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Analyzing Reactive Routing Protocols in Mobile Ad Hoc Networks

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ABSTRACT

Mobile Ad Hoc Network (MANET) is an autonomous mobile nodes forming network in an infrastructure less environment and has dynamic topology. MANET reactive protocols always not have low control overhead. The control overhead for reactive protocols is more sensitive to the traffic load, in terms of the number of traffic rows, and mobility, in terms of link connectivity change rates, than other protocols. Therefore, reactive protocols may only be suitable for MANETs with small number of traffic loads and small link connectivity change rates. It is already proved that, it is more feasible to maintain full network topology in a MANET with low control overhead. In this Research Paper through simulations that were carried out by using Network Simulator-2 (NS-2) we had analyze Reactive/ On-demand protocols such as Ad Hoc On-Demand Distance Vector Routing (AODV), Temporally-Ordered Routing Algorithm (TORA), and Dynamic Source Routing (DSR).

Keywords - Reactive Protocols, AODV, DSR, MANET, TORA

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I. INTRODUCTION

The The network topology in a MANET usually changes with time. Therefore, there are new challenges for routing protocols in MANETs since traditional routing protocols may not be suitable for MANETs. [1] Researchers are designing new MANET routing protocols and comparing and improving existing MANET routing protocols before any routing protocols are standardized using simulations. However, the simulation results from different research groups are not consistent with each other [2]. This is because of a lack of consistency in MANET routing protocol models and application environments, including networking and user traffic profiles.

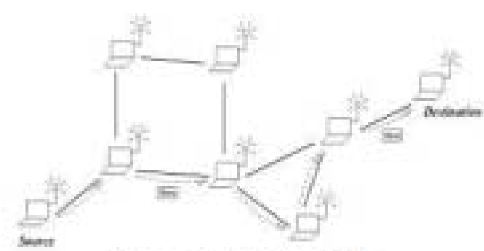

Fig 1: The MANET

Design of routing protocols is a crucial problem in mobile ad hoc networks [3, 4], and several routing algorithms have been developed [6]. One desirable qualitative property of a routing protocol is that it should adapt to the tic patterns. Conventional routing protocols are insufficient for ad hoc networks, since the amount of routing related traffic may waste a large portion of the wireless bandwidth, especially for protocols that use periodic updates of routing tables [7]. They proposed using DSR (Dynamic Source Routing), which is based on on-demand route discovery. A number of protocol optimization is proposed to reduce the route discovery overhead [8]. AODV (Ad hoc On Demand Distance vector routing) protocol are used a demand-driven route establishment procedure. More recent TORA (Temporally-Ordered Routing Algorithm) is designed to minimize reaction to topological changes by localizing routing related messages to a small set of nodes near the change [9].

Routing protocols that are based on a source initiated query/reply process have also been introduced. Such techniques typically rely on the flooding of queries to discover a destination. In the temporally ordered routing algorithm (TORA) [5], the resulting route replies are also flooded in a controlled manner to distribute routes in the form of directed acyclic graphs (DAG's) rooted at the destination. In contrast, protocols such as dynamic source routing (DSR) [10] and ad hoc on demand distance vector (AODV) (Perkins *et al.*, 1999) unicast the route reply back to the querying source along a path specified by a sequence of node addresses accumulated during the route query phase. In the case of DSR, the node addresses are accumulated in the query packet and are returned to the source to be used for source routing. AODV, on the other hand, distributes the discovered routes in the form of next hop information stored at each node in the route.

There are several quantitative performance metrics that can be used to assess the performance of routing protocols within a mobile ad hoc network. First, throughput and end-to-end delay are typical performance measures that show a routing protocol's effectiveness in doing its job (i.e. delivering data packets). Second, for certain protocols that acquires routes on-demand the amount of time it takes to acquire a route or route discovery latency is also an important performance measure. This measurement more easily conforms to those protocols that are of a demand-base property and thus should be acquired. Third,

Volume:03 Issue:06 Pages:1416-1421 (2012) ISSN : 0975-0290.

bandwidth utilization should be observed to see how effective the protocol is if both routing packets and data packets share the same channel. One such measure would be to obtain the number of bytes (or packets) of routing packets transmitted per number of bytes (or packets) of data packets delivered. Another such measurement may be the amount of data bits transmitted per data bit delivered to show the efficiency of data delivery throughout the network.

2 DYNAMIC SOURCE ROUTING (DSR)

Dynamic Source Routing (DSR) is a reactive protocol based on the source route approach [10]. The principal of this approach is that the whole route is chosen by the source, and it is put within each packet sent. Each node keeps in its cache the source routes learned. When it needs to send a packet, it first checks its cache, if it finds a route to the corresponding destination then it uses it, otherwise, it launches a cache, if it finds a route to the corresponding destination then it uses it, otherwise, it launches a Route discovery by broadcasting a Request (RREQ) packet through the network. When receiving the RREQ, a node seeks a route in its cache for the RREQ's destination, if it finds such a route, it sends a Route Reply (RREP) packet to the source, if no appropriate route exists then it adds its address to the request packet and continues the broadcasting. When a node detects a route failure, it sends a Route Error (RER) packet to the source that uses this link, and then this one applies again the route discovery process. In source routing algorithm, each data packet contains complete routing information to reach its dissemination. Additionally, in DSR each node uses caching technology to maintain route information that it has learnt.

There are two major phases in DSR [11], the route discovery phase and the route maintenance phase. When a source node wants to send a packet, it firstly consults its route cache. If the required route is available, the source node includes the routing information inside the data packet before sending it. Otherwise, the source node initiates a route discovery operation by broadcasting route request packets. A route request packet contains addresses of both the source and the destination and a unique number to identify the request. Receiving a route request packet, a node checks its route cache. If the node doesn't have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors. To limit the communication overhead of route request packets, a node processes route request packets that both it has not seen before and its address is not presented in the route record field. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node's route cache.

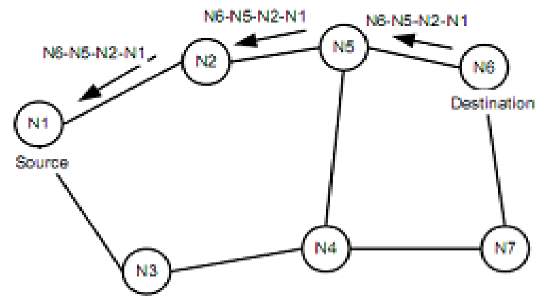

Fig 2: Route reply with route record with DSR

After being created, either by the destination or an intermediate node, a route reply packet needs a route back to the source. There are three possibilities to get a backward route. The first one is that the node already has a route to the source. The second possibility is that the network has symmetric (bidirectional) links. The route reply packet is sent using the collected routing information in the route record field, but in a reverse order as shown in Figure 2. In the last case, there exists asymmetric (unidirectional) links and a new route discovery procedure is initiated to the source. The discovered route is piggybacked in the route request packet.

In DSR, when the data link layer detects a link disconnection, a ROUTE_ERROR packet is sent backward to the source. After receiving the ROUTE_ERROR packet, the source node initiates another route discovery operation. Additionally, all routes containing the broken link should be removed from the route caches of the immediate nodes when the ROUTE_ERROR packet is transmitted to the source. DSR has increased traffic overhead by containing complete routing information into each data packet, which degrades its routing performance.

DSR Protocol the DSR is a simple and efficient routing protocol designed specifically for use in multihop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self configuring, without the need for any existing network infrastructure or administration. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance', which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network All aspects of the protocol operate entirely on DSR protocol include easily guaranteed loop free routing, operation in networks containing unidirectional links, use of only "soft state" in routing, and very rapid recovery when routes in the network change. In DSR, Route Discovery and Route Maintenance each operate entirely "on demand". In particular, unlike other protocols, DSR requires no periodic packets of any kind at any layer within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbor detection packets, and does not rely on these functions from any underlying protocols in the network.

The sender of a packet selects and controls the route used for its own packets, which together with support for multiple routes also allows features such as load balancing to be defined [12]. In addition, all routes used are easily guaranteed to be loop-free, since the sender can avoid duplicate hops in the routes selected. The operation of both Route Discovery and Route Maintenance in DSR are designed to allow unidirectional links and asymmetric routes to be supported [13].

3 AD HOC ON DEMAND DISTANCE VECTOR (AODV)

Ad hoc on Demand Distance Vector (AODV) is a hop by hop routing. When a node needs to send a data packet to a destination to which it has no route, it has to broadcast a RREQ to its entire neighbor, then each neighbor do so until reaching destination. This one sends a RREQ packet that travels the inverse path until the source. Upon the reception of this reply, each intermediary updates its routing table. In this way, a route between the source and the destination is built. Unlike DSR, the source does not put the whole route within the packet, but the decision about the next hop is made separately after each hop [14].

The AODV algorithm is an improvement of DSDV protocol described above. It reduces number of broadcast by creating routes on demand basis, as against DSDV that maintains mutes to each known destination (Perkins *et al.,* 1998). When source requires sending data to a destination and if route to that destination is not known then it initiates route discovery. AODV allows nodes to respond to link breakages and changes in network topology in a timely manner. Routes, which are not in use for long time, are deleted from the table. Also AODV uses Destination Sequence Numbers to avoid loop formation and Count to Infinity Problem.

An important feature of AODV is the maintenance of timer based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with RERR packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves [14].

The Ad Hoc On-demand Distance Vector Routing (AODV) protocol is a reactive unicast routing protocol for mobile ad hoc networks. As a reactive routing protocol, AODV only needs to maintain the routing information about the active paths. In AODV, routing information is maintained in routing tables at nodes. Every mobile node keeps a next-hop routing table, which contains the destinations to which it currently has a route. A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time. Moreover, AODV adopts the destination sequence number technique used by DSDV in an on-demand way.

In AODV, when a source node wants to send packets to the destination but no route is available, it initiates a route discovery operation. In the route discovery operation, the source broadcasts route request (RREQ) packets. A RREQ includes addresses of the source and the destination, the broadcast ID, which is used as its identifier, the last seen sequence number of the destination as well as the source node's sequence number. Sequence numbers are important to ensure loop-free and up-to-date routes. To reduce the flooding overhead, a node discards RREQs that it has seen before and the expanding ring search algorithm is used in route discovery operation. The RREQ starts with a small TTL (Time-To-Live) value. If the destination is not found, the TTL is increased in following RREQs.

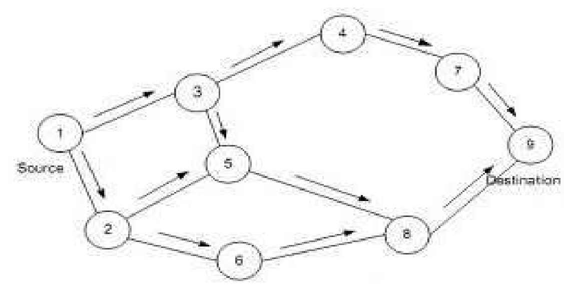

Fig 3: The Route Request packets flooding in AODV

In AODV, each node maintains a cache to keep track of RREQs it has received. The cache also stores the path back to each RREQ originator. When the destination or a node that has a route to the destination receives the RREQ, it checks the destination sequence numbers it currently knows and the one specified in the RREQ. To guarantee the freshness of the routing information, a route reply (RREP) packet is created and forwarded back to the source only if the destination sequence number is equal to or greater than the one specified in RREQ. AODV uses only symmetric links and a RREP follows the reverse path of the respective RREP. Upon receiving the RREP packet, each intermediate node along the route updates its next-hop table entries with respect to the destination node. The redundant RREP packets or RREP packets with lower destination sequence number will be dropped.

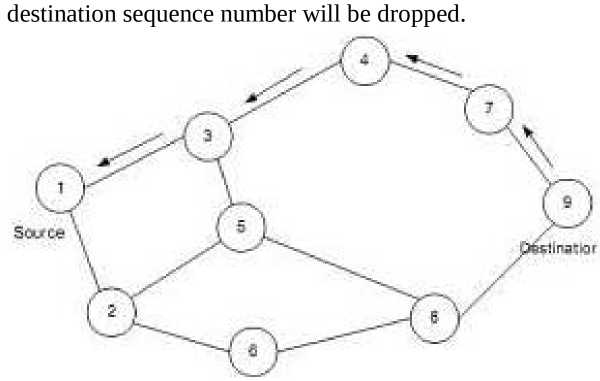

Fig 4: The forwarding of Route Reply packet in AODV

In AODV, a node uses hello messages to notify its existence to its neighbors. Therefore, the link status to the next hop in an active route can be monitored. When a node discovers a link disconnection, it broadcasts a route error (RERR) packet to its neighbors, which in turn propagates the RERR packet towards nodes whose routes may be affected by the disconnected link. Then, the affected source can re-initiate a route discovery operation if the route is still needed [15].

Ad hoc on demand distance vector protocol is reactive protocol. It constructs route on demand and aims to reduce routing load [4]. It uses a table driven routing framework, destination sequence numbers for routing packets to destination mobile nodes and has location independent algorithm. It sends messages only when demanded and it has bi-directional route from the source and destination. When it has packets to send from source to destinations mobile node (MN) then it floods the network with route request (RREQ) packets. All mobile nodes that receive the RREQ from neighbor or update message then it checks routing table to find out that if it is the destination node or if it has fresh route to the destination then it unicast route reply (RREP) which is routed back on a temporary reverse route generated by RREQ from source node, or else it re-broadcast RREQ.

4 TEMPORARY ORDERED ROUTING ALGORITHM (TORA)

Temporary ordered routing algorithm is hybrid protocol, which is distributed and routers only maintain information about adjacent routers [16]. During reactive operation, sources initiate the establishment of routes to a given destination on demand. Where in dynamic networks, it is efficient with relatively sparse traffic patterns; as it does not have to maintain routes at all the time. It does not continuously execute a shortest path computation and the metric used to establish the routing structure does not represent a distance. TORA maintains multiple routes to the destination when topology changes frequently.

It consists of link reversal of the Directed Acyclic Graph (ACG). It uses internet MANET encapsulation protocol (IMEP) for link status and neighbor connectivity sensing. IMEP provide reliable, in-order delivery of all routing control messages from a node to all of its neighbors, and notification to the routing protocol whenever a link neighbors is created or broken. As TORA is for multihop networks which is considered to minimize the communication overhead associated with adapting to network topological changes by localization of algorithmic reaction. Moreover, it is bandwidth efficient and highly adaptive and quick in route repair during link failure and providing multiple routes to destination node in wireless networks.

In TORA, the network topology is regarded as a directed graph. A Directional Acyclical Graph (DAG) is accomplished for the network by assigning each node *i* a height metric *hi*. A link directional from *i* to *j* means *hi* > *hj*. In TORA, the height of a node is defined as a quintuple, which includes the logical time of a link failure, the unique ID of the node that defines the new reference level, a reflection indicator bit, a propagation ordering parameter and a unique ID of the node. The first three elements collectively represent the reference level. The last two values define an offset with respect to the reference level. Like water flowing, a packet goes from upstream to downstream according the height difference between nodes. DAG provides TORA the capability that many nodes can send packets to a given destination and guarantees that all routes are loop-free.

TORA has three basic operations: route creation, route maintenance and route erasure. A route creation operation starts with setting the height (propagation ordering parameter in the quintuple) of the destination to 0 and heights of all other nodes to NULL (i.e., undefined). The source broadcasts a QRY packet containing the destination's ID. A node with a non-NULL height responds by broadcasting a UPD packet containing the height of its own. On receiving a UPD packet, a node sets its height to one more than that of the UPD generator. A node with higher height is considered as upstream and the node with lower height is considered as downstream. In this way, a directed acyclic graph is constructed from the source to the destination and multiple paths route may exist [16]

The DAG in TORA may be disconnected because of node mobility. So, route maintenance operation is an important part of TORA. TORA has the unique feature that control messages are localized into a small set of nodes near the occurrence of topology changes. After a node loses its last downstream link, it generates a new reference level and broadcasts the reference to its neighbors. Therefore, links are reversed to reflect the topology change and adapt to the new reference level. The erase operation in TORA floods CLR packets through the network and erase invalid routes.

5 COMPARISON OF DSR, AODV AND TORA

As reactive routing protocols for mobile ad hoc networks, DSR, AODV and TORA are proposed to reduce the control traffic overhead and improve scalability. DSR exploits source routing and routing information caching. A data packet in DSR carries the routing information needed in its route record field. DSR uses flooding in the route discovery phase. AODV adopts the similar route discovery mechanism used in DSR, but stores the next hop routing information in the routing tables at nodes along active routes. Therefore, AODV has less traffic overhead and is more scalable because of the size limitation of route record field in DSR data packets. Both DSR and TORA support unidirectional links and multiple routing paths, but AODV doesn't.

In contrast to DSR and TORA, nodes using AODV periodically exchange hello messages with their neighbors to monitor link disconnections. This incurs extra control traffic overhead. In TORA, utilizing the "link reversal"

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algorithm, DAG constructs routing paths from multiple sources to one destination and supports multiple routes and multicast [11]. In AODV and DSR, a node notifies the source to re-initiate a new route discovery operation when a routing path disconnection is detected. In TORA, a node re-constructs DAG when it lost all downstream links. Both AODV and DSR use flooding to inform nodes that are affected by a link failure. However, TORA localizes the effect in a set of node near the occurrence of the link failure [17]. AODV uses sequence numbers to avoid formation of route loops. Because DSR is based on source routing, a loop can be avoided by checking addresses in route record field of data packets. In TORA, each node in an active route has a unique height and packets are forwarded from a node with higher height to a lower one. So, a loop-free property can be guaranteed in TORA. However, TORA has an extra requirement that all nodes must have synchronized clocks.

In TORA, oscillations may occur when coordinating nodes currently execute the same operation. Performances of DSDV, TORA, DSR and AODV are compared in (Perkins et.al., 1998) based on simulation. The simulation results showed that DSDV performs well when node mobility rates and speed of movements are low. When the number of source nodes is large, the performance of TORA decreases. As shown in [13], both AODV and DSR perform well for different simulation scenarios. DSR outperforms AODV because it has less routing overhead when nodes have high mobility. A simulation-based comparison of two reactive mobile ad hoc network routing protocols, the AODV and DSR. The general result of was that DSR performs better than AODV when number of nodes is small, lower load and /or mobility, and AODV outperforms DSR in more demanding situations.

Table 1: Comparison of Reactive Protocols

Protocols	Update destination	Update period	Structure	Route Computation
DSR	source	Evident driven	flat	reactive
AODV	source	Evident driven	flat	reactive
TORA	Neighbors	Evident driven	flat	reactive

Protocols	Multicast capability	Hello message	Route metric	Unidirectional link
DSR	No	No	Shortest path	Yes
AODV	Yes	Yes	Fastest and Shortest path	No
TORA	No	No	Shortest path	Yes

Protocols	Multiple Routes	Storage Capacity	Communication Complexity	Time Complexity
DSR	Yes	O(D)	O(2N)	O(2d)
AODV	Yes	O(D)	O(2N)	O(2d)
TORA	Yes	Yes (DAG)	O(D^2 *A)	O(2N)

6 CONCLUSION

Reactive / On-demand protocols look for a route only when need to send a packet. It has two advantages that low routing table storage (only routes in use) and no periodic control traffic. The only disadvantage is that route search overhead with high mobility and many short lived flows. Reactive protocols, invoke a route determination procedure only on demand. Thus, when a route is needed, some sort of global search procedure is employed. The classical flood search algorithms are reactive protocols. The global search procedure of the reactive protocols requires significant control traffic. Because of this long delay and excessive control traffic, pure reactive routing protocols may not be applicable to real-time communication. However, purely proactive schemes are likewise not appropriate for the RWN environment, as they continuously use a large portion of the network capacity to keep the routing information urrent. Since nodes move quite fast in an RWN, and as the changes may be more frequent than the route requests, most of this routing information is never even used. This results in a further waste of the network capacity. Where as, the reactive protocols, also called On-Demand Protocols, don't establish a route between a pair of nodes until the source one asks for it.

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