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Research Article

Performance of Various Routing Protocols in Mobile Ad Hoc Networks-A Survey

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Abstract: The aim of this survey is to analyze the performance of various routing protocols in Mobile Ad hoc Network (MANET). Routing of packets in MANETs is a challenging task due to the error prone wireless channel and the dynamic network topology. A number of routing protocols have been proposed in recent years that include the traditional topology based protocols such as the DSDV, AODV and DSR followed by geographic routing protocols to the latest position based opportunistic routing protocol. This research study gives an overview of these routing protocols along with their characteristics, functionality, advantages and limitations. The study also provides the various advantages of Position based Opportunistic Routing protocol (POR) over all the other routing protocols used in MANET's. Finally it focuses on various enhancements that could be made to the latest POR protocol to achieve even better performance in highly mobile networks.

Keywords: Geographic routing, opportunistic forwarding, quality of service, reliable data delivery, routing protocols, void handling

INTRODUCTION

Mobile Ad hoc Networks (MANETs) are self organizing collection of wireless mobile nodes that form a temporary and dynamic wireless network without any fixed infrastructure. Some of the unique characteristics of these networks are, having no centralized control and administration, ability to self organize and restore, transmission through multiple hops, frequent link breakages and dynamic change of network topology. All these features lead to a number of advantages which includes support for mobility, robustness, flexibility and rapid deployment (Perkins, 1998). In MANET's the nodes could join or leave the network dynamically at any required time.

Over these years they have gained a great deal of attention because of its significant advantages brought about by multi-hop, infrastructure-less transmission. As MANET allow ubiquitous service access, anywhere, anytime without any fixed infrastructure they are widely used in battlefield communication, in sensor networks, personal area networking using PDAs, laptops and hand phones, search-and-rescue, cellular network and wireless hot spot extension, crisis management services, classrooms and conference halls etc. The most important challenge that arises in these networks is packet routing which had been a core area of research over these years. The highly dynamic nature of these networks and the absence of a centralized control makes packet routing a very tough task in MANET's. Various aspects of the ad hoc network must be considered while designing a routing protocol so that a good performance can be achieved.

A routing protocol is needed whenever a packet needs to be transmitted to a destination via number of nodes in an efficient manner. Various features of many routing protocols have been an active area of research for many years. A number of issues and features of mobile ad hoc networks has to be considered before choosing a routing protocol for a particular ad hoc network. Due to the error prone wireless channel and the dynamic network topology, reliable data delivery in MANETs, especially in challenging environments with high mobility remains an issue (Aleksi, 2007). Many protocols have been suggested over these years for reliable delivery and high performance. All the different routing protocols proposed so far for mobile ad hoc networks aim at attaining four basic goals. They aim at maximizing throughput, minimizing packet loss, minimizing control overhead and minimizing energy usage. However, the relative priorities of these goals changes from each protocol to the other depending on the targeted application for which it was designed. All the routing protocols proposed so far can be categorized into two types:

- Topology based routing protocols
- Location-aware (Geographical or Position based Routing Protocols)

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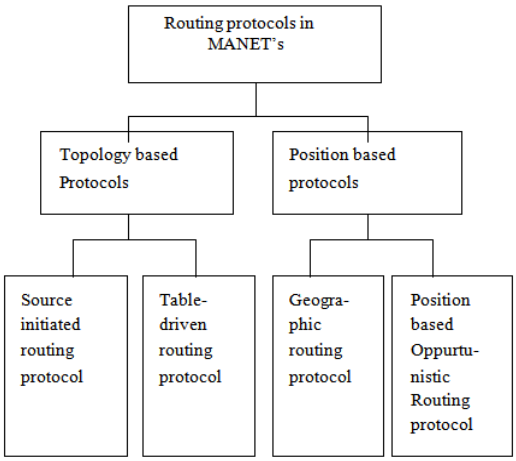

Fig. 1: Categorization of various routing protocols used in MANET's

Figure 1 shows the categorization of various protocols used in mobile ad hoc networks starting with the traditional topology based protocol to the geographic routing protocol to the latest position based opportunistic routing protocol.

Objective of the survey: The main purpose of this study and survey is to show the various benefits and drawbacks of the most widely used routing protocols in the mobile ad hoc networks. The survey would specifically:

- List out the various issues and challenges that must be taken into consideration while designing and using a routing protocol in mobile ad hoc networks.
- Compare the benefits and drawbacks of various routing protocols when used in mobile ad hoc networks.
- Present the various advantages of the position based Opportunistic Routing Protocol (POR) over all the previous protocols used in MANET's.
- Focus on the enhancements that could be made to POR in the future to achieve even better performance.

ISSUES AND CHALLENGES

Routing protocols needs to take care of a number of issues and challenges while providing the required Quality of Service. The protocol must address these issues in a balanced manner so that it does not lead to an increase in computational and communicational cost. Some of the major problems faced by the routing protocol in MANET's are listed below.

Absence of a centralized control: An ad-hoc network is decentralized as the members of the network can leave or join the network at any time dynamically. There is no centralized control over the network. Here the network is set up dynamically for some purpose by a group of mobile nodes. As there is no centralized control, it leads to increased overhead and complexity in algorithm's, as Quality of Service (QoS) state information must be disseminated efficiently.

Node mobility: The ad-hoc network is set up by a group of mobile nodes which moves independently at various directions at different times. This leads to the need of frequent updating of any information on network topology and this information has to be provided to required packets dynamically by the routing protocol so that the packet reaches the final destination. This would lead to a better packet deliver ratio.

Error prone wireless channel: The bit errors caused due to unreliable channels is a major issue faced in ad-hoc networks. Due to high interference, multipath fading and thermal noise there is a high bit error rate in the channel which leads to low packet delivery ratio. Since the medium is wireless in MANETs, it may also lead to leakage of information into the surroundings.

Route maintenance: The dynamic nature of the network topology and changing behavior of the communication medium makes the maintenance of network state information very difficult. The established routing paths may be broken even during the process of data transfer. Hence there is a need for maintenance and reconstruction of routing paths with minimal overhead and delay.

Limited bandwidth: The bandwidth in ad-hoc network is often limited and this should be taken into consideration while designing a protocol to provide better QoS to the network.

Constrained power supply: One of the major issues that need to be considered is the limited power supply in ad-hoc networks compared to the wired networks. It may also be noted that providing required QoS in these networks consumes more power due to the overhead created by the mobile nodes (Anne and Jie, 2001). This may lead to a rapid drain in the node's power.

Security: Providing adequate security is often a tough task in all kinds of networks. The job is even a bigger challenge in ad-hoc networks as there is no centralized control and also due to the dynamic network topology and the broadcast nature of the wireless medium. Without adequate security, unauthorized accesses and usages may lead to violation of QoS parameters (Mueller *et al*., 2004). Due to all these issues we need to design a security-aware routing algorithm for ad hoc networks.

TOPOLOGY BASED PROTOCOLS

Destination sequenced distance vector protocol: The Destination Sequenced Distance Vector Protocol is

based on Bellman-Ford routing mechanism. The most important feature of this protocol is its freedom from loops in the routing table (Perkins and Bhagwat, 1994). DSDV protocol had gained wide popularity over these years due to its dynamic nature and also due to the fact that it has less convergence time. The working of this protocol is very simple as all the nodes in the network maintains individual routing table containing a list of all possible target or destination nodes along with the number of hops required to reach the particular node. Every individual entry in the table is marked with a sequence number assigned by the destination node which identifies the stale routes and thus avoids formation of loops in the routing table. If any router receives new information, then it uses the latest sequence number. If the sequence number is the same as the one already in the table, the route with the better metric is used. The entries that have not been updated for a while are found to be stale entries and those entries along with the routes using those nodes as next hops are deleted (Perkins and Bhagwat, 1994).

Benefits and limitations of DSDV: The major advantage of this protocol is the freedom from loops in the routing table. Thus the protocol avoids stale entries and routes. But there are major areas of concern while using this protocol in mobile ad hoc networks. DSDV requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle. The major concern for this protocol is when the topology of the network changes as it requires creating a new sequence before the network re-converges. Thus DSDV gives very low performance in highly dynamic networks including MANET's.

Dynamic source routing: Dynamic Source Routing (DSR) (Johnson *et al*., 2002) is one of the most popular routing protocols used for wireless mesh networks. DSR is designed in a way that all the information in the network is maintained at the mobile nodes and the information is continuously updated. This source based routing strategy gives the protocol an advantage over table based routing. The main benefit of using DSR protocol is that it does not need any existing network infrastructure or administration and this allows the network to be completely self-organizing and self-configuring. The protocol works in two phases which are route discovery and route maintenance. If the message that is sent reaches the intended destination then a route reply phase is used. Every node in the network maintains a cache which stores the recently discovered paths. Every time a node decides to send a packet to some other node in the network, it first checks for its entry in the particular cache. If the entry is found then that path is used to transmit the packet and also attaches its source address on the packet. If the entry is unavailable in the cache route request packet is broadcasted by the sender to all its neighbors requesting for a path to the destination. The sender waits till the route gets discovered. The sender is free to perform any other task during this waiting time. As the route request packet arrives at various nodes, the nodes would perform a check with their neighbor or from their caches whether the destination specified is known or unknown to them. A route reply packet is send back to the destination, if the route information is known or else they would broadcast the same route request packet. As soon as the route gets discovered, all the required packets will be transmitted by the sender on the newly discovered route. The node also maintains the age information of the entry to know whether the cache is fresh or not. When any intermediate node receives a data packet, it first checks whether the destination specified is that particular node or not. If it is meant for it the packet is received otherwise the same will be forwarded using the path attached on the data packet. Since in an ad hoc network, any link could fail at anytime. Therefore, route maintenance process would constantly monitor and would notify the nodes about the failure in any path. Consequently, the nodes will change the entries of their route cache.

Benefits and limitations of DSR: The main benefit of the DSR protocol is that there is no need to maintain a routing table to route a data packet as the entire route is contained in the packet header itself. Adding to this feature the protocol also uses a reactive approach, thereby eliminating the need to periodically flood the network with the messages to update the information in the table which are required in a table-driven approach.

The limitations of DSR protocol is that this is not scalable to large networks and even requires significantly more processing resources than most other protocols. Another concern is about the route maintenance mechanism as it has no ability to locally repair a broken link. Stale route cache information could also result in inconsistencies during the route reconstruction phase. Compared to the table-driven protocols the connection setup delay is higher. In highly mobile networks the protocol often gives low performance. Also considerable routing overhead is involved due to the source-routing mechanism employed in DSR. In order to obtain the routing information, each node must spend lot of time to process any control data it receives, even if it is not the intended recipient.

Ad hoc on demand distance vector: AODV is a distance vector routing protocol which tries to minimize the requirement of system-wide broadcast to its extreme. The protocol combines some of the features of DSDV and DSR protocols. The protocol discovers routes from one node to the other dynamically on

demand. And the routes are maintained only as long as they are required. This reactive protocol establishes a route to a destination only on demand. The most common routing protocols discussed so far are proactive, as they would find routing paths independently of the usage of the paths. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV. The protocol is capable of both unicast and multicast routing.

Benefits and limitations of AODV: The main benefit of AODV protocol is that it favors the least congested route instead of the shortest route. The protocol also supports both unicast and multicast packet transmissions even for nodes in constant movement. The protocol gives better performance in dynamic networks compared to the previously discussed protocols. It also responds very quickly to the topological changes that affects the active routes. AODV does not put any additional overheads on data packets as it does not make use of source routing (Perkins *et al*., 2003). The limitation of AODV protocol is that it requires that the nodes in the broadcast medium can detect each others' broadcasts. It is also possible that a valid route is expired and the determination of a reasonable expiry time is difficult. The reason behind this is that the nodes are mobile and their sending rates may differ widely and can change dynamically from node to node. In addition, as the size of network grows, various performance metrics begin decreasing. AODV is vulnerable to various kinds of attacks as it based on the assumption that all nodes must cooperate and without their cooperation no route can be established.

POSITION BASED ROUTING PROTOCOLS

Location-aware routing (Mauve *et al*., 2001) schemes in mobile ad hoc networks assume that the individual nodes are aware of the locations of all the nodes within the network. Usually the Global Positioning System (GPS) is used to determine the coordinates of these individual nodes in any geographical location. The information about the location of these nodes is of extreme importance in geographic routing. All the routing mechanisms are carried out based on this location information. One of the early proposed protocols, using location information for routing purposes was "Location Aided Routing (LAR)". The LAR protocol is based on DSR, but limits the propagation of route request packets to a geographic region where it is most probable for the destination to be located (Atekeh *et al*., 2011).

Here actually geography is not used for packet forwarding decisions and is only used to limit the propagation area. In fact, LAR is classified as a position-based routing protocol. The recent research activities have exactly referred "geographic routing" as mainly a solution that employs geographic information for the purpose of routing and data forwarding (Karp and Kung, 2000). The major two advantages that give Geographic Routing high importance in mobile ad-hoc networks are:

- There is no need to keep routing tables up-to-date
- No need to have a global view of the network topology and its changes

Therefore, geographic routing protocols have attracted a lot of attention in the field of routing protocols for MANETs. These geographic approaches allow routers to be nearly stateless because forwarding decisions are based on location information of the destination and the location information of all one-hop neighbors. Most of these protocols keep state only about the local topology No routing table is constructed. As a result, establishment and maintenance of routes are not required, reducing the overhead considerably.

There are various approaches used in geographic routing. Some of them are single-path, multi-path and flooding-based strategies. Most single-path strategies rely on two techniques: greedy forwarding and face routing. Greedy forwarding always chooses the node that has maximum progress towards the destination as the next best forwarder. Usually the node nearer to the destination is selected as the next best forwarder. It always tries to bring the message closer to the destination in each step using only local information. The most suitable neighbor can be the one who minimizes the distance to the destination in each step. Greedy forwarding can lead into a dead end, where there is no neighbor closer to the destination. In order to recover from this sort of a situation face routing is used. Face routing helps to find a path to another node, where greedy forwarding can be resumed. A recovery strategy such as face routing is necessary to assure that a message can be delivered to the destination.

Benefits and limitations of geographic routing: The most important advantage of Geographic forwarding is that it does not require any maintenance of routing tables or route construction prior to or during the forwarding process. Also if an intermediate node used by previous packets for forwarding purpose becomes unavailable, the protocols allows the packet being forwarded to adapt to changes in the topology by selecting the next best choice. These approaches do not require the nodes to maintain the topology information. The major disadvantages of Geographic routing are in the complexity and overhead required for a distributed location database service. Also the dependence of geographic forwarding on the physical network topology leads to some obstacles such as a building or the lack of radio coverage may result in voids in the physical network topology. These voids may inhibit

forward progress of packets local minima where there are no neighbors available that are closer to the destination resulting in the failure of the forwarding strategy.

OPPURTUNISTIC ROUTING PROTOCOLS

The design of Position based Opportunistic Routing Protocol (POR) (Shengbo *et al*., 2012) is based on geographic routing and opportunistic forwarding. All the nodes are assumed to be aware of their own location and the positions of their direct neighbors. Usually a one-hop beacon is used to exchange the neighborhood location information between the nodes. The information about the location can also be piggybacked in the data packet's header. In the POR protocol several forwarding candidates cache the packet that has been received using MAC interception. If the best forwarder does not forward the packet in certain time slots, suboptimal candidates will take turn to forward the packet according to a locally formed order. In this way, as long as one of the candidates succeeds in receiving and forwarding the packet, the data transmission will not be interrupted. Potential multi-paths are exploited on the fly on a per packet basis, leading to POR's excellent robustness. The concept of in-the-air backup significantly enhances the robustness of the routing protocol and reduces the latency and duplicate forwarding caused by local route repair. In the case of communication hole (Chen and Varshney, 2007), a Virtual Destination-based Void Handling (VDVH) scheme in which the advantages of greedy forwarding and opportunistic routing can still be achieved while handling communication voids.

Benefits and limitations of POR: POR can be deployed without complex modification to MAC protocol and achieve multiple reception without losing the benefit of collision avoidance provided by 802.11. The concept of in-the-air backup significantly enhances the robustness of the routing protocol and reduces the latency and duplicate forwarding caused by local route repair. The major drawback identified in POR is in memory consumption. Also duplicate relaying is not addressed when there is interference. All types of communication voids are not handled and more emphasis on security could be provided.

CONCLUSION

In this research study, an effort was made for a comparative study on performance of various types of routing protocols used in MANET's. The various types of routing protocols including topology based, location aware geographic routing and position based opportunistic routing protocols were studied in detail. The various benefits and limitations of these protocols were discussed. The latest proposed Position based Opportunistic Routing Protocol (POR) which had a number of advantages over all the previous protocols was discussed. The various limitations of POR were listed. Further the performance of POR protocol could be optimized to obtain even better performance by combining some of the features of already existing routing algorithms along with it.

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