Destination Sequenced – Distance Vector Algorithm

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Abstract

Mobile Ad Hoc Network (MANET) is an infrastructure where nodes communicate without any central administration. Nodes are connected through wireless channels and can use multiple hops to exchange data. Routing protocols are needed for communication in such networks. Each node acts both as a router and host concurrently, which can move out or join the network freely. The instantly created network does not have any base infrastructure as used in conventional networks, but it is compatible with conventional networks. This paper discusses about the Destination – Sequenced Distance Vector (DSDV) which is a modification of the conventional Bellman-Ford routing algorithm. It addresses the drawbacks related to the poor looping properties of Routing Information Protocol (RIP) in the face of broken links. The modification adapted in DSDV makes it more suitable routing protocol for MANETs. This paper discusses about the DSDV protocol and analyses the properties of DSDV when it is used for MANET routing.

Keywords- Bellman – Ford; DSDV; MANET; RIP.

I. INTRODUCTION

A Mobile ad hoc network is an autonomous system of mobile routers connected by wireless links. The routers are free to move randomly and organize themselves arbitrarily, thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a stand – alone fashion or may be connected to the larger internet. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each device must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to internet. They may contain one or multiple and different transceivers between nodes. This results in a highly dynamic, autonomous topology.

In proactive routing protocol, every node maintains routing information to every other node in the network. The routing information is usually kept in a number of different tables. These tables are periodically updated. The difference between these protocols exists in the way the routing information is updated, detected and the type of information kept at each routing table. Proactive protocols are not suitable for large networks as they need to maintain node entries for each and every node in the routing table of every node. These protocols maintain different number of routing tables varying from protocol to protocol. There are various well known proactive routing protocols, example: DSDV, OLSR, WRP, etc.

Ad Hoc networks differ significantly from conventional networks in dynamic topology of interconnections and automatic administration for setting up the network. From a graph theory point of view, an ad hoc network is a graph G(N, E(t)), which composes of a set of nodes N and a set of edges E(t). Each mobile host can be a node of the graph. Each edge of the set E(t) is formed by two nodes within the service range, it can be unidirectional or bi-directional. E(t) changes with time as the mobile nodes in the ad hoc network freely move around. The topology of the ad hoc network can be arbitrary at any time. With the change of topology of an ad hoc network, the nodes in the network have to update their routing information immediately.

Routing protocols in packet-switched networks traditionally use either distance vector or link-state routing algorithm. Both algorithms allow a host to find the next hop to reach the destination through shortest path. The metric of the shortest path may be the number of hops, time delay in milliseconds, total number of packets queued along the path, etc. Such shortest path protocols have been used in dynamic packet switched networks successfully. The main drawback of both link – state and distance vector protocol are that they take too long to converge and have a high message complexity. Because of the limited bandwidth of wireless links in ad hoc network, message complexity must be kept low and because of the rapidly changing topology, new routing protocols have to be developed to fulfill the basic philosophy.

II. DSDV PROTOCOL

DSDV belongs to the Proactive type of routing protocols. In this protocol, each mobile node in the network keeps a routing table listing all other nodes it has known either directly or through some neighbors. Every node has a single entry in the routing table. The entry will have information about the node's IP address, last known sequence number and the hop count to reach that node. Along with these details, the table also keeps track of the next hop neighbor to reach the destination node.

DSDV routing is adapted from the conventional Routing Information Protocol (RIP) to ad hoc networks routing. It adds a new attribute, sequence number, to each route table entry of the conventional RIP. Using the newly added sequence number, the mobile nodes can distinguish state route information from the new and thus prevent the formation of routing loops. The main contribution of the algorithm was to solve the routing loop problem.

A. Managing Routing of Packets and Routing Table

In DSDV, each mobile node of an ad hoc network maintains a routing table, which lists all available destinations, the metric and next hop to each destination and a sequence number generated by the destination node. Using such routing table stored in each mobile node, the packets are transmitted between the nodes of an ad hoc network. Each node of the ad hoc network updates the routing table with advertisement periodically or when significant new information is available to maintain the consistency of the routing table with dynamically changing topology of the ad hoc network.

When the network topology changes are detected, each mobile node advertises the routing information using broadcasting or multicasting a routing table to update a packet. The update packet starts out with a metric of one to direct connected nodes. This indicates that each receiving neighbor is one hop away from the node. It is different from that of the conventional routing algorithms. After receiving the update packet, the neighbors update their routing table with incrementing the metric by one and retransmit the update packet to the corresponding neighbors of each of them. The process will be repeated until all the nodes in the ad hoc network have received a copy of the update packet with a corresponding metric. The update data is also kept for a while to wait for the arrival of the best route for each particular destination node in each node before updating its routing table and retransmitting the update packet.

If a node receives multiple update packets for a same destination during the waiting time period, the routes with more recent sequence numbers are always preferred as the basis for packet forwarding decisions, but the routing information is not necessarily advertised immediately, if only the sequence numbers have been changed. If the update packets have the same sequence number with the same node, the update packet with the smallest metric will be used and the existing route will be discarded or stored as a less preferable route. In this case, the update packet will be propagated with the sequence number to all mobile nodes in the ad hoc network. The advertisements of routes that are about to change may be delayed until the best routes have been found. Delaying the advertisement of possibly unstable route can damp the fluctuations of the routing table and reduce the number of rebroadcasts of possible route entries that arrive with the same sequence number. The elements in the routing table of each mobile node change dynamically to keep consistency with dynamically changing topology of an ad hoc network. To reach this consistency, the routing information advertisement must be frequent or quick enough to ensure that each mobile node can almost always locate all the other mobile nodes in the dynamic ad hoc network. Upon the updated routing information, each node has to relay data packet to other nodes upon request in the dynamically created ad hoc network.

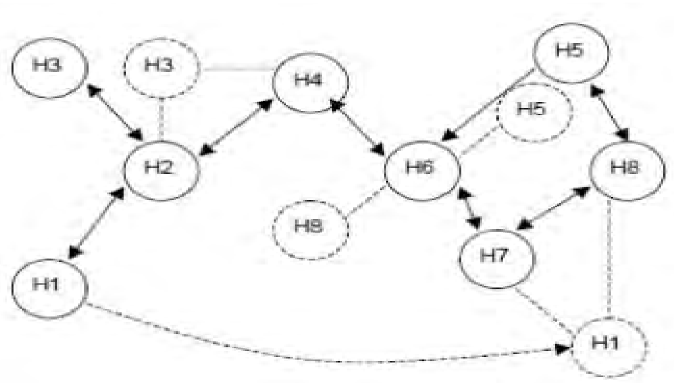


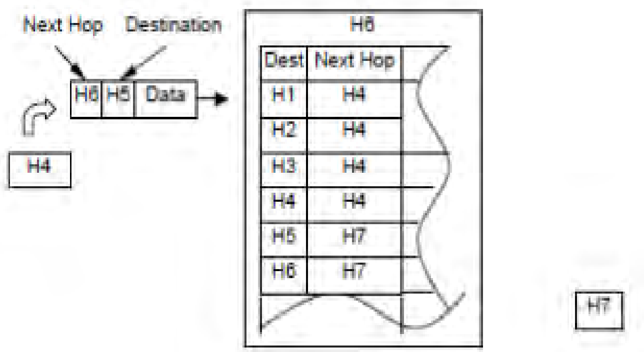
Figure 1: An example of Mobile Ad Hoc Networks

Figure 1 shows an example of a mobile ad hoc network before and after the movement of the mobile nodes. Table 1 is the routing table of the node H6 at the moment before the movement of the nodes. The install time field in the routing table helps to determine when to delete state routes.

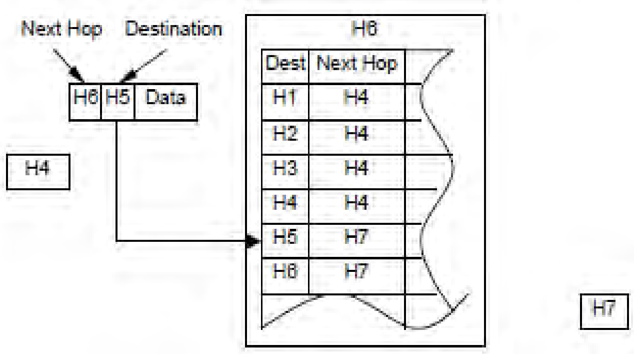
Table 1: The routing table of node H6 at an instance

Dest	Next Hop	Metric	Seq.No.	Install
H1	H4	3	S406_H1	T001_H6
H2	H4	2	S128_H2	T001_H6
H3	H4	3	S564_H3	T001_H6
H4	H4	1	S710_H4	T002_H6
H5	H7	3	S392_H5	T001_H6
H6	H6	0	S076_H6	T001_H6
H7	H7	1	S128_H7	T002_H6
H8	H7	2	S050_H8	T002_H6

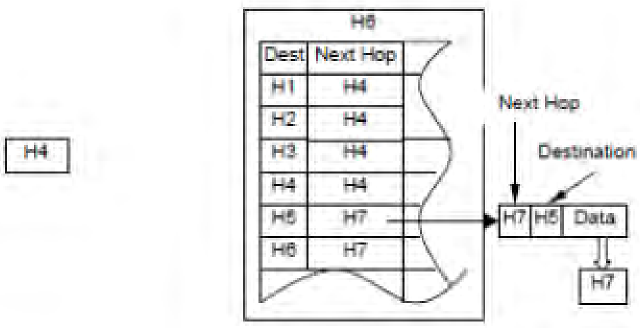
Figure 2 shows an example of packet routing procedure in DSDV. Node H4 wants to send a packet to the node H5 as shown in Figure 1. The node H4 checks its routing table and locates the next node for routing the packet as H6. Then H4 sends the packet to H6 as shown in Figure 2a. Node H6 looks up the next hop for the destination node H5 in its routing table when it receives the packet as in Figure 2b. Node H6 then forwards the packet to the next hop H7 as specified in the routing table as shown in Figure 2c. The routing procedure repeated along the path until the packet finally arrives at its destination H5.



a) Node H4 transmits a packet to node H6 for forwarding



b) Node H6 looks up the destination and route for forwarding the packet in its routing table



c) Node H6 forwards the packet to the next hop

Figure 2: DSDV Packet Routing Example

In the routing information updating process, the original node tags each update packet with a sequence number to distinguish state updates from the new one. The sequence number is monotonically increasing number that uniquely identifies each update from a given node. As a result, if a node receives an update from another node, the sequence number must be equal to or greater than the sequence number of the corresponding node already in the routing table, or else the newly received routing information in the update packet is state and should be discarded. If the sequence number of one node in the newly received routing information update packet is same as the corresponding sequence number in the routing table, then the metric will be compared and the route with the smallest metric will be used.

Destination	Next Hop	Metric	Sequence Number
H7	H7	0	S238_H7
H1	H1	1	S516_H1
H2	H6	3	S228_H2
H3	H4	4	S764_H3
H4	H6	2	S820_H2
H5	H6	2	S502_H5
H6	H6	1	S204_H6
H8	H7	1	S148_H8

a) H7 advertised table (update packet)

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Dest	Next Hop	Metric	Seq.No.	Install
H1	H4	3	S406_H1	T001_H6
H2	H4	2	S238_H2	T001_H6
H3	H4	2	S764_H3	T001_H6
H4	H4	1	S820_H4	T002_H6
H5	H5	1	S502_H5	T812_H6
H6	H6	0	S204_H6	T001_H6
H7	H7	1	S238_H7	T002_H6
H8	H6	1	S160_H8	T811_H6

b) H6 Routing Table

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Dest	Next Hop	Metric	Seq.No.	Install
H1	H7	2	S516_H1	T810_H6
H2	H4	2	S238_H2	T001_H6
H3	H4	2	S764_H3	T001_H6
H4	H4	1	S820_H4	T002_H6
H5	H5	1	S502_H5	T812_H6
H6	H6	0	S204_H6	T001_H6
H7	H7	1	S238_H7	T002_H6
H8	H6	1	S160_H8	T811_H6

Figure 3: An example of updating route information

In addition to the sequence number and the metric for each entry of the update packet, the update route information contains also both the address of the final destination and the address of the next hop. There are two types of update packets, one is the full dump which carries all of the available routing information. The other is called incremental, which carries all of the routing information changed since the last full dump.

Figure 3 shows an example that a node handles an incremental update packet. It indicates that the node H7 in the figure 1 advertises its routing information with broadcasting the update packet to its neighbors. When the node H6 receives the update packet, it will check the routing information of each item contained in both the update packet and its routing table and update the routing table. The entries with higher sequence numbers are always entered into the routing table, regardless of whether each of them has a higher metric or not. In the Figure3a, the entry H1 has newer sequence number – S516H1 in the packet. This sequence number is entered into the updated routing table in Figure 3c after the routing update. If an entry has the same sequence number, the route with smaller metric is entered into the routing table. In Figure 3a, the entry H5 has the same sequence number – S502_H5 in both the update packets and in the current routing table in Figure 3b, it has a lower metric, so it enters the updated routing table in Figure 3c. The items with old sequence numbers in the update packet are always ignored. In Figure 3a, H2 and H8 have old sequence number respectively in the update packet, both of them are ignored in the updated routing table in Figure 3c.

Each node in the ad hoc network must periodically transmit its entire routing table to its neighbors, most likely using multiple Network Protocol Data Units (NPDUs). The full dumps (transmitting the entire routing table) of the nodes can be transmitted relatively infrequently when little movement of mobile nodes is occurring. Incremental update packets are transmitted between the full dumps for partial changes of the routing table such as receiving new sequence numbers and fewer significant route changes as in Figure 3a. The incremental routing update should be fitted in one NPDU. The mobile nodes are expected to determine the significance of the routing information changes to be sent out with each incremental advertisement. As shown in Figure 3a, the significant route change of H1 has to be included first, then others with sequence number changes. When the significant changes increase with frequent changes of the network topology and the size of an incremental approach will be the maximum size of a NPDU, a full dump is scheduled to make the next increment become smaller.

B. Responding to Topology Changes

Links can be broken when the mobile nodes move from one place to another or has been shut down etc. The broken link may be detected by the communication hardware or be inferred if no broadcasts have been received for a while from a former neighbor. The metric of a broken link is assigned to infinity. When a link to next hop has broken, any route through that next hop is immediately assigned an infinity metric and an updated sequence number. Because link broken qualifies as a significant route change, the detecting node will immediately broadcast an update packet and disclose the modified routes.

Destination	Next Hop	Metric	Sequence Number
H7	H7	0	S238_H7
H1	H1	∞	S517_H1
H2	H6	3	S228_H2
H3	H4	4	S764_H3
H4	H6	2	S820_H2
H5	H8	2	S502_H5
H6	H6	1	S204_H6
H8	H7	1	S148_H8

a) H7 advertised table (update packet)

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Dest	Next Hop	Metric	Seq.No.	Install
H1	H4	3	S516_H1	T001_H6
H2	H4	2	S238_H2	T001_H6
H3	H4	2	S764_H3	T001_H6
H4	H4	1	S820_H4	T002_H6
H5	H5	1	S502_H5	T812_H6
H6	H6	0	S204_H6	T001_H6
H7	H7	1	S238_H7	T002_H6
H8	H6	1	S160_H8	T811_H6

b) H6 Routing Table

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Dest	Next Hop	Metric	Seq.No.	Install
H1	H7	∞	S517_H1	T810_H6
H2	H4	2	S238_H2	T001_H6
H3	H4	2	S764_H3	T001_H6
H4	H4	1	S820_H4	T002_H6
H5	H5	1	S502_H5	T812_H6
H6	H6	0	S204_H6	T001_H6
H7	H7	1	S238_H7	T002_H6
H8	H6	1	S160_H8	T811_H6

Figure 4: An example of broken link

To describe the broken links, any mobile node other than the destination node generates a sequence number, which is greater than the last sequence number received from the destination. This newly generated sequence number and a metric of infinity will be packed in an update message and flushed over the network. To avoid conflicting sequence numbers, nodes and their neighbor nodes generating conflicting sequence numbers for themselves, and neighbors only generate odd sequence numbers for the nodes responding to the link changes.

The following figure illustrates an example of broken link. Let's assume the link between the node H1 and H7 is broken in figure 1. Node H7 detects the link broken and broadcasts an update packet (Figure 4a) to node H6. Node H6 updates its routing table with the newly received routing information (odd sequence number – S517_H1 and ∞ metric) of entry H1 (Figure 4c). It means that the link to node H1 is broken. If node H6 sends route update information to node H1 with the even sequence number generated by node H1 previously which is smaller than the current sequence number – S517_H1 in Figure 4c, it knows that the route information is stale, thus preventing routing loop. If other nodes generate a newer odd sequence number with infinity metric for node H1 and it is sent to node H6, which knows that the link to node H1 is broken through the odd sequence number and infinity metric.

The routes to a lost node will be re – established when the lost node comes back to the network and broadcasts its next update message with an equal or later sequence number and a finite metric. The update message will be disseminated over the whole network to indicate that the broken links have come back into service again. In any case, the entry containing a finite metric and an equal or later sequence number will supersede the corresponding entry with a metric infinity in the routing table of a node. DSDV also contains substantially more procedures for handling layer 2 and layer 3 routing and for dealing with the extension of base station coverage.

III. PROBLEMS OF DSDV

The main purpose of DSDV is to address the looping problem of the conventional distance vector routing protocol and to make the distance vector routing more suitable for ad hoc networks routing. However, DSDV has route fluctuation because of its criteria of route updates. At the same time, DSDV does not solve the common problem of all distance vector routing protocols like the unidirectional problem.

A. Damping Fluctuation

Fluctuation is a general problem arising in DSDV by the following criteria of routing update:

- Routes are always preferred when the sequence numbers are newer and the routes with older sequence number are discarded.
- A route with a sequence number equal to that of an existing route is preferred if it has a better metric and the existing route is discarded or stored as less preferable.

The broadcasts of routing information by mobile nodes are asynchronous events, though some regularity is expected. In the case of many mobile nodes independently transmitting update messages and having marked different transmission intervals, it may turn out that a particular mobile node receives new update packets in a way that causes this mobile node to consistently change route back forth between different next hops, even though no network topology change has taken place. This fluctuation happens because of the above two route selection criteria. Conceivably, a mobile node can always receive two routes with equal sequence numbers or with a newer sequence number one after the other through different neighbors to the same destination, but the mobile node always gets the route with the worst metric first. This situation leads to the fluctuation with a continuing burst of new update packets. This can happen when there are many mobile nodes, all transmitting their updates irregularly. Alternatively, if the mobile nodes are acting independently and with different transmission intervals, the situation can occur with fewer mobile nodes.

Suppose in the case of Figure 5, there are enough mobile nodes to cause the fluctuation problem. Two separate collections of mobile node connect to a common destination H8 but with no other mobile nodes in common. Let's assume that all mobile nodes are transmitting updates every 15 seconds, that mobile node H5 has a route to H8 with 20 hops and the mobile node H7 has a route to H8 with 19 hops, but that routing information update from H5 arrives at H6 about 8 seconds before the routing information update from H7 to H6. This might happen every time when a new sequence number is issued from the mobile node H8. Thus the routing information in H6 for H8 is fluctuated back and forth for every newly issued sequence number of H8.

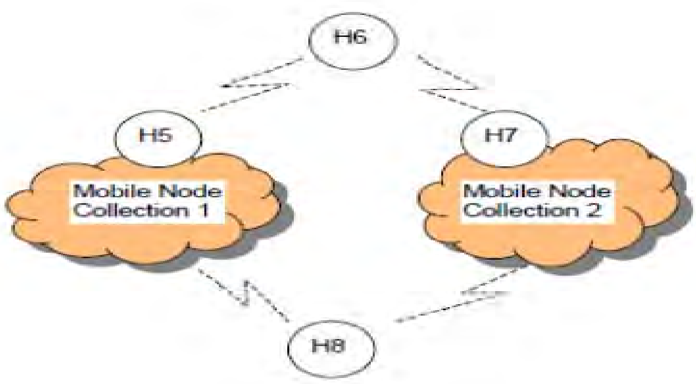

Figure 5: Receiving Fluctuating Routes

For solving this problem, DSDV requires that a mobile node receives a new update message. The route with the later sequence number must be available for the mobile node forwarding decisions, but it does not have to advertise immediately unless the route is unreachable to its previous destination. The mobile node has to first consult its route settling time table as illustrated in Table 2 to decide the length of time to wait for a route with a better metric before advertising the update message. It requires that each node has 2 routing tables, 1 for forwarding packets and the other for advertising the incremental routing information packets. The settling time is stored in the latter with fields, destination address, last settling time and average settling time. It is calculated by maintaining a running weighted average over the most recent updates of the routes for each destination. The average settling time is used to determine the delay of an update advertisement.

Table 2: Route settling time table of H6 at one instant

Dest Addr	Last settling time (Sec.)	Average settling time (Sec.)
H1	15	13
H2	13	11
H3	15	13
H4	8	8
H5	8	8
H6	8	8
H7	8	8
H8	12	11

Note: The time values here is only for demonstration, not reality values

The average settling time in Table 2 is calculated with $Average\ settling\ time = \sum x_j T_j / \sum x_j$, where xj is the metric from the current node to node j along the path to a destination. Tj is the last settling time of node j.

Suppose that a new routing information update arrives at H6 and sequence number in the new entry is newer than the sequence number in the currently used entry but has a worse metric. Then H6 must use the new entry in making subsequent forwarding decisions. However, H6 does not have to advertise the new route immediately and can consult its route settling time table to decide how long to wait before broadcasting the update. The average settling time is used to decide the delay (Delay=Average settling time × 2) before advertising a route.

B. Unidirectional Links

DSDV assumes that all wireless links in an ad hoc network are bi-directional. However, this is not true in reality. Wireless media is different from wired media due to its asymmetric connection. Unidirectional links are prevalent in wireless networks.

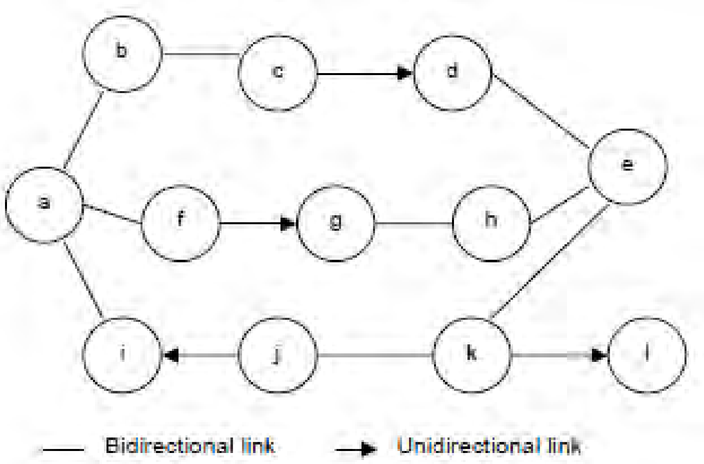

Figure 6: An ad hoc network with unidirectional and bi-directional links

The presence of unidirectional links creates the following problems for DSDV as illustrated in Figure 4.

- *Knowledge Asymmetry*: Over the unidirectional links, the sink nodes know the existence of the source nodes, but the source nodes cannot assume the existence of the sink nodes.
- *Sink Unreachability*: In DSDV, the destination node initiates the path updates. Over a unidirectional link, there might be no way that a sink node can broadcast its existence like the node l in Figure 6.

In fact, these problems are very serious for DSDV in the case of Figure 6. As DSDV can only use bi-directional links for routing packets, it will ignore the links $\overrightarrow{cd}, \overrightarrow{fg}, \overrightarrow{ji}\ and\ \overrightarrow{kl}$. As a result, the network will be perceived as three different parts.

A proposed solution for handling unidirectional links problem requires that each node maintain enough information to distinguish between bi-directional and unidirectional links to its neighbors. Once knowledge of link orientations is available, appropriate routing decisions can be made. However, this proposed approach incurs higher communication and storage overheads of O(n2).

C. Other Drawbacks

It is difficult to determine the maximum setting time. DSDV does not support multi-path routing. The destination central synchronization suffers from latency problem. It has excessive communication overhead due to periodic and triggered updates. Each node must have a complete routing table.

IV. CONCLUSION

DSDV is a well-known routing algorithm proposed for ad hoc network routing, but it has many problems as mentioned in the previous topics. Currently, there are no standard specifications and commercial implementations available yet for DSDV, but one DSDV simulator has been implemented with C++ at UC, Berkley[13]. Research work on improvement of DSDV is still active. Many improved protocols based on DSDV have been developed. These improvements of DSDV include Global State Routing (GSR), Fisheye State Routing (FSR), Ad Hoc On-Demand Distance Vector Routing (AODV), etc. DSDV is a protocol under study which may be substituted with its improvements in real applications in future.

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