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Research paper

Comparison analysis of MANET routing protocols to identify their suitability in smart environment

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Abstract

Mobile Ad Hoc Network (MANET) is a temporary structure; it is self-adjustable, random network without any topology. MANET is guiding in varied area of smart environment and applications to deal with the issues faced by individuals in daily life. Routing is a very interesting research area in mobile networks. Many researchers have come up with their opinion but it is very difficult to say which protocol performs best in different network scenarios such as more overload, increasing load density, etc. This paper highlights different categories of protocols and also provides a performance comparison of these protocols, and tries to suggest which protocol may perform best in a large network. Several routing protocols are compared with respect to Routing Approaches, Routing Table, Route Selection, Route Discovery, Route Maintenance, Protocol Type, Operation, Advantages, Disadvantages, etc. By looking at performance characteristics and metrics of all categories of routing protocols, a number of conclusions can be drawn for each category that may help the researchers.

Keywords: *ADHOC; AODV; DSR; DSDV; MANET; TORA.*

1. Introduction

Mobile networks possess certain features like Dynamic Network Topology, Frequent Routing Updates, Limited Physical Security, Power Constrained operation, Variable Capacity Links, Bandwidth Constrained, etc. The network topology may change unpredictably and rapidly over time due to mobile behavior of nodes. MANET does not require any fixed network infrastructure or centralized administration such as, access point or base station etc. Here the routing protocols are categories into various types Reactive, Proactive and Hybrid routing protocols. The Hybrid protocols are designed to increase the scalability of mobile network but they have their own issues. The primary purpose of the routing protocol is to find the effective and correct path between mobile nodes so that the packets can be sent within active route timeout interval. Routing protocols must guarantee fairness, quality of service, connectivity among the nodes in network [1]. There are various routing protocols in the network and each has its own pros and cons.

2. Protocols classification

The role of routing protocols in an ad hoc network is to allow the source to find routes to destination with the cooperation of other nodes. Due to mobility the network topology changes randomly. Hence the routing protocol must be able to react to these changes and must enable the nodes to identify new routes to maintain connectivity. MANET routing protocols can be categorized into various types as shown below [2]:
Proactive (Table Driven) Routing Protocols: Here request is regularly sent by the protocols to their neighbor's nodes to maintain the routing table and to arrange their network topology. Here routing table is created first and then packets are transported from one host to other [3].
Reactive (On Demand) Routing Protocols: Here when a host transfers packets to a second host it asks for a route to its neighbor node. If neighbor nodes not contain route, the message is broadcasted to their neighbor nodes and so on.
Hybrid Routing Protocols: Hybrid Protocols are mixture of Table Driven and On Demand routing protocols. Here the system is partition into small sections and each section has a gateway, intersection use table routing protocols and innermost section use on demand routing protocol. Minimum latency is important feature of these protocols.

3. Proactive routing protocols

These protocols are also known as Table Driven Routing protocols. Here route is available to us even before it is needed. Here routing information of other nodes are kept by every node in the network. Routing tables are used to keep the routing information [4]. These are periodically updated when network topology changes. Different numbers of tables are maintained by the proactive protocols. And these protocols are not efficient for big networks, because they required updating entries for all nodes in the routing table. This portion narrates various table driven protocols. Comparison is also done among them in table. These routing protocols mainly uses shortest path algorithm. Example of proactive protocols: DSDV, OLSR, WRAP, GSR, FSR etc.
Destination Sequenced Distance Vector (DSDV) [5, 6] is Table Driven (Proactive) routing protocol. This protocol resolves the key issue (Count to Infinity) of distance vector routing using distance sequence number. Here routing table is maintained by each node in the network. Shortest path is selected for destination nodes. It

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has flat routing structure. Multiple routes are not supported by it. Routing information is always available and it should be periodically updated. This protocol does not support scalability, but supports reliability. And here throughput is indirectly proportional to the mobility i.e. as the mobility increases, throughput decreases or vice versa. Load balancing and congestion control is also not supported by this protocol. There is inefficient utilization of network resources because DSDV creates more control traffic in the network. Here the rendering and inefficient utilization of network resources is high. It needs periodic updates, which requires less amount of bandwidth and more battery power even when the network is idle. Every mobile station is required to advertise for each of its current neighborhoods. Here four routing tables are maintained by each node. DSDV has low delays when mobility stays low [7]. Table 1 represents popular quantitative and qualitative features of network routing protocols.

Table 1: Performance Metrics [8]

Qualitative metrics	Quantitative metrics
Reliability	Mobility
Scalability	Packet Delivery Ratio
On-demand or proactive	Overhead
Route stability	Throughput
Loop-freedom	End-to-End Delay

Wireless Routing Protocol (WRP) gets the idea of Distance Vector Routing Protocol [9]. Here four tables are maintained by each node in the network. These four tables are:

Message Retransmission List (MRL): The information in the MLR is that the visiting of the node reveals which neighbors have not accepted their update message and represented the update message to the neighbor.

Link Cost Table: Link cost of each neighbor node is maintained by link cost table. After receiving the error free message from the neighbor, the number of timeouts is recorded in the link cost table.

Routing Table: Routing table maintains the routing information between different nodes. It also has a tag that recognizes whether the entry is a loop, invalid or a simple path.

Distance Table: Each node consists of a distance table which contains information of distance of each destination node.

By using hello messages WRP ensures its connectivity. Whenever there is no recent packet transmission, these hello messages are exchanged. This processor consumes more energy and bandwidth since each node needs to be active all the time.

Global State Routing (GSR) [10] uses the concept of link state algorithm. GSR nodes contain a distance table, next hope table, topology table and a neighbor list. In GSR the shortest distance to each target node is maintained by distance table. The next hope table maintains the next hope for each destination. Time stamp and link state information is maintained by topology table. Neighbors list consists of the list of neighbors. It uses full topology and single channel for communication. It has high memory overhead. GSR needs to address the excessive usage of bandwidth issue.

Fisheye stable routing (FSR) [11] is related to GSR. The FSR minimizes the size of packets in GSR by updating the network information for close nodes at a higher frequency compared to remote nodes. This improvement makes FSR more suitable for big networks. However, the enhancement in the size of the networks comes at the cost of less accuracy. FSR has reduced control overhead as compared to GSR. And it has high memory overhead and reduced accuracy. It contains same number of tables as GSR.

Optimized link State Routing (OLSR) [12] is a table driven protocol. This protocol uses topology control (TC) and hello messages to identify and then spread link state information within network. It gets idea of traditional link state method and it is a point to point routing protocol. For forwarding control traffic, it uses multipoint relays (MPR) concept into the network. To control the protocol overhead it uses various parameters like TC redundancy parameter, MPR coverage parameter, TC interval parameter, Hello- interval parameter etc. By using multipoint relays (selected nodes) it reduces the control traffic overhead into the network. It minimizes the number of repetitions expected to disseminate a packet to every node in the network. Updated topology information is periodically sent by OLSR throughout the whole network. It requires more processing power and bandwidth to compute best or optimal route. OLSR provides scalability but does not provide reliability. The throughput is better when compared to other protocol (DSDV). Load balancing and congestion control factors also not supported by this protocol. It uses the shortest path algorithm for computation of optimal path in the network. Multipoint relay concept is used for efficient flooding of control traffic. OLSR minimizes the Rebroadcasting nodes and reduces the size of control messages. OLSR supports three mechanisms: Sufficient topology information, Efficient flooding of control traffic and Neighbor sensing.

4. Comparison of proactive protocols

Due to the consumption of more bandwidth, flat table driving protocols do not provide better scalability. Among flat protocols OLSR provides better scalability in the network. A mobility management problem in hierarchical table driven protocols causes additional overhead. This protocol scales better than flat protocols. A summary of various studied table driven protocols is presented in table 2.

Table 2: Basic Characteristic of Proactive Routing Protocols in MANETs

Parameters	DSDV	OLSR	GSR	WRP	FSR
Name	Destination Sequenced Distance Vector	Optimized Link State Routing	Global State Routing	Wireless Routing Protocol	Fisheye State Routing
Routing Structure	Flat Structure	Flat Structure	Flat Structure	Flat Structure	Flat Structure
Frequency of Updates	Periodic and as required	Periodic	Periodic, Local	Periodic	Periodic, local
No. of Tables	Two	Three	Three & a list	Four table	Three & a list
Hello Messages	Yes	Yes	No	Yes	No
Characteristic Features	Loop Free	Minimize control overhead using MPR, Loop Free	Localized Updates	Loop Free but not Instantaneous	Controlled Frequency of updates, Loop Free
Critical Nodes	No	No	No	No	No
Route Selection	Link State	Link State	Link State	Shortest Path	Shortest Path
Method	Broadcast	Broadcast	Broadcast	Broadcast	Broadcast
Multiple Routes	No	Yes	May be	No	May be
Overhead	High Overhead	Reduced Control Overhead	High Memory Overhead	High Memory Overhead	High Memory Overhead
Advantages	Loop Free, Shortest Route to every destination is selected	Reduced Control Overhead& Contention, Good Transmission Quality	Localized updates	Loop Free, Avoid Count to Infinity problems, updates message is sent to the neighbors periodically, Routing infor-	Reduced Control Overhead

				mation is correct.	
Disad-vantages	High Over-head	Two hop neighbor knowledg e required	High Memor y Over-head	High Memory Overhead due to Hello messages	High Memor y Over-head, Re-duced Accura-cy

5. Reactive routing protocols

These are also known as On-Demand Routing protocols because these find out the route in on demand manner i.e. route will be available only when it is demanded. Such protocols have mainly two components: Route Discovery and Route Maintenance [13].

Route Discovery: If there is no any information about the destination route in the table of source node, then the node will broadcast a route Discovery message in the network. After the route is established between the source and the target node, the packets are sent through the chosen route.

Route Maintenance: Route maintenance procedure was brought to manage the package problem within the system. By using, these three types of mechanism: Network layer, Passive, link level; node can confirm that the packet has received in the correct condition from the backward route. Some of the most popular On demand routing protocols with their features are discussed below.

Ad hoc On Demand Distance vector (AODV) [14] Routing Protocol is a mixture of DSDV and DSR protocols. It presents three types of communication unicast, multicast and broadcast. It uses the same sequence numbering and periodic beaconing processor as it is used in DSDV. And it uses the route Discovery method of DSR. Well there is a lot of difference between these two protocols (DSR, AODV). The biggest difference is that in AODV the message only contains the target address whereas in DSR each message contains full routing information. It shows that AODV has less routing overhead than DSR. AODV has flat routing structure and it uses shortest path for route selection. Concept of destination sequence number is used to find the most suitable route [15]. Throughput becomes poor for very big networks. It also provides information of expiry routes. AODV is loop free, self-starting, and scales to large number of mobile nodes. To handle routing process it does not require any central administrative system. It has low delay for detection and connections of the fresh route to target. It support both multicast and unicast message transmission. And it is adaptable to highly changeable network. But it requires more bandwidth. Time taken to create the routing tables is also very high. Sometimes it is difficult to find the expiry time of the route in this protocol. It provides good performance with the increasing load. It has low protocol overhead. Its objective is to reduce the demands of system wide broadcasts. A simple route reply mechanism is used by this protocol. It uses three types of messages: Route Request (RREQ), Reply message (RREP) and Route error (RERR) message [16].

Dynamic Source routing (DSR) [17] is reactive protocol. As already mentioned each packet carries the full address of route from source to destination. As the network size increases the packet overhead also grows, hence this protocol does not perform well for large network. This protocol provides loop free routing. Here routes are maintained in route cache. It also supports multiple routes. Expiry of routing information is not provided here. This saves the consumption of more bandwidth; it does not need exchange of periodic hello messages. It is good for low mobility networks. Here multiple routes are stored by the nodes in there cache and hence before initializing route Discovery process, source node can easily check it's its route cache for a valid route. This protocol performs better for small network [18].

Light weight mobile routing (LMR) [19] is a reactive routing protocol; it pursues flooding method to find the route in the network. Multiple paths are maintained by LMR nodes to each desired target node. Flooding technique increases protocol reliability by allowing each node to select a path to the target node without starting the Discovery process. Here each node keeps routing information to its neighboring nodes instead of all the other nodes in the network. It avoids storage overhead and extra delays connected with maintaining complete path. However, production of temporary invalid path in LMR can generate extra delays in network. LMR also supports multiple routes. It follows route repair and link reversal route configuration strategy. It has less flooding overhead.

Temporally Ordered Routing Algorithm (TORA) [20] uses the idea of LMR. Link reversal and route repair methods are also used here. Hence it includes the advantages of LMR protocol also. The combination of both lightweight adaptive multicast (LAM) algorithm and TORA protocol is used to support multicasting. The production of temporary invalid routes in the network is the major limitations of this protocol. Various operations of this protocol are route generation, route repair & servicing and route erase.

A query reply technique is used in Associativity Based Routing (ABR) [21] protocol to find the routes. Stability is one of the main factors for selecting route in this protocol. For selecting stable route a collaborative tick is maintained by each node with its neighbors and preference is given to the higher collaborative tick. There is no availability of immediate alternate routes, because multiple routes are not maintained at once.ABR overcome this limitation up to some extent by initializing a localized route Discovery process (LBQ) in network. Requirement of periodic becoming for the determination of degree of associativity of the links is the main disadvantage of this protocol, because the periodic beaconing needs each node to stay active all time, due to which more energy consumes in network.

Cluster Based Routing Protocol (CBRP) [22] is also On Demand Protocol, but unlike other reactive protocols, nodes make clusters. Each cluster has its own cluster head which maintains the details/statistics communication among cluster and other clusters. It also contains temporary routing loop. The main limitation of this hierarchical approach is the more number of overhead attached with cluster creation and its maintenance. Several times, some nodes may keep inconsistent topology information because of long propagation delay. This routing information is exchanged by cluster head only.

6. Comparison of reactive routing protocols

Usually reactive protocols have the similar routing expense because of the same route discovering and maintenance process. The routing structure of these protocols is mostly flat, except CBRP.CBRP tries to reduce the control overhead in route Discovery phase, by launching a hierarchical on demand routing protocol. To reduce the number the number of control packets, reactive protocols chooses routes on the basis of stability factor. For example in ABR nodes are chosen according to stability factor. This protocol may give better performance than DSR. Here each packet needs to contain its complete destination address. It may cause scale ability problem in network.

In discovering routes, on demand protocols shows higher latency [19]. The benefit of these protocols is the less overhead of control packets in network. Among other on demand protocols only DSR takes benefit of maintaining route cache. Here the source node can select the valid route from the multiple routes stored in nodes routing cache. A local broadcast query (LBQ) is started in ABR routing protocol, when the link goes down. A summary of on demand protocols is presented in table3.

Table 3: Basic Characteristics of Reactive Routing Protocols

Parame-ters	AOD V	DSR	ABR	CBRP	LMR	TORA
Protocol Name	Ad hoc On De-mand	Dy-namic Source Rout-ing	Associ-ativity Based Routing	Cluster Based Rout-ing Proto-	Low Based Mul-tipath Rout-	Tempo-rally Ordered Routing Algo-

	Distance Vector Routing			col	ing	rithm
Routing Approach	Reactive	Reactive	Reactive	Reactive	Reactive	Reactive
Routing Structure	Flat Structure	Flat Structure	Flat Structure	Hierarchical Structure	Flat Structure	Flat Structure
Route Configuration	Erase route then Source notification or local route repair	Erase route then Source notification	Localized Broadcast Query	Erase route then Source notification and local route repair	Link reversal & Route Repair	Link reversal & Route Repair
Route Metric Method	Updated and Shortest Path	Shortest Path or next available	Strongest Associatively and Shortest Path	First available path	Shortest Path, or next available	Shortest Path or next available
Multiple Routes	Yes	Yes	No	No	Yes	No
Protocols Operations	1.RREQ broadcast 2.RREP Propagation 3.RERR message	1.RREQ broadcast 2.RREP Propagation 3.RERR message	Users Query –Reply technique to determine routes	Cluster head exchange routing information	Uses flooding technique to determine routes	Route Creation, Route Maintenance, Route Erasure
Route Maintenance	Routing Table	Route cache	Routing Table	Routing Table at cluster	Routing Table	Routing Table
Hello Messages	Yes	No	Yes	No	No	No
Advantages	Low overhead, Higher Bandwidth Efficiency, Loop Free, Adaptable to high dynamic topology	Support multipath routing, Promiscuous overhead, Loop Free	Route stability	Only clusterheads exchange routing information	Multiple routes	Multiple routes, less communication overhead, able to rapidly build routes
Disadvantages	Takes more time to build the routing tables, scalability problem.	Flooding & source routing creates scalability problems, High route discovery latency	Overall complexity, High overhead, Scalability problems	Temporary loops, Cluster maintenance	Temporary routing loops	More complexity & overhead in large network, temporary routing loops, consume more bandwidth in big network

7. Hybrid routing protocols

Reactive protocols consist of more latency and low overhead and proactive protocols have less latency and more overhead. So new hybrid routing protocols were included, which were the combination of both. To avoid overhead and latency problems it uses route Discovery process of on demand protocols and table maintenance process of table driven protocols. But still these hybrid protocols have their own major issues. Examples of hybrid protocols are ZRP, ZHLS.

Zone Routing Protocol (ZRP) [23] is a combination of both on demand and table driven protocol. It has various models like: Interzone routing protocol, Intrazone routing protocol.

Interzone Routing Protocol: This schema is taken from the On Demand Protocol, which is used when the path between various zones is required for the connection between source and target.

Intrazone Routing Protocol: This scheme is taken from table driven protocol which is used to keep only the local topology. This routing protocol performs in a particular zone only. Congestion problem is reduced here. And it also provides better scalability in network. But it has various disadvantages also.ZRP protocol must determine optimum zone radius for each station. Practically, it has more overhead then on demand and table driven protocols.

Zone based Hierarchical Link Structure (ZHLS) has hierarchical routing structure. It contains simple location management, because there is no any location manager or cluster head used here. And so it does not contain additional overhead problem. As compared to AODV and DSR it has low communication overhead. This protocol may not feasible in applications, where the geographical boundary of network is dynamic.

Table 4: Basic Characteristics of Hybrid Routing Protocols

Parameters	ZRP	ZHLS
Name	Zone Routing Protocol	Zone based Hierarchical Link Structure
Routing structure	Flat Structure	Hierarchical Structure
Route Maintainability	Route Maintaining in Routing tables	Route Maintaining in Routing tables
Multiple routes	Yes	Yes
Route Selection	Link reversal	Zone based hierarchical link state
Configuration strategy	Route tables	Based on the performance of Table Driven and On Demand routing protocol chosen.
Loop Free	Yes	Yes
Route reconstruction	At failure Point	Sent the Location request
Beacons	Yes	No
Zones information	Zones are overlapped	Static zone map needed
Advantages	Reduces the no. of control messages & Latency In Route Discovery	Less Overhead than the approaches based on flooding ,Reduces Traffic
Disadvantages	More Memory Required	Extra traffic is generated by building and maintain zone level topology

8. Comparison analysis of reactive, proactive and hybrid routing protocols

The table-driven routing protocols maintain network connectivity proactively whereas On-demand routing protocols do the routing when it is needed. Reactive protocols consist of more latency and low overhead and proactive protocols have less latency and more overhead. So new hybrid routing protocols were included, which were the combination of both. By looking at performance metrics a number of conclusions can be made from each category. A comparative summary of various studied Table Driven, On Demand and Hybrid protocols is presented in table below [24].

Table 5: Comparison of Proactive, Reactive and Hybrid Routing Protocols in MANETs

Parameters	On- Demand (Reactive)	Table-Driven (Proactive)	Hybrid
Network Organization	Usually Flat, except Cluster Based Routing Protocol	Both, Hierarchical & Flat	Usually Hierarchical
Traffic Control	Lower than Table Driven	Mostly high	Lower than both Reactive and Proactive
Managing Effects of Mobility	Route maintains Local Route- AODV LBQ-ABR	Usually periodically updates	Availability of multiple route
Routing Scheme	On- Demand	Table- based	Combination of both
Storage Demand	Less (depends on no. of path available)	More(due to use of routing table)	Based on dimension of each cluster or zone
Periodic Updates	Not required	Yes required	Yes required inside the zone
Routing/Communication Overhead	Less	More	Medium
Scalability Factor	Point to point-scale higher Source routing protocol- up to few 100 nodes	Mostly up to 100 nodes	Designed for large network
Delay Level	High	Low, because routes are pre decided	Small Destination –Low Inter zone- High
Topology Dissemination	On- Demand	Periodical	Both
Route Availability	Determined as per requirement	Stored in table available	Combination of both
Latency	More, due to flooding	Less	Inside Zone- Low Outside Zone-Similar to On Demand Protocols
Quality of Service Support	Mostly support shortest path	Shortest path as quality of service metric	As per requirement
Routing information	Does not store	Stored in table	Depends on requirements
Energy Requirement	Less	More	Medium
Bandwidth Demand	Less	More	Medium
Advantages	-Loop free -Resource saving -Reduction f routing load	-Small delay -Routes always available -Quick establishment of routes. -Up to date routing information -Routing detail is not fully used	-Up to date routing information -More resources for big zones -Routing latencies -Arbitrary proactive scheme within zones.
Disadvantages	-Control traffic and overhead cost -Large delay -Not always up to date	-Requirement of more resources -Create loops -Slow convergence	- limited search cost -scalability

9. Conclusion

In this paper various routing schemes have been categorized according to On Demand, Table Driven and Hybrid Routing strategies and comparison has been drawn among these schemes. Comparison has been done by taking various routing parameters. On the basis of these comparison still there are many open research concepts in mobile network that require more investigation. MANET's protocols still have various limitations like Packet Loss, Frequent Disconnection, Short Battery Lifetime, More Overhead, Issue of Adaptation, Power Consumption Problem, Security Implementation etc. MANET's protocols require more attention and investigation to be more suitable in the upcoming smart environment. It is not clear that any class of algorithm or any specific algorithm is accurate and sufficient for all circumstances, each protocol has their own pros and cons and is well suited for certain conditions. It is really difficult to design a routing protocol which satisfies all the parameters in MANETs. The focus of this paper is to provide an overview of various existing techniques, methods and schemes of routing for Mobile Ad Hoc Networks.

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