

ENSC 835: COMMUNICATION NETWORKS  
SPRING 2011  
FINAL PROJECT

# Analysis of Mobile IP in Wireless LANs

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## **Abstract**

Wireless networks have become more popular nowadays, especially for people who always use PDA (Personal Digital Assistant) or laptops. Wireless networks enable us to have access to internet regardless of where we are. With the development of mobile equipment, such as mobile phones and laptops, we want to have an uninterrupted service while using wireless networks even when we are moving from one area to another area. So, this project discusses about Mobile IP and related issues. It will show how Mobile IP works and will address some weakness of this protocol. At last, similar scenarios are used for simulating this project in OPNET 14 and NS-2-.31 to analyze the performance of Mobile IP.

Keywords: Mobile IP, Mobile Node (MN), Home Agent (HA), Foreign Agent (FA)

# Introduction

Mobile IP, as proposed by the Internet Engineering Task Force (IETF) in RFC 2002 and subsequent RFCs, provides an efficient, scalable mechanism for node mobility within the internet. Nodes may move and change their point of attachment to the internet without changing their IP address. This allows them to maintain transport and higher-layer connections while moving. Node mobility is realized without the need to propagate host specific routes throughout the internet routing fabric. The mobile node uses two IP addresses: a fixed home address and a care-of address that changes at each new point of attachment. The mobile node has only one fixed IP address, which means mobile node does not have to worry about the local or global address.

In terms of application, Mobile IP is most often found in wired and wireless environments where users need to carry their mobile devices across multiple LAN subnets. Examples of use are in roaming between overlapping wireless systems, e.g., IP over WLAN, WIMAX and BWA (Broadband Wireless Access). One of the major problem for mobile users is to have uninterrupted connectivity when they roam between different networks. Because moving between different networks make them to get a new IP address and the application that they are using at that point will be restarted. Mobile IP protocol was designed to support seamless and continuous network connectivity.

## Related Works

- Planning and Analyzing Wireless LANs and Mobile IP Networks , *OPNETWORK 2003*
- Wireless LAN Model User Guide , *OPNET*

# 1. Mobile IP overview

## 1.1. Mobile IP Terminology

- *Mobile Node.* A host or router that changes its point of attachment from one network or sub network to another. A mobile node may change its location without changing its IP address. It might continue to communicate with the other internet nodes at any location using its original IP address, assuming link layer connectivity to a point of attachment is available.
- *Corresponding Node.* A host that mobile node communicates with which can be any servers (e.g., FTP, Web) or just some devices either mobile or stationary.
- *Home Agent.* A router on a mobile node's home network that tunnels packets for delivery to the mobile node when the mobile node is away from home, and maintains current location information for the mobile node.
- *Foreign Agent.* A router on a mobile node's visited network that provides routing services to the mobile node while registering. The foreign agent untunnels and delivers packets to the mobile node that were tunneled by the mobile node's home agent. For packets sent by a mobile node, the foreign agent may serve as a default router for registered mobile nodes.
- *Agent Advertisement.* An advertisement message constructed by attaching a special extension to a router advertisement message.
- *Agent Solicitation.* An advertisement message sent by the mobile node when it wants to join a network.
- *Care-of Address.* This address is assigned by foreign network subnet and when the mobile node is assigned this address, it will inform its home agent. The protocol can use two different types of care-of addresses: a "foreign agent care-of address" is an address of a foreign agent with which the mobile node is registered, and a "co-located care-of address" is an externally obtained local address that the mobile node has associated with one of its own

network interfaces (e.g., DHCP).

- *Home Address.* The address is assigned by home network subnet, and this is a static address for mobile node, which means that the mobile node will never change its IP address once it gets that.
- *Tunnel.* The path followed by a packet while it is encapsulated. It is routed to a knowledgeable decapsulating agent which decapsulates the datagram and then correctly delivers it to its ultimate destination.

## **1.2. Operation of Mobile IP**

There are three main steps in Mobile IP operation that include getting started and agent discovery, registration and eventually packet tunneling and transmission.

### **1.2.1. Getting started and agent discovery**

Once the mobile node turns on at the first time, it will choose one network subnet to be its home network, and then it will be assigned a home address that will never be changed. After that the mobile node registers with a home agent that belongs to the same subnet with the mobile node.

During agent discovery, both home agent and foreign agent advertise their agent advertisement periodically (i.e., once per second or once in few seconds). At the same time, a new arrived node (this mobile node has already got the home address, but it does not know which subnet it belongs to) can send agent solicitation in the channel to learn if there is any prospective network to join and check where it is.

When the mobile node detects that it is located on its home network, it operates without mobility services. When it returns to its home network from being registered elsewhere, the mobile node deregisters with its home agent through exchange of a registration request and registration reply message with it.

While a mobile node detects that it has moved to a foreign network, it obtains a care-of address on the foreign network. The care-of address can either be determined from a foreign agent's advertisements (a foreign agent care-of address), or by some external assignment mechanism such as dynamic configuration protocol (DHCP) (a co-located care-of address). Mobile IP provides two alternative modes for the acquisition of a care-of address:

- Foreign agent care of Address. A care of address provided by a foreign agent through its agent advertisement. This care-of- address is also an IP address of the foreign agent.
- Co-located Care of Address. A local address that is acquired by mobile node through some external network interfaces.

This simulation just uses foreign agent care of address rather than co-located care of address, because the later one requires other network protocol support such as dynamic host configuration protocol (DHCP), which is out of the scope in this project.

## **1.2.2. Registration**

In Mobile IP there are two kinds of registration, one is called indirect registration, and another is called direct registration. For the second kind of registration, there is an assumption that two different access points of subnet are overlapping otherwise, the direct registration does not work. In both registrations, mobile node will send a registration request to foreign agent or home agent with a binding message and there are three parts in this binding message, which are home agent's address that the mobile node wants to send request to, care of address that the mobile node gets from foreign agent and the expiry time for registration. If the registration time expires, home agent will remove the mobile node's registration record, which means that home agent will not tunnel any packets to foreign agent of the mobile node. If the mobile node still needs the tunneled packets from its home agent, it will send a re-registration request to its home agent through foreign agent. After the re-registration, home agent will keep tunneling the packets for the mobile node.

### **1.2.2.1. Indirect Registration**

There are five steps for indirect registration:



- The mobile node will send the registration request with binding message to foreign agent.
- Foreign agent relays the request to home agent.
- Home agent receives the request and registers the information (care of address, expiry time) of the mobile node into its routing table.
- After home agent registered, it sends the reply to foreign agent.
- Foreign agent relays the reply to the mobile node.

### **1.2.2.2. Direct Registration**

There are three steps for direct registration as the following:

- The mobile node sends the registration request with binding message to home agent directly.
- Home agent receives the request and registers the information of the mobile node into its routing table.
- Home agent sends the reply to the mobile node.

In this simulation, both OPNET and NS-2.31, use indirect registration, because it is a simple way to analyze how Mobile IP works. Another reason is, this way is more intuitive and there are not so many constrains.

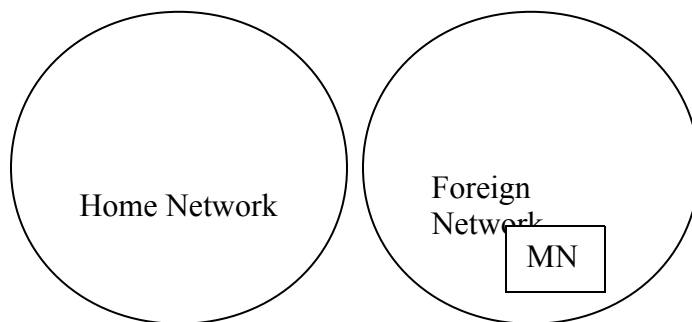
In order to send request to the home agent directly, the home agent and foreign agent must be overlapping and the user has to make sure that during the roaming time and registration, the mobile node will not totally leave home network until it receives the reply from home agent otherwise, mobile node can not communicate with home network and the registration fails.

In the first situation which has been shown in figure.1, if two subnets are not overlapping, the mobile node (MN) can only perform indirectly registration; because mobile node is not able to communicate with home agent due to home agent's access point range limitation.

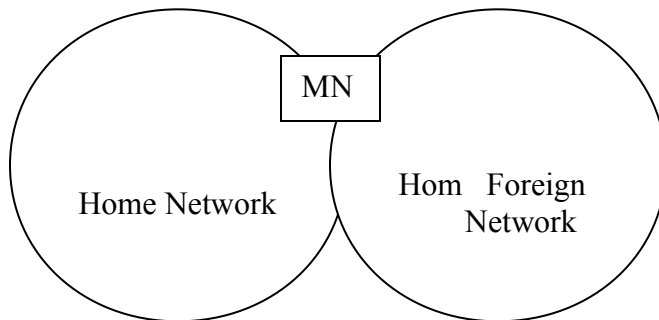
In the second situation, since mobile node is in the common area of home agent and foreign agent, it can communicate with them but, it will leave that area very soon because the size of common area is very small. In this area the mobile node will use direct registration and it will send the request to home agent

directly. However, it may not receive the reply from its home agent, because the mobile node is moving out of the range of home network. The stay time of mobile node in this common area is too short to guarantee that mobile node receives the reply message from its home agent and therefore, the registration can fail.

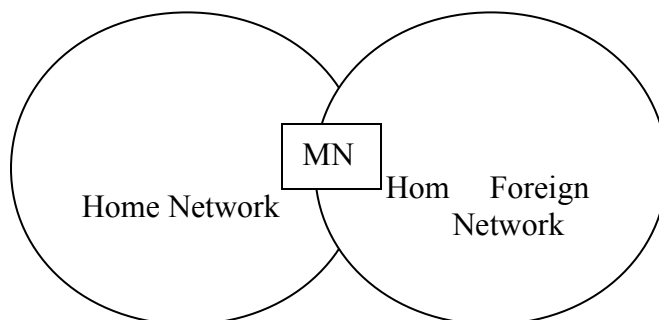
In the last situation as depicted in figure.3, two subnets are overlapping perfectly, which means that the area is big enough for mobile node to perform direct registration, not only the request-send but also the reply-receive but, this topology is very difficult to set and there are lots of constrains. So, this simulation just used indirect registration. However this can be done as a future work.



**Fig.1. No-overlapping Topology**



**Fig.2. Overlapping Topology**



**Fig.3. Perfect Overlapping Topology**

### 1.2.3. Packet Tunneling and transmission

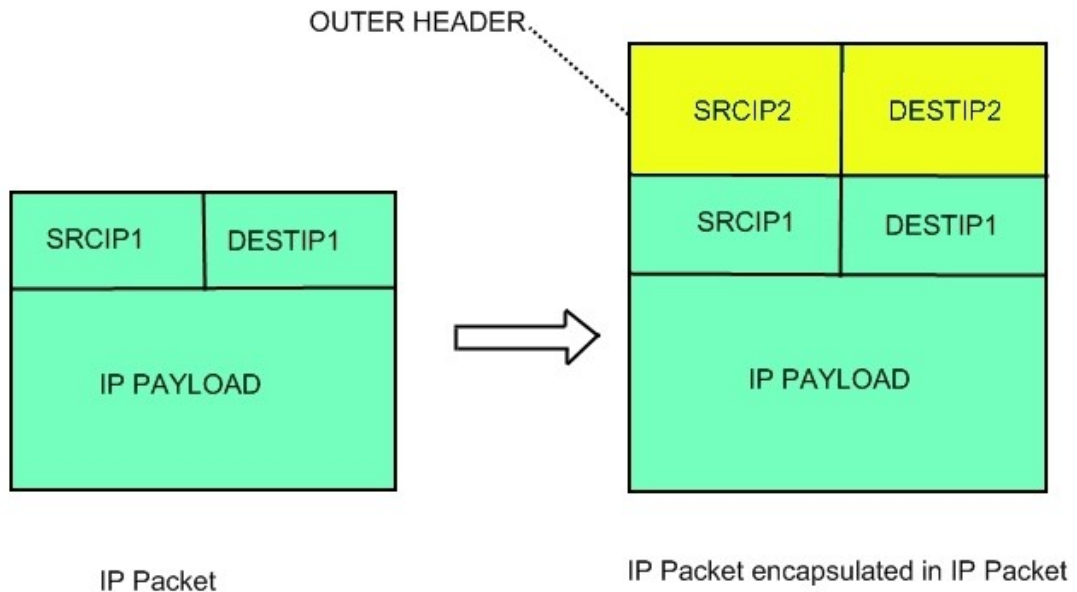
After registration (only use indirect registration in our project), home agent will forward all the packets from corresponding node to foreign agent, and foreign agent relays the packets to the mobile node. In Mobile IP it uses IP-in-IP encapsulation for packet tunneling.

#### 1.2.3.1. IP-in-IP

IP-in-IP is a very simple and intuitive tunneling protocol that bridges portions of internet which have disjoint capabilities. It encapsulates one IP packet in another IP packet. To encapsulate an IP packet in another IP packet, an outer header is added with source IP, the entry point of the tunnel and the destination point as an exit point of the tunnel. See figure. 4 and figure.5.



**Fig.4. IP-in-IP (1)**



**Fig.5. IP-in-IP (2)**

In Mobile IP, SRCIP1 is home agent's IP address, DESTIP1 is the mobile node's home address that was assigned by home agent, and IP PAYLOAD is just the data. SRCIP2 is also the home agent's address, but DESTIP2 is the care of address that home agent receives from registration request. Thus, home agent can tunnel all the packets to the mobile node. But for the reverse direction, the mobile node can communicate with corresponding node directly in foreign network, see figure.6.

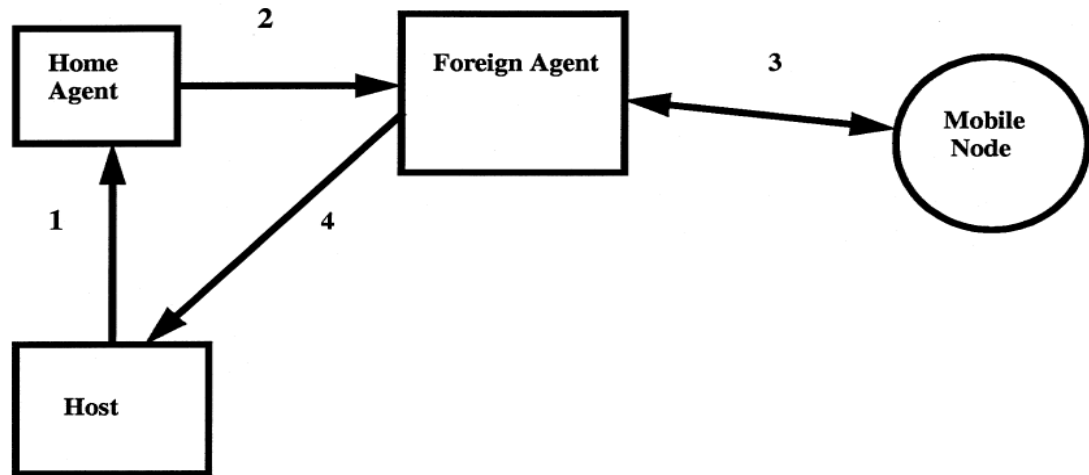


Fig.6. Packet Tunneling and Transmission

## 2. Simulation in OPNET 14 and NS-2.31

Both NS-2.31 and OPNET are used to simulate mobile IP protocol. The reasons are, first, both OPNET and NS-2 have their own strength. In OPNET, it can show the model very clearly and the graphs are very convenient to analyze. On the other hand, it is easier to trace the packet from the trace file in NS-2. It can let the user know where the packets come from and where the packets are going. Secondly, using two tools is more persuasive than use one if the user gets similar results from two different simulators. Before the simulation there are some important notes here for both simulators.

- To get better result, we use overlapping topology between different subnets to reduce the packet loss during handoff.
- Use the same scenario which we have three subnets include home agent, foreign agent one and foreign agent two, mobile node and one FTP server. Mobile node starts at its home network subnet, passes by foreign network subnet one and arrives at foreign network subnet

two.

- Use indirect registration.
- Use foreign agent care-of- address rather than co-located care-of-address.

## 3. OPNET Models for Mobile IP in Wireless LANs

### 3.1. Node Models

• In OPNET Modeler 14, there are an existing recommended nodes and configurations for Mobile IP scenario. The plan is to explain in details how Mobile IPv4 is simulated in OPNET 14. First, the nodes which they have used are introduced and then their attributes will be addressed. In order to simulate Mobile IP in OPNET 14, the following nodes are needed

- Mobile IP capable router for WLAN with an Ethernet interface that supports IEEE 802.11 standard. Figure.7 shows the detail of this node model.

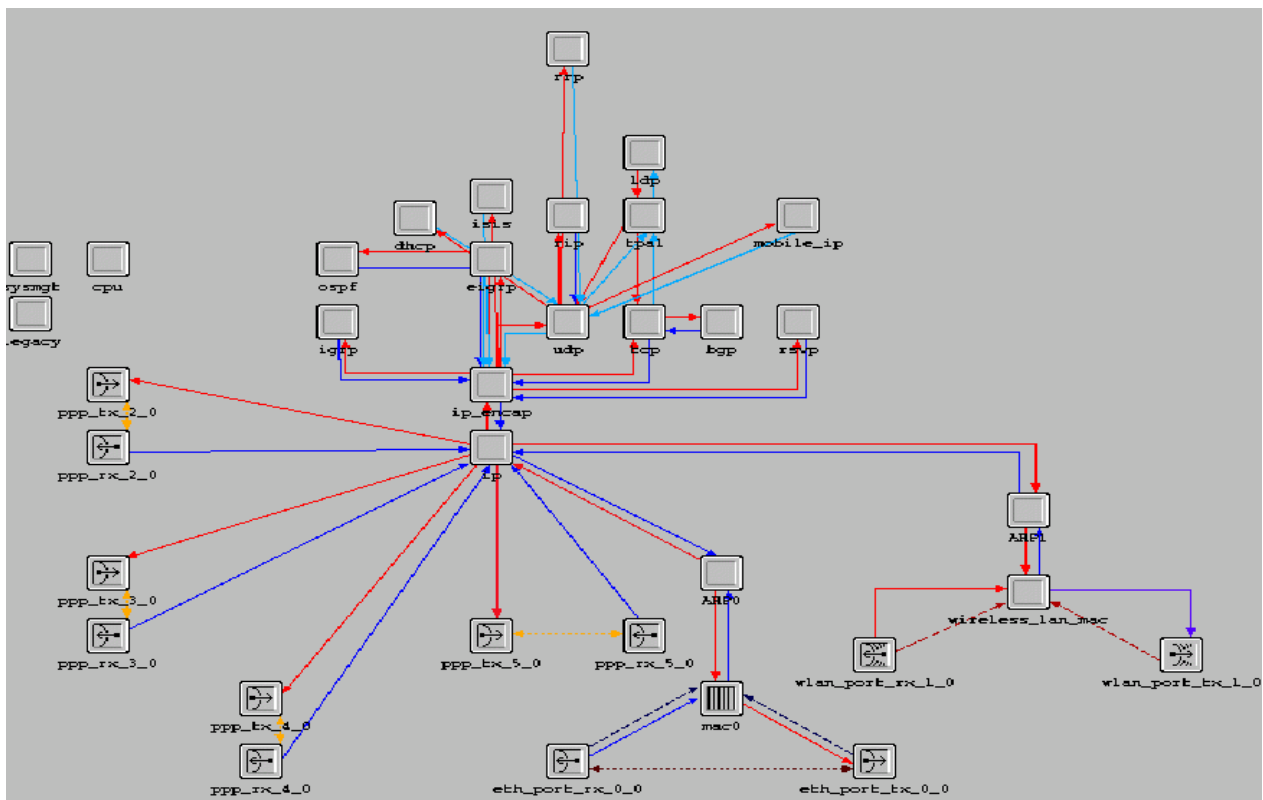


Fig.7. Mobile IP Wireless LAN Ethernet Rout

A mobile subnet can move with trajectory feature of OPNET. A trajectory is the path that the mobile node follows through space as a function of time. The user can find more details about how to make the desired trajectory in OPNET tutorial <sup>[10]</sup>

An Ethernet work station with client – server applications running over TCP/IP or UDP/IP. This workstation supports one Ethernet connection at 10,100 and 1000 Mb/s.

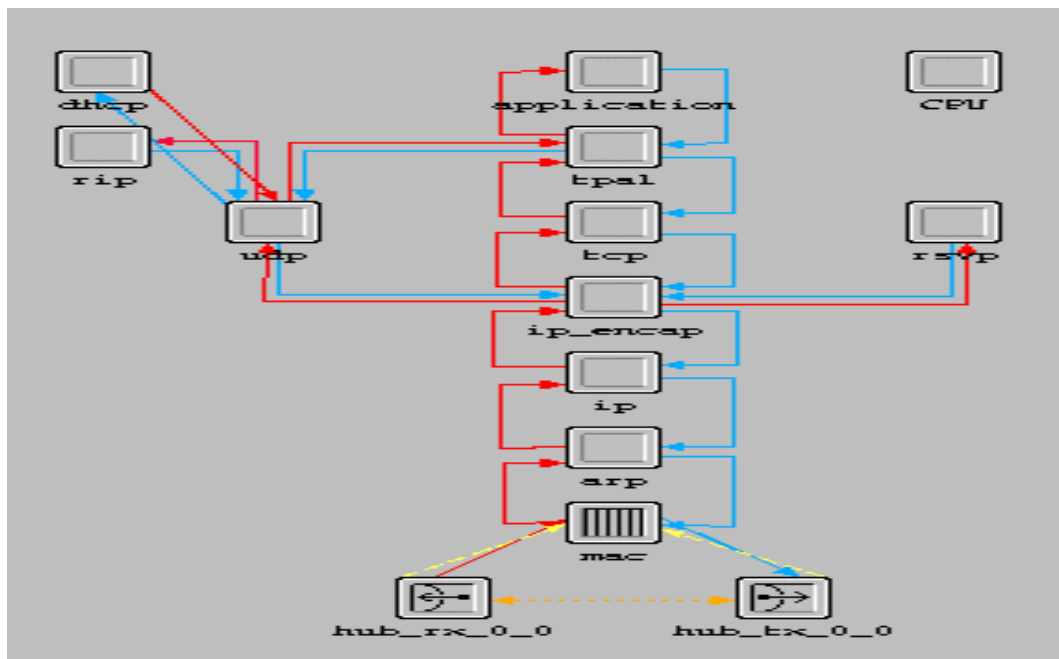


Fig.8. OPNET Ethernet Workstation node model

A Cisco-7000 series router is used in the simulation as a gateway node for interconnecting home agent and foreign agent routers to the FTP server. The mobile subnet consists of a mobile router and an Ethernet work station that are connected via a 100BaseT duplex link which will be explained in details later.

### 3.2. Node Attributes

This section explains how the user has configured and which parameters have been set for Mobile IP scenario on the nodes. It is important to know that there is no configuration requirement on Cisco 7000 series and FTP server.

The goal is to simulate Mobile IP in Wireless LANs so based on OPNET Wireless LAN user guide; the nodes should be configured as follow.

### 3.2.1. Mobile Router Node

This node is in the same network as the home agent and moves between different subnets.

Since the mobile node is a mobile subnet consists of a Mobile IP capable router, then the configuration should be according to the figure 9. There is no required configuration on the Ethernet work station.

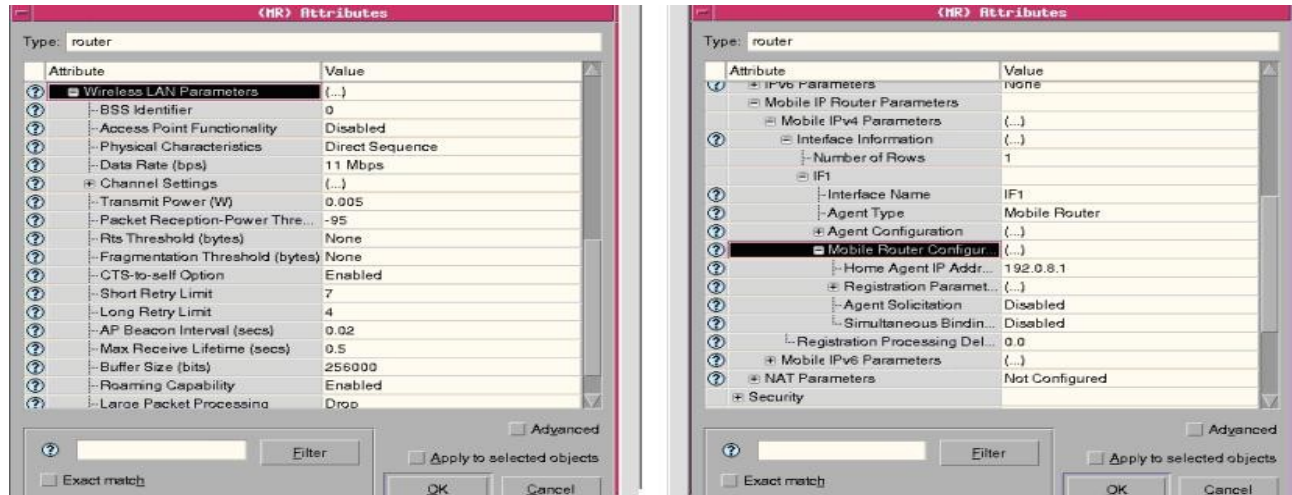


Fig.9. Mobile Router Attribute

### 3.2.2. Home Agent Node

This node is a fixed Mobile IP capable router with the following configured attributes that has been presented in figure 10.

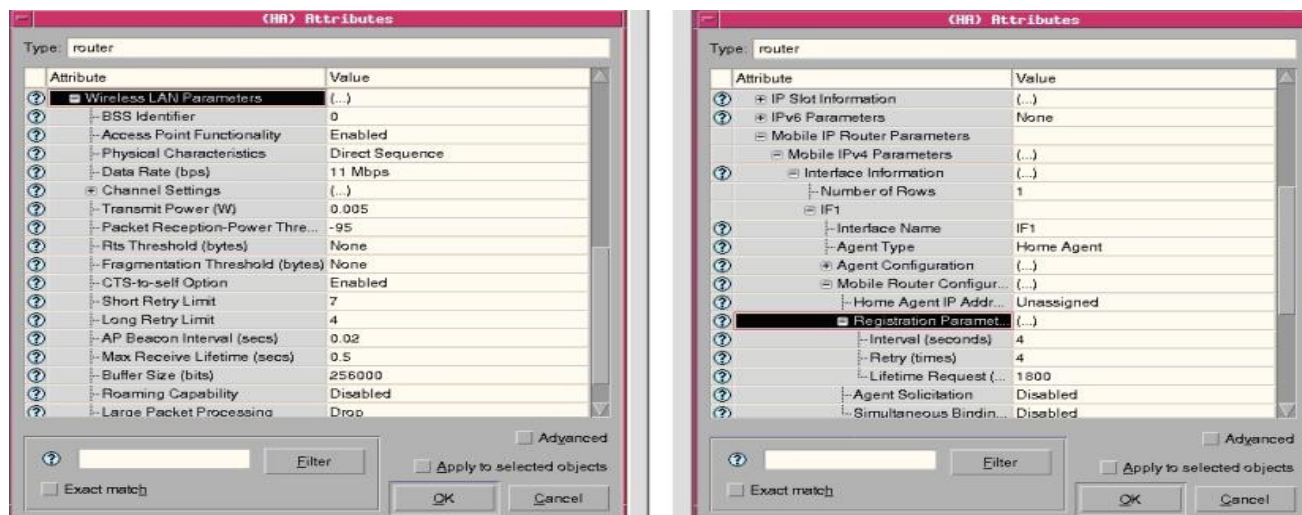


Fig.10. Home Agent Attributes

According to the figure 10, this node has to support access point functionality and has the same BSS ID as the mobile node. It is very important to note that if the user sets the BSS ID as “Auto Assigned”, the

entire OPNET subnet will be considered as a single subnet. In this case the user sets different BSS ID for the home agent and foreign agent nodes in order to have different subnets for Mobile IP scenario. Also the user does not need to set any IP address on the home agent.

### 3.2.3. Foreign Agent

This node is configured same as the home agent, except the BSS ID for each foreign agent is different than home agent and agent type is foreign agent. Figure 11 shows the parameters which have been set on foreign agent access points.

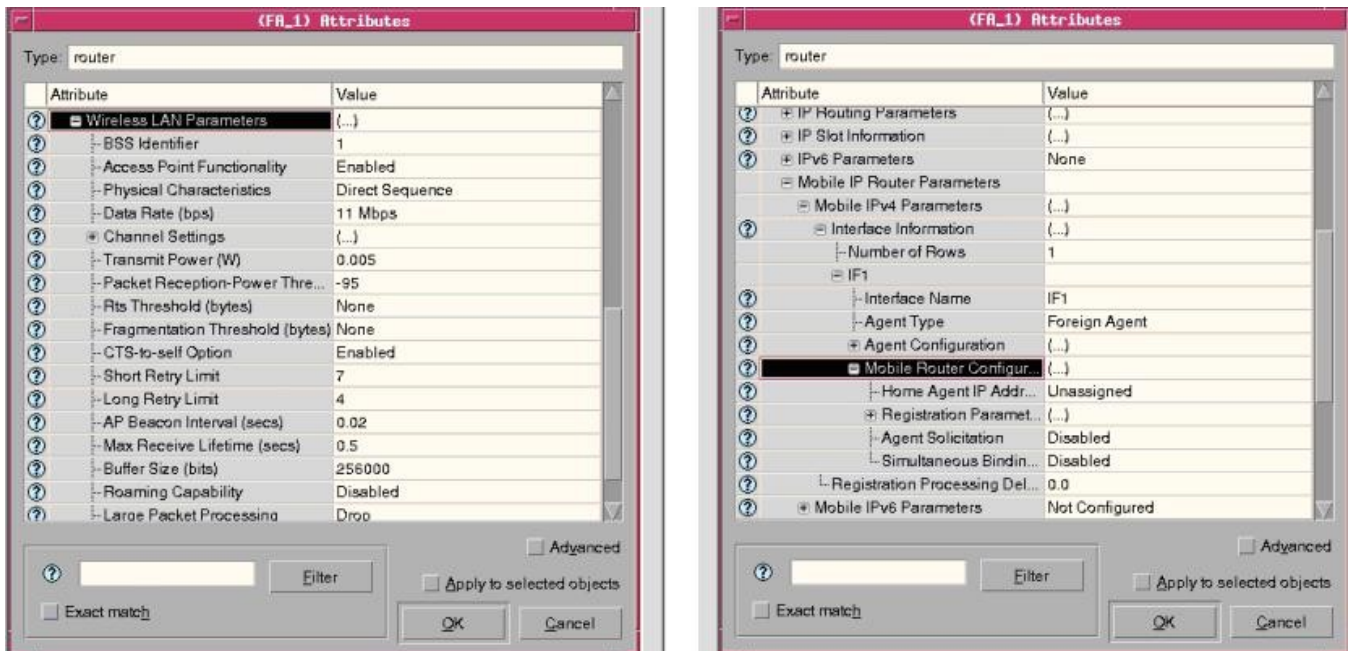


Fig.11. Foreign Agent Attributes

## 3.3. Project Implementation in OPNET Modeler 14

This section plans to show how the OPNET Mobile IP model can be used to simulate the Mobile IPv4 scenario in Wireless LANs.

Figure 12 shows the network architecture which has been designed for the simulation. The Cisco 7000 series router is used in order to make a connection between the fixed nodes. Also an FTP-Heavy Load application is used for making traffic between FTP server that is the corresponding node and the mobile node. The home agent and foreign agent are wireless LAN routers that have been designed for Mobile IP by OPNET 14.



In order to keep track of average beacon numbers received from the home agent, the user has to enable roaming capability on the mobile router in the mobile subnet. When the mobile subnet starts to move by trajectory feature which is implemented in this OPNET modeler, the beacon number that are received from the home agent access point will get low and then the mobile router switches to the foreign agent access point that a real handoff happens at this point.

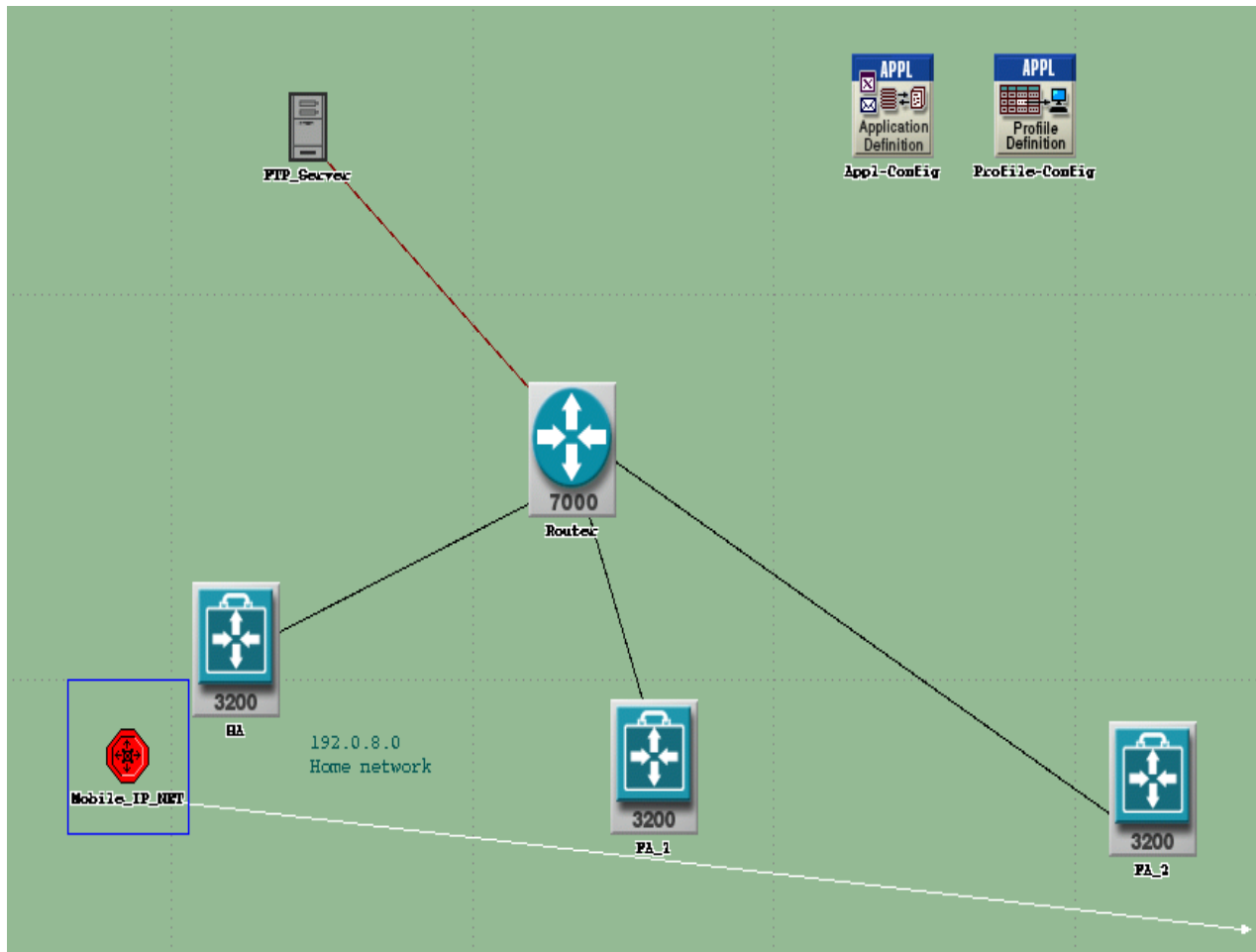


Fig.12. Mobile IP scenario in Wireless LANs

## 3.4. Simulation Results

### 3.4.1. Access Point Connectivity

One of the interested statistics that the user is looking after is, access point connectivity feature. This feature shows whether the mobile node is connected to an access point or not. According to figure 13 when the MAC address of mobile node is disconnected from its current access point (Home Agent) a

value of “-1” is written into this statistic, and when its is connected to a new access point (Foreign Agent) then the “BSS ID” of the new access point is recorded. The MAC address is assumed to be disconnected while it is in scanning mode, during which it searches for an access point with a satisfactory connection quality.

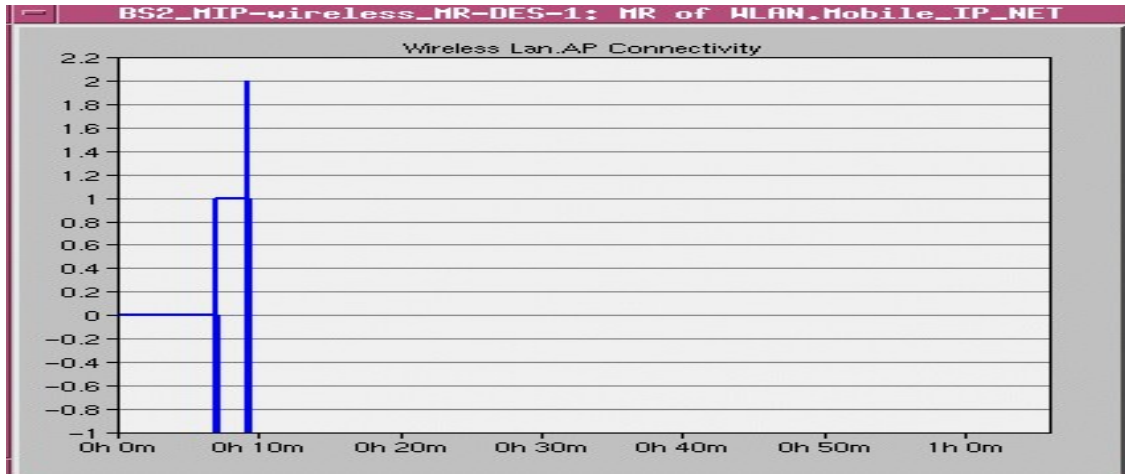


Fig.13. Mobile Node AP Connectivity

### 3.4.2. Mobile Node Registration

This data shows the first step that mobile node knows its IP address at its attachment point and then it registers with its home agent. When the mobile node is away from its home network it registers its care-of address with its home agent via foreign agent. The first dot in figure 14 shows that the mobile node registers with its home agent. The second and third dots show when the mobile node registers with foreign agents after it moves toward them. While the mobile node stays at a foreign network it needs to re-register after a certain period which is depicted by the last dot.

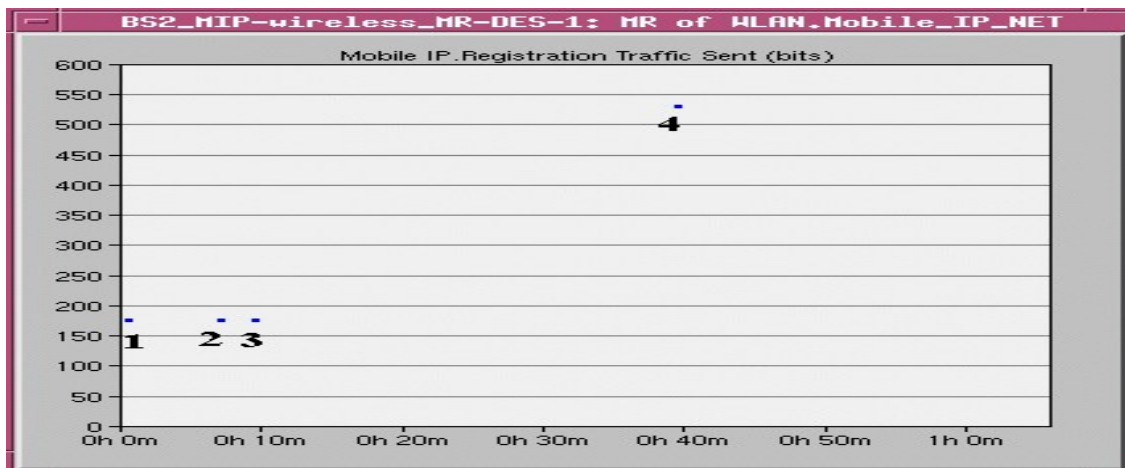


Fig.14. Mobile Node Registration Steps

### 3.4.3. Tunneled traffic sent by home agent

As it is shown in figure 15, this is amount of data traffic sent through Mobile IP tunnels by the home agent. Traffic destined to mobile node when it is away from its home network is tunneled by home agent node and sent to foreign agent.

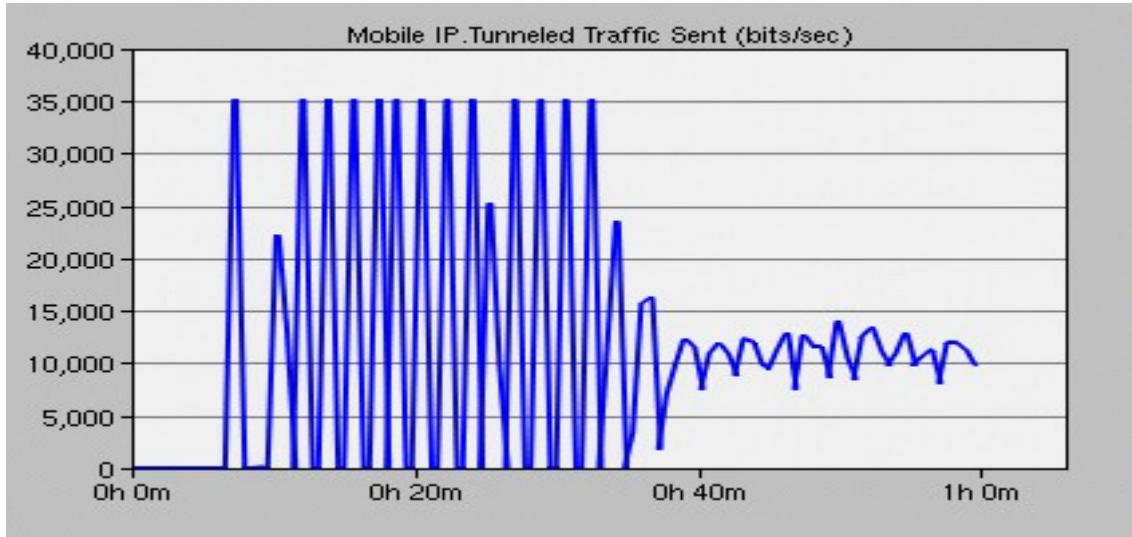


Fig.15. Tunneled traffic sent by home agent

### 3.4.4. Tunneled traffic received by foreign agent

This is amount of data traffic received through Mobile IP tunnels by the foreign agent 2 as it has been shown in figure 16.

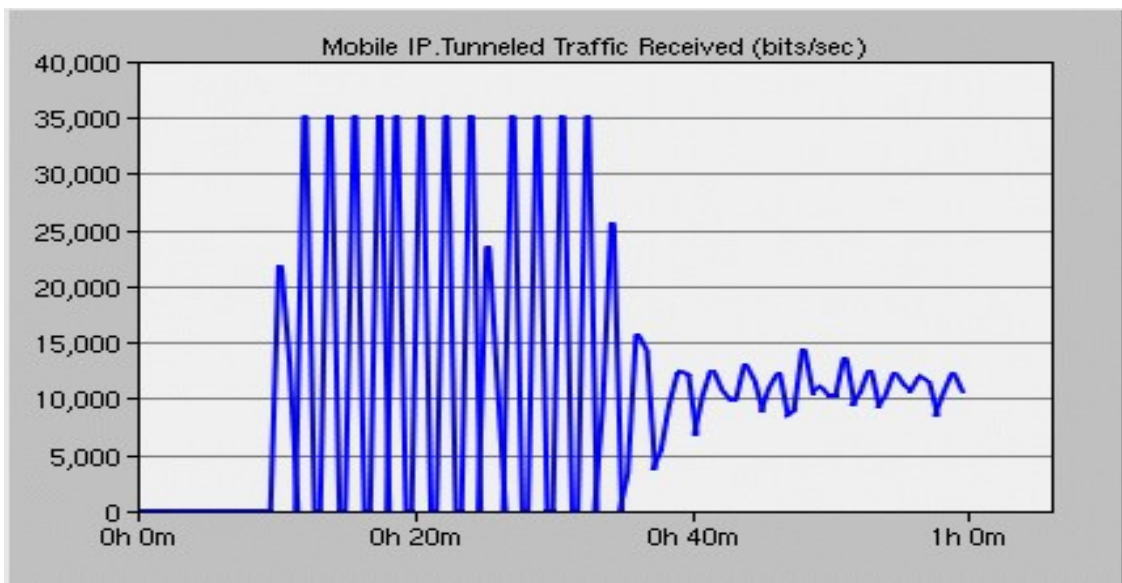


Fig.16. Tunneled Traffic Received by foreign agent

# 4. Project Implementation in NS-2-31

## 4.1. Introduce Mobile IP in NS-2

Although Mobile IP in NS-2 works very similarly to OPNET, it will be briefly described its implementation in NS-2.

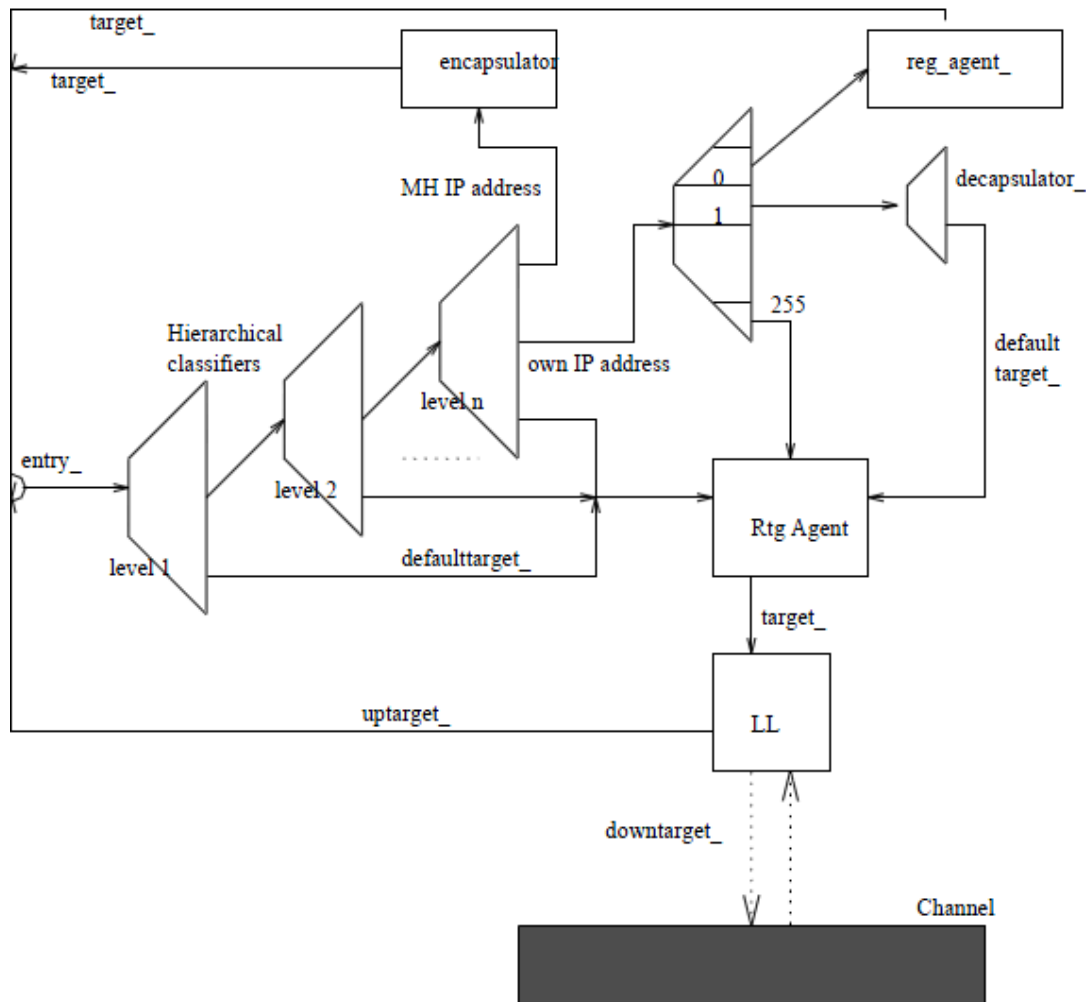


Fig.17. Base Station Node (home agent and foreign agent) Model in NS-2

According to the figure 17, home agent and foreign agent have a registering agent (reg\_agent\_). This agent sends out the beacons (agent advertisement) to the mobile node, set up encapsulator and decapsulator. If a base station node (either home agent or foreign agent) receives a registration request from a mobile node, it will check if it is home agent of its mobile node. If the destination address is its own IP address, it will set up decapsulator, and forward the request to home agent. If the base station

node receives a request from the mobile node, it will check if its care-of-address matches its own IP address, if it does not, the base station node will set up encapsulator, and send a reply to this care-of-address. When foreign agent receives this reply message from home agent, it will perform decapsulator and forward this reply to the mobile node.

## 4.2. Mobile IP Simulation in NS-2

Before the simulation in NS-2, there are some important notes here:

- In NS-2, for simplicity, the user only use TwoGrayGround propagation, which means there is no signal fade in the range of access point, all the signal strength is equal.
- The mobile node can only receive advertisement from its home agent at the beginning.
- Once mobile node receives another advertisement from other subnet, it will start performing registration with its home agent using indirect registration.
- Only foreign agent care-of-address will be used.

### 4.2.1. Building Scenario

The similar scenario like OPNET in NS-2 is built according to the Fig.

The following nodes are used:

- One mobile node, three base stations (one home agent and two foreign agents).
- One FTP server
- One gateway (regular router)

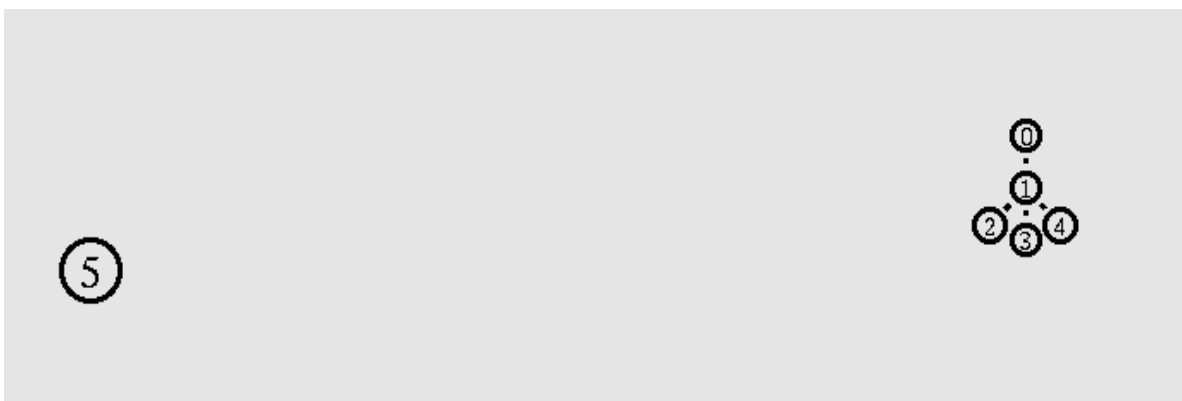
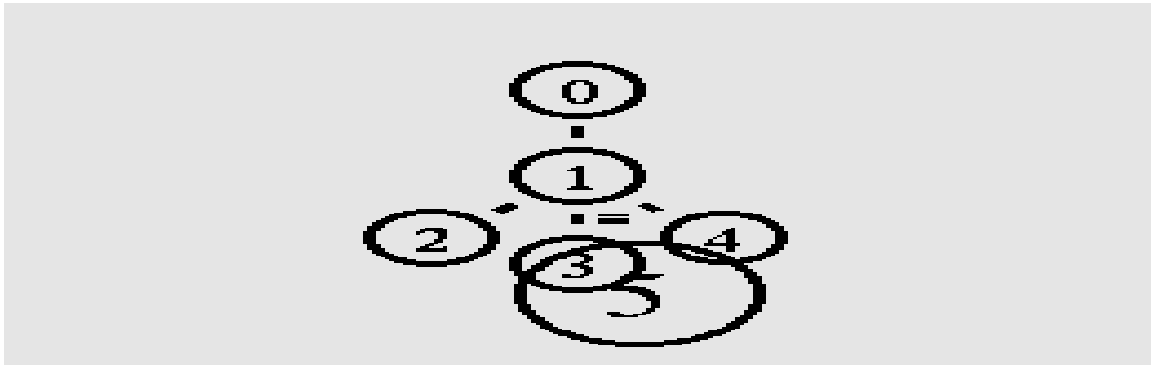


Fig.18. Scenario in NS-2

Node 0 is the FTP server, node 1 is gateway, node 2 is home agent, node 3 and node 4 are foreign agent 1 and foreign agent 2, respectively and node 5 is the mobile node.

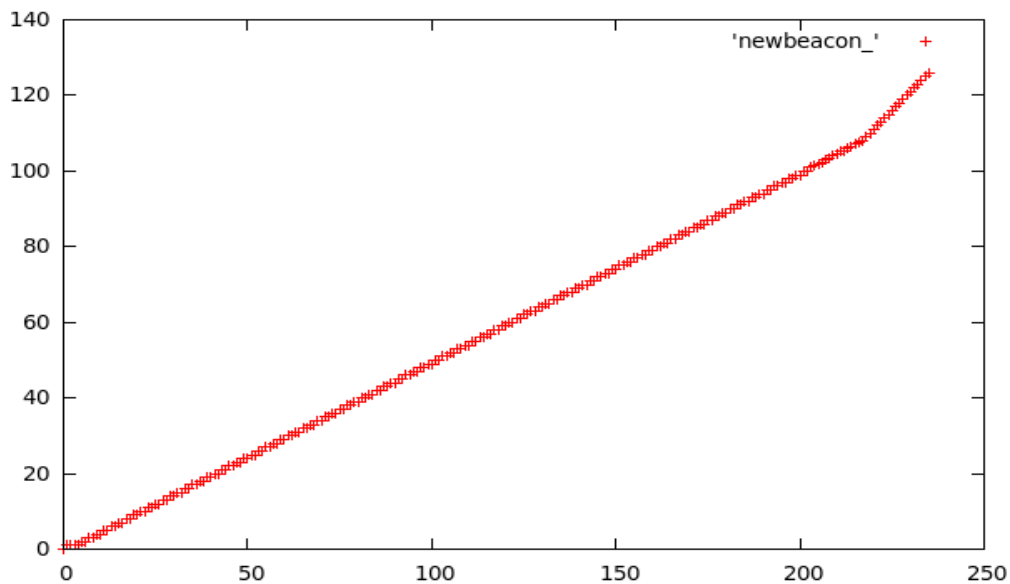


**Fig.19. Roaming of Mobile Node**

At the 100<sup>th</sup> second, the mobile node starts moving with the speed of 10m/s, passes by the subnet of foreign agent 1 and stays at the subnet of foreign agent 2. The simulation totally takes 400 seconds.

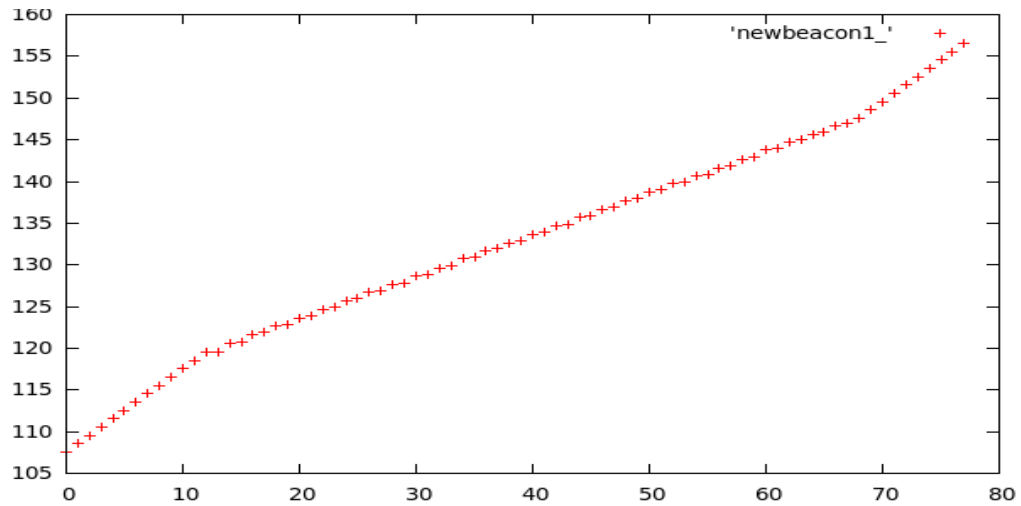
#### 4.2.2. Simulation result

According to the figure 20, the mobile node receives advertisement from home agent, and the node can receive the advertisement from the beginning of simulation until around 127<sup>th</sup> second, but after that moment, mobile node can not receive anything from home agent, which means mobile node has totally left its home network.



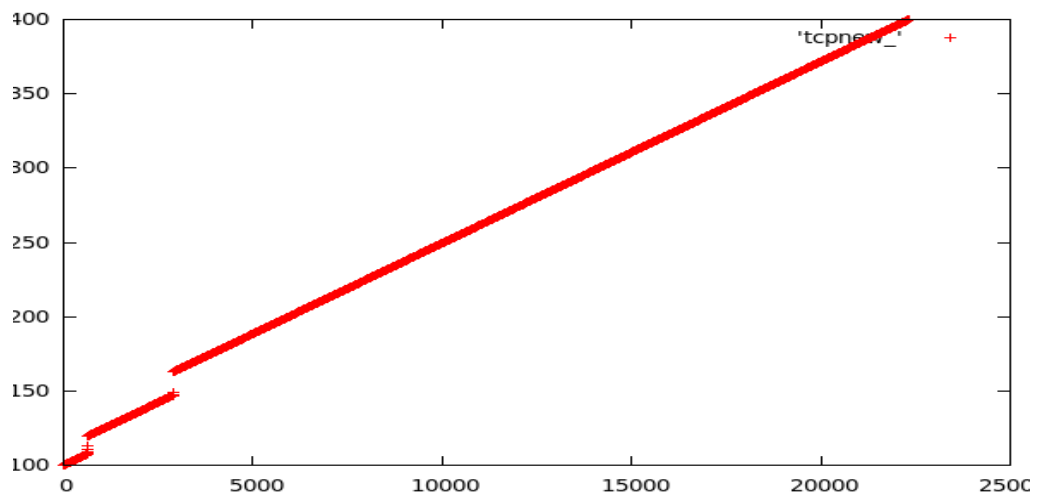
**Fig.20. Advertisement from Home Agent**

According to the figure 21, the mobile node can receive the advertisement from foreign agent after the 107<sup>th</sup> second until the 157<sup>th</sup> second, which means that the mobile node passed by foreign network 2 during this period. What's more, the registration happened at the 107<sup>th</sup> second when the mobile node received the first advertisement from foreign agent 1.



**Fig.21. Advertisement from Foreign Agent One**

Figure 22 shows tunneled packets flow that the mobile node receives. According to the figure 22, around the 107<sup>th</sup> second, there is a small gap in this figure, which means that mobile node is sending registration request to its home agent. Same situation happens at the 150<sup>th</sup>. Because another registration happens when mobile node moves to foreign agent 2 from foreign agent 1. Based on the figure 23; mobile node receives the first advertisement from foreign agent 2 at 150<sup>th</sup> second. During the time after the second registration until the end of simulation, the mobile node stays in the foreign agent 2's network



**Fig.22. Packet Flow of Mobile Node Received**

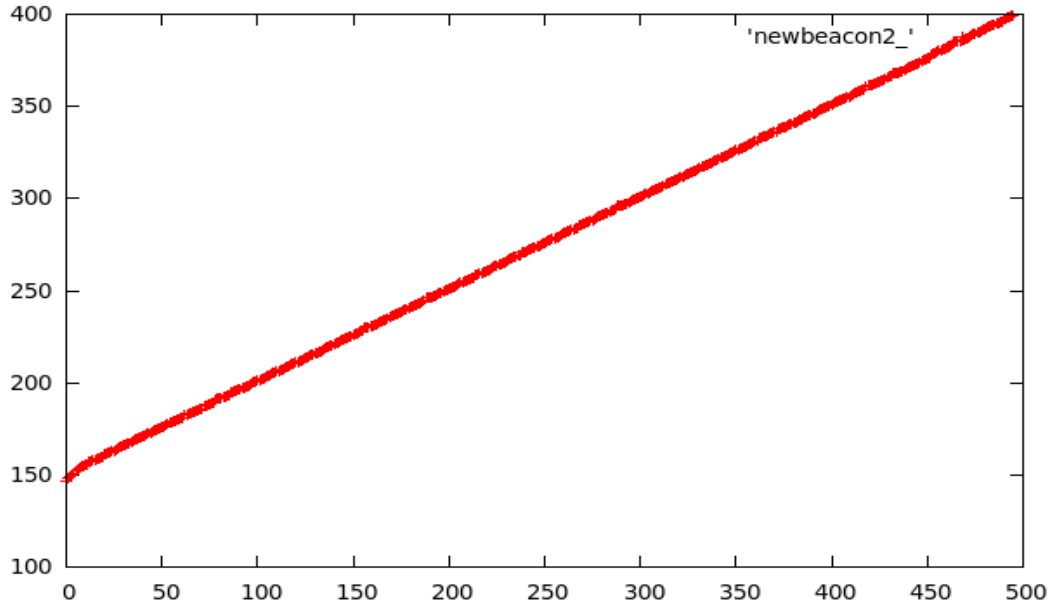


Fig.23. Advertisement from Foreign Agent Two

### 4.3. Analysis

According to figure 22, the three access points are overlapping and handover should be seamless. But, there are two gaps around 105second and 150second, which there is some packet loss. In our case our FTP server packet rate is about 100 packet/second (one packet every 10ms), the figure 24.

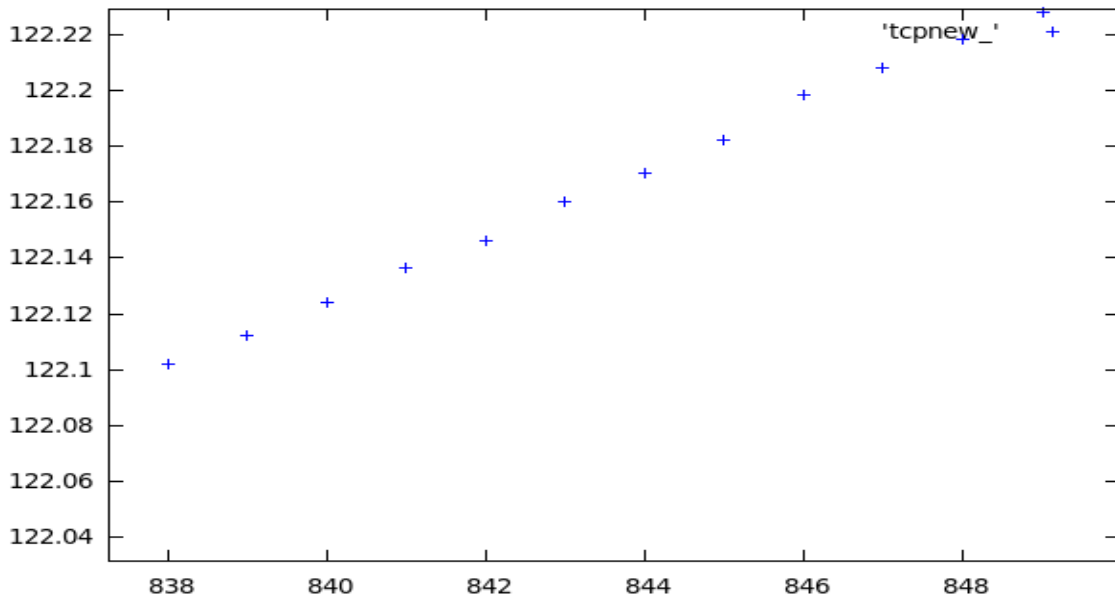


Fig.24. FTP Server Transmission Rate



In NS-2, since the mobile node can hear the advertisement from a foreign agent until receives the registration reply from its home agent, it takes few seconds, particularly the process of assigning the care-of-address to the mobile node takes most of this time. It takes about 6 seconds. If the user assumes that time is 0 and only see the registration time, it is about 25ms which also indicates that during the registration procedure mobile node can not receive any packet from its home agent and there might be some packet loss. Although the number of lost packets is very small, it is very bad for file transmission. So, there is no seamless handover in Mobile IP protocol even though the subnets are overlapping. For improving the performance of the handover of Mobile IP, there is a new idea of handover.

#### **4.4. Handoff Optimization**

If home network and foreign network are overlapping, which means that the mobile node is at their common area and it can receive advertisement from both networks. Once the mobile node receives the care-of-address from foreign agent, the mobile node sends registration request to its home agent directly without going through its prospective foreign agent, which is called direct registration. This method can greatly reduce the time of registration procedure but, it has higher requirement of topology of network, such as perfect overlapping we mentioned before.

## **Conclusion and Discussion**

In this project the user simulated Mobile IP scenario both in OPNET and NS-2 and then gets similar result.

As the user shows in the result section, the mobile node can keep communicating with corresponding node through the tunnel between home agent and foreign agent nodes.

The user also found that there is some packet loss in Mobile IP protocol due to registration process, even though there is overlapping between subnets.

## **Future Work**

The future plan is to simulate Mobile IP protocol with direct registration that can reduce the time of registration process and we will have less packet loss in this case.

Also co-located care-of-address (DHCP) and IPv6 can be used in our future simulation.

# References

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10. OPNET 14 Tutorial

## Appendix-NS-2 Code List (modified Tcl code)

```
set opt(chan) Channel/WirelessChannel ;# channel type
set opt(prop) Propagation/Shaadowing ;# radio-propagation model
set opt(netif) Phy/WirelessPhy ;# network interface type
set opt(mac) Mac/802_11 ;# MAC type
set opt(ifq) Queue/DropTail/PriQueue ;# interface queue type
set opt(ll) LL ;# link layer type
set opt(ant) Antenna/OmniAntenna ;# antenna model
set opt(ifqlen) 50 ;# max packet in ifq
set opt(nn) 1 ;# number of mobilenodes
set opt(adhocRouting) DSDV ;# routing protocol

set opt(cp) "" ;# cp file not used
set opt(sc) "" ;# node movement file.

set opt(x) 1000 ;# x coordinate of topology
set opt(y) 1000 ;# y coordinate of topology
set opt(seed) 0.0 ;# random seed
set opt(stop) 400 ;# time to stop simulation

set opt(ftp1-start) 100.0

set num_wired_nodes 2
#set num_bs_nodes 2 ; this is not really used here.

# =====

# check for boundary parameters and random seed
if { $opt(x) == 0 || $opt(y) == 0 } {
    puts "No X-Y boundary values given for wireless topology\n"
}
if {$opt(seed) > 0} {
    puts "Seeding Random number generator with $opt(seed)\n"
    ns-random $opt(seed)
}

# create simulator instance
set ns_ [new Simulator]

# set up for hierarchical routing
$ns_ node-config -addressType hierarchical

AddrParams set domain_num_ 4 ;# number of domains
lappend cluster_num 2 1 1 1 ;# number of clusters in each domain
AddrParams set cluster_num_ $cluster_num
lappend eilastlevel 1 1 2 1 1 ;# number of nodes in each cluster
AddrParams set nodes_num_ $eilastlevel ;# of each domain

set tracefd [open wireless3-out.tr w]
set namtrace [open wireless3-out.nam w]
$ns_ trace-all $tracefd
$ns_ namtrace-all-wireless $namtrace $opt(x) $opt(y)

# Create topography object
```

```

set topo [new Topography]

# define topology
$topo load_flatgrid $opt(x) $opt(y)

# create God
# 2 for HA and FA
create-god [expr $opt(nn) + 3]

#create wired nodes
set temp {0.0.0 0.1.0} ;# hierarchical addresses
for {set i 0} {$i < $num_wired_nodes} {incr i} {
    set W($i) [$ns_node [lindex $temp $i]]
}

# Configure for ForeignAgent and HomeAgent nodes
$ns_node-config -mobileIP ON \
    -adhocRouting $opt(adhocRouting) \
    -llType $opt(ll) \
    -macType $opt(mac) \
    -ifqType $opt(ifq) \
    -ifqLen $opt(ifqlen) \
    -antType $opt(ant) \
    -propType $opt(prop) \
    -phyType $opt(netif) \
    -channelType $opt(chan) \
    -topoInstance $topo \
    -wiredRouting ON \
    -agentTrace ON \
    -routerTrace OFF \
    -macTrace OFF

# Create HA and FA
set HA [$ns_node 1.0.0]
set FA1 [$ns_node 2.0.0]
set FA2 [$ns_node 3.0.0]
$HA random-motion 0
$FA1 random-motion 0
$FA2 random-motion 0

# Position (fixed) for base-station nodes (HA & FA).
$HA set X_ 100.000000000000
$HA set Y_ 20.000000000000
$HA set Z_ 0.000000000000

$FA1 set X_ 400.000000000000
$FA1 set Y_ 20.000000000000
$FA1 set Z_ 0.000000000000

$FA2 set X_ 800
$FA2 set Y_ 20
$FA2 set Z_ 0

# create a mobilenode that would be moving between HA and FA.
# note address of MH indicates its in the same domain as HA.
$ns_node-config -wiredRouting OFF

```

```

set MH [$ns_ node 1.0.1]
set node_(0) $MH
set HAaddress [AddrParams addr2id [$HA node-addr]]
[$MH set regagent_] set home_agent_ $HAaddress

# movement of the MH
$MH set Z_ 0.000000000000
$MH set Y_ 10.000000000000
$MH set X_ 80.000000000000

# MH starts to move towards FA
$ns_ at 100.000000000000 "$MH setdest 900.000000000000 20.000000000000
10.000000000000"
# goes back to HA
#$ns_ at 200.000000000000 "$MH setdest 20.000000000000 5.000000000000
20.000000000000"

# create links between wired and BaseStation nodes
$ns_ duplex-link $W(0) $W(1) 5Mb 2ms DropTail
$ns_ duplex-link $W(1) $HA 5Mb 2ms DropTail
$ns_ duplex-link $W(1) $FA1 5Mb 2ms DropTail
$ns_ duplex-link $W(1) $FA2 5Mb          2ms DropTail

$ns_ duplex-link-op $W(0) $W(1) orient down
$ns_ duplex-link-op $W(1) $HA orient left-down
$ns_ duplex-link-op $W(1) $FA1 orient down
$ns_ duplex-link-op $W(1) $FA2 orient right-down

# setup TCP connections between a wired node and the MobileHost

set tcp1 [new Agent/TCP]
$tcp1 set class_ 2
set sink1 [new Agent/TCPSink]
$ns_ attach-agent $W(0) $tcp1
$ns_ attach-agent $MH $sink1
$ns_ connect $tcp1 $sink1
set ftp1 [new Application/FTP]
$ftp1 attach-agent $tcp1
$ns_ at $opt(ftp1-start) "$ftp1 start"

# source connection-pattern and node-movement scripts
if { $opt(cp) == "" } {
    puts "*** NOTE: no connection pattern specified."
    set opt(cp) "none"
} else {
    puts "Loading connection pattern..."
    source $opt(cp)
}
if { $opt(sc) == "" } {
    puts "*** NOTE: no scenario file specified."
    set opt(sc) "none"
} else {
    puts "Loading scenario file..."
    source $opt(sc)
    puts "Load complete..."
}

```

```

}

# Define initial node position in nam

for {set i 0} {$i < $opt(nn)} {incr i} {

    # 20 defines the node size in nam, must adjust it according to your
    # scenario
    # The function must be called after mobility model is defined

    $ns_ initial_node_pos $node_($i) 20
}

# Tell all nodes when the simulation ends
for {set i 0} {$i < $opt(nn)} {incr i} {
    $ns_ at $opt(stop).0 "$node_($i) reset";
}
$ns_ at $opt(stop).0 "$HA reset";
$ns_ at $opt(stop).0 "$FA1 reset";

$ns_ at $opt(stop).0 "$FA2 reset";

$ns_ at $opt(stop).0002 "puts \"NS EXITING...\" ; $ns_ halt"
$ns_ at $opt(stop).0001 "stop"
proc stop {} {
    global ns_ tracefd namtrace
    close $tracefd
    close $namtrace
}

# some useful headers for tracefile
puts $tracefd "M 0.0 nn $opt(nn) x $opt(x) y $opt(y) rp \
    $opt(adhocRouting)"
puts $tracefd "M 0.0 sc $opt(sc) cp $opt(cp) seed $opt(seed)"
puts $tracefd "M 0.0 prop $opt(prop) ant $opt(ant)"

puts "Starting Simulation..."
$ns_ run

```