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Routing Issues in Mobile Ad Hoc Networks: A Survey

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ABSTRACT
Mobile Ad Hoc Networks (MANETs) are an independent network of mobile nodes connected by wireless links wherein position of each mobile node changes rapidly. Every node acts as a host as well as a router. MANETs are used in various and varied applications like setting up of conferences, e-classrooms, detection of earthquakes etc. Due to the limited transmission range of the nodes, it is necessary to develop routing protocols that support efficient communication between various nodes. Moreover, the routing protocols should support stringent bandwidth and resource limitation of MANETs. This paper gives an overview of the various issues in designing a routing protocol for MANETs and describes in detail the existing proactive, reactive and hybrid routing protocols, their behaviour and limitations in the context of MANETs.
Keywords:- MANETs, Routing protocols, Reactive routing protocols, AODV BR, AODV nthBR.

I. INTRODUCTION

A Mobile Ad Hoc Network (MANET) is a collection of mobile nodes with no pre-established fixed infrastructure [1] [2]. In MANETs, network nodes act as routers by relaying each other's packets and all the nodes form their own cooperative infrastructure [3]. The nodes communicate through single hop or multi-hop paths. Such networks are characterized by dynamic topologies, bandwidth constraints, variable capacity links, energy constrained operations etc. MANETs are increasingly becoming popular due to their advantages such as low cost and ease of deployment. Also, nodes in a MANET should be able to perform the necessary routing functions to discover the optimum route and also be able to forward data packets in such a network [4] [5]. As MANETs gain popularity, their need to support real time and multimedia applications is growing as well. Real time and multimedia applications supported by MANETs have stringent Quality of Service (QoS) parameters such as efficient bandwidth utilization, minimum delay, minimum packet loss, good throughput etc. Providing QoS is difficult in MANETs due to a lack of centralized infrastructure based system, limited bandwidth availability, and constant movement of nodes, contention for channel access and the highly dynamic topology of the wireless network. Hence, design and development of MANETs with necessary QoS parameters like low packet loss, good throughput, less delay is very important. To provide a reliable MANET set up that adheres to certain QoS parameters, it is necessary to ensure that an optimum route is found between source and destination but due to dynamic nature of MANETs, the routing problem is much more complicated as compared to wired networks [6]. Since the inherent nature of MANETs is characterized by frequent link breakages and node failure [7], it is imminent to have a system supported by efficient routing which results in improved QoS parameters.

II. MANET CLASSIFICATION

In MANETs, each node has a router or switch connected by a wireless connection. The interconnection of all these nodes is an arbitrary topology [8]. MANET can function independently or it can be connected to Internet Protocol version 4 (IPv4) or Internet Protocol version 6 (IPv6) or other protocol. As the MANETs are an independent entity, their performance or their organization depends on the location of the individual nodes, their connectivity, and ability of the nodes to discover routes and send messages using the shortest path or nearby nodes. An important characteristic of such networks is that their organization can change due to the constant movement of nodes.

A. Single-hop MANETs

Fig. 1 represents a simple single- hop MANET. A single-hop MANET is the simplest network that can be formed by a collection of several stations. Here, stations that are within the range of each other dynamically configure themselves to set up a single-hop MANET. The major limitation of this system is that it connects only those devices that are within the same transmission range.

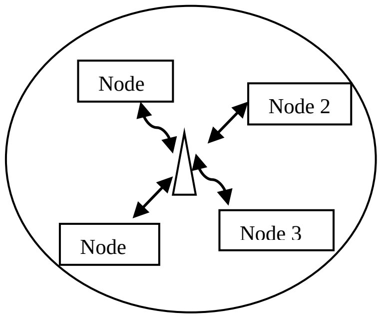

Fig.1 A Single-hop MANET

B. Multi-hop MANETs

Fig. 2 represents a multihop MANET. Multi-hop systems try to overcome the limitation of single-hop networks. Nearby nodes can communicate directly whereas the devices that are not connected directly forward the packets via intermediate nodes for communication. Common examples are vehicle-to-vehicle communication, military network set ups etc.

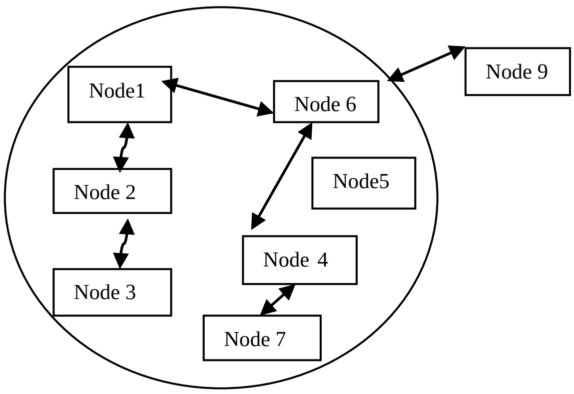

Fig.2 A Multi-hop MANET

One of the major issues for routing in MANETs is the constant movement of nodes or node mobility Disruption and frequent path breaks occur due to the movement of intermediate nodes in the path and end nodes. Efficient mobility management for dynamic MANETs should be an important feature for routing protocols in MANETs. The other major design issue in MANETs is bandwidth constraint. In a wireless network, the radio band is limited, hence the routing protocols should be designed in such a way that bandwidth is used optimally by keeping the overhead as low as possible. Wireless networks also face collision and congestion problem [9]. Transmission in MANETs may cause collisions of data and control packets due to arbitrary and sudden movement of nodes. The solution is to find alternate routes through better quality links, with less congestion and low packets. Hidden terminal and exposed terminal problems are the other problems faced by dynamic system like MANETs. Hidden terminal problem refers to collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the direct transmission range of the sender, but are within the transmission of the receiver. Collision occurs when both nodes transmit packets at the same time without knowing about the transmission of each other and exposed terminal problem refers to the inability of a node to transmit to another node due to transmission by a nearby transmitting node. These problems also effect reusability of available radio spectrum. Hence, hidden and exposed terminal problems need to be considered when designing routing protocols.

III. DESIGN ISSUES FOR ROUTING PROTOCOL IN MANETs

One of the major issues for routing in MANETs is the constant movement of nodes or node mobility Disruption and frequent path breaks occur due to the movement of intermediate nodes in the path and end nodes. Efficient mobility management for dynamic MANETs should be an important feature for routing protocols in MANETs. The other major design issue in MANETs is bandwidth constraint. In a wireless network, the radio band is limited, hence the routing protocols should be designed in such a way that bandwidth is used optimally by keeping the overhead as low as possible. Wireless networks also face collision and congestion problem [9]. Transmission in MANETs may cause collisions of data and control packets due to arbitrary and sudden movement of nodes. The solution is to find alternate routes through better quality links, with less congestion and low packets. Hidden terminal and exposed terminal problems are the other problems faced by dynamic system like MANETs. Hidden terminal problem refers to collision of packets at a receiving node due to the simultaneous transmission of those nodes that are not within the direct transmission range of the sender, but are within the transmission of the receiver. Collision occurs when both

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IV. MANET ROUTING PROTOCOLS

Routing protocols are used to set up and maintain routes that essentially support data transmission between various nodes in the system [10]. Routing is extremely challenging in MANETs as due to the frequent change in position of nodes even the efficient nodes may become unusable or inefficient. Several routing protocols have been specifically designed for ad hoc networks. Routing should be fully distributed in nature since centralized routing involves high control overhead and also there is a chance of single point failure. Moreover, routing maintenance should be localized so as to reduce control overhead. Resources such as bandwidth, computing power, memory and battery power should be optimally used. The routing protocol can be classified as follows:

C. Proactive or Table Driven Routing Protocols

Here, every node maintains the network topology information in the form of routing tables [11] [12]. To find a path from source to destination, the node runs an appropriate path finding algorithm. This type of protocol immediately provides the required routes when needed but at the cost of bandwidth which is used in periodic updates of topology. This type of protocol utilizes a large amount of bandwidth especially in systems like MANETs which already has strict bandwidth constraints. Also, it results in the formation of long and short loops. Proactive routing protocol causes unnecessary routing overhead and more bandwidth is required for constantly maintaining routing table information. The overhead and bandwidth consumption becomes all the more high when nodes are dynamic. Some of the important proactive routing protocols are DSDV, OLSR etc.

1) ***Destination Sequence Distance Vector (DSDV):*** In DSDV, every node maintains a routing table with one route entry for each destination in which the shortest path is recorded [13]. The shortest path is decided on the number of hops. All the nodes maintain a sequence number. These sequence numbers are updated whenever there is a change in the neighbourhood. This type of a routing protocol is distance vector shortest path based [14]. DSDV can also be extended with the help of clustering. This improves the protocol stability and heuristic methods like path reservation, priority scheduling can also be incorporated to improve the performance of the protocol [15].They are quite complex during link failure and also result in a large routing overhead and bandwidth consumption due to the constant maintenance and updation of routing table. So, this is not very suitable for MANETs

2) ***Optimized Link State Routing (OLSR):*** This protocol avoids packet transfer over unidirectional nodes. Instead, bi-directional links are chosen for packet transfer [16]. Among several nodes, one node is selected for multipoint relay. So, to send a message to all the neighbouring nodes, the message is relayed to the multipoint relay and from there it is broadcasted to all the neighbouring nodes. Although this protocol reduces the problem of routing overhead considerably but the concept of fixing a node as multipoint relay is not suitable for a dynamic system like MANET where the position of the nodes changes very fast.
3) ***Topology Dissemination Based on Reverse- Path Forwarding (TBRPF):*** Here, every node computes a shortest path tree to all other nodes [17]. However, the entire tree is not forwarded, only the difference between the previous and the current network state are transmitted to other nodes. This reduces the routing overhead and also routing tables are updated quite regularly. However, the number and size of routing transmissions is still very high and bandwidth usage is more.

D. Reactive or on-demand routing protocols

Reactive routing protocols discovers the routes between source and destination as and when necessary[18][19] .These protocols do not maintain any network topology information and save a lot of control overhead as there is no need to exchange routing information periodically. This reduces routing overhead as protocols are built and maintained only through the required routes. Some of the popular reactive routing protocols are discussed below.

1) ***Dynamic Source Routing (DSR)***

In DSR protocol the path set up for data transfer is done only when there is some data that needs to be transferred to a destination. That is why, DSR is called an on-demand routing protocol. The main aim of this algorithm is to find and maintain a route for communication. DSR operation is divided into two phases: route discovery and route maintenance. During route discovery operation, route request (RREQ) packets are flooded in the network. Route reply (RREP) packets are sent to the source node. These RREP packets are sent either by the destination node or any intermediate nodes having the destination address. The information conveyed by the RREP packets is stored for future reference. Route error (RERR) packets are used to convey information about broken links. DSR is quite suitable for dynamic MANETs as it adapts quickly to changes in node movements. For every destination several routes are stored. This results in improved packet delivery. Moreover, having multiple routes means not refreshing cache memory again and again; hence it saves bandwidth as well as power. However, storing several routes also results in large overhead. So, DSR needs to be modified to suit large dynamic MANETs.

2) *Split Multipath Routing (SMR):*

SMR protects the primary path by providing backup routes between source and destination [20]. In SMR, the data is split among multiple paths to avoid network congestion. This protocol builds multiple routes using various cycles of request and reply [21]. A RREQ message is flooded in the entire network, when a route from source to the destination is not available. The flooding results in several duplicate routes reaching the destination and among the several routes, the destination node selects the best possible route. Packet delivery ratio is better because of the availability of multiple routes. Also, there is no need for route recovery process. However, their utility in a dynamic and large MANET set up needs to be tested.

3) *Ad Hoc On Demand Distance Vector Routing (AODV):*

It closely adapts the Destination Sequenced Distance Vector (DSDV) protocol in ad hoc wireless networks [22]. The DSDV is a proactive table-driven protocol. In DSDV protocol, a routing table is maintained by all nodes in the network. This routing table contains the route information of all nodes that exist in that ad hoc network. Every destination is assigned a sequence number that is maintained in the route table. Table is updated whenever a destination with new sequence greater than the previous one is initiated. In AODV the route is established only when there is a need for data transfer at the source node. Hence, AODV is also an on-demand scheme. AODV also employees a data sequence number to identify the most recent path. AODV maintains a routing table that stores a single route between source and destination. RREQ packets are broadcasted to the neighbouring nodes [23]. These neighbouring nodes broadcast it to their neighbours and RREP from the most recently updated node is sent back to the source node. Route entries are made in the routing table when the RREP is sent back to the source nodes. Obsolete entries, which are not used within a specified time, are deleted. The inclusion of localized flooding during routing leads to better packet delivery ratio. AODV was further improvised by including a hop count in routing table and data packets. However, it is not possible to maintain a hop count when the systems become large and dynamic. This results in a scalability problem. So, AODV protocol also needs to be modified suitably with the help of optimization and other techniques so as to solve the routing problems of dynamic and large systems.

4) *Ad Hoc On Demand Multipath Distance Vector (AOMDV):*

Ad Hoc On Demand Multipath Distance Vector (AOMDV). AOMDV is designed to provide efficient and fast recovery from route failures [24]. This is done by finding multiple paths during route discovery. This is suitable for dynamic MANETs as the presence of multiple paths lead to less packet loss when route breaks occur. The routing information available in the underlying AODV protocol is utilized to reduce overhead and provide loop free routing. Packet delay time is reduced significantly when using AOMDV protocol, often by more than a factor of two. The AODMV protocol still needs to be tested for scalability and for heavy traffic. Moreover when the nodes move frequently, multipath connections cannot provide back up support for routing.

5) Ad Hoc On Demand Distance Vector Backup routing (AODV-BR):

This protocol provides an alternate path also called the backup route to the already existing route between source and destination. This technique reduces packet loss. However, the problem of data or packet loss persists when the backup route to the destination also fails [25].

6) *Ad Hoc On Demand Distance Vector nth Backup*

routing (AODV nthBR):

This protocol provides n multiple (n back up routes) for data transmissions and is quite suitable for MANETs [26] [27]. Here, on the failure of a route to destination, a backup route is calculated by finding the most nearest and energy efficient node for transmission. In case the backup route also fails, another node is searched for data transmission using distance vector calculation and checking the node for its energy efficiency. This method ensures that data packet loss, end to end delay is minimal and throughput is high as suitable routes are always available for data transmission. Moreover, availability of suitable routes also ensures good QoS parameters.

E. Hybrid Routing protocols

Hybrid Routing Protocols are a combination of proactive as well as reactive routing protocols. It combines the merits of proactive and reactive routing protocols to give the best possible result.

1) Zone Routing Protocol (ZRP):

All the nodes that are within a certain radius of a particular node are said to be within the routing zone of the given node and for these nodes a table driven approach is used. For the nodes outside this radius, an on-demand approach is used. An Intra zone Routing Protocol (IARP) is used in the zone where proactive routing protocol. Certain subsets within the network represent a routing zone. An Inter zone Routing Protocol (IERP) is used to find paths to nodes outside the routing zone.

2) ***Hybrid Routing Protocol with Broadcast Reply (HRP-BR)***:

HRP-BR can be divided into route discovery and route maintenance phase. In route discovery, the RREP packets are broadcast to all nodes along with the destination node. The neighbouring nodes update their entries correspondingly while the destination node makes its own entry in the RREP packet. In route maintenance, on finding a link failure a RERR message is sent to the source. After which, new route discovery process is started again.

Although these protocols reduce the routing overhead considerably but they become quite complex when the system is large and dynamic. Since mobile ad hoc networks have dynamic topology and also have to operate with limited bandwidth and limited battery power. So, the important task is to find routes that result in least overhead, consume less bandwidth and also provide necessary QoS parameters.

V. CONCLUSION

MANETs are characterized by dynamic topology, limited bandwidth availability and a constraint on resource utilization; so they generally employ on-demand or reactive routing protocols. These factors also make routing extremely challenging in MANETs. However, due to frequent change in position of nodes, even the efficient nodes may become unusable or inefficient. To ensure stable routing it is necessary to update routing information regularly. This in itself can pose a problem as it results in more control overhead which needs to be avoided due to limited resources availability. The problem is more when the MANETs are dynamic and large sized. AODV nthBR protocol, which have been successfully implemented for small, medium and large sized MANETs, provide an efficient solution to the problem of routing by providing multiple back up routes to the destination. Multiple transmissions are avoided since the routes are found in an efficient way and also QoS of the protocol is much better.

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