INTER PROTOCOL SWITCHING FOR EFFICIENT BROADCASTING IN MANET's

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
COMPUTER SCIENCE AND ENGINEERING

By

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JUNE, 2008

CANDIDATE'S DECLARATION

I here by declare that the work which is being presented in this dissertation entitled **"INTERPROTOCOL SWITCHING FOR EFFICIENT BROADCASTING IN MANET'S"** in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **Computer Science & engineering**, submitted in the Department of Electronics and Computer Engineering of the Indian Institute of Technology Roorkee, Roorkee, is an authentic record of my work carried out for a period from June 2007 to June 2008, under the supervision and guidance of **Dr. Kuldip Singh.**

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

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Place: Roorkee

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

All endeavors over a long period can be successful only with the support of many well-wishers; I take this opportunity to express my gratitude and appreciation to all of them.

It is my privilege and pleasure to express my profound sense of respect, gratitude and indebtedness to my supervisor **Dr. Kuldip Singh,** Professor, Department of Electronics and Computer Engineering, Indian Institute of Technology, Roorkee, for his inspiration, guidance, constructive criticisms and encouragement during the entire course of this work. His cooperation and in depth knowledge have made my work possible.

I am greatly indebted to my parents, who have graciously applied themselves to the task of helping me with ample moral support and valuable suggestions. Finally, I would like to extend my gratitude to my friends and all others who directly or indirectly helped me in the process and contributed towards this work.

(DRONA PRATAP CHANDU)

ABSTRACT

Broadcasting, the process in which one MN sends a packet to all the other nodes in the network, functions as a foundation of MANET communication. A number of unicast, multicast, and geocast protocols utilize broadcasting as a building block, providing important control and route establishment functionality. Therefore, any improvements to the process of broadcasting can be immediately realized by several MANET applications. Several efficient broadcast protocols have been proposed, but previous research based on simulation discovered that no single protocol for broadcasting works well in all possible network conditions in a MANET. Furthermore, each of the protocols fails catastrophically when the severity of the network environment is increased.

A new broadcast protocol have been developed and presented in this thesis. Two broadcast protocols Ad hoc broadcast protocol (AHBP) and Light weight efficient network wide broadcasting (LENWB) were simulated under wide range of conditions. A new protocol that switches between AHBP and LENWB depending on congestion and speed was developed and the switching protocol that switches between AHBP and LENWB has better delivery ratio than AHBP and LENWB.

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Overview of MANET'S

A wireless mobile ad hoc network consists of mobile nodes that are interconnected by wireless-multi-hop communication paths. These ad hoc wireless networks are self-creating, self-organizing, and self-administering. *Figure 1.1* depicts a sample mobile ad hoc network.

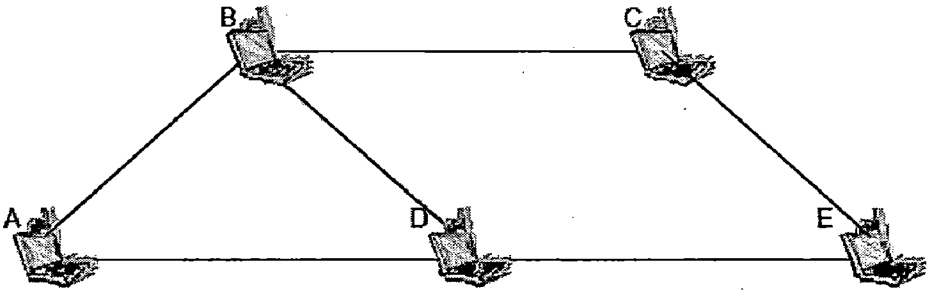

Figure 1.1 *A sample ad hoc netork consisting of mobile nodes*

These mobile ad hoc networks offer unique benefits and versatility for certain environments and applications. With no prerequisites of fixed infrastructure or base stations, they can be created and used anytime, anywhere. Such networks could be intrinsically fault-resilient, for they do not operate under the limitations of a fixed topology. Since all nodes are allowed to be mobile, the topology of such networks is necessarily time varying. The addition and deletion of nodes occur only by interactions with other nodes. Thus these types of networks offer many advantages where setting up wired- line networks is not feasible. Such advantages attracted immediate interest in its early use among military, police, and rescue agencies, and especially under disorganized or hostile environments, including isolated scenes of natural disaster and armed conflict.

Recently, home or small-office networking and collaborative computing with laptop computers in a small area (e.g., a conference or classroom, single building, convention center, etc.) have emerged as other major areas of application. In addition, people have recognized from the beginning that ad hoc networking has an obvious, potential use in all the traditional areas of interest for mobile computing.

This concept of mobile ad hoc networking emerged as an attempt to extend the services provided by the traditional Internet to the wireless mobile environment. All current works, as well as our research here, consider the ad hoc networks as a wireless extension to the Internet, based on the ubiquitous IP networking mechanisms and protocols. Today's Internet possesses an essentially static infrastructure where network elements are interconnected over traditional wire- line technology, and these elements, especially the elements that provide the routing or switching functions, do not move. In a mobile ad hoc network, by definition, all the network elements move. As a result, numerous more stringent challenges must be overcome to realize the practical benefits of ad hoc networking.

In addition, the mobility of nodes imposes limitations on their power capacity, and hence, on their transmission range. These nodes must often also satisfy stringent weight limitations for portability. Further these mobile hosts are no longer just end systems; they are also required to relay packets generated by other nodes, hence each node must also be able to function as a router. As the nodes move in and out of range with respect to each other, including those that are operating as routers, the resulting topology needs to be communicated to all other nodes as appropriate to maintain the connectivity information.

In accommodating the communication needs of the user applications, the limited bandwidth of wireless channels and their generally- hostile transmission characteristics, impose additional constraints on how much administrative and control information may be exchanged, and how often. Ensuring effective routing is one of the major challenges for ad hoc networking. As these mobile ad hoc networks are being increasingly considered for more and more complex applications, the various Quality of Service (QoS) attributes for these applications must also be satisfied as a set of pre-determined service requirements. In addition, because of the increasing use of the ad hoc networks for military/police use, and also due to the increasing commercial applications being envisioned to be supported on these type of networks, various security issues also need to be addressed. These issues, however, are out of the scope of this thesis.

1.2 MANET: Operating Principles

To illustrate the general operating principles of a mobile ad hoc network, consider *figure 1.2,* which depicts the peer-level, multi-hop representation of a sample ad hoc network. Here, mobile node A communicates directly (single-hop) with another such node B whenever a radio channel with adequate propagation characteristics is available between them. Otherwise, multi-hop communication is necessary where one or more intermediate nodes must act as a relay (router) between the communicating nodes. For example, there is no direct radio channel (shown by the lines) between A and C or between A and E as shown in *figure* 1.2. Nodes B and D must serve as intermediate routers for communication between A and C, and between A and E, respectively. Thus, a distinguishing feature of ad hoc networks is th at all nodes must be able to function as routers on demand along with acting as source and destination for packets. To prevent packets from traversing infinitely long paths, an obvious essential requirement for choosing a path is that it must be loop-free. And this loop- free path between a pair of nodes is called a route.

An ad hoc network begins with at least two nodes, broadcasting their presence(*beaconing*) with their respective address information. If node A is able to establish direct communication with node B as in *figure 1.2,* verified by exchanging suitable control messages between them, they both update their routing tables. When a third node C joins the network with its beacon signal, two scenarios are possible.

The first is where both A and B determine that single-hop communication with C is feasible. The second is where only one of the nodes, say B, recognizes the beacon signal from C and establishes direct communication with C. The distinct topology updates, consisting of both address and route updates, are made available in all three nodes immediately afterwards. In the first case, all routes are direct. For the other, the route update first happens between B and C, then between B and A, and then again between B and C, confirming the mutual reachability between A and C via B.

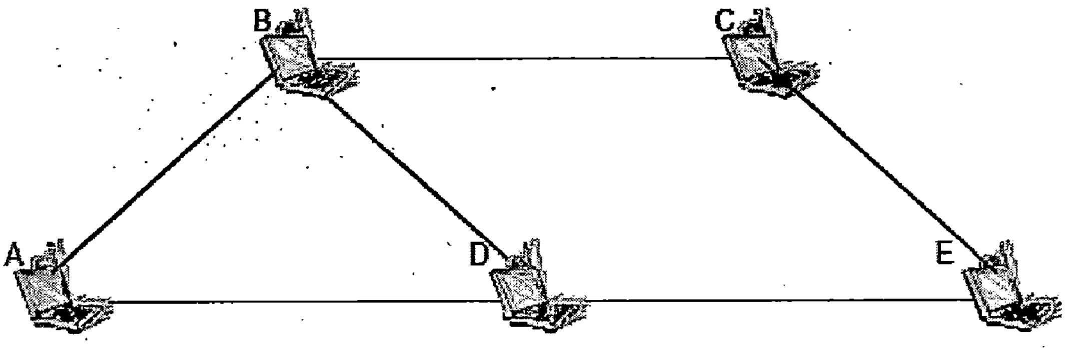

Figure 1.2 *Example of an ad hoc network*

The distinct topology updates, consisting of both address and route updates, are made available in all three nodes immediately afterwards. In the first case, all routes are direct. For the other, the route update first happens between B and C, then between B and A, and then again between B and C, confirming the mutual reachability between A and C via B.

As the node moves, it may cause the reachability relations to change in time, requiring route updates. Assume that, for some reason, the link between B and C is no longer available as shown in *figure 1.3* . Nodes A and C are still reachable from each other, although this time only via nodes D and E. Equivalently, the original loop- free route $C\ B$ $A \leftrightarrow \leftrightarrow$ is now replaced by the new loop- free route $C\ E\ D\ A \leftrightarrow \leftrightarrow \leftrightarrow$. All five nodes in the network are required to update their routing tables appropriately to reflect this topology change, which will be first detected by nodes B and C, then communicated to A, E, and D.

This reachability relation among the nodes may also change for various reasons. For example, a node may wander too far out of range, its battery may be depleted, or it may just suffer from software or hardware failure. As more nodes join the network, or some of the existing nodes leave, the topology updates become more numerous, complex, and usually, more frequent, thus diminishing the network resources available for exchanging user information.

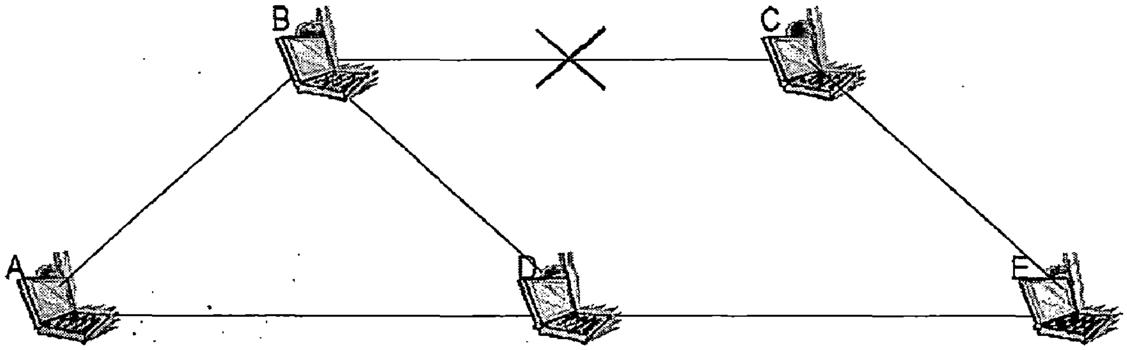

Figure 1.3: Topology update owing to a link failure

Finding a loop-free path between a source-destination pair may therefore become impossible if the changes in network topology occur *too frequently*. *Too frequently* here means that there may not be enough time to propagate to all the pertinent nodes the changes arising from the last change in network topology. Thus the ability to communicate degrades with increasing mobility and as a result the knowledge of the network topology becomes increasingly inconsistent. A network is combinatorially stable if, and only if, the topology changes occur slow enough to allow successful propagation of all topology updates as necessary or if the routing algorithm is efficient enough to propagate the changes in the network before the next change occurs. Clearly, combinatorial stability is determined not only by the connectivity properties of the networks, but also by the efficiency of the routing protocol in use and the instantaneous computational capacity of the nodes, among others. Combinatorial stability thus forms an essential consideration for attaining efficient routing objectives in an ad hoc network.

Broadcasting is the process in which a source node sends a message to all other nodes in MANET. Broadcasting is a common operation in a network to resolve many issues. Broadcasting is important in MANET for routing information discovery, for instance, protocols such as dynamic source routing (DSR) , ad hoc on demand distance vector (AODV) , zone routing protocol (ZRP) and location aided routing (LAR) use broadcasting to establish routes. In a mobile ad hoc network (MANET) in particular, due to host mobility, such operations are expected to be executed more frequently (such as finding a route to a particular host, paging a particular host, and sending an alarm signal). Because radio signals are likely to overlap with others in a geographical area, a straightforward broadcasting by flooding is usually very costly and will result in serious redundancy, contention, and collision, to which we refer as the broadcast storm problem. Broadcasting MANET poses more challenges than in wired networks due to node mobility and scarce system resources. Because of the mobility there is no single optimal scheme for all scenario.

1.3 Problem Statement

Network-wide broadcasting, simply referred to as "broadcasting", is the process in which one MN sends a packet to all MNs in the network. In unicast communications, a packet is sent from a single source to a specified destination in the network. Multicast protocols provide a delivery of the same packet simultaneously to a group of clients. Geocast protocols allow for the delivery of packets to a group of nodes in a specified geographical area.

Broadcasting is a building block for most other network layer protocols (unicast, multicast and geocast). For example, unicast routing protocols such as Dynamic Source Routing (DSR), Ad hoc On-demand Distance Vector (AODV), Zone Routing Protocol (ZRP) -, and Location Aided Routing (LAR) use broadcasting or a derivation of it to establish routes. Other unicast routing protocols, such as the Temporally-Ordered Routing Algorithm (TORA) , use broadcasting to transmit an error packet for an invalid route. Broadcasting is also often used as a building block for multicast protocols and geocast protocols .

The preceding network protocols typically use a simplistic form of broadcasting called Simple Flooding, in which each node (or every node in the localized area) retransmits each received unique packet exactly once. However, Simple Flooding often causes unproductive and harmful bandwidth congestion (e.g., called the "broadcast storm problem" in [16]) and wastes node resources. On the other hand, a number of research groups have proposed more efficient broadcasting techniques whose goal is to minimize the number of retransmissions while attempting to ensure that a broadcast packet is delivered to each node in the network. Each of these protocols operates differently and can be categorized into four groups according to their inherent characteristics.

The performance evaluation of MANET broadcast protocols in [3] illustrates that no single protocol for broadcasting works well in all possible network conditions in a MANET. Furthermore, every protocol fails catastrophically when the severity of the network environment is increased. Comparison of the protocols indicates that the performance of Neighbor Knowledge Methods is superior to the performance of other methods proposed for flat network topologies.

1.4 Solution Methodology

The performance evaluation of broadcast protocols in [3] shown that local decision Neighbor Knowledge Methods appear to adapt to mobility more easily than non-local decision Neighbor Knowledge Methods. However, local decision neighbor knowledge methods (such as LENWB) suffer more from congestion than non-local decision Neighbor Knowledge Methods.

We can improve delivery ratio by creating a protocol that behaves like local decision neighbor knowledge protocol and behaves like a nonlocal decision neighbor knowledge protocol depending on the speed and congestion level.With sufficient training data and expert knowledge, it is possible to train an MN to switch from one broadcasting protocol to another that is more suitable. A protocol that automatically switch a MN between LENWB[1] and AHBP[2] can be created.

Both LENWB[1] and AHBP[2] have special conditions that require the protocol to default to retransmit. If an LENWB[1] node receives a packet from a new neighbor, it is unlikely to know of any common 1- or 2-hop neighbors previously reached; thus the node is more likely to rebroadcast. Nonlocal decision Neighbor Knowledge Methods suffers at higher speeds and the performance evaluation of broadcast protocols have shown that delivery ratio of non-local decision Neighbor Knowledge Methods was low at high speeds. Delivery ration of Local decision Neighbor Knowledge Methods (such as LENWB[1]) was low at higher congestion levels. Thus, we develop a protocol that will combine the benefits of these two types of Neighbor Knowledge Methods. Specifically, a node in this combined protocol will track the amount of congestion and its speed to decide which protocol to use.

We will collect training data to train our inter-protocol learner. We will run LENWB[1] and AHBP[2] simulations over the range of speeds and congestion levels and the number of nodes fixed, and we will measure the delivery ratio of each node.

To facilitate a node switching between LENWB[1] and AHBP[2], we make some changes to the structure and behavior of a broadcast packet. As shown in chapter 4, the two protocols have a similar header format, so our combined header is the union of the two, with the most notable change including the BRG information from AHBP[2]. Specifying the header also explains most of a node's behavior; it must implement a subset of both protocols, enough to fill the headers in a packet. When sending a packet, a node must specify the BRG nodes, whether that node is implementing AHBP[2] or not. A node implementing LENWB[1] already knows its uncovered two-hop neighbors, so it simply chooses the BRG in a greedy way. When a node receives a packet, it can choose to ignore the BRG fields in the header if it is implementing LENWB[1], or follow them if it is implementing AHBP[2]. In this way, the local behavior of LENWB[1] is preserved, and so is the non-local behavior of AHBP[2].

1.5 organization of this report

Chapter 1 presents the overview of MANETs and briefly explains about problems of broadcasting and about inter protocol switching.

Chapter 2 describes the various broadcasting methods and contains a performance evaluation of broadcast protocols and shortcomings of existing protocols.

Chapter 3 describes the about LENWB & AHBP and their delivery ration under a wide range of MANET scenario and concludes that LENWB & AHBP are suitable for inter protocol switching.

Chapter 4 discusses about performance of local decision neighbor knowledge protocols and nonlocal decision neighbor knowledge protocols.

Chapter 5 presents the simulation results of AHBP & LENWB and implementation of inter protocol switching.

CHAPTER 2

BROADCAST PROTOCOLS & PERFORMANCE

Twelve broadcast protocols are described in this chapter. A comprehensive comparison of these protocols include simulating all twelve under a wide range of parameters is available in [3]. The protocols were classified into four families

Simple Flooding
Probability Based Methods,
Area Based Methods
Neighbor Knowledge Methods.

In performance evaluation of broadcast protocols in [3] one or two representative protocols from each category are evaluated and make conclusions regarding applicability of all protocols within each family. A brief overview of each category in the following paragraph and details were followed.

Simple Flooding requires each node to rebroadcast all packets. Probability Based Methods use some basic understanding of the network topology to assign a probability to a node to rebroadcast. Area Based Methods assume nodes have common transmission distances, a node will rebroadcast only if the rebroadcast will reach sufficient additional coverage area. Neighbor Knowledge Methods maintain state on their neighborhood, via "Hello" packets, which is used in the decision to rebroadcast. Note that our four categories are presented in order of increasing algorithm complexity and per node state requirement. The goal of the added cost is to reduce the number of redundant transmissions.

2.1 Simple Flooding

The algorithm for Simple Flooding starts with a source node broadcasting a packet to all neighbors. Each of those neighbors in turn rebroadcast the packet exactly one time and this continues until all reachable network nodes have received the packet. In , Flooding is a scheme to achieve reliable broadcast and multicast in highly dynamic networks. [15] is an IETF Internet Draft proposing the use of Flooding as a "Simple Protocol" for broadcasting and multicasting in ad hoc networks which are characterized by low node densities and/or high mobility.

2.2 Probability Based Methods

2.2.1 Probabilistic Scheme

The Probabilistic scheme from [16] is similar to Flooding, except that nodes only rebroadcast with a predetermined probability. In dense networks multiple nodes share similar transmission coverage. Thus, randomly having some nodes not rebroadcast saves node and network resources without harming delivery effectiveness. In sparse networks, there is much less shared coverage; thus, nodes won't receive all the broadcast packets with the Probabilistic scheme unless the probability parameter is high. When the probability is 100%, this scheme is identical to Flooding.

2.2.2 Counter-Based Scheme

[16] shows an inverse relationship between the number of times a packet is received at a node and the probability of that node being able to reach additional area on a rebroadcast. This result is the basis of their Counter-Based scheme.

Upon reception of a previously unseen packet, the node initiates a counter with a value of one and sets a RAD (which is randomly chosen between 0 and Tmax seconds). During the RAD, the counter is incremented by one for each redundant packet received. If the counter is less than a threshold value when the RAD expires, the packet is rebroadcast. Otherwise, it is simply dropped. From [16], threshold values above six relate to little additional coverage area being reached.

The overriding compelling features of the Counter-Based scheme are its simplicity and its inherent adaptability to local topologies. That is, in a dense area of the network, some nodes won't rebroadcast; in sparse areas of the network, all nodes rebroadcast.

2.3 Area Based Methods

Suppose a node receives a packet from a sender that is located only one meter away. If the receiving node rebroadcasts, the additional area covered by the retransmission is quite low. On the other extreme, if a node is located at the boundary of the sender node's transmission distance, then a rebroadcast would reach significant additional area, 61% to be precise [16]. A node using an Area Based Method can evaluate additional coverage area based on all received redundant transmissions. We note that area based methods only consider the coverage area of a transmission; they don't consider whether nodes exist within that area.

2.3.1 Distance-Based Scheme

A node using the Distance-Based Scheme compares the distance between itself and each neighbor node that has previously rebroadcast a given packet. Upon reception of a previously unseen packet, a RAD is initiated and redundant packets are cached. When the RAD expires, all source node locations are examined to see if any node is closer than a threshold distance value. If true, the node doesn't rebroadcast.

2.3.2 Location-Based Scheme

The Location-Based scheme [16] uses a more precise estimation of expected additional coverage area in the decision to rebroadcast. In this method, each node must have the means to determine its own location, e.g., a Global Positioning System (GPS).

Whenever a node originates or rebroadcasts a packet it adds its own location to the header of the packet. When a node initially receives a packet, it notes the location of the sender and calculates the additional coverage area obtainable were it to rebroadcast. If the additional area is less than a threshold value, the node will not rebroadcast, and all future receptions of the same packet will be ignored. Otherwise, the node assigns a RAD before delivery. If the node receives a redundant packet during the RAD, it recalculates the additional coverage area and compares that value to the threshold. The area calculation and threshold comparison occur with all redundant broadcasts received until the packet reaches either its scheduled send time or is dropped.

2.4 Neighbor Knowledge Methods

2.4.1 Flooding with Self Pruning

The simplest of the Neighbor Knowledge Methods is what Lim and Kim refer to as Flooding with Self Pruning [17]. This protocol requires that each node have knowledge of its 1-hop neighbors, which is obtained via periodic "Hello" packets.

A node includes its list of known neighbors in the header of each broadcast packet. A node receiving a broadcast packet compares its neighbor list to the sender's neighbor list. If the receiving node would not reach any additional nodes, it refrains from rebroadcasting, otherwise the node rebroadcasts the packet.

2.4.2 Scalable Broadcast Algorithm (SBA)

The Scalable Broadcast Algorithm (SBA) [18] requires that all nodes have knowledge of their neighbors within a two hop radius. This neighbor knowledge coupled with the identity of the node from which a packet is received allows a receiving node to determine if it would reach additional nodes by rebroadcasting. 2-hop neighbor knowledge is achievable via periodic "Hello" packets; each "Hello" packet contains the node's identifier (IP address) and the list of known neighbors.

After a node receives a "Hello" packet from all its neighbors, it has two hop topology information centered at itself. Suppose Node B receives a broadcast data packet from Node A. Since Node A is a neighbor, Node B knows all of its neighbors, common to Node A, that have also received Node A's transmission of the broadcast packet. If Node B has additional neighbors not reached by Node A's broadcast, Node B schedules the packet for delivery with a RAD. If Node B receives a redundant broadcast packet from another neighbor, Node B again determines if it can reach any new nodes by rebroadcasting. This process continues until either the RAD expires and the packet is sent, or the packet is dropped.

The authors of [18] propose a method to dynamically adjust the RAD to network conditions; they weight the time delay based on a node's relative neighbor degree. Specifically, each node searches its neighbor tables for the maximum neighbor degree of any neighbor node, *dNmax*.

It then calculates a RAD based on the ratio of:

dNmax / dme

where *dme* is the node's current number of neighbors. This weighting scheme is greedy; nodes with the most neighbors usually broadcast before the others.

2.4.3 Dominant Pruning

Dominant Pruning also uses 2-hop neighbor knowledge, obtained via "Hello" packets, for routing decisions [17]. Unlike SBA, however, Dominant Pruning requires rebroadcasting nodes to proactively choose some or all of its 1-hop neighbors as rebroadcasting nodes. Only those chosen nodes are allowed to rebroadcast. Nodes inform neighbors to rebroadcast by including their address as part of a list in each broadcast packet header. When a node receives a broadcast packet it checks the header to see if its address is part of the list. If so, it uses a Greedy Set Cover algorithm to determine which subset of neighbors should rebroadcast the packet, given knowledge of which neighbors have already been covered by the sender's broadcast. The Greedy Set Cover algorithm, as adapted in [17] from [21], recursively chooses 1-hop neighbors which cover the most 2-hop neighbors and recalculates the cover set until all 2-hop neighbors are covered.

2.4.4 Multipoint Relaying

Multipoint Relaying [4] is similar to Dominant Pruning in that rebroadcasting nodes are explicitly chosen by upstream senders. For example, say Node A is originating a broadcast packet. It has previously selected some, or in certain cases all, of it one hop neighbors to rebroadcast all packets they receive from Node A. The chosen nodes are called Multipoint Relays (MPRs) and they are the only nodes allowed to rebroadcast a packet received from Node A. Each MPR is required to choose a subset of its one hop neighbors to act as MPRs as well. Since a node knows the network topology within a 2-hop radius, it can select 1-hop neighbors as MPRs that most efficiently reach all nodes within the two hop neighborhood. The authors of [4] propose the following algorithm for a node to choose its MPRs:

1. Find all 2-hop neighbors that can only be reached by one 1-hop neighbor. Assign those 1-hop neighbors as MPRs.
2. Determine the resultant cover set (i.e., the set of 2-hop neighbors that will receive the packet from the current MPR set).
3. From the remaining 1-hop neighbors not yet in the MPR set, find the one that would cover the most 2-hop neighbors not in the cover set.
4. Repeat from step 2 until all 2-hop neighbors are covered. Multipoint Relaying is described in detail as part of the Optimized Link State Routing (OLSR) protocol defined

by an Internet draft [6]. In this implementation, "Hello" Packets include fields for a node to list the MPRs it has chosen. Anytime a node receives a "Hello" packet, it checks if it is a MPR for the source of the packet.

If so, it must rebroadcast all data packets received from that source. Clearly, the update interval for "Hello" packets must be carefully chosen and, if possible, optimized for network conditions.

2.4.5 Ad Hoc Broadcast Protocol

The Ad Hoc Broadcast Protocol (AHBP) [2] utilizes an approach similar to Multipoint Relaying In AHBP, only nodes who are designated as a Broadcast Relay Gateway (BRG) within a broadcast packet header are allowed to rebroadcast the packet. BRGs are proactively chosen from each upstream sender which is a BRG itself. The algorithm for a BRG to choose its BRG set is identical to that used in Multipoint Relaying (see steps 1-4 for choosing MPRs).

AHBP[2] differs from Multipoint Relaying in three ways:

1. A node using AHBP informs 1-hop neighbors of the BRG designation within the header of each broadcast packet. This allows a node to calculate the most effective BRG set at the time a broadcast packet is transmitted. In contrast, Multipoint Relaying informs 1-hop neighbors of the MPR designation via "Hello" packets.
2. In AHBP, when a node receives a broadcast packet and is listed as a BRG, the node uses 2-hop neighbor knowledge to determine which neighbors also received the broadcast packet in the same transmission. These neighbors are considered already "covered" and are removed from the neighbor graph used to choose next hop BRGs. In contrast, MPRs are not chosen considering the source route of the broadcast packet.
3. AHBP is extended to account for high mobility networks. Suppose Node A receives a broadcast packet from Node B, and Node A does not list Node B as a neighbor (i.e., Node A and Node B have not yet exchanged "Hello" packets). In AHBP-EX (extended AHBP), Node A will assume BRG status and rebroadcast the node. Multipoint relaying could be similarly extended.

2.4.6 CDS-Based Broadcast Algorithm

Peng and Lu describe the Connected Dominating Set (CDS)-Based Broadcast Algorithm, a more calculation intensive algorithm for selecting BRGs, in [8]. Where AHBP only considers the source of the broadcast packet to determine a receiving node's initial cover set, CDS-Based Broadcast Algorithm *also* considers the set of higher priority BRGs selected by the previous sender [8]. For example, suppose Node A has selected Nodes B, C and D (in this order) to be BRGs. When Node C receives a broadcast packet from Node A, AHBP requires Node C to add neighbors common to Node A to the initial cover set. CDS-Based Broadcast Algorithm *also* requires that Node C adds neighbors common to Node B, because Node B is a higher priority BRG. Likewise, Node D is required to consider common neighbors with nodes A, B and C. Once the initial cover set is determined, a node then chooses which neighbors should function as BRGs. The algorithm for determining this is the same as that for AHBP and Multipoint Relaying (see steps 1-4 for choosing Multipoint Relays).

2.4.7 LENWB

The Lightweight and Efficient Network-Wide Broadcast (LENWB) protocol [1] also relies on 2-hop neighbor knowledge obtained from "Hello" packets. However, instead of a node explicitly choosing nodes to rebroadcast, the decision is implicit.

In LENWB, each node decides to rebroadcast based on knowledge of which of its other one and two hop neighbors are expected to rebroadcast. The information required for that decision is knowledge of which neighbors have received a packet from the common source node and which neighbors have a higher priority for rebroadcasting.

The priority is proportional to a node's number of neighbors, the higher the node's degree the higher the priority. Since a node relies on its higher priority neighbors to rebroadcast, it can proactively compute if all of its lower priority neighbors will receive those rebroadcasts; if not, the node rebroadcasts.

2.5 Performance Evaluation of Broadcast protocols

Performance evaluation of broadcast protocols in [3] shows the following:

1. Increasing node count in a static network disproportionately hurts the Probability Based and Area Based schemes in terms of number of rebroadcasting nodes. LENWB and SBA and AHBP [2], two Neighbor Knowledge methods, approximate the MCDS fairly closely as the number of nodes in the network is increased.
2. The schemes that utilize a RAD suffer in congestive networks unless a mechanism to adapt a node's RAD to its local congestion level is implemented.
3. The Neighbor Knowledge methods that do not use local information to determine whether to rebroadcast have difficulty in mobile environments; outdated 2-hop neighbor knowledge corrupts the determination of next-hop rebroadcasting nodes.

Given the inability of the Probability Based and Area Based methods to minimize the number of rebroadcasting nodes, protocols in these two categories fail to operate efficiently in congested networks. We could improve the protocols in these two categories by adapting the protocol to a node's neighbor count and local congestion level. The implementation of this improvement, however, would require the addition of both Hello packets and an adaptive RAD. Unfortunately, these extensions negate the inherent simplicity of the protocols, which is their most attractive feature. Furthermore, if "Hello" packets are used, a protocol which makes more intelligent use of the obtained neighbor knowledge is preferred.

We show that adapting RAD to the current congestion level improves SBA's performance in congested networks; at the highest congestion levels, the delivery ratios of Adaptive LENWB and SBA were higher than AHBP. However, the gain in performance of our Adaptive SBA and LENWB protocol requires a higher number of rebroadcasting nodes than AHBP. In addition, because SBA and LENWB naturally adapts to dynamic topologies by increasing the number of rebroadcasting nodes, the RAD adaptive version of the protocol is unable to cope with a severe network environment (i.e., high node mobility, high node count and high bandwidth congestion).

AHBP-EX provides the best performance in the most severe network environment studied. Unfortunately, its sensitivity to node mobility produces the lowest delivery ratio in networks where the environment is dominated by topological changes.

Generally, one would expect the tradeoff between algorithm complexity and redundant retransmissions to be a net gain; that is, power requirements for more complex calculations is likely to be less than that required to transmit redundant packets. Combining the power ramifications with performance results leads us to conclude that Neighbor Knowledge methods are preferred over other types of broadcast protocols. Unfortunately, there is no clear choice between the two Neighbor Knowledge methods we have evaluated. That is, based on performance evaluation, we conclude that LENWB and AHBP-EX each fit a niche area.

AHBP-EX is recommended for semi-static topologies or extremely congested networks. Adaptive SBA and LENWB is recommended for all other expected scenarios. Based on the conclusions from our study, we recommend further performance evaluations and improvements of Neighbor Knowledge methods. Performance evaluation of broadcast protocols provides other directions for valuable future research as well. We demonstrate that AHBP approximates MCDS within 10% in dense networks. While the CDS-Based Broadcast Algorithm and other algorithmic optimizations provided in [16] and [18] may improve the approximation of MCDS, the fact that these protocols all rely on extremely accurate neighbor knowledge information makes them unattractive in dynamic networks; in other words, they share AHBP's deficiency in non-static networks. Therefore, further research in algorithmic optimizations should take a back seat to research in making these protocols effective in mobile networks.

Another important area for future research relates to SBA's RAD. Recall that SBA weights the RAD to a node's relative neighbor degree. We recommend that SBA's RAD determination be modified such that nodes with isolated neighbors rebroadcast first, similar to both AHBP and Multipoint Relaying. The goal of this proposed SBA modification is to minimize the number of rebroadcasting nodes and make it more effective in networks characterized by high congestion. Similarly, more research into adapting RAD to congestion might provide a more robust solution than the simple scheme proposed in [3].

2.6 The shortcomings of existing broadcast protocols

1. Non-Neighbor Knowledge Methods require more rebroadcasts than the other methods studied, with respect to the number of retransmitting nodes.
2. The schemes such as SBA and LENWB[1])suffer in congestive networks unless a mechanism to adapt itself local congestion level is implemented .
3. The Neighbor Knowledge methods that do not use local information to determine whether to rebroadcast (such as AHBP[2]) have difficulty in mobile environments . The mobility extension for AHBP[2] (AHBP-EX) marks an improvement over AHBP[2]; however, it still under performs the other protocols. LENWB[1] and SBA naturally adapts to mobility by requiring more nodes to rebroadcast.
4. No single Neighbor Knowledge protocol evaluated performed the best in all studies . Based on these shortcomings, none of the existing broadcasting protocols are satisfactory for wide-ranging MANET environments.

CHAPTER 3

LOCAL DECISION AND NONLOCAL DECISION IN NEIGHBOUR KNOWLEDGE PROTOCOLS

3.1 Local Neighbor knowledge protocols and Non local neighbor Knowledge protocols

Neighbor Knowledge protocols where each mobile node makes its own decision whether to rebroadcast or not can be called as local decision neighbor knowledge protocols. Neighbor Knowledge protocols where a mobile node receives the instruction whether to rebroadcast or not in the header of the packet received can be called as nonlocal decision neighbor knowledge protocols. Performance of as local decision neighbor knowledge protocols is discussed in the following sections.

3.2 Delivery ratio in environments of high speed

Consider network topology in Figure 3.1 and suppose the AHBP is the broadcast protocol in the MANET. Consider the situation where node 1 has received a broadcast packet from node 9. After receiving the packet suppose that the network topology is changed as shown in Figure 3.2 and still node 1 has not updated its neighbor information as Hello messages were not exchanged.

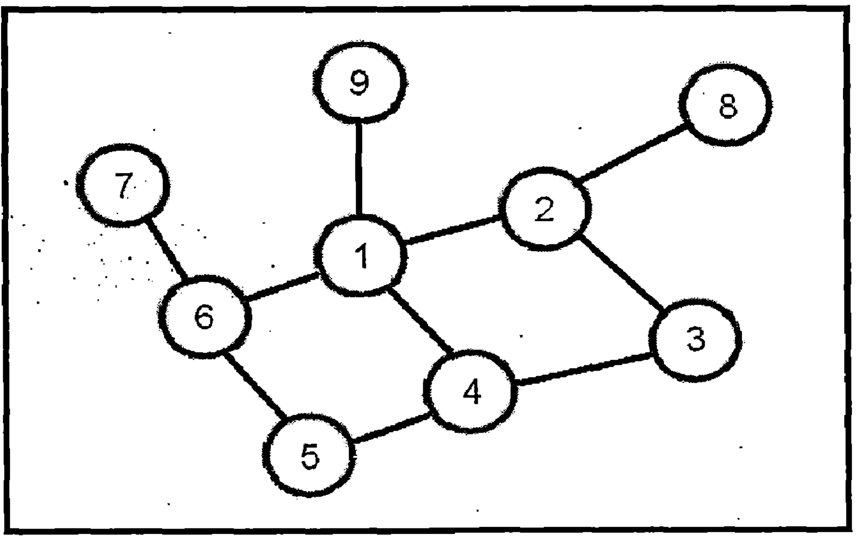

Figure 3.1An Example Network Topology

Depending on the network topology show in Figure 3.1 node can specify nodes 2 and 6 BRG nodes. The packet will be received by all the neighbors { 2,3,7,9} of node 1 shown in Figure 3.2 .None of the nodes 2,3,7,9 were listed in the BRG set {2,6}. As a result none of those nodes will rebroadcast the packet.

Thus the broadcast packet originated by node 9 has reached only 2 nodes in the MANET which has 9 nodes. Delivery ratio was 22 %. When the MNs are moving with high speeds it is possible that frequently nodes specified in the BRG set may be outside of the wireless range of transmitting node. Thus nonlocal decision neighbor knowledge protocols have very low delivery ratio at higher speeds.

Now suppose the nodes are using local decision neighbor knowledge protocols (such as SBA) . Node 1 has Consider the situation in Figure 3.1 the nodes reachable by node 2's broadcasting of are {1,4,3,8,9} and neighbors of node 1 are {2,4,5,6,9}.As node 1 has neighbors {2,5,6} that are not reachable by node 2's transmission of the broadcast packet, node 1 chooses to rebroadcast the packet.

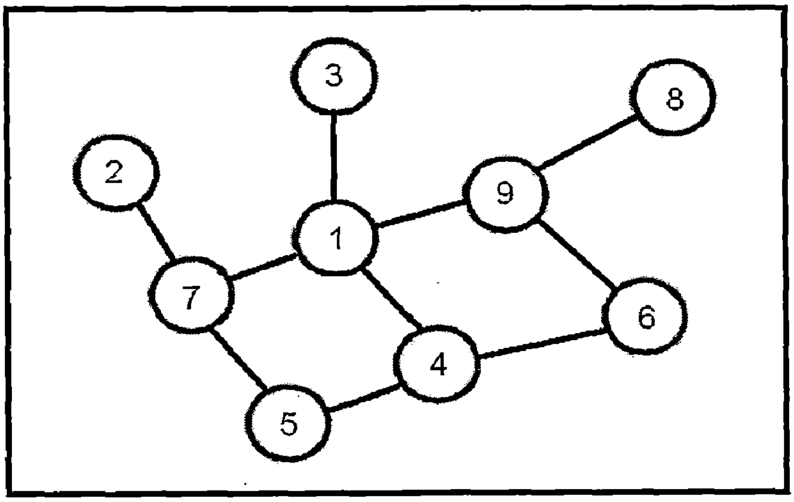

Figure 3.2 An Example Network Topology

Actually the packet will be received by nodes {3,4,5,7,9} as they are in the wireless range of node 1 (as show in Figure 3.2). Further they can rebroadcast it. Thus delivery ratio of local decision neighbor knowledge protocols is better than the delivery ratio of nonlocal decision neighbor knowledge protocols at high speeds.

3.3 Delivery ratio in environments of high congestion.

Consider the network topology in figure 3.3 .Suppose node 1 has transmitted a broadcast packet.

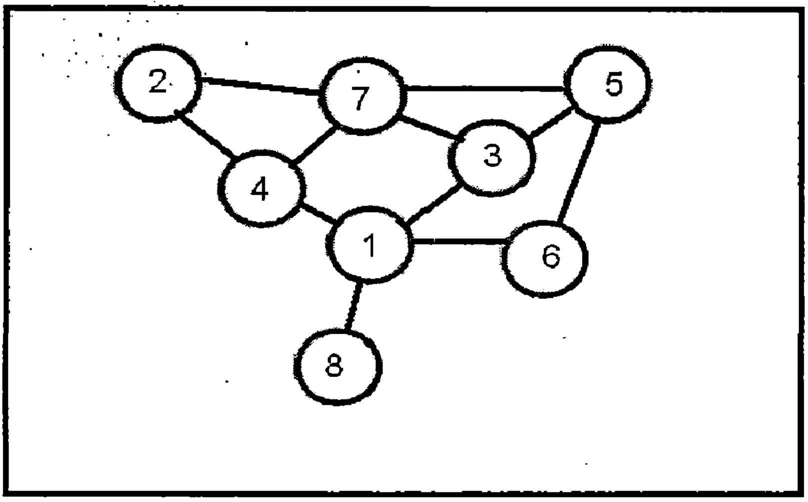

Figure 3.3 An Example Network Topology

When the MANET is using a nonlocal decision neighbor knowledge protocol (such as AHBP).Node 7 which is neighbor of node 1 is in the wireless range of all two hop neighbors {2,5} of node 1. Node 1 specifies 7 as BRG node. Among all the neighbors {3,4,6,7,8} of node 1 only the node 7 will rebroadcast the packet and total number of MNs transmitting the packet originated at 1 is 2 including the node 1.

When the MANET is using a local decision neighbor knowledge protocol (such as SBA) , among the neighbors of node 1 the nodes {3,4,6,7} has neighbors which has not received the packet by the node 1's transmission. The four nodes {3,4,6,7} will rebroadcast the packet total number of MNs transmitting the packet originated at 1 is 5 including the node 1.

Thus numbers of rebroadcasting nodes with local decision neighbor knowledge protocols are high when compared with nonlocal decision neighbor knowledge protocols.With more number of rebroadcasting nodes, as the congestion is increasing number of packet collisions will increase. As a result delivery ratio of local decision neighbor knowledge protocol is low at higher congestion levels. Thus delivery ratio of non local decision neighbor knowledge protocols is better than the delivery ratio of local decision neighbor knowledge protocols when the congestion is high.

CHAPTER 4

LENWB & AHBP

Performance evaluation of MANET broadcasting protocols in [3] has shown that as network topology changes more rapidly nonlocal decision Neighbor Knowledge Methods (such as AHBP) suffers and have low delivery ratio. However local decision Neighbor Knowledge Methods have low delivery ratio at high congestion levels. Thus, we develop a protocol that behaves like local decision neighbor knowledge protocol under the conditions favorable to local decision and behaves like nonlocal decision neighbor knowledge protocol under the conditions favorable to nonlocal decision A node in this combined protocol will track the amount of congestion and its speed to decide which protocol to use.

Two protocols chosen are AHBP[2] and LENWB[1]. AHBP is from nonlocal neighbor knowledge class and LENWB is from local neighbor knowledge class.

4.1 The Lightweight and Efficient Network-Wide Broadcast protocol

The Lightweight and Efficient Network-Wide Broadcast (LENWB[1]) protocol The LENWB[1] algorithm presupposes that the routing protocol incorporates a form of Hello protocol where nodes periodically advertise their presence. The associated Hello packet transmitted by a given node, call it node *v*, is assumed to contain the following data items:

i. The node ID or IP address of node *v*.
ii. The degree of *v*, i.e., the number of neighbors of node *v*, *deg(v)*.
iii. The node ID or IP address of each neighbor of *v*.
iv. The degree of each neighbor of *v*.

The following definitions are relevant to the algorithm's description.

v :Node ID of an arbitrary network node at which LENWB[1] is being run.

N(v) : Set of neighbors of *v*.

***nwb_id* :** ID of a particular packet that requires NWB service.

u : Forwarding node from whom a RREQ packet, with request ID *nwb_id*, has been received at v.

C(u) :Set of nodes covered by the RREQ broadcast of u. Note, since v knows its neighbors' neighbors, $C(u)$ is known to v.

***X*:** Set of all transmitting nodes for a given RREQ instantiation.

C(X) : Set of nodes covered by the transmissions of X Successful NWB occurs when $C(X) = V$.

PC(w,v) :Priority condition. A node w satisfies the priority condition with respect to the node v if one of the following is true:

- $deg(w) > deg(v)$.
- $deg(w) = deg(v)$ and $w < v$.

π : A path denoted by the sequence of bidirectional links (edges), $\{(u,x_1),(x_1,x_2),\ldots,(x_{k-1},x_k)\}$ connecting node u with node x_k, such that each node x in the path lies not more than two hops from v, satisfies $PC(x,v)$, and each edge of the path has at least one terminal vertex in $N(v)$.

P : Set of nodes such that for each p *is in* P, $PC(p,v)$ is true, p lies exactly two hops from v and there is a path π connecting u to p.

Q : Set of nodes such that for each q is in Q, $PC(q,v)$ is true, q *is in* $N(v)$ and there is a path π connecting u to q..

For each unique instantiation of a NWB packet received by node v, the packet ID (*nwb_id*) and predecessor node (u) is maintained in a database record. The LENWB[1] algorithm, as described below, assumes reliable delivery of NWB packets to all neighbors of a transmitting node. In practice, however, successful receipt of NWB packets may be disrupted by packet collisions and/or node mobility that invalidates the neighbor status data available at a transmitting node. Implementation of the algorithm under the assumption that NWB packets may not be received by all neighbors may require extensions to enhance its reliability.

The LENWB[1] algorithm under the reliable delivery condition is as follows.

LENWB[1] Algorithm:

```
1)If the received packet represents the first copy of a NWB packet with ID nwb_id, then
    write nwb_id and u into the appropriate fields of a NWB record and set $U = \{u\}$.
    Otherwise, disregard the redundant packet arrival and STOP.
2) If $N(v) \leq C(U)$, STOP.
3) Calculate $P$ and $Q$.
4) Until $N(v) = C(U)$ or $U = \{u\} \cup P \cup Q$ do
    a) Select a node $x$ satisfying $x$ is not in $U$, $x$ is in($P \cup Q$)and $x$ is in $C(U)$.
    b) $U = U \cup \{x\}$.
5) If $C(U) \cap N(v) \neq N(v)$, queue the NWB packet for transmission. Else, discard the NWB
    packet.
```

Based on this pseudo code, it is evident that the local decision to block or transmit can be made in at worst $O(K^2)$ time where K is the maximum node degree of the network.

An Example

Let us consider the network topology in Figure 4.1. When node 1 receives a broadcast packet from node 2.It makes a decision about to rebroadcast it or not to.

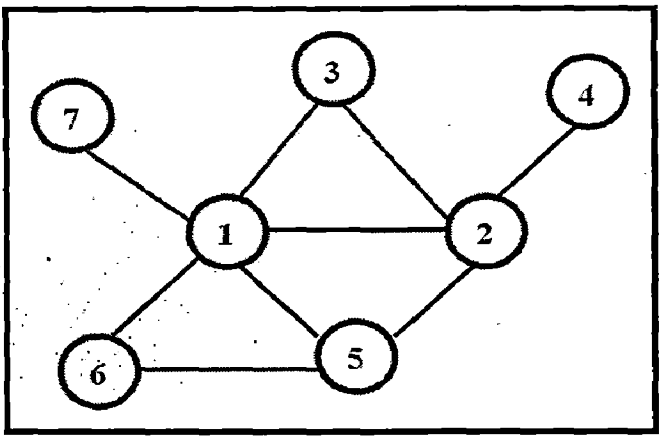

Figure 4.1. An example network topology

Initially U={2} and c(U) = {1,5,3,4}

N(1)={5,6,7,3,2}

As N(1) is not a subset of c(U) node 1 continues to calculate P & Q

Nodes lie exactly two hops from node 1 is node 4 only but PC(4,1) is false and therefore P={}

None of nodes connected to 2 with in two hops of node 1 satisfying Q={}

and finally U={2} and c(U)={1,5,3,4}

$c(U) \cap N(1) = \{5,3\}$

N(1) not equal to {5,3}

So node 1 rebroadcast the packet.

When node 7 receives broadcast packet from 1. U={1} and c(U)={2,3,5,6,7}

N(7)={2} and is a subset of c(U)

So node 7 will not rebroadcast it

4.2 Ad Hoc Broadcast Protocol

Like LENWB[1], the Ad Hoc Broadcast Protocol (AHBP[2]) is in the Neighbor Knowledge family of protocols. Where as LENWB[1] can be called a "local" Neighbor Knowledge protocol because each mobile node makes its own decision whether to rebroadcast or not, AHBP[2] is a "non-local" Neighbor Knowledge protocol because a mobile node receives the instruction whether to rebroadcast or not in the header of the packet it receives AHBP[2], is based on another protocol, Multipoint Relaying.

In the Ad Hoc Broadcast Protocol (AHBP[2]) , only nodes designated as a Broadcast Relay Gateway (BRG) within a broadcast packet header are allowed to rebroadcast the packet.

The algorithm for a BRG to choose its next BRG set is:

1. Find all 2-hop neighbors that can only be reached by one 1-hop neighbor. Assign those 1-hop neighbors as BRGs.

2. Determine the resultant cover set (i.e., the set of 2-hop neighbors that will receive the packet from the current BRG set)

3. From the remaining 1-hop neighbors not yet in the BRG set, find the one that would cover the most 2-hop neighbors not in the cover set. Assign this 1-hop neighbor as a BRG.

4. Repeat steps 2 and 3 until all 2-hop neighbors are covered.

5. When a node receives a broadcast packet and is listed as a BRG, that node determines which of its neighbors also received the packet in the same transmission. These neighbors are considered already "covered" and are removed from the neighbor graph used to choose the next hop BRGs.

6. AHBP[2] is extended to account for high mobility networks. Suppose Node *B* receives a broadcast packet from Node *A*, and Node *B* does not list Node *A* as a neighbor (i.e., Node *A* and Node *B* have not yet exchanged "Hello" packets).In AHBP-EX (extended AHBP[2]), Node *B* will assume BRG status and rebroadcast the packet.

While both LENWB[1] and AHBP[2] use two-hop neighbor knowledge to infer node coverage, they use this knowledge in different ways. In LENWB[1], when a node receives a broadcast or rebroadcast packet, it assumes that other neighbors of the sender have been covered. In AHBP[2], when a node sends a broadcast or rebroadcast packet, it assumes that neighbors of the designated BRG nodes will be covered.

An Example

As an example, consider the network topology given in Figure 4.2.

In the scenario in figure 4.2 , **Node 1**'s two-hop topology information:

One Hop	Two Hop Via the One hop
2	4,5
3	6
7	5

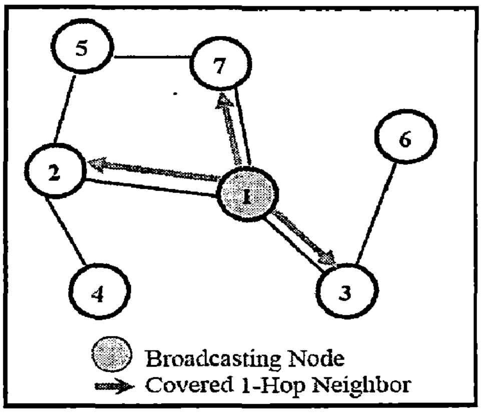

Figure 4.2 An Example network topology

When node 1 has to send a broadcast packet, so it chooses Node 2 and Node 3 as BRGs as, it an cover all the two hop neighbors. According to Node 1's two-hop topology table, Node 1's two-hop neighbors are Node 4, Node 5, and Node 6. As it is shown in Figure 4.3, choosing Node 2 as a BRG covers Node 4 and Node 5; choosing Node 3 as a BRG covers Node 6.

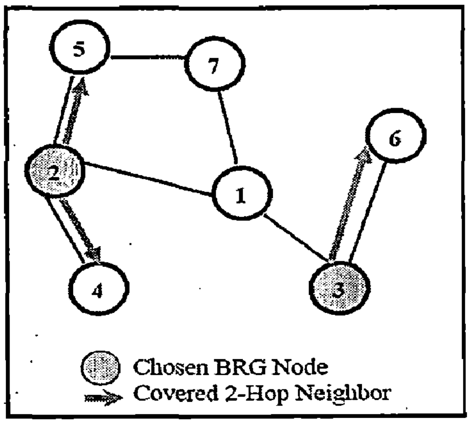

Figure 4:3 An Example network topology

When Node 7 receives the packet, it updates its table, but does not resend the packet because Node 1 did not choose it as a BRG. When Node 3 and Node 2 receive the packet, they also update their tables, and since they have been chosen as BRGs, they choose new

BRGs from their neighbor list and rebroadcast the packet. These steps are recursively repeated until the message is propagated to all possible receivers.

4.3 Simulation Environment

The chosen protocols AHBP & LENWB were simulated under a wide range of conditions using Network Simulator2. We ran LENWB and AHBP simulations over a wide range of speeds and congestion levels and we measured the delivery ratio of each node .Delivery ratios of AHBP & LENWB were compared to design inter protocol switching. Simulations were run with speed ranging from 1m/sec to 30 m/sec and the congestion ranging from 1pkt/sec to 120 pkt/sec. Simulation was run with 36 trials with different speeds and different congestion levels. In every trial average speed and average congestion delivery ratio were measured. Simulation parameter were shown below

Input Parameters

Simulation Area Size	360m x 600m
Transmission Range	100m

Derived Parameters

Node Density	1 node per 3,600 sq.m
Coverage Area	31,416 sq.m
Maximum Path Length	700 m
Network Diameter	7 hops

Range of speed

1m/sec to 30 m/sec

Range of congestion

1 pkt/sec to 120 pkt/sec

Simulator

Simulator Used NS-2 (version 2.1b7a)

Medium Access Protocol IEEE 802.11

4.4 Delivery ratio of AHBP & LENWB

The delivery ratio of LENWB & AHBP was shown in figure 4.1 at congestion level 60pkt/sec. Simulation results (see Figure 4.1) has shown that local decision LENWB[1] appear to adapt to mobility more easily than AHBP[2]. However, LENWB suffer more from congestion than AHBP.

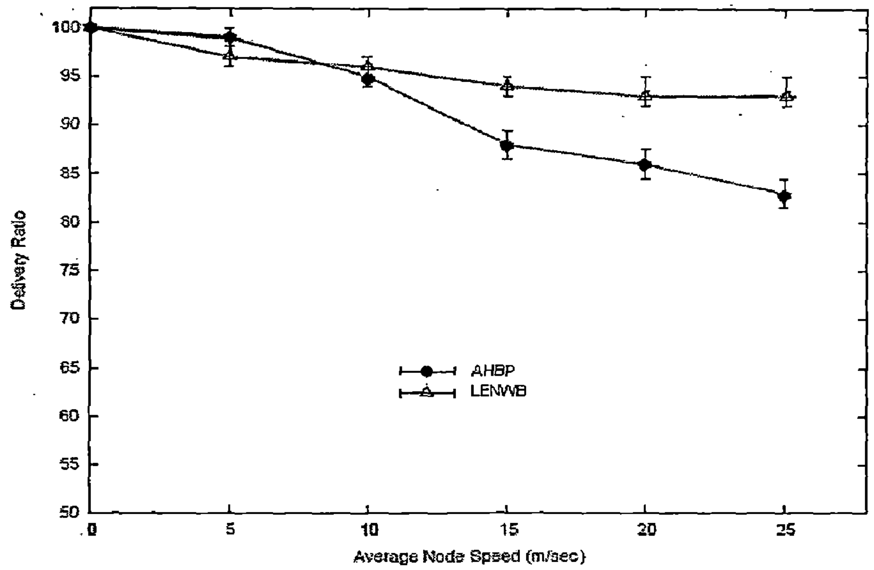

Figure 4.1 Speed Vs Delivery ratio

Table 4.2.1 is showing number of nodes that had better delivery ratio with AHBP better than LENWB in a column named as AHBP at various speed and congestion levels and it is also showing number of nodes that had better delivery ratio with LENWB better than LENWB in a column named as LENWB at various speed and congestion levels.

At high speeds number of nodes favorable to AHBP is 0 indicating that LENWB is outperforming AHBP. At the higher congestion level many entries in LENWB column are zero's and it is indicating that LEWNB is suffering at higher congestion levels. By this observation it can be concluded that AHBP & LENWB are suitable for inter protocol switching. As LENWB is outperforming AHBP at higher speeds and AHBP is outperforming LENWB at higher congestion levels, we can expect our protocol that switches between AHBP & LENWB can have better delivery ratio under a wide range of MANET scenarios.

Speed

	0- 4		4-8		9-12		13-16		17-20		21-24		25-28	
	LENWB	AHBP	LENWB	AHBP	LENWB	AHBP	LENWB	AHBP	LENWB	AHBP	LENWB	AHBP	LENWB	AHBP
0-10	13	10	21	6	19	0	22	0	27	0	29	0	14	0
11-20	13	14	15	10	25	0	26	0	19	0	25	0	25	0
21-30	13	15	9	5	8	14	21	0	21	0	27	0	25	0
31-40	14	11	14	13	9	16	28	5	23	1	22	0	23	0
41-50	17	6	13	14	17	12	0	23	19	3	23	0	30	0
51-60	12	14	7	9	13	7	0	24	19	11	25	0	21	0
61-70	7	13	8	13	5	21	0	27	0	29	13	16	25	0
71-80	10	19	5	16	0	20	0	27	0	20	13	12	23	0
81-90	0	16	0	25	0	25	0	25	0	19	6	14	14	3
91-100	0	30	0	26	0	25	0	22	0	27	0	24	7	20
101-110	0	24	0	26	0	23	0	29	0	24	0	19	2	18
111-120	0	22	0	22	0	23	0	24	0	23	0	27	0	32

Table 4.2.1 Number of nodes favorable to AHBP & LENWB

CHAPTER 5

SWITCHING BETWEEN LENWB & AHBP

5.1 Inter protocol switching

We can switch between two protocols by simulating the protocols under wide range of conditions. We can store each network scenario completely including node positions, speeds , neighbors , and congestion level and which protocol performs well (can be derived by simulation). The network condition can be checked periodically and entire MANET can be switched to favorable protocol in current scenario.

But it needs enormous amounts of memory which is impractical. It also results in very high overhead and that kind of switching is impractical because the MANET topology changes rapidly. Hence It was chosen to switch individual node (rather than entire network) between two protocols depending on local scenario around the node. With sufficient training data and expert knowledge, it is possible to train an MN to switch from one broadcasting protocol to another that is more suitable.

Performance evaluation of MANET broadcasting protocols in [3] has shown that local decision neighbor knowledge Methods appear to adapt to mobility more easily than non-local decision neighbor knowledge methods. However, local decision neighbor knowledge methods (such as LENWB and SBA) suffer more from congestion than non-local decision neighbor knowledge methods. Two protocols chosen were AHBP and LENW. AHBP is from nonlocal neighbor knowledge class and LENWB is from local neighbor knowledge class.

We create a new protocol that automatically switch a MN between LENWB and AHBP. We are switching between two complicated Neighbor Knowledge protocols to improve the delivery ratio under wide range of conditions.

Any combination of broadcasting protocols that do not have specialized headers would be a good candidate, such as Simple Flooding, Probabilistic, Counter-based, Distance-based, or Location-based, One obvious inter-protocol learner is to use any advanced broadcasting protocol whenever possible; but fall back to Simple Flooding when the network conditions are too extreme. In the present case, however, we hope to combine LENWB and AHBP in to a protocol that performs better than either one individually because we know that neither one is always better than the other over a wide range of simulations. The header of switching protocol was shown in table 5.1.

LENWB	AHBP	InterProtocl
Packet Type	Packet Type	Packet Type
Send Time	Send Time	Send Time
Node ID	Node ID	Node ID
Packet Route	Packet Route	Packet Route
Neighbor Nodes	Neighbor Nodes	Neighbor Nodes
Neighbor Count	Neighbor Count	Neighbor Count
	BRG Nodes	BRG Nodes
	BRG Count	BRG Count
Hop Count	Hop Count	Hop Count
Origin Address	Origin Address	Origin Address
Destination Address	Destination Address	Destination Address
Data Length	Data Length	Data Length

Table 5.1 Switching protocol header

Both LENWB and AHBP have special conditions that require the protocol to default to retransmit. Recall that if an LENWB node receives a packet from a new neighbor, it is unlikely to know of any common 1- or 2-hop neighbors previously reached; thus the node is more likely to rebroadcast. Performance evaluation of MANET broadcasting protocols in [3] has shown that as network topology changes more rapidly nonlocal decision Neighbor Knowledge Methods (such as AHBP) suffers and have low delivery ratio. However local decision Neighbor Knowledge Methods have low delivery ratio at high congestion levels. Thus we can develop a new protocol, in which each node track the amount of congestion and its speed to decide which protocol to use and better deliver ratio can be expected.

To facilitate a node switching between LENWB and AHBP, we make some changes to the structure and behavior of a broadcast packet. As shown above, the two protocols have a similar header format, so our combined header is the union of the two, with the most notable change including the BRG information from AHBP. Specifying the header also explains most of a node's behavior; it must implement a subset of both protocols, enough to fill the headers in a packet. When sending a packet, a node must specify the BRG nodes, whether that node is implementing AHBP or not. Node implementing LENWB already knows its uncovered two-hop neighbors, so it simply chooses the BRG in a greedy way. When a node receives a packet, it can choose to ignore the BRG fields in the header if it is implementing LENWB, or follow them if it is implementing AHBP. In this way, the local behavior of LENWB is preserved, and so is the non-local behavior of AHBP.

Speed

Congestion

	0- 4	4-8	9-12	13-16	17-20	21-24	25-28	28 -30
0-10	L	L	L	L	L	L	L	L
11-20	A	L	L	L	L	L	L	L
21-30	A	L	A	L	L	L	L	L
31-40	L	L	A	L	L	L	L	L
41-50	L	A	L	A	L	L	L	L
51-60	A	A	L	A	L	L	L	L
61-70	A	A	A	A	A	A	L	L
71-80	A	A	A	A	A	L	L	L
81-90	A	A	A	A	A	A	L	L
91-100	A	A	A	A	A	A	A	L
101-110	A	A	A	A	A	A	A	A
111-120	A	A	A	A	A	A	A	A

Table 5.2 Better performing protocol

Above Table shows the training data we collected to train our inter-protocol learner. We ran LENWB and AHBP simulations over the range of speeds and congestion levels. and we measured the delivery ratio of each node. An L indicates where LENWB is performing better and an A indicates AHBP is better. Speed is increasing column wise and congestion is increasing on row wise.

For an environment of high speed and low congestion, a node will use LENWB, and it will use AHBP when it encounters low speed and high congestion. When both speed and congestion are low or high, the delivery ratio is nearly equally good and bad, respectively, and the choice doesn't matter that much. (The model tends to choose LENWB under low speed and low congestion and choose AHBP under high speed and high congestion.) The more critical choices are in the middle of the above table 5.2, and these are also the cases in which the network will have some nodes running LENWB and some running AHBP.

5.2 Implementation of inter protocol switching

Switching between LENWB & AHBP was implemented by

```
    If( congestion >100 OR
       congestion >90  && speed <28  OR
       congestion > 80  && speed <25  OR
       congestion >60  && speed <21   OR
       congestion >40  &&  speed <17  && speed >12   OR
       congestion >40  &&  speed < 9  && speed >3   OR
       congestion > 60  && congestion<71  &&  speed <25   OR
       congestion > 11  &&  congestion<30  && speed <5   OR
       congestion  > 20  &&  congestion<41  && speed <13 && speed
  >8)
              use AHBP
```

CHAPTER 6
SIMULATION

6.1 Network Simulator

NS (version 2) is an object-oriented, discrete event driven network simulator developed at UC Berkely written in C++ and OTcl (Tcl script language with Object-oriented extensions). It implements network protocols such as TCP and UPD, traffic source behavior such as FTP, Telnet, Web, CBR and VBR, router queue management mechanism such as Drop Tail, RED and CBQ, routing algorithms such as Dijkstra, and more. NS also implements multicasting and some of the MAC layer protocols for LAN simulations.

NS-2 includes a tool for viewing the simulation results, called NAM. NAM is a Tcl/TK based animation tool for viewing network simulation traces and real world packet trace data. The first step to use NAM is to produce the trace file. The trace file should contain topology information, e.g., nodes, links, as well as packet traces. Usually, the trace file is generated by NS. During an ns simulation, user can produce topology configurations, layout information, and packet traces using tracing events in ns.

When the trace file is generated, it is ready to be animated by NAM. Upon startup, NAM will read the trace file, create topology, pop up a window, do layout if necessary, then pause at the time of the first packet in the trace file. Through its user interface, NAM provides control over many aspects of animation.

6.2 Simulation Environment

Extensive simulations were performed to compare the three protocols. All three of our traversal methods are implemented in the Network Simulator, NS-2 [11]. The simulator uses the IEEE 802.11 MAC sub layer. The performance of each method is tested in a network of 60 mobile nodes with a transmission range of 100 m in a 360 m x 600 m area. The nodes move according to the steady-state distribution for the Random Waypoint Mobility Model with the speed set to 1-4,5-8 , 9-12,13-16, 17-20, 21-24,25-28,28-30 m/s and pause time set to 10 s ±15%.Congestion level was set to 1-10,11-20,21-30,31-40,41-50,51-60,61-70,71-80,81-90,91-100,101-110,111-120. This mobility model initializes node positions and movements in such a way as to avoid the problems caused by the distribution of node movements changing over the simulation duration . Simulation parameters were shown below.

Input Parameters

Simulation Area Size	360m x 600m
Transmission Range	100m

Derived Parameters

Node Density	1 node per 3,600 sq.m
Coverage Area	31,416 sq.m
Maximum Path Length	700 m
Network Diameter	7 hops

6.3 Simulation Results

6.3.1 Number of switched nodes

As expected (see Figure 6.1) nodes more often chose AHBP at low speeds and LENWB at high speeds, and at the extreme cases the protocol follows AHBP or LENWB completely. At moderate speeds, the behavior of our learned protocol exhibits more of a gradual transition than a quick switch.

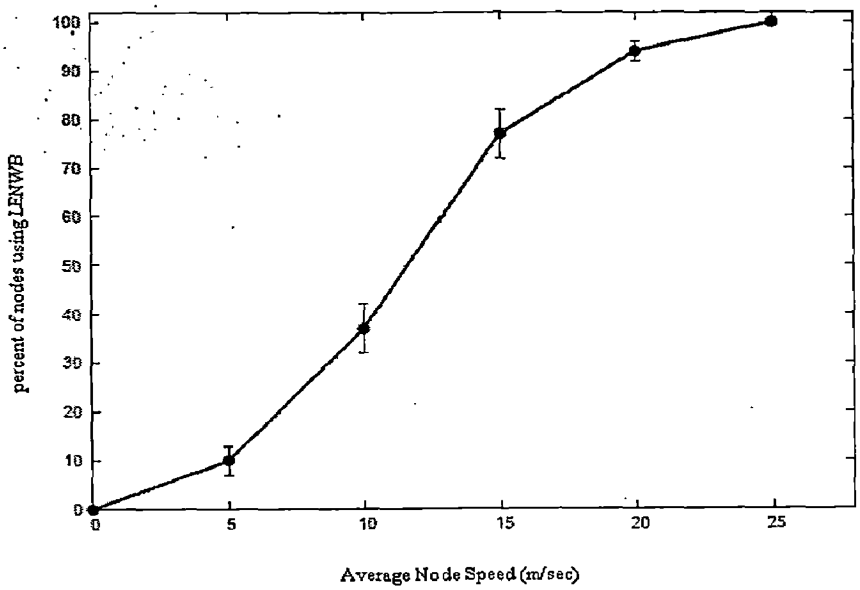

Figure 6.1 percent of nodes using LENWB

6.3.2 Speed vs Delivery ratio

Figure 6.2 is showing delivery ratio at fixed congestion level 60 packets/sec. There are some cases in which our protocol has a higher delivery ratio than AHBP or LENWB. Providing a node with the flexibility to implement the protocol that is best suited for its local conditions is the cause of the improvement.

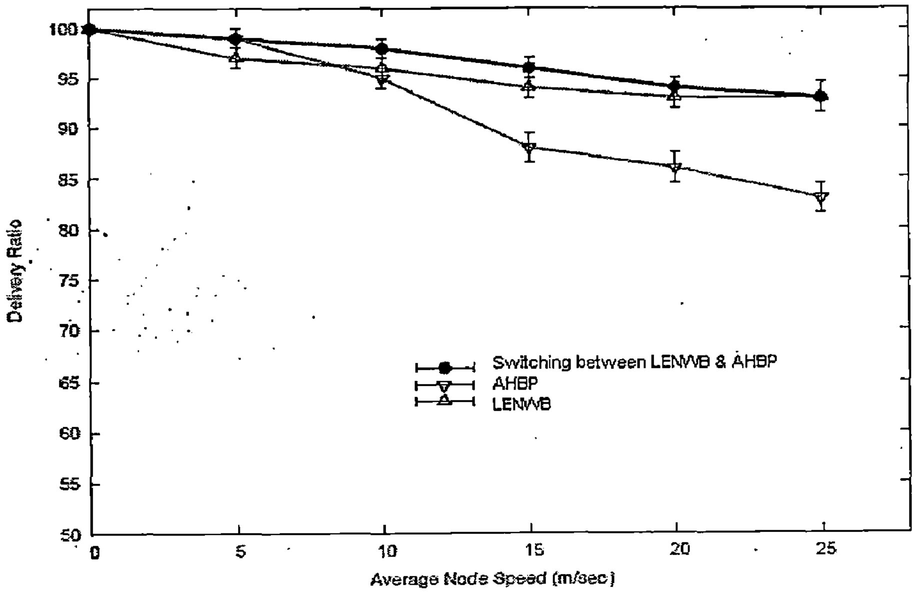

Figure 6.2 Speed Vs Delivery ratio

6.3.3 Number of Rebroadcasting nodes

Figure 6.3 is showing that there is some additional overhead cost in switching between protocols in terms of the number of rebroadcasting nodes. As Table V shows, there is also extra overhead in terms of number of bytes per broadcast packet.

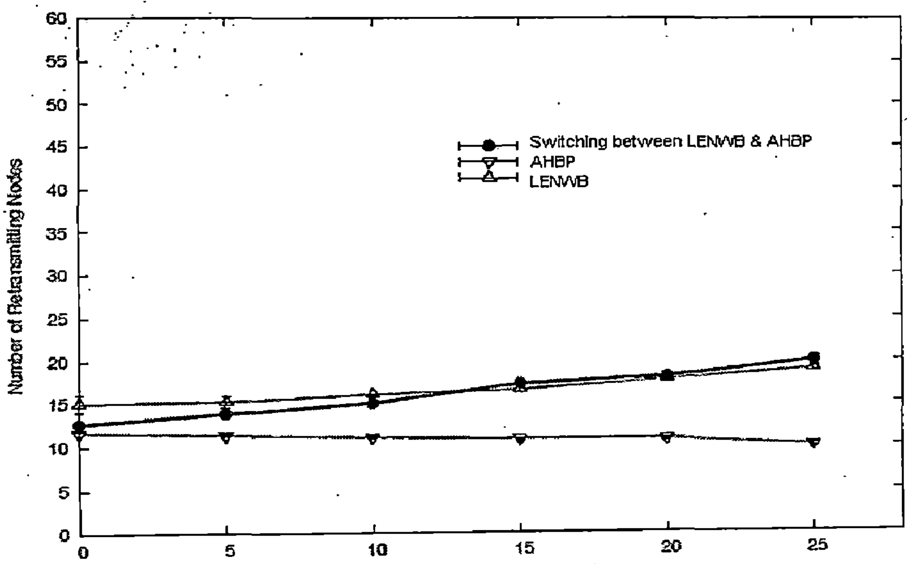

Figure 6.3 Number of Retransmitting nodes

6.3.4 Congestion vs Delivery ratio

Figure 6.4 is showing delivery ratio of AHBP, LENWB and switching protocol when speed was fixed at 25. Delivery ratio of switching protocol is just below LENWB at low congestion level and is just below AHBP delivery ratio

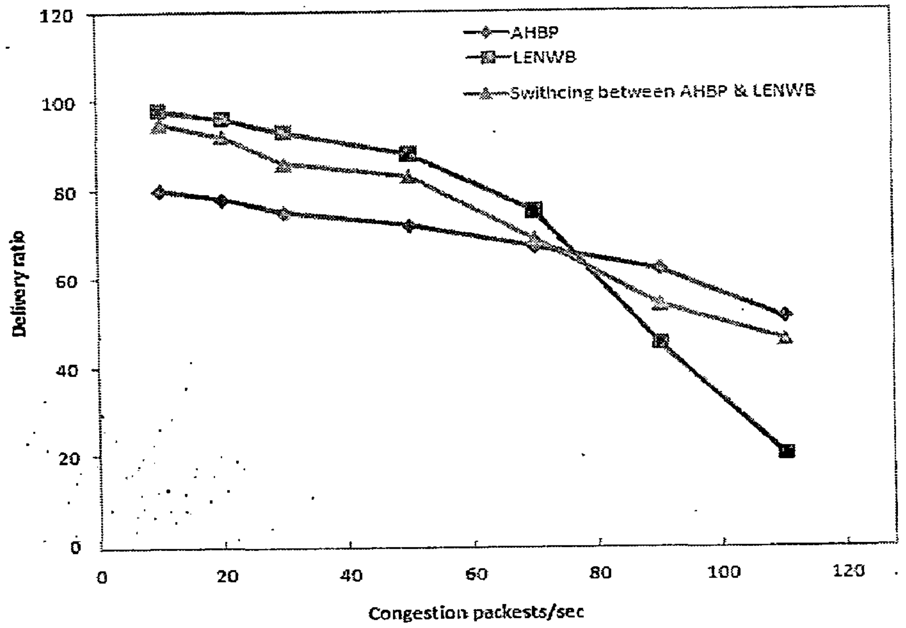

Figure 6.4 Congestion Vs Delivery ratio

For an environment of high speed and low congestion, Switching protocol has the delivery ratio closer to LENWB, and at low speed and high congestion Switching protocol has the delivery ratio closer to AHBP. In some cases Switching protocol has a higher delivery ratio than both AHBP and LENWB as the nodes can choose between two protocols depending on local scenario of the network.

CHAPTER 7

FUTURE WORK and CONCLUSION

A broadcast protocol is a building block of any MANET, so it is imperative to have the most efficient broadcast protocol possible for a reliable network. Because of this ,there has been interest in developing new broadcast protocols for MNs in a MANET.

This thesis carries out the development of a broadcast protocol based on inter-protocol switching which is efficient than existing protocols under the widest range of network conditions. We developed and compared our broadcast protocol.

Based on the performance investigation, the comparison of protocols indicates that the performance of Neighbor Knowledge is superior to the other methods proposed for a flat network topology. We compared our new broadcast protocols (that switches between AHBP & LENWB) with two Neighbor Knowledge and Methods (i.e., LENWB and AHBP).

Based on the performance results LENWB and AHBP are preferred over other broadcast protocols. Unfortunately, there is no clear choice between them because they each fit different niche areas.

It was demonstrated that protocol switching can be recommended for all expected scenarios (e.g., extremely congested network, and etc.). For an environment of high speed and low congestion, switching protocol has the delivery ratio closer to LENWB, and at low speed and high congestion Switching protocol has the delivery ratio closer to AHBP. In some cases switching protocol has a higher delivery ratio than both AHBP and LENWB. Delivery ratio can be improved considerably including other parameter like number of neighbors and speed of neighbors. It can be believed that choosing switching protocol is more desirable than choosing a static broadcasting protocol.

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