Simulating Dynamic Node Movements for MANET in NS-2

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Bachelor of Computer Science, KAU, 2008

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Computer Science

In the Graduate Academic Unit of Computer Science

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This report is accepted by the

Dean of Graduate Studies

THE UNIVERSITY OF NEW BRUNSWICK

January, 2013

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Abstract

MANETs are self-configuring infrastructure-less characterized by changing topology and intermittent connectivity. In these networks, nodes are able to move freely and change their locations due to dynamic nature. Because of mobility, nodes can be controlled and paused at any time based on the change of connections in the network. This report proposes two strategies: Following Nodes and Controlling the Random Waypoint Model. It also intends to show the effects of controlled mobility by simulating a variety of scenarios for MANET in the network simulator NS-2. Performance comparison is also conducted over many cases. Results illustrate that the performance of the node movement varies across different node densities, node distances, and node statuses.

Dedication

This work is dedicated to my parents who have given me the motivation to achieve my goals in this life.

Acknowledgements

All thanks due to Allah.

Indeed, I would like to express my deepest gratitude to my instructors whose guidance, assistance and support enabled me to choose this problem domain and achieve my targets. Surely, I would not have come this far without their support.

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List of Symbols, Nomenclature or Abbreviations

AODV	Ad hoc On-Demand Distance Vector
CBR	Constant Bit Rate
DSDV	Destination Sequence Distance Vector
DSR	Dynamic Source Routing
FTP	File Transfer Protocol
GPS	Global Positioning System
MAC	Media Access Control
MANET	Mobile Ad-Hoc Network
MH	Multi Hop
NAM	Network Animation Tool
NS	Network Simulator
RED	Random Early Detection
RPGM	Reference Point Group Mobility
RREP	Routing Reply

RREQ Routing Request

RWPM Random way point Model

TCL Tool Command Language

TCP Transmission Control Protocol

TTL Time To Live

TORA Temporally Ordered Routing Algorithm

UDP User Datagram Protocol

VANET Vehicle Ad-Hoc Network

WWW World Wide Web

Chapter 1

INTRODUCTION

1.1 Background

Wireless networks have brought fundamental changes to data networking, telecommunications and marketing integrated solutions in the interconnected world. These changes have revolutionized the meaning of the wireless by freeing users from wired connections and allowing them to communicate with fully distributed access at any time regardless of location. Wireless networks support a variety of user devices that become increasingly important for the communication of consumer's interests. These networks operate as a connection by using radio waves to link a number of devices, including laptops, mobile phones, etc. to the web world, for the purposes of business networks and other applications. These devices can be connected via the Wi-Fi hotspot to the web. Any areas with Wi-Fi coverage or connecting hotspots

can allow users to access the internet world as their usage requires. Hotspots are currently found at various public places, such as cafes, hotels, airports, lounges, and cinemas, where they can be under the wireless access network. Several benefits of using wireless networks are [16]:

- Convenience of Access: Every user can connect to the internet through a wireless network medium to the internet regardless of location and without the hassle of a wired medium in an area under wireless coverage.

- Increased Productivity: The wireless network medium gives users the chance to collaborate more without the necessity of desks and provides freedom from mess and restriction, as well as easy application execution.

- Effective Setup Installation: With a wireless network, there is no need to set up a wired connection channel. It is simple to install an automated approach for successful setup, while at the same time providing a cost-effective solution.

- Increased Security: Robust security protections are available in this medium.

Contrary to what has been mentioned above, however, there is the concept of a cellular networking that is important in order to analyze thoroughly

to get a better idea of a mobile service computation that suits one requirement. With cellular networks, the speed of internet access is not varied as per changes in the location of users. Cellular networks also offer more coverage range than mobile networks, but their ultimate flaw is that outside the coverage range over the internet access is really close to zero. They have low and costly bandwidth limitations, meanwhile extensive usage may also limit connectivity. Unlike wireless networks which require a fixed infrastructure, one of the characteristics of Mobile Ad-Hoc Network (MANET) is that the wireless nodes can dynamically form a network to exchange information without relying on fixed points. Furthermore, the MANET requires a proper protocol to quickly establish connections between the nodes, since the nodes change their positions frequently. The mobility of nodes affects the network performance; for example transmission speed, and receiving data. Currently we expect that the pattern of the node movement may have an impact on the performance of such a network.

Due to the difficulties and cost of building a real prototype of a network, many simulators have been developed for the purposes of network modeling. A large number of researchers utilize the network simulator NS-2 to represent the scenarios and models that include wired and wireless networks. NS-2 supports popular network protocols, generates node movements automatically for mobile networks, and generates trace file results for analysis. We are also able to simulate the node movement within the NS-2 simulator by using setdest. This tool generates using a random waypoint model the

positions of nodes, their speed, their moving directions, and stores it in a file. Setdest does not only generate a mobility pattern, but also calculates some topology metrics obtained from that pattern and adds them as comments at the end of the output file. There are many of the variants of the original setdest program written by the Monarch group such as setdest rwp, setdest cm, and setdest cm af [24]. Owing to the behaviour studies of both the wireless and cellular networks, wireless networks are more compatible for the MANET simulation process as an access limitation is not affordable for its use [4].

In the MANET community, simulation research is the fundamental concern relating to proposing effective methodologies for its beneficial use. The control of many mobile devices around the world is required in order to establish connectivity among each other or to deliver a message. The main fields that are gaining the beneficial aspects of node mobility in wireless Ad-Hoc networks are robotics, controlling traffic military applications, etc. The proposed solutions to the problems faced in these fields are essentially based on simulations by the NS-2 of the MANET.

1.2 Problem and Objectives

Currently, it is expected that the pattern of the node movement may have an impact on the performance of such a network. There are limitations in controlling the node mobility dynamically in NS-2 when using the built-in

generators for MANET. Namely, the available NS-2 node movement generators are normally used to generate a movement file *before* the simulation, modeling the nodes moving along pre-planned or random paths. In this project, we plan to simulate the mobility in NS-2 further beyond the available built-in models. The main objective of this project is to simulate a node movement dynamically *during* the simulation. We plan to generate node movement dynamically by using the values produced during the simulation and considering different parameters. One important aspect of this research is to develop appropriate simulation methods where mobile node movement is controlled based on the state of the network. In addition, it is intended within this project to propose and test by simulating a few different mobility strategies based on the actual state of the network. The main reason for proposing these strategies is to maximize the network performance measured, for instance by a throughput. This project anticipates the following:

- To understand the theoretical possibilities of node movements in order to enhance quality of services in wireless communication using MANETs.
- Understanding the main concepts related to MANETs and using routing protocols.
- Understanding the performance and difficulties of dynamic routing protocols in MANETs, while taking into account the dynamic node movements.

- To implement different scenarios of node movement during the simulation in an effective simulation environment NS-2.

This project reinforces the concepts in MANETs and the existing methods, in addition to accepting its efficiency in diverse cases. A complete analysis will reveal the requirements for extra optimization of traffic and a routing layer protocol. This project can prove that many factors can affect the performance of routing protocols such as changes in the topologies, number of nodes, and node movements. Thus, it will support researchers in building a traffic type and routing protocol in order to meet the needs of most environments and network parameters.

1.3 Related Work

This report has been inspired by different studies of the concept [10,11,12,13,21] of dynamically controlling node movements. Goldenberg, Lin, Morse, Rosen and Yang [6] investigated in their paper some of the algorithms to: first controlled mobility approach, finds a route to destination D, and relay nodes moving in rounds (MR) to their optimal spots along the S-D straight line for energy conservation. Chen, Jiang and Wu [7] did a study about mobility control schemes with quick convergence in WSNs where they attempted to: Improve MR with two more advanced mobility schemes (still in rounds), Straight mobility never considered as it can break, and path connectivity during node movement. Another related work entitled [8] Ns2 SetDest Ac-

celeration Enhancement, EEC 787 Final Project Mid Report by Brian Krupp and Limei Hou was done in which they tried to work around the primary objective of bringing in the inherent acceleration and deceleration support of nodes. NS-2 has no built-in support for this issue. This acceleration and deceleration supports the theory of nodes as they move with sedest command. Krupp and Hou tried to use this capability to break a movement using setdest into several setdest commands. This approach will cause nodes capability to bring changes in node movement in such a way that the node moves away from its origin position; it decelerates in speed, and after reaching a specified point while on the path to its destination, the speed becomes constant again. According to Krupp and Hou, they can implement an approach where each setdest command that makes up each component slowly increases or decreases the speed. According to Krishna Gorantala [9] in Routing Protocols in Mobile Ad-hoc Networks, he tried to work with study the various mobile ad-hoc routing protocols and their relative behavior in ad-hoc networks and specifically analyzing variety of routing protocols.

1.4 Report Organization

Chapter 1 gives an introduction and brief overview illustrating the general composition and working terms of a wireless network. Preliminary research on wireless networks and their introduction is discussed in detail.

Chapter 2 discusses the main concept of MANETs with information about

the research on the issues faced in Ad-Hoc network. This chapter also contains an analysis of various routing protocols in the MANET covering technical details and important concepts for developing a better understanding of routing protocols and their working techniques.

Chapter 3 discusses about the literature contributed in this field and existing node mobility models of the Ad-Hoc networks. The other details in this chapter include an in-detail analysis and advanced IEEE lectures research for the mobile networks.

Chapter 4 gives an introduction about the network simulator NS-2 as well as the features and capabilities of this simulator. This chapter discusses the component of a MANET inside the NS-2, traffic generators, and mobility. A complete of setdest tool and its limitations is included.

Chapter 5 illustrates controlled node movement methods, including strategies for expected scenarios.

Chapter 6 discusses the results obtained from the NS-2 simulations and the resources utilized for analyzing trace files, along with plotted graphs and screenshots.

Chapter 7 the final conclusion and recommendations for further research will be mentioned in this chapter.

Chapter Summary:

This chapter introduces the report with an overview on Wireless networks, and states the aims, objectives and deliverables of the chosen topic. Brief theoretical information about Mobile Ad-hoc and some of its related work are discussed. Finally, this chapter concludes by explaining the methodology used in reaching the aim of the project.

Chapter 2

MANET

2.1 Mobile Ad-Hoc Networks

The Mobile Ad-Hoc Network (MANET) is a kind of wireless network that consists of a group of mobile nodes that communicate with each other without relying on fixed infrastructure. They are arbitrarily located and move dynamically in such a way that the interconnections between nodes change constantly. Each node in this collection acts as a host and as a router, serving the communication processes in the MANET. A routing node is a connection point in the network, and it uses a protocol to forward data from a source to a destination point. As mentioned in the previous chapter of this report the wireless networks facilitate mobility of usage for all the connecting nodes in the network. These nodes utilize the varying random access of wireless channels. Enlisting them is the multi hop forwarding channel via the wireless

mobile ad hoc. In the network routing channel that is analyzing the path through which the packets of information are to be transmitted via a wireless channel is determined. For the mobile ad-hoc network, complete routing is done in a very friendly manner; the nodes of network are not restricted to host functionality alone; they also act as intermediary routers in the channel of transmission to route data packets from one node to another within the network range [2,11].

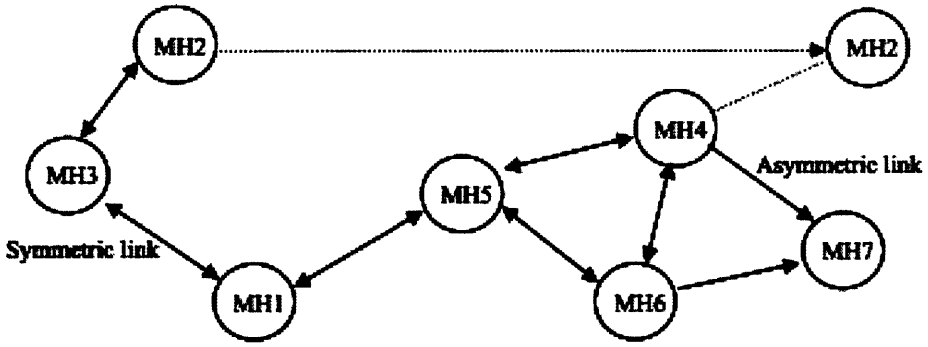

Figure 2.1: Connecting nodes in MANET [39]

For example, Figure 2.1 shows the MH [1- 7] are the nodes placed in a small Ad-Hoc network illustrating the connection between them with arrows. Figure 2.1 is indicating the information transmission between the nodes. These nodes are free to move within range of wireless network. Along with the tremendous range of a benefit package, however, the wireless ad-hoc networks have also some issues that are mentioned below [5]:

- **Asymmetric Links**: An ad-hoc network does not support symmetry

in the connection channel between the nodes, which is a big issue when dealing with the quality of connection established in direct and reverse directions. Nodes are allowed to move freely in the wireless network range, thus it proves to be troublesome in this perspective.

- **Routing Overhead**: As the nodes in ad-hoc routing network are completely free to move constantly in the bounds of network, there is much routing overhead in the tables maintained by the routers for continuously changing positions of the nodes. Because nodes act as the routers for forwarding information packets, therefore this mobility leads to the serious issue of overhead in the routers.

- **Interference**: Total transmission between the nodes can be completely corrupted if one node in the routing channel with another one interferes. Links are settled according to the transmission characteristics, thus there is a very strong possibility of interference between nodes in the wireless channel. This is really a serious flow through this network routing.

- **Dynamic Topology**: The router table in an ad-hoc network updates very slowly since nodes move continuously in the channel and the respective updating as per the movements is affected by this mobility of nodes. This is the greatest issue for analyzing the effectiveness of wireless Ad Hoc routing networks. The problems incurred in the wireless ad hoc routing networks are often very unpredictable and badly

affect the efficiency of a system causing multiple delays and qualitative suffering.

2.2 Research Challenges of MANETs

MANET is essentially an infrastructure less, self-configuring network that facilitates the mobility of nodes within the coverage range of all nodes or devices connected through the means of a wireless link. Links to the connected devices change as per the change in location of the network access range. Each node is allowed to change the link connection with other devices frequently. Working as routers, the connecting nodes forward network traffic that is not related to them. The MANET possesses all the mentioned characteristics and issues stated in the above section of mobile ad-hoc networks. The broad research challenges associated with the MANET are broadly categorized as follows [11]:

- Incorporation of wireless network elements, i.e. MDs and ad-hoc routers in the existing networking protocol of Ad-Hoc routing framework.
- Providing end-to-end service abstraction to facilitate application development.
- The assurance of security and credentials are very difficult to maintain each from different attacks due to the nodes' mobility.

2.2.1 Throughput

Throughput is an important dimensional parameter of the network. It is the average number of data packets transmitted through a channel with successful delivery. Overall system throughput is calculated by the sum of data rates over time [14].

2.2.2 Mobility

Mobility is the tendency of nodes connected in a wireless network to move freely and within the bounds of network coverage. In mobile networks, this capability free movement is allowed for the nodes. It consists of great featuring benefits for the network users in terms of collaboration, interaction and increased productivity. Today mobility is responsible for many beneficial uses of mobile networks freeing the users from the hassle of wired connections and locations. Along with the many benefits of the tendency to mobility in wireless networks, there are also several disadvantages for this issue, including the measurement parameters for node location computation which causes inaccuracies due to their mobile tendency, and free movement in the network [15].

2.2.3 Scalability

It is the overall capability of a system to handle and increase the throughput in case of the increased load or the addition of more resources. Scalability is

basically the ability of the network to handle its growing load over it. The routing in a network system is considered scalable if its routing table for each node grows as O (logN), where N represents the number of nodes [3].

2.2.4 Restricted Bandwidth and Power

The participating nodes in MANET topologies are different. They have propagation parameters and varying of signal strength. Losses of attenuation and interferences require extra signal strength, thus the use of restricted resources must be developed in an efficient way.

2.3 Significant Features of MANET

In a MANET, nodes move in many directions therefore network topology may rapidly change at any time which is known as multi-hop. Wireless links tend to have lower capacities than the wired ones. Typically, congestion occurs in these types of networks that frequently exceed network capacity. In terms of energy, all the nodes in a MANET rely on batteries. Thus, power conservation is significant for these nodes. MANETs are more prone to security attacks compared to the fixed networks [26].

Performance Issues:

1. In a MANET, the nodes are reliable on batteries; therefore, they can be designed for long lasting batteries.

2. In terms of security, the mobile networks are more aware of the online network attacks, compared to wired or fixed networks. MANETs have decentralized networks and therefore provide the security against failure that does not exist in wired networks.

3. In terms of scalability, MANET plays a significant role and can be managed in time.

4. The mobile ad-hoc network working group is developing peer to peer mobile routing in mobile ad-hoc networks that will have similar functionality to fixed networks.

5. The traditional connectionless IP services are going to be supported by MANET. [26]

2.4 Types of MANET Protocols

Routing protocols in MANETs can be classified in many ways based on routing strategy and network structure. In routing strategy, routing protocols can be classified as table-driven and source initiated, while in network structure, routing protocols can be classified as flat routing, hierarchical routing and geographic position assisted routing Figure 2.2 [18,19].

- **Table-Driven routing protocols (Proactive):**

Proactive protocols maintain routing information even before it is needed. All the nodes in a network maintain routing information to other nodes in the

network. This is kept in the routing tables and is updated with the changes in network topology. These routing protocols belong to the category of link-state routing. Proactive protocols are not very suitable for larger networks; to maintain entries for every single node in the routing table of each node causes more overheads in the routing table thus consuming more bandwidth [19].

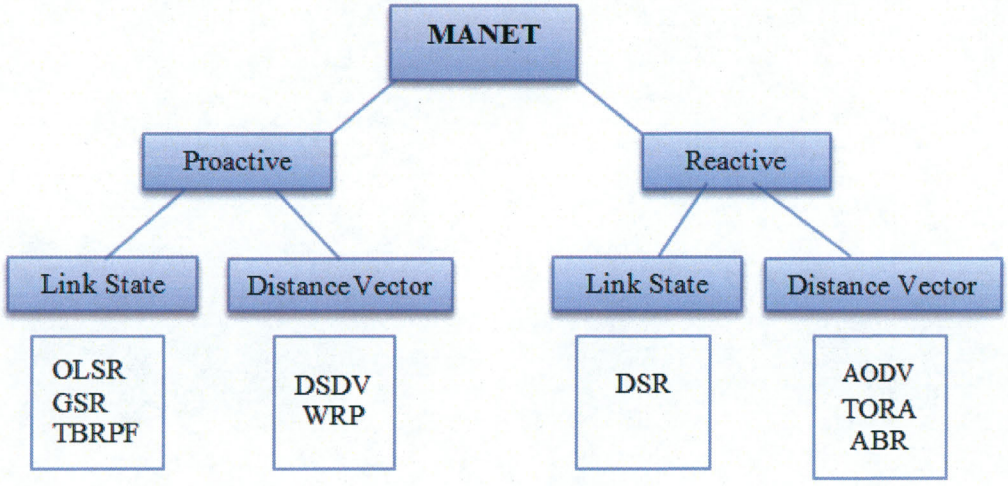

Figure 2.2: Types of MANET protocols

- **On Demand routing protocols (Reactive):**

Reactive protocols are also called on demand protocols, and they do not require maintaining routing information or routing activity in idle network node status. In cases of communication initiation by a node to another node, the protocol searches for the route in an on-demand manner. A connection is

then established to transmit and receive packets. This discovery of the route usually occurs through flooding the requesting packets on the entire network [18,19,20].

2.5 General Issues for MANET Routing

The wireless ad-hoc network is a non-centralized wireless network. The coverage media are termed as Ad Hoc because the channel for delivering data packets through the network is not pre-determined. This network is established in a spontaneous manner as per necessity. Such networks function as a walkie talkie for all the connected devices with them. It is basically a temporarily formed group of stations or nodes in a network that carry out a specific task. In MANETs, there are a number of associated problems with routing which includes asymmetric links. Wired networks depend on the symmetric or fixed links while in ad-hoc networks as the nodes are always mobile and dynamic constantly changing their position in the network. Therefore, when one node sends a signal to another node, it can be unaware of the quality of the connection in the reverse direction about the source node. Another problem with ad-hoc networks is routing overhead when nodes frequently change their location, causing stale routes to be generated in the routing table which creating unnecessary routing overhead. Interference is also major problem with mobile ad-hoc networks. The frequent connections and disconnections of their specific transmission characteristics might inter-

fere with another transmission, and nodes might be overhead transmissions of other nodes that corrupt the total transmission. The topology is not constant in ad-hoc networking. Nodes move and change medium characteristics and with this mobility, there must be adaptability in routing tables and routing algorithms. Ad-hoc networking topology requires a more frequent updating of the routing table [25,26]. The Figure 2.3 below better illustrates the composition of wireless network among several connecting nodes in an ad-hoc network.

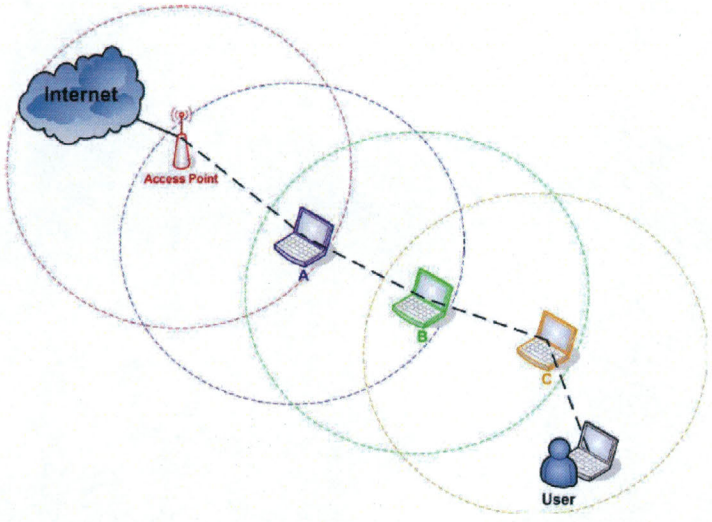

Figure 2.3: Composition of wireless network among several connecting nodes

Along with providing potential advantages in an ad-hoc approach, there are also other issues related to this channel. Several issues related to the wireless ad-hoc networks are highlighted below [26]:

- Security is the biggest concern while dealing with the wireless ad-hoc network routing. Because the data delivery takes place from node to node. It is extremely difficult to maintain the security standard at every node of the ad hoc wireless network.

- Medium access is another issue while dealing with ad-hoc networks because there is no time synchronization or direction specification.

- Extensive delays in routing are another major issue of Ad Hoc networks.

There are other issues in the ad-hoc wireless networks as well relating to their self-organizing behavior. This causes the connection link failures on and off in the network including the issues for addressing and service discovery in the network [26]:

1. Distributed operation is an important feature of the MANET.

2. Solving the spinning of a small fraction of packets in the network for an unknown period of time by TTL values.

3. Assuming that the traffic in the MANET is not always uniform, it changes as time passes. Thus the routing algorithms can be modified in such a way to accomplish the demands or needs if this executed in a better method, then the energy and bandwidth of the network can be utilized more efficiently.

4. Network nodes in MANETs try to maximize the way in which they can

save energy. This is known as sleep mode. For this reason there should be a routing protocol that can accommodate the issue of sleep periods.

5. Reducing the end to end delay of the data packet.

6. To establish the route from one node to another requires a specific amount of time. That time should be decreased to a certain range.

7. The measure of the bit efficiency is the average number of data bits transmitted/data bits delivered.

Chapter Summary: This chapter describes the necessary background for the MANETs, and all of the related issues with challenges, routing, and performance. There is also some brief information about the type of routing protocols in MANETs.

Chapter 3

EXISTING MOBILITY MODELS FOR AD HOC WIRELESS

3.1 Introduction

The rapid growth in the field of wireless communication leads researchers to develop and enhance the quality of service that in line with the demand of the digital world. Satellite, WiFi, and WiMax all make continuous improvement in this communication field. There is a bandwidth limit of data delivery for each type of technology in order to improve the supporting infrastructure. In emergency cases and disaster, these architectural types of communication are hard tasks and time consuming. Therefore, a dynamic infrastructure

communication networks play an important role in these cases since they can provide support without relying on a fixed infrastructure. Even though mobile ad-hoc networks are in the phase of development and study, they have served the purpose of networking. Furthermore, once the network does not have any basic support, then the nodes in this of networks simply depend on the routing protocol and node mobility.

3.2 Reliability in MANETs

Many researchers have studied ad-hoc protocols performances via simulations assuming that the parameters of an environment are unchanged. It is difficult to represent the complexities of real time in a simulation. In order to study the differences between protocols the reliance upon this type of technology depends on this accurate output from simulations. Because of the limited functions of nodes, once the network is partitioned at different times, the main role of reliable nodes became a significant factor in forwarding packets. Therefore, routing protocols and node mobility can efficiently address issues that are needed in MANETs.

3.3 Mobility Models

The purpose of modeling is to evaluate the impact of using different routing protocols and mobility patterns in MANET performance. Further, modeling

permits the analysis of the MANET performance over a wide range of scenarios. Testing these models and topologies on a small scale helps to avoid errors in a real network. Rather than building an actual mobile network consisting of physical nodes, we can visualize the interactions between network nodes in a model. Therefore, a network model can be constructed in a simulator.

Table 3.1: The categories of mobility models in MANET [28]

<table>
<tr><th colspan="4">Mobility Models</th></tr>
<tr><th colspan="2">Random Models</th><th>Spatial Dependence Models</th><th>Temporal Dependence Models</th><th>Geographic Restriction Models</th></tr>
<tr><td rowspan="3">Random WayPoint Model</td><td>Other</td><td>Reference Point Group Model</td><td>Gauss-Markov Model</td><td>Pathway Mobility Model</td></tr>
<tr><td>Random Direction Model</td><td rowspan="2">Set of Correlated Models</td><td rowspan="2">Smooth Random Mobility Model</td><td rowspan="2">Obstacle Mobility Model</td></tr>
<tr><td>Random Walk Model</td></tr>
</table>

The Random Waypoint model is one of the mobility models that is frequently used in simulations. In this model, nodes choose the destination randomly and then move towards it with randomly chosen velocity. They stop for a predefined pause time and then again choose a random destination. This keeps on repeating till the end of the simulation [12]. There are generally four different mobility models in NS2 simulations of MANETs. These mobility models are differentiated as per their spatial, temporal and geographical dependencies. The mobility model defines the movement pattern of each node in a topological area. Table 3.1 provides the categories of mo-

bility models in MANET. Several existed classes that they are based on their specific mobility characteristics. For some mobility models, the movement of a mobile node is likely to be affected by its movement history. Some of the mobility models rely on the movement history for their node mobility. This type of model is called temporal dependency. Another type is classified as a spatial dependency where the mobile nodes intend to move in a correlated form in some scenarios. If nodes are moving in the same direction, then they have high spatial dependency, and if nodes have the same velocity, then they have high temporal dependency. The nodes follow the model to randomly move within the space. Finally, the node movements that are restricted to geographic environments such bounded bystreets, freeways, and obstacles [28].

Furthermore, the following existing mobility models have been studied and analyzed

- Random Direction Mobility Model.
- A Boundless Simulation Area Mobility Model.
- A Probabilistic Version of the Random Mobility Mode.
- Constant Velocity Random Direction Mobility Mode.
- City Area, Area Zone, and Street Unit Mobility Model.
- A Hierarchy of Mobility Model.

The above models are the important mobility models, which are compatible with NS-2. The mobility files generated by existed tools can be directly exported to the TCL code and run in the simulation NS-2.

Various simulations are used to evaluate MANET routing protocols' performance. In simulations, experiments are modeled with an environment of the network topology, network traffic, and protocols. Another consideration in MANETs is the mobile nature and node mobility on these types of networks. Physical layer issues such as the radio frequency channel, terrain, antenna properties, energy, and battery characteristics are all the considerations to make before simulating the MANETs environments. Through node mobility and physical layer characteristics, the connection status is determined. This also helps to find out the network's dynamic topology. Link connectivity plays an important role by affecting the relative performance of MANET routing protocols. In routing protocol performance, any changes in connectivity trigger routing events. This also determines routing failures and routing updates. If the packet delivery time is increased or if the fraction of delivered packets is decreased, this leads to routing overhead. Therefore, it is important to assume link connectivity as close and exact as possible because these factors affect simulation results for MANET routing protocols significantly. The mobility model determines the positions of nodes to be simulated. This relative node location along with physical layer assumptions determines the link connectivity. Independent mobility models assign movement vectors independently without considering the relative movement of

other nodes. Group mobility models consider related movements of groups of nodes. The random waypoint model, which commonly uses mobility models for simulations of MANETs, does not clearly provide the understanding of the relationship between the random waypoint model's parameters and the rate of change of link connectivity. Also, the random waypoint model takes longer to calculate the average link-up or link-down lifetime to reach a steady state. The computational resources are intense in random waypoint model [12, 21, 26].

Chapter Summary: Various existing mobility models in MANET are discussed, explaining the categories of these networks. Brief information about each category type is discussed, including more details about the most commonly model is used, which is Random Waypoint Model (RWP).

Chapter 4

NETWORK SIMULATOR

4.1 Overview

The NS-2 simulator is a powerful program for network simulation. It is an open source based simulator that uses two languages OTcl/C++, to create a simulation environment. NS-2 includes support for the simulation of both wired and wireless networks especially MANETs. It is a packet-level simulator capable of having a discrete event scheduler for packet and timer expiration. There are a number of network components and protocols that the NS-2 implements [8]. The NS-2 simulator allows experimenting with existing network protocols. It also allows users to research the modifications of network protocols. In NS-2, setdest commands are used for mobility features. Mobile devices are not often stationary. NS-2 provides a mechanism to test the movement of these mobile nodes and allows the simulation the capability

of having an object move at a certain time to a specific coordinate from its current location at a specific constant speed. With the help of 'setdest' functionality, movements of mobile devices can be simulated in NS-2. In terms of size, NS-2 is helpful in a large and small-scale set of nodes [8,22].

4.2 Functional Description of NS-2

- A single simulator accommodating both detailed and high level simulations.
- Abstraction allows examination and validation of protocols without changing simulators.
- Emulation providing the capability to interact with operational network nodes instead of being confined to a simulated world.
- The creation of complex traffic patterns, topologies and dynamic events to achieve valid and useful results through scenario generation.
- Visualization helping to understand the complex behavior of network simulation. The Network Animation Tool (NAM) helps to develop better protocol and debugging.
- Extensibility allowing users to add new functions and explore different scenarios in protocol study. The split programming model in NS makes it capable of adding new scripts in an efficient way.

NS-2 is a valuable tool for network researchers through providing a common simulation platform making protocol engineering simple and providing an insight into the operations and interactions of networking protocols. NS-2 is utilized for three broad reasons in research:

1. Selecting a mechanism or protocol variant.

2. Investigating the performance of composite networks.

3. Exploring unanticipated connections of various protocols.

In routing, NS-2 is utilized for the robustness and convergence speed of integrated distance-vector and link-state routing protocols, multi-hop/wireless routing protocols, and for ad hoc routing in wireless networks, as well as the fairness of routing protocols. For Variable Traffic Sources, NS-2 is utilized to study for various sources of network traffic like the World Wide Web (WWW), file transfer protocol, Telnet and stochastic sources. While studying Queuing Disciplines, NS-2 can be utilized for random early detection (RED), drop-tail, class-based queuing, and others. In multicast transport, Scalable Reliable Multicast (SRM) and variants, PIM variants, router support for multicast, congestion control, protocol validation and testing, reliable multicast can be studied through the NS-2 simulator. It also helps in transcoding layered video, audio and video quality-of-service.

4.3 NS-2 Capabilities in MANET Simulation

Wireless mobile ad-hoc networks the networks without any physical connections. Such networks have no fixed topology due to the mobility of nodes, interference, multipath propagation and path loss. In NS-2, results can be quickly obtained besides testing more ideas in smaller time frame repeatability, which helps in debugging. The main disadvantage, however, is that real systems are too complex to model. For these ad-hoc networks, dynamic routing protocol is required for proper functioning. There are many routing protocols developed for handling the mobility in wireless networks. Therefore, the goal of this project is to come up with different movement methods to overcome the limitations in these routing protocols [8,23].

4.4 Simulator Set Up

Table 4.1 presents the version and the type of machine that has been used for the simulator environment.

Table 4.1: Simulator used for the experiments

NS-2.34 version Components in NS-2.34	Intel® Core™ 2 CPU 6400 @ 2.13 GHz Operating system: Linux Ubuntu 10.04 RAM: 2GB
TCL 8.4.18	
TK 8.4.18	
Otcl 1.13	
TclCL 1.19	
NS 2.34	
Nam 1.14	
Xgraph 12.1	

4.5 Components of a Mobile Ad-Hoc Network

There is a group of mobile nodes in an ad hoc network pattern that have the capabilities of wireless transmission. These nodes' internal architecture is defined as a protocol pack. Another defined component in wireless communication is the propagation media, including transmission and radio models. In the real network, it is infixed into a topological area that can be determined by the environment size and structural specifications. These nodes move in the determined area. Thus, the mobility form must be determined unlikely; in this report, we attempt to defend the movement based on the state of throughput from source to destination. Nodes use battery power which is explained by the energy model; in our case, however, this factor is neglected. Finally, it is required that we define the traffic data in the network as one of the components. All the previous methodologies produce a form to a simulated MANET environment by using NS-2. This report focuses on the effect of mobility on the performance of MANETs [24]. The parameters chosen and methodology implemented are discussed in detail in chapters 5 and 6.

4.6 Mobile Node

The mobile node is a separate object that is implemented in NS-2. It is connected with many more features to the basic ns node. According to defined algorithms, the main function of a mobile node is to receive a packet, test the packet, and then map the packet. The mobile node is defined by the specifications required for its functions in a protocol stack as in Figure 4.1

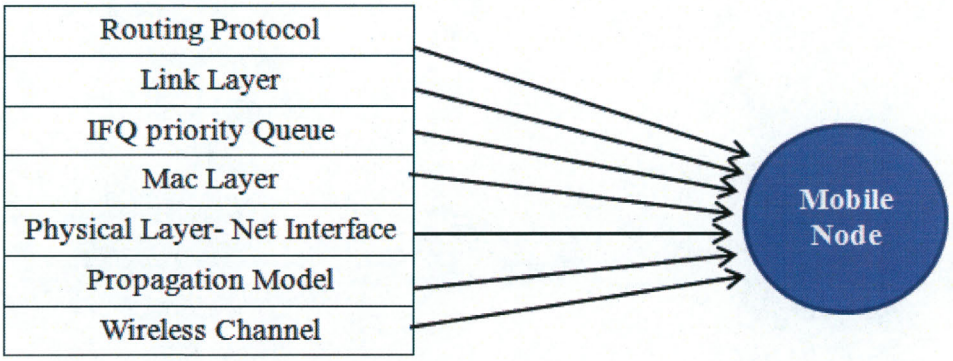

Figure 4.1: Protocol stack for a mobile node in NS-2

4.6.1 Node Configuration

Link Layer: The link layer is attached to the actual transmittal of a packet. It converts IP addresses to MAC addresses and routing agent. All the links are created in the data of the link layer. This layer comes between the Network Layer and Physical layer.

IFq Priority Queue: The IFq is implemented to give priority to routing

protocol packets by inserting them in the queue. It runs like a filter over the packets and removes those with a defined destination address. A few of queuing techniques are available such as DropTail, RED, CMUPriqueue, etc.

Mac Layer: The MAC mechanism is critical for communication. It utilizes the implementation of IEEE 802.11 distributed coordination function (prior to release ns-2.33). Several 802.11 implementations are available in NS-2 along with the one which is used in this report.

Network Interface: It is the physical interface that serves as a hardware interface. The network interface is used by the mobile node in order to access the channel. It is responsible for recording every transmitted packet with data connected with information like energy, power, wavelength, etc. This meta-data in the packet header is used by the propagation model in the receiving network interface. It determines, via the receiving node, if the packet has the minimum power to be received and/ or detected (carrier sense).

Radio Propagation Model: Network simulator NS-2 supports three propagation models which are:

1. Free-Space Model: When there is a direct line-of-sight path between the transmitter and the receiver. The type of network model is called a free space model. In circular formation, when the devices are placed in the operating space of the transmitter then all the packets are received.

2. Two-Ray Ground Model: If a ground reflection is also considered in the

Free - Space model. This type of improved model is called a Two-Ray Ground Model. In this mode, if the distance between the transmitter and the receiver is long, then this model provides comparatively better and more accurate results. In this report, we will use the Two-Ray Ground Model where the power received is given by the equation:

$$P_r(d) = \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4 L} \tag{4.1}$$

Where Pt is the transmitted signal power, and Gt and Gr are the antenna gains of the transmitter and the receiver respectively. L is the system loss and ht and hr are the heights of the transmitter and receiver antennas [24].

3. Shadowing Model: The shadowing model is especially useful for longer distances. For short range models, the free space model and two-ray ground model work well, as in those two models, line-of sight is possible. If the distance between the transmitter and the receiver is longer, then shadowing model is used in simulations for wireless networks.

Antenna: An omni-directional antenna having a unity gain is used by mobile nodes which are used in this report.

Topology: Topology must be created before the node configuration for the nodes to run the simulation scenario. In NS-2, the topology is a flat grid model by default, which determines the width and length of the area to be simulated n x n or n x m.

4.6.2 Traffic Generation and Mobility

Simulations are based on Constant Bit Rate (CBR) applications, like using the internet protocol UDP (User Datagram Protocol), which includes features like the destination node being not required to send back acknowledgements, and predefined packet size. The interval between the packets is pre-set, and the data transmission is not reliable. Although, the File Transfer Protocol (FTP) traffic can also be made through the Transmission Control Protocol (TCP) connection because of the advanced features like congestion control requiring dynamic adjustment of the transmission rate based on the traffic conditions. It becomes difficult to employ uncomplicated and power efficient devices for basic applications. Another reason is that in order to test the limits of a network in network performance analysis CBR traffic can help finding the congestion threshold. In this situation, employing performance metrics like the delivery ratio can be more useful. If we deploy flow controlling like in TCP, the transmission will be automatically adjusted resulting in a 100% delivery ratio. NS-2 supports several classes of agents. This report will use CBR traffic over UDP agent to examine the performance of the chosen protocol in MANETs. The traffic will be based on two fixed nodes (source and destination) far away from the location of each other while the reliable mobile nodes are located in between and around.

```
$ns_ node-config -addressingType flat or hierarchical or expanded
                 -adhocRouting   DSDV or DSR or TORA or AODV
                 -llType         LL
                 -macType        Mac/802_11
                 -propType       Propagation/TwoRayGround
                 -ifqType        Queue/DropTail/PriQueue
                 -ifqLen         50
                 -phyType        Phy/WirelessPhy
                 -antType        Antenna/OmniAntenna
                 -channelType    Channel/WirelessChannel
                 -topoInstance   $topo_instance
                 -wiredRouting   ON or OFF
                 -mobileIP       ON or OFF
                 -energyModel    EnergyModel
                 -initialEnergy  (in Joules)
                 -rxPower        (in W)
                 -txPower        (in W)
                 -agentTrace     ON or OFF
                 -routerTrace    ON or OFF
                 -macTrace       ON or OFF
                 -movementTrace  ON or OFF
                 -reset
```

Figure 4.2: Node configurations in NS-2

4.6.3 Routing Protocol Used

Currently, there are four routing protocols for use in the MANETs supported by the Network Simulator NS-2 which are: the Destination Sequence Distance Vector (DSDV), the Ad-Hoc On-Demand Distance Vector (AODV), the Dynamic Source Routing (DSR), and the Temporally Ordered Routing Algorithm (TORA) [18]. In this report, we use AODV for all the cases.

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

The Ad-hoc On-Demand Distance Vector (AODV) Protocol is an effective

protocol for mobile ad-hoc networks. This algorithm was motivated by the limited availability of bandwidth in mobile networks. AODV protocol uses many positive aspects of DSR like on demand route discovery, route maintenance and hop-by-hop routing of DSDV algorithms. The quality of obtaining the routes on-demand basis of AODV protocol is a desirable algorithm for MANETs [9, 18].

AODV technique:

In MANETs, each node acts as router obtaining routes on the basis of necessity. This makes MANETs self-starting networks. The routing table is maintained at each node with entries for neighboring nodes. When another node initiates communication, the broadcast initiates discovery by advertising a route request packet (RREQ) to other nodes in the network. While moving forward, every route request packet automatically records the reverse path to the source node. Moreover, the receiving nodes continue recording the address receiving the request packet. This algorithm is called Reverse Path Setup. This information is maintained for an appropriate time for the RREQ to traverse the network. For the intermediate nodes, if the desired destination node entry has a newer sequence than that in the RREQ, it rebroadcasts the RREQ to its neighbors, otherwise, it advertises a route reply packet in a unicast way to its neighbor from which it was received. The route packet with the same sequence number is not processed. While traveling back to its source, the RREP travels back based on the reverse path set previously.

During this process, each node sets a forward pointer to the receiving node and records the latest destination sequence number. This algorithm is called Forward Path Setup. In the case that destination sequence number is newer for an intermediate node, or if the hop count is smaller, the routing information is updated and propagates a new RREP. If these parameters are not met, then the intermediate node just skips the new RREP. This algorithm ensures the most effective route usage free of loop [9,18,19,20].

Advantages of AODV:

The potential advantages of AODV protocol are:

- On demand route establishment.
- Latest routes to destination being easily accessible via sequence numbers.
- Lower connection set-up delay.
- Ability to Deal with highly dynamic behavior of Vehicular Ad-hoc networks (VANET).

Disadvantages of AODV:

- Inconsistent routes are often formed by immediate nodes containing old sequence numbers.
- Heavy overhead control over the network due to multiple replays. It responds to the single request originated by one node.
- Comparatively slow working network and high route discovery latency.

4.7 The Setdest Tool and Its Limitations

Wireless network devices are generally not stationary. A mechanism is needed to test the movement of these mobile nodes. The NS2 simulator is capable of providing the simulation the ability of having a mobile object moving at a certain time to a specific coordinate from its current location at a specific constant speed. A utility called setdest was developed in C++ to address the mobility simulation issues in NS2. The setdest utility has two versions. The first version had some limitations like when it picked a random speed, it would be so small that the node might never reach its destination. This was not helpful in providing a true simulation scenario. In the second version of setdest this problem was fixed by making adding the option to set a minimum speed, along with some other features. The piece of the code is called a setdest command. With the help of setdest utility, we can simulate movement within the NS-2 simulator. The Random Waypoint (RWP) mobility model addresses this issue in NS-2. In Random Waypoint mobility, each mobile node will go through the process of pausing at a location, selecting a random waypoint, and then moving towards it at a randomly chosen speed between two numbers. Finally, it repeats this cycle until the end of the simulation [8,18]. This tool is used to generate positions of nodes, their moving parameters, and their directions automatically by performing a command in TCL in NS-2. It generates movement patterns according to random waypoint mobility. The command is: ./setdest v [1 or 2] -n [num of

nodes] p [pause time] M [maxspeed] t [simulation time] X [max x] Y [max y] $\gg output filename.$

where, n is the number of nodes and, p is the pause time, M is the Maximum speed of the nodes, t is the simulation time. X and Y are the values of the topological area defined. The initial node positions are generated by this utility in a two- dimensional region. For example: $ns at 60.000000 "$node(2) setdest x-coordinate y-coordinate velocity"

However, the biggest problem is entering the simulated movements for a set of particular nodes in a large area of the node simulation network. Additionally, sedest does not accept negative values in the commands which lead to lack of movement options. In this report, the setdest command entry is required rather than setdest generator, since the node's movements for some scenario cases will be dynamically controlled according to the nodes' throughput.

Chapter Summary

This chapter describes the main concepts of the network simulator NS-2 including features and capabilities. It also shows the simulator version that is used for this project. A brief explanation of the components of a mobile ad-hoc network is given besides extra details about node configuration and traffic generator in NS-2. Furthermore, a quick overview over the routing protocols used in NS-2. Finally, a complete analysis of setdest tool and its limitations are presented in this chapter.

Chapter 5

DYNAMIC MOBILITY CONTROL FOR MANET

5.1 Overview

The connectivity properties of a dynamic mobile network with average speed mobile nodes and delay constraints will be investigated. New mobility models are developed to represent the node distribution and the random movements. They capture the statistical properties of node location, time-varying node speed, and the distinct behaviours of the nodes following different patterns. These statistical properties of network connectivity are studied and identified with the mobility model [21]. Unlike most previous studies, the changes in topologies for some cases of the proposed scenarios will be during simulation, which is critical for real time applications.

5.2 Localization

There are many techniques for generating movements and localization, using data such as signal strength, sensor power, and time taken for signals to arrive, recognizing the changes of data as mobile devices move (during the simulation) in an environment. Furthermore, in order to acquire an applicable level of accuracy, localization techniques could explain the error of environment-specific operations while indoors. These errors can be affected by physical events and intervention from other wireless activities such as path loss, and (spatial/temporal) fading [40]. Indoor environments require more accurate positioning comparing with other environments. Many localization techniques require a process that should be repeated every time the environment changes, or when it takes place in a new environment. Therefore, this process is costly and time-consuming [36, 40]. This project proposes different scenarios to generate node movement path dynamically during the simulation for such random localization systems, using a combination of received signal strength, transmission range, and network throughput.

5.3 Strategies

5.3.1 Preliminary

The project assumes that all of the nodes have the same communication range R. The nodes inside the range are called neighbours, and two or more

neighbours can communicate. Each node has its location, which is simply denoted as L (v). The location information can be discovered by having Global Positioning System (GPS) receivers at some fixed nodes, some mobile beacon nodes, sensor nodes, or by relying on the relative coordinate system as well. We place the nodes randomly at different ranges in area n x m or n x n size for each topology in order to examine the scenarios. There is one source, S, and one destination, D, in every scenario where there is either fixed or mobile S or D. The number of relay nodes depends on the scenario, and the case that we plan to investigate is the simulation NS-2 in random ad-hoc wireless communications.

5.3.2 Strategy 1: Following Nodes

The group mobility model in general relies on spatial locations where its applications range from data sharing, distributed mobile network calculation, military communications, and emergency relief effort (search, rescue, and control). Some of the main characteristics of these group mobility models are team participation of a large number of mobile systems, confined bandwidth, and the requirements for supporting distributed resources (e.g. sending or receiving data for any operation required of a battlefield). In this new strategy called the following nodes, we propose the use of nodes that follow each other as a group (formations). In each case, we use the clustered infrastructure for placing the nodes. This strategy was inspired by the reference group mobility model [30].

Assumptions:

- The source node, S, is stationary, and is located in a specific location on the far left.

- The destination node, D, is stationary, and is located in a specific location on the far right (see Figure 5.1)

- The distance between S and D is 1000 meters.

- Nodes are being generated randomly at random locations as clusters.

- The intermediate nodes are moving at a constant speed of 10m/s.

- The distribution of the intermediate nodes is divided into a number of formations with different lengths (2, 3, or 4). clustered as an initial placement, F1, F2,..Fn (see Figure 5.2).

- A leader, L, from each formation is elected.

- L then identifies the number of following nodes (N), coordinates, the support topology and movement.

The Movement of Leader and Following Nodes:

The movement of formation leader L at time t can be represented by motion vector Vt. Not only does it define the motion of group leader itself, but it also provides the general motion trend of the whole formation. In our case, the leader changes its directions randomly every $[Vt = 30 * i]$ seconds, where

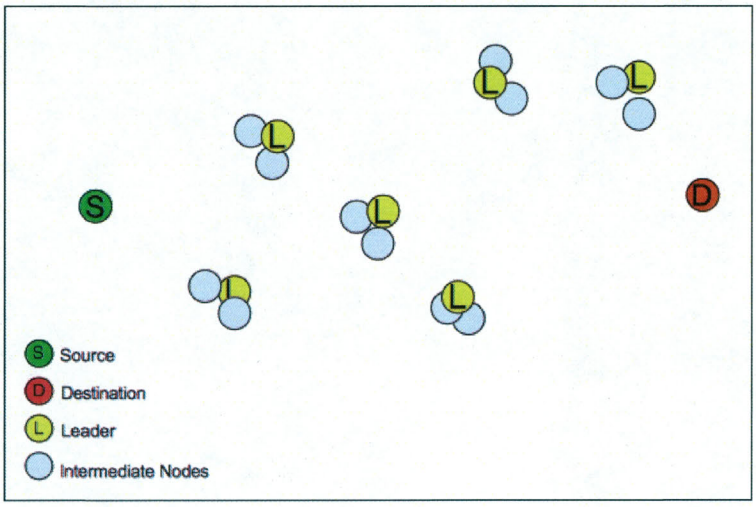

Figure 5.1: The initial placement of the following nodes

$i \in [0, 1, 2, n]$. Due to the dynamic changes in topology, the distance between the following nodes ranges from 100 - 110 meters. Each leader node, L, starts moving at the beginning of the simulation. The leader L randomly chooses the direction of the next move, and sends information to the following nodes N including coordinates and movements. The movement of the following nodes is significantly affected by the movement of its group leader, where every group member lands on the same Leader's X and Y coordinates. Every following node, N, sends directional information to the next N in the same formation F and follows L, etc. The shape of each formation is similar to a short snake (i.e. the leader is the head and the following node(s) will make the tail) Figure 5.2.

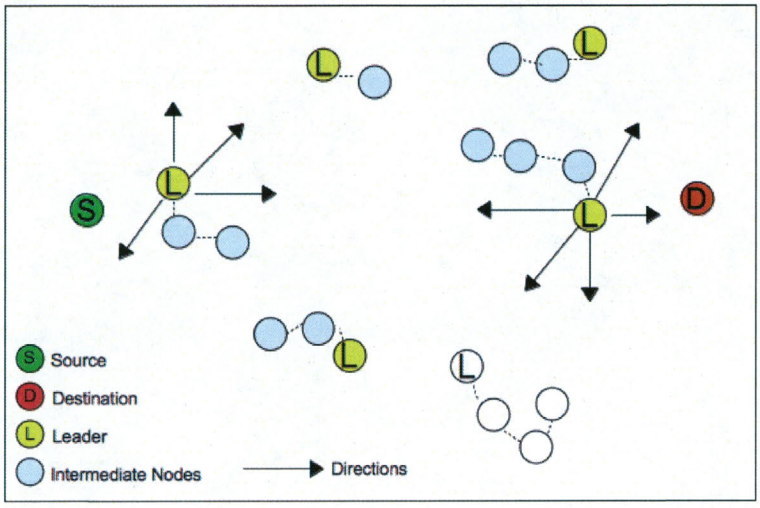

Figure 5.2: The Number of formations movement and structure

5.3.3 Strategy 2: Controlling the Random Waypoint Model (RWP)

This new strategy that we propose can represent different general applications according to the pattern of movements of RWP. In our case, we assume that the area of this scenario is a small zone of surveillance operations such as military or government properties. The movements of source and destination in a specific area can increase the chances for communicating and receiving data.

Assumptions:

- The source S is at the far left and the destination D is at the far right of the topological area.

- The distance between S and D is 1000 meters.

- Assuming at intervals of 120s, the two stations S and D move transversely along a 500m path remaining parallel at all the time at a speed 5m/s Figure 5.3.

- Nodes are being generated randomly at random locations.

- Intermediate nodes are following the Random Waypoint model using setdest random generator.

- Intermediate nodes are moving at a speed of 10m/s.

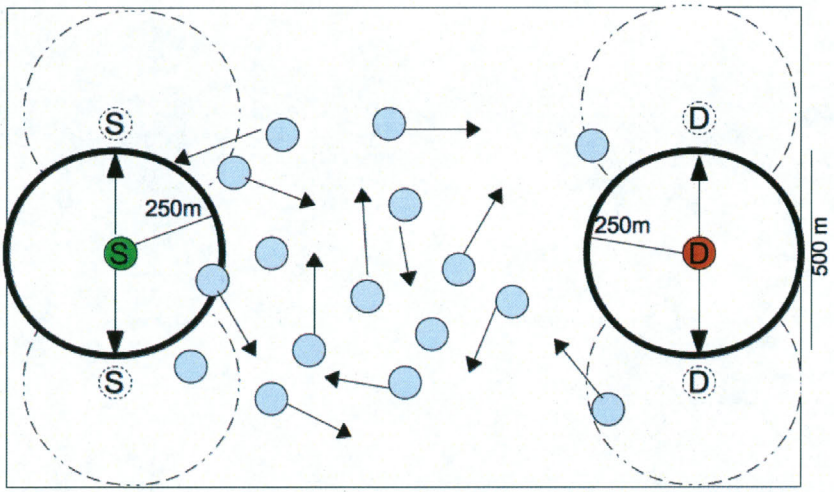

Figure 5.3: Controlling RWP topology

Controlling the Movement During the Simulation:

The intermediate nodes slow their speed to a pause every time they enter

the range of S or D during the simulation that covers a transmission range of 250m around the source and the destination. We use the distance formula to calculate the distance between either the source or the destination and the intermediate nodes:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{5.1}$$

Every node will pause when it enters the range of source or destination during the simulation while S and D are moving Figure 5.3

Chapter Summary

This chapter presents, interprets and justifies the two proposed strategies for our dynamical node movements including their techniques in details. The next chapter will provide all analysis, evaluation, and result for these two strategies.

Chapter 6

ANALYSIS AND RESULTS

6.1 Overview

The methodologies discussed previously are implemented and simulated in NS-2 to produce the results represented in this chapter. Those results and an analysis were documented. To generate a graph output, the results are obtained from trace files in NS-2 using a trace graph. Using AWK scripts through commands is another tool to pipe out the desired outputs from trace files. The Network Animator (NAM) is one of the most important components in NS-2 that visualize the animation of the network and its behavior. It monitors for the network information such as node locations, node movements, traffic, and topology. The trace graph is a trace file analyzer for NS-2 to generate graphs showing the metrics of network performance. A simple output of a NAM animator from a trace file is shown in Figure 6.1:

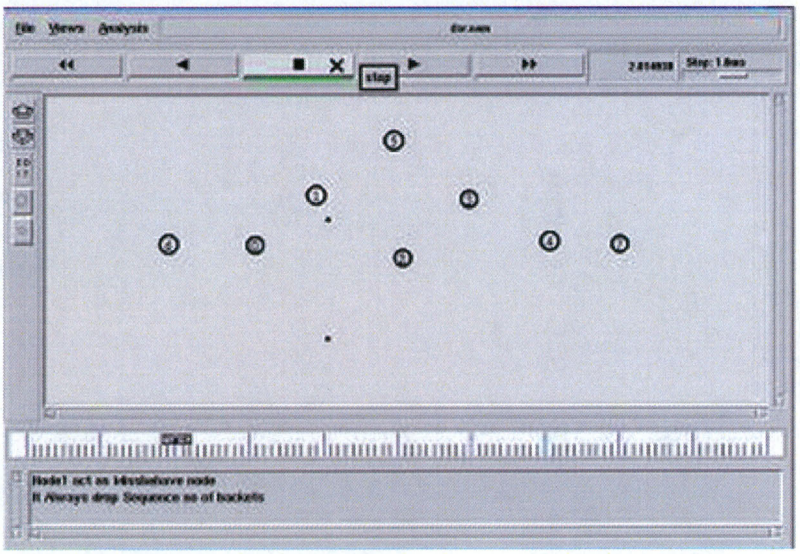

Figure 6.1: NAM shows some mobile nodes in NS-2

6.2 Performance Metrics

1. **Network Throughput:**

   The network throughput is a metric used to calculate the amount of data transmitted from source to destination in a specified period of time. It is usually measured in bits per second or in megabytes per second. It is the average throughput of all nodes in a simulated network:

$$\gamma = \frac{no.\ of\ bits\ received\ by\ node\ D}{Observation\ duration} \tag{6.1}$$

   Simply put, the network throughput is the number of packets passing through the channel in a specific unit of time that can be improved

with increasing node density.

2. **Packet Loss:**

   Packet loss is one of the quality of service parameters of the network. It occurs when one or more packets of data transmitting across a network fail to reach their destination due to buffer overflow and congestion.

6.3 Simulation Environment

In each case the network consists of a different number of nodes roaming in a 1000 x 1000 meters square with a reflecting boundary. The transmission range is 250m. The data is generated at the source node at rate of 1 Mbps. Every packet has a size of 512 bytes. The buffer size at each node is 50 packets. Data packets are generated following a constant bit rate (CBR) process. The experiments will transmit packets from one source to one destination for every case of our strategies in 900 seconds, and measure the effective throughput with increasing mobility range and density.

The simulation parameters:

NS-2 contains parameters and variables that help change the network scenario and settings and control the simulation process. Both strategies share the same parameters for our investigation with the exception of the number of nodes and the technique. The simulation parameters are listed in Table 6.1.

Table 6.1: The simulation parameters

Parameters	
Simulator	**NS-2.34**
Channel Type	**Channel/Wireless channel**
Network interface type	**Phy/WirelessPhy**
Mac Type	**Mac /802.11**
Radio-Propagation Type	**Propagation/Two-ray ground**
Interface queue Type	**Queue/Drop Tail**
Link Layer Type	**LL**
Antenna	**Antenna/Omni Antenna**
Maximum packet in ifq	**50**
Area (N*N)	**1000 X 1000**
Source Type	**(UDP) CBR**
Simulation Time	**900 sec**
Routing Protocols	**AODV**

6.4 Results

In a wireless, ad hoc multi-hop network, small movements of the nodes can lead to changes in network topology and therefore affect the performance of high layer protocols, such as throughput. Ad hoc networks are more sensitive to mobility than cellular wireless networks since, in the latter, the topology changes only when a node leaves the cell, regardless of the relative connectivity with other mobiles. Using the group models introduced in the previous

chapter, we will study in this chapter the impact of mobility on the performance of various architectures and communication patterns using AODV routing protocol. For all of the throughput results for the data received at the destination, we calculate the average by running the simulation three times for every scenario.

Strategy 1:

Case1: We simulate a number of the following nodes where there are leaders (L) and one to three following nodes behind every leader. All of the following nodes follow their leaders' X and Y coordinates. Each leader with its following node is called formation. Figure 6.2 and Figure 6.3 illustrate the node movements for a number of formations which consist of two and three following nodes in NS-2 using NAM tool.

For example, in Figure 6.2, the node n2, n3, and n4 form a formation of 3 nodes (1 leader + 2 following nodes).

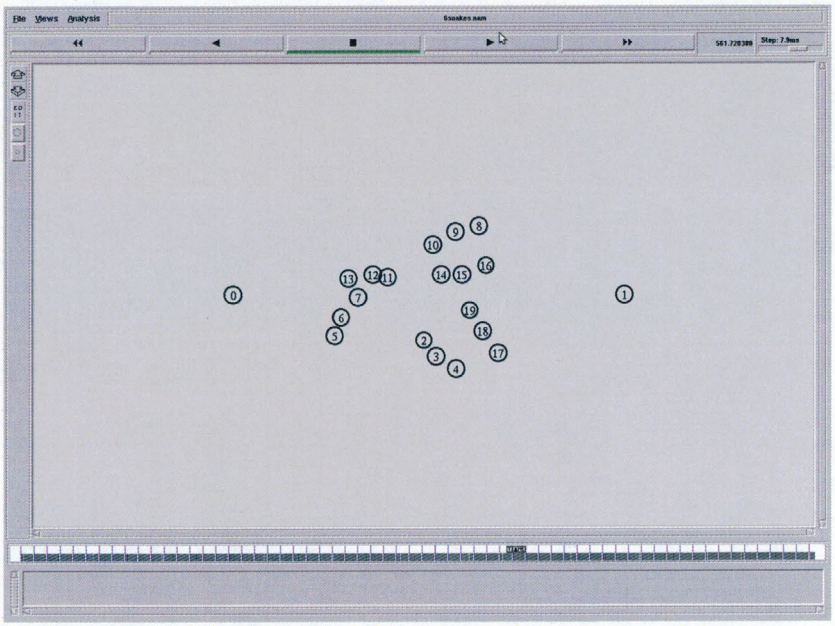

Figure 6.2: The two following nodes pattern

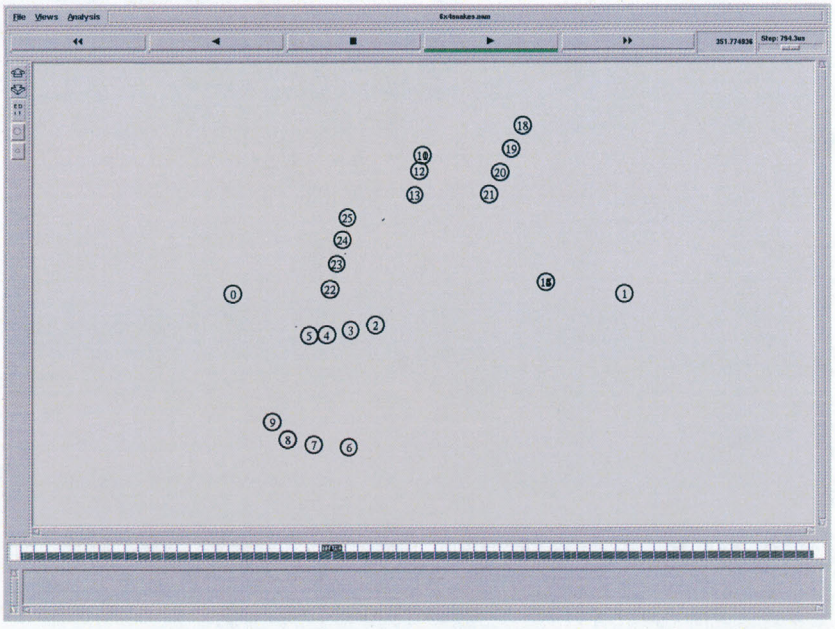

Figure 6.3: The three following nodes pattern

In this case, we try to show the performance impact by running several formations 6, 7, 8, 9, and 10. These formations numbers are shown in Table 6.2.

Table 6.2: Number of formations for strategy1, case 1

Number of Mobile Nodes	L + 1 Following Node	L + 2 Following Nodes	L+ 3 Following Nodes	Number of Mobile Nodes
6 Formations	6*2	6*3	6*4	12, 18,and 24
7 Formations	7*2	7*3	7*4	14, 21, and 28
8 Formations	8*2	8*3	8*4	16, 24, and 32
9 Formations	9*2	9*3	9*4	18, 27, and 36
10 Formations	10 *2	10*3	10*4	20,30,and 40

In Figure 6.4, we try to find the performance aspect when the number of formations is varied. The node density is incrementally adjusted from 12 to 40 within the same topology of 1000 x 1000 m. Because the density of nodes is irregular from one type to another, it shows that the length of 4 gives a better performance for throughput than the lengths of 2 and 3. Since the length of 4 consists of a leader and three following nodes, it generates 24 nodes in the first round where the number of formations is 6 (i.e. 6x4 = 24), while the length of 2 and the length of 3 are 6x2 = 12, and 6x3= 18 nodes.

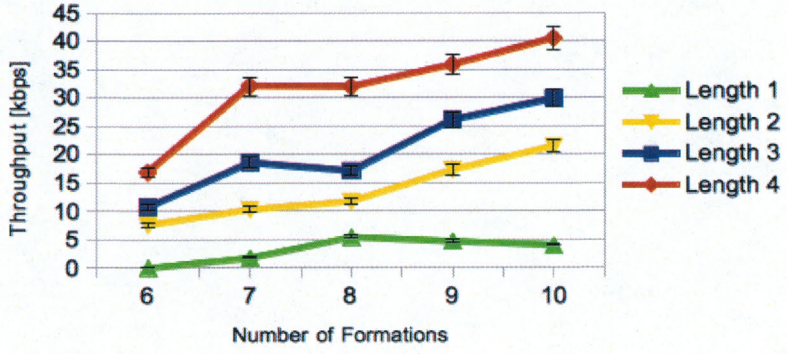

Figure 6.4: Throughput vs. Number of formations for different lengths, Case 1

As a result, the bigger number of formations the better performance can be given. We also note that the bigger number of formations used, the more nodes are required.

Case 2: we test a number of mobile nodes (24, 36, 48, and 60), which can be equally divided over the length of the formations (2, 3, and 4) Table 6.3.

Table 6.3: Number of formations for strategy 1, case 2

Number of Mobile Nodes	Leader + 1 Following Node	Leader + 2 Following Nodes	Leader + 3 Following Nodes	Number of Formations for Comparison
24 Nodes	24/2= 12	24/3= 8	24/4= 6	12 vs. 8 vs. 6
36 Nodes	36/2= 18	36/3= 12	36/4= 9	18 vs. 12 vs. 9
48 Nodes	48/2= 24	48/3= 16	48/4= 12	24 vs. 16 vs. 12
60 Nodes	60/2= 30	60/ 3= 20	60/4= 15	30 vs. 20 vs. 15

In this case, we try to show the effectiveness of increasing the default distance for our strategy with an average of 100m - 110m TO 150m - 210m for the following nodes. Figure 6.5 and Figure 6.6 show the node patterns of two and three following nodes for both deferent distances.

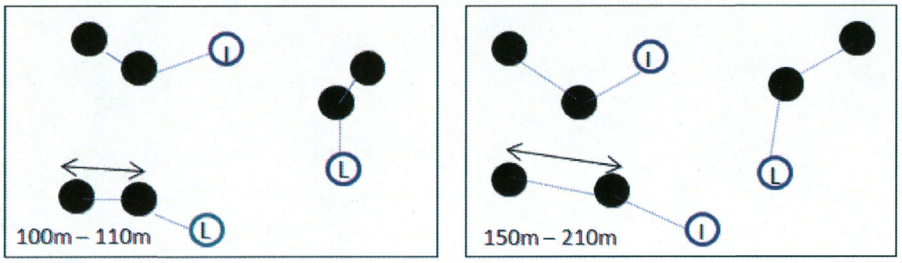

Figure 6.5: The distance between two following nodes

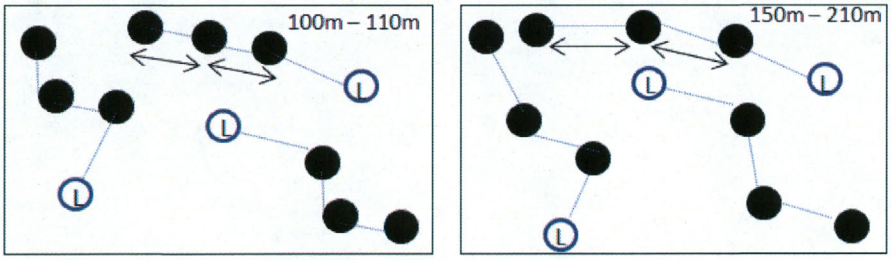

Figure 6.6: The distance between three following nodes

The figures below give a comparison for every length with different distances.

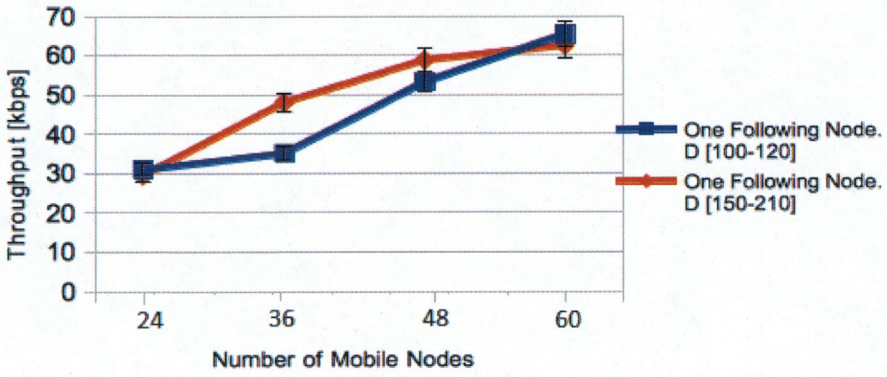

Figure 6.7: The one following node throughput with different distance

Figure 6.7 shows the throughput of the one following node pattern. When the distance is longer, it gives a better performance at 36 and 48 mobile nodes while there is an equal performance at 24 and 60 nodes.

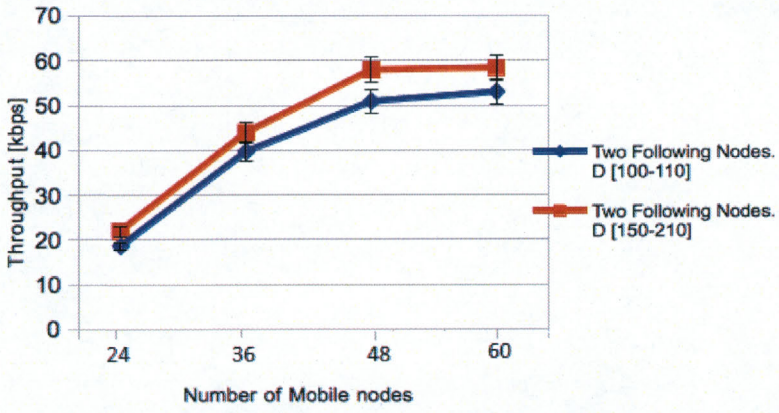

Figure 6.8: The two following nodes throughput for different distances

Figure 6.8 indicates that there is always better performance when we in-

crease the distance among the following nodes. For short formations, the performance is improved with the increased distance between the nodes.

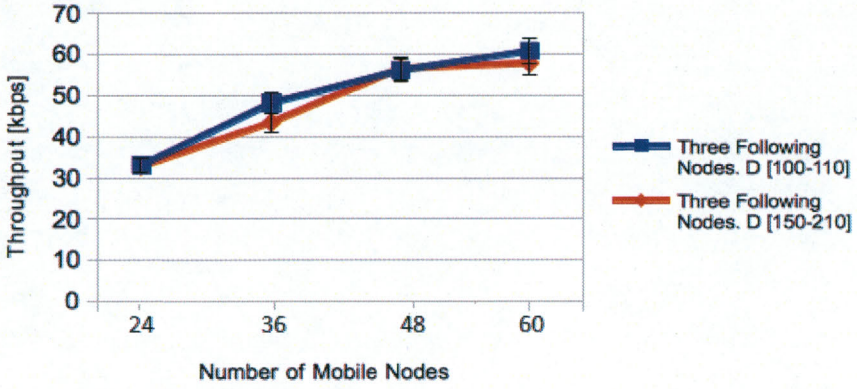

Figure 6.9: The three following nodes throughput for different distances

However, Figure 6.9 shows the opposite: the three following nodes with the short distance give convergent throughput with long distance.

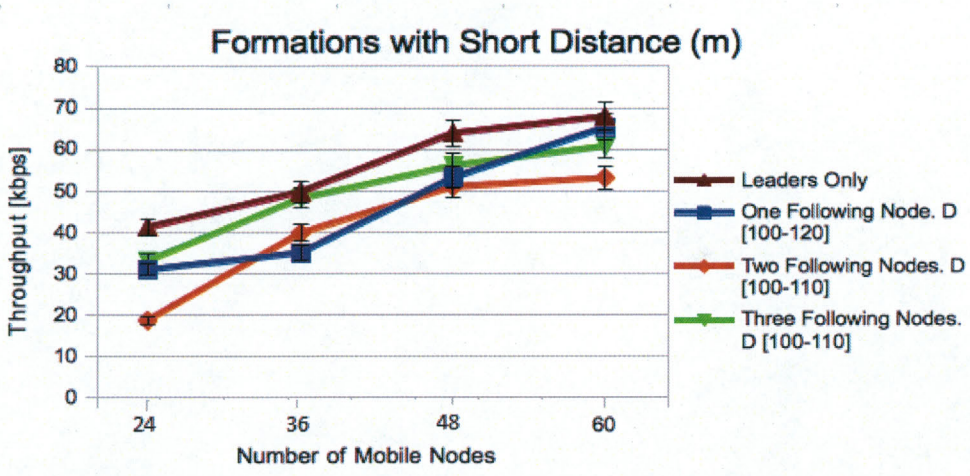

Figure 6.10: Length of the following nodes with short distance

In Figure 6.10, a high throughput is produced over the length of two nodes with the default distance 100m 110m. However, the length of two (i.e., one following node) contains a larger number of formations compared to the other lengths. For instance, for the one following node, 24 nodes divided over two (the leader + one following node) gives us 12 formations, while with the two and three following nodes, they are 24/3= 8, and 24/4 = 6. We note that the one node following outperforms the other types by the distribution, since it has the chance to move with a large number of formations. The length of four has become second, after the length of two, due to the number of following nodes being larger in each group during the mobility.

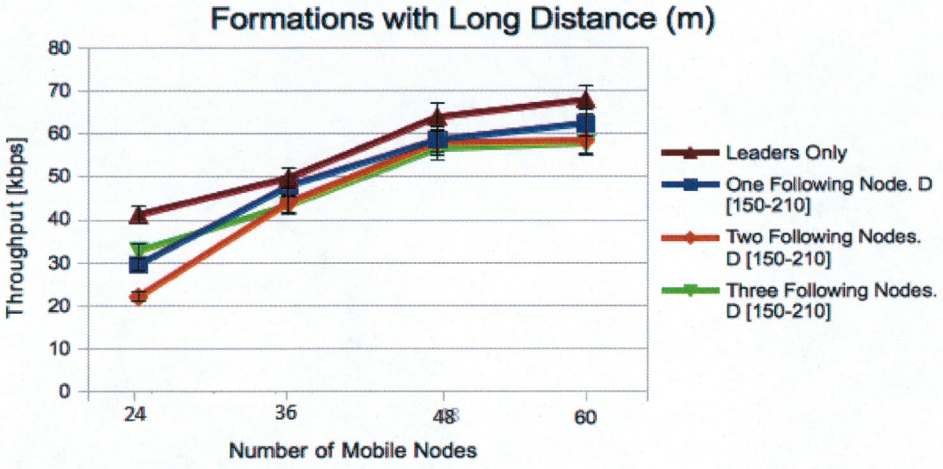

Figure 6.11: Length of the following nodes with long distance

Figure 6.11 above shows that the distance between the following nodes is radically different, since we extended the distance from the average of 100-110m TO 150-210m. It gives a high throughput compared to the short distance

except the three following nodes. The two following nodes give a better performance as the distance increased. We also note that the three following nodes' pattern shows high throughput at the average chosen number of mobile nodes (with 36 and 48 nodes). In both Figure 6.10 and Figure 6.11, we illustrate only the individual movements of leaders with the same number of mobile nodes. Overall, with one and three following nodes, they give a better performance compared to the two following nodes. On the other hand, the two following nodes can provide a decent throughput at 36 and 48 nodes. To conclude, for a given number of nodes, the best performance is obtained when nodes move independently (i.e., leaders). However, we also observed that the formation of length 4 performs better than the formation of length 3.

NS-2 simulations give lots of results. From Figure 6.12 to Figure 6.17, we show a sample of the throughput and packet loss for 60 mobile nodes. These nodes have the default distance of 100m-110m between the following nodes as formations based on the length. We run these samples once for each length type showing throughput and packet loss over time during the simulation. These screenshots were obtained from the graph generator in NS-2.

High throughput is shown in Figure 6.12 during the simulation. Many factors affect the loss packets by changing the topology (such as the number of formations and length of formations) Figure 6.13. For instance, the range of packet loss is reasonable according to the throughput.

Figure 6.14 shows an average throughput, however, it performs poorly in

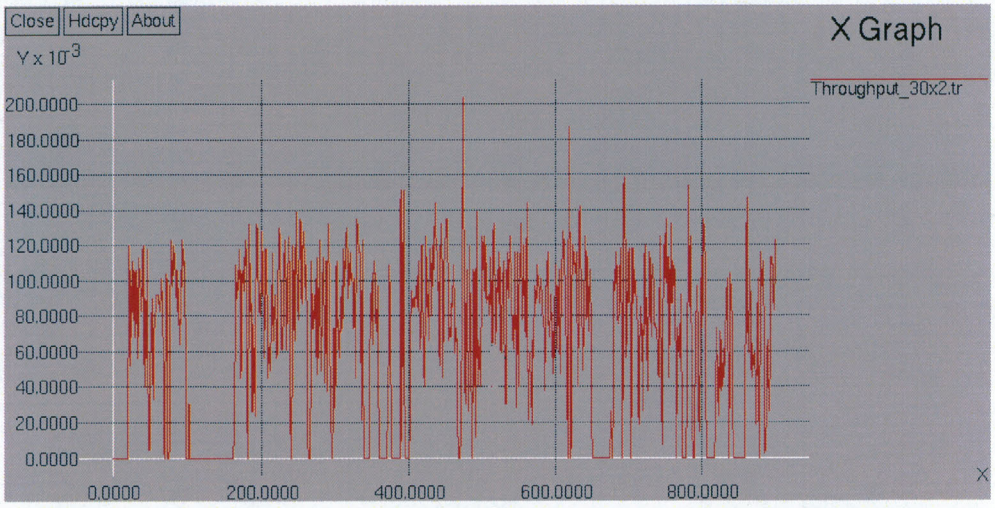

Figure 6.12: Throughput vs. Time for 60 nodes. 1 following node

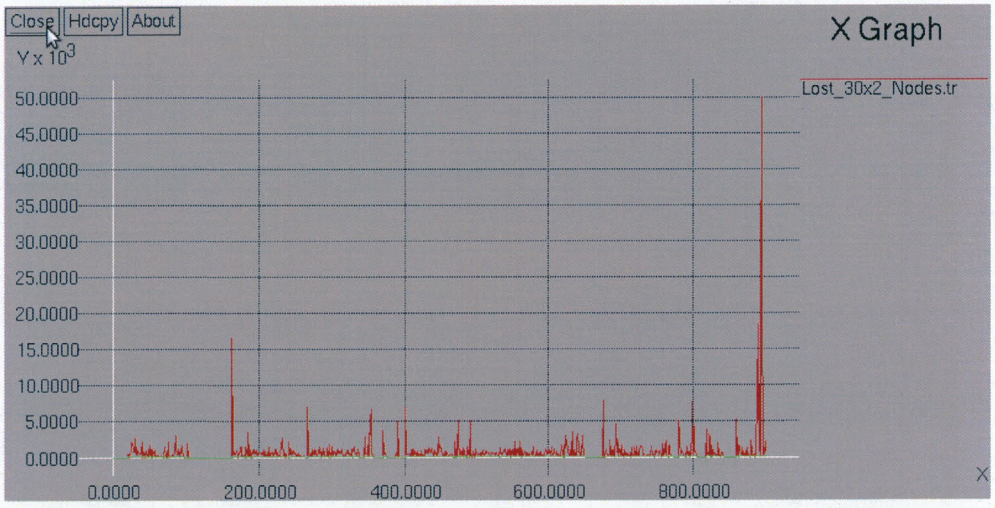

Figure 6.13: Packet Loss vs. Time for 60 nodes. 1 following node

terms of packet loss. It shows that the length of three has a high number of dropped packets for each of the three lengths Figure 6.15.

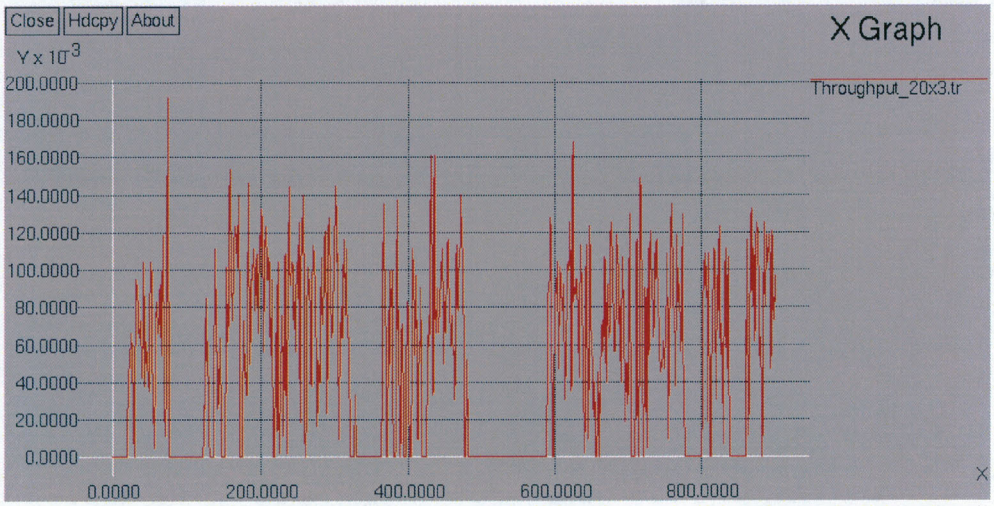

Figure 6.14: Throughput vs. Time for 60 nodes. 2 following nodes

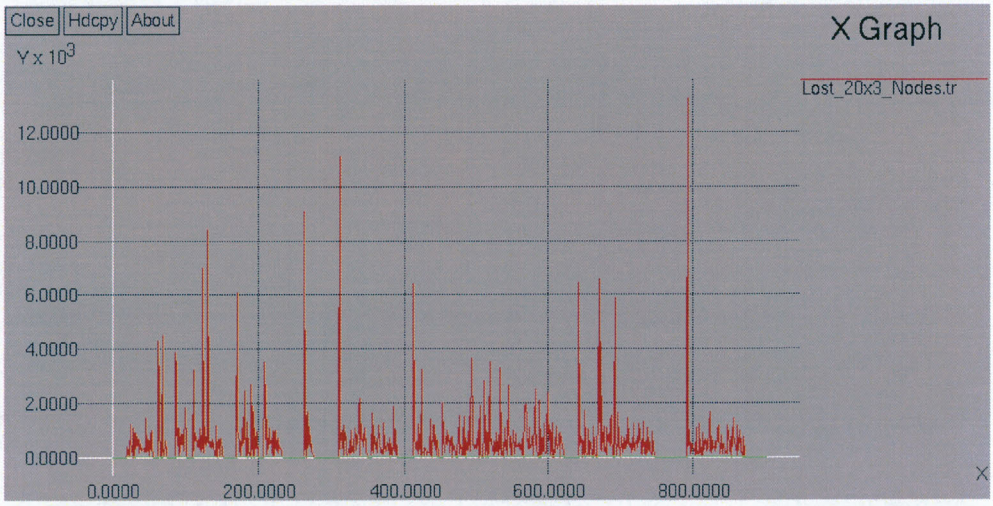

Figure 6.15: Packet Loss vs. Time for 60 nodes. 2 following nodes

Figure 6.17 shows that the length of 4 has low packet loss over the entire simulation time. It has the lowest rate among all the types.

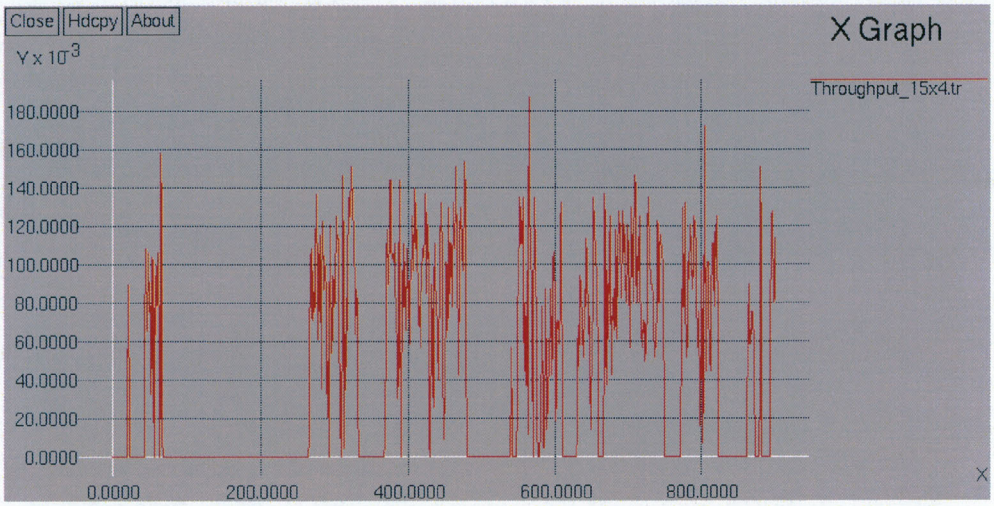

Figure 6.16: Throughput vs. Time for 60 nodes. 3 following nodes

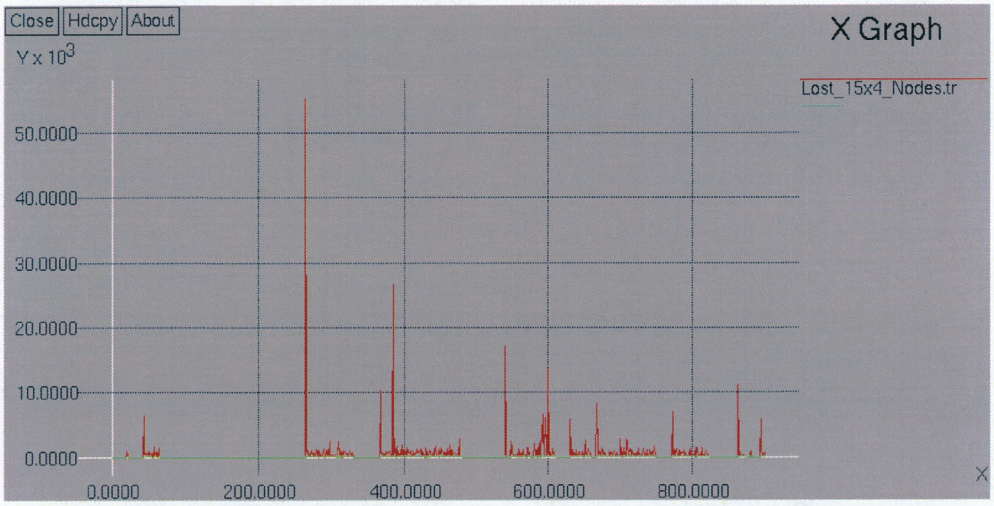

Figure 6.17: Packet Loss vs. Time for 60 nodes. 3 following nodes

Case 3: We assume that the entire area is a small field. All of the groups are sharing the same operations where, for example, different paramedic, police, and firemen teams work in the same region. Therefore, we try to slow the motion of the mobility of each group at the same time, only if there are packets received at the destination. In this scenario, the significant work falls to the leaders' movements. Leader and support nodes sweep the entire space quickly with a speed of 10m/s moving randomly in the network. During the simulations, a support node is within communication range of a sender. The sender is notified that it can send a message. The speed stays constant at 10m/s every time the throughput is equal to zero. It keeps checking the throughput between the source and destination and when the packets start delivering. When the throughput is greater than 0, all the nodes' speeds will drop down from 10m/s to 5m/s to increase the chance of a better performance.

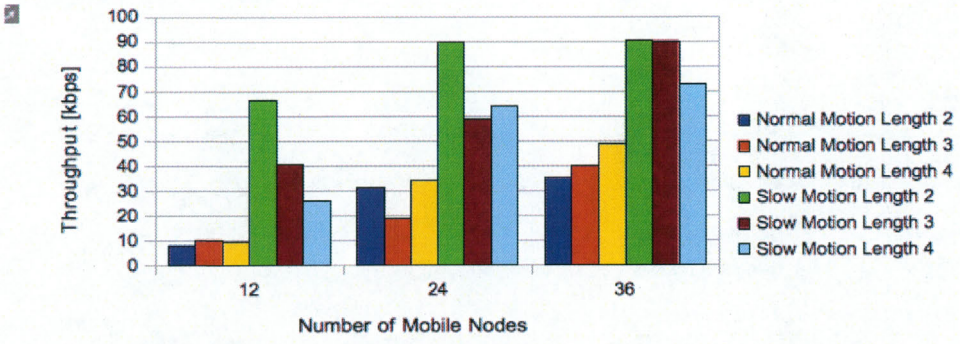

Figure 6.18: Throughput evaluations for Normal 10m/s Slow 5m/s speeds

We try to run a few numbers for mobile nodes 12, 24, and 36 with the default distance 100m 110m. Figure 6.18 it shows that the slow motion has a higher throughput than all the normal motions. For the slow motions, the length of 2 and 3 give a better performance at 36 when the number of nodes is increased. On the other hand, the normal motion shows that the length of three and four give a better throughput at 36 as well. However, this length may not be a good choice when the node density is low, for example at 12 nodes.

Strategy 2:

The Random Waypoint model (RWP) has been used in many previous studies as reference model. It is a simple model used to analyze and implement in NS-2. This is the main reason for using this model for simulations. Further, the RWP model is not sufficient to capture some realistic scenarios. However, in order to model the movements of nodes in a realistic and sophisticated terrain, such as a rescue operation or a battlefield, we try in our strategy to develop a scenario that could be useful in real life, where RWP is controlled during the simulation.

Therefore, as we mentioned in Chapter 5, this strategy is based on the assumption that showing the difference between the nodes being paused inside the range of 250 meters of one mobile source and one mobile destination, in order to use the advantages of RWP in real time. We test many cases containing different numbers of mobile nodes 15, 18, 24, 27, 30, and 40 of

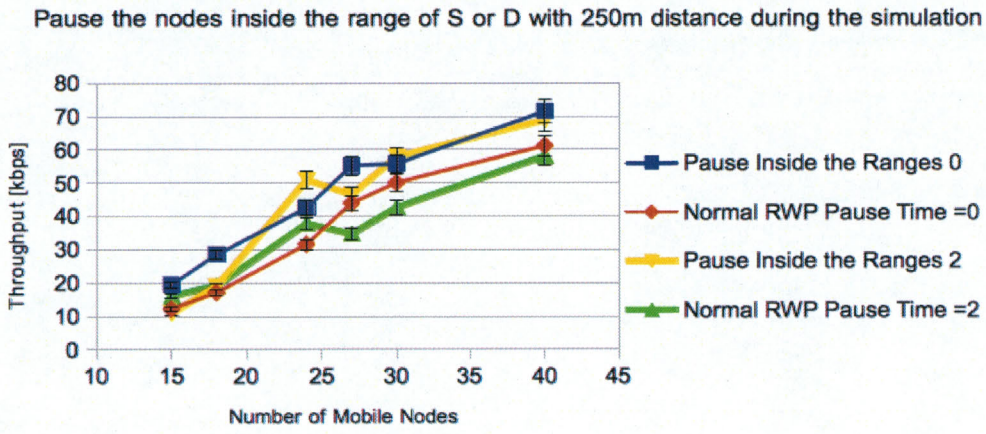

Figure 6.19: Controlling RWP vs. Normal RWP

our strategy, and compare the same number of nodes with normal RWPs movements where the pause time is constant: 0 and 2. It shows that the performance is better when the mobile nodes inside the range of the source and the destination are paused (see Figure 6.19). For the normal RWP, constant pause time = 0 is higher than 2 especially with increasing the number of nodes. Overall, Figure 6.19 shows that pausing nodes inside the ranges during the mobility gives a high throughput than the normal RWP.

Figures 6.20 through 6.23 below show the packet loss rate is less in the controlled RWP. We run these samples once for each type showing the packet loss over time during the simulation.

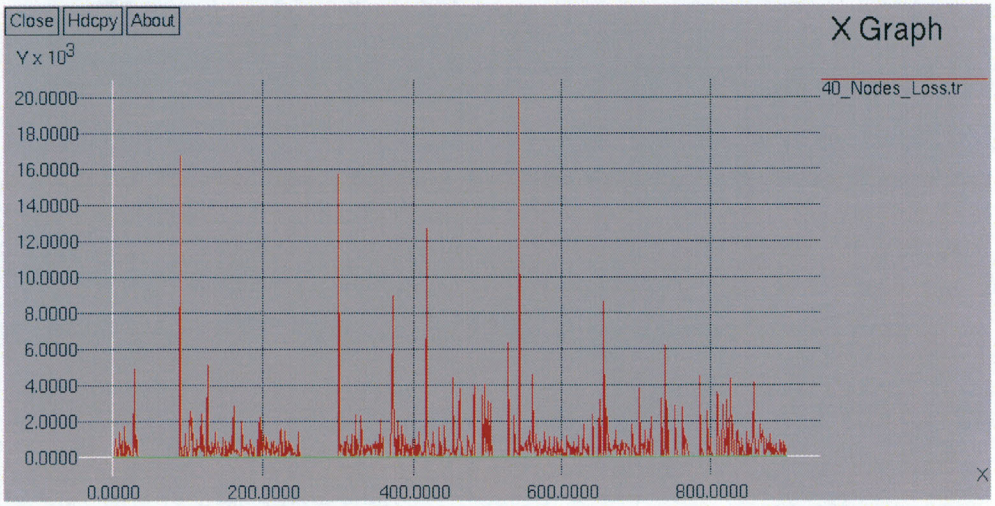

Figure 6.20: The packet loss for 40 nodes of Normal RWP 0

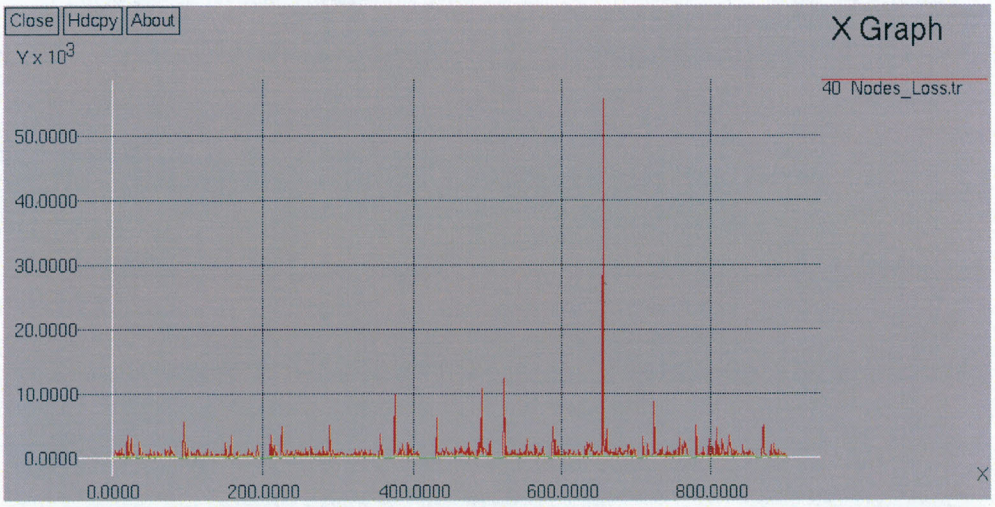

Figure 6.21: The packet loss for 40 nodes pausing inside the ranges 0

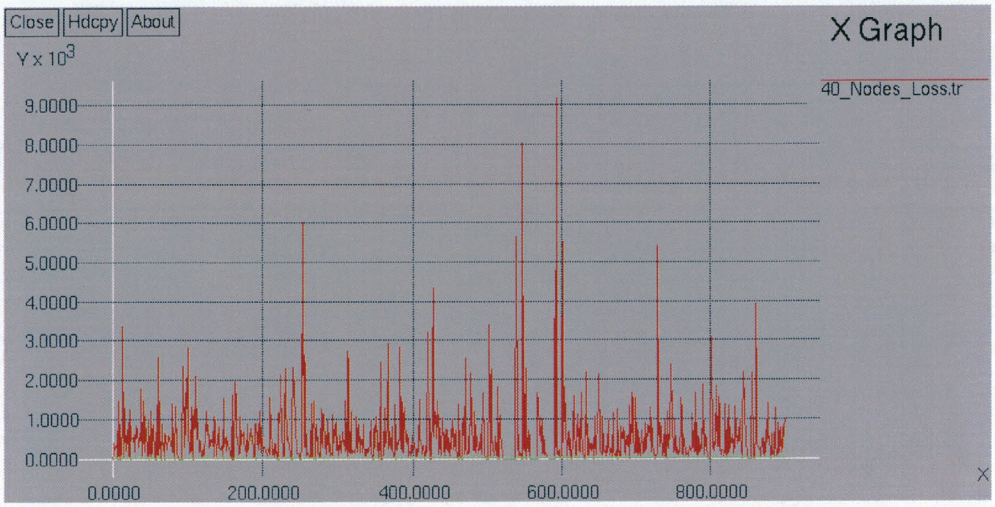

Figure 6.22: The packet loss for 40 nodes of RWP 2

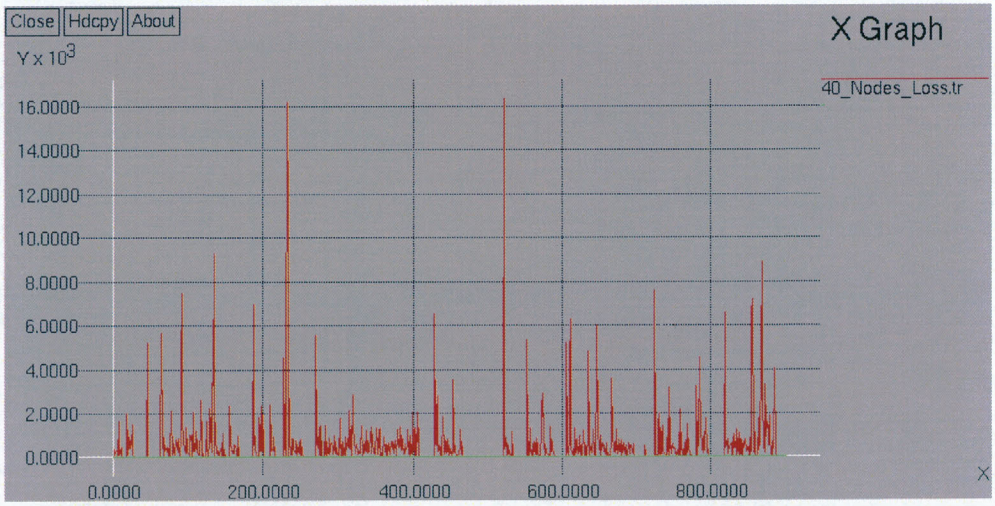

Figure 6.23: The packet loss for 40 nodes pausing inside the ranges 2

Figure 6.21 and Figure 6.23 refer to the paused nodes inside the ranges which show better performance than the normal RWP.

Chapter Summary:

This chapter provides, analyzes, discusses, interprets and justifies the results obtained during simulations. The performance metrics chosen for simulation are defined; the parameters used in simulating all of the cases are presented and explained in detail.

Chapter 7

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The present work has investigated some important issues related to the simulation and use of MANETs with possible applications in general environments and specific ones such as military fields. In particular, we proposed a simulation setup using NS-2 providing similar scenarios to realistic models and at the same time computationally modeling the outdoor propagation, node movement, and user traffic. This report described two strategies. The first strategy implemented the following nodes mobility as formations considering number of assumptions. In this first strategy, we investigated three cases showing the evaluation of the formations mobility based on the length of

each formation, the node density, and the node's status during the simulation. Case 1 showed that the increasing the number formations gives better performance; however, it requires more nodes. Case 2 intended to illustrate the effectiveness when the distance is increased between the nodes for all formations length. The short formations can be improved by increasing the distance between nodes. It also gave a reasonable conclusion that the formations with length of 2 always give a high performance among all the other lengths due to the node distribution; except when nodes move independently, it gives higher performance. For the formations with the length of 3 and 4, the length of 4 performs better than length of 3 at short distance while they give close performance at long distance. In Case 3, we showed the differences between the slow and the normal motions for the following node technique. We concluded that the better performance is given when we slow the formations' motions during the simulation.

The second strategy implemented Controlling the Random Waypoint Model and compared the performance with the normal mobility of RWP. Two scenarios were given in this strategy based on few assumptions can be similar to a real life situation. We paused the nodes inside the ranges of both source and destination considering as well the node density and the status of the nodes while the stimulation was running. We tried two different constant pauses with constant speed. A better performance was given when the Random Waypoint model was controlled for all the case scenarios.

For both strategies, the performance metrics were chosen to evaluate the per-

formances were throughput and packet loss. The ways to evaluate a MANET environment by a theoretical and practical methodology has been presented while using NS-2 simulator. Additionally, an output and screenshots from NS-2 were given using the NAM animation tool where we observed packets loss due to congestion for all the simulations.

7.2 Recommendations for Future Research

MANET is a rather interesting concept in computer communications. This report tested all the strategies using AODV routing protocol and carried out many different simulations, therefore suggesting another type of routing protocol could be investigated. In terms of efficiency, CBR's performance can be improved through further research on modifications. Moreover, more research on the simulation parameters can lead to a better performance for some cases. Also more research on the security issues in MANETs have to be undertaken to make the environment more reliable Finally, NS-2 shows useful support to achieve the goal of this project for many reasons such as the access of documentations, the ease of programming in OTcl, and the visual view of the NAM tool that allows users to understand the nodes' behavior.

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