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A Survey on Routing and Topology Control in Mobile Ad Hoc Networks

Elackya.E.C[1], Mrs.Sasirekha.S[2]

[1]PG Student, Nandha Engineering College (Autonomous), Erode, elackyaec37@gmail.com

[2]Associate Professor, Nandha Engineering College (Autonomous), Erode, rehasenthil@gmail.com

ABSTRACT

A mobile ad hoc network (MANET) is a system of wireless mobile nodes that can freely and dynamically self organize in arbitrary and temporary network topologies without the need of centralized administration or wired backbone. People and devices can be seamlessly internetworked without any pre-existing communication infrastructure and also when the infrastructure requires wireless extension. Lack of fixed infrastructure including base stations as prerequisites, leads to the creation and usage of network anytime and anywhere. And also MANETs are intrinsically fault resilient since they do not operate under the limitations of fixed topology. Every node in the network acts as end system and also as a router to forward packets. The nodes are free to move about and organize themselves in the network. To support changing topology special routing algorithms are needed. A survey of routing protocols and topology control in MANETS is discussed in this paper.

Key Words : AODV, DSDV, DSR, Mobile ad hoc network (MANET).

1. INTRODUCTION

In the past there were several attempts to develop routing protocols for mobile ad hoc networks. The proposed routing protocols have their own strength and weaknesses. Generally routing protocols in MANETs are based on link-state (LS) routing algorithm or distance-vector (DV) routing-algorithm. The common idea in both these algorithms is that they try to find the shortest path from the source node to the destination node. The main difference is that in LS based routing a global network topology is maintained in every node of the network. In DV based routing the nodes only maintain information of and exchange information with their adjacency nodes. Keeping track of many other nodes in a MANET may produce overhead, especially when the network is large. Therefore one of the most important issues in MANET design is to come up with schemes that will contribute to reduce routing overheads. MANET routing protocols fall into two general categories:

- Proactive routing protocols
- Reactive routing protocols

In addition to the above protocols there are multicast routing protocols where the packets are broadcasted over the network. But in case of multicast MANETs security is a major concern. Thus a secure authentication approach is proposed in [8]. A markov chain trust model was proposed with computation of trust value. In addition to this multicast protocols rely on creation of multicast tree in prior before transmission, which in turn requires individual nodes to maintain state information. Thus in case of dynamic networks like MANETs with bursty traffic, this multicast state maintenance leads to large amount of communication, processing and memory overhead. Thus stateless multicast protocol was used in [5].

Proactive routing protocols follow table driven approach where each node maintains a routing table consisting of neighborhood information. Proactive protocols imposes heavy load on the network since each node in the network maintains routing table. A lightweight proactive source routing protocol was uses which imposes less load on the network and supports opportunistic data forwarding [7].

Reactive protocols follow on demand approach where routes are established on demand. Examples of reactive protocols are DSR (Dynamic Source Routing) and AODV (Ad hoc on-demand distance vector routing). These protocols create less overhead over the network when compared to proactive protocols like DSDV (Destination Sequence Distance Vector) and OLSR (Optimized Link State Routing). Another category of routing protocol is geographic routing protocol. Location aware routing for delay tolerant networks known as LAROD [12] uses partial knowledge of geographic position to route packets. Topology control is a major issue in MANETs as nodes are moving in the network so as to adjust the transceiver and reception parameters. The dynamic topologies in MANETs affect the Quality of Service (QoS) and end to end throughput. Recent topology control schemes are focused on improving overall network performance such as network capacity, and energy consumption and interference in MANETs. These schemes ensure that connectivity is maintained during transmission and the interference is reduced. A joint authentication and topology control (JATC) scheme [15] uses cooperative communication and also addresses security issues related to topology control. Capacity optimized cooperative (COCO) topology control scheme [16] improves network capacity in MANETs.

2. RELATED WORK

Clustering in MANETs consists of selecting the most suitable nodes of a given MANET topology as cluster heads, and ensuring that regular nodes are connected to cluster heads such that the lifetime high data transmission rate, extended network coverage area. LVC protocol makes use of the advantages of high power nodes and also avoids its disadvantages such as interference. The Clustering Problem in MANETs consists of selecting the most suitable nodes of a given MANET topology as cluster heads, and ensuring that regular nodes are connected to cluster heads such that the lifetime of the network is maximized. SAT/ILP (Boolean satisfiability and Integer Linear Programming) techniques [4] uses various enhancements like establishment of intra-cluster communication, multihop connections and the enforcement of coverage constraints.

Energy is an important constraint in MANETs. Most nodes will have selfish behaviour by avoiding transmission through them so as to save the resources. These nodes are called as selfish nodes [2] which were detected in the network using collaborative watchdog technique. A mobility aware, local tree-based reliable topology (MA-LTRT) is used in [6] to construct the network with adequate network connectivity while ensuring a low level of power consumption base on cyber physical systems. Multicast routing protocols belonging to different routing philosophies have been proposed in the literature. A proactive multicast routing protocol pre-determines the routes between any two nodes irrespective of the need for such routes. On the other hand, reactive multicast routing protocols discover routes only when required (i.e., on-demand). Some protocols consider all nodes are peers (flat network topology), while others consider a hierarchy among nodes and only nodes in the same level of the hierarchy are treated as peers. A stateless receiver based multicast (RBMulticast) protocol [5] which tracks the geographic location of the nodes and avoids the need of maintaining state information. Nodes are divided into “geographic multicast regions” and packets are splitted based on the location of multicast members. A framework for integrated multicast and unicast routing in mobile ad hoc networks (MANETs) called PRIME [14] is proposed. PRIME establishes meshes that are activated and deactivated by the presence of individual destination nodes. There is unreachability problem in MANETs which may result in link/routing failures and unfairness among multiple traffic flows. A medium access control(MAC)protocol called eMAC [10] maintain double-hop neighborhood (DHN) graphs while exchanging designated eMAC tables to share their knowledge about their neighborhood topology. In wireless MANETs as nodes are free to move, path loss and multipath fading occurs. CA-AOMDV(Channel aware Ad hoc on demand multipath distance vector) protocol [11] is used which reuse the paths rather than simply discarding them at failure.

Geographical routing protocols have become an emerging area in MANETs which focuses on actual geographic coordinates (as obtained through GPS – the Global Positioning System) and reference points in some fixed coordinate system. A geographical routing algorithm called location-aware routing for delay-tolerant networks (LAROD) [12] uses location dissemination service (LoDiS) to suit an intermittently connected MANET(IC-MANET). LAROD is designed to route packets with only partial knowledge of geographic position. Mobile Ad hoc Networks (MANETs) are of the network is maximized. Loose Virtual Clustering (LVC) protocol [1] is used which prevents transmission through high power nodes. Benefits of high power nodes are reduction in transmission delay,

distributed self-organizing networks that can change locations and configure themselves on the fly. An extended VSM (EVSM) algorithm [13] uses new control laws for exploration and expansion to provide blanket coverage, virtual adaptive springs enabling the mesh to expand as necessary and adapts to communications disturbances by varying the density and movement of mobile nodes.

An important task of an ad hoc network consisting of geographically dispersed nodes is to determine an appropriate topology over which high-level routing protocols are implemented. Capacity optimized cooperative (COCO) topology control scheme [16] is used to improve network capability in MANETs. A joint authentication and topology control (JATC) scheme [15] improves throughput in MANETs along with authentication.

There are different routing protocols for ad hoc routing. Section III deals with different categories of routing protocols in MANETs. Comparative studies of these protocols based on different parameters are explained in section IV. Topology control strategies are discussed in section V.

3. ROUTING PROTOCOLS IN MANETs

3.1. Multicasting Routing Protocols

Multicast routing protocols have emerged as one of the most active research areas. There are three basic categories of multicast methods in MANETs.

- A basic method is to simply flood the network. Every node receiving a message floods it to a list of neighbors. Flooding a network acts like a chain reaction that can result in exponential growth.
- The proactive approach pre-computes paths to all possible destinations. To maintain an up-to-date database, routing information is periodically distributed throughout the network.
- The final method is to create paths to other nodes on demand. The idea is based on a query response mechanism or reactive multicast. In the query phase, a node explores the environment. Once the query reaches the destination the response phase starts and establishes the path.

Current multicast protocols generally rely on various tree structures and hence intermediate nodes need to maintain tree states or routing table for route identification and packet delivery. Receiver-Based Multicast (RBMulticast) protocol [5] uses geographic location information to route multicast packets. RBMulticast stores a destination list inside the packet header. This destination list provides information about all multicast members to which the packet is targeted. Thus, there is no need for a multicast tree and therefore no tree state is stored at the intermediate nodes. And additionally RBMulticast also utilizes a receiver-based MAC layer to further reduce the complexity of routing packets. The sender node does not need a routing table or a neighbor table to send packets but instead uses a "virtual node" as the packet destination. Thus, RBMulticast requires the least amount of state of any existing multicast protocol. Integrated routing is an attractive approach for MANETs that attempts to provide either on-demand or proactive unicast and multicast routing using separate protocols. Protocol for Routing in Interest defined Mesh Enclaves (PRIME) [14] which redefines how signaling is done for routing in MANETs by integrating unicast and multicast routing using interest-driven establishment of meshes and enclaves .PRIME establishes meshes (connected components of a MANET)that are activated and deactivated by the presence or absence of data traffic. Dissemination of control packets is given only to those nodes that require information. This property has a positive impact on the scalability of the protocol, particularly from medium to large networks in which the members of the same multicast group tend to be near one another.

3.2. Proactive Routing Protocols

In this type of routing protocol, each node in a network maintains one or more routing tables which are updated regularly. Each node sends a broadcast message to the entire network if there is a change in the network topology. However, it incurs additional overhead cost due to maintaining up-to-date information and as a result throughput of the network may be affected but it provides the actual information to the availability of the network. Distance vector (DV) protocol, Destination Sequenced Distance Vector (DSDV) protocol, Wireless Routing protocol and Fisheye State Routing (FSR) protocol are the examples of Proactive protocols. Proactive source routing (PSR) protocol [7] provides opportunistic data forwarding. This protocol provides more topology information than distance vector (DV) but has significantly smaller overhead than link state (LS) routing protocols. Examples of proactive routing protocols include destination- sequenced distance vector (DSDV) and Optimized link state routing (OLSR). PSR uses three types of messages:

- The periodic route update message to exchange routing information and also hello beacon messages
- Converted binary tree is packaged into the messages to reduce the payload into half
- Full dump messages with differential updates are interleaved

As a result the routing overhead of PSR is less when compared to DSDV, OLSR and DSR.

3.3. Reactive Routing Protocols

In this type of routing protocol, each node in a network discovers or maintains a route on-demand. It floods a control message by global broadcast during discovering a route and when route is discovered then bandwidth is used for data transmission. The main advantage is that this protocol needs less routing information but the disadvantages are that it produces huge control packets due to route discovery during topology changes which occurs frequently in MANETs and it incurs higher latency. The examples of this type of protocol are Dynamic Source Routing (DSR), Ad-hoc On Demand Routing (AODV) and Associativity Based Routing (ABR) protocols. DAWN, a declarative platform that creates highly adaptive policy-based mobile ad hoc network [3] achieve extensible routing and forwarding using declarative languages. DAWN combines several existing protocols with specific criteria which determine the usage of a particular protocol. These compositional capabilities are useful for routing in heterogeneous network settings where features from various routing protocols like DSDV, DSR, OLSR, AODV are adaptively combined based on network conditions like connectivity, mobility and traffic.

Ad-hoc on demand distance vector (AODV) protocol is enhanced and used as channel aware-Ad-hoc on demand multipath distance vector (CA-AOMDV) protocol [11] which considers the average non fading duration (ANFD) and average fading duration (AFD) into account in order to reuse the paths upon failure. ANFD is used to measure the ink stability and AFD determines when to bring the path back to play. CA-AOMDV predicts the path failure and bring back the paths to play when available.

3.4. Geographical Routing Protocols

A geographical routing protocol must be supported by a location service that can provide the current physical location of the destination node for a packet. A location service can be as simple as flooding the network with a request that the destination answers to using quorum-based techniques for updates and requests. For MANETs there have been many suggestions on how location services can be provided. Practical geographic routing protocol must handle intermittent connectivity and the absence of end-to-end connections. A geographical routing algorithm called location aware routing for delay tolerant networks (LAROD) [12] uses location dissemination service (LoDiS), which together are shown to suit an intermittently connected MANET(IC-MANET). LAROD is a geographical routing protocol for IC-MANETs that combines geographical routing with the store–carry–forward principle. LAROD uses a beaconless strategy combined with a position-based resolution of bids when forwarding packets. LoDiS maintains a local database of node locations, which is updated using broadcast gossip combined with routing overhearing. In mobile ad hoc networks the nodes change their positions frequently leading to frequent path failures and route reconstructions and thereby increasing routing overhead. Extended VSM (EVSM) algorithm [13] uses various measures for calculating the topological distance and geographic distance. In addition to that Received Signal Strength (RSS) is exploited to measure the geometrical distance between two nodes.

4. TOPOLOGY CONTROL IN MANETS

Topology control is a technique that aims in reducing power consumption by removing the redundant links and controls the transmission range of each node in ad-hoc networks. In the topology control method, each node broadcasts a Hello Message to neighboring nodes in its maximum transmission range. Each of the neighboring nodes, upon receiving the Hello Message, respond by returning the message including the node's information such as its position. Each node after receiving these returned messages, decides the topology by using neighbors' positions and reduces the transmission range according to the position of the farthest node in the topology. LTRT [6] is based on Tree-based Reliable Topology (TRT). This method follows k-edge connectivity i.e., the network connectivity cannot be lost if the number of broken links is smaller than k. In mobile ad hoc networks (MANETs) based on cooperative communication (CC) present significant challenges to security issues, as well as issues of network performance and management. A joint authentication and topology control (JATC) scheme [15] was proposed to improve the throughput. Specifically, the effective throughput with upper layer authentication schemes and physical-layer schemes related to channel conditions and relay selections for CCs are analyzed. A discrete stochastic approximation approach has been employed in JATC to deal with the imperfect channel knowledge and the dynamically changing topology.

Capacity optimized cooperative (COCO) topology control scheme [16] is used to improve network capability in MANETs. This scheme uses relaying strategy. Two types of relaying strategies are:

- Amplify-and-forward
- Decode-and-forward

5. COMPARISON OF PROTOCOLS

Reactive and Proactive Protocols are the routing protocols that are used in mobile Ad hoc networks to send data from the host to the destination. A packet data is sent from source to destination in an Ad hoc network through multiple nodes that are mobile. This type of network is generally used in a disaster hit area, military field or in space where fixed infrastructure is destroyed or does not exist. The nodes of this network work as the routers to the packet data and transmit it from one node to another till the destination. As the data has to pass several nodes before getting delivered a routing protocol is must so that data can be passed from one node to another and delivered to the correct address.

5.1. Proactive vs. Reactive Protocols

- Average end-to-end delay or the time taken by the data to reach the destination from the source is variable in Reactive Protocols but remains constant in Proactive Protocols for a given Ad hoc network.
- The delivery of packet data is much more efficient in Reactive Protocols than in Proactive Protocols.
- Reactive Protocols are much faster in performance than Proactive protocols.
- Reactive Protocols are much more adaptive and work much better in different topographies than Proactive Protocols.

PROTOCOL PROPERTY	DSDV	DSR	AODV
Table Driven/Source routing	Table driven	Source routing	Table driven
Need of Hello Message	Yes	No	Yes
Route discovery	Periodic	On demand	Periodic
Route maintenance/ mechanism	Route table with next hop	Complete route cached	Route table with next hop
Routing Philosophy	Flat	Flat	Flat
Packet Size	Uniform	Non uniform	Uniform
Routing Overhead	Medium	Low	High
Reactive/ Proactive	Proactive	Reactive	Reactive
Route maintenance	No	Yes	Yes
Route discovery	No	Yes	Yes
Network suitable for	Less number of nodes	Up to 200 nodes	Highly dynamic
Unidirectional link support	No	Yes	No
Multiple routes	No	Yes	No
Loop free	Yes	Yes	Yes
Multi-hop wireless support	Yes	Yes	Yes
Node overhead	Medium	High	Medium
Network overhead	High	Low	Medium

Table 1: Comparison of DSDV, AODV and DSR

5.2. Comparison Table

On analysing the behaviour of routing protocols, reactive protocol namely AODV performs better than the rest of the protocols by means of allowing periodic exchange of data which is an important requirement for a TCP based connection. DSR and AODV outperform DSDV when the scalability of network increases (i.e.) when the number of nodes in the network increases. Hence for real time traffic AODV is preferred over DSR and DSDV. But in case of a network where the node mobility is less and which doesn't allow dynamic topology changes to happen, DSDV performs better than the other routing protocols. DSR/AODV is based on route discovery and route maintenance mechanism. Flat Routing Philosophy is used in DSR, AODV and DSDV. Packet size is uniform for DSDV and AODV. Packet size is non uniform for DSR. Loop free routing Protocol Property is available to DSR, AODV and DSDV. So comparatively proactive protocols are appropriate for less number of nodes in networks, as they need to update node entries for each and every node in the routing table of every node which results in more routing overhead and also consumption of more bandwidth in the routing table.

6. CONCLUSION

In this paper several routing protocols and topology control strategies are discussed. Each protocol has its own strength and weaknesses. The protocols are tested for its efficiency based on certain important parameters like packet delivery ratio (PDR), link quality, throughput and end to end delay. The parameter values differ for each protocol based on their individual characteristics of routing. The performance of both reactive (DSR, AODV) and proactive protocols (DSDV, OLSR) is low when the number of nodes in the network increases. This affects the transmission and increases routing overhead. Proactive source routing protocol imposes light load on the network by means of opportunistic data forwarding. And the overhead caused by this protocol is less when compared to other routing protocols. It's important to monitor the frequent change of topology in MANETs. JATC (Joint Authentication and Topology Control) scheme works well with MANETs and it deals with imperfect channel knowledge and the dynamically changing topology. The above scheme provides both security and topology control in MANETs.

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