Routing Protocols in Mobile Ad-hoc Networks

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Abstract

Wireless mobile ad-hoc networks are characterized as networks without any physical connections. In these networks there is no fixed topology due to the mobility of nodes, interference, mulitpath propagation and path loss. Hence a dynamic routing protocol is needed for these networks to function properly. Many Routing protocols have been developed for accomplishing this task. The purpose of this master thesis is to study, understand, analyze and discuss two mobile ad-hoc routing protocols DSDV and AODV where the first one is a proactive protocol depending on routing tables which are maintained at each node. The other one is a reactive protocol, which find a route to a destination on demand, whenever communication is needed. Considering the bandwidth, throughput and packet loss, in both DSDV and AODV routing protocols, DSDV is best suited for only smaller networks and AODV is suited for general Ad-hoc networks.

Contents

Chapter 1

Introduction

A Network is defined as the group of people or systems or organizations who tend to share their information collectively for their business purpose. In Computer terminology the definition for networks is similar as a group of computers logically connected for the sharing of information or services (like print services, multi-tasking, etc.). Initially Computer networks were started as a necessity for sharing files and printers but later this has moved from that particular job of file and printer sharing to application sharing and business logic sharing. Proceeding further Tenenbaum [27] defines computer networks as a system for communication between computers. These networks may be fixed (cabled, permanent) or temporary.

A network can be characterized as wired or wireless. Wireless can be distinguished from wired as no physical connectivity between nodes are needed.

Routing is an activity or a function that connects a call from origin to destination in telecommunication networks and also play an important role in architecture, design and operation of networks. Chapter 3 deals with more and more details related to routing and its concepts.

Ad-hoc networks are wireless networks where nodes communicate with each other using multi-hop links. There is no stationary infrastructure or base station for communication. Each node itself acts as a router for forwarding and receiving packets to/from other nodes. Routing in ad-networks has been a challenging task ever since the wireless networks came into existence. The major reason for this is the constant change in network topology because of high degree of node mobility. A number of protocols have been developed for accomplish this task. Some of them are DSDV and AODV routing protocols which are explained in the forthcoming chapters.

To summarize, this paper is organized in 9 chapters where Chapter 1 deals with an introduction to Wireless ad-hoc networks. Chapter 2 compare traditional wired and wireless networks. Chapter 3 is about routing. Chapter 4 deals with classification of dynamic routing protocols. Chapter 5 deals with problem with routing in mobile ad-hoc networks and classification of routing protocols in MANET'S. Chapter 6 and Chapter 7 explain briefly about DSDV and AODV routing protocols with their advantages and disadvantages. And finally Chapter 8 is a discussion and conclusion on both the protocols .

1.1 Purpose of this work

Wireless ad-hoc networks have gained a lot of importance in wireless communications. Wireless communication is established by nodes acting as routers and transferring packets from one to another in ad-hoc networks. Routing in these networks is highly complex due to moving nodes and hence many protocols have been developed. This Master thesis concentrate mainly on routing protocols and their functionality in Ad-hoc networks with a discussion being made on two selected protocols DSDV and AODV, ending with their comparison.

Chapter 2

Wired Vs Wireless Networks

The different types of networks available today are Wired and Wireless networks. Wired are differentiated from wireless as being wired from point to point.

2.1 Wired Networks

These networks are generally connected with the help of wires and cables. Generally the cables being used in this type of networks are CAT5 or CAT6 cables. The connection is usually established with the help of physical devices like Switches and Hubs in between to increase the strength of the connection. These networks are usually more efficient, less expensive and much faster than wireless networks. Once the connection is set there is a very little chance of getting disconnected.

2.1.1 Advantages

- A wired network offer connection speeds of 100Mbps to 1000Mbps
- Physical, fixed wired connections are not prone to interference and fluctuations in available bandwidth, which can affect some wireless networking connections.

2.1.2 Disadvantages over wireless networks

- Expensive to maintain the network due to many cables between computer systems and even if a failure in the cables occur then it will be very hard to replace that particular cable as it involved more and more costs.
- When using a laptop which is required to be connected to the network, a wired network will limit the logical reason of purchasing a laptop in the first place.

2.2 Wireless Networks

Wireless networks use some sort of radio frequencies in air to transmit and receive data instead of using some physical cables. The most admiring fact in these networks is that it eliminate the need for laying out expensive cables and maintenance costs.

2.2.1 Advantages of Wireless Networks

- Mobile users are provided with access to real-time information even when they are away from their home or office.
- Setting up a wireless system is easy and fast and it eliminates the need for pulling out the cables through walls and ceilings.
- Network can be extended to places which can not be wired.
- Wireless networks offer more flexibility and adapt easily to changes in the configuration of the network.

2.2.2 Disadvantages of Wireless Networks

- Interference due to weather, other radio frequency devices , or obstructions like walls.
- The total Throughput is affected when multiple connections exists.

2.2.3 Problems in Wireless communications

Some of the problems related to wireless communication are multipath propagation, path loss, interference, and limited frequency spectrum. Multipath Propagation is, when a signal travels from its source to destination, in between there are obstacles which make the signal propagate in paths beyond the direct line of sight due to reflections, refraction and diffraction and scattering. Path loss is the attenuation of the transmitted signal strength as it propagates away from the sender. Path loss can be determined as the ratio between the powers of the transmitted signal to the receiver signal. This is mainly dependent on a number of factors such as radio frequency and the nature of the terrain.It is sometimes important to estimate the path loss in wireless communication networks. Due to the radio frequency and the nature of the terrain are not same everywhere, it is hard to estimate the path loss during communication. During communication a number of signals in the atmosphere may interfere with each other resulting in the destruction of the original signal. Limited Frequency Spectrum is where, frequency bands are shared by many wireless technologies and not by one single wireless technology[14, 13].

Chapter 3

Routing

Routing is the act of moving information from a source to a destination in an internetwork. During this process, at least one intermediate node within the internetwork is encountered. This concept is not new to computer science since routing was used in the networks in early 1970's. But this concept has achieved popularity from the mid-1980's. The major reason for this is because the earlier networks were very simple and homogeneous environments; but, now high end and large scale internetworking has become popular with the latest advancements in the networks and telecommunication technology.

The routing concept basically involves, two activities: firstly, determining optimal routing paths and secondly, transferring the information groups (called packets) through an internetwork. The later concept is called as packet switching which is straight forward, and the path determination could be very complex[4].

Routing protocols use several metrics to calculate the best path for routing the packets to its destination. These metrics are a standard measurement that could be number of hops, which is used by the routing algorithm to determine the optimal path for the packet to its destination. The process of path determination is that, routing algorithms initialize and maintain routing tables, which contain the total route information for the packet. This route information varies from one routing algorithm to another.

Routing tables are filled with a variety of information which is generated by the routing algorithms. Most common entries in the routing table are ip-address prefix and the next hop. Routing table's Destination/next hop associations tell the router that a particular destination can be reached optimally by sending the packet to a router representing the "next hop" on its way to the final destination and ip-address prefix specifies a set of destinations for which the routing entry is valid for.

Switching is relatively simple compared with the path determination. The concept of switching is like, a host determines like it should send some packet to another host. By some means it acquires the routers address and sends the packet addressed specifically to the routers MAC address, with the protocol address of the destination host. The router then examines the protocol address and verifies whether it know how to transfer the data to its destination. If it knows how to transfer the data then it forwards the packet to its destination and if it doesn't then it drops the packet.

Routing is mainly classified into static routing and dynamic routing. Static routing refers to the routing strategy being stated manually or statically, in the router. Static routing maintains a routing table usually written by a networks administrator. The routing table doesn't depend on the state of the network status, i.e., whether the destination is active or not [6]. Dynamic routing refers to the routing strategy that is being learnt by an interior or exterior routing protocol. This routing mainly depends on the state of the network i.e., the routing table is affected by the activeness of the destination.

The major disadvantage with static routing is that if a new router is added or removed in the network then it is the responsibility of the administrator to make the necessary changes in the routing tables. But this is not the case with dynamic routing as each router announces its presence by flooding the information packet in the network so that every router within the network learn about the newly added or removed router and its entries. Similarly this is the same with the network segments in the dynamic routing [3].

Chapter 4

Classification of Dynamic Routing Protocols

Dynamic routing protocols are classified depending on what the routers tell each other and how they use the information to form their routing tables. They are Distance vector protocols and Link state protocols Most of the protocols available in the networks fit into one of the two categories [3].

4.1 Distance Vector Protocols

By using the distance vector protocols, each router over the internetwork send the neighboring routers, the information about destination that it knows how to reach. Moreover to say the routers sends two pieces of information first, the router tells, how far it thinks the destination is and secondly, it tells in what direction (vector) to use to get to the destination. When the router receives the information from the others, it could then develop a table of destination addresses, distances and associated neighboring routers, and from this table then select the shortest route to the destination. Using a distance vector protocol, the router simply forwards the packet to the neighboring host (or destination) with the available shortest path in the routing table and assumes that the receiving router will know how to forward the packet beyond that point [9]. The best example for this is the routing information protocol (RIP).

4.2 Link-State Protocols

In link state protocols, a router doesn't provide the information about the destination instead it provides the information about the topology of the network. This usually consist of the network segments and links that are attached to that particular router along with the state of the link i.e., whether the link is in active state or the inactive state. This information is flooded throughout the network and then every router in the network then builds its own picture of the current state of all the links in the network.

Chapter 5

Mobile Ad-hoc Networks

An ad-hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any stand-alone infrastructure or centralized administration [11]. Mobile Ad-hoc networks are self-organizing and self-configuring multihop wireless networks where, the structure of the network changes dynamically. This is mainly due to the mobility of the nodes [8]. Nodes in these networks utilize the same random access wireless channel, cooperating in a friendly manner to engaging themselves in multihop forwarding. The nodes in the network not only acts as hosts but also as routers that route data to/from other nodes in network [1].

In mobile ad-hoc networks where there is no infrastructure support as is the case with wireless networks, and since a destination node might be out of range of a source node transmitting packets; a routing procedure is always needed to find a path so as to forward the packets appropriately between the source and the destination. Within a cell, a base station can reach all mobile nodes without routing via broadcast in common wireless networks. In the case of ad-hoc networks, each node must be able to forward data for other nodes. This creates additional problems along with the problems of dynamic topology which is unpredictable connectivity changes[5, 25].

5.1 Problems with routing in Mobile Ad-hoc Networks

- Asymmetric links: Most of the wired networks rely on the symmetric links which are always fixed. But this is not a case with ad-hoc networks as the nodes are mobile and constantly changing their position within network. For example consider a MANET(Mobile Ad-hoc Network) where node B sends a signal to node A but this does not tell anything about the quality of the connection in the reverse direction [25].

- Routing Overhead: In wireless adhoc networks, nodes often change their location within network. So, some stale routes are generated in the routing table which leads to unnecessary routing overhead.

- Interference: This is the major problem with mobile ad-hoc networks as links come and go depending on the transmission characteristics, one transmission might interfere with another one and node might overhear transmissions of other nodes and can corrupt the total transmission.

– Dynamic Topology: This is also the major problem with ad-hoc routing since the topology is not constant. The mobile node might move or medium characteristics might change. In ad-hoc networks, routing tables must somehow reflect these changes in topology and routing algorithms have to be adapted. For example in a fixed network routing table updating takes place for every 30sec [25]. This updating frequency might be very low for ad-hoc networks.

5.2 Classification of routing Protocols in MANET's

Classification of routing protocols in MANET's can be done in many ways, but most of these are done depending on routing strategy and network structure[8, 24]. According to the routing strategy the routing protocols can be categorized as Table-driven and source initiated, while depending on the network structure these are classified as flat routing, hierarchical routing and geographic position assisted routing [8]. B oth the Table-driven and source initiated protocols come under the Flat routing see [fig 5.1].

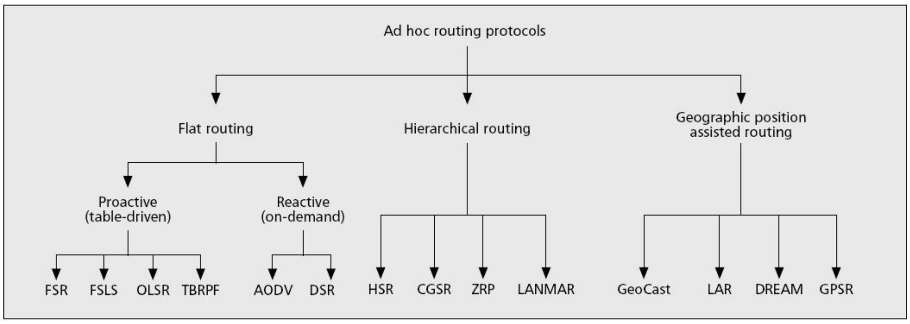

Figure 5.1: Classification of Routing Protocols In Mobile Ad-hoc Networks[8].

5.2.1 Table-Driven routing protocols(Proactive)

These protocols are also called as proactive protocols since they maintain the routing information even before it is needed [17]. Each and every node in the network maintains routing information to every other node in the network. Routes information is generally kept in the routing tables and is periodically updated as the network topology changes. Many of these routing protocols come from the link-state routing [8]. There exist some differences between the protocols that come under this category depending on the routing information being updated in each routing table. Furthermore, these routing protocols maintain different number of tables.The proactive protocols are not suitable for larger networks, as they need to maintain node entries for each and every node in the routing table of every node. This causes more overhead in the routing table leading to consumption of more bandwidth.

5.2.2 On Demand routing protocols(Reactive)

These protocols are also called reactive protocols since they don't maintain routing information or routing activity at the network nodes if there is no communication. If a node wants to send a packet to another node then this protocol searches for the route in an on-demand manner and establishes the connection in order to transmit and receive the packet [28]. The route discovery usually occurs by flooding the route request packets throughout the network.

Chapter 6

Destination Sequenced Distance Vector (DSDV) Protocol

The destination sequenced distance vector routing protocol is a proactive routing protocol which is a modification of conventional Bellman-Ford routing algorithm. This protocol adds a new attribute, sequence number, to each route table entry at each node. Routing table is maintained at each node and with this table, node transmits the packets to other nodes in the network. This protocol was motivated for the use of data exchange along changing and arbitrary paths of interconnection which may not be close to any base station.

6.1 Protocol Overview and activities

Each node in the network maintains routing table for the transmission of the packets and also for the connectivity to different stations in the network. These stations list for all the available destinations, and the number of hops required to reach each destination in the routing table. The routing entry is tagged with a sequence number which is originated by the destination station. In order to maintain the consistency, each station transmits and updates its routing table periodically. The packets being broadcasted between stations indicate which stations are accessible and how many hops are required to reach that particular station. The packets may be transmitted containing the layer 2 or layer 3 address [18].

Routing information is advertised by broadcasting or multicasting the packets which are transmitted periodically as when the nodes move within the network. The DSDV protocol requires that each mobile station in the network must constantly, advertise to each of its neighbors, its own routing table. Since, the entries in the table my change very quickly, the advertisement should be made frequently to ensure that every node can locate its neighbors in the network. This agreement is placed, to ensure the shortest number of hops for a route to a destination; in this way the node can exchange its data even if there is no direct communication link.

The data broadcast by each node will contain its new sequence number and the following information for each new route:

– The destination address

– The number of hops required to reach the destination and

– The new sequence number, originally stamped by the destination

The transmitted routing tables will also contain the hardware address, network address of the mobile host transmitting them. The routing tables will contain the sequence number created by the transmitter and hence the most new destination sequence number is preferred as the basis for making forwarding decisions. This new sequence number is also updated to all the hosts in the network which may decide on how to maintain the routing entry for that originating mobile host.

After receiving the route information, receiving node increments the metric and transmits information by broadcasting. Incrementing metric is done before transmission because, incoming packet will have to travel one more hop to reach its destination.

Time between broadcasting the routing information packets is the other important factor to be considered. When the new information is received by the mobile host it will be retransmitted soon effecting the most rapid possible dissemination of routing information among all the cooperating mobile hosts. The mobile host cause broken links as they move form place to place within the network. The broken link may be detected by the layer2 protocol, which may be described as `infinity`. When the route is broken in a network, then immediately that metric is assigned an infinity metric there by determining that there is no hop and the sequence number is updated. Sequence numbers originating from the mobile hosts are defined to be even number and the sequence numbers generated to indicate `infinity` metrics are odd numbers.

The broadcasting of the information in the DSDV protocol is of two types namely: full dump and incremental dump. Full dump broadcasting will carry all the routing information while the incremental dump will carry only information that has changed since last full dump. Irrespective of the two types, broadcasting is done in network protocol data units (NPDU). Full dump requires multiple NPDU's while incremental requires only one NPDU to fit in all the information.

When an information packet is received from another node, it compares the sequence number with the available sequence number for that entry. If the sequence number is larger, then it will update the routing information with the new sequence number else if the information arrives with the same sequence number it looks for the metric entry and if the number of hops is less than the previous entry the new information is updated (if information is same or metric is more then it will discard the information). While the nodes information is being updated the metric is increased by 1 and the sequence number is also increased by 2. Similarly, if a new node enters the network, it will announce itself in the network and the nodes in the network update their routing information with a new entry for the new node.

During broadcasting, the mobile hosts will transmit their routing tables periodically but due to the frequent movements by the hosts in the networks, this will lead to continuous burst of new routes transmessions upon every new sequence number from that destination. The solution for this is to delay the advertisement of such routes until it shows up a better metric.

6.2 Operation at Layer2

Address stored in the routing table at the mobile hosts will correspond to the layer at which the DSDV protocol is operated. Layer3 will use network layer addresses for the next hop and destination addresses and layer 2 will use the MAC address for its operation. A difficulty is arised at the layer 3 operation and a way must be provided to resolve these layer-3 addresses into MAC addresses. Otherwise, problems like broadcast address resolution would be needed and loss of bandwidth would be observed. This loss could be substantial because such mechanisms will require retransmission by every mobile node. The solution here is to provide layer3 protocol information along with the layer2 information at the layer 2 operation. Each mobile node would advertise, reach ability, information about the layer3 protocols at that destination [19].

6.3 Example for DSDV operation

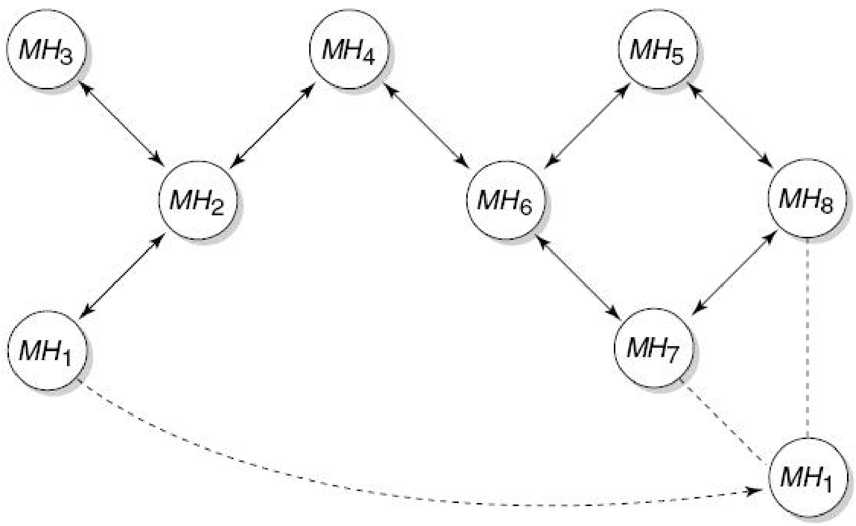

Figure 6.1: Movement of Mobile host in Adhoc Networks[18].

Consider the above fig. 6.1 which has 8 hosts in the network. We will have a look at the changes to the MH4 routing table with reference to the movements of MH1. Initially, all the nodes advertise their routing information to all the nodes in the network and hence the routing table at MH4 initially looks like

Table 6.1: Routing table of MH4[18]

Destination	Next Hop	Metric	Sequence Number	Install	Stable_Data
MH1	MH2	2	S406_MH1	T001_MH4	Ptr1_MH1
MH2	MH2	1	S128_MH2	T001_MH4	Ptr1_MH2
MH3	MH2	2	S564_MH3	T001_MH4	Ptr1_MH3
MH4	MH4	0	S710_MH4	T001_MH4	Ptr1_MH4

MH5	MH6	2	S392_MH5	T002_MH4	Ptr1_MH5
MH6	MH6	1	S076_MH6	T001_MH4	Ptr1_MH6
MH7	MH6	2	S128_MH7	T002_MH4	Ptr1_MH7
MH8	MH6	3	S050_MH8	T002_MH4	Ptr1_MH8

And the forwarding table at the MH4 would look like this

Table 6.2: Forwarding table at MH4[18]

Destination	Metric	Sequence Number
MH1	2	S406_MH1
MH2	1	S128_MH2
MH3	2	S564_MH3
MH4	0	S710_MH4
MH5	2	S392_MH5
MH6	1	S076_MH6
MH7	2	S128_MH7
MH8	3	S050_MH8

But, when the host MH1 moves its location as shown in the fig. 6.1 nearer to MH7 and MH8 then, the link between MH2 and MH1 will be broken resulting in the assignment of `infinity` metric at MH2 for MH1 and the sequence number will be changed to odd number in the routing table at MH2. MH2 will update this information to its neighbor hosts. Since, there is a new neighbor host for MH7 and MH8; they update their information in the routing tables and they broadcast. Now, MH4 will receive its updated information from MH6 where MH6 will receive two information packets from different neighbors to reach MH1 with same sequence number, but different metric. The selection of the route will depend on less hop count when the sequence number is the same. Now the routing table will look like

Table 6.3: Routing table after MH1 movement [18]

Destination	Next Hop	Metric	Sequence Number	Install	Stable_Data
MH1	MH6	3	S516_MH1	T001_MH4	Ptr1_MH1
MH2	MH2	1	S238_MH2	T001_MH4	Ptr1_MH2
MH3	MH2	2	S674_MH3	T001_MH4	Ptr1_MH3
MH4	MH4	0	S820_MH4	T001_MH4	Ptr1_MH4
MH5	MH6	2	S502_MH5	T002_MH4	Ptr1_MH5
MH6	MH6	1	S186_MH6	T001_MH4	Ptr1_MH6
MH7	MH6	2	S238_MH7	T002_MH4	Ptr1_MH7
MH8	MH6	3	S160_MH8	T002_MH4	Ptr1_MH8

And the forwarding table will look like

Table 6.4: Forwarding table at MH4 after Movement of MH1 [18]

Destination	Metric	Sequence Number
MH1	3	S516_MH1
MH2	1	S238_MH2
MH3	2	S674_MH3
MH4	0	S820_MH4
MH5	2	S502_MH5
MH6	1	S186_MH6
MH7	2	S238_MH7
MH8	3	S160_MH8

6.4 Advantages of DSDV

– DSDV protocol guarantees loop free paths [23].

– Count to infinity problem is reduced in DSDV [23].

– We can avoid extra traffic with incremental updates instead of full dump updates.

– Path Selection: DSDV maintains only the best path instead of maintaining multiple paths to every destination. With this, the amount of space in routing table is reduced.

6.5 Limitations of DSDV

– Wastage of bandwidth due to unnecessary advertising of routing information even if there is no change in the network topology [16].

– DSDV doesn't support Multi path Routing.

– It is difficult to determine a time delay for the advertisement of routes [7].

– It is difficult to maintain the routing table's advertisement for larger network. Each and every host in the network should maintain a routing table for advertising. But for larger network this would lead to overhead, which consumes more bandwidth.

Chapter 7

Ad-hoc On-Demand Distance Vector (AODV) Protocol

AODV is a very simple, efficient, and effective routing protocol for Mobile Ad-hoc Networks which do not have fixed topology. This algorithm was motivated by the limited bandwidth that is available in the media that are used for wireless communications. It borrows most of the advantageous concepts from DSR and DSDV algorithms. The on demand route discovery and route maintenance from DSR and hop-by-hop routing, usage of node sequence numbers from DSDV make the algorithm cope up with topology and routing information. Obtaining the routes purely on-demand makes AODV a very useful and desired algorithm for MANETs [20].

7.1 Working of AODV

Each mobile host in the network acts as a specialized router and routes are obtained as needed, thus making the network self-starting. Each node in the network maintains a routing table with the routing information entries to it's neighbouring nodes, and two separate counters: a node sequence number and a broadcast-id. When a node (say, source node 'S') has to communicate with another (say, destination node 'D'), it increments its broadcast-id and initiates path discovery by broadcasting a route request packet RREQ to its neighbors. The RREQ contains the following fields:

– **source-addr**

– **source-sequence#** -to maintain freshness info about the route to the source.

– **dest-addr**

– **dest-sequence#** - specifies how fresh a route to the destination must be before it is accepted by the source.

– **hop-cnt**

The (source-addr, broadcase-id) pair is used to identify the RREQ uniquely. Then the dynamic route table entry establishment begins at all the nodes in the network that are on the path from S to D.

As RREQ travels from node to node, it automatically sets up the reverse path from all these nodes back to the source. Each node that receives this packet records the address of the node from which it was received. This is called Reverse Path Setup. The nodes maintain this info for enough time for the RREQ to traverse the network and produce a reply to the sender and time depends on network size.

If an intermediate node has a route entry for the desired destination in its routing table, it compares the destination sequence number in its routing table with that in the RREQ. If the destination sequence number in its routing table is less than that in the RREQ, it rebroadcasts the RREQ to its neighbors. Otherwise, it unicasts a route reply packet to its neighbor from which it was received the RREQ if the same request was not processed previously (this is identified using the broadcase-id and source-addr).

Once the RREP is generated, it travels back to the source, based on the reverse path that it has set in it until traveled to this node. As the RREP travels back to source, each node along this path sets a forward pointer to the node from where it is receiving the RREP and records the latest destination sequence number to the request destination. This is called Forward Path Setup.

If an intermediate node receives another RREP after propagating the first RREP towards source it checks for destination sequence number of new RREP. The intermediate node updates routing information and propagates new RREP only,

– If the Destination sequence number is greater, OR

– If the new sequence number is same and hop count is small, OR

Otherwise, it just skips the new RREP. This ensures that algorithm is loop-free and only the most effective route is used [20].

The below figure 7.1 is an example, which shows how the route to the destination is found by AODV routing protocol.

Step by step explaination of figure 7.1 is as follows:

1. Source 'S' has to send data to destination.
2. S sends RREQ to its neighbors A, B, C.
3. B finds the path in its routing table (with destn seq-number s1 and hop count c1) and sends RREP to S.
4. C sets up reverse path.
5. C forwards RREQ to its neighbors D and E.
6. E sets up reverse path.
7. E forwards RREQ to its neighbors F and G.
8. E deletes the reverse path after a time out period as it does not receive any RREPs from F and G.
9. D finds the path (with dest seq-number s2 which is greater than s1 and hop count c1) in its routing table and sends RREP to C.
10. C receives RREP from D and sets up forward path and forwards RREP to S.

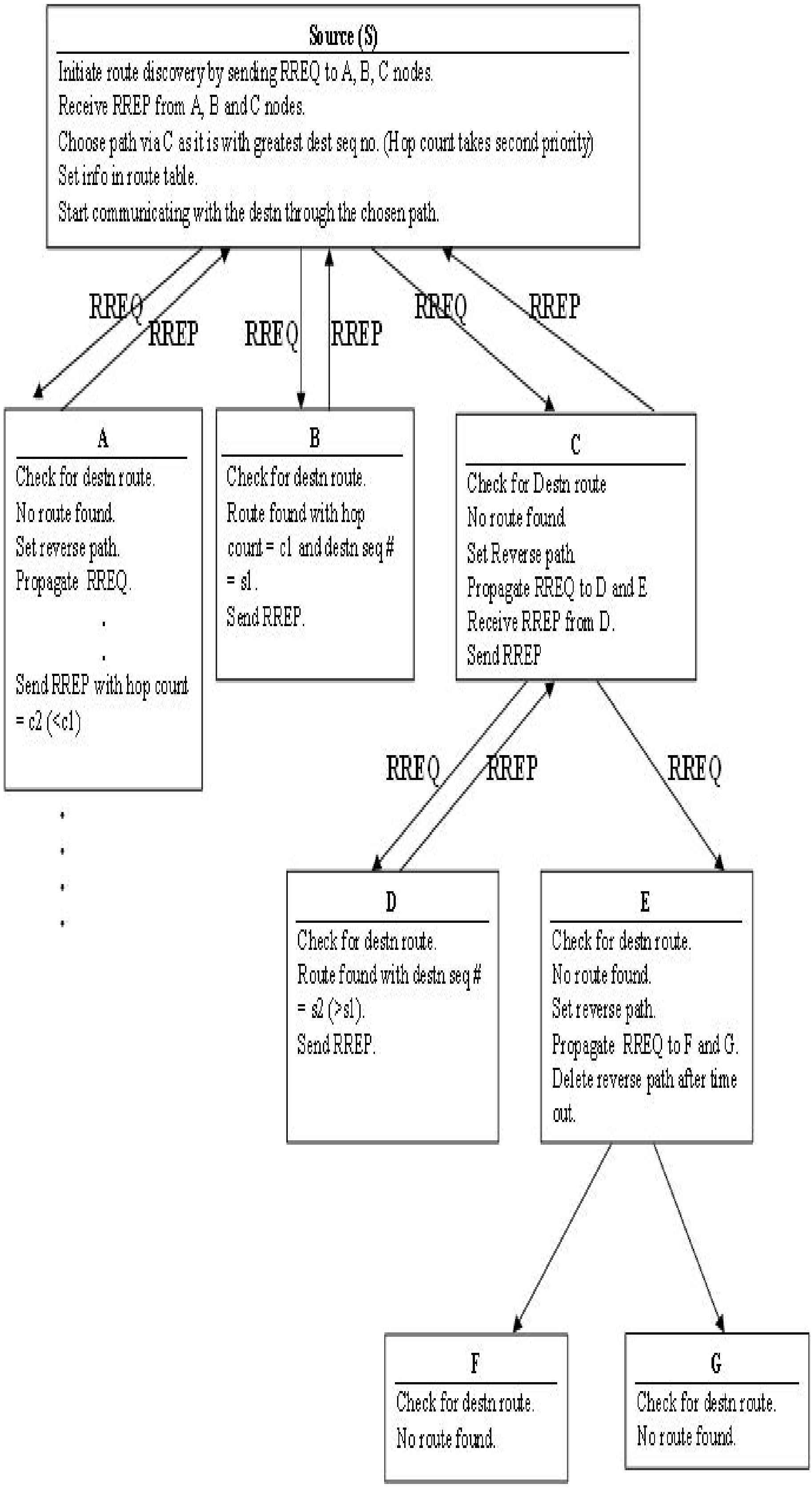

Figure 7.1: Route finding process in AODV Routing Protocol.

11. A sets reverse path; forwards RREQ to its neighbors; receives RREP (with path of hop count c2 which is greater than c1); sets forward path; and forwards this RREP to S.

12. S receives a path info from C (with destn seq-number s2 and hop count c1), another path info from B (with destn seq-number s1 and hop count c1), and another path info from A (with destn seq-number x which is less than s1 and s2 and hop count c2 which is less than c1).

13. S chooses path info from C (which was originated from D), giving first priority to the path with greatest destination sequence number and then second priority to the path with smallest hop count. Though path given by A is of smallest hop count, it is ignored because the destination sequence number is greater than the path from C.

7.2 Route Table Management

Each mobile node in the network maintains a route table entry for each destination of interest in its route table. Each entry contains the following info:

- Destination
- Next hop
- Number of hops
- Destination sequence number
- Active neighbors for this route
- Expiration time for the route table entry

The other useful information contained in the entries along with source and destination sequence numbers is called soft-state information associated to the route entry. The info about the active neighbors for this route is maintained so that all active source nodes can be notified when a link along a path to the destination breaks. And the purpose of route request time expiration timer is to purge the reverse path routing entries from all the nodes that do not lie on the active route.

7.3 Interesting concepts of AODV

The concepts of AODV that make it desirable for MANETs with limited bandwidth include the following:

- **Minimal space complexity:** The algorithm makes sure that the nodes that are not in the active path do not maintain information about this route. After a node receives the RREQ and sets a reverse path in its routing table and propagates the RREQ to its neighbors, if it does not receive any RREP from its neighbors for this request, it deletes the routing info that it has recorded.

- **Maximum utilization of the bandwidth:** This can be considered the major achievement of the algorithm. As the protocol does not require periodic global advertisements, the demand on the available bandwidth is less. And a monotonically increased sequence number counter is maintained by each node in order to supersede any stale cached routes. All the intermediate nodes in an active path updating their routing tables also make sure of maximum utilization of the bandwidth. Since, these routing tables will be used repeatedly if that intermediate node receives any RREQ from another source for same destination. Also, any RREPs that are received by the nodes are compared with the RREP that was propagated last using the destination sequence numbers and are discarded if they are not better than the already propagated RREPs.

- **Simple:** It is simple with each node behaving as a router, maintaining a simple routing table, and the source node initiating path discovery request, making the network self-starting.

- **Most effective routing info:** After propagating an RREP, if a node finds receives an RREP with smaller hop-count, it updates its routing info with this better path and propagates it.

- **Most current routing info:** The route info is obtained on demand. Also, after propagating an RREP, if a node finds receives an RREP with greater destination sequence number, it updates its routing info with this latest path and propagates it.

- **Loop-free routes:** The algorithm maintains loop free routes by using the simple logic of nodes discarding non better packets for same broadcast-id.

- **Coping up with dynamic topology and broken links:** When the nodes in the network move from their places and the topology is changed or the links in the active path are broken, the intermediate node that discovers this link breakage propagates an RERR packet. And the source node re-initializes the path discovery if it still desires the route. This ensures quick response to broken links.

- **Highly Scalable:** The algorithm is highly scalable because of the minimum space complexity and broadcasts avoided when it compared with DSDV[21].

7.4 Advanced uses of AODV

- Because of its reactive nature, AODV can handle highly dynamic behavior of Vehicle Ad-hoc networks [26].

- Used for both unicasts and multicasts using the 'J' (Join multicast group) flag in the packets [21].

7.5 Limitations/Disadvantages of AODV

- **Requirement on broadcast medium:** The algorithm expects/requires that the nodes in the broadcast medium can detect each others' broadcasts.

- **Overhead on the bandwidth:** Overhead on bandwidth will be occured compared to DSR,when an RREQ travels from node to node in the process of discovering the route info on demand, it sets up the reverse path in itself with the addresses of all the nodes through which it is passing and it carries all this info all its way.
- **No reuse of routing info:** AODV lacks an efficient route maintenance technique. The routing info is always obtained on demand, including for common case traffic[22].
- **It is vulnerable to misuse:** The messages can be misused for insider attacks including route disruption, route invasion, node isolation, and resource consumption[15].
- **AODV lacks support for high throughput routing metrics:** AODV is designed to support the shortest hop count metric. This metric favors long, low-bandwidth links over short, high-bandwidth links [22].
- **High route discovery latency:** AODV is a reactive routing protocol. This means that AODV does not discover a route until a flow is initiated. This route discovery latency result can be high in large-scale mesh networks.

Chapter 8

Discussion and Conclusion

8.1 Discussion

After reviewing the concept of wireless ad-hoc networks and two routing protocols namely, AODV and DSDV. We would like to make a comparative discussion of both the protocols with their pro's and con's. Most of the discussion being made is based on previous studies and implementations done by many authors[2, 10, 12].

- DSDV is a proactive routing protocol, which maintains routes to each and every node in the network, while AODV is a reactive routing protocol which finds the path on demand or whenever the route is required.
- Broadcasting in DSDV is done periodically to maintain routing updates and in AODV, only hello messages are propagated to its neighbors to maintain local connectivity.
- DSDV routing algorithm maintains a sequence number concept for updating the latest information for a route. Even, the same concept is adapted by AODV routing protocol.
- Due to the periodic updates being broadcasted in DSDV, bandwidth is wasted when the nodes are stationary. But, this is not the case with AODV, as it propagates only hello messages to its neighbours.
- For sending data to a particular destination, there is no need to find a route as DSDV routing protocol maintains all the routes in the routing tables for each node. While, AODV has to find a route before sending a data.
- Overhead in DSDV is more when the network is large and it becomes hard to maintain the routing tables at every node. But, in AODV overhead is less as it maintains small tables to maintain local connectivity.
- DSDV cannot handle mobility at high speeds due to lack of alternative routes hence routes in routing table is stale. While in AODV this is the other way, as it find the routes on demand.
- Throughput decreases comparatively in DSDV as it needs to advertise periodic updates and even-driven updates. If the node mobility is high then occurrence

of event driven updates are more. But in AODV it doesn't advertise any routing updates and hence the throughput is stable.

8.2 Conclusion

The study reveals that, DSDV routing protocol consumes more bandwidth, because of the frequent broadcasting of routing updates. While the AODV is better than DSDV as it doesn't maintain any routing tables at nodes which results in less overhead and more bandwidth. From the above, chapters, it can be assumed that DSDV routing protocols works better for smaller networks but not for larger networks. So, my conclusion is that, AODV routing protocol is best suited for general mobile ad-hoc networks as it consumes less bandwidth and lower overhead when compared with DSDV routing protocol.

Chapter 9

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