

ENSC 427: Communications Networks

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Mobile IP Over WLAN Simulation Using NS-2

Final Report

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Abstract

Mobile Internet Protocol, or Mobile IP (MIP), is an Internet Engineering Task Force (IETF) protocol that is used to maintain a consistent internet protocol (IP) address while moving through a number of networks. This is done by switching networks overlapping networks once the device has gone out of range of one network. The type of network that will be simulated is the common Wireless Local Access Network (WLAN). MIPv4 will be simulated in the ns-2 simulator to demonstrate how MIP can be used to maintain a connection when moving through several WLANs.

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1. Introduction

Wireless Local Area Network (WLAN) technology is growing rapidly and becoming a crucial component of computer networks. More users are travelling with their mobile devices from place to place trying to connect to networks. Internet Engineering Task Force's (IETF) Request For Comments (RFC) 2002 defines the Mobile Internet Protocol (MIP) as an enhancement to the standard internet protocol (IP)[1] which allows mobile devices to roam seamlessly throughout networks without manually changing their internet protocol address (IP). In other words, when a mobile node is moving across multiple network locations, this should not affect its connectivity and does not require changes to the network configuration.

Imagine a user carrying a mobile device from network A to network B, and wishes to roam with the mobile device in network B, which has a different IP address than network A. As the mobile device detects the new network with a completely different IP address, and as the connection signal to the access point in network A becomes weaker, the mobile protocol will perform a handoff. Mobile IP will notify network A to reroute the packets destined to the mobile device to network B. the mobile device will then receive packets from network B. However, as more users attempt to access the network, the handoff process becomes unstable and causes interruption to connectivity.

1.1 Motivation

It is important to simulate how mobile IP works with the rapidly expanding of mobile usage. Before, the use of cellular phones was for business needs, but today, cellular phones are used by all ages. It has become part of our everyday lives. It is a means of communication, entertainment, and much more. We can use it to find our way when we get lost, or read the newspaper while commuting between destinations; we can even video chat with family and friends across the globe. All those are reasons for research in mobile IP.

In today's technological world, we cannot afford to lose mobile connections with others. We need to have constant access to information. Another reason to research about mobile IP is the fact that every second is money. For stock brokers, it could mean gaining or losing billions of dollars, for students, it could be the difference between good team coordination for projects, while for parents, it is a simple way to track and find their children when they are not home past curfew. In order for us to accomplish all of that and more, we need to find ways to maintain a constant network for mobile users.

2. NS-2 Overview

NS-2 is a simple simulation program that allows us to simulate communication network scenarios. This program provides support for simulation in TCP, routing and multicast protocols over wired and wireless networks [2].

NS-2 is an open-source program that runs best in a Linux machine, however, it is also possible to run on more popular operating systems such as windows and mac with help some from developmental tools available for those platforms. In order to run NS-2 on windows, a program named Cygwin is needed. In terms in running NS-2 in mac, the program X-Code is needed. However, NS-2 runs best using a Linux platform as it was made for such an operating system.

3. Mobile IP

Simply put, mobile internet protocol (MIP) enables seamless transfer between nodes for continuous data transfer for mobile devices. Some basic terminologies what would help the understanding of how mobile IP functions is listed below:

- Mobile Node (MN)

A mobile node is an internet connected entity that is contained within a wireless mobile station. A MN is built into a TCP/IP stack and it allows the wireless devices to connect internet or communicate with other MIP components in the network from a wide range of locations. MN devices are initially identified with the home network address, and it can roam from networks to another without changing its IP address. A MN can be any remote devices, such as laptops, cell phones or even a router.

- Home Agent (HA)

A home agent is located in the home network of the MN, and it registered the MN with its own address. The HA captures the data packets and delivers to the MN. When the MN roam away from its home network and into a foreign network, HA identifies its care-of address and locates the MN's location. HA uses a method called tunneling to forward the packets to the foreign agent.

- Foreign Agent (FA)

Foreign agents are residing in the foreign network. They intercepts the data packets from the HA and redistribute them to the MN. FAs send out beacon signals periodically. As the MN enters the foreign agent range and detects these beacons signals, the FA registers the MN with a care-of address. With the care-of address, the HA now forwards all data packets to the specified FA.

- Correspondent Node (CN)

A correspondent node is another MIP component which a MN is communicating with. A CN may be another mobile or stationary device, or a host.

- Care-Of Address

This is an address assigned to mobile node by foreign network. It might be a foreign care-of address, which is an address of the foreign agent, or a co-located care-of address which is a temporary address assigned to the MN by the MN itself. Care-of Address allows the HA to indicate its current location and delivers the packets respectively. When the MN is registered with this temporary address, the MIP protocol signals HA. Then the HA forwards the data packets to the foreign agent with this address.

- Tunnel

The data packets get transported through a tunnel, where the packets get encapsulated. A tunnel is a connection between the home address and the care-of address. Tunneling is a mechanism used by the MIP to transfer any packets across the network through a tunnel.

A simple schematic scenario of how mobile IP works is depicted in figure 3.1.

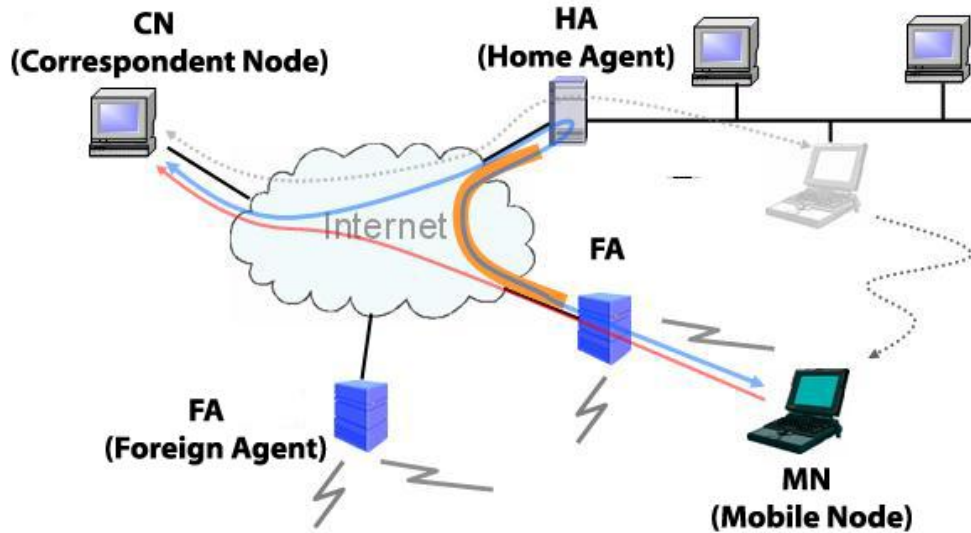


Figure 3.1: Mobile IP Model [3].

The above MIP scenario consists of 4 main components: CN, HA, FA, and MN. A MN is contained within the wireless laptop and it is initially registered to the HA located in the home network as the home address. The CN is in a host device that the laptop is communicating with. FAs are based in foreign networks and they send out beacons periodically. All the components in the MIP scenario are communicating through the Internet cloud. When the MN is in the home network, the HA receives the data packets sent from the host device and distributes to the MN. As the MN moves further away from the HA and moves in a foreign network range, the MN detects the beacon signal sent by the FA. A care-of address is assigned to the MN by the FA. The care-of address informs the HA that the MN is in the range of another network, and notifies the HA to forward all the data packets to the FA to redistribute to the MN. When the MN moves into another FA, the new FA will assign a new care-of address to the MN. Now, the HA will forward all the packets destined to the MN to the new FA, and redistribute to the MN. However, when the MN talks back to the CN, it avoids the complicated data routing process by communicating directly through the Internet cloud.

3.1 Mobile IP Operations

The MIP enables mobile devices to roam from network to network effectively and efficiently. It is important to ensure each function in the MIP operates properly. MIP undergoes several crucial functions: agent discovery, assignment of care-of address, registration, and tunneling.

3.1.1 Agent Discovery

The agent discovery process is important to set up a connection between the MN and the network. All network agents broadcast beacons from time to time. When a mobile device is first turned on, the MN will detect the beacons from an agent and bind with this agent, which acts as the home agent. During this binding process, the MN registers to the HA address.

The MN is responsible to determine its current location and decide which network agent to connect to. If the MN is within the HA range, it remains its address. However, if the MN is in a foreign network, it

acquires a care-of address from the FA. When the MN returns to its home network from the foreign network, it deregisters with the applicable foreign agent.

3.2 Assignment of Care-of Address

When the MN moves to a foreign network, before the packets get reroute to the new network, the MN need to register to a care-of address. As mentioned previously in this paper, there are two methods to assign care-of address in MIP [1].

With the first method, the foreign care-of address is assigned to MN by the FA. Each FA maintains the same care-of address for all mobile devices that enter its range. This improves the use of care-of address by limiting the number of the addresses available.

With the second method, the MN acquires the care-of address, called the “co-location care-of address”, through an external means such as the Dynamic Host Configuration Protocol (DHCP). This allows the MN to function properly without a FA.

In our NS-2 simulation of MIP, we utilized the first method to assign foreign care of address.

3.3 Registration

Registration is a process to identify the care-of address to MN’s home network. Once the MN is assigned with the new care-of address, it registers it to its home agent. By doing so, a connection can be established between the home network and the foreign network. Messages sent between the HA and FA are encrypted, this provides higher security quality as they can reject registration requests.

3.4 Tunneling and Encapsulation

A tunnel is simply the connection between the HA and the care-of address. Data packets are transported through the tunnels from point to point, as shown in Figure 3.2. The HA intercepts the packets destined to the MN and encapsulates the packets before the packets get transmit to the endpoint. When the data packets arrived at the foreign network, the FA de-encapsulates the packets and distributes to the MN.

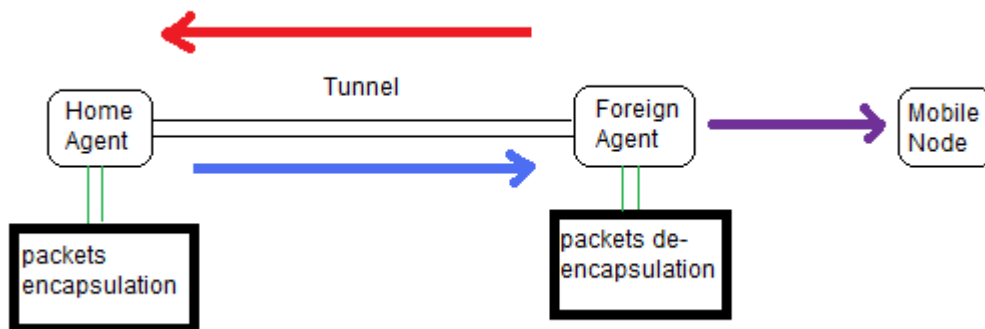


Figure 3.2 Tunneling and Encapsulation Process

4. Implementation

When this project was first proposed, our intention was to create a MIP scenario using NS-3. After discovering that NS-3 does not currently support MIP, we decided to analyze the current MIP models in NS-2 to create a simple handoff scenario.

After changing the version of NS that we would be using, we decided that we should try to improve on existing projects by updating the trace file Application Program Interface (API) to the newest format that has been released. This format is much improved and recommended for all NS users since it gives deeper details about each event in a more organized and readable format. Another feature that was new to our project was the simulation of the MN uploading a file to the CN. All papers that we had read were focused on a MN downloading from a CN and paid little attention to the situation when a MN must upload a file. We believe that this is also an important scenario and decided to simulate that process as the MN moves between networks.

4.1 Model Design

The basic model for our project was acquired from the NS-2 tutorial by Marc's Greis as shown in Figure 4.1.1 [4]. In this model, we have a combination of wired and wireless network links to simulate the basics of mobile IP.

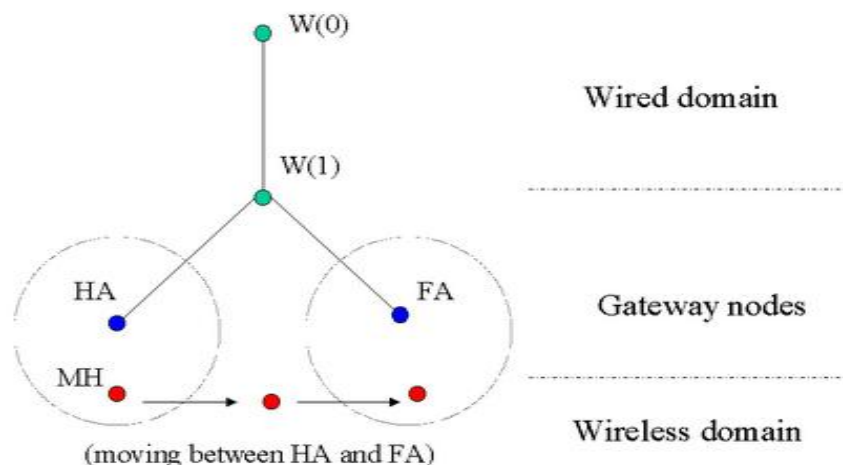


Figure 4.1.1: Model Basic Structure [4].

We decided to improve upon this model much like the ENSC 835 project from the Spring 2011 semester by adding an extra FA to the model [5]. This gives us the opportunity to see how the MN reacts to moving between two FA's instead of just a FA and its HA. The improved structure is shown in Figure 4.1.2 with node two representing the HA and nodes three and four being FA's. In this figure node zero is the CN that will be communicating with the MN using the File Transfer Protocol (FTP) which is built on the Transmission Control Protocol (TCP). Node one represents the network that the CN is connected to and is also connected to the base stations that will be transmitting packets to the MN. Node five in the figure represents the MN and will be travelling from the left side of the grid to the right side, then turning around and returning to its starting point.

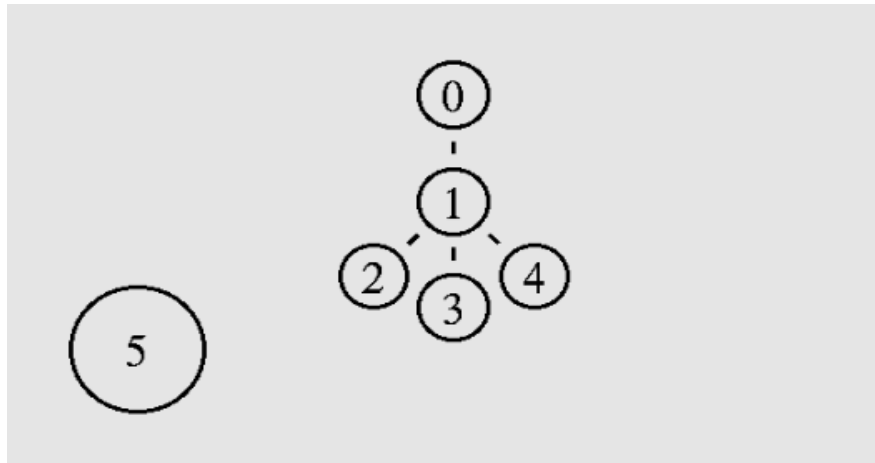


Figure 4.1.2: Basic Implementation Model.

4.2. Scenario One: Downloading to Mobile Node

The first situation that was simulated was a download by the MN from the CN via FTP. During this scenario to MN starts travelling to the right at a speed of 10m/s. At this time the MN is connected to its HA. At 20s the CN begins sending a file to the MN. These packets are originally sent directly to the MN through the HA, but as the MN moves out of range, they must be rerouted through the FA's. At 80s the MN will turn around and proceed back to its starting position at an increased rate of 20m/s. The speed is increased to limit the amount of time that the MN will be out of range of any of the FA's. Once the simulation was finished, a trace file with the new API was generated and used to obtain the data regarding the transmission process. The main objective of the simulation was to discover which base station was forwarding packets to the MN at which time.

4.3. Scenario Two: Uploading from Mobile Node

The second scenario was the opposite of the first situation. Now the MN was to upload a file to the CN while it travelled through the various networks. To ensure the results were comparable to the first scenario, the same path was taken by the MN with the same speeds. In this situation the trace file was also used to retrieve data regarding when packets were sent and received. It also tracked which base station was transferring the packets to the CN.

4.4. Range Testing

To discover the range of the base stations in the simulation a separate test was run involving only one base station node. The test consisted of the base station continuously forwarding packets to the MN as it travelled across the grid. Once simulation was completed the data was analyzed to see when the MN stopped receiving packets from the base station since it had gone out of range. Figure 4.3 shows the range of one base station to have a radius of approximately 245m.

4.5 Other Implementation Details

While the new API for trace files provides plenty of information about the many layers of each event, only certain parameters were necessary to obtain for our project. In order to sort through the details of the trace file and extract only the information that was desired we used a scripting language called AWK.

The purpose of AWK is to sort through a data file and search each row for certain desired parameters. If a row meets the search criteria, you can use C code to perform certain actions using the column data from that row. Our AWK files searched the trace files to determine if the event was a send or receive, where the packet was sent from and which node received it, the packet type, packet ID, and packet size. Once the appropriate details for each event were found, we used simple C code to create a table of all the data that we wanted to plot and saved it in a separate .dat file. AWK was also used to count the number of packets sent and received in each scenario and added this data at the end of each file. [6].

After AWK had finished creating the data file, MATLAB was used to plot the data in each file. We wrote a MATLAB script that would read all the data from the file and sort it in the most appropriate way for well detailed plots. We believed this was the most effective and polished way to present our findings during the simulations.

5. Simulation Results

This section presents all of the results that were obtained from our separate NS-2 simulations for each scenario. The data presented consists mostly of MATLAB plots that were generated from the trace files after they were filtered by our AWK script. The actual time of each simulation was under ten seconds for each the simulation, AWK file, and MATLAB plot development.

5.1 Scenario One: Downloading to a Mobile Node

Figure 5.1.1 shows the MATLAB plot from the first scenario of downloading to the MN. It is colour coded to show which base station receives each packet as the MN moves across the networks. In each of the plots; blue represents the HA, red the first FA, and green the second FA.

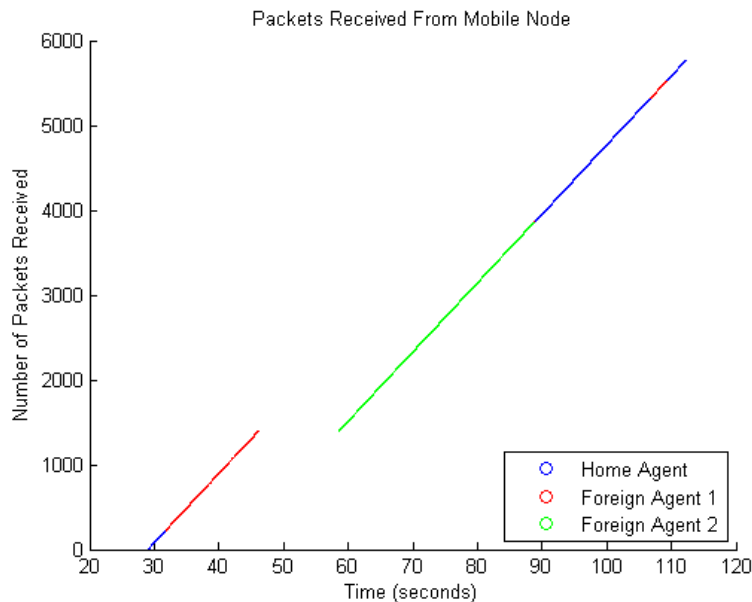


Figure 5.1.1: Scenario One Received vs. Time Results.

Figure 5.1.2 shows the position versus packets received graph to demonstrate where the MN's X position is when each packet is received. This gives a better visual representation of the area covered by each base station.

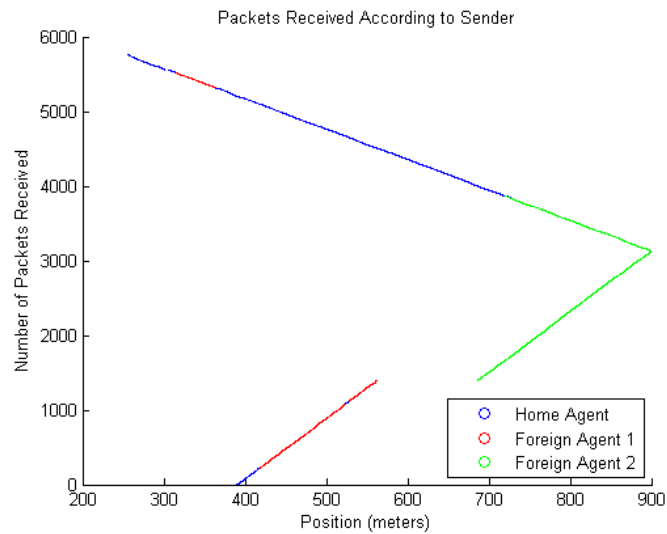


Figure 5.1.2: Scenario One Received vs. Position Results.

5.2 Scenario Two: Uploading from a Mobile Node

Figure 5.2.1 displays the scenario where a MN is uploading data to a CN as it traverses each network. We had hoped to detect which base station each packet was sent to but found it very difficult to detect this in the trace file since each event showed that the packet was destined for the CN and does not indicate which base station the packet was expected to receive each packet. Therefore we were unable to colour code this graph and each packet is just shown to have originated from the MN.

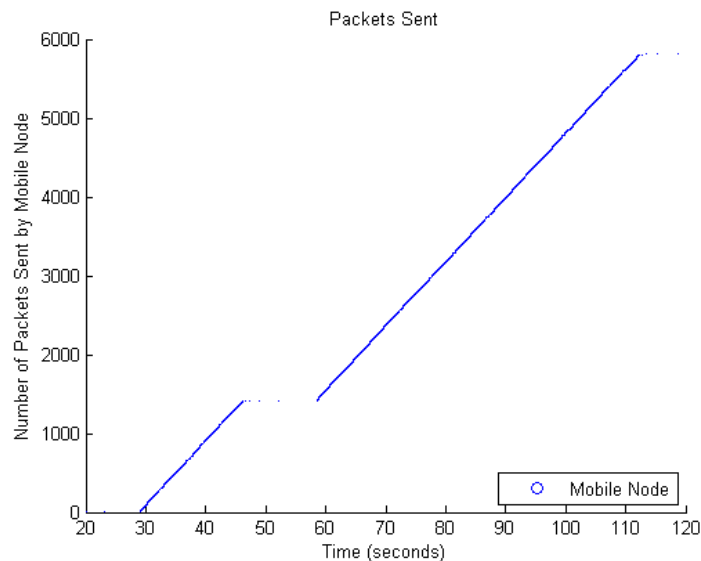


Figure 5.2.1: Packets Sent by Mobile Node

The data file produced for this simulation showed that there were 5810 packets sent by the MN over the duration of the simulation. Since the packets were being sent for an amount of 100s, the bit rate of the transmission is found using Equation (5.2.1).

$$Bit\ Rate = \frac{(\#\ of\ packets)(\#\ of\ \frac{bytes}{packet})(8\ \frac{bits}{byte})}{simulation\ time} \quad (5.2.1)$$

This equation yields an average bit rate of 483Mb/s for this simulation.

Figure 5.2.1 shows the packets received by the CN as well as the base station node that forwarded each packet from the MN. This plot shows similar gaps in transmission just as the previous plots have shown.

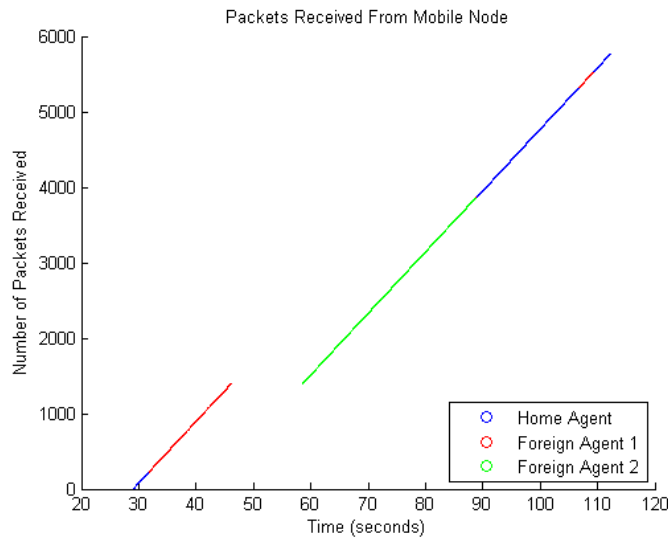


Figure 5.2.3: Packets Received from Mobile Node

Figure 5.2.4 again shows the position of the MN relative to the packets it has sent. We were unable to generate the position plot for the received packets since the trace file did not provide the MN position for those events.

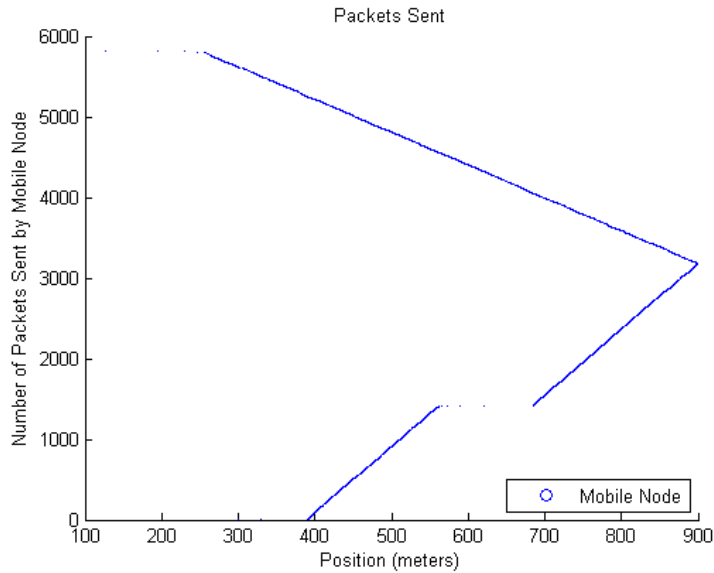


Figure 5.2.4 Packets sent vs. Position of Mobile Node

6. Analysis

After producing a number of plots and analyzing each trace file in detail we were able to gain an understanding of MIP in NS-2. This section will outline the details we found about MIP from the results as well as what we learned about NS-2’s implementation of MIP.

6.1 Results Analysis

The first scenario provided different results that expected for different simulation runs. Our original plots used for the presentation had the MN switching networks as expected as it travelled during the simulation. The graph shown in Figure 5.1 however has an unexpected switch to the HA from FA2. We would expect that its position at the time would lead it to switch first to FA1 and then back to the HA. We believe this behaviour is a great example of the poor handoff procedure used by the current MIP models in NS-2.

Another trend we noticed was the dropping of packets while switching networks from HA to FA1. We originally believed that the cause of this was the MN being out of range of both agents. After analyzing the range of each agent we found that this was not the case since each base station had a wide enough transmission range that the MN would be reached in this position. This led to the conclusion that this situation also occurs because of NS-2’s poor handoff from the HA to FA1.

The second simulation provided similar results to the first scenario. We saw that around the same time and position there was a large gap in transmission where packets were being dropped. This led us to become very unsure of why these packets were being dropped just in this area and every other spot had perfect transmission. We decided that the most likely cause was the poor handling off handoffs by NS-2 and this also led to the same switching behaviour between FA2 and the HA.

From these situations we gathered that, as expected from the known problems with the NS-2 model of MIP, the handoffs were going to be a problem with these simulations. The main problem with travelling at slow speeds was the inability of the MN to register with a new network which led to dropped packets. At higher speeds the MN picked up a further away signal and preferred to register with its HA instead of the closer FA1.

6.2 NS-2 Limitations

While we had very ambitious goals for this project, we found that many of them were stifled by the limitations of NS-2. Our original goal was to simulate the file transfer in the situation of a car driving through a number of different networks. While we were able to move the mobile node at the desired speeds of between 50-80km/h, we were not able to spread the wired base stations in the desired way. We found that once the connections between the base stations and the CN were established, separate node position could not be set as if the links had some fixed length. This limited the amount of freedom we had to separate the base stations to show the effects of overlapping and non-overlapping networks. We coped with this limitation by using much lower speeds and varying speed instead of the distance between base stations to enable to MN to be out of range for varying periods of time.

We found that another shortcoming of NS-2 was actually outlined in a few papers that we had discovered online. The handoff method that is used by NS-2 is very ineffective and does not allow the use of realistic propagation models for packets transfer. NS-2 uses a combination of the two methods outlined in RFC 3344 for handoff. The first method suggests that a new network should be registered once the lifetime of the previous networks connection expires. This can become a problem when the MN is travelling very fast and entering new networks before the connection can expire. The second method requires the MN to switch networks whenever a new beacon is heard. This becomes problematic in the case of overlapping networks since there will be constant switching of networks. The inability to use the Shadowing propagation method causes the transmission of packets to be much more reliable than any realistic scenario which leads to the low rate of dropped packets in our simulations.

7. Related Work

The foundation for this project was based on the works by Babak Shahabi and Shaoyun Yang regarding “Analysis of Mobile IP in Wireless LANs” [5]. Their project compared results between STP and RSTP using NS-2 and OPNET, and we used their NS-2 portion as a reference. Furthermore, we used the NS-2 tutorial about “Creating Wired-cum-Wireless and Mobile IP simulations in NS” by Marc Greis [4]. The tutorial had provided the basic structure for our project to build upon for further research and simulations.

8. Future Work

In this project, MIP was simulated with ns-2 and demonstrated how MIP allowed mobile devices to switch from network to network. One of the problems was the handoff process causing significant delays when the MN travelled at a slow speed. To simulate and to adjust this problem, a different simulation can be built with a different implementation of MIP suggest by Claudio Palazzi [7]. This model

was proven to be much more effective for dealing with MIP handoffs and allowed the use of the Shadowing propagation model.

Another improvement could be the extension to support the latest release of MIP, MIPv6. The latest NS-2 models only support MIPv4 which will soon be phased out by the new installment.

Lastly, the project could be improved further by updating it the latest version of the Network Simulator, NS-3. This would allow all the new features of NS-3 to be used for the best MIP simulations.

9. Conclusion

We found that the research done in this project was very beneficial by giving us an in depth understanding of MIP, NS-2, and other tools. We learned that we use MIP constantly in everyday life and it will continue to be a very important protocol as mobility becomes of increasing importance in networks. It was also interesting to learn how the handoffs between networks are resolved by the MN to allow consistent data transfer between the MN and CN.

Another important lesson learned was about the great capabilities of NS-2 and also its limitations. We found NS-2 could be frustrating to work with at times but was also very rewarding in the fact that we got to program instead of simply using a GUI to click and drag components. It's limitations caused us to think outside the box in some of our implementations and problem solve to discover how to get around those constraints.

Lastly, we learned many skills that are transferrable to a more broad range of subjects. This project introduced us to Tcl and AWK scripting that can be useful in numerous other applications. It also allowed us to extend our previous knowledge of C, MATLAB, and Linux to become much more proficient users of each tool.

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Appendix