TOPOLOGY CONTROL IN MANET WITH COOPERATIVE COMMUNICATION

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Cooperative communication has received tremendous interest for wireless networks. Most existing works on cooperative communications are focused on link-level physical layer issues. Consequently, the impacts of cooperative communications on network-level upper layer issues, such as topology control, routing and network capacity, are largely ignored. In this article, we propose a Capacity-Optimized Cooperative (COCO) topology control scheme to improve the network capacity in MANETs by jointly considering both upper layer network capacity and physical layer cooperative communications. Through simulations, we show that physical layer cooperative communications have significant impacts on the network capacity, and the proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications.

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LIST OF NOMENCLATURE

AODV	Ad Hoc On-Demand Distance Vector Routing Protocol
DSDV	Destination Sequenced Distance Vector Routing
DSR	Dynamic Source Routing
CBR	Constant Bit Rate
IP	Internetworking Protocol
MANET	Mobile Ad-Hoc Network
MAC	Medium Access Control
TCP	Transfer Control Protocol
UDP	User Datagram Protocol
FTP	File Transfer Protocol
PDR	Packet Delivery Ratio
OTcl	Object-Oriented Tool command language
NAM	Network Animator
NS	Network Simulator

CHAPTER 1

INTRODUCTION

The demand for speed in wireless networks is continuously increasing. Recently, cooperative wireless communication has received tremendous interests as an untapped means for improving the performance of information transmission operating over the ever-challenging wireless medium.

Cooperative communication has emerged as a new dimension of diversity to emulate the strategies designed for multiple antenna systems, since a wireless mobile device may not be able to support multiple transmit antennas due to size, cost, or hardware limitations. By exploiting the broadcast nature of the wireless channel, cooperative communication allows single- antenna radios to share their antennas to form a virtual antenna array. This promising technique has been considered in the IEEE 802.16j standard. In cooperative communications, most existing works are focused on link-level physical layer issues, such as outage probability and outage capacity.

Consequently, the impacts of cooperative communications on network-level upper layer issues, such as topology control, routing and network capacity, are largely ignored. Indeed, most of current works on wireless networks attempt to create, adapt, and manage a network on a maze of point-to-point non cooperative wireless links. Such architectures can be seen as complex networks of simple links.

However, recent advances in cooperative communications will offer a number of advantages in flexibility over traditional techniques. Cooperation alleviates certain networking problems, such as collision resolution and routing, and allows for simpler networks of more complex links, rather than complicated networks of simple links.
Therefore, many upper layer aspects of cooperative communications merit further research, e.g., the impacts on topology control and network capacity, especially in mobile ad hoc networks (MANETs), which can establish a dynamic network without a

fixed infrastructure. A node in MANETs can function both as a network router for routing packets from the other nodes and as a network host for transmitting and receiving data. MANETs are particularly useful when a reliable fixed or mobile infrastructure is not available. Instant conferences between notebook PC users, military applications, emergency operations, and other secure-sensitive operations are important applications of MANETs due to their quick and easy deployment. Due to the lack of centralized control, MANET nodes achieve a common goal. The major activities involved in self-organization are neighbor discovery, topology organization, and topology reorganization. Network topology describes the connectivity information of the entire network, including the nodes in the network and the connections between them. Topology control is very important for the overall performance of a MANET. For example, to maintain reliable network connectivity, nodes in MANETs may work at the maximum radio power, which results in high nodal degree and long link distance, but more interference is introduced into the network and much less throughput per node can be obtained. Using topology control, a node carefully selects a set of its neighbors to establish logical data links and dynamically adjust its transmit power accordingly, so as to achieve high throughput in the network while keeping the energy consumption low .

In this project, considering both upper layer network capacity and physical layer cooperative communications, we study the topology control issues in MANETs with cooperative communications.

1.1 OBJECTIVE

The main objective of this project is to provide an efficient topology control in large scale dynamic wireless networks. This is achieved by Capacity Optimized Cooperative topology (COCO). Other Objectives of the project includes

- To study and understand various parameters like end to end delay, packet delivery ratio and control packet overhead.
- To evaluate the performance through simulations in Network Simulator.

1.2 PROPOSED WORK

We propose a Capacity-Optimized Cooperative (COCO) topology control scheme to improve the network capacity in MANETs by jointly optimizing transmission mode selection, relay node selection, and interference control in MANETs with cooperative communications. Through simulations, we show that physical layer cooperative communications have significant impacts on the network capacity, and the proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications.

The simulation results have been obtained using network simulator (ns-2) Different graphs for various parameters like end to end delay, packet delivery ratio and overhead have been obtained.

The results are then compared with AODV, DSDV and DSR routing protocols and it is observed that DSR outperforms AODV and DSDV routing protocols.

CHAPTER 2

MOBILE ADHOC NETWORK WITH COOPERATIVE COMMUNICATION

2.1. COOPERATIVE COMMUNICATION:

Cooperative communication typically refers to a system where users share and coordinate their resources to enhance the information transmission quality. It is a generalization of the relay communication, in which multiple sources also serve as relays for each other.

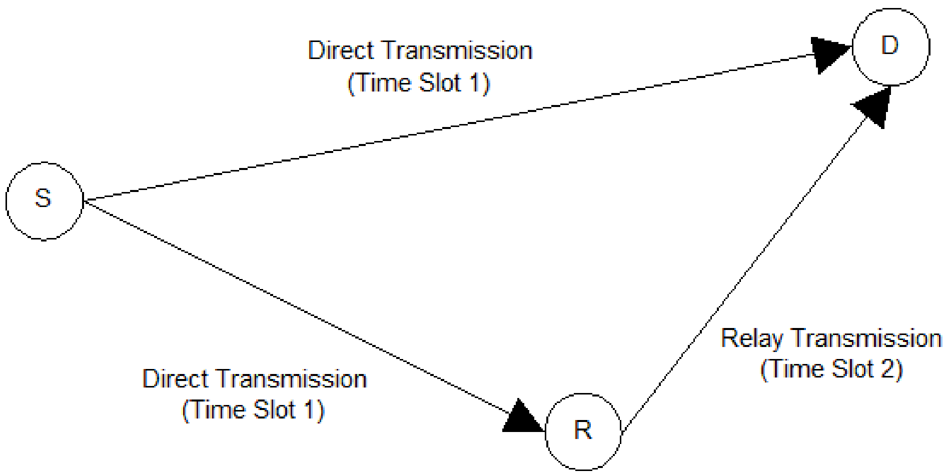

Fig 2.1: Cooperative communication

The main advantages of cooperative communications are Higher spatial diversity ie.resistance to both small scale and shadow fading, Higher throughput/lower delay i.e., higher achievable data rates, fewer retransmissions, and lower transmission delay, Reduced interference/lower transmitted power i.e., better frequency reuse in a Cellular/WLAN deployment, Adaptability to network conditions i.e., opportunistic use and redistribution of network energy and bandwidth.

2.2. NETWORK MODEL:

A network topology involves two aspects: network nodes and the connection links among them. In general, a MANET can be mapped into a graph . A link is generally composed of two nodes which are in the transmission range of each other in classical MANETs. The topology of such a classical MANET is parameterized by some controllable parameters, which determine the existence of wireless links directly. Usually, these parameters can be transmitting power and antenna directions, etc. By the introduction of cooperative communications, we consider three transmission modes in MANETs: direct transmissions, multi-hop transmissions and cooperative transmissions. Direct transmissions and multi-hop transmissions can be regarded as special types of cooperative transmissions. A direct transmission utilizes no relays while a multi-hop transmission does not combine signals at the destination, it is known that the cooperative channel is a virtual multiple input single output (MISO) channel, where spatially distributed nodes are coordinated to form a virtual antenna to emulate multi-antenna transceivers. A cooperative transmission consists of two types of channels: broadcast channel and a multiple access channel. The channel time is divided into two orthogonal consecutive slots to implement cooperative transmissions. The source broadcasts its messages to the relay and destination in the first slot, and the destination obtains the signals from the source and the relay via multiplexing technology in the second slot. Let them be S, R and D respectively.. If the relay is changed, the performance of transmissions for the link is then changed. Therefore, relay selection criteria can also determine the wireless links. To evaluate the capacity for each transmission mode, we assume a Raleigh fading channel. The protocol interference model, which confines concurrent transmissions in the vicinity of the transmitter and receiver, is adopted in this study. This model fits the medium access control function well, e.g., the popular IEEE 802.11 MAC in most mobile devices in MANETs. Herein, interference of a link is defined as some combination of coverage of nodes involved in the transmission, which has been used in the literature.

Definition 1 (Node coverage)**.** The coverage of a node refers to its neighbors, i.e., $Co(u) = VN(u)$ for node u. In the physical meaning, it includes nodes covered by this node.

Definition 2 (Link interference)**.** It refers to the number of influenced nodes during the transmission.

2.3. TOPOLOGY CONTROL FORMULATION:

As topology control is to determine the existence of wireless links subject to network connectivity, the general topology control problem can be expressed as

$$\mathcal{G}* = \text{argmax}(\mathcal{G}) \text{ or } \mathcal{G}* = \text{argmin} f(\mathcal{G}), \text{-----------} (1)$$

s.t. network connectivity.

The above topology control problem consists of three elements, which can be formulated by a triple ⟨𝕄, ℙ,⟩, where 𝕄 represents network model, ℙ represents the desired network property, which often refers to network connectivity for most topology control algorithms, and 𝕆 refers to the optimization objective . The problem (1) uses the original network topology $\mathcal{G}$, which contains mobile nodes and link connections, as the input. According to the objective function, a new good topology will be constructed as the output of the algorithm. $\mathcal{G}*$ should contain all mobile nodes in $\mathcal{G}$, i.e., they have the same node set. The structure of resulting topology is strongly related to the optimization objective function, which is $(\mathcal{G})$ in (1).

For MANETs, it is difficult to collect the entire network information. Therefore, the above centralized topology control should be solved using a distributed algorithm, which generally requires only local knowledge, and the algorithm runs at every node independently. Consequently, each node in the network is responsible for managing the links to all its neighbors only. If all the neighbor connections are preserved, the end-to-end connectivity is then guaranteed via a hop-by-hop manner. Given a neighborhood graph , we can define a distributed topology control problem as

$$\mathcal{G}*\mathcal{N} = \text{argmax}(\mathcal{G}\mathcal{N}) \text{ or } \mathcal{G}*\mathcal{N}$$

$$= \text{argmin}(\mathcal{G}\mathcal{N}) \text{---------------} (2)$$

The objective functions are critical to topology control problems. They may be energy consumption, interference and network capacity, or QoS provisioning under some constraints of delay and bandwidth. They are achieved by adjusting some controllable parameters, such as transmission power, antenna direction, channel assignment and even cooperation level, which affect the link status. The area of energy-saving topology control has attracted a great deal of attention. Under the constraint of network connectivity, topology control adjusts the transmission range of each mobile node in order to save energy. It is pointed out that the problems of minimizing the total power consumption and minimizing the maximum power consumption are NP-hard or NP-complete. Researchers then try to resolve the complex problem into sub-optimized distributed problems, which are more feasible for MANETs. For example, the reference constructs a spanner topology with regard to path energy. The approach of some approximate graph based algorithms is to remove long links while preserve network connectivity in order to force nodes to use multiple short hops, which saves the energy and prolongs network lifetime. It is generally agreed in the literature that the reduced graph should be sparse to mitigate collisions and packet retransmissions, leading to reduce power consumption and extend network lifetime. However, if too many edges are removed from the topology, data packets may traverse along an unacceptably long path. A fundamental issue has been pointed out in that the performance of a multi-hop wireless network will degrade sharply as the number of hops increases. Connecting to the nearest neighbor, which generates a nearest neighbor forest, is not sufficient to reduce interference in the network. With this fact, interference-aware topology control schemes emerge. It is assumed that reducing interference can increase network capacity, which is an important resource for multi-hop wireless networks. The capacity of such a network is revealed to be decreased as the number of nodes in the network increases. To this end, proposed a capacity-aware topology control. It confines the degree of each node in the network to reduce interference and thus increase network capacity. It shares the same principle as interference-aware topology control, but without connectivity guarantee. However, reducing interference merely is not sufficient for network capacity improvement.

Some recent excellent works also address the impacts of physical layer cooperative communications on upper layer performance in wireless networks. They investigate the joint effects of relay assignment and routing, which are different from the network topology control issues studied in this paper. Our previous work shows that topology control can affect network capacity significantly. Based on the observations in, we propose the COCO scheme in this paper with the objective of optimizing network capacity via topology control for MANETs with cooperative communications.

Another fact in MANETs is that nodes are mobile and it is difficult to have the exact knowledge of wireless channels. The relative positions of the relay and the channel state information have considerable impacts on link capacity. The noisy channel estimate may result in inaccurate link capacity calculation and worst relay selection. When nodes are moving, the topology needs to be reconfigured in time to track the changes.

CHAPTER 3

CAPACITY OPTIMIZED COOPERATIVE TOPOLOGY CONTROL

3.1. CAPACITY OPTIMIZATION:

Based on the topology control formulation in the previous section, we will detail the design of COCO to maximize network capacity in this section. The network capacity expression is used as its objective function, which takes link capacity and interference into consideration. The network connectivity and path length are regarded as constraints for the optimization problem. The COCO scheme described in this section formulates topology control as a discrete stochastic optimization problem. A discrete stochastic approximation approach is then adopted to solve the problem. This approach is easily improved to track time-varying changes. Therefore, network topology is reconfigured in time. Before addressing COCO, we introduce some definitions to be used in the discussion.

Definition 3 (Network capacity)**.** Network capacity refers to the maximum achievable throughput of bits per second for each node on average that can be sent to its destination.

The network capacity defined here includes all the end-to-end throughput in the network and it is in fact the average throughput capacity per node.

3.2. OBJECTIVE FUNCTION:

As an optimization problem, the objective function is the most paramount component. In COCO, the objective function is set to reflect the state of network capacity. As concluded in, the expected network capacity is determined by various factors. On one hand, link capacity is one of the main factors. In practice, we adopt a data rate, called outage capacity, which is supported by a small outage probability ε, to stand for the link capacity. The study shows that cooperative transmissions do not always outperform direct transmissions. If there exists no such a relay that makes cooperative transmissions have larger outage capacity, we rather transmit information directly or via multi-hops. For this reason, COCO determines the best link block and the best relay to optimize link capacity. On the other hand, other nodes in the transmission range have to be silent in order not to disrupt the transmission due to the open shared wireless media. The affected nodes include the coverage of the source (see Definition 1), the coverage of the destination, as well as the coverage of the relay. Interference, which refers to the affected nodes, also has a significant impact on network capacity. Higher interference reduces simultaneous transmissions in the network, thus reduces the network capacity, and vice versa. Link capacity and interference model vary for different links. They are discussed in the following session.

3.3. DIRECT TRANSMISSION:

A direct transmission is the conventional point-to-point transmission. Let $\gamma 0$, $\gamma 1$ and $\gamma 2$ denote the received SNRs from the source to the destination, from the source to the relay and from the relay to the destination, respectively. Given a small outage probability ε, its outage link capacity is given by

$$C\ T = \log 2(1 + \gamma 0 \ln 1 / 1 - \varepsilon).$$

Only two nodes are involved in the direct transmission. Therefore, the interference set of a direct transmission is the union of coverage sets of the source node and the destination node:

$$IDT = Co(S)\ U\ Cov(D).$$

According to Definition 2, the interference is set to $|IDT|$, the size of the interference set.

3.4. MULTI-HOP TRANSMISSION:

The multi-hop transmission here is actually a two-hop transmission. It consumes two time slots. In the first slot, messages are transmitted from the source to the relay and the messages will be forwarded to the destination in the second slot. The mutual information of a multi-hop transmission link is calculated by

$$R_{MT} = \frac{1}{2}\min\{R_{S\to R}, R_{R\to D}\}.$$

The outage probability is

$$P_{MT}^{out} = 1 - u^{\frac{1}{\gamma_1}+\frac{1}{\gamma_2}},$$

where $u = e{-}(22R{-}1)$ and R is the link data rate.

If $Pout\ MT = \varepsilon$, the outage capacity then is

$$C_{MT}^{\varepsilon} = \frac{1}{2}\log_2(1 + \frac{1}{\frac{1}{\gamma_1}+\frac{1}{\gamma_2}}\ln\frac{1}{1-\varepsilon}).$$

The multi-hop transmission mode for a link is composed of two hops. The transmission of each hop has its own interference, which happens in different slots, where the interference sets in slots are $IS{\to}R = Co(S)$ U$Cov(R)$ and $IR{\to}D = Cov$(S) $U\ Cov(D)$. Since the transmissions of the two hops cannot occur simultaneously but in two separate and consecutive time slots, the end-to-end interference set of the multi-hop link is determined by the maximum of the two interference sets, i.e.,

$$I_{MT} = \max\{I_{S\to R}, I_{R\to D}\}.$$

3.5. COOPERATIVE TRANSMISSION:

This study uses the fixed decode-and-forward (DF) relaying scheme with only one best relay, which is selected proactively before transmissions. In the DF relaying, the relay node decodes and re-encodes the signal from the source, and then forwards it to the destination. The two signals of the source and the relay are decoded by maximal rate combining (MRC) at the destination. Its maximum instantaneous end-to-end mutual information is

$$R_{CT} = \frac{1}{2}\min\{R_{S\rightarrow R}, R_{MRC}\}.$$

The outage probability is given by

$$P_{CT}^{out} = 1 + \frac{\frac{\gamma_0}{\gamma_2} u^{\frac{1}{\gamma_0}+\frac{1}{\gamma_1}} - u^{\frac{1}{\gamma_1}+\frac{1}{\gamma_2}}}{1 - \frac{\gamma_0}{\gamma_2}}.$$

Then, the outage capacity is expressed as

$$C_{CT}^{\varepsilon} = \frac{1}{2}\log_2(1 + \ln\frac{1}{u_\varepsilon}).$$

The interference of a cooperative transmission is a bit complicated. In the broadcast period, not only the covered neighbors of the source have to be silent, but also the covered neighbors of the relay and the destination have to be silent so as to ensure successful receptions at both the relay and the destination. The interference set of broadcast channel in the first transmission period is $Ibrc$ = $IS\rightarrow R$ U $IS\rightarrow D$ = $Co(S)$U$Cov(R)$U$Cov(D)$. The multiple access channel also consists of two point-to-point links: $S\rightarrow D$ and $R\rightarrow D$, which are active in separate time slots. Its interference is $Imax$ = max$\{IS\rightarrow D, IR\rightarrow D\}$ = max$\{Cov(S)$ U $Cov(D), Cov(R)$U $Cov(D)\}$. Now, we can derive the interference set of cooperative transmissions as

$$\begin{aligned} I_{CT} &= \max\{I_{brc}, I_{ma}\} \\ &= Cov(S) \cup Cov(R) \cup Cov(D). \end{aligned}$$

Direct transmissions and multi-hop transmissions can also be considered as special types of cooperative transmissions. For direct transmissions, we assume that the relay is also the source, while the direct signal is ignored at the destination for multi-hop transmissions. Given a node identified by 0 and its neighbor set $\mathcal{VN} = \{1, 2, \ldots m\}$, the selected relay set for all its neighbors is $\boldsymbol{\theta} = (\theta 1, \theta 2, \ldots, \theta m)$. Let $\boldsymbol{\theta}$ denote the set of all the possible relays for its neighbors. Therefore, $\boldsymbol{\theta}\, U\, \Theta$. For any one of its neighbors j, suppose that $\theta j \in \Theta j = \{0, 1, \ldots,, m + 1, \ldots, 2m\} - \{j, m + j\}$. The link outage capacity attains to

$$C_\varepsilon(\gamma(\theta_j))=\begin{cases}\log_2(1+\gamma_0 \ln \frac{1}{1-\varepsilon}) & \theta_j = 0\\ \frac{1}{2}\log_2(1+\ln \frac{1}{u_\varepsilon(\gamma(\theta_j))}) & 0 < \theta_j \leq m\\ \frac{1}{2}\log_2(1+\frac{1}{\frac{1}{\gamma_1}+\frac{1}{\gamma_2}}\ln\frac{1}{1-\varepsilon}) & m<\theta_j \leq 2m,\end{cases}$$

Herein, combines the three types of transmission protocols together. The case $\theta j = 0$ corresponds to direct transmissions. For the other two relaying cases, if θj is selected for cooperative relaying, $\theta j + m$ is the same selected relay node but for multi-hop relaying. In the smart selective decode-and-forward (SSDF) relaying, a relay is used only when relaying is beneficial. The case of not using the relay corresponds to the direct transmission. Distinct from SSDF, in addition to considering the cooperative transmission, the objective function of COCO extends the link wide behavior into a network-wide perspective by taking into account the interference. Based on the above discussion, the interference set of a link in MANETs with cooperative communications is equal to

$$I(\theta_j) = \begin{cases} I_{DT}(\theta_j), & \theta_j = 0\\ I_{CT}(\theta_j), & 0 < \theta_j \leq m\\ I_{MT}(\theta_j), & m < \theta_j \leq 2m.\end{cases}$$

Link data rate and interference are the primary factors which determine network capacity. Since the links in cooperative networks are determined by relay selection, on the basis of Definition 3 and the discussions in the objective function is set as follows to optimize network capacity,

$$f(\gamma(\boldsymbol{\theta})) = \sum_{j \in \mathcal{V}_N} \frac{C_\varepsilon(\gamma(\theta_j))}{|I(\theta_j)|}.$$

Assume that the MAC function can avoid interference among different adjacent links. Therefore, each node can independently determine its relay. The topology control formulation then is equivalent to

$$\theta * j = \arg\max \theta j \in \Theta j (\gamma(\theta j)), \text{ for all } j \; U \; \mathcal{V}N, \quad (16)$$

Where

$$g(\gamma(\theta_j)) = \frac{C_\varepsilon(\gamma(\theta_j))}{|I(\theta_j)|}.$$

As we can see from the above function, COCO determines the best type of transmission links and the best relay to optimize network capacity.

CHAPTER 4

ROUTING PROTOCOLS

4.1. OVERVIEW OF ROUTING PROTOCOL:

A routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network, the choice of the route being done by routing algorithms. Each router has a priori knowledge only of networks attached to it directly. A routing protocol shares this information first among immediate neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network.

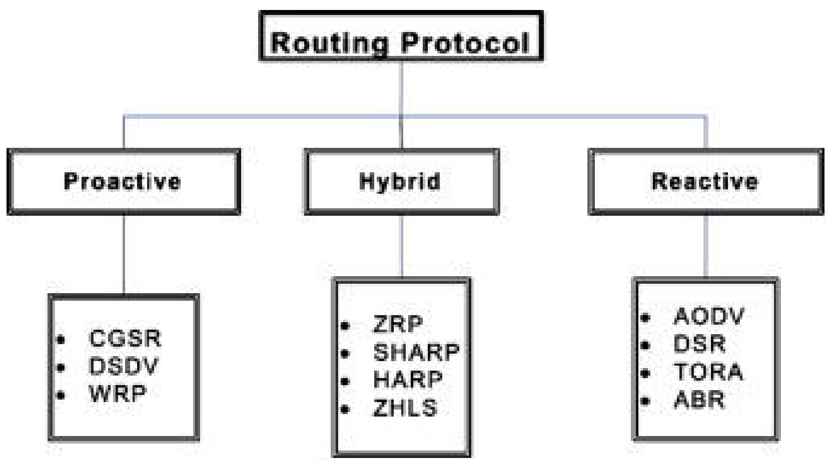

Fig 4.1 Block Diagram of Routing Protocols

Each node in the network maintains for each destination a preferred neighbor. Each data packet contains a destination node identifier in its header. When a node receives a data packet, it forwards the packet to the preferred neighbor for its destination. The forwarding process continues until the packet reaches its destination. The manner in which routing tables are constructed maintained and updated differs from one routing method to another. Popular routing methods however, attempt to achieve the common objective of routing packets along the optimal path. The next-hop routing methods can be categorized into two primary classes link-state and distance-vector.

4.2. LINK STATE:

The link-state approach is closer to the centralized version of the shortest path computation method. Each node maintains a view of the network topology with a cost for each link. To keep these views consistent each node periodically broadcasts the link costs of its outgoing links to all other nodes using a protocol such as flooding. As a node receives this information, it updates its view of the network topology and applies a shortest-path algorithm to choose its next hop for each destination, Some of the link costs in a node' s view can be incorrect because of long propagation delays, partitioned network, etc., Such inconsistent views of network topologies might lead to formation of routing loops. These loops, however, are short-lived, because they disappear in the time it takes a message to traverse the diameter of the network.

4.3. DISTANCE VECTOR:

In distance-vector algorithms, every node I maintains, for each destination x, a set of distances {dxij} where j ranges over the neighbors of i. Node I treats neighbor k as a next-hop for a packet destined for x if {dxik} equals minj {dxij}. The succession of next hops chosen in this manner, lead to x along the shortest path.

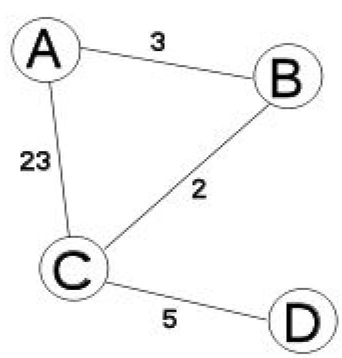

Fig 4.2 Example for Distance Vector

In order to keep the distance estimates up-to-date, each node monitors the cost of its outgoing links and periodically broadcasts, to each one its neighbors, its current estimate of the shortest distance to every other node in the network.

4.4. CATAGORIES OF EXISTING PROTOCOLS FOR MANET

Many protocols have been proposed for MANETs. These protocols can be divided into two categories: proactive, reactive. Proactive methods maintain routes to all nodes, including nodes to which no packets are sent. Such methods react to topology changes, even if no traffic is affected by the changes. They are also called table-driven methods. Reactive methods are based on demand for data transmission. Routes between hosts are determined only when they are explicitly needed to forward packets. Reactive methods are also called on-demand methods. They can significantly reduce routing overhead when the traffic is lightweight and the topology changes less dramatically, since they do not need to update route information periodically and do not need to find and maintain routes on which there is no traffic. Hybrid methods combine proactive and reactive methods to find efficient routes, without much control overhead.

4.4.1. PROACTIVE ROUTING PROTOCOLS

As stated earlier, proactive routing protocols maintain routes to all destinations, regardless of whether or not these routes are needed. In order to maintain correct route information, a node must periodically send control messages. Therefore, proactive routing protocols may waste bandwidth since control messages are sent out unnecessarily when there is no data traffic. The main advantage of this category of protocols is that hosts can quickly obtain route information and quickly establish a session. For example, GSR introduced below is a proactive routing protocol. Global State Routing (GSR) is based on the Link State (LS) routing method. In the LS routing method, each node floods the link state information into the whole network (global flooding) once it realizes that links change between itself and its neighbours. The link state information includes the delay to each of its neighbours. A node will know the whole topology when it obtains all link information. LS routing works well in networks with static topologies. When links change quickly, however, frequent global flooding will inevitably lead to huge control overhead.

Unlike the traditional LS method, GSR does not flood the link state packets. Instead, every node maintains the link state table based on up-to-date LS information received from neighbouring nodes, and periodically exchanges its LS information with its neighbours only (no global flooding). Before sending an LS packet, a node assigns the LS packet a unique sequence number to identify the newest LS information. LS information is disseminated as the LS packets with larger sequence numbers replace the ones with smaller sequence numbers. The convergence time required to detect a link change in GSR is shorter than in the Distributed Bellman-Ford (DBF) protocol. The convergence time in GSR is O(D*I) where D is the diameter of the network and I is the link state update interval. The convergence time is normally smaller than O(N*I) in DBF, where N is the number of nodes in the networks and I is the update interval. Since the global topology is maintained in every node, preventing routing loops is simple and easy.

The drawbacks of GSR are the large size of the update messages, which consume a considerable amount of bandwidth, and the latency of the LS information propagation, which depends on the LS information update interval time. ``Fisheye'' technology can be used to reduce the size of update messages. In this case, every node maintains highly accurate network information about the immediate neighbouring nodes, with progressively fewer details about farther nodes.

4.4.2. REACTIVE ROUTING PROTOCOLS

Reactive routing protocols can dramatically reduce routing overhead because they do not need to search for and maintain the routes on which there is no data traffic. This property is very appealing in the resource-limited environment.

CHAPTER 5

ADHOC ON-DEMAND DISTANCE VECTOR ROUTING

Ad hoc On-Demand Distance Vector (AODV) Routing is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad-hoc networks. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. In contrast, the most common routing protocols of the Internet are proactive, meaning they find routing paths independently of the usage of the paths.

5.1. WORKING OF AODV:

In AODV, the network is silent until a connection is needed. At that point the network node that needs a connection broadcasts a request for connection. Other AODV nodes forward this message, and record the node that they heard it from, creating an explosion of temporary routes back to the needy node. When a node receives such a message and already has a route to the desired node, it sends a message backwards through a temporary route to the requesting node.

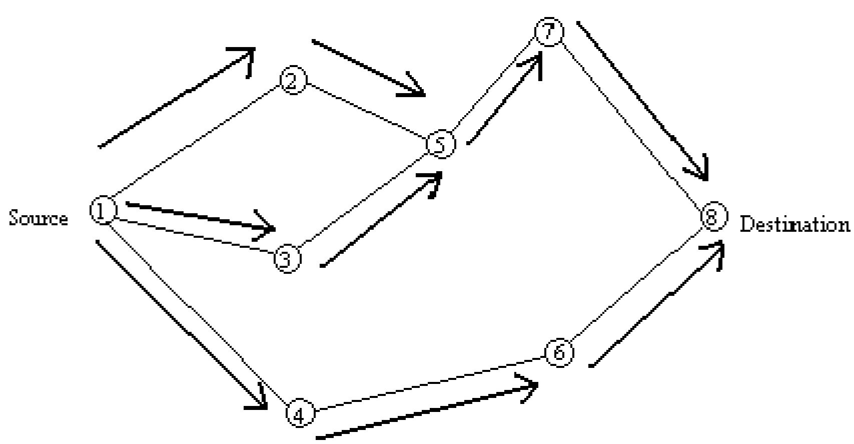

Fig 5.1 Propagation of Route Request Packet

The needy node then begins using the route that has the least number of hops through other nodes. Unused entries in the routing tables are recycled after a time. When a link fails, a routing error is passed back to a transmitting node, and the process repeats. Much of the complexity of the protocol is to lower the number of messages to conserve the capacity of the network.

Also, multiple Route Reply packets in response to a single Route Request packet can lead to heavy control overhead. Another disadvantage of AODV is unnecessary bandwidth consumption due to periodic beaconing.

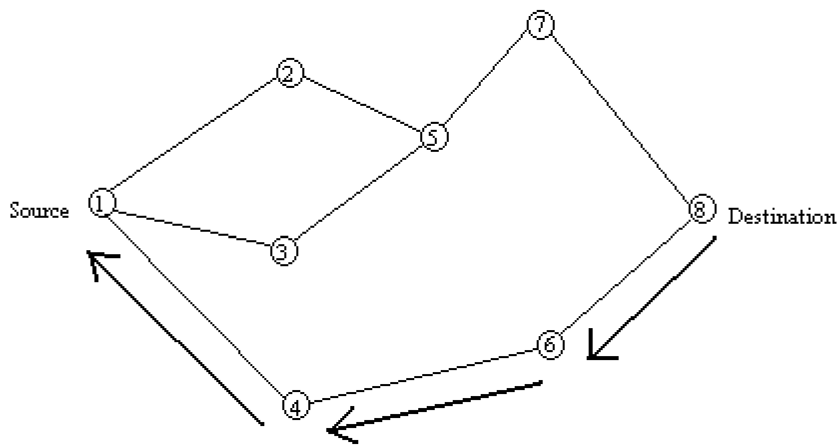

Fig 5.2 Path taken by the Route Reply Packet

5.2. PROTOCOL DESIGN:

Our implementation of AODV is based on a recent draft of the AODV specification.

· RREQ and RREP messages (for route discovery)

· RERR messages, HELLO messages, and precursor lists (for route maintenance)

· Sequence numbers

· Hop counts

· Expanding ring search

Some functionality described in the specification has been omitted, such as Gratuitous RREP messages, RREP acknowledgements, and multicast support, because they are either not essential to the algorithm, or inapplicable given our network model.

5.2.1. BASIC PROTOCOL:

Each AODV router is essentially a state machine that processes incoming requests from the SWANS network entity. When the network entity needs to send a message to another node, it calls upon AODV to determine the next-hop. Whenever an AODV router receives a request to send a message, it checks its *routing table* to see if a route exists. Each routing table entry consists of the following fields:

· Destination address

· Next hop address

· Destination sequence number

· Hop count

If a route exists, the router simply forwards the message to the next hop. Otherwise, it saves the message in a *message queue*, and then it initiates a route request to determine a route. The following flow chart illustrates this process:

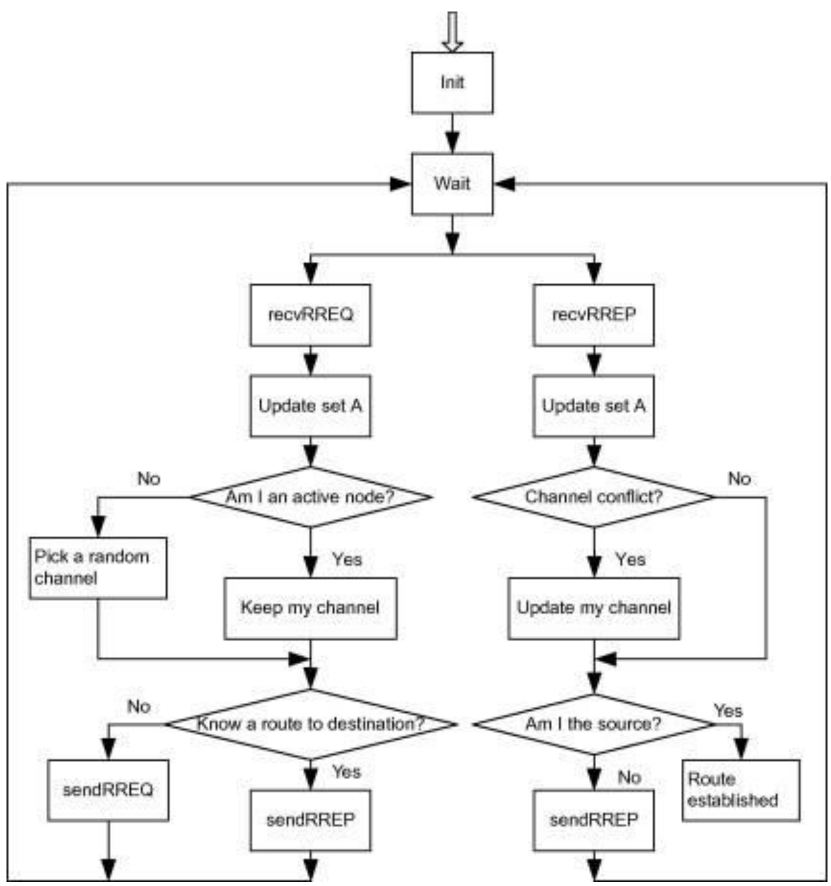

Fig 5.3 Flow Chart for AODV Protocol Design

5.3. ADVANTAGE AND DISADVANTAGE OF AODV

The advantage of AODV is that it creates no extra traffic for communication along existing links. Also, distance vector routing is simple, and doesn't require much memory or calculation. However AODV requires more time to establish a connection, and the initial communication to establish a route is heavier than some other approaches. The main advantage of this protocol is having routes established on demand and that destination sequence numbers are applied for find the latest route to the destination. The connection setup delay is lower.

One disadvantage of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries.

CHAPTER 6

DESTINATION SEQUENCED DISTANCE VECTOR ROUTING

6.1. OVERVIEW OF DSDV:

Destination-Sequenced Distance-Vector Routing (DSDV) is a table-driven routing scheme for ad hoc mobile networks based on the Bellman-Ford algorithm. The main contribution of the algorithm was to solve the routing loop problem. Each entry in the routing table contains a sequence number, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination, and the emitter needs to send out the next update with this number.

Routing information is distributed between nodes by sending *full dumps* infrequently and smaller incremental updates more frequently. Packets are transmitted between the stations of the network by using routing tables which are stored at each station of the network. Each routing table, at each of the stations, lists all available destinations, and the number of hops to each. Each route table entry is tagged with a sequence number which is originated by the destination station. To maintain the consistency of routing tables in a dynamically varying topology, each station periodically transmits updates, and transmits updates immediately when significant new information is available.

6.2. WORKING OF DSDV:

Our proposed routing method allows a collection of mobile computers, which may not be close to any base station and can exchange data along changing and arbitrary paths of interconnection, to afford all computers among their number a (possibly multi-hop) path along which data can be exchanged. In addition, our solution must remain compatible with operation in cases where a base station is available. By the methods outlined in this paper not only will routing be seen to solve the problems associated with ad-hoc networks, but in addition we will describe ways to perform such routing functions at Layer 2, which traditionally has not been utilized as a protocol level for routing. Since we do not assume that the mobile hosts are maintaining any sort of time synchronization, we also make no assumption about the phase relationship of the update periods between the mobile hosts. These packets indicate which stations are accessible from each station and the number of hops necessary to reach these accessible stations, as is often done in distance-vector routing algorithms. It is not the purpose of this paper to propose any new metrics for route selection other than the freshness of the sequence numbers associated with the route; cost or other metrics might easily replace the number of hops in other implementations. The packets may be transmitted containing either layer 2 (MAC) addresses or layer 3 (network) addresses. Routing information is advertised by broadcasting or multicasting the packets which are transmitted periodically and incrementally as topological changes are detected - for instance, when stations move within the network. Data is also kept about the length of time between arrival of the first and the arrival of the best route for each particular destination. Based on this data, a decision may be made to delay advertising routes which are about to change soon, thus damping fluctuations of the route tables. The advertisement of routes which may not have stabilized yet is delayed in order to reduce the number of rebroadcasts of possible route entries that normally arrive with the same sequence number.

The DSDV protocol requires each mobile station to advertise, to each of its current neighbors, its own routing table (for instance, by broadcasting its entries). The entries in this list may change fairly dynamically over time, so the advertisement must be made often enough to ensure that every mobile computer can almost always locate every other mobile computer of the collection. In addition_ each mobile computer agrees to relay data packets to other computers upon request. This agreement places a premium on the ability to determine the shortest number of hops for a route to a destination we would like to avoid unnecessarily disturbing mobile hosts if they are in sleep mode. In this way a mobile computer may exchange data with any other mobile computer in the group even if the target of the data is not within range for direct communication. If the notification of which other mobile computers are accessible from any particular computer in the collection is done at layer 2, then DSDV will work with whatever higher layer (e.g., Network Layer) protocol might be in use.

All the computers interoperating to create data paths between themselves broadcast the necessary data periodically, say once every few seconds. In a wireless medium, it is important to keep in mind that broadcasts are limited in range by the physical characteristics of the medium. This is different than the situation with wired media, which usually have a much more, well defined range of reception. The data broadcast by each mobile computer will contain its new sequence number and the following information for each new route:

• The destination's address

• The number of hops required to reach the destination and

• The sequence number of the information received regarding that destination, as originally stamped by the destination

This total paper is practically applied using the specifications that are defined through Highly Dynamic Destination Sequenced Distance Vector Routing Algorithm.

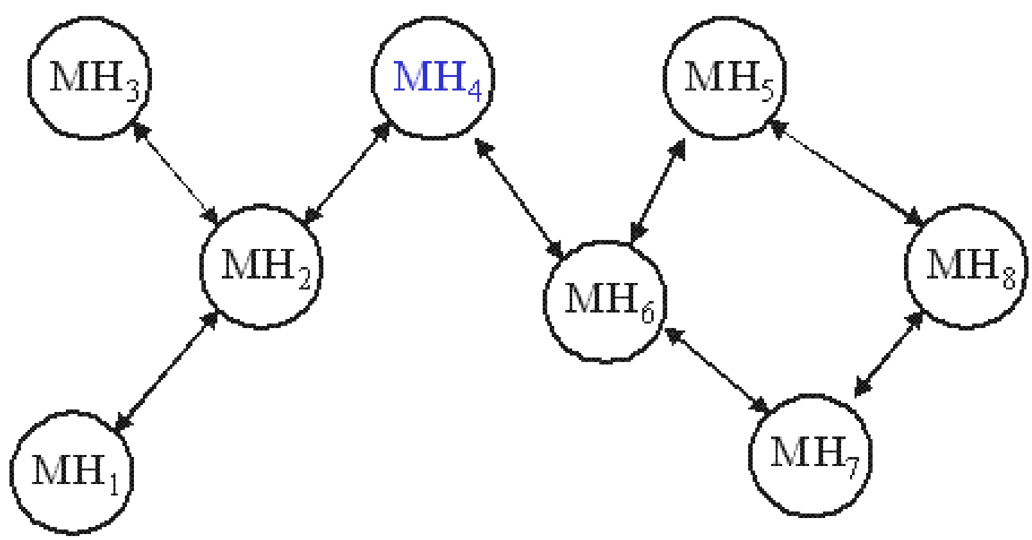

Fig 6.1 Example of DSDV Operation

TABLE .6.1 THE ROUTING TABLE FOR THE ABOVE POSITION OF NODES

Destination	**Next Hop**	**Metric**	**Seq. No**
MH4	MH4	0	S406_MH4
MH1	MH2	2	S128_MH1
MH2	MH1	1	S564_MH2
MH3	MH2	2	S710_MH3
MH5	MH6	2	S392_MH5
MH6	MH6	1	S076_MH6
MH7	MH6	2	S128_MH7
MH8	MH6	3	S050_MH8

6.2.1. SELECTION OF ROUTE:

If a router receives new information, then it uses the latest sequence number. If the sequence number is the same as the one already in the table, the route with the better metric is used. Stale entries are those entries that have not been updated for a while. Such entries as well as the routes using those nodes as next hops are deleted.

6.3. DISADVANTAGE

DSDV requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle. Whenever the topology of the network changes, a new sequence number is necessary before the network re-converges; Thus, DSDV is not suitable for highly dynamic networks. (As in all distance-vector protocols, this does not perturb traffic in regions of the network that are not concerned by the topology change.)

CHAPTER 7
DYNAMIC SOURCE ROUTING

'Dynamic Source Routing' (**DSR**) is a routing protocol for wireless mesh networks. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. However, it uses source routing instead of relying on the routing table at each intermediate device.

7.1. ROUTING IN DSR

Determining source routes requires accumulating the address of each device between the source and destination during route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets. To accomplish source routing, the routed packets contain the address of each device the packet will traverse. This may result in high overhead for long paths or large addresses, like IPv6. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be forwarded on a hop-by-hop basis.

This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply). To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Request message header (this requires that all links are symmetric). In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. Again, the Route Discovery Phase is initiated to determine the most viable route.

7.2.FLOW OF DSR ALGORITHM:

There are two basic parts of DSR protocol: route discovery and route maintenance. Every node maintains a cache to store recently discovered paths. When a node wants to send a packet to a particular node, it first checks the cache whether there is an entry for that. If yes then it uses that path to transmit the packet. Also it attaches its source address on the packet. If there is no entry in the cache or the entry is expired (due to long time unused), the sender broadcasts a route request packet to all its neighbors
asking for a path to the destination.

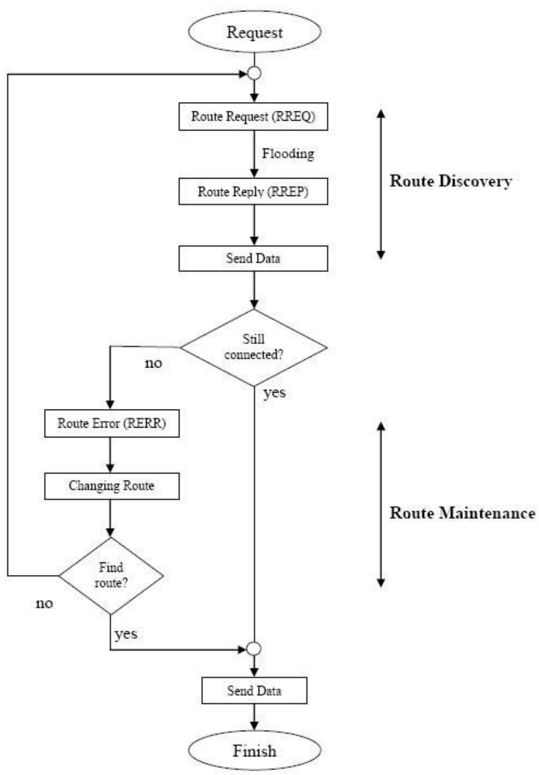

Fig 7.1 Flow Chart for DSR

Until the route is discovered, the sender host will be waiting and during this time it can do other things like sending other packets or forwarding other packets. When the route request packet arrives to any other nodes, they check whether they know the destination asked (may be from neighbor or from their caches). If they have route information, they send back a route reply packet to the destination. Otherwise they broadcast the same route request packet. Once the route is discovered, the sender will send its required packets using the discovered route as well as insert an entry in the cache for future use. Also the node keeps the age information of the entry to recognize whether the cache is fresh or not.

When any intermediate node receives a data packet, it first sees whether the packet is sent to itself or not. If it is the destination, it receives that. Or it forwards the packet using the path attached on the packet. As ad-hoc network is very promiscuous, anytime any link might fail. So route maintenance process monitors and notifies the nodes if there is any failure in the path. And accordingly the nodes change the entries of their route cache.

7.3. ADVANTAGE AND DISADVANTAGE

This protocol uses a reactive approach which eliminates the need to periodically flood the network with table update messages which are required in a table-driven approach. In a reactive (on-demand) approach such as this, a route is established only when it is required and hence the need to find routes to all other nodes in the network as required by the table-driven approach is eliminated. The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead.

The disadvantage of this protocol is that the route maintenance mechanism does not locally repair a broken link. Stale route cache information could also result in inconsistencies during the route reconstruction phase. The connection setup delay is higher than in table-driven protocols. Even though the protocol performs well in static and low-mobility environments, the performance degrades rapidly with increasing mobility. Also, considerable routing overhead is involved due to the source-routing mechanism employed in DSR.

CHAPTER 8
NETWORK SIMULATOR

NS - Network Simulator is a name for series of discrete event network simulators, specifically ns-1, ns-2 and ns-3. All of them are discrete-event network simulator, primarily used in research and teaching. ns-3 is free software, publically available under the GNU GPLv2 license for research, development, and use.

8.1. PURPOSE OF USING NS-2:

The goal of the ns-2 project is to create an open simulation environment for networking research that will be preferred inside the research community; this mainly means two things:

- It should be aligned with the simulation needs of modern networking research and
- It should encourage community contribution, peer review, and validation of the software.

Since the process of creation of a network simulator that contains a sufficient number of high-quality validated, tested and actively maintained models requires a lot of work, ns-2 project spreads this workload over a large community of users and developers. The core of ns-2 is also written in C++, but the C++ simulation objects are linked to shadow objects in OTcl and variables can be linked between both language realms. Simulation scripts are written in the OTcl language, an extension of the Tcl scripting language. This structure permits simulations to be written and modified in an interpreted environment without having to resort to recompiling the simulator each time a structural change is made. In the timeframe in which ns-2 was introduced , this provided both a significant convenience in avoiding many time-consuming recompilations, and also allowing potentially easier scripting syntax for describing simulations. ns-2 has a companion animation object known as the Network Animator, nam-1, originally written by Mark Handley, used for visualization of the simulation output and for (limited) graphical configuration of simulation scenarios. Presently, ns-2 consists of over 300,000 lines of source code, and there is probably a comparable amount of contributed code that is not integrated directly into the main distribution (many forks of ns-2 exist, both maintained and unmaintained). It runs on Linux, FreeBSD, Solaris and Mac OS X. It is licensed for use under version 2 of the GNU General Public License.

8.1.1. LANGUAGES USED IN NS-2:

- C++: Detailed protocol simulations require systems programming language
  - – byte manipulation, packet processing, algorithm implementation
  - – Run time speed is important
  - – Turnaround time (run, find bug, fix bug, recompile, re-run) is slower
- Tcl: Simulation of slightly varying parameters or configurations
  - – Quickly exploring a number of scenarios
  - – Iteration time (change the model and re -run) is more important

8.1.2. OTHER NETWORK SIMULATORS:

➢ OPNET

• Leading Commercial Software

• Support Windows and UNIX

• Graphical Interface

• Not free

➢ GloMoSim

• Simulation environment for wireless network

• Scalable to support thousands of nodes

• Using layered approach to build different simulation layers

• Free for educational users

8.2. STEPS TO CREATE TCL SCRIPT:

8.2.1. BASIC NS-2:

• Create a new simulator object

• [Turn on tracing] – [Open your own trace files]

• Create network (physical layer)

• Create link and queue (data-link layer)

• Define routing protocol

• Create transport connection (transport layer)

• Create traffic (application layer)

• Insert errors

8.2.1. CREATING SIMULATOR INSTANCE:

• Create simulator instance set ns [new Simulator]

- Usually the first non-comment statement in ns-2 script

- Initialize the packet format

- Create a scheduler (default is a calendar scheduler)

- Create a “null agent”

8.2.2. TURNING ON A TRACEFILE:

• Open file for NS tracing

set f [open out.tr w]

$ns trace-all $f

• Open file for nam tracing

set nf [open out.nam w]

$ns namtrace-all $nf

• Open your own trace file

set my_f [open my_out.tr w]

puts $my_f “[$ns now] [expr $x(1) + $y(1)]”

8.2.3. CREATING A NETWORK:

• Creating nodes

set node_(h1) [$ns node]

set node_(h2) [$ns node]

set node_(r1) [$ns node]

set node_(r2) [$ns node]

set node_(h3) [$ns node]

set node_(h4) [$ns node]

• Creating Link and Queue

$ns duplex-link $node_(h1) $node_(r1)

10Mb 2ms DropTail

$ns duplex-link $node_(h2) $node_(r2)

10Mb 3ms DropTail

$ns duplex-link $node_(r1) $node_(r2)

1.5Mb 20ms DropTail

$ns queue-limit $node_(r1) $node_(r2) 50

8.2.4. INSERT ERRORS:

set loss_module [new ErrorModel]

$loss_module set rate_ 0.01

$loss_module unit pkt

$loss_module ranvar [new

RandomVariable/Uniform]

$loss_module drop-target [new Agent/Null]

$ns lossmodel $loss_module $n0 $n1

Start/Stop ns

• Schedule an event to start traffic at time 1.0

$ns at 1.0 "$ftp0 start“

• Schedule an event to stop ns at time 17.0

$ns at 17.0 "$ftp0 stop“

• Start ns

$ns run

- last statement

• Stop ns

exit 0

8.2.5. VISUALIZATION TOOL NAM:

• Replay events from a nam trace file

• The nam trace file can be huge when simulation time is long or events happen intensively.

• Run nam:

– $nam –a nam_trace_file.nam

– In ns-2 script:

Proc finish{} {

……

exec nam –a nam_trace_file.nam &

exit

8.2.6. PLOTS USING XGRAPH:

• Create your own output files

• Collect statistical data synchronized.

• Run xgraph:

– $xgraph out0.tr, out1.tr –geometry 800x400

– In ns-2 script:

Proc finish{} {

……

exec xgraph out0.tr, out1.tr out2.tr –geometry

800x400 &

exit }

CHAPTER 9

SIMULATION RESULTS OF AODV,DSDV AND DSR

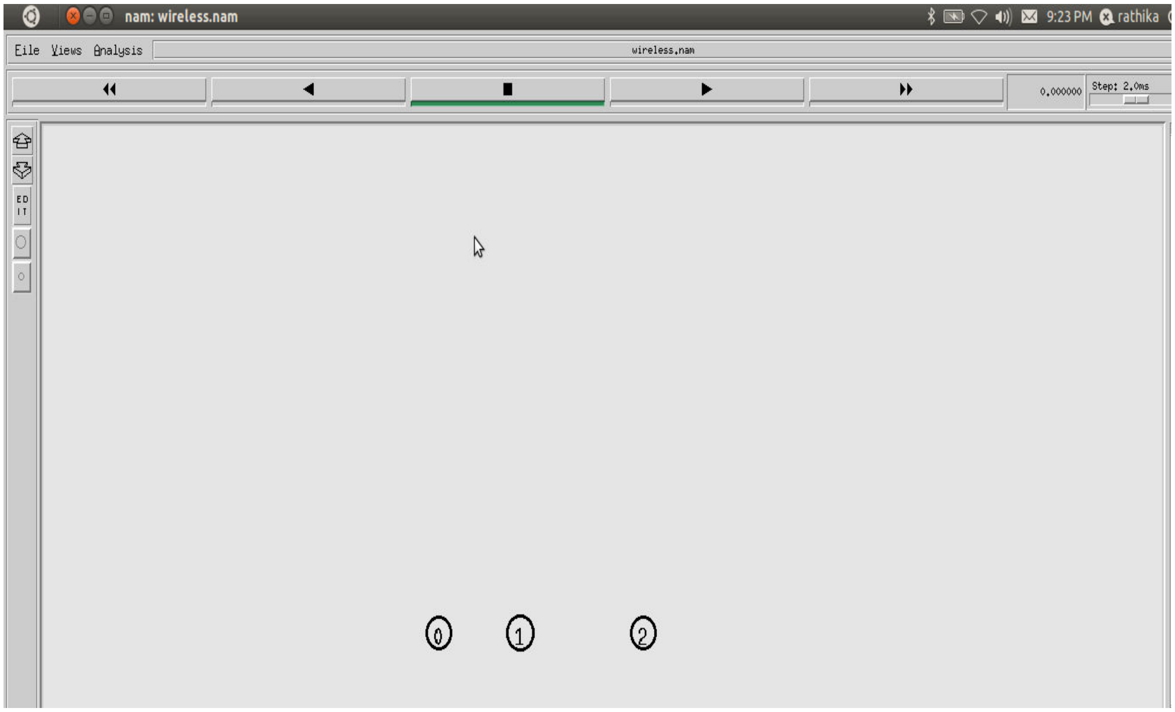

Fig 9.1 CREATION OF NODES

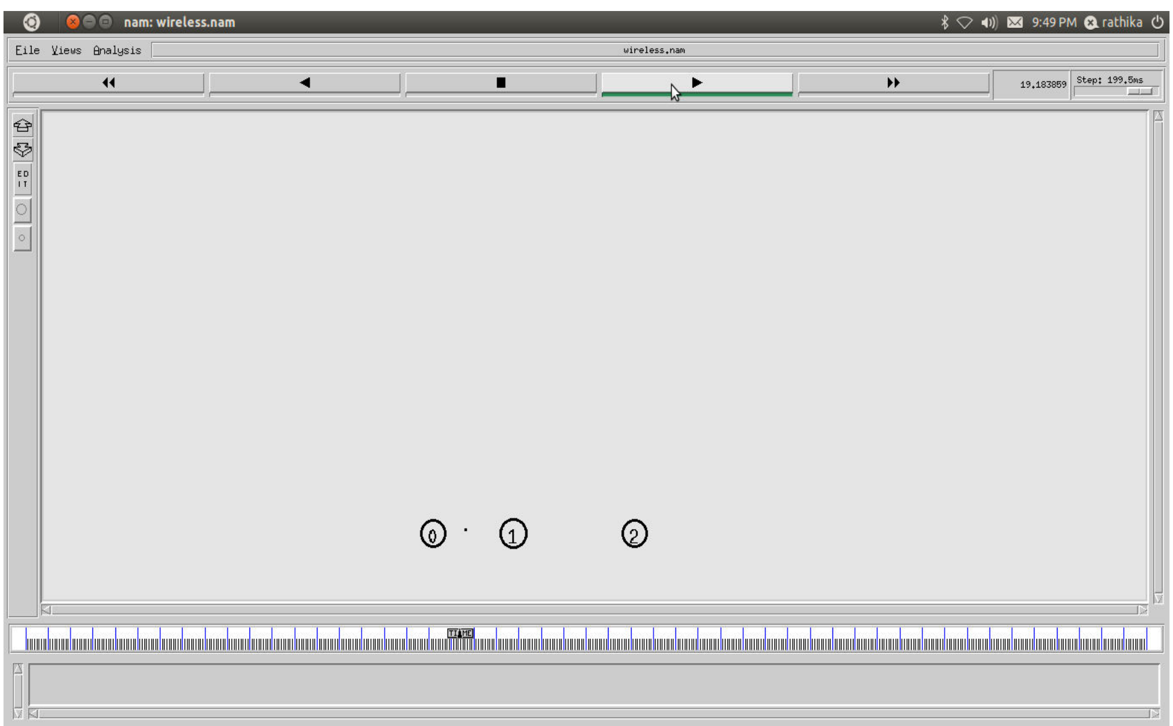

Fig 9.2.TRANSMISSION OF PACKETS USING UDP

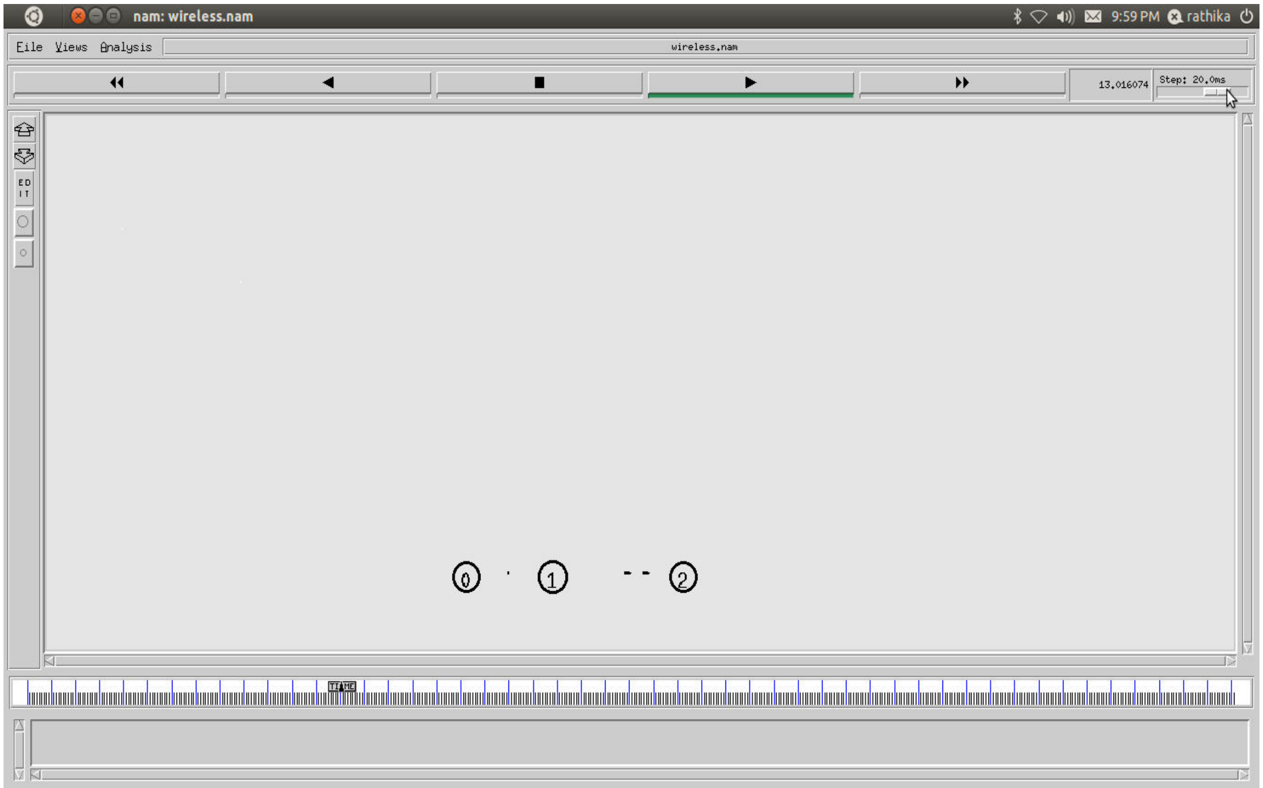

Fig 9.3.TRANSMISSION OF PACKETS USING TCP

TABLE NO 9.1 PERFORMANCE OF AODV:

NO OF NODES	PACKET DELIVERY RATIO	END TO END DELAY
20	99.7953	0.00897853
30	99.5906	0.0139414
40	99.8976	0.011977
50	99.2835	0.0120311

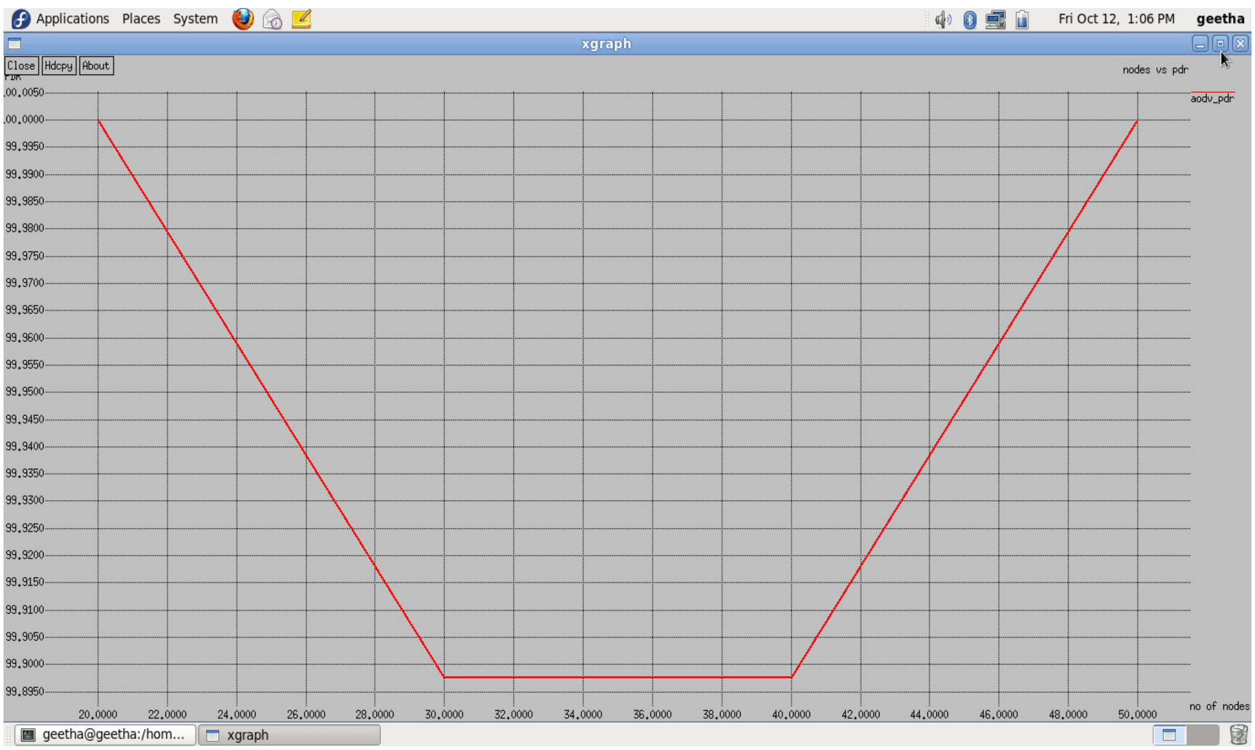

Fig 9.4.NODES VERSUS PDR IN AODV

TABLE NO 9.2 PERFORMANCE OF DSDV:

NO OF NODES	PACKET DELIVERY RATIO	END TO END DELAY
20	98.9949	0.00592228
30	97.9734	0.0119412
40	99.4186	0.0120424
50	99.3265	0.0059386

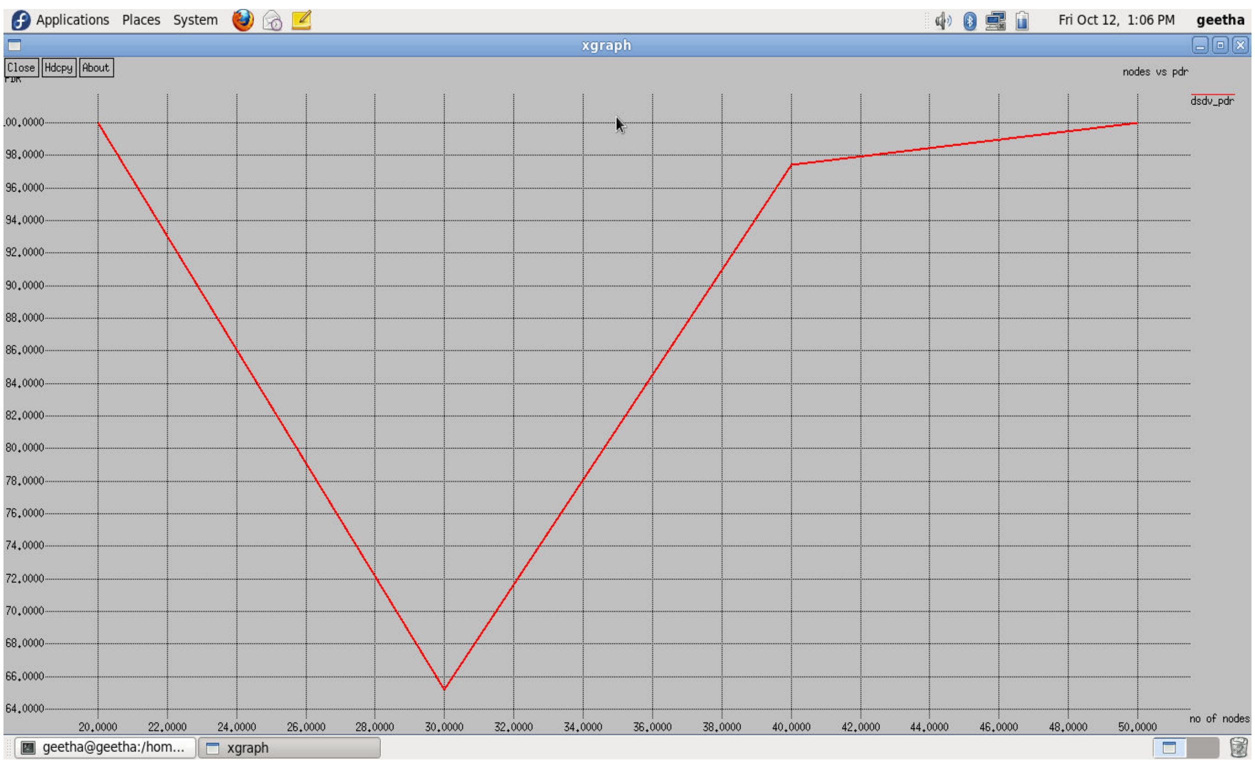

Fig 9.5.NODES VERSUS PDR IN DSDV

TABLE NO 9.3 PERFORMANCE OF DSR:

NO OF NODES	PACKET DELIVERY RATIO	END TO END DELAY
20	99.6257	0.012412
30	99.4358	0.0139956
40	98.3383	0.106257
50	99.8084	0.00583561

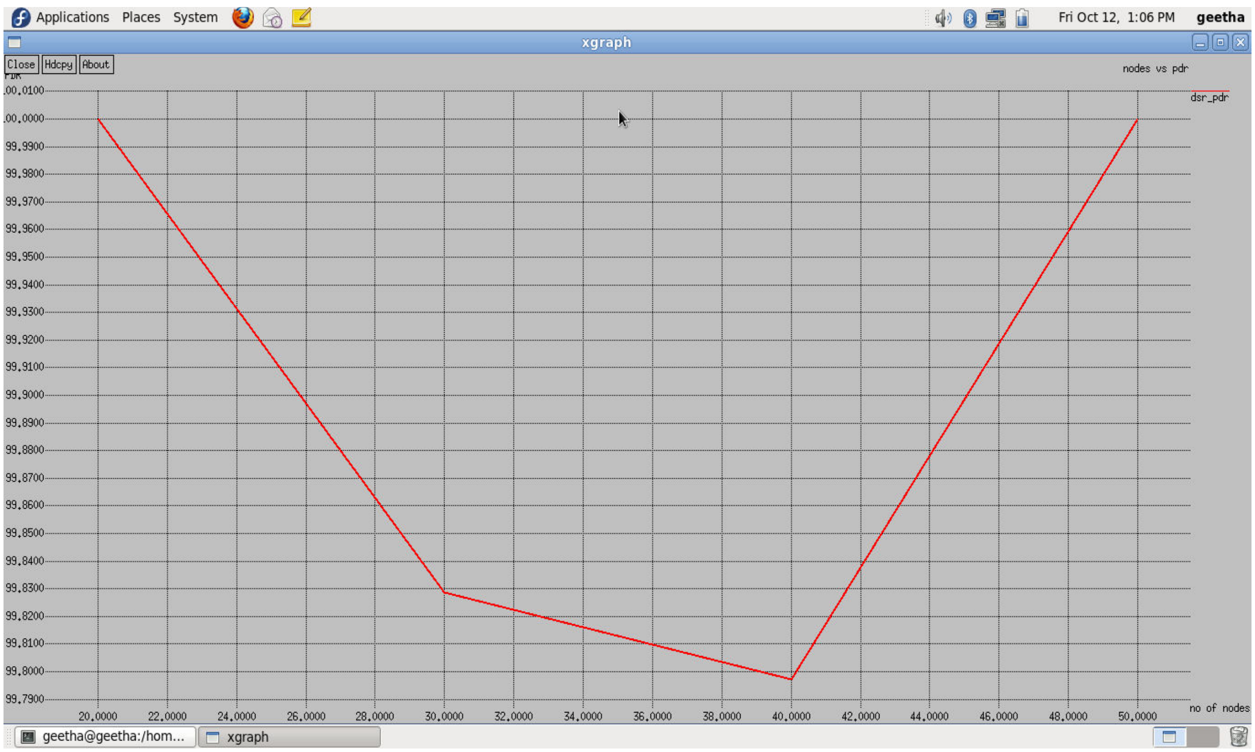

Fig 9.6.NODES VERSUS PDR IN DSR

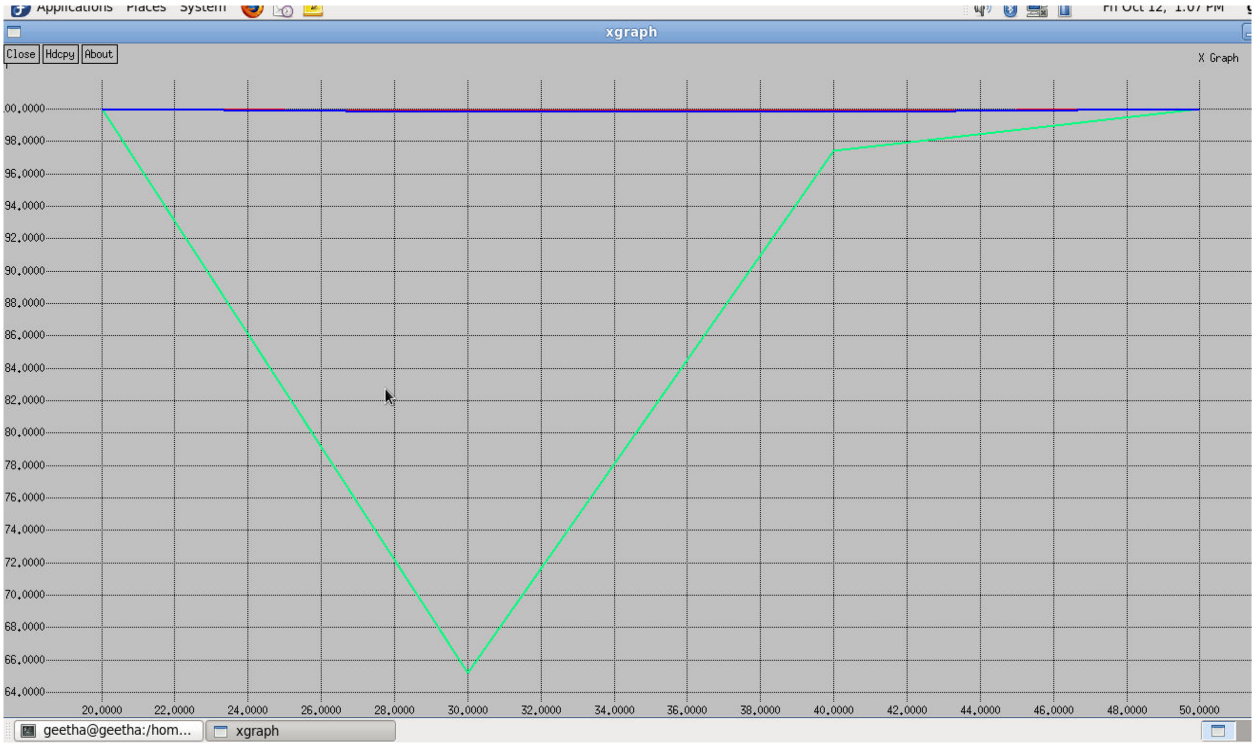

Fig 9.7.COMPARISON OF AODV, DSDV, DSR

Here, we have analyzed various existing routing protocols by measuring the packet delivery ratio, end to end delay with respect to varying number of nodes. Thus, from the above simulation results we conclude that DSR has better performance when compared to the other protocols .In DSR, a route is established only when it is required and hence the need to find routes to all other nodes in the network as required by the table-driven approach is eliminated. The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead.

CONCLUSION

In this project, we have introduced physical layer cooperative communications, topology control, and network capacity in MANETs. To improve the network capacity of MANETs with cooperative communications, we have proposed a Capacity- Optimized Cooperative (COCO) topology control scheme that considers both upper layer network capacity and physical layer relay selection in cooperative communications. Simulation results have shown that physical layer cooperative communications techniques have significant impacts on the network capacity, and the proposed topology control scheme can substantially improve the network capacity in MANETs with cooperative communications. In phase I , we have analyzed various existing routing protocols by measuring the packet delivery ratio, end to end delay with respect to varying number of nodes. In phase II, we will calculate the power considerations of MANETs in the physical layer and develop the proposed Topology Control scheme to improve the Network Capacity in MANETs with cooperative communication. The project can be further enhanced by considering dynamic traffic patterns in the proposed scheme to further improve the performance of MANETs with cooperative communications.

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ANNEXURE-I

```
set val(x)      500
set val(y)      500
set val(nn)     3
set val(stop) 200.0
set val(routing) AODV
set ns_                 [new Simulator]
set topo        [new Topography]
$topo load_flatgrid $val(x) $val(y)
set tracefd     [open wireless.tr w]
$ns_ trace-all $tracefd
$ns_ use-newtrace
set namtrace            [open wireless.nam w]
$ns_ namtrace-all-wireless $namtrace $val(x) $val(y)
set god_ [create-god $val(nn)]
$ns_ node-config -adhocRouting $val(routing) \
                        -llType LL \
                        -macType Mac/802_11 \
                -ifqType Queue/DropTail/PriQueue \
                -ifqLen 50 \
                -antType Antenna/OmniAntenna \
                -propType Propagation/TwoRayGround \
                -phyType Phy/WirelessPhy \
                -channelType Channel/WirelessChannel \
                -topoInstance $topo \
                -agentTrace ON \
                -routerTrace ON \
```

```
                    -macTrace OFF
for {set i 0} {$i < $val(nn) } {incr i} {
          set node_($i) [$ns_ node]
}
$node_(0) set X_ 50.0
$node_(0) set Y_ 50.0
$node_(0) set Z_ 0.0
$node_(1) set X_ 150.0
$node_(1) set Y_ 50.0
$node_(1) set Z_ 0.0
$node_(2) set X_ 300.0
$node_(2) set Y_ 50.0
$node_(2) set Z_ 0.0
for {set i 0} {$i < $val(nn) } {incr i} {
          $ns_ initial_node_pos $node_($i) 30
}
$ns_ at $val(stop).000 "$ns_ halt"
$ns_ run
set udp0 [new Agent/UDP]
$ns_ attach-agent $node_(0) $udp0
set null0 [new Agent/Null]
$ns_ attach-agent $node_(1) $null0

$ns_ connect $udp0 $null0
set cbr0 [new Application/Traffic/CBR]
$cbr0 attach-agent $udp0
$cbr0 set packetSize_ 512
$cbr0 set rate_ 100Kb
```

```
$ns_ at 10.0 "$cbr0 start"
$ns_ at 50.0 "$cbr0 stop"
set tcp0 [new Agent/TCP]
$ns_ attach-agent $node_(1) $tcp0
set sink0 [new Agent/TCPSink]
$ns_ attach-agent $node_(2) $sink0

$ns_ connect $tcp0 $sink0
set ftp0 [new Application/FTP]
$ftp0 attach-agent $tcp0
$ns_ at 10.0 "$ftp0 start"
$ns_ at 50.0 "$ftp0 stop"
$ns_ at 3.0 "$node_(2) setdest 450 100 50"
$ns_ at 3.0 "$node_(1) setdest 250 100 50"
```

- Setdest –n 20 –p 10 –M 20 –t 200 –x 500 –y 500 >scen-50-20
- Setdest –n 30 –p 10 –M 20 –t 200 –x 500 –y 500 >scen-50-30
- Setdest –n 40 –p 10 –M 20–t 200 –x 500 –y 500 >scen-50-40
- Setdest –n 50 –p 10 –M 20 –t 200 –x 500 –y 500 >scen-50-50

s –t 163.001503520 –Hs 0 –Hd -2 –Ni 0 –Nx 300.00 –Ny 500.00 –Nz 0.00 –Ne -1.000000 -Nl AGT –Nw --- -Ma 0 –Md 0 –Ms 0 –Mt 0 –Is 0.0 –Id 2.0 –It cbr –ll 200 –If 1 –Ii 77 –Iv 32 –Pn cbr –Pi 32 –Pf 0 –Po 0