Performance Evaluation of various Routing Protocols used in MANET

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Abstract:A mobile ad-hoc network (MANET) is a kind of wireless ad-hoc network, and is a self-configuring network of mobile routers connected wirelessly. MANET may operate in a standalone fashion, or may be connected to the larger Internet. Many routing protocols have been developed for MANETs over the past few years. This paper compares three specific MANET routing protocols which are Ad-hoc On-demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Dynamic MANET On- demand routing protocol (DYMO) to better understand the major characteristics of these routing protocols. Ad Hoc On-demand Distance Vector (AODV) and Dynamic Manet On-demand (DYMO) routing protocols have been standardized by the IETF MANET WG and are the most popular reactive routing protocols for MANETs.

Index Terms: MANET, AODV, DSR, DYMO

1. INTRODUCTION

In an *ad hoc* network, mobile nodes communicate with each other using multi hop wireless links. There is no stationary infrastructure; for instance, there are no base stations. Each node in the network also acts as a router, forwarding data packets for other nodes. A central challenge in the design of ad hoc networks is the development of dynamic routing protocols that can efficiently find routes between two communicating nodes. The routing protocol must be able to keep up with the high degree of node mobility that often changes the network topology drastically and unpredictably. Such networks have been studied in the past in relation to defence research, often under the name of *packet radio networks*. Recently there has been a renewed interest in this field due to the common availability of low-cost laptops and palmtops with radio interfaces. Interest is also partly fuelled by growing enthusiasm in running common network protocols in dynamic wireless environments without the requirement of specific infrastructures. A *mobile ad hoc networking* (MANET) working group has also been formed within the Internet Engineering Task Force (IETF) to develop a routing framework for IP-based protocols in ad hoc networks. Our goal is to carry out a systematic performance study of three routing protocols for ad hoc networks: the *Dynamic Source Routing* protocol (DSR) , the *Ad Hoc On-Demand Distance Vector* protocol (AODV) and the Dynamic MANET On-demand routing protocol(DYMO). DSR and AODV share an interesting

common characteristic — they both initiate routing activities on an *on demand* basis. This *reactive* nature of these protocols is a significant departure from more traditional *proactive* protocols, which find routes between all source-destination pairs regardless of the use or need for such routes. The key motivation behind the design of on-demand protocols is the reduction of the routing load. High routing load usually has a significant performance impact in low-bandwidth wireless links. While DSR and AODV share the on-demand behaviour in that they initiate routing activities only in the presence of data packets in need of a route, many of their routing mechanics are very different. In particular, DSR uses source routing, whereas AODV uses a table-driven routing framework and destination sequence numbers. The Ad Hoc On-demand Distance Vector (AODV) and Dynamic MANET On-demand (DYMO) are the two most popular reactive routing protocols for MANETs. AODV has already been standardized by the Category, while DYMO was more recently standardized in the standard category.

II. ROUTING PROTOCOLS

There are a large number of routing protocols for MANETs proposed so far. Three most commonly used routing protocols are discussed here.

A. Dynamic Source Routing (DSR) Protocol

The Dynamic Source Routing (DSR) [1] protocol is an on-demand routing protocol that is based on the concept of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware. Entries in the route cache are continually updated as new routes are learned. The protocol consists of two major phases: route discovery and route maintenance. When a mobile node has a packet to send to some destination, it first consults its route cache to determine whether it already has a route to the destination. If it has an unexpired route to the destination, it will use this route to send the packet. On the other hand, if the node does not have such a route, it initiates route discovery by broadcasting a route request packet. This route request contains the address of the destination, along with the source node's address and a unique identification number. Each node receiving the packet checks whether it knows of a route to the destination. If it does not, it adds its own address to the route record of the packet and then forwards

the packet along its outgoing links. To limit the number of route requests propagated on the outgoing links of a node, a mobile only forwards the route request if the mobile has not yet seen the request and if the mobile's address does not already appear in the route record. A route reply is generated when the route request reaches either the destination itself, or an intermediate node, which contains in its route cache an unexpired route to the destination. By the time the packet reaches either the destination or such an intermediate node, it contains a route record yielding the sequence of hops taken.

The key distinguishing feature of DSR[3.4] is the use of *source routing*. That is, the sender knows the complete hop-by-hop route to the destination. These routes are stored in a *route cache*. The data packets carry the source route in the packet header. When a node in the ad hoc network attempts to send a data packet to a destination for which it does not already know the route, it uses a *route discovery* process to dynamically determine such a route. Route discovery works by flooding the network with *route request* (RREQ) packets. Each node receiving an RREQ rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a *route reply* (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed across the network. The RREP routes itself back to the source by traversing this path backward.1 The route carried back by the RREP packet is cached at the source for future use. If any link on a source route is broken, the source node is notified using a *route error* (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed. DSR makes very aggressive use of source routing and route caching. No special mechanism to detect routing loops is needed. Also, any forwarding node caches the source route in a packet it forwards for possible future use. Several additional optimizations have been proposed and have been evaluated to be very effective by the authors of the protocol [7], as described in the following:

• *Salvaging*: An intermediate node can use an alternate route from its own cache when a data packet meets a failed link on its source route.

• *Gratuitous route repair*: A source node receiving an RERR packet piggybacks the RERR in the following RREQ. This helps clean up the caches of other nodes in the network that may have the failed link in one of the cached source routes.

• *Promiscuous listening*: When a node overhears a packet not addressed to itself, it checks whether the packet could be routed via itself to gain a shorter route. If so, the node sends a *gratuitous* RREP to the source of the route with this new, better route. Aside from this, promiscuous listening helps a node to learn different routes without directly participating in the routing process.

B. Ad-Hoc On- Demand Distance Vector Routing Protocol (AODV)

Ad Hoc On-Demand Distance Vector (AODV) [2] is a routing protocol that shares on-demand behaviour with DSR and uses hop-by-hop routing and destination based sequence numbers.

The characteristics of AODV are concluded as follows:
• The topology information is delivered on-demand, i.e.,the routes will be discovered only as needed.
• To avoid the problem of "counting to infinity", the sequence numbers are used to track the accurate route information.
• A node determines the connectivity to its neighbours by listening HELLO messages.

Routes are obtained via a discovery process similar to DSR. However, AODV stores routing information as one entry per destination in contrast to DSR, which caches multiple entries per destination. A node satisfies the Route Request by sending a Route Reply back to the source or by increasing the hop count and rebroadcasting to its neighbours. As the Route Request propagates from the source to various nodes, a reverse path is set up from these nodes back to the source. The destination sequence numbers in control packets ensure loop freedom and freshness of routing information. Timers are used to expire routes that have not been used recently. AODV ensures wider propagation of Route Errors, achieved using a per destination predecessor list at each node, than DSR.

AODV [5, 6] shares DSR's on-demand characteristics in that it also discovers routes on an *as needed* basis via a similar route discovery process. However, AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. Without source routing, AODV relies on routing table entries to propagate an RREP back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine freshness of routing information and to prevent routing loops [5]. These sequence numbers are carried by all routing packets. 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 neighbouring 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. In contrast to DSR, RERR packets in AODV are intended to inform all sources using a link when a failure occurs. 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. The recent specification of AODV [6] includes an optimization technique to control the RREQ flood in the route discovery process. It uses an *expanding ring search* initially to discover routes to an unknown destination. In the expanding ring search, increasingly larger neighbourhoods are searched to find the destination.

The search is controlled by the Time-To-Live (TTL) field in the IP header of the RREQ packets. If the route to a previously known destination is needed, the prior hop-wise distance is used to optimize the search. This enables computing the TTL value used in the RREQ packets dynamically, by taking into consideration the temporal locality of routes.

C. Dynamic On-Demand MANET Routing Protocol (DYMO)

The Dynamic MANET On-demand (DYMO) routing protocol enables reactive, multihop unicast routing between participating DYMO routers. The basic operations of the DYMO protocol are route discovery and route maintenance. During route discovery, the originator's DYMO router initiates dissemination of a Route Request (RREQ) throughout the network to find a route to the target's DYMO router. During this hop-by-hop dissemination process, each intermediate DYMO router records a route to the originator. When the target's DYMO router receives the RREQ, it responds with a Route Reply (RREP) sent hop-by-hop toward the originator. Each intermediate DYMO router that receives the RREP creates a route to the target, and then the RREP is unicast hop-by-hop toward the originator. When the originator's DYMO router receives the RREP, routes have then been established between the originating DYMO router and the target DYMO router in both directions. Route maintenance consists of two operations. In order to preserve routes in use, DYMO routers extend route lifetimes upon successfully forwarding a packet. In order to react to changes in the network topology, DYMO routers monitor links over which traffic is flowing. When a data packet is received for forwarding and a route for the destination is not known or the route is broken, then the DYMO router of source of the packet is notified. A Route Error (RERR) is sent toward the packet source to indicate the current route to a particular destination is invalid or missing. When the source's DYMO router receives the RERR, it deletes the route. If the source's DYMO router later receives a packet for forwarding to the same destination, it will need to perform route discovery again for that destination. DYMO uses sequence numbers to ensure loop freedom. Sequence numbers enable DYMO routers to determine the order of DYMO route discovery messages, thereby avoiding use of stale routing information.

DYMO retains proven mechanisms of previously explored routing protocols like the use of sequence numbers to enforce loop freedom. At the same time, DYMO provides enhanced features, such as covering possible MANET–Internet gateway scenarios and implementing path accumulation as depicted in Figure 1.
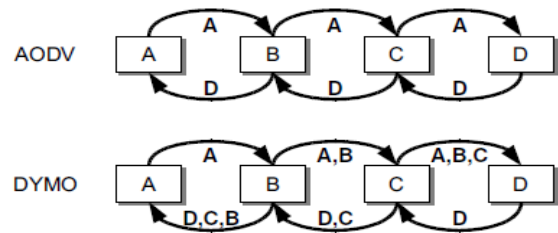

Figure 1: Routing Information Dissemination in AODV and DYMO

Besides route information about a requested target, a node will also receive information about all intermediate nodes of a newly discovered path. Therein lies a major difference between DYMO and AODV, the latter of which only generates route table entries for the destination node and the next hop, while DYMO stores routes for each intermediate hop. This is illustrated in Figure 1. When using AODV, node A knows only the routes to nodes B and D after its route request is satisfied. In DYMO, the node additionally learned a route to node C.

D. Performance metrics

The following metrics are used to evaluate the performance of AODV and DYMO:
- *Total throughput*: the amount of data transmitted through the network per unit time.
- *Relative routing overhead*: the ratio of the number of routing control packets over the sum of the number of delivered data packets and the routing control packets.
- *Average packet size of routing packets*: the average packet size of the RREQ and RREP routing packet.

E. Simulation results

Fig. 2 shows the effect of the node mobility on the relative routing overhead when increasing the mobility of the nodes. This figure shows that the relative routing overhead of DYMO is certainly lower than that of AODV, due to the path accumulation function that reduced the number of RREQ messages.

Fig. 3 compares the average packet size of the routing packets with AODV and DYMO when increasing the number of nodes in the network. To investigate how the path accumulation function of DYMO affects the control packet size for route discovery, a random network topology is used while varying the number of nodes from 30 nodes to 70 nodes and keeping all the nodes stationary. All the other simulation parameters are the same as mentioned above. Fig. 2 shows that, as the number of nodes increases, the size of routing packets with AODV are constant and lower than that of DYMO. Plus, as the number of nodes increases, the average packet size of the routing packets with DYMO increases due to the path accumulation function.
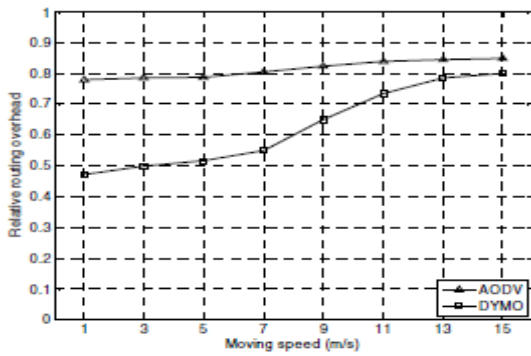
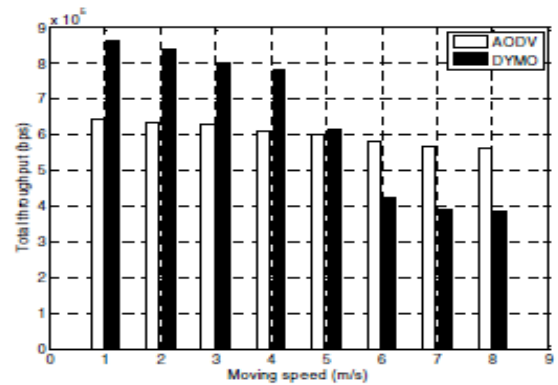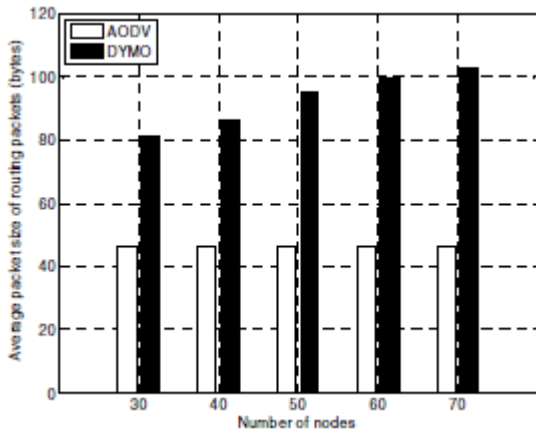Fig.2:- Comparison of relative routing overhead

Fig.3:- Comparison of average packet size of routing packets

Fig.4:- Comparison of total throughput

Fig. 4 shows the total throughput of AODV and DYMO when increasing the mobility of the nodes. This figure shows that, as the moving speed of the nodes increases, the total throughput of the two routing protocols is reduced. Plus, even though DYMO achieves a relative reduction in the routing overhead, at a higher mobility (moving speed > 9m/s), the total throughput of DYMO is lower than that of AODV. The reason for this is that wrong route information from the intermediate routers with DYMO due to frequent topology changes causes more route failure than with AODV.

III. CONCLUSION

This paper briefly described the key features of the AODV, DSR and DYMO routing protocols. AODV could achieve a higher throughput than DYMO.Performance of each routing protocol has been analyzed. Plus, at moving speeds, the total throughput of DYMO could outperform that of AODV.

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