OLSR and IPv6 using Mininet

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This laboratory work consists in setting up an IPv6 ad hoc network controlled by the OLSR routing protocol. It is prepared to be used in FEUP's NetLab or using the Mininet network emulator. This guide is organized in three sections.

The first section explains the Mininet software that will be used to run an emulated network testbed replicating the testbed created in FEUP's NetLab. Read it carefully, as it explains how to use Mininet, as well as how to run OLSR and Wireshark on Mininet.

The second part contains the original OLSR guide, explaining the network setup and tests to perform. Please note that this guide corresponds to the original guide for the OLSR lab work, which was originally thought to be done in FEUP's NetLab. As such, all configurations related to a "PC" should be applied to the corresponding Mininet host (e.g., PC1 corresponds to Mininet host h1).

The final section contains the questions that should be answered on the final report.

1 Mininet

In this work, we will use the Mininet software to emulate a wireless network testbed. Mininet is a network emulator which creates a network of virtual hosts, switches, controllers and links. Mininet hosts are virtualized in Linux network namespaces, which allows the creation of multiple independent TCP/IP network stacks. Also, since they are running on top of the Linux kernel, all Linux software works exactly in the same way.

More information on Mininet is available on their website: http://mininet.org/overview/

1.1 Mininet Installation

Mininet runs on the Linux kernel. Therefore, in order to set-up the Mininet testbed, we will use a standard Linux distribution (e.g., Ubuntu) on a Virtual Machine (VM) or installed directly on a PC.

The official Mininet website provides a prebuilt VM based on Ubuntu 14.04 with all packages already installed. However, this VM does not support IPv6, nor does it contain a graphical user interface.

Therefore, we will install Mininet through Ubuntu's package manager (apt-get). The complete instructions to install Mininet are provided on this website. Ignore the Software Defined Network (SDN) parts (the controller and switch), as they are not used in this work.

http://mininet.org/download/#option-3-installation-from-packages

To install Mininet, run this command on the terminal:

```
$ sudo apt-get update

$ sudo apt-get install mininet xterm
```

To check that everything is working well, run a pingall command on Mininet. This command will create a basic network topology (2 hosts connected through a switch) and perform a ping between both hosts.

```
$ sudo mn --test pingall
```

1.2 Mininet Command Line Interface (CLI)

After starting an instance of Mininet, the Mininet network is controlled through the CLI on the terminal. The Mininet CLI is explained in this website: http://mininet.org/walkthrough/#part-3-mininet-command-line-interface-cli-commands.

In this guide, running commands on the Mininet CLI means that those commands should be run on the Linux terminal where Mininet was launched. This is indicated by the prefix "$ mininet>" on the terminal.

To start a minimal Mininet instance, run these commands (NOTE: Mininet must always be launched with root permissions -- i.e., using sudo):

```
$ sudo mn   # Start Mininet with a minimal topology (2 hosts + 1 switch)

$ sudo mn --help   # See Mininet help and the list of flags
```

After starting a Mininet instance, the network is controlled through the CLI. To see all available commands in the CLI, run this command on the Mininet CLI:

```
$ mininet> help
```

To exit Mininet, run this command on the Mininet CLI:

```
$ mininet> exit
```

There are two methods to run Linux commands on a specific host.

1. Run the command on the Mininet CLI prepending the host on which we want to apply the command. For instance, if we want to run `ifconfig` on host h1:

   ```
   $ mininet> h1 ifconfig
   ```

2. Launch a dedicated terminal for each host. This terminal allows us to run commands directly on that host, without needing to prepend the commands with the host name (e.g., h1, h2, …). This is the preferred method for this work, since it allows us to have one terminal per host, similar to a real testbed. To launch a terminal for host 1 and run ifconfig on the newly created terminal, we can simply run this command on the Mininet CLI

```
$ mininet> xterm h1

$ ifconfig             # On the newly created terminal
```

A useful shortcut to start Mininet with dedicated terminals for every host is to add the flag "-x" when starting a Mininet instance (i.e., `$ sudo mn -x`).

1.3 Association Between Physical and Mininet Network Interfaces

Since Mininet virtualizes each host's TCP/IP network stack, each host has its own network interface. The interface created by Mininet for a host can be seen by running ifconfig on the host's terminal. The convention Mininet uses is "hx-eth0", where x is the host number (e.g., h1-eth0). Therefore, throughout this guide, when referring to the eth0 network interface of PCx, you should instead refer to the Mininet interface "hx-eth0".

Similar to a real testbed, each host in Mininet only has access to its own interface (e.g., h1 can't access h2 interface). However, the Linux PC (outside Mininet) has access to all hosts' interfaces (e.g., s1-eth1, s1-eth2, …).

1.4 Running OLSR in Mininet

In Mininet, only the network stack is virtualized (contrary to a full container). This has two consequences. First, the OLSR daemon (olsrd) only needs to be installed once in the Linux PC, since all hosts share the filesystem. Second, the OLSR daemon (olsrd) does not allow the execution of multiple instances on the same machine. The OLSR daemon checks if there is another instance of olsrd running through a temporary lock file created in "`/var/run/olsrd-ipv6.lock`". In order to circumvent this limitation, we must remove this file before starting a new instance of olsrd on another host.

1.5 Running Wireshark in Mininet

Given the association between physical and Mininet network interfaces, there are two methods to run Wireshark on the hosts:

1. Launch Wireshark on the host's terminal (you can continue to use the terminal normally after wireshark is launched). This method resembles a real testbed, where each host has its own Wireshark.

```
$ sudo wireshark &
```

2. Create a new terminal on Linux (outside Mininet), start Wireshark and capture all the virtual interfaces representing each host (e.g., s1-eth1, s1-eth2, …).
   NOTE: Since we are capturing all interfaces simultaneously, we will need to apply filters when analyzing the logs in order to separate traffic from each host.

```
$ sudo wireshark &
```

1.6 Additional Provided Files

When using Mininet, you should have two additional files provided in Moodle: `mininet_olsr_topology.py` and `mininet_topology_changer.sh`.

The Python script `mininet_olsr_topology.py` defines the network topology to be used in Mininet. The file `mininet_topology_changer.sh` is the updated bash script to change the topology of the network. Contrary to the use of original topology_changer in FEUP's NetLab, this script should be run within each host's terminal.

Place these files on a directory of your choice and give the mininet_topology_changer.sh execution permissions.

```
$ sudo chmod +x mininet_topology_changer.sh
```

1.7 Start the Mininet Network

To start a Mininet instance representing the wireless network testbed, run this command on a Linux terminal, where `<absolute_path_to_mininet_olsr_topology.py>` should be the absolute path to the mininet_olsr_topology.py script file (e.g., `/home/eduardo/como/mininet_olsr_topology.py`).

```
$ sudo mn -x --switch=ovsbr --controller=none
     --custom=<absolute_path_to_mininet_olsr_topology.py>
     --topo=olsr_topo
```

2 Optimized Link State Routing (OLSR)

This section contains the guide for the OLSR lab work. Some hints before starting this work on FEUP's NetLab are listed below.

HINT 1: You can apply filters in Wireshark when analyzing the captured logs, in order to only show traffic from / to a given IP / MAC, application, and so on.

HINT 2 (NetLab): Check that the cables on your network stand are correctly connected, the switch ports are on the same VLAN, and the network settings on the PCs are clear.

HINT 3 (NetLab): Instead of constantly switching the PC monitor, you can use one of the PCs as the main working PC and connect to the remaining PC via SSH, with "-X" to redirect the graphical user interface of Wireshark. You can then launch Wireshark with `$ sudo wireshark &`.

HINT 4 (NetLab): When using FEUP's NetLab, it is recommended to generate pairs of SSH keys between the PC where you are issuing the topology_changer-sh command to the remaining PCs. This avoids the need to input the PC password multiple times, which affects the timing of the network disconnection during topology reconfigurations.

```
$ ssh-keygen -t rsa

$ ssh-copy-id root@tuxX1

$ ssh-copy-id root@tuxX2

$ ssh-copy-id root@tuxX3

$ ssh-copy-id root@tuxX4
```

2.1 Introduction

This work consists in setting up an Ad-Hoc network controlled by the OLSR protocol. Due to the impracticalities of using wireless interfaces in FEUP Netlab, i.e., all nodes would be able to see every other node, thus using routing would be useless; we'll simulate the Ad-Hoc network using wired interfaces connected to the same switch and blocking connectivity between some of the nodes.

2.2 Network Interfaces Setup

Each group has a stand (bancada) with 4 PCs where you are going to setup OLSRd. You'll have to perform the following steps in each one of them. First, make sure you run these commands:

```
$ echo 0 > /proc/sys/net/ipv6/conf/eth0/accept_ra

$ ifconfig eth0 down && ifconfig eth0 up    # Not necessary in Mininet

$ dhclient eth0                             # Not necessary in Mininet

$ echo 1 > /proc/sys/net/ipv6/conf/eth0/forwarding
```

The first command disables Routing Advertiser (RA) messages. RAs are used as a link local mechanism for neighbor discovery, but because the nodes are going to be routers and use global addresses, RAs are not needed in our scenario. If you want to learn more about it check RFC2462. The second command resets the IP configuration in interface eth0. The third sets the IPv4 configuration for the interface which is going to be needed later to download packages, and finally the fourth makes sure that forwarding is enabled. This is a requirement for routing packets.

2.3 OLSR Installation and Configuration

The OLSR daemon (olsrd) can be installed through the Linux package manager (e.g., apt-get) or building it manually. To install olsrd through Ubuntu's package manager, simply run the following command on a Linux terminal:

```
$ sudo apt-get update

$ sudo apt-get install olsrd
```

If olsrd is not available through the OS's package manager, install it manually running the following commands in a Linux terminal:

```
$ git clone --depth=1 https://github.com/olsr/olsrd.git

$ cd olsrd/

$ make && make install
```

The OLSR daemon is configured by editing a special configuration file on Linux. A sample of this file is already installed in the directory `/etc/olsrd/olsrd.conf`. To configure OLSR for this work, we will create a configuration file for each PC based on the sample. To edit the files, use your favorite editor (e.g., nano or vim) using sudo.

To create the configuration files, create one copy of the sample configuration file and place it on the same directory, but with the name "olsrdX.conf", where X corresponds to the PC number. Edit this file with the configurations below. Then, create multiple copies of this edited file for the remaining PCs and change the network interface part.

NOTE (Mininet): When using Mininet, remember two things. First, we need separate configuration files for each host (on a real testbed, each PC would only have its own configuration file). Second, each PC's eth0 network interface must be changed to the Mininet counterpart (e.g., PC1 is "h1-eth0", PC2 is "h2-eth0", …).

NOTE (NetLab): When using FEUP's NetLab, you can edit the configuration files on one PC and copy them to the other PCs in your stand. For that purpose, you can use the secure copy command: e.g., `$ scp /etc/olsrd/olsrd1.conf tux21:/etc/olsrd/olsrd1.conf`

The configuration for each host is given below. The explanation of each command is given in the olsrd's man page and the line comments next to the command. To edit the general OLSR configurations, search the file for the lines indicated below and check / replace the value as indicated below:

```
DebugLevel                1

IpVersion                 6

LinkQualityLevel          0

MprCoverage               1
```

To configure the interfaces where OLSR will run, create a new interface block by adding this configuration to the end of the file. Remember that *HelloInterval* is the interval between HELLO messages which are responsible for letting nodes know their neighbors. *TcInterval* is the interval between Topology Control (TC) messages which are responsible for spreading the Ad Hoc network topology to all nodes. *HnaInterval* is the interval between Host and Network Association (HNA) messages responsible for advertising network routes.

```
Interface "eth0"

{

      HelloInterval           6.0

      HelloValidityTime       60.0

      TcInterval              10.0

      TcValidityTime          60.0

      HnaInterval             10.0

      HnaValidityTime         60.0

}
```

2.4 Testing a Static Scenario

Important: After downloading and installing the packages olsrd on ALL computers, you MUST disconnect the cable that connects the switch in your stand to the Internet (it should be a red ended cable). If you do not do this, then your routers will see the OLSR packets sent by routers on the other stands and the exercises won't function properly.

Before starting make sure that your tuxX1 (where X is the stand number) second interface (eth1) is physically connected to the lab IPv6 Router. Read carefully the *Physical Topology* below.

2.4.1 Configuring the IPv6 Addresses

As mentioned before each group will have a stand **X** with 4 PCs running OLSRd connected to a switch (e.g. BayStack 420-24T Switch). Each PC should be configured with an global IPv6 address 202**X**::**Y**/128, where X is the stand and Y the PC number (e.g. tux32 in stand 3 will have its eth0 configured with the global address 2023::2/128). This configures a different IPv6 network in each of the nodes, so we will end up with four different IPv6 networks.

NOTE (Mininet): When using Mininet, you can choose any number for the stand X (1-6).

Setting a global IPv6 address for PC **Y** in Stand **X**:

```
$ sudo ifconfig eth0 inet6 add 202X::Y/128
```

Additionally, the first PC, tuxX1 (tux31 if you are on stand 3), will have a second interface connected to an IPv6 infrastructured network, which must be configured with a global IPv6 address 3000::**X**/64 (e.g. tux31 in stand 3 will have its eth1 configured with the global address 3000::3/64). Another IPv6 Router was previously set up on that network (don't worry about configuring this router) with the global IPv6 address 3000::254/64.

NOTE (Mininet): When using Mininet, you must configure this router (PC5). The instructions are on Section 2.6.

Setting a global IPv6 address for PC1 in Stand **X**:

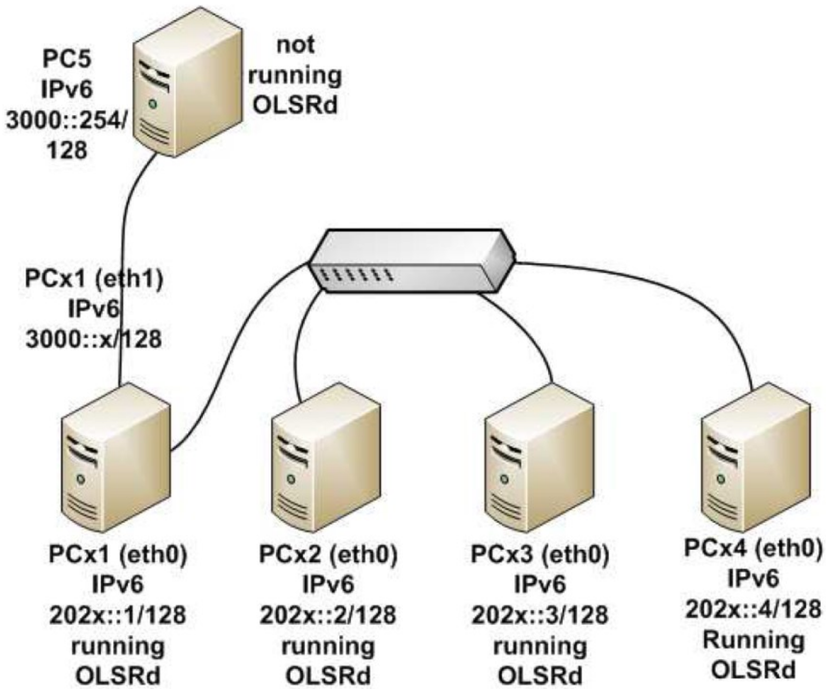
```
$ sudo ifconfig eth1 up

$ sudo ifconfig eth1 inet6 add 3000::X/64
```

2.4.2 Physical Topology

The physical connection of the second interface in your tux**X**1 was also previously set up, but in case of any problems, check if that interface is connected to stand 1 or 4. If you are on stands 1-3, connect this interface to stand 1 (e.g. in stand 3 you connect for instance to 3.13-1.17). If you are on stand 4-6, then you connect this interface to stand 4 (e.g. in stand 6 you connect for instance to 6.13-4.17).

The picture below shows the physical topology of the network.

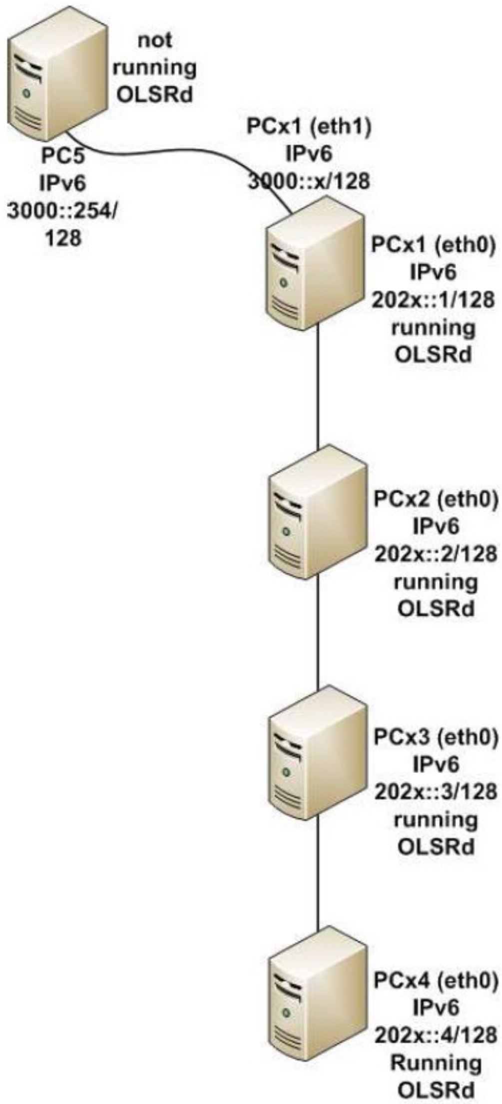


2.4.3 Emulated Ad-Hoc Topology

This is not enough. To emulate the Ad-Hoc topology we want to test, we need to use MAC filtering - we will emulate that a node only "sees" a subset of other nodes by filtering the packets from the nodes we don't want him to "see". This needs special attention when analyzing Ethereal logs as Ethereal will capture those packets. This can also be done using VLANs in the switches, you can go that way if you are able to change the switches VLANs. The mac filtering is done using ip6tables rules.

NOTE: ip6tables operates at the network layer (IP). Therefore, network packets will still be sent and received between the PCs but are discarded by ip6tables before being processed. Remember this when analyzing the logs in Wireshark.

The picture below represents the first ad hoc scenario we want to emulate, where nodes are all inline:



To automatically set the topology above you can use a bash utility developed for this purpose. There are two versions of this script, depending if you are running this work on Mininet or FEUP's NetLab.

```
Mininet

This script should be run on every PC.

Usage: $ ./mininet_topology_changer.sh <topology_number>

     topology_number:

          - 0 for full mesh (every node sees every other node)

          - 1 for line scenario (1-2-3-4)

          - 2 for star topology centered on node 2
```

```
FEUP’s NetLab

This script should be run only once on one of the PCs. This means that
if you run the command on tuxX1, you don't need to run it on tuxX2,
tuxX3 or tuxX4.

Usage: $ topology_changer <bancada> <topology_number>

     bancada: 1-6

     topology_number:

          - 0 for full mesh (every node sees every other node)

          - 1 for line scenario (1-2-3-4)

          - 2 for star topology centered on node 2
```

In case you want to check if everything is ok, execute the following command in the PCs:

```
$ sudo ip6tables -L
```

You should see in the INPUT chain, one mac-filter rule per MAC address it needs to block. So, if you execute this in PC1, you'll see PC3 and PC4 mac addresses blocked. PC1 will only "see" PC2.

IMPORTANT: You may want to cross-check the ip6tables rules with the MAC addresses of the eth0 interfaces of your stand. Sometimes the network interface cards are replaced (and so are the MAC addresses) due to hardware failure. If you find any inconsistency, change the topology_changer script and run it again.

2.4.4 The Actual Test

To test the setup, we need to start olsrd on PC1, PC2, PC3 and PC4 (the IPv6 router will not run olsrd). To start olsrd, run the following command on each PC:

```
$ sudo olsrd -f /etc/olsrd/olsrdX.conf   # Where X is the PC number
```

NOTE: If the configurations are correct, the process will automatically fork and detach from the terminal. If you do not want the process to detach, add the flag “-nofork”.

Now check the connectivity from PC4 to PC1 using the ping6 utility on PC4:

```
$ ping6 202X::1
```

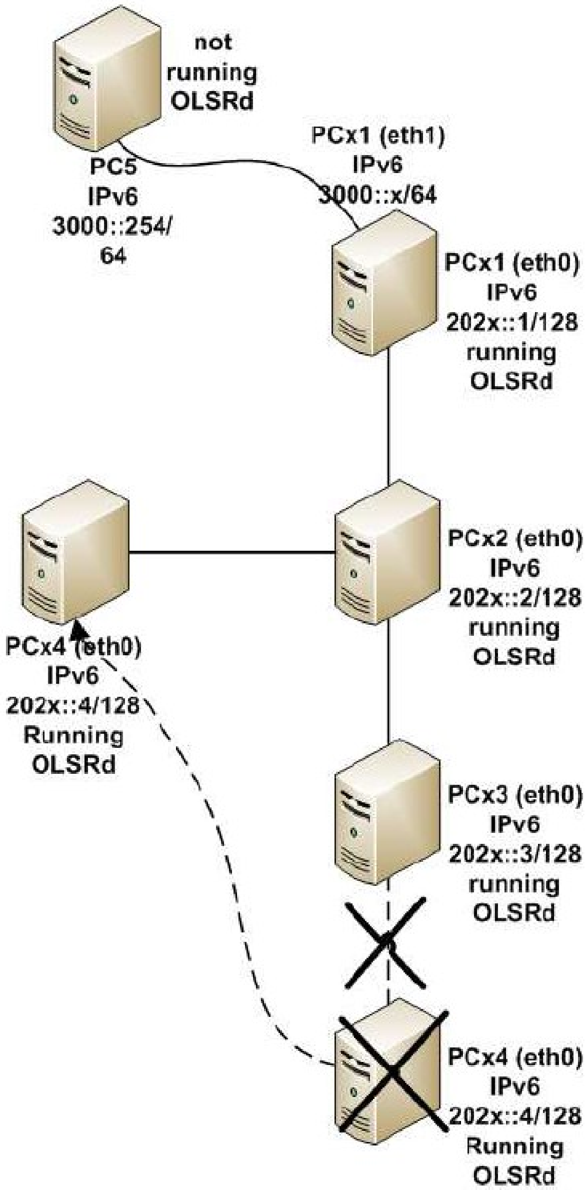
You can list the kernel IPv6 routes by running the route command. Check that the routes to the other PCs are correctly listed (it may take a few seconds to update the routing table):

```
$ route -n6
```

NOTE: Use Wireshark to capture packets in all the PCs during the test. They will be needed to answer some questions later. You can use ping6 to test/measure the time that two nodes stay connected. You may want to reduce ping6 interval with -i interval.

2.5 Simulating Mobility

Now we are going to simulate mobility scenarios, for example like the one shown below:



To automatically set the topology above you can use the bash utility again. So, if you are on stand 3, to set the above topology you just have to type the following command.

```
(Mininet – On every PC):   $ ./mininet_topology_changer.sh 2

(NetLab – Only on one PC): $ topology_changer 3 2
```

And it is all set, the routes should be reconfigured in a few seconds (you should measure the time it takes to reconfigure the routes - using ping6 for instance. You may want to reduce ping6 interval with -i interval) You are welcome to test other mobility scenarios if you want to change the topology_changer.sh script, or/and to alter olsrd parameters (in the configuration file or you can use them as command line parameters) and evaluate their relation with the time required to reconfigure the routes.

It would also be interesting to measure (not very strict – just to have an idea) the average bandwidth used by the protocol messages in each link (beware of the MAC filtering trick), as well as the size of the messages (especially the HELLO and TC messages sent by PC2 before and after PC4 has moved).

NOTE: Use Wireshark to capture packets in all the PCs during the test. They will be needed to answer some questions later.

2.6 Ad Hoc ↔ Infrastructure

Now let's test another feature of the OLSR routing protocol which is the **Home and Network Association (HNA)**. It can be used to establish communication between an Ad Hoc network and an infrastructured one (where nodes aren't running olsrd, just like PC5). Let's assume PC5 is in the infrastructured network and that PC1 is gateway between the Ad Hoc and the infrastructured network.

PC5 has been previously set up with the IPv6 global address 3000::254/64 and with a route for each stand Ad-hoc network. In case you need to set a different PC5, the commands that have been inserted in PC5 are:

```
$ sudo ifconfig eth0 inet6 add 3000::254/64

$ sudo route -A inet6 add 202X:0:0::/64 gw 3000::
```

Try pinging PC5 from PC4:

```
ping6 3000::254
```

This doesn't work (at least if you have followed all the steps of the configuration rightfully), because PC4 doesn't have a route for PC5. This is when we will introduce the OLSR HNA feature. In PC1, edit the olsrd configuration file "`/etc/olsrd/olsrd1.conf`", search for the "Hna6" configuration block and uncomment the "Internet gateway" configuration (see below):

```
Hna6

{

      # Internet gateway:

      ::    0

      # more entries can be added:

      # fec0:2200:106:: 48

}
```

Restart the olsrd daemon (only at PC1). This will cause that all Ad Hoc nodes create a default route using PC1 as the gateway. Now try again to ping PC5 from PC4... it works. You have just integrated an infrastructured network with an Ad Hoc one.

Also try a traceroute from PC4 to PC5 so you are sure everything is working as expected:

```
$ traceroute6 3000::254
```

If everything is well set up the path will be: PC1 → PC2 → PC3 → PC4 (for the line topology).

NOTE: Use Wireshark to capture packets in all the PCs during the test. They will be needed to answer some questions later.

2.7 Understanding Multi-Point Relayers (MPR)

One of the major features of OLSR for wireless link are the so called Multi-Point Relayers which are intended to optimize the way relevant information such as Topology Control (TC) or Home and Network Association (HNA) messages, are disseminated throughout a MANET. With MPRs unnecessary transmissions are kept to the minimum possible so that all nodes in the MANET get the information. To know more you can read OLSR RFC and the paper Multipoint relaying for flooding broadcast messages in mobile wireless networks.

In this section, you should test the 2 scenarios described in sections 2.4 (line topology) and 2.5 (star topology), and for each of them identify which nodes are elected as MPRs (based on Wireshark captures) and argue if these are the ones that you expected or not.

3 Questions

Write a short report answering the following questions:

1. Imagine that we would use IPv4, and that PC1 address was for instance 169.254.1.1/16. What would be the destination IP address of the HELLO packets sent by PC1? Assume that the Ipv4Broadcast configuration of the OLSR daemon is not set.

2. Based on the logs collected determine how much bandwidth-per-node does the OLSR protocol consume in both scenarios. Hint: you can use Wireshark's tool in "Statistics > Protocol Hierarchy".

3. When node 4 moves, there is a period during which there is no network connectivity. Measure this time period and find a relation between its duration and the *HelloInterval* and *TcInterval* parameters.

4. In the mobility scenario, the topology of the network changes after node 4 moves. Based on the Wireshark logs, identify which nodes act as Multi-Point Relayers before *and* after the topology change. Briefly explain how the MPR selection can be verified on the Wireshark logs.

5. (Mininet) Throughout the OLSR guide (section 2), several network configurations had to be made, including routing flags, IPv6 settings and addresses. Taking advantage of the Mininet Python API (see the links in the next section), explain how you can make these network configurations directly on the `mininet_olsr_topology.py` Python script.

6. (Mininet) Consider the scenario explained in section 2.5 where the network topology changes from line to star. Is it possible to change the network topology at runtime (i.e., without stopping and restarting Mininet) using Mininet's API instead of the provided `mininet_topology_changer.sh` script? Briefly explain how you would do this, or why it is not possible.

   HINT: Remember that Mininet supports Software-Defined Networking (SDN).

4 Links and References

OLSR

Optimized Link State Routing Protocol (OLSR): http://www.ietf.org/rfc/rfc3626.txt

OLSRd Linux daemon: http://www.olsr.org/

Linux IPv6 HOWTO: http://tldp.org/HOWTO/Linux+IPv6-HOWTO/index.html

IPv6 syntax

IPv6 address types

$ man olsrd

$ man olsrd.conf

Mininet

Overview: http://mininet.org/overview/

Walkthrough: http://mininet.org/walkthrough

Python API: http://mininet.org/api/annotated.html