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A Qualitative and Quantitative Analysis of Routing Protocols in MANET

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Abstract: Mobile ad hoc networks (MANET) are decentralized, self-configuring, without any fixed infrastructure and temporary network where participating nodes/devices are working as host as well asrouters.Every communicating device/node in MANET is free to movefor making the multi-hop network topology. Selection of a routing protocol for mobile network is an emerging research area in mobile computing and communication. In order to select appropriate routing protocol, IETF (Internet Engineering Task Force) MANET group has given certain parameters. These parameters define the reservedcharacteristics of a protocol. This paper isexplaining different routing protocols and comparing them onqualitative and quantitative parameters. Many qualitative metrics such as security, routing scheme, routing metric, multicasting, nodes with special task and average end-to-end delay are discussed in various protocols like DSDV, AODV, DSR, TORA and OLSR.

Keywords: AODV, DSDV, DSR, Evaluation Metric, OLSR.

I. INTRODUCTION

A mobile ad hoc network (MANET) is a network involving wireless mobile nodes (MNs) that communicate with each other without any central control or established infrastructure [1] (Figure 1).

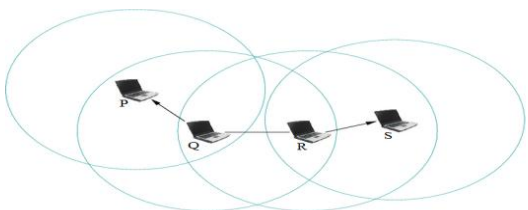

Fig. 1: Ad-hoc Network System.

Node in this network is of movable nature, there for this leads to no fixed topology in the network and network changeable continuously with time. In MANETs each node has also the power of a router for calculating optimal path among nodes for messages forwarding via other nodes. Ad-hoc networks are very useful when communication required like in rescue operations, military operations, vehicular ad hoc networks etc., because of dynamic topologies, routing has become an important issue with this network and selection of suitable routing protocol is thus more important.

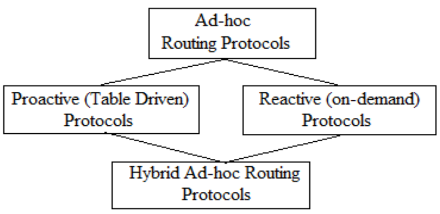

Fig. 2: Classification of Ad-hoc Routing Protocols

In this paper different qualitative and quantitative characteristic of Ad-hoc networks are analyzed.

II. TYPES OF ROUTING PROTOCOLS

A. Proactive (Table Driven) Routing Protocol: Proactive routing protocols are table-driven protocols. Table driven protocols continuously maintain current up-to-date routing information on every node in the form of "routing table".

The routing table contains information about the network topology even without requiring it [2]. Table is updated by sending control messages periodically to each other.

The proactive routing protocols use "link-state routing algorithms" which frequently flood the link information about its neighbors [3] and hence every node in the network has more than one route to any possible destination in its routing table.

Frequently updatable table feature is useful in datagram traffic network [4]. Data received from the upper transport layer are immediately transmitted, as at least one route to the destination is already in the node's routing table.

In large networks proactive protocol need to maintain node entries for each and every node in the routing table at each node [5].

Continuously changeable routing table increase the traffic overhead, reduces the throughput and needed more power consumption.
Mostly used proactive routing protocols are DSDV, OLSR, WRP and CGSR (Figure 3).

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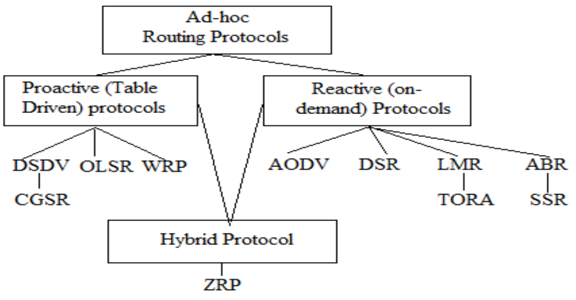

Fig. 3: Family Diagram of Proactive, Reactive and Hybrid Routing Protocol.

B. Reactive (on-demand) Routing Protocol:
In reactive (on-demand) routing protocols routes are not predefined. Routes are created when they are needed by the source host and these routes are maintained while they are needed. Such protocols use distance-vector routing algorithms [6]. A source node demands a route when needed for transmission and a discovery phase is introduced for this. This route finding mechanism is based on flooding algorithm. In flooding technique a node within network just broadcasts the packet to all of its adjacent and adjacent nodes just forward that packet to their neighbors. This is a repetitive technique until it reaches the destination. Reactive techniques have smaller routing overheads but higher latency. Mostly used on-demand protocols are: DSR, AODV, TORA (see above in figure 3).

III. FAMILY OF PROACTIVE ROUTING PROTOCOL

A. Destination-Sequenced Distance-Vector (DSDV) Protocol:
DSDV is a table driven protocol."Distributive Bellman–Ford (DBF) routing algorithm" [7] with some modification is applied in DSDV [8]. In DSDV routing protocol each node keeps routing table. DBF calculate the shortest paths from source to destination nodes, if the distance-vectors to each link are known. DSDV solves the loop tendency of DBF by introducing destination sequence number. In DSDV, every node is responsible for send a sequence number, which is periodically augmented by two and transferred along with any other routing update messages to all its neighboring nodes. When these update are available to adjacent nodes the following steps are used to take appropriate actions whether to reject the update or to make the changes to its routing table [9].
Step I: Receive the update message.
Step II: Update the routing table if any one of the following conditions satisfies:
i) Seqn > Seqp,
ii) Seqn=Seqp. Hop count is less, otherwise, ignore the update message. Here, Seqn and Seqp are the Sequence numbers of "new message" and "existing message" respectively.
When a path becomes invalid/disable, due to movement of nodes, the node that identified the broken link is mandatory to inform the source, which simply removes the old path and searches for a new one for communication. Low latency for route discovery, loop-free path is assured in DSDV as an advantage. The disadvantage is the huge volume of control messages. The routing updates could be sent in two ways: one is called a "full dump" and another is "incremental". In case of full dump, the entire routing table is directed to the adjacent nodes, where as in case of incremental update only the entries that require changes are sent [10].

B. Optimized Link State Routing (OLSR) Protocol: OLSR is a table driven (proactive routing) protocol. OLSR is an improved version of a "pure link state protocol". Therefore changes in infrastructure (topology) due to node movement cause the flooding/broadcasting of the routing table information to all available hosts in the network [11]. Multipoint Relays (MPR) broadcast is used in OLSR to decrease the potential overhead in the network. The idea of MPR is to decrease flooding of broadcasts by reducing the same broadcast in some regions in the network (see in figure 4).

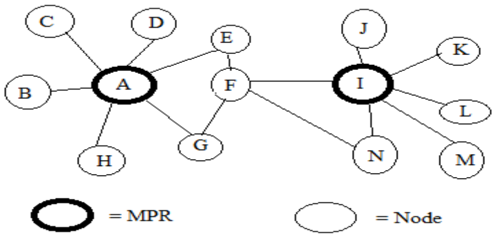

Fig. 4: MPR Broadcast in OLSR Protocol.

The control messages in OLSR are of two types: i) "HELLO" and ii) "Topology Control" (TC). HELLO messages are used for finding the information about the link status and the host's neighbors and TC messages are used for broadcasting information about own advertised neighbors which includes at least the MPR selector list. OLSR protocol provides that the protocol has all the routing information to all participated hosts in the network. OLSR protocol having disadvantages, this protocol requires each host periodically to send the updated routing table information (topology information) throughout the entire network.

C. Wireless Routing Protocol (WRP):
WRP is a table driven protocol which reduces the number of cases in which a temporary routing loop can arise. For the purpose of routing, each node maintains four things: i) A distance table, ii) A routing table, iii) A link-cost table, iv) A message retransmission list (MRL) [12]. WRP uses periodic update message broadcasts to the neighbors of a node. The nodes MRL should send acknowledgments. If routing update is no change from the last update table, the nodes in the response list should send an "idle Hello message" to ensure connectivity. A node can decide whether to update its routing table after receiving an update message from an adjacent node and always it looks

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for a better communication path using the new information. If nodes gets a better paths then table updated by node. After getting an acknowledgment original node update its MRL. In this way it reduces loops in network [10].

D. Cluster Gateway Switch Routing Protocol (CGSR):
CGSR is also a table driven/proactive routing protocol. CGSR [13] prefers a clustered mobile wireless network. For constructing the network into separate but interrelated groups, cluster heads are elected using a cluster head selection algorithm [12]. By establishing numerous clusters, this protocol achieves a distributed processing mechanism in the network. CGSR is an enhanced version of DSDV protocol (see in figure 3). However, it modifies DSDV by using a hierarchical cluster-head-to-gateway routing approach to route traffic from source node to destination node. Gateway nodes are nodes that are within the communication ranges of two or more cluster heads (see in figure 5). A packet firstly received bya cluster head from source node, then from that cluster head packet received at gateway to next cluster head, packet travels so on in the network until the cluster head of the destination node is reached. The packet is then transmitted to the destination from its own cluster head. Disadvantage of this protocol is that, frequent change or selection of cluster heads might be resource hungry and it might affect the routing performance.

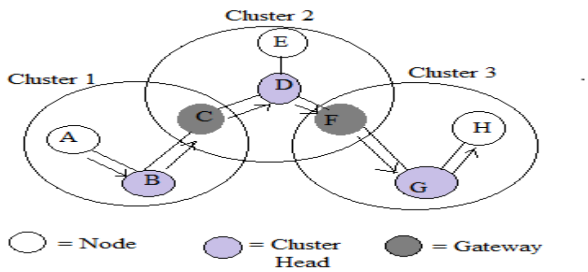

Fig. 5: Communication Diagram of CGSR via Cluster Head and Gateway.

IV. FAMILY OF REACTIVE ROUTING PROTOCOL

A. Ad-hoc On Demand Distance Vector (AODV):
As AODV protocol is a flat routing protocol it does not need any central controlled system to handle the routing procedure. AODV tends to reduce the control traffic messages overhead. AODV have three types of control messages: i) Route Request (RREQ), ii) Route Reply (RREP), iii) Route Error (RRER) [14].

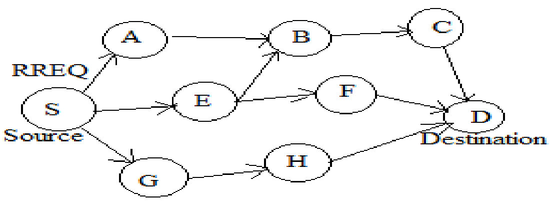

Fig. 6: Route Request in AODV for Path Finding.

When a source node wants to establish a path from source to destination node, it broadcast RREQ messages to all its neighbors and all the neighbor nodes which receive RREQ messages broadcast this RREQ to their neighbor and this broadcasting is going on until it reaches to destination node. When destination node receives RREQ message and there is a valid path between sources to destination, then destination node replays with unicast message RREP.

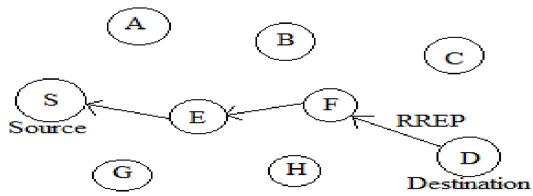

Fig. 7: Route Reply from Source to Destination in AODV

If the node has been missing or moved out of network then RRER message is used to inform source node to stop sending (see in figure 6,7).

B. Dynamic Source Routing (DSR) Protocol:
The Dynamic Source Routing (DSR) is an on-demand unicast routing protocol that utilizes source routing algorithm [15]. In DSR, each node uses cache technology to maintain route information of all the nodes. There are two main phases in DSR such as: i) Route Discovery ii) Route Maintenance.

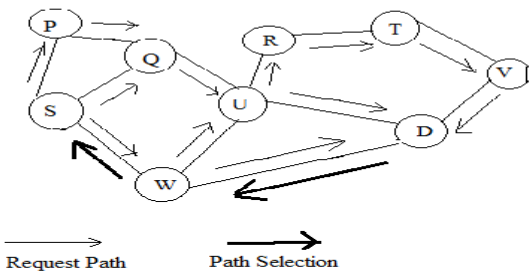

Fig. 8: Path Selection in DSR Protocol.

If a source wants to transmit data, it looks up into its cache [16]. If the requested route is available already, then the source node sends the packet along the path. Otherwise, the source node starts a route "Route Discovery Process" by broadcasting route request packets. The benefit of DSR is reduction of route discovery control overheads with the use of route cache. While route discovery process the address of intermediate node also added to packet header which leads to increase the size of packet header, this is a big disadvantage for DSR. The DSR used for multi hop networks in small diameter of area (see in figure 8).

C. Associatively-Based Routing (ABR) Protocol:
ABR [17] protocol introduces a new type of routing metric "degree of association stability" for MANETs. In ABR, a route is selected based on the "degree of association stability" of mobile nodes. Each node periodically generates ideal to broadcast its presence. Upon receiving

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the ideal message, a neighbor node updates its own associatively table. For each ideal received, the associatively tick of the receiving node with the ideal nodes growing.

A high value of associatively tick for any particular ideal node means that the node is relatively static. Associatively tick is reset when any neighboring node moves out of the neighborhood of any other node [10].

D. Temporarily Ordered Routing Algorithm (TORA):
TORA is an on-demand/reactive routing protocol. A link between source and destination nodes is created by Direct Acyclic Graph (DAG) algorithm [18]. “Link Reversal Technique” is used in route discovery phase of TORA.

Route discovery message are broadcasted and propagated throughout the network until it reaches the destination or a node that has information about how to reach the destination.

TORA defines a parameter, termed height. Height is a measure of the distance of the responding node’s distance up to the required destination node. In the route discovery phase, this parameter is returned to the querying node.

V. PERFORMANCE EVALUATION METRICS

Two types of metrics are provided by IETF in RFC 2501 for evaluating the performance of routing protocols for MANETs [19]. These are: i) qualitative metrics, ii) quantitative metrics. The process of evaluating the performance of routing protocols for MANETs is shown in figure 9 [20].

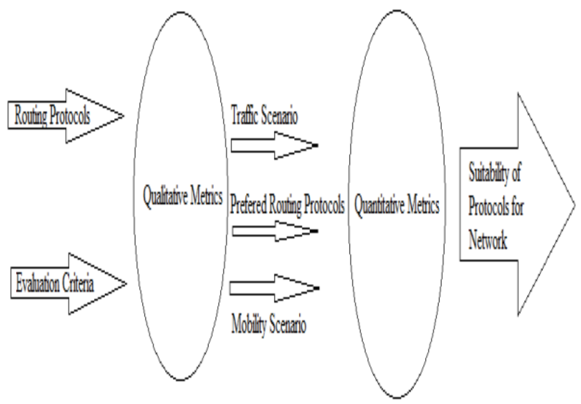

Fig. 9: Performance Evaluation Process in Qualitative and Quantitative Metric for MANETs.

A. Qualitative Metrics:
Qualitative metrics are like security, multicasting, loop freedom, sleep mode, unidirectional link support and on-demand routing behavior etc. is compared in table I [20].

I. Security: MANETs are visible to different type of attacks as there is no security at network and link level. A protocol should aware of security to its users.

Table I: Qualitative Comparison Table of Proactive and Reactive Routing Protocol.

Ad-hoc Network Routing Protocols									
Qualitative Metric	Proactive (Table Driven) Routing Protocol				Reactive (on-demand) Routing Protocol				
	DSDV	OLSR	WRP	CGSR	AODV	DSR	TORA	ABR	SSR
Security	NO	NO	NO	NO	NO	NO	YES	YES	YES
Loop Freedom	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sleep Mode	NO	YES	--	NO	NO	NO	NO	NO	NO
Multicasting	NO	NO	NO	NO	YES	NO	NO	NO	NO
Unidirectional Link Support	NO	YES	--	NO	NO	YES	NO	NO	NO
On-demand Routing Behaviour	Proactive	Proactive	Proactive	Proactive	Reactive	Reactive	Reactive	Reactive	Reactive
Routing Scheme	Flat	Flat	Flat	Heirarchical	Flat	Flat	Flat	Flat	Flat
Routing Metric	Shortest Path	Shortest Distance	Shortest Path	Shortest Path	Shortest path & freshest	Shortest Path	Shortest Path	Associ-ativity & Shortest Path	Associ-ativity & Stability
Route Maintained In	Route Table	Route Table	Route Table	Route Table	Route Table	Route Cache	Route Table	Route Table	Route Table

II. Loop freedom: Routing information based on the Bellman–Ford algorithm having loop freedom. In a wireless network having limited bandwidth, packet collisions rate is high, therefore it is essential to prevent a packet from looping in the network and thus consuming both processing time and bandwidth.

III. Sleep mode: In general, nodes in a MANET use batteries for their energy source. The protocol should be able to operate, Even if some nodes are in “sleep mode” for short periods, without affecting protocol’s performance.

IV. Multicasting: Multicasting support is essential for the communication of real-time data in many nodes at the same time.

V. Distributed environment: The way of interconnecting nodes under distributed environment.

VI. Routing metric: It provides the path of connecting nodes for sending packets.

VII. Routing scheme: It indicates the scheme of routing like flat routing.

VIII. Unidirectional link support: Nodes in the wireless environment may be able to communicate only through unidirectional links. It is desirable that routing protocols can support both unidirectional and bidirectional links.

IX. Proactive behavior: Proactive behavior is preferable when low latency is the main concern and where bandwidth and energy resources permit such behavior.

B. Quantitative Metrics:
Route acquisition time, out-of-order delivery, efficiency, end-to-end data throughput and delay quantitative metrics should be based on the same network attributes, such as network density, mobility, data density, bandwidth, energy resources, transmission and receiving power, antenna types, etc.
The "packet delivery ratio" and "average end-to-end delay" are more important for "best-effort traffic". The "normalized routing load" will be used to evaluate the efficiency of the routing protocol.

I. Route acquisition time: it indicates how much time does a protocol need to discover a route? This is a core concern in reactive routing protocols, as the longer the time is, the higher the latency is in the network.

II. Out-of-order delivery: Out of order delivery percentage of packets may disturb the performance of higher-layer protocols such as TCP, which favors in-order data delivery of packets.

III. Average end-to-end delay:
Average_end_to_end_delay = ∑ (Time_Received – Time_Sent) ÷ Total_Data_Packets_Received.

IV. Packet Delivery Ratio: Number of packets successfully conveyed to their final endpoint per unit time. It is the ratio between the numbers of received packets vs. sent packets.
Packet Delivery Ratio = Total_Data_Packet_Received ÷ Total_Data_Packet_Send.

V. Normalized MAC load: The normalized MAC load is defined as the fraction of all control packets. The control packets are these: i) Clear-to-Send (CTS), ii) Request-to-Send (RTS), iii) Address Resolution Protocol (ARP) requests and replies, iv)MAC ACKs). Formula is given as ratio between total control packets sent and the total number of successfully received data packets. Normalized_MAC_Load = Total_Control_Packets_Send ÷ Total_Data_Packets_Received.

VI. Media Access Delay: The time a node takes to access media for starting the packet transmission is called as media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.
VII. Efficiency: One can use them to measure the portion of the available bandwidth that is used by the protocol for route discovery and maintenance.

VIII. Normalized routing load: This qualitative metric defines, "how efficient the routing protocol is?"
Normalized_Routing_Load = Total_Routing_Packets_Sent ÷ Total_Data_Packets_Received.

IX. Optimal path length: It is the ratio of total forwarding times to the total number of received packets.

VI. CONCLUSION

In this article, all the mostly used protocols are disused and qualitative metrics based comparative study and performance analyses of mobile ad hoc routing protocols are entitled. Paper shows that the effort has been made on the comparative study of Reactive, Proactive MANET protocols and its corresponding routing family protocols. The qualitative comparisons based on some metrics are also compared corresponding to each protocol and shown in table. On the behalf of qualitative and quantitative metrics some conclusions are made in this article. The study of these routing protocols shows that OLSR is more efficient in high density networks with highly sporadic traffic. OLSR requires that it continuously have some bandwidth in order to receive the topology updates messages. AODV keeps on improving in packet delivery ratio with moderate dense networks. TORA performs much better in packet delivery owing to selection of better routes using acyclic graph. It has been concluded that performance of TORA is better for dense networks. There are many tradeoffs among these protocols which lead in difficulty in choosing the appropriate protocols. The future work suggested that the effort will be made to enhance ad hoc network routing protocol by tackling core issues.

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