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Performance Comparison of MANET Routing Protocols

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ABSTRACT
Since the emergence in 1970's Wireless networks have become increasingly popular in computing industry. These networks provide mobile users with computing capability and information access regardless of the location. An Ad-Hoc Network is a collection of wireless mobile hosts, forming a network without the aid of any established infrastructure or centralized administration. Due to limited transmission range of wireless mobile hosts,, multiple network hops may be needed for one node to exchange data with another across the network. The key feature of Mobile Ad-Hoc Networks (MANETs) that distinguish them from ordinary infrastructured networks are Dynamic Topology, Bandwidth Constraints, Variable Capacity Links, Energy Constrained operations and Limited Physical Security. The infrastructure-less networks having no fixed routers, are known as Mobile Ad-Hoc Networks (MANETs). All nodes are capable of movement and can be connected dynamically in arbitrary manner. This entire network is mobile so responsibilities for organizing and controlling the network are distributed among the terminals themselves. In this type of networks some pairs of terminals may not be able to communicate directly with each other & relaying of some messages is required towards destination.
DSDV (Destination Sequenced Distance Vector) Routing protocol is a logical extension of Distance Vector Routing algorithm. DSDV is a Hop-by-Hop distance vector routing protocol requiring each node to periodically broadcast routing updates. The key advantage of DSDV is that it guarantees loop freedom. DSR (Dynamic Source Routing) uses source routing rather than hop-by-hop. The key advantage of DSR is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward, since the packets themselves, already contain all the routing decisions. The AODV (Ad-Hoc On Demand Distance Vector) Routing Protocol is essentially a combination of both DSR and DSDV Routing protocols. It borrows the basic On-Demand mechanism of Route Discovery and Maintenance from DSR, plus the use of hop-by-hop routing, sequence number & periodic beacons from DSDV.

KEYWORDS
Ad-Hoc Networks, Dynamic topology,Routing protocol, Destination Sequenced Distance Vector, Dynamic Source Routing, On-Demand Routing, Multipath Routing, Scalability.

1. INTRODUCTION

With recent performance advancements in computer and wireless communication technologies, advanced mobile wireless computing is expected to see increasingly widespread application, much of which will involve the use of Internet Protocol (IP) suite. The infrastructured networks, also known as Cellular Networks [1,2], have fixed and wired gateways. They have fixed base stations, which are connected to other base stations through wires. The transmission range of a base station constitutes a cell. All mobile nodes lying within this cell connect to and communicate with the nearest base station. A "hand off" [12] occurs as mobile hosts travels out of range of one base station and into the range of another . Thus the mobile host is able to continue communication throughout the network. The infrastructure-less networks are known as Mobile-Ad-Hoc networks (MANETs) [1,3]. The networks have no fixed routers. All nodes are capable of movement & can be connected dynamically. The responsibilities of organizing and controlling the network are distributed among the terminal themselves. Some pairs of terminals may not be able to communicate directly with each other & relaying of some messages is required, so that they are delivered to their destinations. The nodes of these networks function as routers to other nodes in the network. Since there is no fixed infrastructure, a wireless Ad-Hoc network can be deployed quickly.

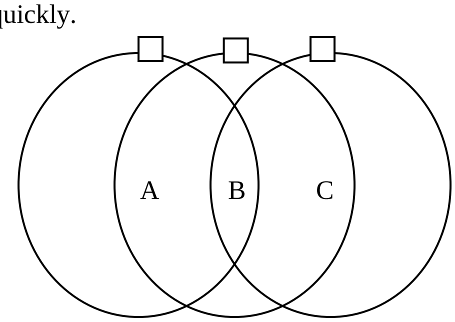

Figure 1.1 A simple Ad-Hoc Network.

Figure 1.1 shows a simple Ad-Hoc network in which mobile A wants to send a packet to mobile C, but C is out of range, so mobile B relays A's packet to mobile C. Indeed the routing problem in a real ad-hoc network may be more complicated than this example suggests due to inherent non-uniform propagation characteristics of wireless transmission & due to the possibility that any or all of the hosts involved may move at any time.

The remaining section of this paper is organized as follows: Section 2, routing protocols, three routing protocols DSDV[4,11], DSR[9], & AODV[10] are discussed in details. Section 3, presents comparison of these three MANET routing protocols. Section 4, describes our plans for future work and finally Section 5 concludes the paper.

2. ROUTING PROTOCOLS IN MANETS

Within the Internet community routing support of mobile hosts is presently being formulated as "Mobile IP" [1]. Mobile IP supports roaming, where a roamer may be connected to Internet other than its fixed, well-known address domain space. Here, it requires to have multi-hop [3] before a packet reaches its destination, a routing protocol is needed. The routing protocol has two main functions: -

To make a table of source-destination pairs[2,11] with some additional information and deliver the packet to their correct destination. These functions can be performed with two conventional techniques ie. Source routing & flooding. Source routing [11] means that each packet must carry the complete path that the packet should take through the network. Therefore the routing decision is made at the source. Flooding [1,2] is the widely used form of broadcasting, which is used by many routing protocols to distribute control information ie. Send the control information from an origin node to all other nodes.

All the protocols of MANET at node-to-node level have to use broadcast. Source routing also involves broadcasting while path learning.

2.1 DESTINATION-SEQUENCED DISTANCE VECTOR (DSDV) ROUTING

DSDV [4,11] is a logical extension of Distance Vector Routing, suitable for MANETs. The primary concern for using Distance Vector algorithm in the ad-hoc environment is its susceptibility towards forming routing loops. Hence, to provide loop- free path, a scheme is required all time without requiring nodes to participate in any complex update. Each node maintains a routing table, having entries consists of the following:

- Destination Address
- Number of hops required to reach the destination.
- Sequence number as stamped by the destination.
- Next hop.

The key advantage of DSDV over traditional distance vector protocols is that it guarantees loop freedom. DSDV tags each route with a sequence number and consider a route with R more favorable than R', if R has a greater sequence number, Or if two routes have equal sequence number but R has a lower metric. When a node B decides that its route to a destination D has broken, it advertises the route to D with an infinite metric and a sequence number one greater than its sequence number for the route has broken (making an odd sequence number). This causes any node A routing packets through B to incorporate the infinite – metric route into its routing table until node hears a route to D with a higher sequence number.

Loop- Free Property:- This protocol is loop -free, potentially a loop may form each time a node I changes its next hop. This can happen in two cases: -

- Node I detects that the link to its next hop is broken (this action cannot form a loop involving I).
- Node I receives from one of its neighbors k, a route to D, with a sequence number S(K) such that S(K) > S(I) (where S(I) is sequence number for the destination D as originally stored in node I).

A node I propagate sequence number S(I) to its neighbors only after receiving it from it current next hop. The next hop chosen by node I will only provide the information of destination to it. So, at all times the sequence number value stored at the next hop is always greater or equal to the value stored at i. Suppose, node A forms a loop by choosing K as its next hop, this implies I lies both before and after k. Since it lies after K, thus , S(K) <= S(I), but this contradicts the initial assumption that S(K)>S(I). Hence loop formation cannot occur if nodes use newer sequence number to choose routes.

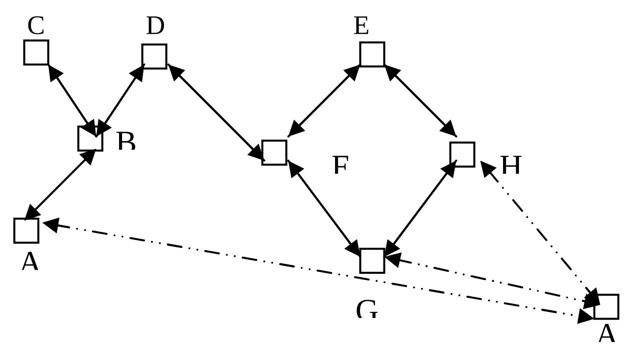

Fig 2: Movement of node in MANET.

Fig 2 shows a MANET, in which node A is in neighborhood of B, which is in neighborhood of D and so on. The routing table for node D is maintained in table 1. All sequence number are denoted by SNi, specifies the mobile node which created the sequence number. Now suppose that A moves closer to G &H and away from B. Then new table is required as appear in table 2. Only the next hop entry is changes for A, as it moved away. The sequence number field changes due to periodic updates propagated in the network.

Destination	Next Hop	Metric (No. of hops)	Seq_no
A	B	2	S043_A
B	B	1	S062_B
C	B	2	S053_C
D	D	0	S069_D
E	F	2	S045_E

F	F	1	S048_F
G	F	2	S054_G
H	F	3	S058_H

Table 1: Routing table for D (Before Move)

Destination	Next Hop	Metric (no. of hop)	Seq_no
A	F	3	S056_A
B	B	1	S062_B
C	B	2	S053_C
D	D	0	S069_D
E	F	2	S045_E
F	F	1	S048_F
G	F	2	S054_G
H	F	3	S058_H

Table 2: Routing table for D (After Move)

DSDV is effective for creating ad-hoc network for small populations of mobile nodes, but the approach depends for its correct operation on the periodic advertisement and global dissemination of connectivity information.

2.2 DYNAMIC SOURCE ROUTING (DSR)

DSR uses source routing rather than hop-by-hop routing, with each packet to be routed carrying in its header the complete, ordered list of nodes through which the packet must pass. The key advantage of source routing is that intermediated nodes donot need to maintain up-to-date routing information in order to route the packets they forward, since the packets themselves already contain all the routing decisions. The DSR protocol consists of two mechanisms: *Route discovery and Route maintenance*.

Route Discovery: Route discovery is the mechanism by which a node wish to send a packet to the destination, obtains a source route to the destination. Route discovery packets are initiated if a mobile node wants to send a packet to another node, which is not in the cache (Routing table). Sender (S) first checks the route cache, if Destination (D) is not found, it runs the route discovery function and initiates Route Request Packets (RRP). A RRP is broadcasted containing four fields: Source address, Destination address, Request id specifier to the mobile and A Route Record List (RRL) that holds the path that the packet passes through. When the RRP is received by a mobile, it first checks if the source and request id pairs had been seen before. If yes it discard the packet. If its mobile number exists in the RRL, it also discards the packet. If the destination is the node itself, it copies the route record list to the route replier packet reversibly and sends it to source. If none of the above condition hold, all the packets, except for the ones from which it received are broadcasted.

A node receiving the request records its own address. If the request does not look familiar and the address does not exists in RRP, a modified packet is broadcasted to the neighbors. A node receiving the request may know how to complete the route using a local route cache. The destination node returns the reply packet to the sender using the recorded path.

Route Maintenance: DSR uses two types of packets for route maintenance: Route Error Packet (REP) and Acknowledgement (ACK). If the next hop is not in the range of a mobile node, then the source receives an REP. The sender then eliminates the unavailable link from all the route entries of the cache. Other nodes on the route can use this information to update the route caches. S then initiates a new route discovery. ACK packets are used to verify the correct operation of the routes.

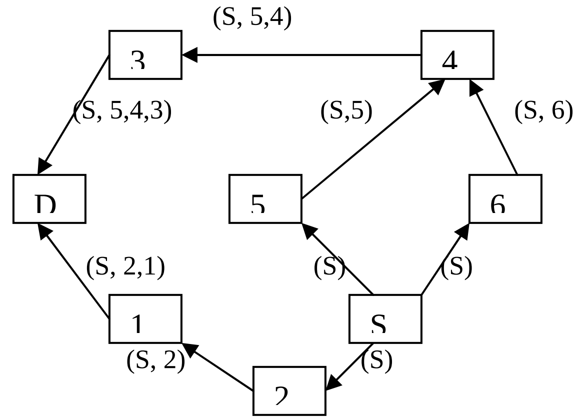

Figure 2.2(a): Building Route Record in DSR

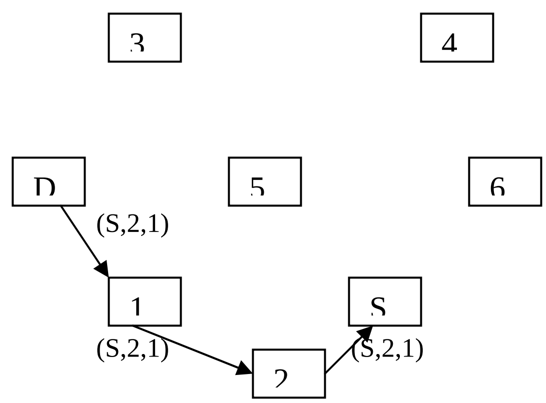

Figure 2.2(b): Route Reply Propagation

Figure 2.2(a) shows the propagation of route request from S to D. The paths learned by the packets at the intermediate nodes are also shown. Figure 2.2(b) shows the path followed by route reply packet. At the intermediate nodes the route record list is shown.

2.3 AD-HOC ON DEMAND DISTANCE VECTOR ROUTING (AODV)

The AODV is essentially the combination of both DSR and DSDV. It borrows the basic on demand mechanism of Route Discovery and Route Maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers and periodic beacons from DSDV.

When a source S needs a route to some destination D, it broadcasts a route request message to its neighbors, including the last known sequence number for that destination. The route request is flooded in a control manner through the network until it reaches a node that has a route to the destination. Each node that forwards the route request creates a **reverse route** for itself back to node S. When the route request reaches a node with a route to D, that node generates a route reply that contains the number of hops necessary to reach D and the sequence number for D most recently seen by the node generating the reply. Each node that participate in forwarding this reply back towards the originator of the route request i.e S, creates a **forward route** to D. The state created in each node along the path from S to D is hop-by-hop state, i.e each node remembers only the next hop and not the entire route.

Inorder to maintain route, AODV normally requires that each node periodically transmit a HELLO message, with a rate of 1/sec. Failure to receive three consecutive HELLO messages from a neighbor is taken as an indication that the link to the neighbor is down. Alternatively the AODV specification suggest that a node may use physical layer to detect link breakages to nodes that it considers neighbors[ ]. When a link goes down, any upstream node that has recently forwarded packets to a destination using that link is notified via unsolicited route reply containing an infinite metric for that destination. While receiving of such a route reply, a node must acquire a new route to the destination using the route discovery.

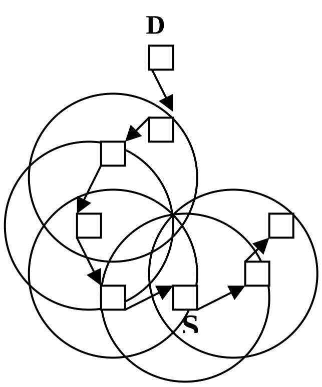

Figure 2.3 (a): Formation of reverse pointers

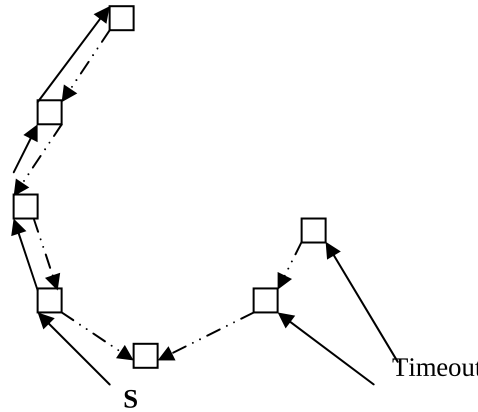

Figure 2.3 (b): Formation of forward pointers

Figure 2.3(a) shows the process in the formation of reverse pointers when the route requests are in propagation. In figure 2.3(b) the formation of forward pointer is shown with the help of reverse pointers and the process initiates from the destination.

3 QUANTITATIVE COMPARISON OF MANET ROUTING PROTOCOLS

Key characteristics of the three protocols [ ] are summarized in table 3. Here N is the number of nodes in the network and e is the number of communication link pairs.

Property	AODV	DSR	DSDV
Routing Philosophy	Reactive	Reactive	Proactive
Routing Metrics	Shortest Path	Shortest Path	Not Necessarily shortest path
Frequency of Updates	As Needed	As Needed	Periodic
Nature of Protocol	Distributed	Distributed	Distributed
Use Sequence Number	Yes	No	Yes
Multiple Path	No	Yes	No
Storage Complexity	O(e)	O(e)	O(N)

Table 3:Quantitative comparison of MANET Routing Protocol

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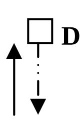

4 SUGGESTIONS FOR FUTURE WORK

In the following points we give a few improvements that could be made to the simulation developed:

- Other routing protocol such as OLSR (Optimized Linked State Routing), CBRP (Cluster Based Routing Protocol) etc can be simulated by defining new Event types.
- Here only four metrics for the performance evaluation are considered. However the model can also be extended to find performance of the protocols based on other metrics such as transmission delay, computing complexity and power consumption.

5 CONCLUSIONS

5.1 RESULT FOR PACKET DELIVERY RATIO

At lower node movements speeds, all three protocol deliver above 99% of the transmitted packet. At higher speeds, DSDV performs poor on the other hand AODV consistently outperforms DSR too.

5.2 RESULT FOR ROUTING OVERHEAD

DSR and AODV are both on-demand protocol hence give almost identical results. However, the absolute overhead required by AODV is about 1.5 times that required by DSR. DSDV has approximately constant overhead, regardless of movement rate or offered traffic load. This constant behavior is there because each node broadcast a periodic update with a new sequence number.

5.3 RESULT FOR PATH OPTIMALITY

As this simulation model internally uses Dijkstra's algorithm [ ] to find the shortest path between a pair of nodes at any instant of time. Both DSDV and DSR use roots very close to optimal, whereas AODV has a significant tail. This is because DSDV is a periodic protocol, so it keeps on refreshing the routing entries and thus the shortest path are discovered.

5.4 RESULT FOR SCALABILITY OF PROTOCOLS

DSDV in particular does not scale well , whereas DSR and AODV perform well at higher number of nodes in the network. The use of periodic updates, limits the DSDV protocol for small network. The main reason for its poor performance for a large network is that every node has only the information about the neighbouring node , so updates must propagate from one end to another, inorder to reflect changes in the topology. This takes time in large sized networks.

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