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Mobile Ad-hoc Network Routing Protocols: Comparative Study

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Abstract: A Mobile Ad-Hoc Network has not possessed any fixed infrastructure. Due to mobility of nodes, and frequent link breakage carry out, no central administrator is required. Hence, in MANET's routing is challenging job and it generating multiple types of routing protocols. In this paper, the author describe on routing techniques that have the major challenges in ad hoc networks due to the dynamic topology. Therefore, to determine the actual suitability of the routing protocol for MANET is very difficult for different network conditions. At this point, the author suggests about the routing protocols with comparative opinions for reactive, proactive and hybrid routing protocols.

Keywords: MANETs, Routing Protocols, Reactive, Proactive, Hybrid.

1 INTRODUCTION

Ad hoc wireless networking is a new approach to wireless communication with potential applications in very unpredictable and dynamic environments. In contrast to cellular and wired networks, an ad hoc wireless network does not depend on any established infrastructure or centralised administration such as a base station. It is a set of autonomous system of mobile nodes that move freely and randomly. Therefore, its network topology is dynamic in nature and may change speedily and unpredictably. Hence, the intercommunications among nodes will change continuously. Such networks have no infrastructure for achieving end-to-end routing of packets. The nodes communicate with each other without the intervention of a centralized administration; thus each acts both as a router and as a host.

Mobile Ad Hoc network [1, 13] is a collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration; in which each node cooperate by forwarding packets to each other to allow nodes to communicate beyond direct wireless transmission range. Routing is a process of sharing information from one station to other stations of the network. Routing protocols of mobile ad-hoc network tend to need different approaches from existing Internet protocols because of mobile host, dynamic topology, and distributed environment, less battery power and less bandwidth. Mobile Ad Hoc routing protocols can be categorized into two parts: table-driven (proactive schemes) and on-demand routing (reactive scheme) based on when and how the routes are discovered. In Proactive routing protocols [15] each node maintains one or more tables containing routing information about nodes in the network whereas in on-demand routing the routes are created as and when required. The security of ad hoc wireless networks is becoming an increasingly complex issue. Many applications today, especially emergency and military ones, are based upon mobile ad hoc wireless networks, where security requirements are harder to achieve than in traditional networks. Securing routing creates particular difficulties, since these networks have neither centrally administrated secure routers nor strict policies of use. The network topology is rapidly changing due to nodes in the networks being highly mobile, thus creating the presence or absence of links. Therefore, routing is especially harder to accomplish robustly, securely and efficiently at the same time. Security requirements such as non-repudiation, data integrity, confidentiality and authentication which would otherwise be provided by a central machine must be enabled and provided by all nodes.

1.1 Main characteristics of MANET are [2, 13] :-

1.1.1 Dynamic Topologies nodes are free to move arbitrarily, the network topology may change rapidly and randomly at unpredictable times. The links may be unidirectional and bidirectional.

1.1.2 Bandwidth constrained, variable capacity links: Wireless links have significantly lower capacity than their hardwired counterparts. Also, due to multiple access interference conditions, fading, and noise etc. the wireless links have low throughput.

1.1.3 Energy constrained operation: All or Some of the nodes in a MANET may rely on batteries. In this scenario, the most important system design criteria for optimization may be energy conservation.

1.1.4 Limited physical security: Mobile wireless networks are generally more prone to physical security threats than are fixed- cable nets. The increased possibility of denial-of-service, spoofing and eavesdropping attacks should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. As a benefit, the decentralized nature of network control in MANET provides additional robustness against the single points of failure of more centralized approaches.

1.1.5 Autonomous and infrastructure less: Network is self-organizing and is independent of any fixed infrastructure or centralized control. The operation mode of each node is distributed peer-to-peer capable of acting as an independent router as well as generating independent data.

1.1.6 Multi hops Routing: There is no dedicated router and every node acts as a router to pass packets to other nodes.

1.1.7 Security Threats: There are higher chances of physical security threats like spoofing, eavesdropping and denial of service (DoS) in wireless networks as compared to wired networks.

2. DESIGN ISSUES AND IT'S CHALLENGES

Ad hoc wireless networks inherit the traditional problems of wireless communications, such as bandwidth optimization, power control and transmission quality enhancement, while, in addition, their mobility, multi-hop nature and the lack of fixed infrastructure create a number of complexities and design constraints that are new to mobile ad hoc networks.

2.1 Bandwidth Efficiency and Overhead: Since the radio spectrum is limited, the bandwidth available for communication is very limited. The MAC protocol must be designed in such a way that the scarce bandwidth is utilized in an efficient manner .The control overhead involved must keep as minimum as possible.

2.2 Quality of Support (Qos): The nodes are mobile most of the time, providing QoS support to data sessions in such networks is very difficult. Bandwidth reservation made at one point time may become invalid once the node moves out of the region where the reservation was made. QoS support is essential for supporting time critical traffic sessions.

2.3 Synchronization: A MAC protocol must take into consideration the synchronization between nodes in the network and bandwidth reservation by nodes. The exchange of control packets may be required for achieving time synchronization among nodes .The control packets must not consume too much of work band width.

2.4 Hidden and Exposed Terminal Problems: The hidden terminal problem refers to the collision of packets at a receiving node due to simultaneous transmission of those nodes that are not within the direct transmission range of the sender, but are within the transmission range of receiver. Collision occurs when both nodes transmit packets at the same time. The hidden and exposed terminal problems significantly reduce the throughput of a network when the traffic load is high. It is therefore desirable that the MAC protocol be free from the hidden and exposed terminal problems.

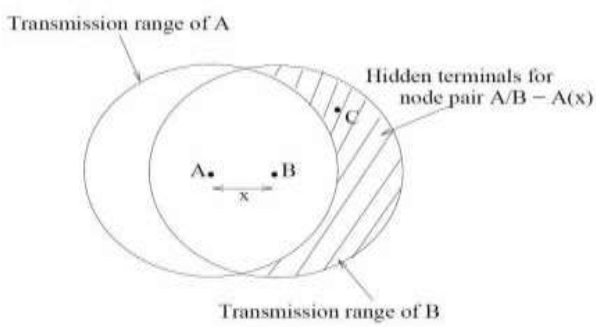

Figure 1: Hidden Terminal Problem

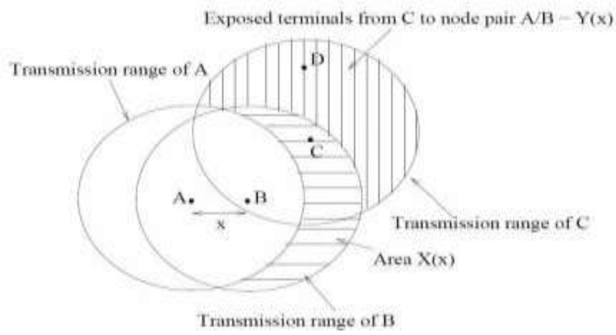

Figure 2: Exposed Terminal Problem

2.5 Error Prone Shared Broadcast Channel: Because of broadcasting nature of transmission, collisions may occur. A MAC protocol should grant channel access to nodes in such a manner that collisions are minimized. Also, the protocol should that all nodes are treated fairly with respect to bandwidth allocation.

2.6 Distributed Nature/ Lack of Central Coordination: In MANET nodes move continuously, therefore nodes must be scheduled in a distributed fashion for gaining access to the channel. This may require exchange of control information. The MAC protocol must make sure that the additional overhead, in terms of bandwidth consumption, incurred due to this control information exchange is not very high.

2.7 Mobility of Nodes: Nodes are mobile most of the time in wireless network. The bandwidth reservation made or control information exchange may end up being of no use if node mobility is very high. The MAC protocol has no role to play in influencing the mobility. The MAC protocol design must take this mobility factor into consideration such that the performance of the system is not significantly affected due to node mobility.

3. APPLICATIONS OF MANET

Because of their flexibility, MANETS are seen as important components in 4G architecture and ad hoc networking capabilities are believed to form a significant part of overall functionalities of next generation. The application of MANET has become wide and varied from email to ftp to web services. Some common MANET applications are:

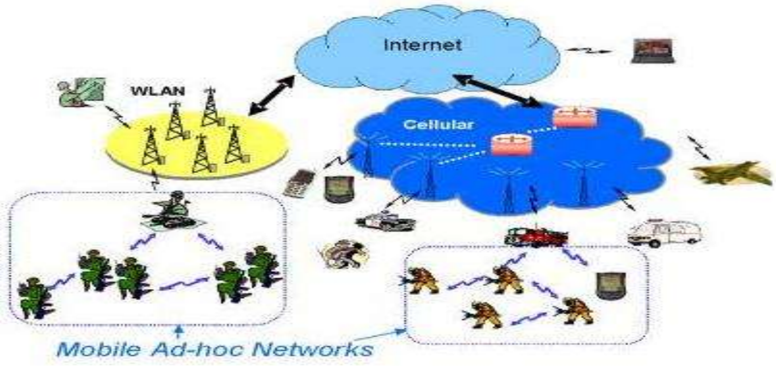

Figure 3: Application of MANET

3.1 Military Environments: Since it is not possible to install base station in the enemy territories or inhospitable terrain MANET provides communication services where soldiers act like nodes. The required coordination among the soldiers and in military objects can be seen as another application of MANET in military services.
3.2 Civilian Environments: MANET finds its use in many civilian activities like meeting room, boats, taxi cab network, small aircraft, sport stadium etc
3.3 Emergency Operations: Because of its easy deployment, the use of MANET in situations like crowd control, search and rescue, disaster recovery and commando operations, the use of mobile ad hoc networks is very much suitable. MANET can also be established when conventional infrastructure based communication is damaged due to any calamities.
3.4 Local Level: Ad hoc networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at e.g. conference a classroom. Another appropriate local level application might be in home networks where devices can communicate directly to exchange information.

4. ROUTING PROTOCOLS IN MANET

The highly dynamic natures of the mobile nodes create frequent and unpredictable network topology changes. This topology change increases the routing complexity among the mobile nodes within the network. There for traditional routing algorithms are not sufficient to the successful routing in MANET. Routing in a MANET [15] depends on many other factors including topology, selection of routers, and location of request initiator and specific underlying characteristics that could serve as a heuristic in finding the path quickly and efficiently. This makes the routing area perhaps the most active research area within the MANET domain. Especially over the last few years, numerous routing protocols and algorithms have been proposed and their performance under various network environments and traffic conditions closely studied and compared.

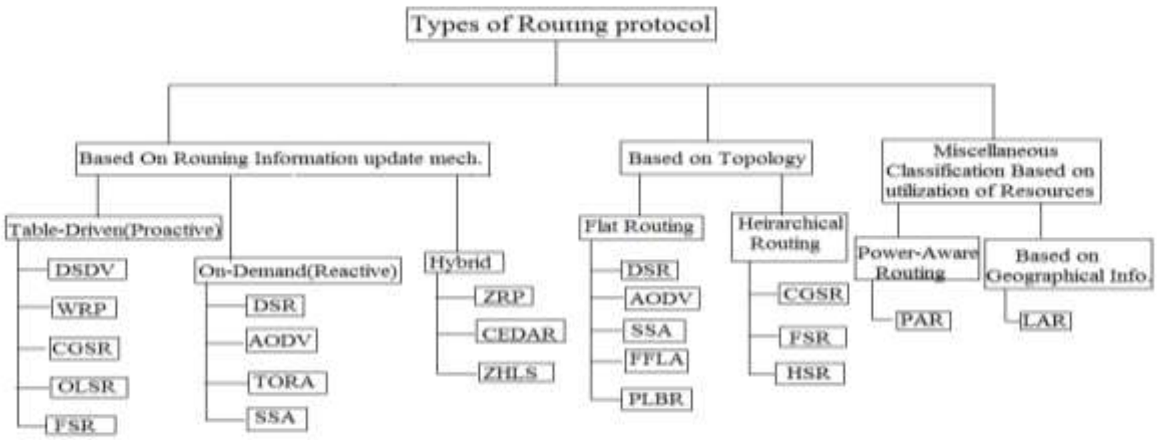

Figure 4: Classification of Routing Protocol in MANET

4. 1 Proactive or Table-Driven Routing Protocol

Proactive routing protocols [1, 2] attempt to maintain consistent, up-to-date routing information between every pair of nodes in the network by propagating, proactively, route updates at fixed time intervals. These protocols are sometimes referred to as table-driven protocols since the routing information is maintained in tables. The proactive routing approaches designed for ad hoc networks are derived from the traditional routing protocols. The primary characteristic of proactive approaches is that each node in the network maintains a route to every other node in the network at all times. Route creation and maintenance is accomplished through some combination of periodic and event-triggered routing updates. Periodic updates consist of routing information exchanges between nodes at set time intervals. The updates occur at specific intervals, regardless of the mobility and traffic characteristics of the network. Event-triggered updates, on the other hand, are transmitted whenever some event, such as a link addition or removal, occurs. The mobility rate directly impacts the frequency of event-triggered updates because link changes are more likely to occur as mobility increases. Proactive approaches have the advantage that routes are available the moment they are needed. Because each node consistently maintains an up-to-date route to every other node in the network, a source can simply check its routing table when it has data packets to send to some destination and begin packet transmission. However, the primary disadvantage of these protocols is that the control overhead can be significant in large networks or in networks with rapidly moving nodes. Further, the amount of routing state maintained at each node scales as O(n), where n is the number of nodes in the network. Proactive protocols tend to perform well in networks where there is a significant number of data sessions within the network. In these networks, the overhead of maintaining each of the paths is justified because many of these paths are utilized. Different Types of Proactive Routing Protocol are: Destination-Sequenced Distance-Vector (DSDV) protocol, Wireless Routing Protocol (WRP), Optimized Link State Routing Protocol (OLSR), Fisheye State Routing (FSR), Cluster Head Gateway Routing (CGSR).

In DSDV every node in the network maintains a routing table in which all the possible destinations within the network as well as the number of hops to reach each destination are recorded. Each route entry is marked with a sequence number. Nodes periodically transmit routing table updates throughout the network in order to maintain table consistency. Route updates contains the address of some node, the number of hops to reach the destination, the destination sequence number as well as a sequence number that uniquely identifies the update.

In OLSR is an optimization over the classical link state protocol. The key idea is to reduce duplicate broadcast packets in the same region. This is achieved with the use of the so called multipoint relay nodes. Each node selects a minimal set of multipoint relay nodes from among its one-hop neighbours. The goal behind the MPR principle is to achieve efficient flooding. When a node want to flood a message it sends the message only to the nodes in MPR, which in turn send the message to their MRP nodes and so on. A node retransmits a message if it has not received the message before, and the node is selected as multipoint relay by the node from which the message is received.

WRP is another loop-free proactive protocol whereby four tables are used to maintain distance, link cost, routes, and message retransmission information. General route updates are sent among neighbouring nodes with distance and second-to-last hop information for each destination, resulting in faster convergence. In FSR protocol is also an optimization over Link State algorithm using the fisheye technique. In essence, FSR will propagate link state information to other nodes in the network based on how far away the nodes are. The protocol will propagate link state information more frequently with nodes that are in a closer scope as opposed to ones that are further away. This means that a route will be less accurate the further away the node is, but once the message gets closer to the destination, the accuracy increases.

In CGSR is a routing protocol that has a hierarchical-based design. CGSR organized nodes into cluster entrusted to a special node named cluster-head. This cluster-head is elected dynamically by employing a least cluster change (LLC) algorithm [3]. According to this algorithm, a node ceases to be a cluster-head only if it comes under the range of another cluster-head where the tie is broken either using the lowest id or highest connectivity algorithm. Clustering provides a mechanism to allocate bandwidth, which is a limited resource, among different clusters, thereby improving reuse. All member nodes of a cluster can be reached by a cluster-head to provide improved coordination among nodes that fall under its cluster. A token based scheduling [4] is used within a cluster for sharing the bandwidth among the member of the cluster. CGSR assume that all communication passes through the cluster-head. Communication between two clusters takes place through the common member nodes that are member of both the clusters. These nodes which are members of more than one cluster are called gateways.

4.2 Reactive Routing or On-Demand Routing Protocol

Reactive routing [13, 14] techniques, also called on-demand routing, take a very different approach to routing than proactive protocols. A large percentage of the overhead from proactive protocols stems from the need for every node to maintain a route to every other node at all times. In a wired network, where connectivity patterns change relatively infrequently and resources are abundant, maintaining full connectivity graphs is a worthwhile expense. The benefit is that when a route is needed, it is immediately available. In an ad hoc network, however, link connectivity can change frequently and control overhead is costly. Because of these reasons, reactive routing approaches take a departure from traditional Internet routing approaches by not continuously maintaining a route between all pairs of network nodes. Instead, routes are only discovered when they are actually needed. When a source node needs to send data packets to some destination, it checks its route table to determine whether it has a route. If no route exists, it performs a route discovery procedure to find a path to the destination. Hence, route discovery becomes on-demand. If two nodes never need to talk to each other, then they do not need to utilize their resources maintaining a path between each other. The route discovery typically consists of the network- wide flooding of a request message. To reduce overhead, the search area may be reduced by a number of optimizations. Different Types of Proactive Routing Protocol are: Dynamic Source Routing (DSR) protocol, Ad hoc On-demand Distance Vector (AODV) protocol, Temporally Ordered Routing Algorithm (TORA).

DSR is based on the concept of source routing. In source routing each packet carries the complete ordered list of nodes in which the packet should pass through the network. This is done by maintaining a cache with route from source to destination. It includes two phases: Route discovery and Route maintenance. Route discovery is based on flooding the network with a RREQ packet. A RREQ message includes the senders address, the target address, a unique number to identify the request and a route record listing the addresses of each intermediate node through which the RREQ is forwarded. On receiving RREQ packet, the destination replies to the originator with a RREP packet.

AODV is an improvement on the DSDV protocol. AODV minimizes the number of route broadcasts by creating routes on an on-demand basis, as opposed to maintaining a complete list of routes as in the DSDV algorithm. Like DSR, route discovery is initiated on an on-demand basis, the route request is then forward to the neighbours, and so on, until either the destination or an intermediate node with a fresh route to the destination are located.

TORA is another source-initiated on-demand routing protocol, built on the concept of link reversal of Directed Acyclic Graph (ACG). In addition to being loop-free and bandwidth-efficient, TORA has the property of being highly adaptive and quick in route repair during link failure, while providing multiple routes for any desired source/destination pair. These features make it especially suitable for large highly dynamic mobile ad hoc environments with dense populations of nodes. The limitation in TORA's applicability comes from its reliance on synchronized clocks. If a node does not have a GPS positioning system or some other external time source, or if the time source fails, the algorithm cannot be used.

4.3 Hybrid Routing Protocols

Hybrid protocols [1, 2] combine the features of reactive and proactive protocols. These protocols have the advantage of both proactive and reactive routing protocols to balance the delay which was the disadvantage of Table driven protocols and control overhead (in terms of control packages). Main feature of Hybrid Routing protocol is that the routing is proactive for short distances and reactive for long distances. The common disadvantage of hybrid routing protocols is that the nodes have to maintain high level topological information which leads to more memory and power consumption. Different Types of Hybrid Routing Protocol are: ZRP (Zone Routing Protocol), CEDAR (Core Extraction Distributed Ad Hoc Routing).

ZRP divides the topology into zones and seek to utilize different routing protocols within and between the zones based on the weaknesses and strengths of these protocols. ZRP is totally modular, meaning that any routing protocol can be used within and between zones. The size of the zones is defined by a parameter r describing the radius in hops. Intra-zone routing is done by a proactive protocol since these protocols keep an up to date view of the zone topology, which results in no initial delay when communicating with nodes within the zone. Inter-zone routing is done by a reactive protocol. This eliminates the need for nodes to keep a proactive fresh state of the entire network.

5. COMPARATIVE STUDY

After a deep study about Mobile Adhoc Network, the author observed that there is many differences among all the routing protocols and explain these differences in the following tables: Table 1, Table 2 and Table 3.

Parameters	DSDV	CGSR	WRP
Routing philosophy	Flat	Hierarchical	Flat
Storage Space	Low	Low	High as each node stores 4tables
Critical Node	No, all the node have same capability	Yes, the cluster head is critical node	No, all nodes have same capability
Hello Message	Yes, hello message is used	No, hello message is not used	Yes, hello message is used
Update frequency	Periodic and where is a change	Periodic	Periodic
Update transmitted to	Neighbor	Neighbor and to cluster head	Neighbor

Table 1: Comparisons of various Proactive Routing Protocols

Parameters	DSR	AODV	TORA
Routing Type	Source Routing	Distance Vector	Link Traversal
Loop Freedom	Yes	Yes	No
Multiple Routes	Multiple routes not there	There are multiple routes	Multiple routes are not there
Destination update Procedure	Source	Source	Neighbor
Route Stored	In Route cache	In routing table	In routing table

Table 2: Comparisons of various Reactive Routing Protocols

Parameters	Reactive	Proactive	Hybrid
Routing Philosophy	Flat	Flat/Hierarchical	hierarchical
Routing Technique	On demand	Table Driven	Combination of both
Overhead in Routing	Low	High	Medium
Route availability	Set up when needed	Always available	Depends upon destination's location
Latency	High	Low	Zone dependent
Periodic updates	No	Yes	Required inside Zone
Storage need	Depends upon number of routes kept	Low	Depends upon size of the zone
Scalability	Not scalable, suited to small network	Not scalable	Scalable to large network

Table 3: Comparisons of Proactive, Reactive and Hybrid Routing Protocols

CONCLUSION

The author concludes here that there are various routing protocols in MANETs with different network behaviour. Reactive protocols have less overhead as their dynamic routing technology. It set up route when it needed and it needs high latency and more memory for storage. Proactive routing protocols on the other hand have more routing overhead due to static routing technology and they require less memory for storage and low latency. Hybrid protocols combine the features of both protocols and they perform well and are designed for larger network. The author define on the previous paragraph that the area of mobile Adhoc networks is very huge. In the future, the networks are going to be widespread for its usefulness relating to power control, its stability and network security. This will make Mobile ad hoc networks more secure, scalable and power efficient.

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