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Review of Different Routing Protocols in Mobile Ad-Hoc Networks

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Abstract— A Mobile ad-hoc network (MANET) is an infrastructure less network formed by collection of mobile nodes. Due to mobility of mobile nodes it supports Distributed routing protocols which are different from the conventional routing protocols like Distance-Vector Routing (what the routers tell each other) and Link-State Routing (how they use the information to form their routing tables). This paper discussed the issues and challenges of mobile ad hoc network responsible for the desire of different categories of routing protocols like proactive (table-driven), reactive (on-demand) and hybrid protocols with their comparisons based on different parameters.

Keywords— Mobile ad-hoc network, Routing protocol, Issues, Characteristic

I. INTRODUCTION

Mobile Ad-hoc networks are self adaptive and self configuring dynamic network of mobile nodes and devices. The communication between nodes takes place using multi-hop links in absence of static infrastructure or base station in these networks. The mobile nodes in these networks not only act as hosts but also as routers that route data to other nodes in network. So, routing in ad-networks is very important and challenging task since it came into existence.

Routing [15] is defined as the process of transferring data packets from source node to destination node with the help of intermediate nodes for selecting the specific route for the data transfer. Based on different conditions and characteristics of the network several routing protocols are needed for routing. The traditional routing protocols (Distance Vector and Link State) are unable to deal with the frequent link changes in Mobile ad-hoc networks, resulting in poor route convergence and very low communication throughput. Hence, new routing protocols are needed. Routing protocols in adhoc networks need to deal with the mobility of nodes and constraints in power and bandwidth. This also leads to the frequent path failure in these types of networks. In order to adapt frequent path failures, special routing protocols are required. Routing protocol for adhoc networks can be broadly classified into four categories [1]:

Based on the Routing information update mechanism: They are categorized as Proactive (Table-driven), Reactive (On-demand) and Hybrid routing protocols.

Based on the use of Temporal information for routing: They are categorized by using past temporal information and by using future temporal information.

Based on the Routing topology: They are categorized as Flat topology and Hierarchical topology routing protocols

Based on the Utilization of specific resource: They are categorized as Power-aware routing and Geographical information assisted routing.

This paper mainly focuses on the classification of routing protocols based on the Routing information update mechanism. It also gives the advantages and disadvantages of the protocols lies in this category.

The rest of the paper is organized as follows: Section II presents Issues in designing routing protocol for MANET, Section III presents Characteristics of an Ideal Routing protocols for MANET and Section IV presents Classification of routing protocols. Finally Section V concludes the paper.

II. ISSUES IN DESIGNING A ROUTING PROTOCOL FOR MOBILE ADHOC NETWORK

A routing protocol for adhoc wireless networks has the following issues in designing [1]:

Mobility of Nodes: Due to mobility of mobile nodes the adhoc network leads to frequent path breaks. This

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interruption is due to the movement of (i) end nodes or (ii) the intermediate nodes in the path. So, there is a need to develop dynamic routing protocols for adhoc networks which are able to perform effective and efficient mobility management.

This is in contrast to wired networks where all the nodes are stationary placed on reliable links and finds alternative routes during path breaks but results in slow convergence rate.

Bandwidth Constraint: The radio band is limited in Wireless Network and hence the data rates it can offer are much less than wired network. It requires that the routing protocols use the bandwidth optimally by keeping the overhead as low as possible. Limited bandwidth availability imposes a constraint on routing protocols in maintaining topological information as topology changes frequently. This results in more bandwidth wastage in maintaining consistent topological information at all the nodes.

This is in contrast to wired networks where ample bandwidth is available due to the arrival of Fibre Optics and usage of Wavelength Division Multiplexing (WDM) technologies.

Resource Constraint: Battery life and processing power are the two essential resource constraints for nodes in adhoc wireless network. In most cases the devices used in in adhoc wireless network require portability and hence they also have size and weight constraints along with the restrictions on the power source.
Increasing the battery power and processing ability makes the nodes bulky and less portable. Hence, there is a need to optimally manage these resources by ad hoc wireless network routing protocols.

Error-Prone Shared Broadcast Radio Channel: The broadcast nature of the radio channel sets challenge in Adhoc Wireless Networks. The wireless links have time-varying characteristics in terms of link capacity and link-error probability. This requires that the required routing protocols interact with the MAC layer to find alternate routes through better quality links. Also, transmissions in Adhoc Wireless Networks result in collisions of Data and Control packets. This is attributed to the hidden terminal problem. Hence, it is required that the Adhoc Wireless Network routing protocols find paths with less congestion.

Hidden and Exposed Terminal Problem: The hidden terminal problem refers to the 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 range of the receiver. Collision occurs when both nodes transmit packets at the same time without knowing about the transmission of each other.
The exposed terminal problem refers to the inability of a node which is blocked due to transmission by a nearby transmitting node to transmit to another node.
Hence, it is required that the Adhoc Wireless Network routing protocols should take the hidden and exposed terminal problem into account.

III. CHARACTERISTICS OF AN IDEAL ROUTING PROTOCOL FOR MOBILE ADHOC NETWORK

A routing protocol for mobile ad-hoc networks should have the following characteristics [1]:

- It must optimally use scare resources such as Bandwidth, Computing Power, Memory and Battery Power.
- It must converge to optimal routes once the network topology becomes stable. Also, the convergence must be quick.
- It must be localized, as global state maintenance involves a huge state propagation control overhead.
- It must be loop-free and free from stale routes.
- It must be adaptive to frequent topology changes caused by the mobility of nodes.
- It must be fully Distributed and is more fault tolerant. As Centralized routing involves high control overhead and also involves the risk of single point of failure.
- It should be able to provide a certain level of QoS as demanded by the applications and should also offer support for time-sensitive traffic.
- Route computation and maintenance must involve a minimum number of nodes. Each node in the network must have quick access to the routes i.e. minimum connection setup time is desired.

IV. CLASSIFICATIONS OF ROUTING PROTOCOLS

In this paper, we classified the routing protocol Based on the Routing information update mechanism. They are categorized as Proactive or Table-driven, Reactive or On-demand and Hybrid routing protocols [1, 11, 12, 13].

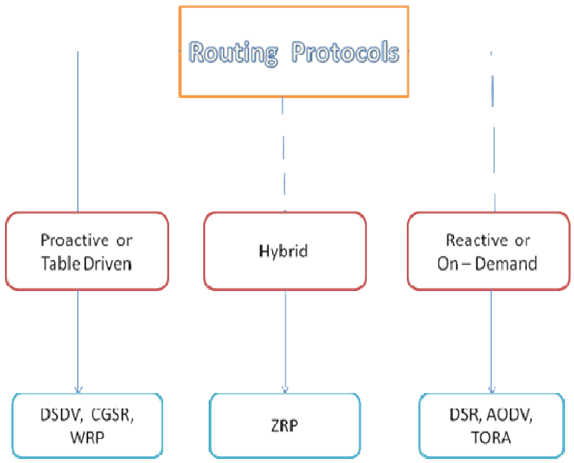

Figure 1: Classification of Routing Protocols

IV. I Proactive or Table-Driven routing protocols:

In these protocols every node in the network maintains routing information to every other node in the network. Routes information is kept in the routing tables and is periodically updated when the network topology changes. There exist some differences between the protocols that belong to this category depending on the routing information being updated in each routing table. Moreover, these routing protocols maintain different numbers of routing tables.

The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth. Some examples of table driven ad hoc routing protocols include Dynamic Destination Sequenced Distance-Vector Routing Protocol (DSDV) [2], Cluster Head and Gateway Switching Routing (CGSR) [3], Wireless Routing Protocol (WRP) [4]. These protocols differ in the number of routing related tables and how changes are broadcasted in the network structure.

IV. I. I Destination Sequence Distance Vector (DSDV)

This routing protocol is based on the concept of the classical Bellman-Ford Routing Algorithm [1,2] with improvement, to make it loop-free. Here, every node maintains a routing table in which the information of all possible destinations is saved. Each entry of route is marked with a sequence number assigned by the destination. The route with the most recent sequence number is always used, whereas on having the same sequence number, the route with smaller metric is used. In order to maintain consistency, the routing table updates are periodically transmitted throughout the network.

Here, two types of packets are employed to reduce the routing update overhead.

- Full Dump packet

This type of packet carries all available routing information and can require multiple Network Protocol Data Units (NPDUs). During periods of occasional movement, these packets transmitted infrequently.

- Incremental packet

This type of packets fitted into a standard NPDU. It is used to relay only that information which has changed since last full dump.

Advantages:

- The availability of routes to all destinations at all times implies that much less delay is involved in the route setup process.
- The updates are propagated throughout the network in order to maintain an up-to-date view of the network topology at all the nodes.

Disadvantages:

- This protocol suffers from excessive control overhead that is proportional to the number of nodes in the network and therefore is not scalable in Adhoc Wireless Networks, which have limited bandwidth and whose topologies are highly dynamic.
- In order to obtain information about a particular destination node, a node has to wait for a table update message initiated by the same destination node. This delay could result in stale routing information at nodes.

IV. I. II Cluster Head and Gateway Switching Routing (CGSR)

This routing uses hierarchical network topology, instead of a flat topology [1,3]. It organizes nodes into clusters, which coordinate among the members of each cluster through a special node named cluster head. A cluster head can control a group of adhoc hosts and clustering provides a framework for code separation among clusters, channel access, routing and bandwidth allocation. Least Cluster Change (LCC) algorithm is applied to dynamically elect a node as the cluster head. Here, each node keeps two tables

- Cluster member table
- It stores the destination cluster head for each mobile node in the network.
- Being broadcasted by each node periodically using DSDV manner.

Nodes receiving this update will refresh their cluster member tables to ensure their validity.

- Routing table
- Being used to determine the next hop in order to reach the destination.

On receiving a packet, a node will consult its Cluster Member and Routing Tables to determine the nearest cluster head along the route to the destination. The node can checks its routing table to determine the next hop node to reach the cluster head.

Updates are needed for both Cluster Member and Routing Tables in CSGR.

Advantages:

- It enables partial coordination between nodes by electing cluster-heads. Hence, better bandwidth utilization is possible.
- It is easy to implement priority scheduling schemes with token scheduling and gateway code scheduling.

Disadvantages:

- The increase in path length and instability in the system at high mobility when the rate of change of cluster-heads is high.
- The power consumption at the cluster-head node is also a matter of concern because the battery-draining rate at the cluster-head is higher than at a normal rate. This could lead to frequent changes in the cluster-head, which may result in multiple path breaks.

IV. I. III Wireless Routing Protocol (WRP)

The Wireless Routing Protocol [1,4] inherits the properties of Bellman-Ford Algorithm. Its main aim is to maintain routing information among all nodes in the network regarding the shortest distance to every destination. WRP is a path-finding algorithm with the exception of avoiding the count-to-infinity problem by forcing each node to perform consistency checks of predecessor information reported by all its neighbors.

In WRP each node in the network uses a set of four tables to maintain more accurate information.

- **Distance Table:** It indicates the number of hops between a node and its destination.
- **Routing Table:** It indicates the next hop node.
- **Link-Cost Table:** It reflects the delay associated with a particular link.
- **Message Retransmission List (MRL) Table:** The MRL contains the sequence number of the update message, a retransmission counter, an acknowledgement required flag vector and a list of the updates sent in the update message. The MRL records which updates in an update message need to be retransmitted and which neighbors should acknowledge the retransmission.

For ensuring accurate routing information, mobiles send update messages periodically to their neighbors. The update message contains a list of updates (the destination, the distance to destination, the predecessor of the destination) and also a list of responses indicating which mobile should acknowledge the update. An Update message is sent after processing updates from neighbors or a change in link to a neighbor is detected.

After receiving an update message free of errors, a node is required to send a positive acknowledgment (ACK). If link failure occurs, nodes detecting the failure will send update messages to their neighbors and those neighbors will modify their distance table entries and check for new possible paths through other nodes.

Advantages:

- It has faster convergence and involves fewer table updates.

Disadvantages:

- The complexity of maintenance of multiple tables demands a large memory and greater processing power from nodes in the Adhoc Wireless Network.
- At high mobility, the control overhead involved in updating table entries is almost the same as that of DSDV and hence is not suitable for highly dynamic and also for very large Adhoc Wireless Networks.

Table 1: Comparison of Table Driven routing protocols

Parameters	DSDV	CGSR	WRP
Routing philosophy	Flat	Hierarchical	Flat
Loop-free	Yes	Yes	Yes, but not instantaneous
No. of required tables	2	2	4
Frequency of update transmissions	Periodically and as needed	Periodically	Periodically and as needed
Updates transmitted to	Neighbors	Neighbors and cluster head	Neighbors
Utilize hello message	Yes	No	Yes
Critical nodes	No	Cluster head	No

IV. II Reactive or On-Demand routing protocols:

In these protocols if a node wants to send a packet to another node then they searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet [14]. The route discovery usually occurs by flooding the route request packets throughout the network.

As such, such protocols are often also referred to as on demand. The common element in reactive protocols is the mechanism used for discovering routes. The source node emits a request message, requesting a route to the destination node. This message is flooded, i.e. relayed by all nodes in the network, until it reaches the destination. The path followed by the request message is recorded in the message, and returned to the sender by the destination, or by intermediate nodes with sufficient topological information, in a reply message. Thus multiple reply messages may result, yielding multiple paths of which the shortest is to be used. Some examples of source initiated ad hoc routing protocols include the Dynamic Source Routing Protocol (DSR) [5], Ad Hoc On-Demand Distance Vector Routing Protocol (AODV) [6], and Temporally-Ordered Routing Algorithm (TORA) [7].

IV. II. I Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [1,5,12] is a reactive protocol i.e. it doesn't use periodic updates. It computes the routes when necessary and then maintains them. It determines the use of source routing technique. Here, the sender of a packet determines the complete sequence of nodes through which the packet has to travel; the sender explicitly lists this route in the packet's header, identifying each forwarding "hop" by the address of the next node to transmit the packet on its way to the destination host. Every node maintains a cache to store recently discovered paths. There are two basic parts of DSR protocol: Route Discovery and Route Maintenance.

Route Discovery:

When a node wants to send a packet, it first checks the cache whether there is an entry for that. If yes then it uses that path to transmit the packet and also attaches its source address on the packet. If there is no entry in the cache or the entry is expired, the sender broadcasts a route request packet to all its neighbors asking for a path to the destination. Each node receiving the route request packet searches throughout its route cache for a route to the destination. If no route is found in the cache, it adds its own address to the route record of the packet and then forwards the packet to its neighbors. This request propagates through the network until either the destination or an intermediate node with a route to destination is reached. A route reply is unicasted back to its originator whenever route request reaches either to the destination itself or to an intermediate node to the destination.

Route Maintenance:

Route is maintained by using route error packets and acknowledgments. When a packet with source route is originated or forwarded, each node sending the packet is responsible for confirming that the packet has been received by the next hop.

The packet is retransmitted until the conformation of receipt is received. If the packet is transmitted by a node the maximum number of times and yet no receipt information is received, this node returns a route error message to the source of the packet.

When this route error packet is received, the hop in error is removed from the host's route cache and all routes containing the hop are truncated at that point.

Advantages:

- It uses a reactive approach which eliminates the need to periodically flood the network with table update messages which are required in a Table-Driven approach.
- The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead.

Disadvantages:

- The route maintenance mechanism does not locally repair a broken link.
- Stale route cache information could also result in inconsistencies during the route reconstruction phase.
- The connection setup delay is higher than in Table-Driven protocols.
- The performance of DSR protocol degrades rapidly with increasing mobility. Although it performs well in static and low mobility environments.
- A considerable amount of routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

IV. II. II Ad-hoc On-Demand Distance Vector Routing (AODV)

Ad hoc On-demand Distance Vector, AODV [1,6,12] is a reactive protocol that finds routes to a particular destination only when needed. The latest path will be identified through the support of destination sequence number. AODV [9] is a combination of both DSR and DSDV. It follows the basic on-demand mechanism of Route Discovery and Route Maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers, and periodic beacons from DSDV.

AODV follows route discovery and route maintenance phase through route request (RREQ) and route reply (RREP) messages. The source node floods RREQ and when each node rebroadcasts this request, reverse path pointing to the source is formed such that when an intended destination receives the route request, it replies back by forwarding a RREP message through the reverse path.

Advantages:

- In AODV the routes are established on demand and destination sequence numbers are used to find the latest route to the destination.
- The connection setup delay is less.
- It reduces control message overhead and it responds quickly to the changes in network topology.

Disadvantages:

- Here, intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries.
- Multiple ***RouteReply*** packets in response to a single ***RouteRequest*** packet can lead to heavy control overhead.
- The periodic ***beaconing*** leads to unnecessary bandwidth consumption.
- The optimal performance is achieved only in low traffic and denser networks.

IV. II. III Temporally Ordered Routing Algorithm (TORA)

The Temporally Ordered Routing Algorithm (TORA) [1,7] is source-initiated on-demand routing protocol built on the concept of link reversal of the Directed Acyclic Graph. TORA is proposed to operate in a highly dynamic mobile networking environment. It provides multiple routes for any desired source/destination pair. The key design concept of TORA is the localization of control messages to a very small set of nodes near the occurrence of a topological change. To accomplish this, nodes need to maintain routing information about adjacent (one-hop) nodes. The protocol performs three basic functions:

- Route Creation
- Route Maintenance
- Route Erasure

During the route creation and maintenance phases, nodes use a "height" metric to establish a directed acyclic graph (DAG) rooted at the destination. Thereafter, links are assigned a direction (upstream or downstream) based on the relative height metric of neighboring nodes. In times of node mobility the DAG route is broken and route maintenance is necessary to reestablish a DAG rooted at the same destination.

Links are reversed to reflect the change in adapting to the new reference level. This has the same effect as reversing the direction of one or more links when a node has no downstream links. Timing is an important factor for TORA because the "height" metric is dependent on the logical time of a link failure.

TORA assumes that all nodes have synchronized clocks established by Global Positioning System. TORA's metric [8] is a quintuple comprising five elements, namely:

- Logical time of a link failure
- The unique ID of the node that defined the new reference level
- A reflection indicator bit
- A propagation ordering parameter
- The unique ID of the node

The first three elements collectively represent the reference level. A new reference level is defined each time a node loses its last downstream link due to a link failure.

TORA's route erasure phase involves flooding a broadcast clear packet (CLR) throughout the network to erase invalid routes. In TORA there is a potential for oscillations to occur, especially when multiple sets of coordinating nodes are concurrently detecting partitions, erasing routes and building new routes based on each other.

Advantages:

- By limiting the control packets for route reconfigurations to a small region, TORA incurs less control overhead.

Disadvantages:

- Concurrent detection of partitions and subsequent deletion of routes could result in temporary oscillations and transient loops.
- The local reconfiguration of paths results in non-optimal routes.

Table 2: Comparison of On Demand routing protocols

Parameters	DSR	AODV	TORA
Overall complexity	Medium	Medium	High
Overhead	Medium	Low	Medium
Routing philosophy	Flat	Flat	Flat
Loop-free	Yes	Yes	Yes
Multicast capability	No	Yes	No
Beaconing requirements	No	No	No
Multiple route support	Yes	No	Yes
Routes maintained in	Route cache	Route table	Route table
Route reconfiguration methodology	Erase route; notify source	Erase route; notify source	Link reversal; route repair
Routing metric	Shortest path	Freshest and shortest path	Shortest path

IV.III Hybrid (both proactive and reactive) routing protocols:

These protocols combine the advantages of proactive and of reactive routing. The routing is initially established with some proactively explored routes and then serves the demand from additionally activated nodes through reactive flooding. The difficulty of all hybrid routing protocols is how to organize the network according to network parameters. Zone Routing Protocol (ZRP) is the popular example of hybrid routing protocol.

IV.III. I Zone Routing Protocol (ZRP)

Zone Routing Protocol, ZRP [1,10] is a hybrid routing protocol for mobile ad hoc networks which localizes the nodes into sub-networks (zones). It comprises the merits of on-demand and proactive routing protocols. Within each zone, proactive routing is adapted to speed up communication among neighbors. The inter-zone communication uses on-demand routing to reduce unnecessary communication.

Here, the network is divided into routing zones according to distances between mobile nodes. Given a hop distance d and a node N, all nodes within hop distance at most d from N belong to the routing zone of N. Peripheral nodes of N are N's neighboring nodes in its routing zone which are exactly d hops away from N. An important issue of zone routing is to determine the size of the zone.

Advantages:

- By combining the best features of proactive and reactive routing schemes, ZRP reduces the control overhead compared to the *RouteRequest* flooding mechanism employed in On-Demand approaches and the periodic flooding of routing information packets in Table-Driven approaches.

Disadvantages:

- In the absence of query control, ZRP tends to produce higher control overhead than the proactive and reactive routing schemes.
- The query control must ensure that redundant or duplicate *RouteRequests* are not forwarded.
- The decision on the zone radius has a significant impact on the performance of the protocol.

Table 3: Comparison between On Demand & Table Driven categories of routing protocol

Parameters	On Demand Routing Protocol	Table Driven Routing Protocol
Availability of Routing Information	Available when needed	Always available regardless of need
Routing Philosophy	Flat	Mostly Flat except for CGSR
Periodic route updates	Not Required	Yes
Coping with Mobility	Using Localized route discovery in ABR	Inform other nodes to achieve consistent routing tables
Signaling Traffic Generated	Grows with increasing mobility of active nodes as in ABR	Greater than that of On Demand Routing
QoS Support	Few can support QoS	Mainly Shortest Path as QoS Metric

V. CONCLUSION

In this paper, we highlight issues and challenges of mobile ad hoc network those are important to proposed feasible solution of routing. We have showed the classification of routing protocols in MANET based on the routing information update mechanism like Proactive (Table-driven), Reactive (On-demand) and Hybrid routing protocols. For each classified category we reviewed and compared several representative protocols. These protocols differ in the ways of finding and maintaining the routes between source-destination pairs. Each protocol has definite advantages and disadvantages, and is well suited for certain situations. We wish that the classification presented in this paper will be helpful and provide researchers a platform for choosing the right protocol for their work in future.

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