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A Survey on Routing Protocols and Enhancing Quality of Service Metrics

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Abstract-**Mobile ad hoc network (MANET) is a self-governing system of mobile nodes which is an infrastructure less network and requires no centralized management. Mobile adhoc networks are self-organizing and self-configuring network where, the structure of topology is changed arbitrarily and communication will take place via radio waves at anywhere and anytime. The goal of Quality of service (QoS) is to provide a better service to the selected network traffic. QoS for wireless is more challenging than wired network due to node mobility and resource constraints. This paper discusses various classification of routing protocols in MANET and the QoS parameters like end-to-end delay, energy, bandwidth, packet delivery ratio, jitter, throughput and so on for different types of routing protocols such as proactive, reactive, hybrid, power-aware, position based routing protocols which are used in mobile adhoc networks.**

Keywords-**MANET, Quality of Service, QoS metrics, routing protocols**

I. INTRODUCTION

MANET (Mobile Adhoc Network) is an autonomous network of mobile devices. The mobile nodes are not having fixed infrastructure for communication. In MANET all the nodes can move freely at any time and it can connect to other nodes. Every node is an independent which acts as a router and host devices.

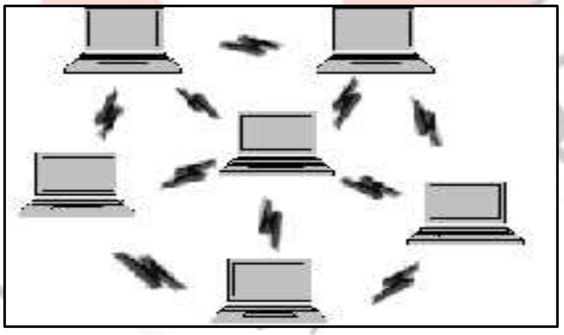

Figure.1 Representation of MANET

MANET has wide variety of applications such as Personal area networking, Military environments, disaster relief, battlefields, civilian environments, emergency operations, etc. MANETs have several salient features which are dynamic topologies, energy -constrained, bandwidth -constrained operation. The graphical representation of MANET is shown in Fig.1. The mobile nodes are able to find out routing paths and forward data in an adaptive, optimal, self-healing and robust manner. The need for MANET is increasing, and it can be connected to wired or wireless links using one or more different technologies. In Mobile Ad hoc Networks, each node has narrow wireless transmission range, so the routing in MANET depends on the cooperation of intermediate nodes.

A MANET routing algorithm should not only be proficient of finding the shortest path between the source and destination, and it should also be adaptive, in terms of the changing state of the nodes, the load conditions of the network and the state of the environment. MANET routing algorithms can be classified into three categories as proactive, reactive or hybrid [1]. Proactive algorithms try to retain up-to-date routes between all sets of nodes in the network at all times. Examples of proactive algorithms are Optimized Link State Routing (OLSR) [3] and Destination-Sequence Distance-Vector routing (DSDV). Reactive algorithms only maintain routing information that is firmly necessary. The routes are set upped on demand when a new communication session is started, or current communication session fails without route. Examples of reactive routing algorithms include Adhoc On-demand Distance-Vector routing (AODV) [6] and Dynamic Source Routing (DSR). Finally, hybrid algorithm uses both proactive and reactive elements, which combines both routing methods. An example for hybrid routing is the Sharp Hybrid Adaptive Routing Protocol (SHARP) [5].

II. ANALYSIS OF VARIOUS ROUTING PROTOCOLS

A. Routing Protocol

The routing protocol shows correct and updated information of the topology and link states. The state of information can be at three levels – local, global and aggregated [2]. In the local state representation each node maintains up-to-date information about state of the node and the link state. The local state representation is used in the Distance vector protocols. In the global state, each node maintains a whole topological database of the network. The link state protocols exploit this scheme. The whole of the local state information for all nodes creates the global state information and is formed by interchanging the local sate information for all nodes among all the network nodes at approximate intervals.

The global state is considered as an approximation of the actual state. The spreading of the state information can extremely increase the communication overhead. The global state algorithms converge faster but involve more CPU power and memory than the local state algorithms. To decrease the protocol overhead accompanying with the often distribution of update, aggregated global state is suggested. It is obtained by first dividing the network into hierarchical clusters and then accumulating the information. Such aggregation signifies partially true global state [4] but scales better.

Routing protocols have been proposed in MANET are routing table based (proactive, reactive, hybrid), position based, multipath, multicast, unicast, hierarchical, power aware routing etc.

B. Based on Route Discovery

- ***Proactive/table driven Routing***

Each node maintains the global topology information in table form. These tables are updated often in order to maintain consistent and accurate information.Fig.2 shows the general taxonomy of routing protocols in MANET. Some of protocols are listed below:

- ***Destination Sequence Distance Vector (DSDV)***

Destination Sequence Distance Vector [1], uses destination sequence numbers to reach loop freedom without an yinter-nodal coordination. Each node maintains a monotonically increasing sequence number for itself. Each destination maintains the greatest sequence number in the routing table (known as "destination sequence numbers").Every destination typically interchanges the distance information via routing updates among neighbors in distance-vector protocols, is identified with the equivalent destination sequence number. These sequence numbers are used to determine the relative aliveness of distance information created by two nodes for the same destination (the node with a higher destination sequence number has the more up-to-date information). Routing loops are prohibited by maintaining a variable destination sequence numbers along any effective route and monotonically increase toward the destination.

- ***Optimized Link State Routing (OLSR)***

Optimized Link State Routing (OLSR) [3] is an enhanced version of traditional link state protocol such as OSPF. OLSR uses only periodic updates for link state propagation. The total overhead is estimated by the product of number of nodes creating the updates, number of nodes forwarding each update and the size of each node update.

- ***Reactive/On demand Routing***

In reactive [1] routing protocol, every node maintains in formation of only active paths to the destination nodes. For every new destination requires route search which leads to the communication overhead is reduced at the expense of delay to search the route.

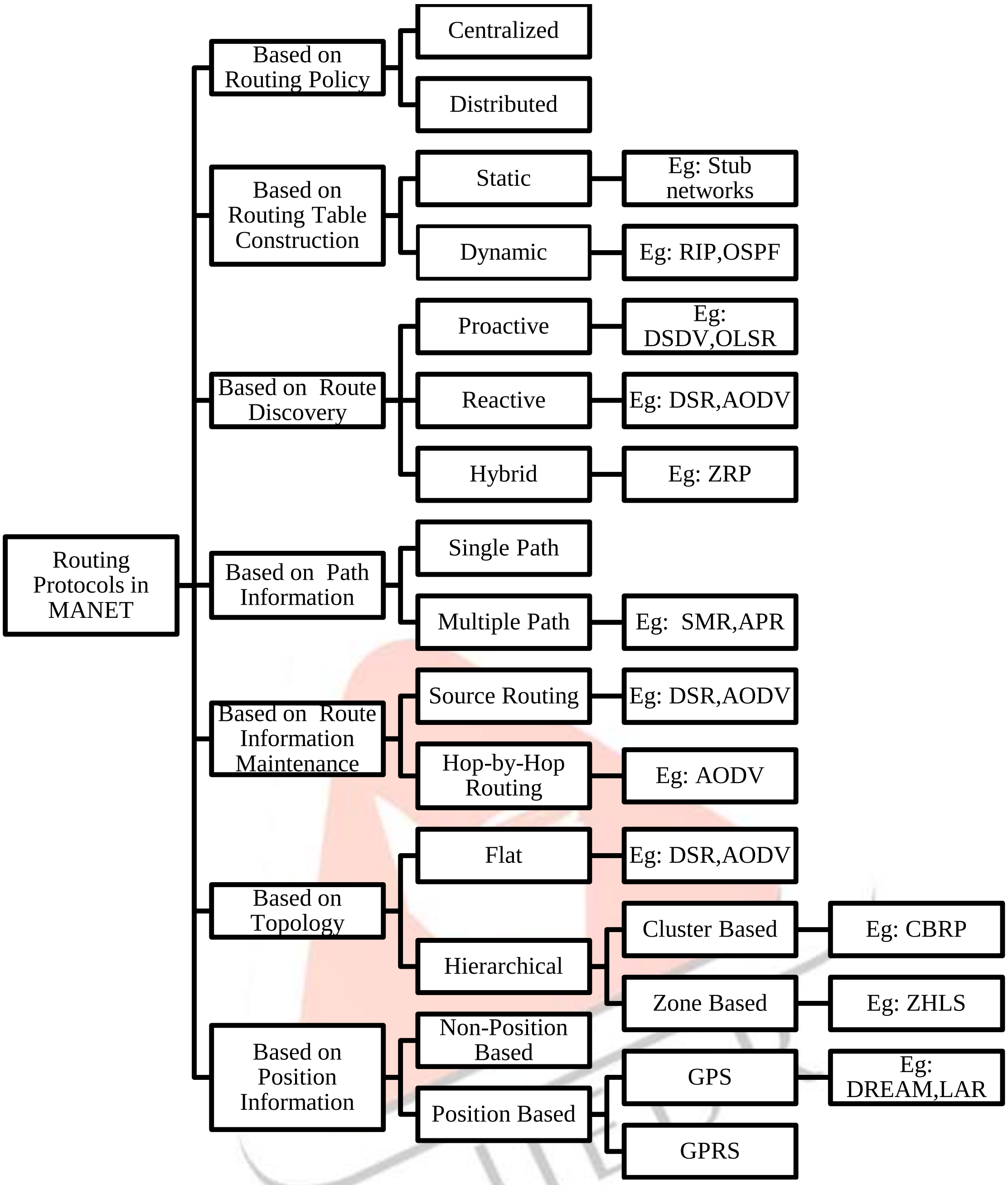

Figure.2 Taxonomy of Routing Protocols in MANET

a) On-demand source routing protocol (DSR)

In DSR, route paths are discovered after source node sends a data packet to a destination node in the mobile ad-hoc network. The source node initially does not have a path to the destination during the first packet is sent. The DSR has two roles namely:

a. Route discovery
b. Route maintenance

b) Ad hoc- On Demand Distance Vector (AODV)

Ad hoc- On Demand Distance Vector [6] implements a very different mechanism to sustain routing information. Entry per destination routing table is used. This is contrast to DSR, each destination which maintain multiple route cache entries. Without source routing, AODV relies on routing table entries to propagate a RREP back to the source and, consequently, route the data packets to the destination.

- ***Hybrid routing***

Hybrid is the combination of both reactive and proactive routing protocols [1]. It was proposed to reduce the control overhead of proactive routing and also to reduce the latency caused by route discovery in reactive routing protocols. (Zone routing protocol) is Hybrid routing protocol.

a) Zone Routing Protocol (ZRP)

ZRP consists of several element gives the benefits of ZRP. Each component work autonomously to give the efficient result. Elements of ZRP are IARP (Intrazone Routing Protocol), IERP (Interzone Routing Protocol), BRP (Boarder cast resolution protocol), IARP is first element of ZRP.IARP is used to communicate with the interior node inside the zone. Changes in the network topology which lead the node to change rapidly it allow for only local route. IERP is global reactive element of ZRP. It uses reactive method to communicate for outside zone.

It changes the way route discovery handled. BRP is used to direct the route request commenced by global reactive IERP.

C. ***Based on Path Information***

Routing protocols are categorized into two types based on path information which are single path and multiple paths.

a) Single Path: Single route between a source and destination node.

b) Multiple Paths: Multiple routes between a source and destination node.

1. Alternate Path Routing (APR)

APR's ability to provide a load balancing and enhanced survivability makes it an efficient method for bandwidth-limited MANETs that are considered as packet-radio extensions to the wired Internet.

D. ***Based on Routing Policy***

Protocols based on routing policy classified into

a) Centralized Routing

Only one node develops the routing table and other nodes make use of it.

b) Distributed Routing

In distributed routing each node obtains some information about the network from its neighboring nodes and uses the information to determine the manner in which it forwards its traffic.

E. Based on Route Information Maintenance

Protocols are categorized into Source Routing and Hop by Hop routing based on route information maintenance.

a) Source Routing

Source Routing, also called as path addressing, allows a sender of a packet to partially or completely specify the route to the packet which takes through the network.

b) Hop by Hop Routing

Routing table on each node encompasses the next hop node and a cost parameter for each destination. Data packet has only the destination address.

F. Based on Topology

Protocols are distinguished into two flat and hierarchical routing.

a) Flat Routing

Flat routing protocol allocates routing information to routers that are associated to each other without any defined or segmentation structure between them. The overall participating node addressed by flat routing protocol performs an equivalent role in the overall routing mechanism. DSR, AODV routing protocols are flat routing.

b) Hierarchical Routing

In hierarchical routing, routers are categorized into groups known as regions. Each router contains the information about the routers only in its own region and has no information about routers in other regions. It is classified into two categories:

i) Cluster Based:

CBRP protocol divides the nodes of the ad hoc network into a more number of clusters in a distributed manner. A cluster head is chosen for each cluster to maintain the information about its cluster membership. Routes for Inter- cluster are discovered dynamically using the cluster membership information maintained at each cluster head. By clustering nodes into groups, during route discovery process the protocol efficiently minimizes the flooding traffic and speed up the process.

ii) Zone Based:

ZHLS uses a hierarchical addressing scheme that contains zone ID and node ID. A two-level of network topology structure is defined in ZHLS, the node level topology and the zone level topology.

G. Based on Position Information
Position based routing protocols

Recent development of Global Positioning System (GPS) makes it possible to provide location information with accuracy for a few meters. They also provide universal timing. For directional routing, location information can be contributions in distributed ad hoc system; the widespread clock can provide global synchronization for the nodes equipped with GPS. In position based routing protocols, the routing decisions are made on the basis of the current position of the source and the destination nodes rather than using routing tables and network addresses. Typical position based routing protocol share Location Aided Routing (LAR) and Distance Routing Effect Algorithm for Mobility (DREAM) for mobile ad hoc networks. According to a number of experimental works, routing schemes that use positional information scale well. In all of the unicast routing protocols, the strength of the route is generally not considered as a necessity for route selection. Subsequently, route breakups will frequently take place, due to the nodal mobility or nodal and link failures as well as by variations in the communications across the networks links. They are also caused by signal interferences, fading multi-path, ambient and environmental noise and signal interference processes. Route breakage leads to the rebuilding of routes that takes lots of the network resources and the energy of nodes.

a) ***Location-Aided Routing (LAR)***

Location-Aided Routing (LAR) is an optimization for reactive protocols to decrease flooding overhead. LAR uses an assessment of destination's locality to restrict the flood to a small region (called *request zone*) relative to the whole network region.

b) The Distance Routing Effect Algorithm for Mobility (DREAM)

The Distance Routing Effect Algorithm for Mobility (DREAM) is a proactive routing which constructs routing table of a node holds location information of all other nodes in the network. When source sends a packet, initially it checks its routing table and acquires the respective location information about the destination. Then, the source node forwards the packet to neighbor nodes in the direction to reach the destination.

H. Based on Route Table Construction

Routing is characterized into two types based on routing table are Static routing and Dynamic routing

a) Static routing is called as non-dynamic routing. Smaller networks may use manually configured.

Table. 1 Routing Table for Different Protocols

b) tables. Large

Protocol Name	Table Driven/ Proactive	On demand/ Reactive	Hybrid	Hierarchical	Source Routing
1.DSDV[Destination Sequence Distance Vector]	**Yes**	-	-	-	-
2.DSR[Dynamic Source Routing]	-	**Yes**	-	-	-
3.AODV[Ad hoc On demand Distance Vector]	-	**Yes**	-	-	-
4.ZRP[Zone Routing Protocol]	-	-	**Yes**	-	-
5.OLSR[Optimized Link State Routing]	**Yes**	-	-	-	-
6.WRP[Wireless Routing Protocol]	**Yes**	-	-	-	-
7.GSR[Global State Routing]	**Yes**	-	-	-	-
8.FSR[Fisheye State Routing]	**Yes**	-	-	-	-
9.STAR[Source Tree Adaptive Routing]	**Yes**	-	-	-	-
10.CGSR[Cluster Gateway Switch Routing]	-	-	-	**Yes**	**-**
11.HARP[Hybrid Ad hoc Routing Protocol]	-	-	**Yes**	-	-

12.TORA[Temporally Ordered Routing Algorithm]	-	**Yes**	-	-	-
13.HSR[Hierarchical State Routing]	**Yes**	-	-	-	-
14.LAR[Location Aided Routing]	-	**Yes**	-	-	
15.SSRR[Strict Source and Record Route]	-	-	-	-	**Yes**

a.) Lajos Hanzo Ii et al [7] defined energy as ,

$$E_{i,j} = \frac{T_{i,j}}{(1-P_{i,j})^H}$$

Where, $L_{i,j}$ is lifetime of a link between nodes (i,j), $R_{i,j}$ is Residual battery charge at node, $E_{i,j}$ is Energy required to transmit a data packet of given size over link(i,j) , $T_{i,j}$ is the energy required for one transmission attempt, $P_{i,j}$ is the packet error probability of the link (i, j) and $H = 1$ if hop-by-hop retransmissions are performed by the link layer.

b. Author May Cho Ayeet al [8] defines energy by,

$$RE = E_1 - E_C(t) \qquad \text{(b.1)}$$

$$TE_C = N * \text{initial energy} - RE$$

Where, $E_C(t)$ is energy consumed by a node after time t, E_1 is initial energy of a node, RE is residual energy , TE_C is total energy consumption of all nodes, and N denotes number of nodes in the network

c. Marco Fotino et al[9] proposed energy as,

$$E(n_i) = E_{rx}(n_i) + E_{tx}(n_i) + E_0(n_i) \qquad \text{(c.1)}$$

Where, E_{tx} , E_{rx}, E_0 denotes the amount of energy expenditure by transmission, reception and overhearing of packet respectively.

d. Yun Zhang et al [10] uses power for defining energy as,

$$P_r = P_t X d^{-\propto} \qquad \text{(d.1)}$$

where, P_r , P_t is receive power , transmit power, α is path loss exponent and d is the transmission distance

B. End to end delay

End to end delay refers to the time taken for a packet to be transmitted across a network from source to destination. It includes processing delay, queuing delay, transmission delay and propagation delay. Different formulae for estimating the end-to-end delay of the node by various authors are as follows,

a.) Sankararajan Radha et al [11], expressed delay as

$$Delay = \frac{time\ between\ the\ reception\ of\ the\ last\ packet}{total\ number\ of\ packets\ send} \qquad \text{(a.1)}$$

b.) Anelise Munaretto et al [12], calculated the delay as

$$average\ delay = \propto.\ old\ average\ delay + (1-\propto) measured\ delay \qquad \text{(b.1)}$$

Average delay presents the new weighted average, $old\ average\ delay$: stores a weighted average, which is slowly changed based on measured_ delay and $measured\ delay$: computed from the elapsed time between sending hello message and receiving it.

c.) Shiva Shankar et al [13], defined the delay as

$$AverageEndtoEnddelay = 1/S \sum_{i=1}^{S} r_i - s_i \qquad \text{(c.1)}$$

Where, S is number of packets received successfully, r_i is time at which packet is received and s_i is time at which it is sent and i is unique packet identifier

d.) Qi Xue et al [14] ,expressed the delay as,

$$T_{down} = [T_{queue}(I) + T_{trans}(I)] + T_{prop}(I = S, A, B, C)$$

$$T_{up} = [T_{queue}(I) + T_{trans}(I)] + T_{prop}(I = D, A, B, C)$$

$$T_{diff} = T_{down} - T_{up}$$

$$T_{diff} = T_{queue}(S) - T_{queue}(D)$$

Using the computations above we obtain

$$T_{round} = T_{down} + T_{up} = 2T_{down} - T_{diff} \qquad \text{(d.1)}$$

$$T_{down} = [T_{round} + T_{diff}]/2 \qquad .$$

Where,$T_{queue}(I)$- the queueing delay at each relaying node, T_{trans}(I)-the packet transmission time at node I, T_{prop}-the end-to-end packet propagation delay, T_{down} - delay from the source to destination and T_{up}- delay from the destination to source

e.) Khaja et al [15] defined the delay as,

$$Total\ nodal\ delay = processing\ delay + queuing\ delay + transmission\ delay + propagation\ delay \qquad \text{(e.1)}$$

$$d_q = d_t \sum_{n=1}^{n-1}(n-1)$$

$$d_q = \frac{d_t\,(n(n-1))}{2}$$

Average Queuing delay, $d_{qa} = \frac{d_t\,(n-1)}{2}$

Transmission delay, $d_t = \frac{p}{r}$

Propagation delay, $d_g = (D/_C)$

Where, D-Total geometric distance of the route, c - Link speed, P-Packet size and r -Data rate.

C. Bandwidth

Bandwidth is the maximum data transfer rate of the network. Different formulae for computing the bandwidth of the node by various authors are as follows,

a.) Mounir et al [16], defined bandwidth as

Average used bandwidth,

$$Bandwidth(bps) = \frac{N\ X\ S\ X\ 8}{T} \qquad \text{(a.1)}$$

Where, N-number of packet sent and received by a node over a time T and S-size of the packet

$$Available\ bandwidth = maximum\ bandwidth - used\ bandwidth$$

b.) Sumathi [17], proposed bandwidth as

$$Available\ bandwidth = channel\ capacity - utilized\ bandwidth \qquad \text{(b.1)}$$

$$\text{Here,} \; utilized\ Bandwidth = \frac{(N\ X\ S\ X\ 8)}{T}$$

Where, N- No. of packets, S- Size of packet and T- Time duration

c. Sridhar [18], defined bandwidth as

$$B_{available}(I) = \frac{B(I) X\ T_{idle}}{T_{interval}} \quad \text{(c.1)}$$

Where I – node,$T_{idle} = T_{interval}$-T_{busy}respectively

d.) Shilpa et al [19], defined bandwidth as

Available end to end bandwidth,

$$ABW = \frac{8\ X\ S_d}{t_{lpr} - t_{fpr}}\ X\ (P_r - 1) \quad \text{(d.1)}$$

Where,S_d is the size of the data segment of each packet,t_{lpr} is the time at which the last packet received, $t_{fpr}$is the time at which the first packet received and P_r is number of packets received

e.) Vinh Dien HOANG et al [20], defined bandwidth as

Available bandwidth of node s,

$$B_s = channel\ capacity\ X\ \left({T_{idle}(S)}/{T_s} \right) \quad \text{(e.1)}$$

Where,$T_{idle}(S)$ is the total idle periods during measurement time T_s of node s and $B_s$is the available bandwidth of node s.

D. Throughput

Throughput is defined the rate of successful message delivery over a communication channel. Different formulae for computing the throughput of the node by various authors are as follows,

a.) Joni et al [21] defined throughput as

$$TP = \sum \frac{\text{PacketSize}}{(\text{PacketArrival} - \text{PacketStart})} \quad (a.1)$$

Where, Packet Size is the packet size of the i^{th} packet reaching the destination, Packet Start is the time when the first packet left the source and Packet Arrival is the time when the last packet arrived.

b.) Boomarani et al [22], defined throughput as

$$\text{Throughput} = \text{ information whether data packets are correctly delivered to the destinations or not} \quad \text{(b.1)}$$

c.) Ahmed et al [23], defined throughput as

$$\text{Throughput} = \frac{Total\ number\ of\ delivered\ data\ packets}{TOtal\ duration\ of\ simulation\ time} \quad \text{(c.1)}$$

IV. CONCLUSION

Routing in MANET determines the best path for data to reach the destination in the network. The path availability and stability of routes at an instance is an issue in MANET that affects the quality of service in the network. This survey provides a classification of routing protocols and various ways to improve the QoS metrics such as Delay, Energy, Bandwidth, Throughput estimation for various routing protocols in MANET.

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