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Classification of Network Layer Unicast Routing Protocols in MANETs

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Abstract: Mobile ad hoc network (MANETs) is a collection of the nodes which autonomously maintain network without the fixed network support. In a mobile ad hoc network, nodes in the network are not fixed; therefore it leads to the change in the position of nodes in network, changing the topology. The transmission ranges of different nodes are limited, due to this reason the nodes are not able to communicate directly with each other. Routing paths in MANETs are multi hop and every node in the MANETs can behave as the route or the host. In order to setup communication within the nodes of network, a routing protocol is used to discover best path between nodes. The main motive of such an ad hoc network routing protocol is the perfect and efficient route setup between a pair of nodes (terminals/devices) so that information packets may be delivered in a proper time. Route establishment should be done with less overhead and bandwidth consumption. This paper explains the various routing protocols for ad hoc networks and classifies these protocols on the basis of a set of parameters. The article summarizes different protocols by explaining their characteristics and functionality, and also provides a classification of these different routing protocols available for the communication in ad hoc networks.

Keywords: - MANETs, Unicast, Network, Classification, Routing

I. INTRODUCTION

Wireless network has become very important in the computing and mobile network world. There are basically two types of wireless networks, infrastructure network (wired network) and infrastructure less network which is known as ad hoc network. The infrastructure network consists of fixed and wired gateways. While the infrastructure less network is a multi-hop wireless network and have no pre-defined infrastructure. The nodes or terminals in ad hoc networks are dynamic in nature i. e they have the capacity of moving and are connected in an arbitrary fashion with another different nodes. Routing is to find and maintain routes between nodes in a dynamic topology with possibly uni-directional links, using minimum resources. Therefore, routing is the core part of ad hoc communications. The ad hoc networks are mostly used in many civilian forums, military, business and emergency etc. Desirable properties of ad-hoc routing protocols are as follows:

- Distributed operation: This signifies that there is no central node in the network should be centralized it should free to establish a connection with any node of any network.
- Loop free: To improve the working, the routing protocol should guarantee that the path is followed in network should be loop free. This will prevent any type of wastage of bandwidth or CPU consumption.
- Demand based operation: To reduce the control overhead in the network and thus not waste the network resources the protocol should be reactive. This means that the protocol should react only when needed.
- Unidirectional link support: The radio environment can cause the formation of unidirectional links and with the help of this we can improve the routing protocol performance.

Many classification criteria have already been proposed for unicast routing protocols in MANETs. In this work, the unicast routing protocols are considered and classified on the basis of the various characteristics possessed by them. This paper presents the comprehensive survey of such protocols describing the various characteristics of some prominent unicast routing protocols. The main contributions of this paper are:

- To propose a new classification criteria for network layer unicast routing protocols considering the various common characteristics possessed by them.
- To granulize the classification criteria on the basis of routing capability, route acquisition, routing structure and the state information of the protocol to study the protocols more minutely.
- To identify and review typical unicast routing protocols according to the proposed classification criteria.

II. CLASSIFICATION OF UNICAST ROUTING PROTOCOLS

Classification of unicast routing protocols are based on following criteria [1]:

A. Communication Channels [1]

A channel is a medium through which a data signal is transmitted from one node to another node. For example a digital bit stream. A channel has a certain capacity to transmit the bulk of data though this communication channels. There are two types of communication channel in unicast routing protocols.

1) *Single Channel Routing*: **-** In this routing channel a single path is followed to transmit the message to other nodes. It automatically adjusts the conventional link state routing in which each node tries to maintain information about the network topology. Each node checks the connection establishment with its neighbor by sending the hello message to different nodes. Whenever there is a change in the link costs, the node broadcasts this information to all other nodes. Nodes use this information to find the shortest paths.
2) *Multi-Channel Routing*:-In this type of channel, many routes are used in the network to send the information or message from the source to destination. Best path is used to send the information to the destination.

B. Routing structure [1]

This classification explains how different nodes in the network are selected to do different types of work. According to this classification, the addressing is done in two ways hierarchical or flat.

1) *Non-Uniform Routing*: - In this type, there is an effort to limit routing complexity by reducing the number of nodes participating in routing computation.
2) *Uniform Routing:* **-** In uniform routing, all nodes acts as same way as that of other nodes. Sending and receiving messages is the main operation perform by all nodes. Hierarchy is absent in this type of routing structure**.**

C. State information [1]

Protocols may be described in terms of the state information obtained at each node and or exchanged among nodes. State information can be categorized further as follows:

1) *Topology Based Routing:* **-** In this type, every node in a network maintains large scale topology information for making routing decisions. For example, DSR is a topology based routing protocol.
2) *Destination Based Routing:* - In a destination–based routing protocol, when forwarding a packet to the destination, a node only need to know the next hop along the routing path. Large-scale topology information is not maintained in this case. Information needed to know only the nearest neighbors is collected. The best known such protocols are distance-vector protocols, which maintain a distance and a vector to a destination.
3) *Neighbor selection*: - In neighbor selection protocol each node maintains a subset of network topology information to minimize the cost of distributed routing scale. For e.g. OLSR is a proactive protocol, because it exchanges the topology information with other nodes regularly to maintain information required for routing .When a node sends a broadcast message, all of its neighbors receive and processes the data.

D. Scheduling [1]

This classification criterion specifies that how the route information is conserved at each node and shared among the other nodes simultaneously.

1) *Proactive Routing***: -** In proactive routing protocols, each node has the routing information of every other node in the network beforehand. This information is usually placed in a number of tables. These tables are updated when the network topology changes. Each node has one routing table associated with it. Proactive routing protocols are also known as table-driven protocols.
2) *Reactive Routing*: - Reactive routing protocols are designed to minimize the load in proactive protocols by maintaining information for active routes only. The routes are determined and maintained for those nodes that need to send data to a particular sender. Reactive routing protocols are also called as on demand routing protocol.

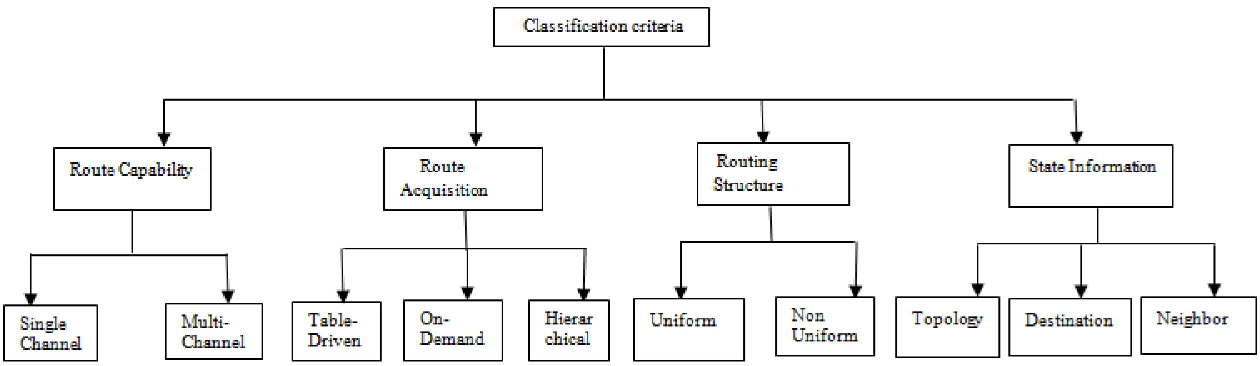

Fig. 1 Classification of routing protocols

III. COMPREHENSIVE SURVEY OF UNICAST ROUTING PROTOCOLS

A. Destination-Sequenced Distance-Vector (DSDV)

Destination-Sequenced Distance-Vector Routing (DSDV)[2-4] is a table-driven and proactive routing scheme for wireless networks based on the Bellman-Ford algorithm. Bellman-ford algorithm is used to solve the Routing loop problem. In DSDV each routing table has an entry with attached sequence number which is obtained from the destination station. The routing information is sent and shown periodically and incrementally. After receiving the routing information, routes with high recent sequence numbers are selected as the basis for making forwarding decisions of the paths with the matching sequence number. Shortest path is selected to send the information. The information about that route is added in the routing table, along with the sequence number tag. When the route link to the next hop is disabled, any route through that next hop is immediately given a 1 infinite hop distance and also the sequence number is updated. When a node accepts a broadcast with an infinite 1 metric, and it has a number of recent sequence number to that destination, it broadcasts the route update to disseminate the important messages about that destination. Each node in the network makes its own routing table related to its neighbor node. The information is sent only by neighbors and contains only the updated entries. The advantage of DSDV is that the number of nodes required in network is lesser in number. The DSDV protocol gives the guarantee that the path followed is the loop-free path to each destination. It requires a regular update of its routing tables and is suitable for highly static networks

B. Wireless Routing Protocol (WRP)[2]

In this protocol four data structures are used to maintain the network information- a distance table, a routing table, a link cost table and a message retransmission list (MRL). Message retransmission list is shared through the neighbor nodes .If there is no change in the network then the node sends the hello message to confirm the connection .It is up to the node to update its routing table after receiving the update message from the neighbor node. It always follows the best path by using that message received from the neighbor node. When the node having information about the path followed, decides that best path is actually followed by the node then a message is sent back to main node and that main node updates its routing table.

C. Adhoc on-demand distance vector routing (AODV) **[2-4]**

AODV is a very popular routing protocol for Mobile Ad-hoc Networks which do not have static topology. The algorithm of AODV is appreciative due to limited bandwidth that is available in the media that are used for wireless communications. It is the combination of the concepts from DSR and DSDV algorithms. It is on demand based protocol and hop-by-hop routing is done. Node sequence number feature is taken from DSDV thus makes the algorithm, topology and routing information dependent. AODV a very useful and desired algorithm for MANETs because it is purely on-demand. Each mobile host in the network acts as an important router and routes are obtained as needed, thus making the network self-starting. Each node in the network possesses and updates a routing table with the routing information entries of its neighboring nodes. Two separate counters are maintained to store a node sequence number and a broadcast-id. When a node has to communicate with another it increments its broadcast-id and initiates path discovery by broadcasting a route request packet RREQ to its neighbors node.

D. Optimized Link State Routing (OLSR)[1-3]

OLSR is a proactive routing protocol. It is an adaptation of conventional link state routing in which each node in the network collect the information about the network topology. Each node checks the link costs to each of its neighbors by broadcasting HELLO messages to other nodes in network. Whenever any change occurs in the network then that information is send to each other. Nodes use this information about the change in network to apply a shortest path algorithm (such as Dijkstra’s shortest path algorithm) to check the best route to a required destination. OLSR uses the link-state protocol in two different ways. First, it minimizes the size of the update packets sent during the broadcasts with only a subset of links to its neighbors. Selected set of neighbors are given with the links known as the multipoint relays (MPR). Each node calculates its MPR set from receiving information from all its neighbors. Second, in place of every neighbor broadcasting the update packets sent out by a node, only the MPR nodes take part in broadcasting of these packets in OLSR. With this the traffic of control packets during flooding gets reduced. These two techniques save the bandwidth but come at a cost of propagating incomplete topology information in the network. The updates include only MPR sets and not the sets of all neighbors of the broadcasting nodes.

E. Temporarily ordered routing protocol (TORA)[2]

TORA is known as uniform, destination-based, reactive protocol. In this a destination- oriented cyclic graph is built for every destination. If link establishment of node changes it will result in a node losing its entire outbound links, the node “reverses" the direction partially .In TORA it is assumed that each node is informed of link-status modification for any of its immediate neighbors. When a sender has no path to a receiver then it broadcasts a path request for the receiver. The request is resent until it reaches the destination. The destination broadcasts an update message, indicating its height. Each node that receives the update message updates its height to be one higher than the height in the update message and broadcasts an update message, indicating its new height. The updates must be broadcasted reliably and ordered by a synchronized clock or logical timestamp in order to prevent long-lived loops. This process develops a DAG from the sender to the receiver, which is used for hop-by-hop routing. A route failure is propagated only when a node destroys its last downstream link. The advantage is that a large number of routes are used, so multiple paths are created. Hence provide good reliability.

F. Cluster-head Gateway Switch Routing (CGSR) [2]

This Protocol is a type of the hierarchical protocol which depends upon the DSDV Routing algorithm .In this cluster head is used to manage a group of action nodes which in return send it to the gateway of the destination cluster .Then the destination cluster-head sends it to the destination node. There are many number of optimized cluster-head election mechanisms. When the node receives the data packet then that node finds the nearest cluster-head along the path to the destination relevant to the cluster member table and the routing table. Then the node check its routing table to know the next hop is in a proper manner to reach the cluster-head selected in step one and send the packet to that node.

G. Associativity Based Routing (ABR)[2]

Associativity Based Routing (ABR) is destination-based reactive protocol. End-to-end topology information in route selection is used in ABR, preferring routes that have long-lived associations. In this only destination-vectors are updated during routing. Whenever the intermediate node gets the request, it starts route discovery as follows: When a source do not find a path to reach destination, it send a route request's ID to the route request and re-broadcasts it again. The associativity of each hop is accumulated in the route request. Routes which have high threshold and aggregate associatively are known as superior, even it has the smallest routes. Route reply is sent back to the source by the destination. Every intermediate node currently sends appropriate forwarding information in its routing table. The route maintenance process is very difficult. Nodes downstream of the link failure send route error messages toward the destination, removing invalid route entries. If the query fails to find a new half route, the next node in the upstream is informed and a local request is initiated. If the process traverses too much of the path back to the source, it is abandoned and a route error is sent to the sender, which reinitiates the route discovery process.

H. Zone Routing Protocol (ZRP) [2]

It is defined as the hybrid routing protocol for mobile ad hoc networks. The hybrid protocols are proposed to minimize the control overhead of proactive routing approaches and also minimize the latency caused by route search operations in reactive routing approaches. Zone Routing Protocol (ZRP) is a framework of hybrid routing protocol suites, which is the combination of these protocols- Intra-zone Routing Protocol, Inter-zone Routing Protocol and Border cast Resolution Protocol. ZRP is also known to the locally proactive routing component as the Intra-zone Routing Protocol (IARP). The globally reactive routing component is known as Inter-zone Routing Protocol (IERP).

I. Zone-based Hierarchical Link State (ZHLS) [2]

ZHLS is a hybrid routing protocol. In ZHLS, mobile nodes are assumed to know their physical locations with assistance from a locating system like GPS. The network is divided into non-overlapping zones based on geographical information. ZHLS uses a hierarchical addressing scheme that contains zone ID and node ID. A node determines its zone ID according to its location and the pre-defined zone map is well known to all nodes in the network. It is assumed that a virtual link connects two zones if there exists at least one physical link between the zones. A two-level network topology structure is defined in ZHLS, the node level topology and the zone level topology. Respectively, there are two kinds of link state updates, the node level LSP (Link State Packet) and the zone level LSP. A node periodically broadcast its node level LSP to all other nodes in the same zone. In ZHLS, gateway nodes broadcast the zone LSP throughout the network whenever a virtual link is broken or created. Consequently, every node knows the current zone level topology of the network. Before sending packets, a source firstly checks its intra-zone routing table. If the destination is in the same zone as the source, the routing information is already there. Otherwise, the source sends a location request to all other zones through gateway nodes. After a gateway node of the zone, in which the destination node resides, receives the location request, it replies with a location response containing the zone ID of the destination. The zone ID and the node ID of the destination node is specified in the header of the data packets originated from the source. During the packet forwarding procedure, intermediate nodes except nodes in the destination zone use inter -zone routing table, and when the packet arrives the destination zone, an intra-zone routing table will be used. The advantage is no overlapping zones are here. The zone-level topology information is distributed to all nodes. Reduces the traffic and avoids single point of failure. But additional traffic produced by the creation and maintaining of the zone-level topology is difficult.

J. Dynamic Source Routing (DSR) [2]

K. It is the competent and simple routing protocol. It follows the source routing technique. In this the complete sequence of nodes is determined by the sender of the node through which the packet is forwarded. Then the route is listed in the packet header and each hop is identified by the address of the next node and the packet is transmitted to the destination host. DSR is completely self-organizing and self-configuring and requires no existing network infrastructure. The DSR protocol allows dynamically discovery of a source route across multiple network hosts to any destination in the network. Two mechanisms that make up the operations of DSR are Route Discovery and Route Maintenance.

Table I Comparison of Routing Protocols in Mobile Ad Hoc Network

Protocols	**Rout acquisition**	**Routing Structure**	**Bandwidth Requirement**	**Power Requirements**	**Route Capability**	
DSDV	Table Driven	Flat	High	High	S	
DSR	Demand Driven	Flat	Low	Low		M
AODV	Demand Driven	Flat	Low	Low	S	
ZRP	Hybrid	Hierarchical	Medium	Medium		M
CGSR	Table Driven	Hierarchical	High	High	S	
WRP	Table Driven	Flat	High	High	S	

OLSR	Table Driven	Flat	High	High	S	
TORA	Demand Driven	Flat	Low	Low		M
ABR	Demand Driven	Flat	Low	Low	S	
ZHLS	Hybrid	Hierarchical	Low	Low	S	
S=Single Route and M=Multiple Route						

Table II List of Protocols

Protocol	**Description**
DSDV	Dynamic destination sequenced distance-vector
WRP	Wireless routing protocol
CGSR	Cluster gateway switch routing protocol
DSR	Dynamic source routing
AODV	Adhoc on-demand distance vector routing
ABR	Associativity-based routing
TORA	Temporarily ordered routing protocol
ZRP	Zone routing protocol
OLSR	Optimized link state routing
ZHLS	Zone based hierarchical link state

IV. CONCLUSIONS

In this article we provide taxonomy of network layer unicast routing protocols. We have divided the network layer unicast ad hoc routing protocols into four categories. For each of these categories, we reviewed and discussed several prominent protocols. While different protocols operate under different scenarios, they do share some common features for e.g. reducing control packet overhead, minimizing the end-to-end delay and maximizing throughput. The classification criteria proposed tries to reveal the main design and implementation principles behind the protocols. This review can be used to study the protocols more effectively and easily by the researchers as it highlights the key features of the protocols. Further classification can be done according to the various QoS metrics and security mechanisms used in the unicast protocols. To obtain maximum performance in an ad hoc network very careful analysis of the scenario is required so that the appropriate choice of the routing protocol can be made .We hope that the simple taxonomy presented here will help in making that decision.

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