- **Query-Based Routing:** These kinds of routing protocols are based on the queries. The destination node propagates a query for data in the network, and a node that matches the query, sends the data back to the node that initiated the query.

- **Coherent and Non-coherent Processing:** In WSNs, sensor nodes cooperate with each other to process the different data. In coherent data processing routing, the data is forwarded to aggregators after minimum processing. The minimum processing includes tasks like duplicate suppression and time stamping [6]. In non-coherent data processing routing [18], nodes will locally process the raw data before it is sent to other nodes for further processing. The nodes that perform further processing are called aggregators [6].

1.5 Design Issues of Routing Protocols in WSNs

- **Fault Tolerance**

  In WSNs, some sensor nodes may fail due to lack of power. Some node may have physical damage due to environmental interferences. The failure of such sensor nodes may affect the overall task of the network. Fault tolerance [19] is the ability to sustain sensor network functionalities without any problem.

- **Scalability**

  WSNs consist of a large number of sensor nodes. These may be in the order of hundreds, thousands or more. So routing schemes must be scalable without losing its behavior of responding the events. If any number of nodes come into the network, the robustness of the network should not be affected.

- **Production Costs**

  Because WSNs consist of a large number of sensor nodes, the cost of each node is very important because it affects the overall cost of the networks. So the cost of each sensor node has to be kept low.

- **Power Consumption**

  The lifetime of a node is strongly dependent on its battery lifetime. So routing schemes should be able to make a node, consume less power to increase the lifetime of the network.

- **Quality of Service (QoS)**

  The quality of service means the quality service required by the application, it could be the lifetime of network, reliable data transfer, energy efficiency, delay. In some applications e.g. Military applications, the data must be delivered within a certain period of time from the moment it is sensed the data.

- **Self-configurability**

  Sensor nodes in WSNs, once deployed, should be able to autonomously organize themselves into a communication network. These nodes should have ability to reconfigure their connectivity in the situation of topology changes and node failure.

- **Data Aggregation**

  In WSN, sensor nodes may generate redundant data. A node may gets many copies of the same packet from different nodes. So an aggregation operation can be performed on these similar packets to reduce the number of transmissions. So routing schemes should deal with data aggregation technique to achieve energy efficiency and data transfer optimization [19].

1.6 Problem Statement

A wireless sensor networks consist of a large number of sensor nodes with a limited transmission range. When a node detects an event, it must report this to the destination. The transmission range of a node itself is not strong enough to send its detected packet directly to the destination. But it can reach its neighboring nodes, because sensor nodes are densely deployed in the area. The intermediate nodes can now cooperate to forward the packets until it reaches to destination. Since all nodes are battery powered, an efficient algorithm is needed to forward the packets where much energy and time can be saved.

1.7 Objective

Our main purpose is to design a position based routing algorithm with the followings set of objectives that :-

- Reduces the control packet overhead to find the optimal path from source to destination.
- Provides the guaranteed delivery of packets.
- Provides multiple links, if any link gets failure then other suitable link can be selected to forward the packets.
- Saves energy.

- Selects an optimal path to forward the packets.
- Is scalable, any number of nodes can be connected to the network.
- Take less time in delivery.
- Solves the problem of looping.

The proposed algorithm will be simulated in open source network simulator GlomoSim.

1.8 Dissertation Organization

First chapter of dissertation contains introduction to wireless sensor networks. It describes the characteristics of WSNs, application of WSNs, and design Issues of routing protocols in WSNs, problem statement, and objectives. Second chapter contains related work that describes the different greedy forwarding schemes. This chapter also gives the description of different type of position based routing protocol in WSNs. The third chapter contains the proposed work that defines the phases of proposed routing algorithm, how to calculate the size of a zone, function of VIP node and working of proposed algorithm. In fourth chapter Experimental Results and Analysis part is described. Finally, the fifth chapter concludes the work done and future scope to extend the current work.

Chapter 2

RELATED WORK

Position-based routing algorithms reduce some of the limitations of topology-based routing. In position based routing the information about the physical position of the nodes is available. Each node knows its own position through the use of GPS or some other type of positioning service. A location service has the information about the position of nodes. This service is used by the sender of a packet to determine the position of the destination.

In position-based routing, a node takes forwarding decision based on the position of a packet's destination and the position of the node's one-hop neighbors. A node can gets the position of its neighbor through one-hop broadcasting.

2.1 Greedy Packet Forwarding Scheme

Greedy routing algorithms provide the forwarding methods on the basis of location of the current forwarding node, its neighbors, and the packet destination. Based on this information each node takes decision to forward the data. Each intermediate node applies this greedy principle [20] until the packets reaches to the destination node. Greedy routing can be based on progress, distance and direction.

2.1.1 Progress based

In the progress based scheme [21], the next forwarding node is selected based on the progress. Given a transmitting node S, the progress of a node A is defined as, the distance between a node S and the projection A' of a neighbor node A onto the line connecting S and destination D.

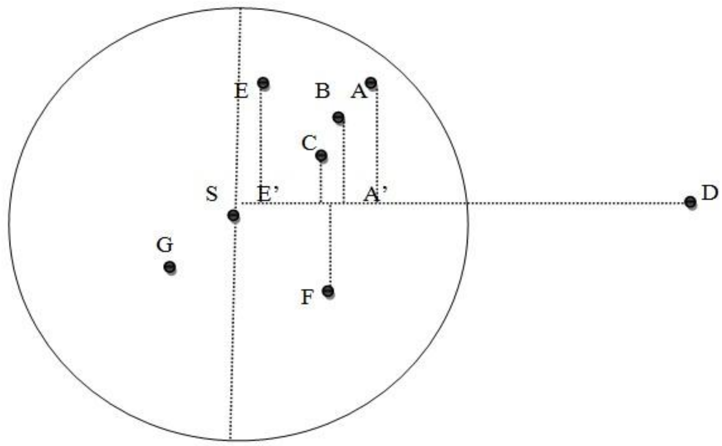

Fig. 2.1 Progress based [21]

Neighbors with positive progress are said to be in forward direction. For example in Fig. 2.1, the neighbors A, B, C, E and F are in forward direction. The remaining node G is in backward direction.

2.1.2 Distance based

This distance based [21] greedy routing scheme is based on the distance. This scheme considers the Euclidean distance between all neighbors of sender S and the destination D. To forward the packets, forwarding node is selected based on the distance.

2.1.3 Direction-based

This greedy routing is based on direction. It considers the deviation (angle between next hop, current, and destination node) from the line connecting current sender and destination [21]. Based on the direction, this current node selects next node to forward the packets.

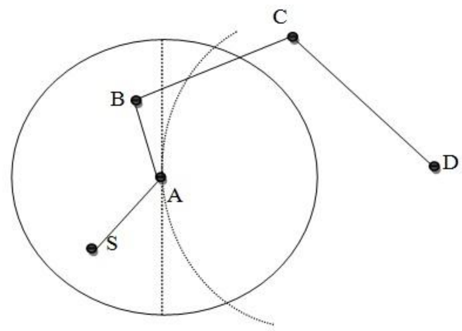

Fig. 2.2 Local minimum problem [21]

A packet addressed to node D will be dropped at node A, because each neighbor of A (node S and node B) is in backward direction.

These greedy routing schemes cannot guarantee packet delivery even if there exist a path from source to destination. For example in Fig. 2.2, there exists a path from source node S to destination node D. But a packet addressed to node D is dropped at node A, because each neighbor node that is in its transmission range is in backward direction of this node. Such a situation is called local minimum. The node where greedy forwarding is stopped is termed as concave node [21].

Based on the notion of progress, Takagi and Kleinrock [22] proposed the first position-based routing scheme.

2.1.4 Most forward within radius

Takagi and Kleinrock [22] introduced the first position-based routing algorithm, called most forward within radius (MFR). Based on this scheme, a packet with destination D is forwarded in the forward direction. The neighbor with the maximum progress on the straight line is selected as next hop for sending packets [23]. In Fig. 2.1, node A is the neighbor of S with most forward progress.

2.1.5 Nearest with forward progress

Hou and Li [24] proposed nearest with forward progress (NFP) routing algorithm. In this algorithm each node sends the packet to the nearest neighbor with forward progress. In Fig. 2.1, node E is selected.

2.2 Routing Protocols Based on Position

2.2.1 Compass routing

Kranakis defined compass routing (DIR) [25], in which source or intermediate node selects the neighbor that is closest to the straight line between sender and destination node. For example in Fig. 2.3, node C is in the closest direction respective the line connecting node S and destination D.

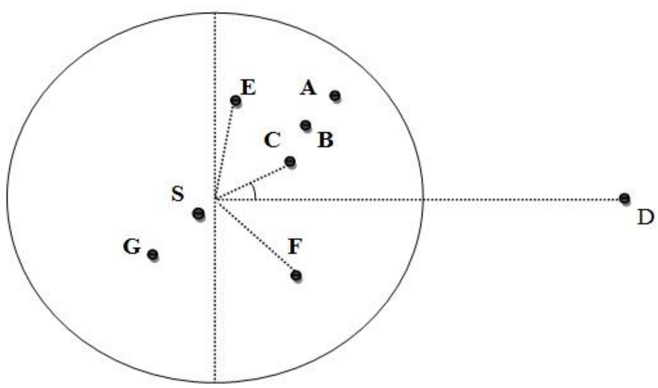

Fig. 2.3 Compass routing [21]

In DIR method, when a packet is forwarded to the neighbor with closest direction may create a loop [26], as shown in Fig. 2.4. The loop consists of four nodes, denoted E, F, G and H. Let the source node is E and the destination node is D. Node E selects node F to forward the packet, because the direction of F is closer to destination D than the direction of its other neighbor node H. Similarly node F selects G, node G selects node H and node

H selects node E. In this Figure, a loop EFGHE is created. So, it is clear that DIR is not loop free.

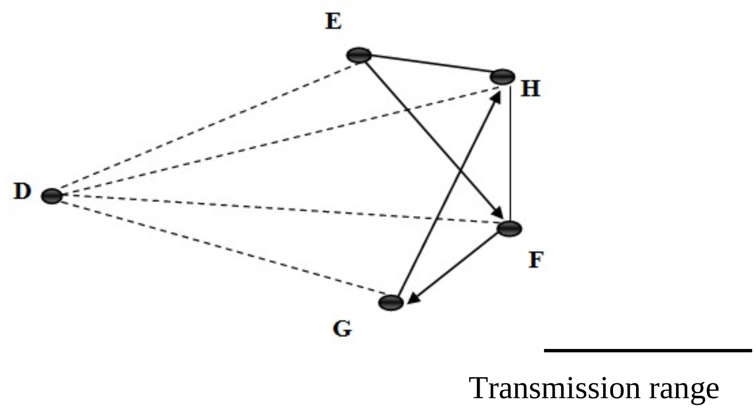

Fig. 2.4 A loop in the directional routing [26]

2.2.2 Geographic distance routing (GEDIR)

GEDIR [27] is a position based greedy forwarding algorithm . It deals with the situations when the sending node itself is a local minimum (dead-end). A dead end problem occurs when a node which is nearest to the destination node in comparison to all its neighbors and not within the transmission range of the destination. For example, in Fig. 2.5, assume node F wants to send a message to destination node D, but F and D are not within the transmission range of one another. In this case F is a dead-end but according to GEDIR scheme, node F will still forward message to node B, hoping that B may have another neighbor which is closest to the destination D [27].

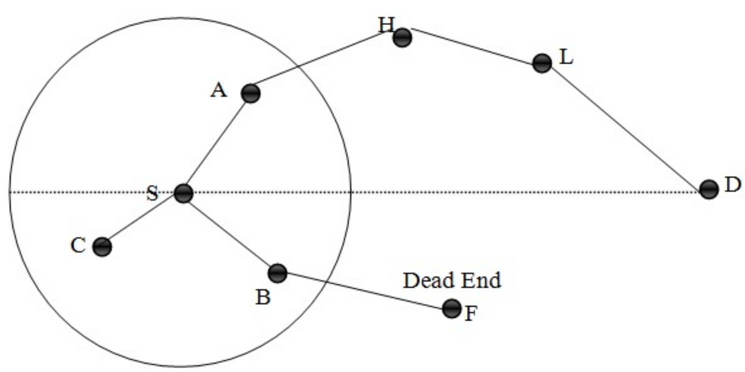

Fig. 2.5 GEDIR routing [27]

2.2.3 Greedy perimeter stateless routing (GPSR)

GPSR is a routing strategy based on combining two different forwarding strategies, greedy forwarding and right hand rule [28]. GPSR protocol is a recovery approach based on planar graph traversal. A packet enters the recovery mode when it arrives at local minimum. It returns to greedy mode when it reaches a node closer to the destination than the node where the packet entered the recovery mode. Greedy forwarding schemes do not give the guaranteed delivery of message. The problem with greedy forwarding scheme is that the packets are dropped by concave nodes. To deal with such local minimum problem a recovery strategy known as FACE Routing [28] exists, that guarantees the delivery of packets. It is applied on planar connected geometric graphs. A geometric graph is said to be planar graph if any two edges of a graph is not intersecting to each other.

- **Face routing principle**

  In this routing, a planar graph traversal is used to find a path towards the destination. A geometric planar graph partitions the plane into faces surrounded by the polygons. The concept of the FACE algorithm is to route a packet along the interiors of the faces intersected by the straight line connecting source node and destination [21]. On each face, the packet is forwarded along the interior of the face by using the right-hand rule (left-hand rule). According to this rule a packet is forwarded along the next edge clockwise (counterclockwise) from the edge on which it arrived [21].

  When the packet arrives at an edge intersecting the line connecting source and destination , by skipping that edge the next face that is intersected by this line is handled in the same way [21].

2.2.4 Distance routing effect algorithm for mobility (DREAM)

In DREAM, each node maintains a position database that stores position information about each node that exists in the network [26]. This information contains a node identifier, the direction and distance to the node. It also includes a time value that indicates when this information was generated.

In DREAM, a packet with sender node S and destination node D, is forwarded to all one-hop neighbors that lie in the direction of D. To determine this direction, a node calculates an expected region that is probable to contain D. Fig. 2.7 shows the expected region, which is a circle around the position of D and it is known to S. The radius *r* of the expected region is set to $(t1 - t0)\ V_{max}$, where *t*1 is the current time, *t*0 is the timestamp of the position information when node S has about D [29]. V_{max} is the maximum speed that a node may travel in the wireless network. In the expected region, the line between S and D and the angle ϕ defines the direction toward D. The neighboring nodes repeat this procedure by using the information about position of node D [29].

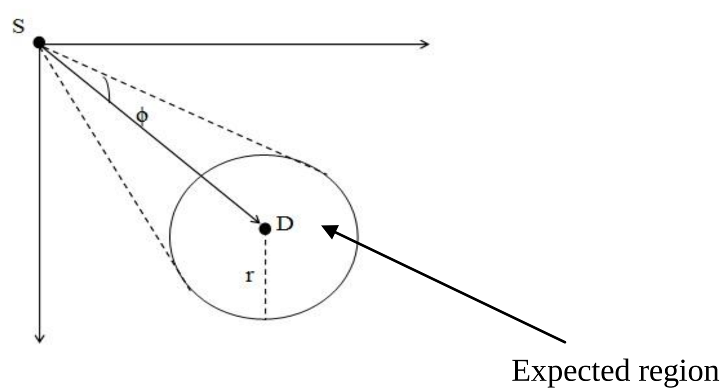

Fig. 2.6 Expected region in DREAM [29]

2.2.5 Location-Aided routing

Location-aided routing (LAR) [2] protocol uses the location information.This protocol assumes that each node is equipped with the GPS for obtaining the geographical position information. LAR uses two geographical regions for forwarding of control packets. These two regions are ExpectedZone and RequestZone [2]. The ExpectedZone is the region in which the destination node is expected to be present. The RequestZone is a geographical region in which all nodes exist that participates to forward the packets. This area is determined by the sender of a data. The control packets are used to find the path from source node to destination. The control packets are forwarded by nodes which appear in the RequestZone and discarded by nodes that exist outside the zone. There may be some situations where the sender or the intermediate nodes are not present in the RequestZone, in that situation additional area is included for forwarding the packets. LAR protocol uses flooding, but here flooding is restricted to a small geographic region. There are two algorithms LAR1 and LAR2.

- **LAR1:** In LAR1 algorithm [2], the information of RequestZone is explicitly specified in the RouteRequest packet. This is done by the source node S. It is shown in Fig. 2.8 that the RequestZone is the rectangle that includes the source node S and the ExpectedZone. The node S is outside the ExpectedZone. In this algorithm every intermediate node that receives the RouteRequest packet, verifies the RequestZone information. This node can forward it further if it is within the RequestZone, otherwise the packet is discarded [2]. In Fig. 2.8, the source node 1 originates a RouteRequest packet. This packet is broadcast to its neighbor nodes 2, 5 and 6. These nodes verify their own locations to check whether they belong to the ExpectedZone or not. Only node 2 and 5 find that they are inside the RequestZone and hence they forward the RouteRequest packet to their neighbor nodes. But node 6 discards the packet because it is not in the RequestZone. After reaching the RouteRequest packet at the destination node 4, it originates a RouteReply packet that contains the current location and current time of the node.

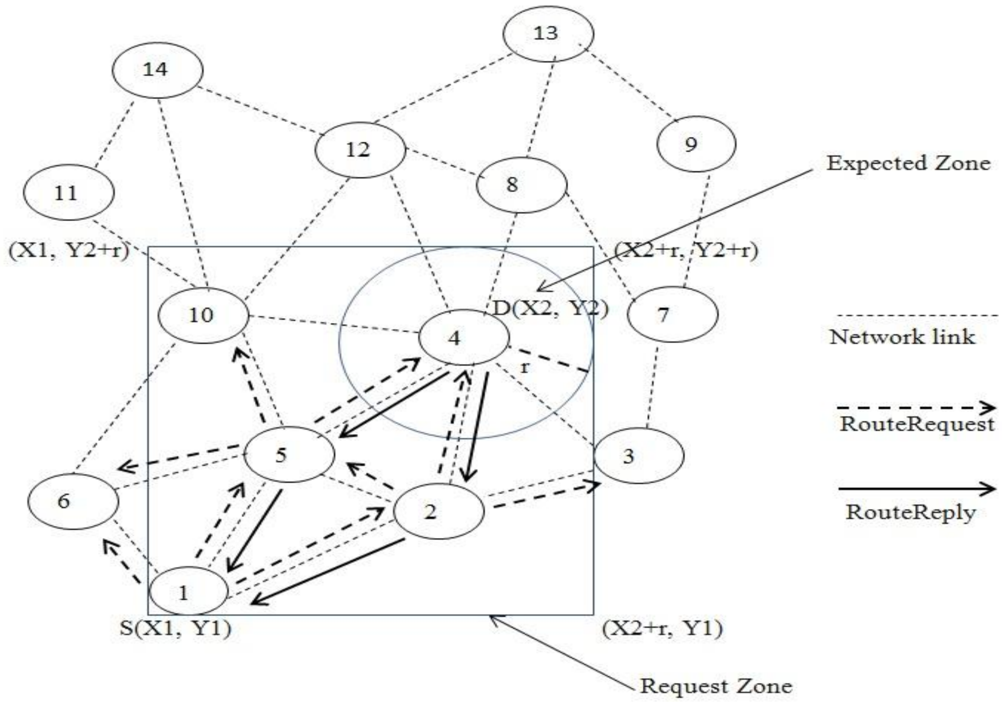

Fig. 2.7 RequestZone and ExpectedZone in LAR1 [2]

- **LAR2:** In LAR2 algorithm [2], source node does not contain the explicit information about the ExpectedRegion. In RouteRequest packet, the source S includes the distance between itself and the destination D. This RouteRequest packet also contains the (X, Y) coordinates of the destination node D. Source node broadcasts this RouteRequest packet to the neighbor nodes. When an intermediate node receives this RouteRequest packet, it computes the distance from itself to the destination node D. An intermediate node takes forwarding decision based on distance. If this distance is less than the distance from S to node D, then the RouteRequest is forwarded. Otherwise, the RouteRequest is discarded [2]. From Fig. 2.9, the RouteRequest packet is originated by node 5. This packet is received by neighbor nodes 1, 2, 4, 6 and 10. After receiving the packet only nodes 4 and 10 find that the distance between them and the destination is less than the distance between the node 5 and destination node D. The other nodes 1, 2 and 6 discard the RouteRequest packet. The distance between the forwarding node and D is updated in the RouteRequest packet for further transmission. An intermediate node 4 forwards the RouteRequest packet after updating the packet with the distance between itself and the destination node D. When this packet is received by neighbor node 3, is discarded because the distance between node 3 and the node 8 is greater than the distance between node 4 and the node 8. After reaching the RouteRequest packet at node 8, it originates a RouteReply packet back to the source node 5, containing the path through which future data packets are to be propagated [2].

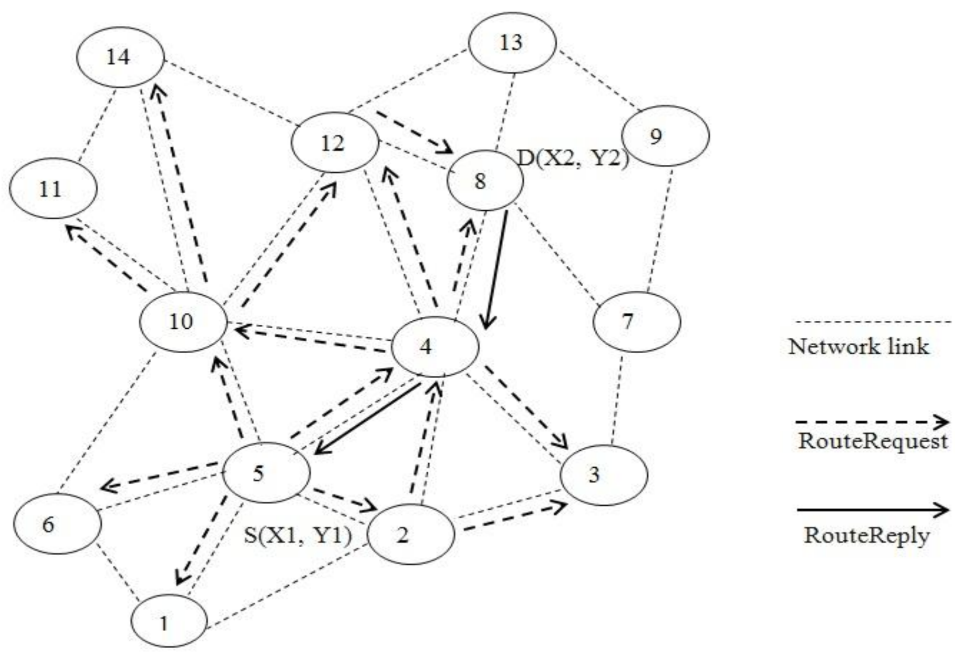

Fig. 2.8 Route establishments in LAR2 [2]

Chapter 3

PROPOSED POSITION BASED ROUTING ALGORITHM

Wireless sensor networks consist of a large number of small, low-cost, radio equipped, battery-powered sensors. These sensors are called nodes. After deploying of these nodes they have to localize themselves and form a network autonomously. If any event happens in the network area, it must be detected by a node. The information regarding the event must forward towards the destination.

Because of limited transmission range, it may be possible that the destination node is not in the direct transmission range of a node that wants to send packets. For transmitting a packet, intermediate nodes participate and forward the packet towards the destination.

Bandwidth is most consideration part when designs a protocol. The protocol must fulfill the requirement of application but in an efficient way. There should not be unnecessary control packet overhead.

Other most important consideration is energy, since each node has limited energy. Once the nodes are deployed in the area, they should work for a long time. So the protocol should be designed such that, there is efficient use of energy.

One more consideration is scalability, because WSNs consist of a large number of nodes. They may be hundreds or thousands in numbers. So the protocol must be scalable. If any number of nodes come into the network, it should maintain the behavior.

In position based routing, the existing protocols have some drawback as already discussed above. The proposed algorithm overcomes these drawbacks and solves the problems related to the issues of network in WSNs.

- The proposed protocol used the greedy forwarding approach that restricts the flooding. A greedy node is selected and the packet is forwarded towards the destination. So it saves the bandwidth by avoiding unnecessary transmission.

- The proposed protocol used the concept of clustering in a zone. By using clustering it saves the energy. After a time period, some nodes in a zone go to sleep mode.

- The proposed protocol solves the looping problem because the packet forwarding nodes are always selected in forwarded direction. So there is no possibility of creating a loop.

- The proposed protocol ensures the guaranteed delivery of packets. After getting a packet, a node sends an acknowledgement to the node from which it receives a packet.

- It is scalable also. Any number of nodes can be connected to the network.

The location of nodes may be available by using GPS if nodes are equipped with a small low power GPS receiver. Each node knows its own location, its neighbor location and destination location.

3.1 The Proposed Routing Algorithm has Three Phases

Phase 1: Network area is divided into fixed size of zones such that all the nodes that exist in a zone are in Transmission range R of each other.

Phase 2: In each zone, selection of VIP node.

Phase 3: Forwarding of packet from one zone to another.

3.2 Calculation of the Size of a Zone

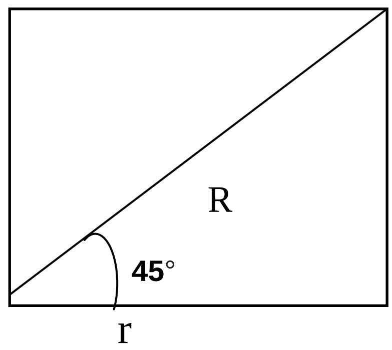

Fig. 3.1 Size of zone

$$r = R \cos 45°$$

$$r = R / \sqrt{2}$$

The procedure of selection of VIP node is as follows:

- Each node in its zone calculates a Priority value P by using a formula

$$P = \frac{Ni}{d}$$

  Where, Ni is the total number of neighbors of a node, in the next zone.
  d is the distance of a node from destination.

- The node that has a highest Priority value P gets high priority to become a VIP node.
- Now all the nodes in the same zone exchange this information (Priority value P) and decide the priority and select a VIP node with highest Priority value P.
- In the zone where destination node exists, there is no need of VIP node.

3.3 Function of VIP Node

- This VIP node will be in ACTIVE mode and responsible for selecting a node in next zone and forwarding the data to that node.
- This VIP node uses DIR greedy forwarding method to forward the data to the next zone.
- If any link gets failure then VIP node selects another suitable link, because VIP node has multiple links.

3.4 Working of Algorithm

- If any sender node S wants to send data to destination node D, it will send data to its VIP node.
- Now this VIP node selects a node in next zone and forwards the data through this node.
- If the VIP node of the next zone is in the transmission range of the VIP node of previous zone then the data is forwarded directly to the VIP node of the next zone.
- After getting the data, this node sends an ACK message to the VIP node of previous zone and this current VIP node sends an ACK message to the sender of data.
- Now this VIP node waits for a fixed time period.
- If during this period, VIP node does not get any data from any node this VIP node sends SLEEP message (For energy saving) to the entire nodes existing in its zone.
- The current node (that holds the data, if it is not VIP node) sends this data directly to its VIP node.
- If the destination node D is in the transmission range of VIP node of previous zone, then this VIP node directly transmits the data to the destination node.
- Otherwise, this VIP node uses the DIR forwarding method and selects one node in destination zone and forwards the data to that node. After that this node transmits data to destination node D, since D is in the range of that node.
- This process is repeated until the data reaches at the destination node D.

3.5 Advantage

- It reduces the control packets overhead.
- Guaranteed delivery of data.
- Robust: It is robust because VIP node has multiple links, if one link gets failure then VIP node selects another link.
- Energy saving: It saves energy by making some nodes in sleeping mode.
- No loop formation: It is loop free since data is forwarded to nodes lying towards the destination.
- Restricted flooding.
- Scalable: It is scalable in terms of number of nodes in the network.

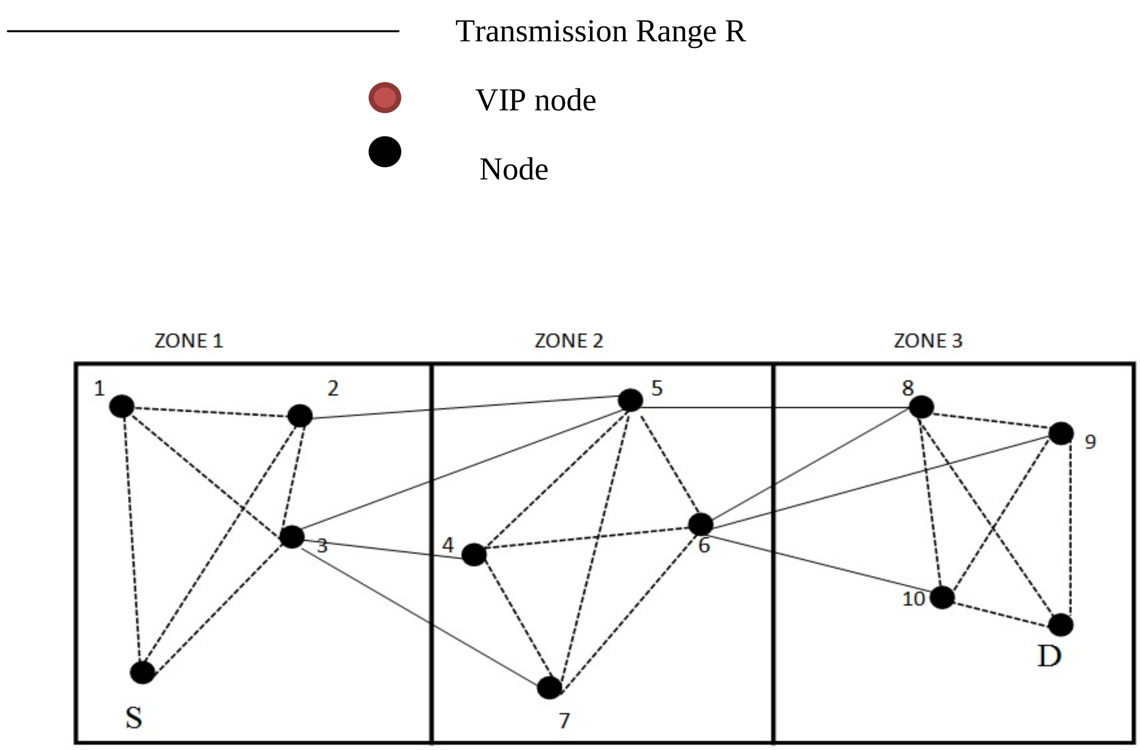

Fig. 3.2 (a) Zone division

- Fig. 3.2 (a) shows that the whole network area is divided into the fixed size of the zones.

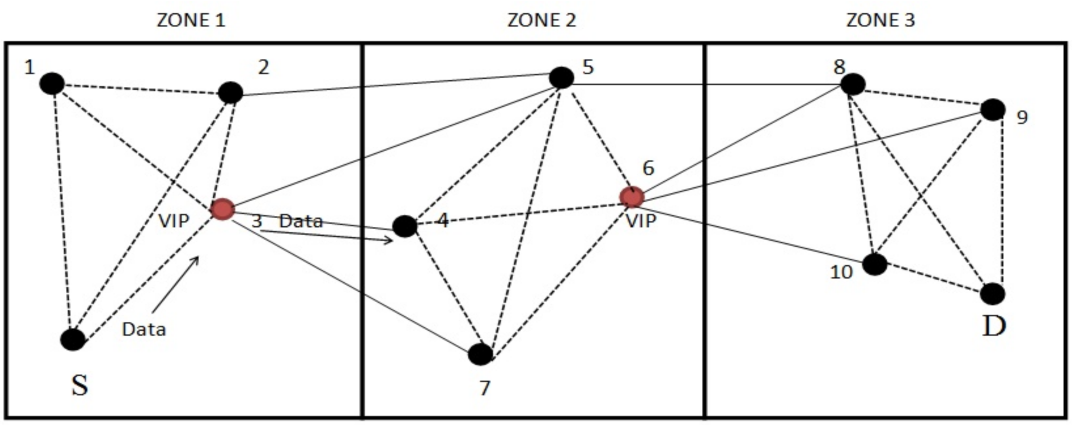

Fig. 3.2 (b) VIP node creation

- Fig. 3.2 (b) shows that after creating the zones, a VIP node is selected in each zone except the destination zone.

- Source node S sends the data to its VIP node and this VIP node selects the next node in next zone and forwards the data to it.

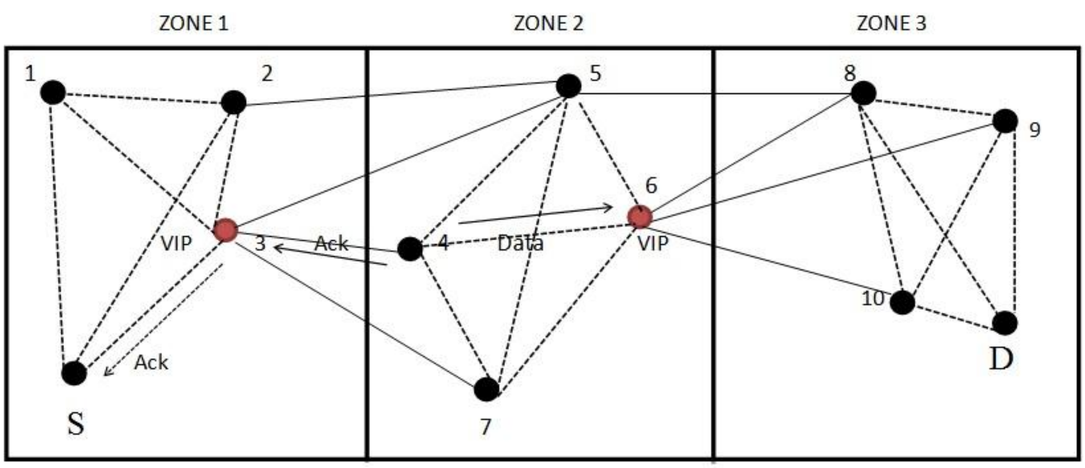

Fig. 3.2 (c) VIP node working

- Fig. 3.2 (c) shows that, after getting the data a node sends an ACK message to the VIP node of previous zone.
- VIP node sends the ACK message to the source node.

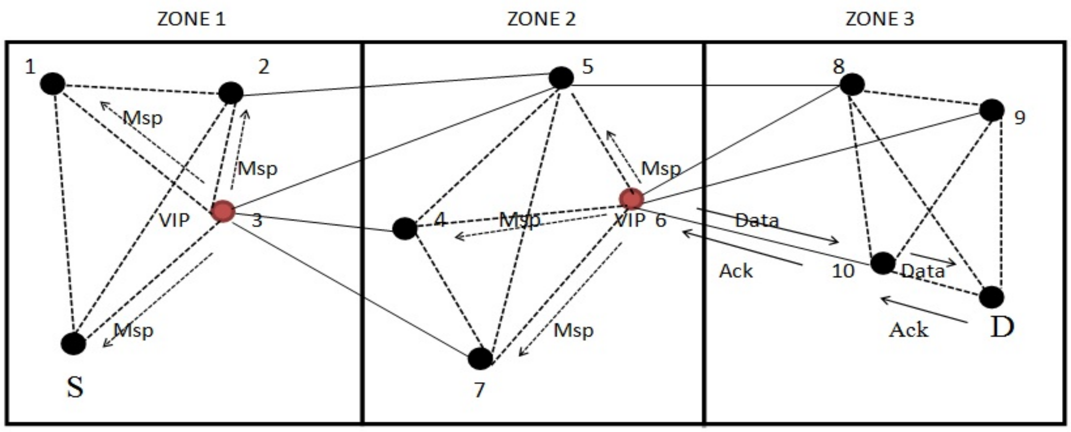

Fig. 3.2 (d) Data at destination

- Fig. 3.2 (d) shows that, VIP node waits for a fixed time period.
- If during this period VIP node does not get any data from any node, this VIP node sends SLEEP message to the entire nodes existing in its zone.
- Data is transmitted to the next zone and ACK message is sent back to a node that sends the data.

3.6 VIPAlgorithm

```
// Structure of coordinate
 typedef struct Cord
{
   float X;
   float Y;
} Cord;

// Structure of Zone
typedef struct Zone
{
       int name;
       Cord A;
       Cord B;
       Node VIP;
        Node *N;       // front pointer to the node link list
 } Zone;


// Structure of Node
typedef struct Node
{
     int  NodeAdd;
     Cord C;
 } Node;

typedef struct NodeAdd
{
 int i;
} NodeAdd;
```

/* Algorithm to create number of zones in a simulation area, so that within a zone all nodes are in direct Transmission Range R*/

```
struct Zone* CreatesZones(Cord A, Cord B, float R)
{
    Front= NULL;
    Rear =NULL;
    float X=A.X;
    int i=0;
   while(X<B.X)
     {
        i++;
        X=X + R/√ 2;
        struct Zone *Z;
        Z= (struct Zone *) malloc(struct Zone);
        Z→ A.X=A.X;
        Z→ A.Y=A.Y;
        Z→ B.X=X;
        Z→ B.Y=A.Y;
        Z→ name=i;
        Z→ next=NULL;
         if (Front==NULL)
          {
             Front=Z;
             Rear=Z;
           }
           else
           {
                Reae →next=Z;
```

```
                Rear=Z;
            }
        }
                return Front;
    }
```

/* This function returns the node pointer which points to the link list of nodes, exists within that zone */

```
Node * Nodeswithin_zone(Zone Z, NodeInfo I)
{
    Front=NULL;
     for ( all nodes  // info get from I)
         {
          Node X=get from I ;
            if (X.C.X >=Z.A.X && X.C.X<=Z.B.X)
              {
                    1.   Link  this node X in its link list.
                    2.   Set the link pointer.
                    3.   Set the Front pointer.
               }
                        return Front;
             }
   }
```

// Algo to set Node pointer for each zone

```
void set_Nodepointer()
{
       Zone *Z1;
       Z1=Front;
       Node *N;
```

```
    while( Z1 !=Rear)
      {
        N=Nodeswithin_Zone(Z1, Nodeinfo  I)
        Z1 →N=N;
        Z1= Z1 →next ;
      }
  }
```

//Algo to find VIP node in a Zone

```
Node VIPfind(Zone Z)
{

  1. Define array of size of number of nodes in a zone and store all Nodeadd in
     it.
     Array Node [no. of nodes in zone]; // set all nodes  Nodeadd in it
     if( Destination node D is not in this zone)
      {
        for ( all the nodes in Array)
          {
            1. For this node, find the number of nodes in the next zone which
               are in transmission range and store it in Ni.
            2. Find the distance of this node from destination node and store it
               in Di.
            3. Find  Pi
                              Pi=Ni / Di;
            4. Store it in Array A [no. of nodes].
            }
            Now in Array A [no. of nodes], find the Pi with maximum value.
            Corresponding node i will be considered as VIP node of this zone.
             Then set Zone i.VIP=node i;
          }
```

```
}

// Algo to Forward a packet from one zone to next zone
void Zone_toZoneforward(Zone Z1 , Zone Z2 , packet)
{
    if(Z2 is the destination Zone)
      {
        1. NodeAdd N= Z1.VIP;
        2. Link list L is created which store the nearest or one hop neighbor
           of VIP node N.
        if( Above list contain destination node D)
          {
            1.  Direct transfer of packet from VIP node of Z1 to
                destination node.
            2.  Call BackAck(NodeAdd N1, NodeAdd N2);
          }
          else
            {
             1.     Apply DIR to find next hop in this zone and transfer packet
                    to it.
             2.     Call BackAck(NodeAdd N1, Nodeadd N2)
             3.     Direct transfer of packet from that node to destination.
            }
                exit;
        }

      else
        {
         1.    NodeAdd N= Z1.VIP;
         2.    Link list L is created which store the one hop neighbor of
               VIP node N.
```

```
                    if(above list contain next zone VIP node)
                    {
                    1. Transfer the packet from  VIP of Z1  to VIP of Z2.
                    2. Call BackAck(NodeAdd N1, NodeAdd N2);
                    3. Call  Zone_toZoneforward(Zone Z2, Zone Z2+1, packet);
                      }
                else
                {
                 1.  Apply DIR to find next hop.
                 2.  Transfer packet to it.
                 3.  Call BackAck(NodeAdd N1,NodeAdd N2);
                 4.  Call Zone_InZoneForward(NodeAdd N, packet, Zone Z);
                 5.  Call Zone_toZoneForward(Zone Z2, Zone Z2+1, packet);
                 }
            }
        }
```

// Algo for Acknowledgement

```
void BackAck(NodeAdd N1, NodeAdd N2)
{
  Transfer Ack message from node N2 to node N1.
}
```

// Algo to Forward a packet from one node to VIP node in a Zone.

```
void Zone_InZoneForward(NodeAdd N, packet, Zone Z)
{
    1.  NodeAdd N1=Z.VIP
    2.  Transfer packet from Node N to Node N1( VIP node) i.e. direct transfer.
    3.  Call BackAck(NodeAdd N, NodeAdd N2);
 }
```

Chapter 4

SIMULATION AND RESULTS

4.1 Assumptions

- Each node is equipped with a low power GPS receiver to know the location of the node.
- All nodes in a network are homogenous.
- In an environment, there is no packet loss.
- Battery life and processing capabilities are capable enough to meet the network environment constraints.
- Mobility model here is of simple type where nodes movement is low.
- In this work, we are only concentrating on data delivery. So, we are ignoring **Ack** and **Sleep messages** proposed to increase node's efficiency in this algorithm.

4.2 Simulation setup

This chapter provides a description of simulation and result for the proposed VIP routing algorithm. This proposed VIP algorithm is an improvement on LAR1 in respect of generating control packets. The tool used to simulate our work is open source simulator GlomoSim.

The simulation parameters used for studying VIP algorithm in GlomoSim are as below:-

Parameters	Values
Area	1000 X 300
Nodes	100
Mobility Model	Random way point
Speed	5 to 10 (m/s)
Transmission Range	250 m
Traffic type	CBR

Fig. 4.1 Simulation setup

The proposed algorithm mainly focuses on the improvement in control packets generation. Thus we here analytically analyze the improvement in our protocol over LAR1 in respect of control overheads, which are a major concern for any routing protocol's scalability, throughput, and delay.

4.3 Discussion Parameters

In our simulation, we compare the performance of VIP algorithm on various parameters like, throughput, end-to-end delay, Packet delivery ratio (PDR) and overheads counts. These performance metrics are then compared against LAR1 with various numbers of established connections in the networks.

Simulation results provide us number of events occurred (E) and execution time (T) of the simulation. These parameters are directly proportional to overhead counts (OC).

$$\mathbf{OC \propto E}$$

$$\mathbf{OC \propto T}$$

$$\text{Thus,} \quad \mathbf{OC \propto E * T} \qquad \textbf{Eq. 1}$$

Thus Eq.1 can be scaled in a way, so that it gives us an idea about the number of packet overhead units. We relatively take it **OC = (E*T/10^6)** for our scaling purpose**.**

4.4 Results

Here, we compare and discusses the VIP algorithm's results in terms of PDR, End-to-End Delay, and overhead associated with its operation.

4.4.1 Case 1: End-to-End delay comparison with LAR1

This comparison provides an idea about our protocol working in terms of average delay associated in comparison to LAR1.

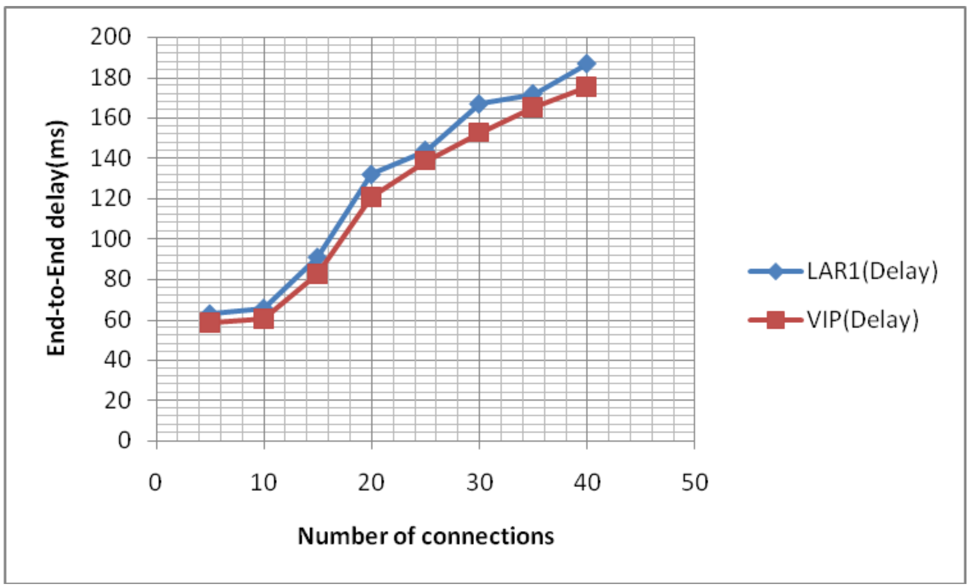

Fig. 4.2 End-to-End Delay

Discussion

Here, the Fig 4.2 represents that as the number of simultaneous connections increases results into increments of average delay linearly. Our proposed algorithm competes LAR1 and even gives better performance.

4.4.2 Case 2: PDR Comparison with LAR1

This comparison provides an idea about our protocol working in terms of PDR associated in comparison to LAR1.

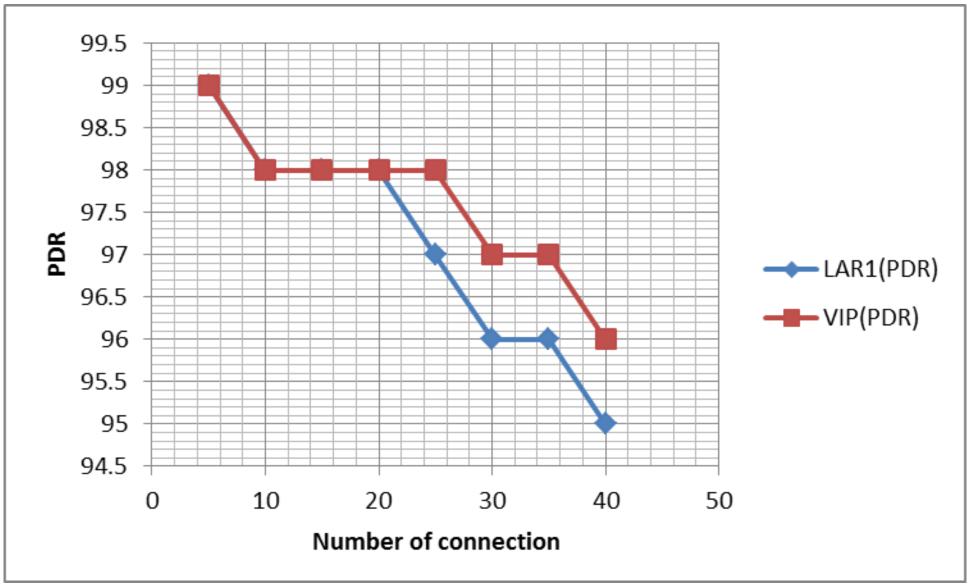

Fig. 4.3 PDR

Discussion

Fig 4.3 shows that for both protocols as the number of simultaneous connections increases in the network PDR decreases. This observation is justified in the way that as the number of simultaneous connections increases the burden on intermediate nodes increases in terms of processing and storage. Thus, results into packet drop.

The comparison between VIP and LAR1 depicts that VIP performs well as comparisons to LAR.

4.4.3 Case 3: Overhead counts Comparison with LAR1

This comparison provides an idea about our protocol working in terms of overhead counts associated in comparison to LAR1's overhead counts.

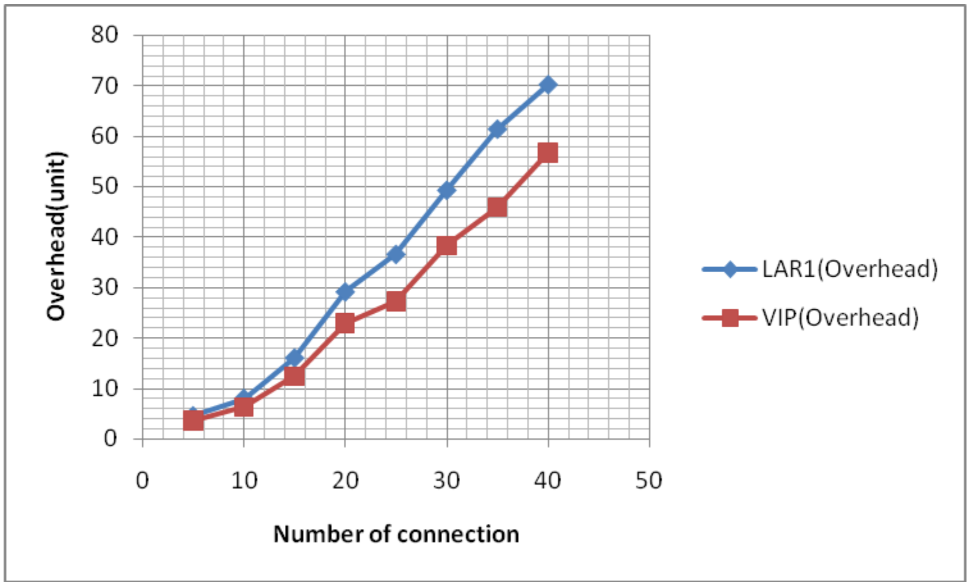

Fig. 4.4 Overhead count

Discussion

Here, finally our results beat the LAR1 protocol in terms of overhead counts associated with network maintenance and route finding. For both the protocols as the number of connections increases number of overheads also increases. Our protocol makes routes from source to destination on demand but maintains and makes route without generating control packets on the network layer. The improvement in our case is 20% to 24%.

Chapter 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

In our work we started with an objective to design a protocol which uses a minimum number of control packets in creating a route from source to destination. Our design and its analysis theoretically prove that the VIP protocol uses a minimum number of control packets on the network layer. In simulation and results analysis we are able to confirm our objective in a satisfactory manner. Control packet overhead in VIP algorithm reduces by 20% to 24% as compare to well-known routing protocol LAR1. It is also observed that VIP algorithm attaining a lower end-to-end delay and higher packet delivery ratio. As our algorithm uses DIR algorithm for forwarding packets only in one direction which results into loop free routing. Our results are satisfactory and fulfill most of our initial stage objectives.

5.2 Future Work

Our algorithm works well for low mobility. So, we want to make it compatible with real life average mobile node speed. This algorithm is very simple and easy to modify as per the application requirement. It can be modified for energy optimization by using SLEEP messages. We want to improve our algorithm in terms of Throughput and PDR by modifying our design, for a mobile environment. As our algorithm finds the route from source to destination on demand but this route may break in a mobile environment. Our algorithm tackles this problem presently by updating route in fixed time intervals. In future we want to optimize the time duration in which once the route is updated, in order to utilize minimum network resources and resolve the above problem comfortably.

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