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PERFORMANCE ANALYSIS OF GEOGRAPHIC ROUTING PROTOCOLS IN HIGHLY MOBILE AD HOC NETWORK

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ABSTRACT

Routing in Mobile Ad Hoc Networks (MANETs) has always remained a challenging task due to its dynamic topology and lack of centralized control. Several routing protocols have been proposed over these years starting with the traditional topology based protocols to the geographic routing protocols. The research over these years shows that the geographic routing protocols like Greedy Perimeter Stateless Routing (GPSR) obtains much better performance compared to all other previous routing protocols. The aim of this research paper is to survey and analyse the performance of various geographic routing protocols in highly mobile ad hoc networks and to perform a comparative analysis using their advantages and disadvantages.

Keywords: *Dynamic Topology, Geographic Routing, Location Information, MANET, Routing Protocols.*

1. INTRODUCTION

MANETs are collections of wireless nodes that can dynamically establish a network at any time at any place without using any fixed infrastructure. This unique feature of MANETs has led to its growing popularity over these years. Applications of MANETS vary from commercial use, private sector to military and emergency purposes. MANETs do not have a centralized control and every node in the network will have to act as a router to find out the optimal path to forward a packet. All the nodes in the network may be mobile, entering and leaving the network at any time and thus the topology changes continuously. As the medium of the communication is wireless, only limited bandwidth is available. Another important constraint is energy due to the mobility of the nodes in nature. MANETs have gained a great deal of attention because of its significant advantages brought about by multi-hop, infrastructure-less transmission. However, due to dynamic network topology and error prone wireless networks, the reliable data delivery in network, especially in challenging environments with high mobility remains an issue. These issues make routing a very difficult and challenging task in MANETs.

Over these years a number of protocols have been proposed to implement routing in these ad hoc networks. Numerous researches have been done over the performance analysis of various protocols in MANETs. Various studies show that the traditional topology based protocols does not perform well in highly mobile environments [1]. Geographic routing has become one of the most suitable routing strategies in wireless mobile ad hoc network mainly due to its scalability and better performance in these dynamic networks [2]. The main advantage with geographic routing protocols is that it does not need to maintain explicit routes. The main approach used in this routing algorithm is greedy forwarding. Geographic Routing (GR) uses location information to forward data packets, in a hop-by-hop routing fashion making use of the broadcast nature of wireless networks. Greedy forwarding is used to select next hop forwarder with the largest positive progress toward the destination while void handling mechanism is triggered to route around communication voids No end-to-end routes need to be maintained, leading to GR's high efficiency and scalability. One of the main issues with GR is that it is very sensitive to the inaccuracy of location information. In the operation of greedy forwarding, the neighbor which is relatively far away from the sender is chosen as the next hop. If the node moves out of the sender's coverage area, the transmission will fail. Face routing strategy has been introduced as a recovery when the greedy forwarding algorithm fails. A

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number of geographic routing protocols and algorithms have been proposed over these years with some variations. Each protocol tries to minimize the limitations of its predecessors and to improve its performance in mobile environments. This research paper performs a detailed survey on the various geographic routing protocols used in mobile ad hoc networks and compares their advantages and limitations.

2. FACTORS AFFECTING ROUTING DESIGN

A number of parameters have to be considered while designing a routing protocol for MANETs. Various challenges of MANETs like lack of centralized control, dynamic topology, error prone wireless channel etc has to be considered while designing and selecting the appropriate routing protocol in the network. Geographic routing protocols give good performance in ad hoc networks. Different geographic routing protocols are designed to suit various ad hoc networks differing in various features [3]. In highly mobile ad hoc networks selection of an appropriate geographic routing protocol is a very tough task and has great importance in the performance of the network. Due to the increasing popularity of these networks, proper selection of routing protocol should be done to provide good Quality of Service to the network.

The various parameters that have to be considered while designing and selecting a routing protocol are listed below.

Support for Mobility: The protocol must be designed in such a way that it should support the highly dynamic nature of the ad hoc networks. The protocol should be able to adapt to the changing positions of the nodes and also must be able to make proper routing decisions for the data packets. Good performance must be guaranteed by the protocol even in highly mobile environments.

Reliable Delivery: This is one of the most important issues faced by the routing protocols in the ad hoc networks. As the nodes constantly change their positions, the protocol has to be designed to guarantee reliable delivery of the data packets over the network.

Packet Forwarding: Forwarding decisions must be made by the protocol in an efficient way considering many factors like transmission range of the nodes, traffic in the link etc.

Lack of Centralized Control: Design and selection of the protocol must be done considering the fact that the ad hoc network does not have a centralized control. Every node can join or leave the network at any time and can move freely throughout the network.

Free of Loops: The routing protocol must make sure that the data send across is not circulated around the network on the same paths or between the same nodes which consider each other equally close to the destination. If proper consideration is not given to issue, performance degradation in the network can occur.

Memory: As the ad hoc network has mobility, routing algorithms with additional memory requirements may face some problem. Maintaining current accurate location information subject to topological changes causes high traffic, queues, congestion, overhead, latency and energy expenditure. Therefore it is desirable to avoid solutions which involve large memory demands at node level

Delay: Protocol must make sure that the delay experienced by the data packets in the ad hoc network is minimum and good performance is guaranteed always.

Guaranteed Message Delivery: In ad hoc networks reliable and guaranteed delivery of data packets is a very difficult task. It would be very difficult for the protocol to make sure that all the data has been delivered properly to the destination.

Selection of Optimal Path: Selection of the optimal path to send the data packet is a very important factor with the routing protocol. The algorithm has to be designed to select the most optimal path to the destination for the data packet.

Overhead: While including all these features and characteristics, the routing protocol must make sure that the additional overhead required is minimum and it does not affect the performance of the network significantly[4] [5].Both the routing overhead and the control overhead should be kept minimum to provide a good performance for the routing protocol in the ad hoc network.

3. GEOGRAPHIC ROUTING PROTOCOLS

3.1 Greedy Perimeter Stateless Routing (GPSR): GPSR is one of the most popularly used Geographic routing protocols in ad hoc networks. GPSR uses the location of the node in the network to selectively forward the packets based on the

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distance [6] [7]. Two algorithms are used in GPSR: Greedy forwarding and Face routing. The forwarding is carried out on a greedy basis by selecting the node closest to the destination. This process continues until the destination is reached [8]. Whenever this method is not applicable or when this method fails, the algorithm uses face routing strategy to route around the communication voids and reaches the destination. Once the other node comes in transmission range, the algorithm switches back to the Greedy forwarding, reducing the delay and increasing the performance.

3.2 Most Forward within Radius (MFR): It is a progress-based algorithm, in which data is forwarded to the neighbour with the greatest progress. Its objective is to maximize obtainable expectable progress in a certain direction[9]. If no node is in the forward direction, within the range of the sender, the message is sent to the neighbour node with the least backward progress. This algorithm minimizes the number of hops, but doesn't minimize energy consumption

3.3 Greedy Other Adaptive Face Routing (GOAFR): This algorithm starts with greedy forwarding and switches to face routing when reaching to a local minimum with respect to the distance of the current node from the destination. There wouldn't be any neighbouring nodes in the transmission range of the home node. The face routing technique that GOAFR employs has two major differences compared to the traditional face routing [10] [11]. GOAFR also explores the boundaries of a face by employing the right hand rule; however, the algorithm is adaptive in doing so by restricting face traversal to a searchable area, which will be resized during algorithm execution such that it contains a complete optimal path. This restriction is applied with the goal of staying competitive with the shortest path between the source and the destination. In other words, this is to bind the cost of the algorithm by the cost of an optimal path between the source and the destination.

3.4 Algorithm for Robust Routing in Volatile Environments (ARRIVE): It is a probabilistic algorithm which uses localized information and leverages high node density and the broadcast medium to achieve robust routing. One of its goals is to secure message transmission. It is based on a tree-like topology, with the sink as a root. It uses a breadth first search beaconing algorithm to initialize levels, parents and neighbour state information. The nodes evaluate their neighbours and parents to make probabilistic forwarding decisions. Different packets representing the same event can be sent on multiple routes. Event aggregation is optional. The algorithm adapts to large node failures while the trade-off is moderate energy consumption and transmission latency.

3.5 Geographic and Energy Aware Routing (GEAR): The protocol assumes a localization system and targets an increased network life time. It consists of two forwarding phases: forwarding the packet towards a targeted region and disseminating the information within that region. The first phase routes packets based on distance to destination. Each node maintains an estimated and a learned cost value for each destination. The learned cost value is used for forwarding to nodes which are further from destination, to avoid holes in the network. When the learned cost is the same with the estimated value, there are no network voids [12]. The dissemination stage is based either of recursive geographic forwarding for dense networks or flooding in sparse networks.

3.6 Dynamic route maintenance (DRM) for geographic forwarding: The proposed routing strategy uses a dynamic beaconing scheme to obtain the information about the neighbours. In beacon based protocols, each mobile node transmits periodic beacons to its neighbours to update and maintain its routing table [13] [14]. The beacons are generally forwarded at fixed intervals of time. During low mobility, a longer interval would be the best as it would reduce control overhead while providing accurate location information. However, in cases of higher mobility, determining an appropriate beacon interval is rather difficult. In DRM, beacon interval and route information are carried out dynamically. Based on the node's mobility information, its beacon interval is computed while the route management function updates the routing table entries. The DRM algorithm is applied to GPSR forwarding algorithm.

3.7 Energy Efficient Forwarding Strategies for Geographic Routing (EEFS): This geographic protocol assumes a positioning system to account for the location knowledge. It assumes nodes are randomly distributed in the network and aims to improve energy efficiency considering distance and reception rate in the routing decisions. The study is performed with and without ARQ, considering aggregation possibilities. Neighbours are classified based on link reliability and neighbour selection is

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used. Some neighbour links are weaker than others and some even have a different loss characteristic [15][16]. A compromise between shortest path in greedy forwarding and most energy efficient path has to be made by considering the transitional region between the two possible strategies.

3.8 A region-based routing protocol for wireless mobile ad hoc networks (REGR): This geographic routing technique dynamically creates a pre-routing region between the source and the destination, hence control the flooding of route request packets within this region [17]. The correct selection of the region, which should not be too small, is important for the discovery of the optimal routes.

3.9 Least Expected Distance (LED): This algorithm takes into account the inevitable presence of location errors in the localization process inherent to geographic routing. By incorporating location errors into the routing objective function, the algorithm maximizes the probability to achieve minimum power consumption from source to destination [24]. By determining the optimal next forwarding position which optimizes the energy consumption over a single hop, the optimization of the energy over the total path is achieved.

3.10 Geographic Routing with Environmental Energy Supply (GREES): This algorithm makes routing decisions based on realistic wireless channel conditions, packet advancement to destination, residual energy battery level and environmental energy supply. It uses piggybacking in Hello-messages to update each node and his neighbour with the energy status. As a result, it maintains higher mean residual energy among nodes, demonstrates gradual acceptable degradation on end-to-end delay, does not compromise on performance and achieves better load balancing.

3.11 Location aided knowledge extraction routing for mobile ad hoc networks (LAKER): This geographic routing protocol minimizes the network overhead during the route discovery process by decreasing the zone area in which route request packets are forwarded [18]. During this process, LAKER extracts knowledge of the nodal density distribution of the network and remember a series of ‘‘important’’ locations on the path to the destination. These locations are named ‘‘guiding routes’’ and with the help of these guiding routes the route discovery process is narrowed down.

3.12 Movement-based algorithm for ad hoc networks (MORA): Here the algorithm takes into account the direction of the movement of the neighbouring nodes in addition to forwarding packets based on the location information [19][20]. The metric for making the forwarding decision is a combination of the number of hops which have an arbitrary weight assigned and a function independent of each node.

3.13 On-demand geographic path routing (OGPR): This geographic routing protocol does not depend on a location service to find the position of the destination [21] [22]. OGPR is stateless and uses greedy forwarding; reactive route discovery and source based routing. It is a hybrid protocol incorporating the effective techniques of other well known routing protocols for MANETs. OGPR constructs geographic paths to route packets between a source and a destination node.

3.14 Blind Geographic Routing (BGR): This geographical routing algorithm aims to minimize energy consumption. It is a beacon-less geographic routing algorithm which forwards packets towards the destination in a certain forwarding area, while nodes in the network compete through timers to become the next hop. The node whose timer stops first continues the forwarding process. Simultaneous forwarding is prevented through a novel strategy called Avoidance of Simultaneous Forwarding which uses the stored number of hops in the packet header to compare it with the number of hops stored in the node. Depending on this comparison, the nodes in the forwarding area cancel or continue their timing. The algorithm also implements a recovery strategy by changing the forwarding area.

3.15 Sociological orbit aware location approximation and routing (SOLAR): This algorithm is a macro level mobility framework which identifies the orbital movement pattern of mobile users along specific places called hubs. The movement pattern is based on the fact that most mobile nodes are not truly random in their movements but actually move around in an orbit from hub to hub. Each hub may be a rectangle and movement may take place either inside a hub or in between hubs. Example orbital models discussed are random orbit, uniform orbit, and restricted orbit, and overlaid orbit, service to find the position of the destination.

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3.16 Load balanced local shortest path (LBLSP) routing: This distributed routing algorithm uses both local shortest path (LSP) and weighted distance gain (WDG) to finalize the forwarding node [23]. The two non-Euclidian distance metrics provide load balanced routing around obstacles and hotspots. Static nodes with lifetimes longer than the time required to route around an obstacle are considered.

3.17 Geographic landmark routing (GLR): One of the new geographic routing protocol, solves the blind detouring problem and the triangular routing problem in MANETs [24]. The blind detouring problem occurs when a packet arrives at a dead-end when the next node is blindly selected.

3.18 Maximum expectation within transmission range (MER): This is a packet forwarding algorithm for location aware networks. In most cases, location estimates have significant error rates which may be overlooked in most location based routing protocols [25]. These location errors could induce either transmission failures or backward progress in greedy mode. The former occurs when the selected node is out of transmission range while the latter takes place when the next hop node is actually farther than the destination. This leads to looping within the network.

3.19 Energy Efficient Beaconless Geographic Routing (EBGR): It is designed for highly dynamic scenarios with changing topology in which location information is known. The algorithm aims to provide loop-free, energy-efficient sensor to sink routing at low communication overhead. The forwarding process avoids beacons, but uses the RTS/CTS handshaking mechanism and calculates the ideal next-hop relay position on the straight line between source and destination based on an energy-optimal forwarding distance. Each forwarding node chooses as next hop the neighbor closest to the ideal next hop relay position within a predefined relay search region. In the recovery mode beaconless angular relaying is employed with two phases: selection and protest. The selection is based on RTS/CTS between source and neighbors in counter clock order, while in the protest phase, the first node that protests is selected as the next hop relay. The algorithm also tries to provide energy efficient routing in the presence of unreliable communication links by employing blacklisting and a discrete delay function.

3.20 Energy Aware Geographic Routing Protocol (EAGPR): One of the latest variations of geographic routing has a number of advantages. It has higher packet delivery ratio when compared with GPSR. This geographic routing algorithm is based on greedy forwarding. Nodes have only local knowledge of neighbours' position and energy levels and the location of the destination. The forwarding decision is based on distance calculations and energy levels above a certain threshold. The packet is forwarded to the neighbour closest to destination and with the highest energy level, by first adjusting the transmission power. The objective of the algorithm is to prolong the lifetime of the sensors and hence the network lifetime. Various studies show that this protocol is scalable and conserve more energy than other topology based protocols.The algorithm performs better in energy consumption and there is a performance gain in network lifetime. One of the issues concerning this algorithm is that it suffers from diffusion hole problem.

4. COMPARATIVE ANALYSIS

Table 1 presents a comparative analysis of the most popular geographic protocols listing the various advantages that are unique to each protocol and also the various issues and drawbacks existing in each of them.

Table 1 Comparative Analysis Of Geographic Routing Protocol

Routing Protocol	Advantages	Limitations
GPSR	Freedom from loops. Processing overhead is low.	Medium level scalability only. Packet overhead is more.
MFR	Very less overhead.	Reliable data delivery is not ensured.
GOAFR	Highly scalable. Ensures reliable delivery of data.	Lack of a recovery method when forwarding in greedy mode in an empty area.
ARRIVE	The time taken for route	Complexity over the

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	discovery is less.	control packets is high
GEAR	Not completely free from loops.	Memory is High and low processing overhead.
DRM	Dynamic beacons used	Low performance in highly mobile networks
EEFS	Not completely free from loops and some processing overhead.	Low routing overhead.
REGR	Sensitive to selection of the region.	Some control overhead.
LED	High scalability.	No guaranteed delivery.
GREES	Guaranteed delivery.	High packet overhead.
LAKER	Minimum routing overhead.	Not sure about guaranteed data delivery.
MORA	Better performance compared to a number of other protocols.	Complex metrics used for forwarding packets.
OGPR	Does not rely on location service.	Routing overhead
BGR	Low packet overhead.	No guaranteed delivery of data.
SOLAR	Slightly improved performance.	Data overhead involved.
LBLSP	Good forwarding strategy.	Processing overhead.
GLR	Avoids the triangular routing problem in MANET's.	Processing overhead.
MER	Good performance in mobile networks.	Chances of loop formations.
EBGR	Work well in highly mobile networks. Guaranteed delivery.	Forwarding scheme avoids beacons
EAGPR	Has higher packet delivery ratio.	Suffers from diffusion hole problem.

5 CONCLUSION AND FUTURE WORK

Routing in mobile ad hoc networks is a very challenging task due to the dynamic topology and error prone wireless channel. Initially we discussed the various parameters involved in designing and choosing a routing protocol for ad hoc networks. All these parameters have to be considered to design a protocol that would lead to a good performance in these networks. We then discussed the characteristics and features of some of the most popular geographic routing protocols in detail. Each protocol differs from the other in many features introduced. All these protocols have a number of advantages unique to them. We then discussed some of the issues and drawbacks faced by these protocols in highly mobile networks. A detailed study of these protocols would enable us to develop a new hybrid geographic routing protocol by combining some features from each of them that would help us to attain a very good performance in highly mobile ad hoc networks.

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