Performance Evaluation of Location Update Schemes in Mobile Ad Hoc Networks

Khaled Omer and Daya Lobiyal

School of Computer and Systems Sciences, Jawaharlal Nehru University, India

Abstract: *Over the past few years, several position-based routing algorithms for mobile ad hoc networks have been proposed. The success of all these algorithms depends on the availability of up-to-date location information of the nodes in the network. To achieve the requirement of up-to-date location information, many location update schemes have been proposed. Authors of each scheme argue that their scheme is better and scalable for a given network scenario. However, these schemes need to be experimented together for common network scenarios – network size, network density, and network connectivity. In this paper, we present an overview of home agent, quorum based, grid location service, and doubling circles location update schemes. Further, we have proposed a scheme independent metric for performance evaluation of the location update schemes. Based on this performance metric, we have compared the location update schemes referred here and suggest which scheme may perform best for a large network. In the simulation, we use random waypoint mobility model. The results show that home agent scheme performs better than other schemes.*

1. Introduction

Mobile Ad Hoc NETworks (MANET) are a set of wireless mobile nodes that do not require a pre-established infrastructure. They consist of autonomous nodes that collaborate in order to transport information without specific user administration or configuration. Usually, each node in the network acts as a router and as an end system at the same time, thus contributing to and maintaining connectivity of the network.

Due to the frequent change in topologies, routing in MANET becomes a challenging task to deal with. Therefore, to cope with the dynamic change in topology, routing algorithms proposed for MANET use either the information about the links that exist in the network or use of the information about the physical position of participating nodes. The former is known as topology-based routing, and latter is known as position-based routing [9, 13].

In Position-based routing a node works as a location server for routing by keeping location information of either all nodes or only few nodes in the network. The nodes obtain location information of other nodes by exchanging location information based on time, distance or movement [5]. This exchange of location information involves communication overheads. To reduce the communication overheads of location information exchange, the researchers have proposed various location update schemes that are discussed in the next section.

1.1. Related Location Update Schemes

The position based routing algorithms assume that each node knows its physical location. Global Positioning System (GPS) [10] is one of the services that can be used by a node to know its geographical location, if a node is equipped with small low power GPS receiver. In position based routing, each node in the network maintains a database of location information of other nodes. The location databases may contain a node ID, physical location of the node, timestamp, velocity, and direction. There are two types of update schemes: proactive and reactive. In the proactive scheme, each node updates its location servers regularly and independently of destination search, like Distance Routing Effect Algorithm for Mobility (DREAM) [2], home agent, quorum base, grid location service, and doubling circles. Whereas in the reactive scheme, a node updates the location servers while it is searching for the destination like Location Aided Routing (LAR) scheme [6]. In this paper, we consider the proactive update schemes.

Basagni, Chlamtac, Syrotiuk, and Woodward described a DREAM algorithm [2] as an integrated location dissemination and geographic routing system. In this scheme, each node maintains a location database that stores location information about other nodes in the network. A restricted flooding algorithm is used for location updates, so that each node floods messages to update the location information maintained by other nodes. These updates are propagated for varying distances. Moving nodes

originate two kinds of update messages - short distance updates and long distances updates. Short distance updates are generated more frequently than long distance updates. In this algorithm, the precision of a location update for a destination is greatest in nodes near that destination, and least in nodes increasingly far away from the destination. If a node fails to deliver an update message using restricted flooding, it initiates a recovery procedure by using full flooding.

Woo and Singh proposed a geographic location database management strategy for a scalable routing protocol for MANET. In this strategy, each node is assigned a home region. A node registers its location information in other nodes that are located within the home region of this node. Thus, all the nodes within the home region know the approximate location of the registered node. In this scheme, every node sends its location updates to a set of location servers in its home region, and destination search queries are sent also to these location servers. This algorithm is based on a combination of geographical routing and a simple static mapping procedure to maintain approximate location information of the nodes [16].

Haas and Liang proposed a variant of quorum based location management scheme. They used a class of Uniform Quorum System (UQS). In this scheme, location databases are stored in the network nodes forming a self-organizing virtual backbone within a flat network. The databases are dynamically organized into quorums where is any intersection of pair of quorum contains a constant number of databases. A mobile node sends location update messages to the nearest backbone node, which then chooses a quorum of backbone nodes to host the location information. The querying node is guaranteed to obtain at least one response with desired location information due to the quorum intersection [4]. Later, Haas and Liang proposed another update scheme called Randomized Database Groups (RDG). In this scheme, in response to location update or destination search, a node's location information is written or read respectively, from a group of randomly chosen databases comprising a virtual backbone with a flat network [3].

In this work, we intend to provide a quantitative performance evaluation of home agent, quorum based, Grid Location Service (GLS), and doubling circles update schemes. These schemes are evaluated using connectivity based and density based approaches since home agent and quorum based schemes are originally proposed with connectivity-based approach, whereas GLS and doubling circles schemes are proposed with density based approach.

2. Details of Location Update Schemes

In this section we give the details of the update schemes that are studied in our paper.

2.1. Quorum Based Location Update Schemes

In quorum systems, information updates are sent to a group (quorum) of available nodes, and information queries are sent to another quorum. Therefore, updated information can be found only at the nodes available at the intersection of these quorums.

Given a set S of location servers, a quorum system is a set of m subsets of S whose union is S and intersection is non empty, namely $S_0, S_1, \dots ,S_{m-1}$; such that:

$$\bigcup_{i=0}^{m-1} S_i = S$$

$$S_i \bigcap S_j \neq \Phi \qquad for \quad 0 \leq i, j \leq m-1$$

Stojmenovic and Pena described quorum based location information management scheme. This scheme is based on replicating location information of a node at multiple nodes acting as location servers along north and south directions of a node updating its location servers, i. e., column of current location of the updating node with certain thickness of reporting. In this scheme, movement based strategy for triggering update is used [5]. Therefore, a location update is triggered whenever a link or edge is broken or created. When a link is created or broken, a moving node forwards message containing its new location to all nodes located in the north and south direction (column) of its current location. The destination search then begins by sending two messages. One of these messages is sent in the east and west direction (row) of the source node with certain thickness, looking for most up-to-date location information of destination. Then at least one location server can be found at the intersection of the updating column and the row on which destination search is performed. This information obtained from destination search is further used to continue the route search for the destination. Other message can be sent directly from source to destination using available location information with the source [15].

2.2. Home Agent Based Location Update Scheme

The concept of home agent scheme is similar to the one used in cellular phone network and mobile IP. Stojmenovic proposed a home agent based strategy for location updates and destination searches. In this scheme, each node selects a certain circular area as its home agent, and informs other nodes about it. Therefore, when a node moves away to a new location, it sends regularly its location update messages only to the nodes located within its home agent using greedy algorithms [8, 13]. For destination search, a source node sends a query message toward its home agent, which supplies the latest available location information about destination, and then the request is forwarded

toward destination to complete the destination search [11].

2.3. Doubling Circles Scheme

Amouris, Papavassiliou, and Li proposed a position based multi-zone routing protocol for wide area mobile ad hoc networks. In this protocol, a set of routing zones (circles) is defined for each node, where the ith routing zone is a geographic circle with radius $R(i)$ such that $R(1) < R(2) < R(3) < .. < R(i-1) < R(i)$. Their algorithm is based on position updates within circles of increasing radii with the current radius is double of the previous one. Each node updates its location to all nodes located within circles of radii R, 2R, 4R, 8R, etc. Location update takes place when a given node moves outside one of these circles of radius $2^i R$ for some i. Therefore this node broadcasts its location to all nodes available inside the circle centered at the current node position, and with a radius $2^{i+1} R$. We note that the circles with larger radius include almost all nodes of the network [1].

2.4. Grid Location Service Scheme

Li, Jannotti, De Couto, Karger, and Morris described a distributed location service called Grid's Location Service (GLS). This scheme is similar to the doubling circles scheme, where the researchers use squares instead of circles. In this scheme, they divide the area that contains the network into a hierarchy of squares called first order square, second-order square, and so on till n^{th} order square. An ith order-square is made of four $(i - 1)$ squares and so on. Each node selects a small set of nodes as its location servers with ID's closest and greater than the ID of the node distributed in three squares belonging to the same order-squares excluding the square in which the node exists. Therefore, each node updates its location servers with its current location information when it moves a threshold distance using geographic forwarding algorithm. A node sends its new position to the location servers without knowing their actual identities, by using a predefined ordering on node identifiers and a predefined geographic hierarchy. A node can direct a location query to a known node with ID nearest to the ID of destination node by using predefined identifier ordering and predefined geographic hierarchy [7].

3. Performance Metrics

To analyze the performance of location update schemes, several update scheme independent metrics are proposed. To update location information between nodes far apart from each other multi-hop routing is needed. Any routing algorithm can be used for transmitting location information. Therefore, success of a location update also depends on the routing

algorithms. However, effect of routing algorithms on performance of location update schemes is not considered within the scope of the current study. Hence, in our study, we have used GEographic DIstance Routing (GEDIR) algorithm that is common in all update schemes. GEDIR is a greedy algorithm [8, 13] that forwards a packet from the current node to a neighbour whose distance to the destination is minimum. Therefore, we propose the following quantitative metrics for performance evaluation:

3.1. Percentage of Successful Updates

It is defined as the total number of successful updates divided by the total attempts number of updates. It shows the ability of a scheme to provide an up-to-date location information to be used for efficient routing. An update scheme with higher percentage of successful updates will provide most recent location information of nodes.

3.2. Average Hop Count

It is defined as the total number of hop count divided by the total number of successful updates. It is approximately the time needed to update the location servers, and signifies the end-to-end delay involved for a given successful update. A network with lower average hop count will transmit the location update messages faster.

3.3. Average Update Cost

It is defined as number of update messages that participates in originating, forwarding and broadcasting location information in a particular zone divided by the total number of successful updates in the network. This result is further, divided by the number of nodes in the network. Thus, average update cost is defined as the total number of update messages per successful update per node. A scheme having lower average update cost will efficiently use the scarce resources of the network such as battery power, bandwidth, etc.

3.4. Database Size per Location Server

Database size or average number of entries per location server is defined as the average size of the database in each node of the network. This signifies workload time on each node to perform searching and updating of up to date location information in the database of the node. Lower number of entries in location server will make searching and updating in the database of the node faster.

3.5. Percentage of Update Failures duet o Non-Availability of Location Servers

It is defined as the updates failure due to non-availability of location servers divided by the total attempts of updates. An update may fail either due to the limitation of a routing algorithm used for transmitting location information or due to the non-availability of a location server. Availability of a location server depends on the location update scheme used. In our study, we consider the non-availability of a location server since routing algorithm is common in all schemes.

4. Simulation Environment and Experimentation

Each location update scheme is implemented in C++ programming language using discrete-event simulation. In this section we give details of the simulation and the experimentation for location update schemes.

4.1. Simulation Environment

In our simulation, a random unit graph (A graph with randomly distributed vertices where each edge is of unit length) is used to represent the network, such that each node has equal transmission range R. For each graph, n nodes are randomly distributed in the square region, such that all nodes are allowed to move only within this square region. Therefore, n nodes select their x and y coordinates at random from a given interval [a, b].

The mobility model for movement of nodes is random waypoint model that is similar to the one discussed in [12]. Each node selects a random number *wait* in interval [0, *maxwait*]. This node does not move for *wait* seconds. When this time expires, the node generates a random number *travel* in interval [0, *maxtravel*], and then the node generates a new random position within the same area. Then the node moves from its old position to new position along the line joining them at equal speed for the duration of *travel* seconds. When the node arrives at a new location, it repeats the mobility model as described above. The *mobility rate* is given by the formula:

$$Mobrate = maxtravel / (maxtravel + maxwait)$$

GEDIR algorithm is used for searching and updating location servers for different update schemes. As in [1, 14, 15], no link details like MAC protocols are modeled. We assume that no collisions occur in any of simultaneous message transmissions, and all transmitted messages are correctly received. This is because we have used single path routing strategy and one routing task at a time. Therefore, even if we implement MAC layer, there will be no collision within the routing traffic.

In our simulation we have used two approaches – connectivity based and density based. This is because home agent and quorum based schemes are originally proposed with connectivity based approach, whereas GLS and doubling circles schemes are proposed with density based approach. We have simulated all schemes for both approaches.

4.1.1. Connectivity Based Approach

In connectivity based approach, the degree d of a node (i. e., the average number of neighbours of a node in the network) becomes part of the network scenario. In this approach, a given number of nodes is uniformly distributed over a fixed geographic region maintaining average degree of nodes constant in the network. In this approach the transmission range R (approximately) is obtained using the formula:

$$\pi * R * R * (n - 1) = d * Area$$

Therefore, the transmission range varies proportionately as the average degree of the network varies.

4.1.2. Density Based Approach

In density based approach, the number of nodes distributed per unit area is constant. Here nodes are uniformly distributed keeping the density fixed. Transmission range R of a node is considered constant.

4.2. Experimentation

In our experiments, we have selected the column thickness (north-south direction) for quorum-based scheme such that this zone is approximately equal to that of the home agent scheme. Thus we have taken this thickness as 10% of the total network area. The threshold value of number of links created or broken for triggering column update is taken to be 5.

In home agent, we have selected home zone in the form of a circle with the area to be the same as that of a column in quorum based scheme. The threshold value for the number of links created or broken for triggering updates in the home agent zone is same as in quorum scheme.

In GLS, first order square side is taken equal to the transmission range (i. e., 250 meters). The threshold value of distance for GLS triggering update is set to 200 meters for the second order square, 400 meters for the third order square. Thus for each order we are doubling the distance of previous threshold value.

In doubling circles, core zone area is taken equal to the transmission range (i. e., 250 meters). Doubling circles scheme triggers update when a moving node crosses one of the circles zones.

As described in the simulation environment, mobility model considered for movement of the nodes is the random waypoint model. In this model *maxwait* and *maxtravel* are two constants. In our experimentation, we have taken *maxtravel* equal to 100 seconds and *maxwait* also equal to 100 seconds such that the mobility rate (*Mobrate*) remains 50%. We have fixed the speed of nodes to 10 meters per second (simulation clock tick). An experiment is conducted for 1000 seconds and it is repeated for 10 runs.

4.2.1. Connectivity Based Approach

In connectivity based approach, a number of nodes *n* in the network is considered 200 and average node degree *d* varies as 4, 6, 8, ..., 20 for experiments. Here network area of 1414 * 1414 square meters is considered for experimentation so that the density of network remains the same as that used in GLS scheme. For each graph, *n* nodes are randomly distributed in square region with edges of 1414 meters. All nodes are allowed to move only within this square region. Therefore, *n* nodes select their *x* and *y* coordinates at random from interval [0, 1414].

4.2.2. Density Based Approach

In density based approach, we have chosen implementation parameters same as those used in GLS scheme [7]. The density of 0.0001 nodes per square kilometers, and transmission range of 250 meters are used. The number of nodes *n* in the network is varying as 100, 200, 300, 400, 500, and 600.

5. Results and Discussions

In this section, the results of experiments for both connectivity and density-based approach for the four location update schemes under study are discussed.

5.1. Connectivity Based Approach

The results of each metric for connectivity based approach along with graphs are discussed below.

5.1.1. Percentage of Successful Updates

Figure 1 gives percentage of successful updates. It describes that GLS has minimum successful updates and other three schemes have closer and better successful updates, with home agent has the best result. In GLS scheme, a node will have one location server for each square of the three squares of order-i square with ID of the server be the least and greater than that of the node. This criteria in GLS reduces the probability of finding servers in this scheme than that of finding servers for the other schemes

5.1.2. Average Hop Count

Figure 2 illustrates average hop count for different schemes. GLS scheme has maximum hop count, where as home agent scheme has minimum hop count. In GLS scheme, first hop count is sum of hops between the node and its location servers in different squares of different orders, and second successful updates are least in GLS scheme. But home agent has minimum average hop count, because hop count contains hops from source node to its home zone plus hops inside its home zone.

5.1.3. Database Size or Number of Entries

Figure 3 gives database size or data entries per location server. It is clear that GLS scheme is having the least number of entries and doubling circles scheme has a number closer to the total number of nodes of the network. In GLS scheme each node works as a location server in a particular square for other nodes with IDs less than the ID of the node. In addition, there may be at most one location server for a given node per square in grid. For doubling circles, each node works as location server for most of the nodes in circle zones.
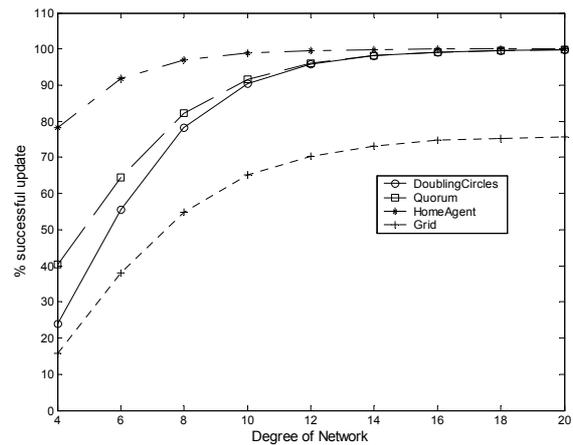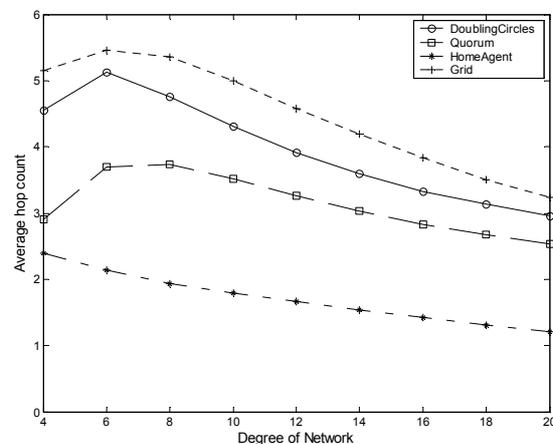

Figure 1. Percentage of successful updates.

Figure 2. Average hop count.

5.1.4. Percentage of Update Failures Due to Non-Availability of Location Servers

In Figure 5, we examined the update failures due to non availability of location servers. Practically, this points out that the location servers of a node are not updated with current location information, and this results in reduction of successful queries for destination. In the figure, GLS scheme shows high update failures compared to home agent and doubling circles schemes with zero update failures. This is because in GLS scheme, each node selects location server with ID's closest and greater than its ID (which is not available always), whereas other schemes do not have such restriction.

5.1.5. Average Update Cost

In Figure 4, we compared average update cost for the schemes under study. The results show that doubling circles scheme has more average update cost. This is because doubling circles uses flooding to update location servers in a given zone. Home agent has small average update cost since update messages are forwarded along the path from a node to its home zone and then broadcast within the home zone. But in GLS, the routes between a node and its location servers in different squares contain more update messages and in each ith order square, three servers are updated at most. Therefore, average update cost in GLS is lower than doubling circles, and higher than home agent

5.2. Density Based Approach

The results of each metric for density based approach along with graphs are discussed below.
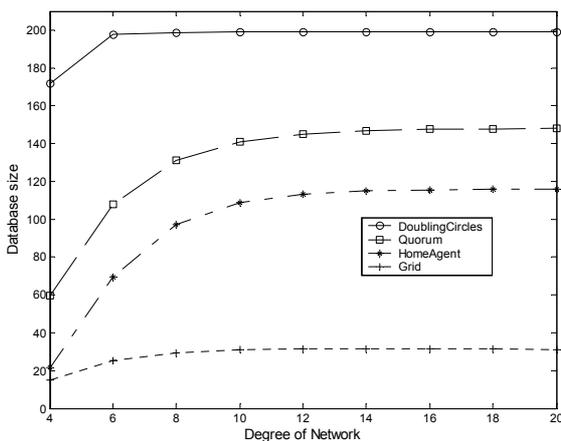

Figure 3. Database size.
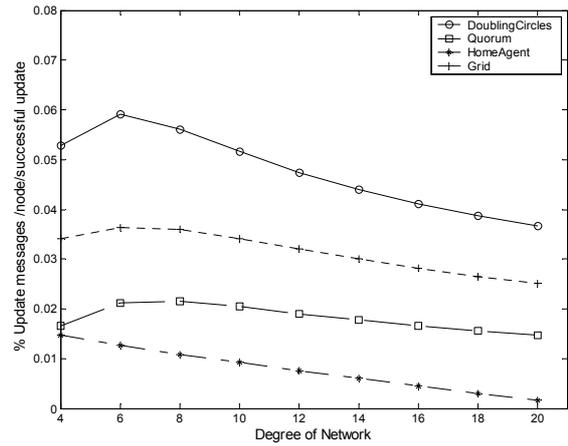

Figure 4. Average update cost.

5.2.1. Percentage of Successful Updates

Figure 6 gives percentage of successful updates. It describes that GLS has minimum successful updates and the other three schemes have closer and better successful updates. This is because, in GLS scheme a node will have one location server for each square of the three squares of order-i square with ID of the server be the least and greater than that of the node. The probability of finding this server in GLS scheme is less than that of finding servers for other schemes.

5.2.2. Average Hop Count

Figure 7 illustrates the average hop count for different schemes. GLS has maximum hop count since the hop count is sum of hops between the node and its location servers in different squares of different orders, and number of successful updates is least in this scheme. But home agent has minimum average hop count, because hop count contains hops from the node to its home zone only plus hops inside its home zone.
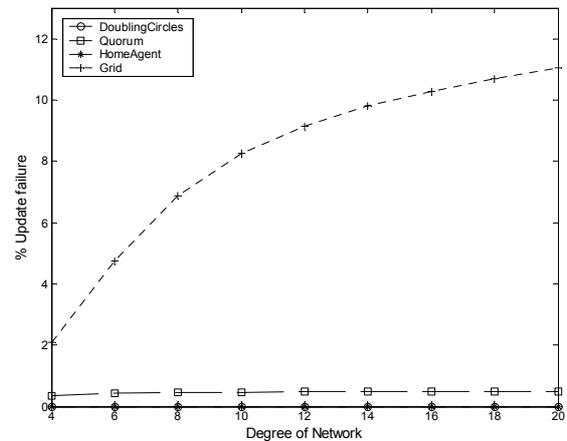

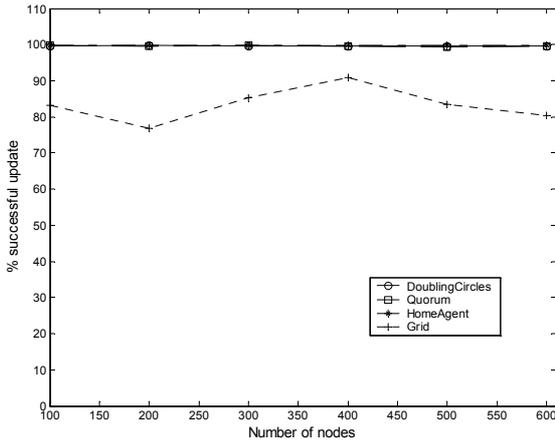Figure 5. Update failures due to non availability of location server.

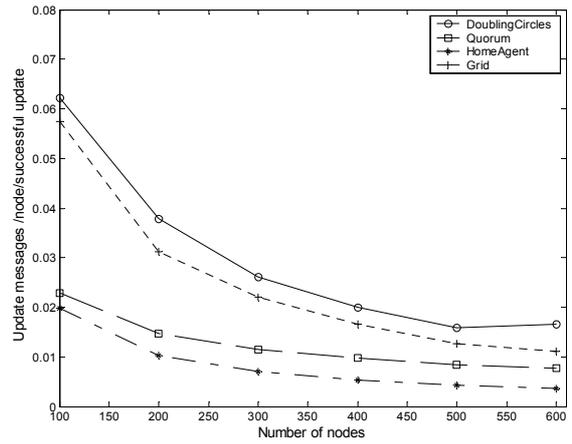Figure 6. Percentage of successful updates.

Figure 9. Average update cost.

5.2.3. Database Size or Number of Entries

Figure 8 gives the number of data entries per location server. It is clear that GLS scheme is having least number of entries and doubling circles scheme has a number closer to total nodes of the network. In GLS scheme, each node works as location server in a particular square for nodes with IDs less than the ID of the node. In addition to this, there may be at most one location server for a given node per square in the grid. But for doubling circles, each node works as location server for the most of the nodes in circle zones.
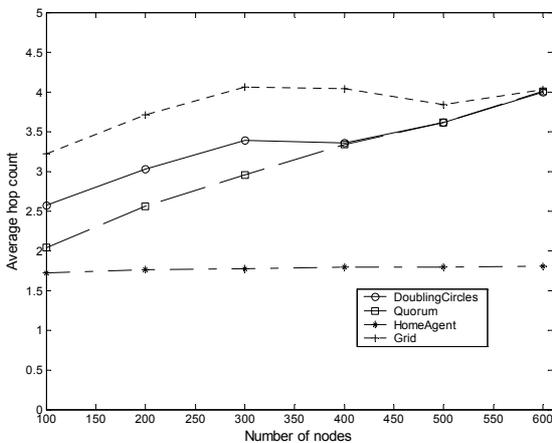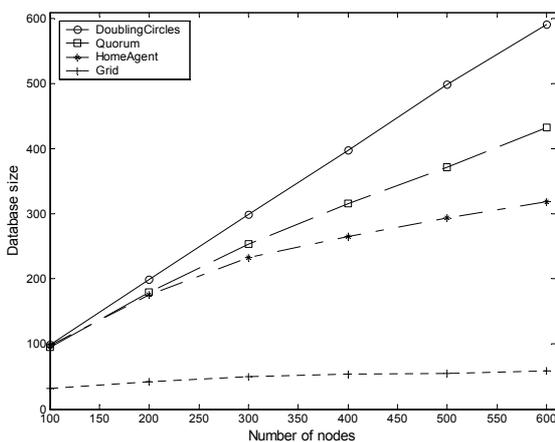
5.2.4. AverageUpdate Cost

In Figure 4, we compare average update cost for the schemes under study. The results show that doubling circles scheme has more average update cost compared to other schemes. This is due to that doubling circles uses flooding to update location servers in a given zone. Home agent has small average update cost since update messages are forwarded along the path from a node to its home zone and then broadcast within the home zone. But in GLS, the routes between a node and its location servers in different squares contain more update messages and in each ith order square, three servers are updated at most. Therefore, average update cost in GLS is lower than doubling circles, and higher than home agent.

5.2.5. Percentage of Update Failures due to Non-Availability of Location Servers

In Figure 10, we examine update failures due to non availability of location servers. GLS scheme has high update failures compared to home agent and doubling circles schemes with zero update failures. This is because GLS scheme selects its location server based on a given criteria (i. e., can not be satisfied always) where as other schemes do not have such criteria.
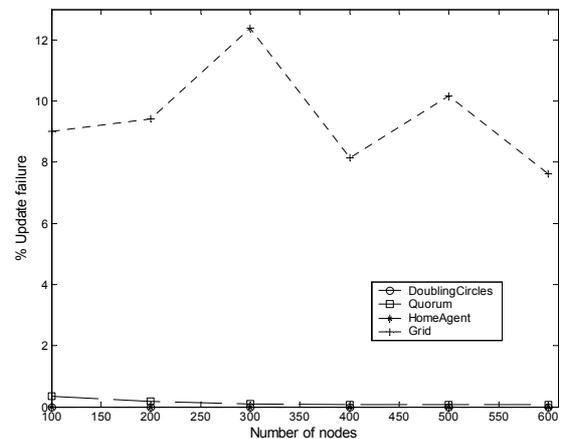

Figure 7. Average hop count.

Figure 8. Database size.

Figure 10. Update failures due to non availability of location server.

6. Conclusion

In this paper, we have conducted a study to evaluate the performance of four location update schemes in MANET. Simulations are run for different scenarios based on connectivity and density approaches.

According to the above results and discussion, we found that home agent scheme outperforms quorum based, GLS and doubling circles schemes.

The study conducted reveals that the home agent based update scheme gives the highest percentage of successful updates. It also takes least number of nodes for transmitting a message and it ensures high availability of location servers. Further, the study also reveals that density based approach is better in terms of successful updates. The performance of the update schemes needs to be evaluated using other routing algorithms for transmitting update messages. No single update scheme under study provides the best results for the entire performance metrics used here in this work. Therefore, possibility of either a new location update scheme or modifications to some of existing ones needs to be investigated.

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Khaled Omer received his BE degree from the University of Aden, Yemen in 1994, MScdegree from Indian Institute of Technology, Kharagpur, India in 1999. He is a lecturer at the University of Aden. Currently, he is a PhD student in the School of Computer and Systems Sciences at Jawaharlal Nehru University, India. His research interest includes mobile ad hoc networks.

Daya Lobiyal received his Bachelor of Technology in computer science from Lucknow University, India, and his Master of Technology and PhD both in computer science from Jawaharlal Nehru University, New Delhi, India. Presently, he is an associate professor in the School of Computer and Systems Sciences at Jawaharlal Nehru University, Delhi. His areas of research interest are mobile ad hoc networks and video on demand.