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NWEN302 LAB4 BGP Routing

Introduction

This report documents the procedures in LAB4 of NWEN302 in which the Border Gateway Protocol Version 4 (BGP4) was configured in an emulated network environment called Marionnet. This included configuring the network for both IPv4 and IPv6 addresses so two different Autonomous Systems could send traffic between each other. Setting policies between the two AS's was added using prefix lists and then the network was extended by adding a third AS to gain more BGP and network configuration experience.

Apparatus

A capable computer running.

1) Marionnet Version: 0.90.6
   Copyright © 2007, 2008, 2009, 2010, 2011 Jean-Vincent Loddo, Luca Saiu, Université Paris 13.
   http://www.marionnet.org/EN/
2) GNU/Linux Distribution (Debian based, Red Hat based or OpenSuse)
   (Arch Linux 3.7.5-1 licensed under the GNU GPLv2 used)

Proceedures

Creating an initial setup

The topology shown in Appendix 1, page 9, was created in Marionnet by adding devices using the device buttons on the left hand side of the screen. When added, each device was given a name as shown in the network topology. For the router configuration, the amount of ports was set, the port 0 address set and the "Show unix terminal" checkbox ticked with all other fields left as default.

Numbering the interfaces

The machines were connected via crossover cables to the routers and the routers were connected to the switch with a straight ethernet cable. When connecting up the links, the network table in appendix 2, page 10 was completed to record the connected interfaces and corresponding IP addresses. The network diagram is shown in appendix 3, page 10.

Configuring the router interfaces

As Marionnet uses virtual Linux hosts as Routers and Machines, actual Linux based software is installed on them. These are the command line tools such as ping, ping6, route, nano and a software package called Quagga that handles different routing protocols, this effectively turns a Linux machine into a router.

Using the Quagga package and connecting to the Zebra process, each routers interface, IPv4 and IPv6 addresses were set. This was done by being logged on to the router and doing the following:

1) Using ***chown quagga.quagga /etc/quagga*** at first startup of the router to change the ownership of the quagga directory so quagga changes can be saved.

2) ***telnet localhost 2601*** used to start the Zebra process. Then logging in with the password ***zebra***, and using ***enable*** to allow administrator privileges. This asked for the administrator password which was ***zebra***.

3) Next ***configure terminal*** was used to change the configuration of the router.

4) Then a router interface was selected to be modified, for example ***interface eth0*** to set eth0 as the interface to modify.

5) The IPv4 and IPv6 addresses were now set for the interface. For example the IPv4 address set to 10.10.0.1/24 is ***ip address 10.10.0.1/24*** the IPv6 address set, ***ipv6 address 2404:4000:2:112::1/64.***

6) ***exit*** was used to stop modifying the interface and step 4 and 5 were repeated for all interfaces on the router. Once all interfaces were configured, ***exit*** was used again to exit the router configuration, ***write memory*** used to save the changes and finally ***exit*** used again to quit the Zebra process.

Enabling IPv6

As IPv6 forwarding is turned off by default in Marionnet, each router was configured to turn on IPv6 forwarding by editing the /etc/sysctl.conf file. "net.ipv6.conf.all.forwarding=1" was added to this file and the router restarted so IPv6 forwarding was enabled on each router at bootup.

Configuring the Unix hosts

The hosts were then configured so they could communicate to the neighbouring router. To achieve this, the IP addresses and subnet masks were set, as well as the default gateway for IPv4 and IPv6.

The procedure in doing this involved adding the following lines to the file */etc/network/interface* like in the example for m1 below:

```
iface eth0 inet static
        address 192.168.10.2
        netmask 255.255.255.0
        gateway 192.168.10.1
iface eth0 inet6 static
        address 2404:2000:2002:110::2
        netmask 64
        gateway 2404:2000:2002:110::1
```

Once the interface file was saved, eth0 had to be initialised on every startup of the machine by using ***ifup --force eth0.*** It was now possible for the machines to communicate to their neighbouring router.

IPv4 BGP

To setup the BGP session between two IPv4 autonomous systems, the BGP management process was connected to on port 2605 on each router.

Once connected, a new BGP process for each autonomous system was created by using the configuration mode terminal.

ISP_A_R1 was configured as follows:

```
router bgp 64000
 bgp router-id 172.16.1.10
 neighbor 172.16.1.11 remote-as 64555
 neighbor 172.16.1.11 description ISP B
 neighbor 172.16.1.11 password zaq123
 neighbor 172.16.1.11 soft-reconfiguration inbound
```

ISP_B_R1 was configured as follows:

```
router bgp 64555
  bgp router-id 172.16.1.11
  neighbor 172.16.1.10 remote-as 64000
  neighbor 172.16.1.10 description ISP A
  neighbor 172.16.1.10 password zaq123
  neighbor 172.16.1.10 soft-reconfiguration inbound
```

Once this was done, the autonomous systems were checked by using the **show ip bgp summary** command and the results are shown in appendix 4, page 11. The output of this showed if each AS was aware of its neighbor.

Although each autonomous system was aware of its neighbor they still couldn't communicate between each other because routing information still had to be passed between systems.

Using the BGP process and the configuration mode terminal, BGP communication was implemented as follows:

ISP_A_R1 was setup by:

```
router bgp 64000
  network 192.168.10.0/24
  network 192.168.11.0/24
```

ISP_B_R1 was setup by:

```
router bgp 64555
  network 10.10.0.0/23
  network 10.10.2.0/23
```

Communication between the two AS was successfully tested using the ping, traceroute and ssh commands. These results appear in Appendix 5, page 12.

IPv6 BGP

As IPv4 was successfully setup, IPv6 was now configured so the two systems could communicate using IPv6 datagrams. This was achieved in a similar way to IPv4 where the BGP process was connected to and the BGP process configured.

ISP_A_R1 was configured as follows:

```
router bgp 64000
neighbor 2404:3000:1:1::2 remote-as 64555
 neighbor 2404:3000:1:1::2 description ISP B
 neighbor 2404:3000:1:1::2 password zaq123
 no neighbor 2404:3000:1:1::2 activate

 address-family ipv6
 neighbor 2404:3000:1:1::2 activate
 neighbor 2404:3000:1:1::2 soft-reconfiguration inbound
 exit-address-family
```

ISP_B_R1 was configured as follows:

```
router bgp 64555
neighbor 2404:3000:1:1::1 remote-as 64000
 neighbor 2404:3000:1:1::1 description ISP A
 neighbor 2404:3000:1:1::1 password zaq123
 no neighbor 2404:3000:1:1::1 activate

 address-family ipv6
 neighbor 2404:3000:1:1::1 activate
 neighbor 2404:3000:1:1::1 soft-reconfiguration inbound
 exit-address-family
```

The Autonomous systems were now aware of each other using IPv6 and this was tested by using the "show ipv6 bgp summary" command and the results are shown in appendix 6, page 13.

Now routing information had to be passed between the two systems so they could communicate. This was done by connecting to the BGP process and entering configuration mode.

For ISP_A_R1:

```
router bgp 64000
  address-family ipv6
    network 2404:2000:2002:110::/64
    network 2404:2000:2002:111::/64
```

For ISP_B_R1

```
router bgp 64555
  address-family ipv6
    network 2404:4000:2:112::/64
    network 2404:4000:2:114::/64
```

Connections between ISP A and ISP B were tested using the ping6, traceroute6 and ssh commands and the successful results are shown in appendix 7, page 14.

Creating filters

Filters were added to each ISP to prevent the ISP from sending or recieving possible false data. This is done in networks to prevent other neighboring systems that could be competitors or have misleading values from causing anomalies in the autonomous system.

To achieve this, prefix lists are created in configuration mode.

For ISP_A_R1:

```
ip prefix-list as64000-ipv4-out permit 192.168.10.0/24
ip prefix-list as64000-ipv4-out permit 192.168.10.0/24
ip prefix-list as64000-ipv4-in permit 10.10.0.0/23
ip prefix-list as64000-ipv4-in permit 10.10.2.0/23

ipv6 prefix-list as64000-ipv6-out permit 2404:2000:2002:110::/64
ipv6 prefix-list as64000-ipv6-out permit 2404:2000:2002:111::/64
ipv6 prefix-list as64000-ipv6-in permit 2404:4000:2:112::/64
ipv6 prefix-list as64000-ipv6-in permit 2404:4000:2:114::/64
```

For ISP_B_R1:

```
ip prefix-list as64555-ipv4-out permit 10.10.0.0/23
ip prefix-list as64555-ipv4-out permit 10.10.2.0/23
ip prefix-list as64555-ipv4-in permit 192.168.10.0/24
ip prefix-list as64555-ipv4-in permit 192.168.10.0/24

ipv6 prefix-list as64555-ipv6-out permit 2404:4000:2:112::/64
ipv6 prefix-list as64555-ipv6-out permit 2404:4000:2:114::/64
```

```
ipv6 prefix-list as64555-ipv6-in permit 2404:2000:2002:110::/64
ipv6 prefix-list as64555-ipv6-in permit 2404:2000:2002:111::/64
```

These lists are then applied to the bgp connections to other peers.

For ISP_A_R1:

```
neighbor 172.16.1.11 prefix-list as64000-ipv4-out out
neighbor 172.16.1.11 prefix-list as64000-ipv4-in in

address-family ipv6
 neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-out out
 neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-in in
```

For ISP_B_R1:

```
neighbor 172.16.1.10 prefix-list as64555-ipv4-out out
neighbor 172.16.1.10 prefix-list as64555-ipv4-in in

address-family ipv6
 neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-out out
 neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-in in
```

The network still functioned correctly but any false BGP information wouldn't be sent through the network.

Full BGP configuration files shown in appendix 8, page 15 for each ISP/Router.

Additional Work

A third ISP was setup in the network. Appendix 9, page 17 shows the updated network table and appendix 10, page 18 shows the network diagram.

When configuring the network for ISP_C, ISP_A and ISP_B had to have ISP_Cs Autonomous system added to their configuration and more prefix lists added for the connection otherwise the BGP information would be blocked and it wouldn't be passed around the network.

Appendix 11, page 19 shows the updated BGP configuration for these routers, along with the configuration file for ISP_C.

The communication was tested for IPv4 and IPv6 between ISP C and the rest of the network using the network tools. The successful results are shown in appendix 12, page 24.

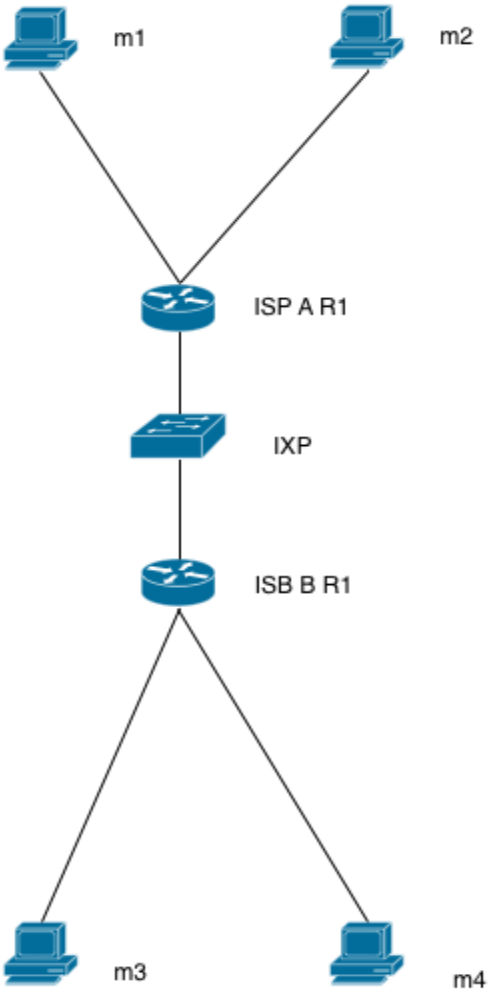
What would happen if you had to setup 50 peering sessions at an IXP?

Setting up 50 peering sessions would take a long time, especially if each network had policies to talk to every other network because you have to direct the BGP routing information to each autonomous system. To get around this problem a route server is introduced. A route server acts as a BGP routing information forwarder which forwards the BGP routing information to the other autonomous systems so all 50 peers would be able to communicate with each other with significantly less manual setup time.

By undertaking this lab, a deeper knowledge of BGP and autonomous systems was gained. This was due to the hands on experience of configuring a network in marionnet and implementing the BGP protocol so two autonomous systems could communicate. This experience will follow over to a real network with ease.

Appendices

Appendix 1



NWEN302 BGP Lab

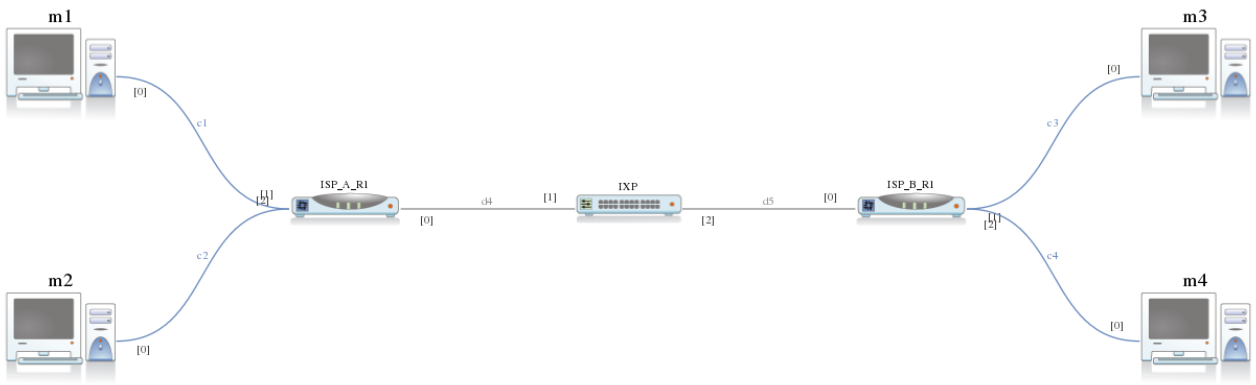
Appendix 2

Routing table

Router	Port	Cable	IPv4 Address	IPv4 Netmask	IPv6 Address
m1	eth0	c1	192.168.10.2	255.255.255.0	2404:2000:2002:110::2/64
m2	eth0	c2	192.168.11.2	255.255.255.0	2404:2000:2002:111::2/64
ISP_A_R1	eth1	c1	192.168.10.1	255.255.255.0	2404:2000:2002:110::1/64
ISP_A_R1	eth2	c2	192.168.11.1	255.255.255.0	2404:2000:2002:111::1/64
ISP_A_R1	eth0	d4	172.16.1.10	255.255.255.0	2404:3000:1:1::1/64
ISP_B_R1	eth0	d5	172.16.1.11	255.255.255.0	2404:3000:1:1::2/64
ISP_B_R1	eth1	c3	10.10.0.1	255.255.254.0	2404:4000:2:112::1/64
ISP_B_R1	eth2	c4	10.10.2.1	255.255.254.0	2404:4000:2:114::1/64
m3	eth0	c3	10.10.0.2	255.255.254.0	2404:4000:2:112::2/64
m4	eth0	c4	10.10.2.2	255.255.254.0	2404:4000:2:114::2/64

Appendix 3

Network Diagram



Appendix 4

ISP_A_R1

Router# sh ip bgp summary
BGP router identifier 172.16.1.10, local AS number 64000
RIB entries 0, using 0 bytes of memory
Peers 1, using 2512 bytes of memory

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd
172.16.1.11 4 64555 13 14 0 0 0 00:11:32 0

Total number of neighbors 1

ISP_B_R1

Router# sh ip bgp summary
BGP router identifier 172.16.1.11, local AS number 64555
RIB entries 0, using 0 bytes of memory
Peers 1, using 2512 bytes of memory

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd
172.16.1.10 4 64000 10 12 0 0 0 00:09:49 0

Total number of neighbors 1

Appendix 5

Testing IPv4 communication between Autonomous Systems

```
m1:~# ping -c 3 10.10.0.2
PING 10.10.0.2 (10.10.0.2) 56(84) bytes of data.
64 bytes from 10.10.0.2: icmp_seq=1 ttl=62 time=36.0 ms
64 bytes from 10.10.0.2: icmp_seq=2 ttl=62 time=0.834 ms
64 bytes from 10.10.0.2: icmp_seq=3 ttl=62 time=0.863 ms
--- 10.10.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2020ms
rtt min/avg/max/mdev = 0.834/12.589/36.071/16.604 ms

m1:~# ping -c 3 10.10.2.2
PING 10.10.2.2 (10.10.2.2) 56(84) bytes of data.
64 bytes from 10.10.2.2: icmp_seq=1 ttl=62 time=14.4 ms
64 bytes from 10.10.2.2: icmp_seq=2 ttl=62 time=0.856 ms
64 bytes from 10.10.2.2: icmp_seq=3 ttl=62 time=2.87 ms
--- 10.10.2.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2029ms
rtt min/avg/max/mdev = 0.856/6.054/14.436/5.983 ms

m2:~# ping -c 3 10.10.2.2
PING 10.10.2.2 (10.10.2.2) 56(84) bytes of data.
64 bytes from 10.10.2.2: icmp_seq=1 ttl=62 time=1.49 ms
64 bytes from 10.10.2.2: icmp_seq=2 ttl=62 time=0.850 ms
64 bytes from 10.10.2.2: icmp_seq=3 ttl=62 time=1.01 ms
--- 10.10.2.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2015ms
```

rtt min/avg/max/mdev = 0.850/1.117/1.490/0.273 ms

m2:~# ping -c 3 10.10.0.2
PING 10.10.0.2 (10.10.0.2) 56(84) bytes of data.
64 bytes from 10.10.0.2: icmp_seq=1 ttl=62 time=2.69 ms
64 bytes from 10.10.0.2: icmp_seq=2 ttl=62 time=3.67 ms
64 bytes from 10.10.0.2: icmp_seq=3 ttl=62 time=1.51 ms
--- 10.10.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2004ms
rtt min/avg/max/mdev = 1.518/2.628/3.676/0.882 ms

Appendix 6

ISP_A

Router# sh ipv6 bgp summary
BGP router identifier 172.16.1.10, local AS number 64000
RIB entries 7, using 448 bytes of memory
Peers 2, using 5024 bytes of memory

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd
2404:3000:1:1::2 4 64555 19 27 0 0 0 00:16:09 2

Total number of neighbors 1

ISP_B

Router# sh ipv6 bgp summary
BGP router identifier 172.16.1.11, local AS number 64555
RIB entries 7, using 448 bytes of memory
Peers 2, using 5024 bytes of memory

Neighbor V AS MsgRcvd MsgSent TblVer InQ OutQ Up/Down State/PfxRcd
2404:3000:1:1::1
4 64000 20 21 0 0 0 00:16:45 2

Total number of neighbors 1

Appendix 7

Testing IPv6

M1 to M4

```
m1:~# ping6 -c 3 2404:4000:2:114::2
PING 2404:4000:2:114::2(2404:4000:2:114::2) 56 data bytes
64 bytes from 2404:4000:2:114::2: icmp_seq=1 ttl=62 time=43.9 ms
64 bytes from 2404:4000:2:114::2: icmp_seq=2 ttl=62 time=2.34 ms
64 bytes from 2404:4000:2:114::2: icmp_seq=3 ttl=62 time=2.40 ms

--- 2404:4000:2:114::2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2024ms
rtt min/avg/max/mdev = 2.341/16.243/43.990/19.620 ms
```

M1 to M3

```
m1:~# ssh 2404:4000:2:112::2
The authenticity of host '2404:4000:2:112::2 (2404:4000:2:112::2)' can't be
established.
RSA key fingerprint is 0e:a7:ed:ce:57:50:97:52:a5:93:a1:97:b6:2e:a6:b1.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '2404:4000:2:112::2' (RSA) to the list of known
hosts.
root@2404:4000:2:112::2's password:
Last login: Thu Oct 3 03:26:43 2013
Linux ISP_A_R1 2.6.18 #2 Fri Jun 22 15:24:51 CEST 2007 i686

The programs included with the Debian GNU/Linux system are free software;
```

the exact distribution terms for each program are described in the individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent permitted by applicable law.

M2 to M4

```
m2:~# traceroute 2404:4000:2:114::2
traceroute to 2404:4000:2:114::2 (2404:4000:2:114::2), 30 hops max, 40 byte packets
1 (2404:2000:2002:111::1) 0.491 ms 0.419 ms 0.294 ms
2 (2404:3000:1:1::2) 1.229 ms 4.940 ms 5.257 ms
3 (2404:4000:2:114::2) 7.923 ms 7.720 ms 7.525 ms
```

Appendix 8

ISP_A BGP configuration file

```
!
! Zebra configuration saved from vty
! 2013/10/03 23:07:20
!
hostname Router
password zebra
enable password zebra
log stdout
!
router bgp 64000
bgp router-id 172.16.1.10
network 192.168.10.0/24
network 192.168.11.0/24
neighbor 172.16.1.11 remote-as 64555
neighbor 172.16.1.11 description ISP B
neighbor 172.16.1.11 password zaq123
neighbor 172.16.1.11 soft-reconfiguration inbound
neighbor 172.16.1.11 prefix-list as64000-ipv4-in in
neighbor 172.16.1.11 prefix-list as64000-ipv4-out out
neighbor 2404:3000:1:1::2 remote-as 64555
neighbor 2404:3000:1:1::2 description ISP B
neighbor 2404:3000:1:1::2 password zaq123
no neighbor 2404:3000:1:1::2 activate
!
address-family ipv6
network 2404:2000:2002:110::/64
network 2404:2000:2002:111::/64
neighbor 2404:3000:1:1::2 activate
neighbor 2404:3000:1:1::2 soft-reconfiguration inbound
neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-in in
```

```
neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-out out
exit-address-family
!
ip prefix-list as64000-ipv4-in seq 5 permit 10.10.0.0/23
ip prefix-list as64000-ipv4-in seq 10 permit 10.10.2.0/23
ip prefix-list as64000-ipv4-out seq 5 permit 192.168.10.0/24
ip prefix-list as64000-ipv4-out seq 10 permit 192.168.11.0/24
!
ipv6 prefix-list as64000-ipv6-in seq 5 permit 2404:4000:2:112::/64
ipv6 prefix-list as64000-ipv6-in seq 10 permit 2404:4000:2:114::/64
ipv6 prefix-list as64000-ipv6-out seq 5 permit 2404:2000:2002:110::/64
ipv6 prefix-list as64000-ipv6-out seq 10 permit 2404:2000:2002:111::/64
!
line vty
```

ISP_B Configuration file

```
!
! Zebra configuration saved from vty
! 2013/10/03 23:24:48
!
hostname Router
password zebra
enable password zebra
log stdout
!
router bgp 64555
bgp router-id 172.16.1.11
network 10.10.0.0/23
network 10.10.2.0/23
neighbor 172.16.1.10 remote-as 64000
neighbor 172.16.1.10 description ISP A
neighbor 172.16.1.10 password zaq123
neighbor 172.16.1.10 soft-reconfiguration inbound
neighbor 172.16.1.10 prefix-list as64555-ipv4-in in
neighbor 172.16.1.10 prefix-list as64555-ipv4-out out
neighbor 2404:3000:1:1::1 remote-as 64000
neighbor 2404:3000:1:1::1 description ISP A
neighbor 2404:3000:1:1::1 password zaq123
no neighbor 2404:3000:1:1::1 activate
!
address-family ipv6
network 2404:4000:2:112::/64
network 2404:4000:2:114::/64
neighbor 2404:3000:1:1::1 activate
neighbor 2404:3000:1:1::1 soft-reconfiguration inbound
neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-in in
```

```
neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-out out
exit-address-family
!
ip prefix-list as64555-ipv4-in seq 5 permit 192.168.10.0/24
ip prefix-list as64555-ipv4-in seq 10 permit 192.168.11.0/24
ip prefix-list as64555-ipv4-out seq 5 permit 10.10.0.0/23
ip prefix-list as64555-ipv4-out seq 10 permit 10.10.2.0/23
!
ipv6 prefix-list as64555-ipv6-in seq 5 permit 2404:2000:2002:110::/64
ipv6 prefix-list as64555-ipv6-in seq 10 permit 2404:2000:2002:111::/64
ipv6 prefix-list as64555-ipv6-out seq 5 permit 2404:4000:2:112::/64
ipv6 prefix-list as64555-ipv6-out seq 10 permit 2404:4000:2:114::/64
!
line vty
```

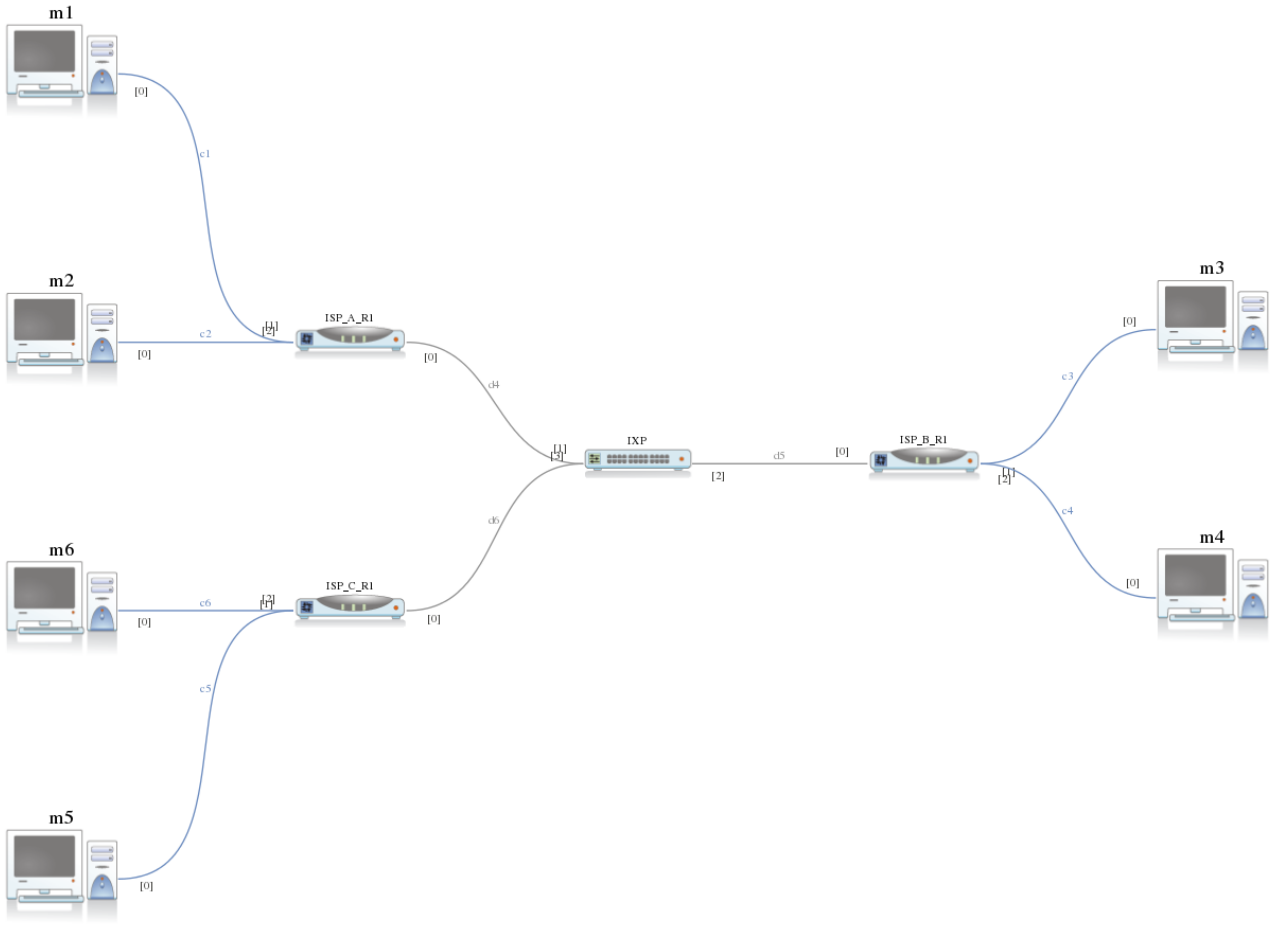
Appendix 9

Extension - Routing Table

Router	Port	Cable	IPv4 Address	IPv4 Netmask	IPv6 Address
m1	eth0	c1	192.168.10.2	255.255.255.0	2404:2000:2002:110::2/64
m2	eth0	c2	192.168.11.2	255.255.255.0	2404:2000:2002:111::2/64
ISP_A_R1	eth1	c1	192.168.10.1	255.255.255.0	2404:2000:2002:110::1/64
ISP_A_R1	eth2	c2	192.168.11.1	255.255.255.0	2404:2000:2002:111::1/64
ISP_A_R1	eth0	d4	172.16.1.10	255.255.255.0	2404:3000:1:1::1/64
ISP_B_R1	eth0	d5	172.16.1.11	255.255.255.0	2404:3000:1:1::2/64
ISP_B_R1	eth1	c3	10.10.0.1	255.255.254.0	2404:4000:2:112::1/64
ISP_B_R1	eth2	c4	10.10.2.1	255.255.254.0	2404:4000:2:114::1/64
m3	eth0	c3	10.10.0.2	255.255.254.0	2404:4000:2:112::2/64
m4	eth0	c4	10.10.2.2	255.255.254.0	2404:4000:2:114::2/64
ISP_C_R1	eth1	c5	192.168.254.1	255.255.255.0	2404:4000:2002:3000::1/64
ISP_C_R1	eth2	c6	192.168.255.1	255.255.255.0	2404:4000:2002:3200::1/64
ISP_C_R1	eth0	d6	172.16.1.12	255.255.255.0	2404:3000:1:1::3/64
m5	eth0	c5	192.168.254.2	255.255.255.0	2404:4000:2002:3000::2/64
m6	eth0	c6	192.168.255.2	255.255.255.0	2404:4000:2002:3200::2/64

Appendix 10

Extension - Network Diagram



Appendix 11

Extension - ISP_A BGP Configuration

```
!
! Zebra configuration saved from vty
!   2013/10/04 03:36:08
!
hostname Router
password zebra
enable password zebra
log stdout
!
router bgp 64000
 bgp router-id 172.16.1.10
 network 192.168.10.0/24
 network 192.168.11.0/24
 neighbor 172.16.1.11 remote-as 64555
 neighbor 172.16.1.11 description ISP B
 neighbor 172.16.1.11 password zaq123
 neighbor 172.16.1.11 soft-reconfiguration inbound
 neighbor 172.16.1.11 prefix-list as64000-ipv4-in in
 neighbor 172.16.1.11 prefix-list as64000-ipv4-out out
 neighbor 172.16.1.12 remote-as 26000
 neighbor 172.16.1.12 description ISP C
 neighbor 172.16.1.12 password zaq123
 neighbor 172.16.1.12 soft-reconfiguration inbound
 neighbor 172.16.1.12 prefix-list as64000-ipv4-in in
```

```
 neighbor 172.16.1.12 prefix-list as64000-ipv4-out out
 neighbor 2404:3000:1:1::2 remote-as 64555
 neighbor 2404:3000:1:1::2 description ISP B
 neighbor 2404:3000:1:1::2 password zaq123
 no neighbor 2404:3000:1:1::2 activate
 neighbor 2404:3000:1:1::3 remote-as 26000
 neighbor 2404:3000:1:1::3 description ISP C
 neighbor 2404:3000:1:1::3 password zaq123
 no neighbor 2404:3000:1:1::3 activate
!
 address-family ipv6
 network 2404:2000:2002:110::/64
 network 2404:2000:2002:111::/64
 neighbor 2404:3000:1:1::2 activate
 neighbor 2404:3000:1:1::2 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-in in
 neighbor 2404:3000:1:1::2 prefix-list as64000-ipv6-out out
 neighbor 2404:3000:1:1::3 activate
 neighbor 2404:3000:1:1::3 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::3 prefix-list as64000-ipv6-in in
 neighbor 2404:3000:1:1::3 prefix-list as64000-ipv6-out out
 exit-address-family
!
ip prefix-list as64000-ipv4-in seq 5 permit 10.10.0.0/23
ip prefix-list as64000-ipv4-in seq 10 permit 10.10.2.0/23
ip prefix-list as64000-ipv4-in seq 15 permit 192.168.254.0/24
ip prefix-list as64000-ipv4-in seq 20 permit 192.168.255.0/24
ip prefix-list as64000-ipv4-out seq 5 permit 192.168.10.0/24
ip prefix-list as64000-ipv4-out seq 10 permit 192.168.11.0/24
!
ipv6 prefix-list as64000-ipv6-in seq 5 permit 2404:4000:2:112::/64
ipv6 prefix-list as64000-ipv6-in seq 10 permit 2404:4000:2:114::/64
ipv6 prefix-list as64000-ipv6-in seq 15 permit 2404:4000:2002:3000::/64
ipv6 prefix-list as64000-ipv6-in seq 20 permit 2404:4000:2002:3200::/64
ipv6 prefix-list as64000-ipv6-out seq 5 permit 2404:2000:2002:110::/64
ipv6 prefix-list as64000-ipv6-out seq 10 permit 2404:2000:2002:111::/64
!
line vty
!
```

Extension ISP_B Configuration

```
!
! Zebra configuration saved from vty
!   2013/10/03 23:24:48
!
hostname Router
password zebra
enable password zebra
log stdout
!
router bgp 64555
 bgp router-id 172.16.1.11
 network 10.10.0.0/23
 network 10.10.2.0/23
 neighbor 172.16.1.10 remote-as 64000
 neighbor 172.16.1.10 description ISP A
 neighbor 172.16.1.10 password zaq123
 neighbor 172.16.1.10 soft-reconfiguration inbound
 neighbor 172.16.1.10 prefix-list as64555-ipv4-in in
 neighbor 172.16.1.10 prefix-list as64555-ipv4-out out
 neighbor 172.16.1.12 remote-as 26000
 neighbor 172.16.1.12 description ISP C
 neighbor 172.16.1.12 password zaq123
 neighbor 172.16.1.12 soft-reconfiguration inbound
 neighbor 172.16.1.12 prefix-list as64555-ipv4-in in
 neighbor 172.16.1.12 prefix-list as64555-ipv4-out out
 neighbor 2404:3000:1:1::1 remote-as 64000
 neighbor 2404:3000:1:1::1 description ISP A
 neighbor 2404:3000:1:1::1 password zaq123
 no neighbor 2404:3000:1:1::1 activate
 neighbor 2404:3000:1:1::3 remote-as 26000
 neighbor 2404:3000:1:1::3 description ISP C
 neighbor 2404:3000:1:1::3 password zaq123
 no neighbor 2404:3000:1:1::3 activate
!
 address-family ipv6
```

```
 network 2404:4000:2:112::/64
 network 2404:4000:2:114::/64
 neighbor 2404:3000:1:1::1 activate
 neighbor 2404:3000:1:1::1 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::3 activate
 neighbor 2404:3000:1:1::3 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-in in
 neighbor 2404:3000:1:1::1 prefix-list as64555-ipv6-out out
 neighbor 2404:3000:1:1::3 prefix-list as64555-ipv6-in in
 neighbor 2404:3000:1:1::3 prefix-list as64555-ipv6-out out

 exit-address-family
!
ip prefix-list as64555-ipv4-in seq 5 permit 192.168.10.0/24
ip prefix-list as64555-ipv4-in seq 10 permit 192.168.11.0/24
ip prefix-list as64555-ipv4-in seq 15 permit 192.168.254.0/24
ip prefix-list as64555-ipv4-in seq 20 permit 192.168.255.0/24
ip prefix-list as64555-ipv4-out seq 5 permit 10.10.0.0/23
ip prefix-list as64555-ipv4-out seq 10 permit 10.10.2.0/23

!
ipv6 prefix-list as64555-ipv6-in seq 5 permit 2404:2000:2002:110::/64
ipv6 prefix-list as64555-ipv6-in seq 10 permit 2404:2000:2002:111::/64
ipv6 prefix-list as64555-ipv6-in seq 15 permit 2404:4000:2002:3000::/64
ipv6 prefix-list as64555-ipv6-in seq 20 permit 2404:4000:2002:3200::/64
ipv6 prefix-list as64555-ipv6-out seq 5 permit 2404:4000:2:112::/64
ipv6 prefix-list as64555-ipv6-out seq 10 permit 2404:4000:2:114::/64
!
line vty
!
```

Extension ISP_C Configuration

```
!
! Zebra configuration saved from vty
!   2013/10/04 01:53:02
!
hostname Router
password zebra
```

```
enable password zebra
log stdout
!
router bgp 26000
 bgp router-id 172.16.1.12
 network 192.168.254.0/24
 network 192.168.255.0/24
 neighbor 172.16.1.10 remote-as 64000
 neighbor 172.16.1.10 description ISP A
 neighbor 172.16.1.10 password zaq123
 neighbor 172.16.1.10 soft-reconfiguration inbound
 neighbor 172.16.1.10 prefix-list as26000-ipv4-in in
 neighbor 172.16.1.10 prefix-list as26000-ipv4-out out
 neighbor 172.16.1.11 remote-as 64555
 neighbor 172.16.1.11 description ISP B
 neighbor 172.16.1.11 password zaq123
 neighbor 172.16.1.11 soft-reconfiguration inbound
 neighbor 172.16.1.11 prefix-list as26000-ipv4-in in
 neighbor 172.16.1.11 prefix-list as26000-ipv4-out out
 neighbor 2404:3000:1:1::2 remote-as 64555
 neighbor 2404:3000:1:1::2 description ISP B
 neighbor 2404:3000:1:1::2 password zaq123
 no neighbor 2404:3000:1:1::2 activate
 neighbor 2404:3000:1:1::1 remote-as 64000
 neighbor 2404:3000:1:1::1 description ISP A
 neighbor 2404:3000:1:1::1 password zaq123
 no neighbor 2404:3000:1:1::1 activate
!
 address-family ipv6
 network 2404:4000:2002:3000::/64
 network 2404:4000:2002:3200::/64
 neighbor 2404:3000:1:1::2 activate
 neighbor 2404:3000:1:1::2 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::1 activate
 neighbor 2404:3000:1:1::1 soft-reconfiguration inbound
 neighbor 2404:3000:1:1::1 prefix-list as26000-ipv6-in in
 neighbor 2404:3000:1:1::1 prefix-list as26000-ipv6-out out
 neighbor 2404:3000:1:1::2 prefix-list as26000-ipv6-in in
 neighbor 2404:3000:1:1::2 prefix-list as26000-ipv6-out out
```

```
 exit-address-family
!
ip prefix-list as26000-ipv4-in seq 5 permit 192.168.10.0/24
ip prefix-list as26000-ipv4-in seq 10 permit 192.168.11.0/24
ip prefix-list as26000-ipv4-in seq 15 permit 10.10.0.0/23
ip prefix-list as26000-ipv4-in seq 20 permit 10.10.2.0/23
ip prefix-list as26000-ipv4-out seq 5 permit 192.168.254.0/24
ip prefix-list as26000-ipv4-out seq 10 permit 192.168.255.0/24
!
ipv6 prefix-list as26000-ipv6-in seq 5 permit 2404:2000:2002:110::/64
ipv6 prefix-list as26000-ipv6-in seq 10 permit 2404:2000:2002:111::/64
ipv6 prefix-list as26000-ipv6-in seq 15 permit 2404:4000:2:112::/64
ipv6 prefix-list as26000-ipv6-in seq 20 permit 2404:4000:2:114::/64
ipv6 prefix-list as26000-ipv6-out seq 5 permit 2404:4000:2002:3000::/64
ipv6 prefix-list as26000-ipv6-out seq 10 permit 2404:4000:2002:3200::/64
!
line vty
!
```

Appendix 12

ISP C communication to other ISP/Autonomous Systems

```
ISP_C_R1:~# ping -c 3 172.16.1.11
PING 172.16.1.11 (172.16.1.11) 56(84) bytes of data.
64 bytes from 172.16.1.11: icmp_seq=1 ttl=64 time=21.1 ms
64 bytes from 172.16.1.11: icmp_seq=2 ttl=64 time=0.672 ms
64 bytes from 172.16.1.11: icmp_seq=3 ttl=64 time=0.567 ms

--- 172.16.1.11 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2027ms
rtt min/avg/max/mdev = 0.567/7.452/21.118/9.663 ms
```

IPv6

```
ISP_C_R1:~# ping6 -c 3 2404:3000:1:1::1
PING 2404:3000:1:1::1(2404:3000:1:1::1) 56 data bytes
64 bytes from 2404:3000:1:1::1: icmp_seq=1 ttl=64 time=21.4 ms
```

```
64 bytes from 2404:3000:1:1::1: icmp_seq=2 ttl=64 time=0.610 ms
64 bytes from 2404:3000:1:1::1: icmp_seq=3 ttl=64 time=0.713 ms

--- 2404:3000:1:1::1 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2025ms
rtt min/avg/max/mdev = 0.610/7.592/21.453/9.801 ms
```