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A Strategic Review of Routing Protocols for Mobile Ad Hoc Networks

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***Abstract*— In recent years, a rapid growth of research interests in mobile ad hoc networking has been see. The infrastructureless and the dynamic nature of these networks demand an efficient and reliable routing strategy. Due to the mobility and the limited resources in mobile ad hoc networks (MANET), routing is a challenging task and has received tremendous amount of attention from researchers. This has led to the development of many different routing protocols for MANET. It is quite difficult to determine which protocols may perform well under a number of different network scenarios such as network size and topology etc. In this paper an overview of a wide range of the existing routing protocols with a particular focus on their characteristics and functionality have been provided.**

***Keywords*— Mobile ad hoc networking, *infrastructureless, routing protocols, topology*.**

I. Introduction

The wireless network can be classified into two types: Infrastructured and Infrastructure less [1]. In Infrastructured wireless networks, the mobile node can move while communicating, the base stations are fixed and as the node goes out of the range of a base station, it gets into the range of another base station [2]. In Infrastructureless or Ad hoc wireless network, the mobile node can move while communicating, there are no fixed base stations and all the nodes in the network act as routers. The mobile nodes in the Ad hoc network dynamically establish routing among themselves to form their own network 'on the fly'. A Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes forming a temporary/short-lived network without any fixed infrastructure where all nodes are free to move about arbitrarily and all the nodes configure themselves. In MANET, each node acts both as a router and as a host and even the topology of network may also change rapidly. The mobility of nodes is also a major factor within MANETs due to limited wireless transmission range. This can cause the network topology to change unpredictably as nodes enter and leave the network [3]. Node mobility can cause broken routing links, which forces nodes to recalculate their routing information. This consumes processing time, memory, device power and generates traffic backlogs and additional overhead [4].

This paper is structured as follows; Section II discusses classification of routing protocols in MANET, Section III discusses the proactive routing protocols ; DSDV, STAR WRP, DREAM, CGSR, GSR and FSR. Section IV discusses the reactive routing protocols; AODV, DSR, LAR, ARA, CBRP, ABR and TORA. Section VI discusses the hybrid routing protocols; ZRP, ZHLS, CEDAR, DST and SHARP Section VII compares the three types of protocols and Section VII concludes the paper.

II. Classification Of Routing Protocols

The routing protocols for ad hoc wireless networks can be basically classified into three categories. They are Proactive (Table-driven), Reactive (On-demanded) and Hybrid routing protocols. This classification is diagrammatically shown in the Fig. 1.

III. Proactive Protocols

Proactive protocols maintain unicast routes between all pairs of nodes regardless of whether all routes are actually used. Therefore, when the need arises, the source node has a route readily available and does not have to incur any delay for route discovery. These protocols also can find optimal routes. These protocols are broadly classified into the two traditional categories: distance vector and link state. In distance vector protocols, a node exchanges with its neighbours a vector containing the current distance information to all known destinations; the distance information propagates across the network transitively and routes are computed in a distributed manner at each node. On the other hand, in link state protocols, each node disseminates the status of each of its outgoing links throughout the network in the form of link state updates.

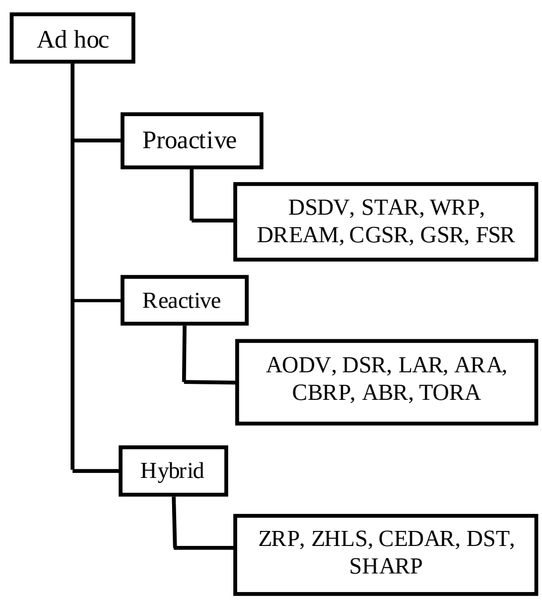

Fig.1 Classification of Ad hoc Routing Protocols

A .Destination Sequenced Distance Vector routing (DSDV)

DSDV is the proactive protocol, based upon the Bellman-ford algorithm to calculate the shortest path to the destination [5]. Each DSDV node maintains a routing table which stores; destination addresses, next hop addresses and number of hops as well as sequence numbers. Routing table updates are sent periodically as incremental dumps limited to a size of 1 packet containing only new information [6]. DSDV compensates for mobility using sequence numbers and routing table updates. If a route update with a higher sequence number is received, it will replace the existing route thereby reducing the chance of routing loops. When a major topology change is detected a full routing table dump will be performed, this can add significant overhead to the network in dynamic scenarios.

B. Source-Tree Adaptive Routing protocol (STAR)

The STAR protocol [7] is also based on the link state algorithm. Each router maintains a source tree, which is a set of links containing the preferred paths to destinations. This protocol has significantly reduced the amount of routing overhead disseminated into the network by using a least overhead routing approach (LORA), to exchange routing information. The optimum routing approach obtains the shortest path to the destination while LORA minimizes the packet overhead. In STAR each node maintains a source tree which contains preferred links to all possible destinations. The routes are maintained in a routing table containing entries for the destination node and the next hop neighbour. The link state update messages are used to update changes of the routes in the source trees. Since these packets do not time out, no periodic messages are required.

C. Wireless Routing Protocol (WRP)

WRP [8] belongs to the general class of path-finding algorithms [9], defined as the set of distributed shortest path algorithms that calculate the paths using information regarding the length and second-to-last hop of the shortest path to each destination. WRP reduces the number of cases in which a temporary routing loop can occur. For the purpose of routing, each node maintains four tables; Distance table, routing table, Link-cost table and a message retransmission list (MRL). The nodes in the response list of update message should send acknowledgments. If there is no change from the last update, the nodes in the response list should send an idle Hello message to ensure connectivity. A node can decide whether to update its routing table after receiving an update message from a neighbour and always it looks for a better path using the new information. If a node gets a better path, it relays back that information to the original nodes so that they can update their tables. After receiving the acknowledgment, the original node updates its MRL. Thus, each time the consistency of the routing information is checked by each node in this protocol, which helps to eliminate routing loops and always tries to find out the best solution for routing in the network.

D. Distance Routing Effect Algorithm for Mobility (DREAM)

In DREAM, each node knows its geographical coordinates through a GPS [10]. These coordinates are periodically exchanged between each node and stored in a routing table called a location table. The advantage of exchanging location information is that it consumes significantly less bandwidth than exchanging complete link state or distance vector information, which means that its is more scalable. In DREAM, routing overhead is further reduced, by making the frequency at which update messages are disseminated proportional to mobility and the distance effect. This means that stationary nodes do not need to send any update messages.

E. Cluster Gateway Switch Routing (CGSR)

CGSR [11] considers a clustered mobile wireless network as a hierarchical network instead of flat network. CGSR organizes nodes into clusters, with coordination among the members of each cluster entrusted to a special node named cluster-head. For structuring the network into separate interrelated groups, cluster heads are elected using a cluster head selection algorithm. By forming several clusters this protocol achieves a distributed processing mechanism in the network. One disadvantage of using this protocol is that, frequent change or selection of cluster head might be resource hungry and it may affect the routing performance. CGSR uses DSDV as underlying scheme. It modifies DSDV by using hierarchical cluster head gateway routing approach to route traffic from source to destination. A packet sent by a node is first sent to the cluster head and then it sends to gateway to another cluster head and so on until it reaches from cluster head to the destination.

F. Global State Routing (GSR)

The GSR protocol [12] is based on the traditional Link State algorithm. However, GSR has improved the way information is disseminated in Link State algorithm by restricting the update messages between intermediate nodes only. In GSR, each node maintains a link state table based on the up-to-date information received from neighboring nodes, and periodically exchanges its link state information with neighboring nodes only. This has significantly reduced the number of control message transmitted through the network. However, the size of update messages is relatively large, and as the size of the network grows, they will get even larger. Therefore, a considerable amount of bandwidth is consumed by these update messages.

G. Fisheye State Routing (FSR)

FSR is an improvement of GSR. The large size of update messages in GSR wastes a considerable amount of network bandwidth. In FSR, each update message does not contain information about all nodes. Instead, it exchanges information about closer nodes more frequently than it does about farther nodes, thus reducing the update message size. So each node gets accurate information about neighbours and the detail and accuracy of information decreases as the distance from node increases. Even though a node does not have accurate information about distant nodes, the packets are routed correctly, because the route information becomes more and more accurate as the packet moves closer to the destination. FSR scales well to large networks as the overhead is controlled in this scheme [13]. However, scalability comes at the price of reduced accuracy. This is because, as mobility increases the routes to remote destination become less accurate. This can be overcome by making the frequency at which updates are sent to remote destinations proportional to the level of mobility.

Summary of Proactive Routing Protocols

In summary, most flat routed global routing protocols do not scale very well. This is because their updating procedure consumes a significant amount of network bandwidth. From the flat routed protocols discussed in this section, increase in scalability is achieved by reducing the number of rebroadcasting nodes through the use of multipoint relaying, which elects only a number of neighboring nodes to rebroadcast the message. This clearly has the advantage of reducing channel contention. The hierarchically routed global routing protocols will scale better in most of the flat routed protocols. Since they have introduced a structure to the network, which control the amount of overhead transmitted through the network. This is done by allowing only selected nodes such as a cluster heads and can rebroadcast control information. The common disadvantage associated with all the hierarchical protocols is mobility management.

IV. Reactive Protocols

On-demand (reactive) routing presents an interesting and significant departure from the traditional proactive approach. Main idea in on-demand routing is to find and maintain only needed routes. Recall that proactive routing protocols maintain all routes without regard to their ultimate use. The obvious advantage with discovering routes on-demand is to avoid incurring the cost of maintaining routes that are not used. This approach is attractive when the network traffic is sporadic and directed mostly toward a small subset of nodes.

A. Ad-Hoc On-Demand Distance Vector routing (AODV)

AODV [14] is basically an improvement of DSDV. It minimizes the number of broadcasts by creating routes based on demand. When any source node wants to send a packet to a destination, it broadcasts a RREQ packet. The neighboring nodes in turn broadcast to their neighbors and the process continues until it reaches the destination. During the process of forwarding the RREQ, intermediate nodes records the address of the neighbor from which packets received while broadcasting. This route information is stored in route tables, which helps for establishing reverse path. If additional copies of same RREQ are received later it simply discards it. Then reply is sent using reverse path. For Route Maintenance, when a source node moves, it can re-initiate a route discovery process. If any intermediate node moves with in a particular route, the neighbor of the drifted node can detect the link failure and sends a link failure notification to its upstream neighbor. After receiving the failure notification, source again re-initiate a discovery phase.

B. *Dynamic Source Routing (DSR)*

The function of the DSR protocol is divided into two stages; route discovery phase and route maintenance phase, these phases are triggered on demand when a packet needs routing. Route discovery phase floods the network with route requests if a suitable route is not available in the route [15]. DSR uses a source routing strategy to generate a complete route to the destination, this will then be stored temporarily in nodes route cache [16]. DSR addresses mobility issues through the use of packet acknowledgements. Failure to receive an acknowledgement causes packets to be buffered and route error messages to be sent to all upstream nodes. Route error messages trigger the route maintenance phase which removes incorrect routes from the route cache and undertakes a new route discovery phase [17].

C. Location-Aided Routing (LAR)

LAR [18] is based on flooding algorithms. However, LAR attempts to reduce the routing overheads present in the traditional flooding algorithm by using location information. This protocol assumes that each node knows its location through a global positioning system (GPS). Two different LAR scheme were proposed in [18], the first scheme calculates a request zone which defines a boundary where the route request packets can travel to reach the required destination. The second scheme stores the coordinates of the destination in the route request packets. These packets can only travel in the direction where the relative distance to the destination becomes smaller as they travel from one hop to another. Both schemes limit the control overhead transmitted through the network and hence conserve bandwidth. They will also determine the shortest path to the destination, since the route request packets travel away from the source and towards the destination. The disadvantage of this protocol is that each node is required to carry a GPS.

D. Ant-colony-based Routing Algorithm (ARA)

ARA [19] is an attempt to reduce routing overheads by adopting the food searching behavior of Ants. When ants search for food they start from their nest and walk towards the food, while leaving behind a transient trail called pheromone. This indicated the path that has been taken by the Ant and allows others to follow, until the pheromone disappears. ARA has two phases; route discovery and route maintenance. During route discovery a Forwarding ANT (FANT) is propagated through the network (similar to a RREQ). At each hop, each node calculates a pheromone value depending on how many number of hops the FANT has taken to reach them. The nodes then forward the FANT to their neighbors. Once the destination is reached, it creates a Backward ANT (BANT), and returns it to the source. When the source receives the BANT from the destination node, a path is determined and data packet dissemination begins. The advantage of this strategy is that the size of each FANT and BANT is small, which means the amount of overhead per control packet introduced in the network is minimized. However, the route discovery process it based on flooding. Hence the protocol may have scalability problems as the number of nodes and flows in the network grows.

E. Cluster-Based Routing Protocol (CBRP)

In CBRP [11] the nodes are organized in a hierarchical manner. The nodes in CBRP are grouped into clusters. Each cluster has a cluster-head, which coordinates the data transmission within the cluster and to other clusters. The advantage of CBRP is that only cluster heads exchange routing information, therefore the number of control overhead transmitted through the network is far less than the traditional flooding methods. However, as in any other hierarchical routing protocol, there are overheads associated with cluster formation and maintenance. The protocol also suffers from temporary routing loops. This is because some nodes may carry inconsistent topology information due to long propagation delay.

F. Associativity-Based Routing (ABR)

ABR [20] protocol defines a new type of routing metric “degree of association stability” for mobile ad hoc networks. In this routing protocol, a route is selected based on the degree of association stability of mobile nodes. Each node periodically generates beacon to announce its existence. Upon receiving the beacon message, a neighbor node updates its own associativity table. For each beacon received, the associativity tick of the receiving node with the beaconing node is increased. A high value of associativity tick for any particular beaconing node means that the node is relatively static. Associativity tick is reset when any neighboring node moves out of the neighborhood of any other node.

G. Temporally Ordered Routing Algorithm (TORA)

TORA [21] is a reactive routing protocol. In this, a link between nodes is established creating a Directed Acyclic Graph of the route from source to destination. This protocol uses a “link reversal” for route discovery. A route discovery query is broadcasted to the entire network until it reaches the destination or a node that has information about the destination. Main feature of this protocol is propagation of control messages only around the point of failure or link failure occurs. In comparison, all other protocols need to re-initiate a route discovery when a link fails but TORA would be able to patch itself around the point of failure. TORA involves four major functions: Creating, maintaining, erasing and optimizing routes. Since every node must have a height, any node which doesn’t have a height is considered as a erased node. Sometimes the nodes are given new heights to improve the linking structure. This function is called optimization of routes. The disadvantage of TORA is that the algorithm may also produce temporary invalid routes.

Summary of Reactive Routing Protocols

In summary, reduction in control overhead can be obtained by introducing a hierarchical structure to the network. The hierarchical on-demand routing protocol attempts to minimize control overheads disseminated into the network by breaking the network into clusters. During the route discovery phase, cluster-heads exchange routing information. This significantly reduces the control overhead disseminated into the network when compared to the flooding algorithms. In highly mobile networks, these protocols may incur significant amount of processing overheads during cluster formation/maintenance. These protocols suffer from temporary invalid routes as the destination nodes travel from one cluster to another. The protocol may also best perform in scenarios with group mobility where the nodes within a cluster are more likely to stay together.

V. HYBRID ROUTING PROTOCOLS

Most of the protocols presented for MANET are either proactive or reactive protocols. There is a trade-off between proactive and reactive protocols. Proactive protocols have large overhead and less latency while reactive protocols have less overhead and more latency. So a hybrid protocol is presented to overcome the shortcomings of both proactive and reactive routing protocols. Hybrid routing protocol is the combination of both proactive and reactive routing protocol. It uses the route discovery mechanism of reactive protocol and the table maintenance mechanism of proactive protocol so as to avoid latency and overhead problems in the network. Hybrid protocol is suitable for large networks where large numbers of nodes are present.

A. Zone Routing Protocol (ZRP)

ZRP [22] is a hybrid routing protocol for MANET which localizes the nodes into sub-networks (Zones). It is suitable for networks with large span and diverse mobility patterns. In this protocol, each node proactively maintains routes within a local region, which is termed as routing zone. Route creation is done using a query-reply mechanism. For creating different zones in the network, a node first has to know who its neighbors are. A neighbor is defined as a node with whom direct communication can be established, and that is; within one hop transmission range of a node. Neighbor discovery information is used as a basis for Intra-zone Routing Protocol (IARP). Rather than blind broadcasting, ZRP uses a query control mechanism to reduce route query traffic by directing query messages outward from the query source and away from covered routing zones. A covered node is a node which belongs to the routing zone of a node that has received a route query. During the forwarding of the query packet, a node identifies whether it is coming from its neighbor or not. If yes, then it marks all of its known neighboring nodes in its same zone as covered. The query is thus relayed till it reaches the destination.

B. Zone-based Hierarchical Link State routing (ZHLS)

In ZHLS, the network is divided into non-overlapping zones, and each node has a node ID and a zone ID, which is calculated using a GPS [22]. In ZHLS location management has been simplified. This is because no cluster-head or location manager is used to coordinate the data transmission.

Hence there is no processing overhead associated with cluster-head or Location Manager Selection Another advantage of ZHLS is that it has reduced the communication overheads when compared to pure reactive protocols such as DSR and AODV. In ZHLS, when a route to a remote destination is required, the source node broadcast a zone level location request to all other zones, which generates significantly lower overhead when compared to the flooding approach in reactive protocols. Another advantage of ZHLS is that the routing path is adaptable to the changing topology since only the node ID and the zone This may not feasible in applications where the geographical boundary of the network is dynamic. Nevertheless, it is highly adaptable to dynamic topologies and it generates far less overhead than pure reactive protocols, which means that it may scale well to large networks.

C. Core Extraction Distributed Ad hoc Routing (CEDAR)

CEDAR is a partitioning protocol, integrates routing with QoS support [23]. Each partition includes a core node called dominator node. A Dominator set (DS) of a graph is defined as a set of nodes in the graph such that every node is either present in DS or is a neighbor of some node present in DS. The core nodes use a reactive source routing protocol to outline a route from a source to a destination. CEDAR has three key phases. They are 1. The establishments and maintenance of self-organizing routing infrastructure (core) for performing route computations, 2. The propagation of the link-states of high-bandwidth and stable links in the core and 3. A Quos route computation algorithm that is executed at the core nodes using only locally available state.

D. Sharp Hybrid Adaptive Routing Protocol (SHARP)

SHARP [24] adapts between reactive and proactive routing by dynamically varying the amount of routing information shared proactively. This protocol defines the proactive zones around some nodes. The number of nodes in a particular proactive zone is determined by the node-specific zone radius. All nodes within the zone radius of a particular node become the member of that particular proactive zone for that node. If destination node is not present within a particular proactive zone, reactive routing mechanism (query-reply) is used to establish the route to that node. Proactive routing mechanism is used within the proactive zone. Nodes within the proactive zone maintain routes proactively only with respect to the central node. In this protocol, proactive zones are created automatically if some destinations are frequently addressed or sought within the network. The proactive zones act as collectors of packets, which forward the packets efficiently to the destination, once the packets reach any node at the zone vicinity.

E. Distributed Spanning Trees routing (DST)

In DST [25], the nodes in the network are grouped into a number of trees. Each tree has two types of nodes; route node, and internal node. The root controls the structure of the tree and the rest of the nodes within each tree are the regular nodes. Each node can be in one three different states; router, merge and configure depending on the type of task that it trying to perform. To determine a route DST proposes two different routing strategies; hybrid tree-flooding (HTF) and distributed spanning tree shuttling (DST). In HTF, control packets are sent to all the neighbors and adjoining bridges in the spanning tree, where each packet is held for a period of time called holding time. When a control packet reaches down to a leaf node, it is sent up until it reaches a certain height referred to as the shuttling level. When the shuttling level is reached, the control packet can be sent down. The main disadvantage of the DST algorithm is that it relies on a root node to configure the tree, which creates a single point of failure. Furthermore, the holding time used to buffer the packets may introduce extra delays in to the network.

Summary of Hybrid Routing Protocols

In summary, Hybrid routing protocols have the potential to provide higher scalability than pure reactive or proactive protocols. This is because they attempt to minimize the number of rebroadcasting nodes by defining a structure, which allows the nodes to work together in order to organize how routing is to be performed. By working together the best or the most suitable nodes can be used to perform route discovery. Collaboration between nodes can also help in maintaining routing information much longer. Another novelty of hybrid routing protocols is that they attempt to eliminate single point of failures and creating bottleneck nodes in the network. This is achieved by allowing many nodes to perform routing or data forwarding operation, if the preferred path becomes unavailable.

VI. COMPARISON OF PROTOCOLS

Table 1 below provides an overall comparison of the three categories of routing protocols. In order to make flat addressing more efficient, the number of routing overheads introduced in the networks must be reduced. Another way to reduce routing overheads is by using conditional updates rather than periodic ones. In reactive routing protocols, the flooding-based routing protocols will also have scalability problems. In order to increase scalability, the route discovery and route maintenance must be controlled.

TABLE I

PARAMETRIC COMPARISON

Parameters	**Reactive Protocol**	**Proactive Protocol**	**Hybrid Protocol**
Routing Structure	Flat	Flat/ Hierarchical	Hierarchical
Routing Scheme	On demand	Table driven	Combination of both
Routing overhead	Low	High	Medium
Latency	High	Low	Inside the zone low and outside similar to Reactive protocols
Scalability	Not suitable	Low	Designed for

	for large networks		large networks
Routing information availability	Available when required	Always available	Combination of both
Periodic updates	Not needed	Needed when the topology changes	Needed inside the zone
Storage capacity	Low	High	Depends on the zone size
Mobility support	Route maintenance	Periodical updates	Combination of both

Hybrid routing protocols may also perform well in large networks. It maintains strong network connectivity (proactively) within the routing zones while determining remote route (outside the routing zone) quicker than flooding. Also it can incorporate other protocols to improve its performance.

VII. Conclusion

In this research paper, an effort has been made to concentrate on the comparative study of various on demand/reactive routing protocols on the basis of the above mentioned parameters. The results have been reflected in Table I. It has been further concluded that due to the dynamically changing topology and infrastructure less, decentralized characteristics, security and power awareness is hard to achieve in mobile ad hoc networks. The comparison between the routing protocols indicates that the design of a secure ad hoc routing protocol constitutes a challenging research problem against the existing security solutions. The overall characteristic features of all routing protocols have been provided. At last the overall characteristic features of all routing protocols have been provided and described which protocols may perform best in large networks. Still mobile ad hoc networks have posed a great challenge for the researchers due to changing topology and security attacks, and none of the protocols is fully secured and research is going on around the globe. Further this study will help the researchers to get an overview of the existing protocols and suggest which protocols may perform better with respect to varying network scenarios.

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