Dynamic Routing with OSPF

André Rosa, André Real
DI/FCT/NOVA University of Lisbon, Lisboa, Portugal
Student № 48043, 49831
af.rosa@campus.fct.unl, a.corte-real@campus.fct.unl
Group № 1

***Abstract*—In this work assignment, we were challenged to simulate a network backbone which interconnects several LANs. We leveraged the OSPF routing protocol for the routers to automatically compute the best paths to all the network prefixes. Finally, we conducted an experimental evaluation on the GNS3 simulator, and report in this document the results as well our configurations.**

***Index Terms*—OSPF, dynamic routing**

I. Introduction

This assignment aims to simulate a network backbone of a Wide Area Network (WAN), which inter-connects several Local Area Networks (LANs). An example of such network could be, for instance, a network of offices of a nation-wide corporation or a network of branches of the same bank, where each office/branch has its independent LAN. Each one of the LANs has an associated router, which connects the LAN to the WAN backbone. For this, we need to determine the routes to be used by each router to reach the other LAN's prefixes. However, statically defining them is very challenging, due to the need to compute the best routes, and is not scalable on the number of routers. Furthermore, this solution is also flexible, since when there are topology changes, it is required to statically defining new routes. Therefore, since statically defining each entry of the routing table of each router is a daunting task, each router executes the Open Shortest Path First (OSPF) protocol [1] for dynamically discovering the best routes for each network prefix. Thus, in this document we report the developed work, containing our network configurations as well as the results of a simple experimental evaluation of those configurations.

The remainder of this document is structured as follows: Section II provides an overview of the OSPF protocol; Section III presents our network configurations, including the assigned IP addresses and the OSPF parameters; Section IV contains the the setting and results of the experiemntal evaluation we performed; and finally, Section V concludes this report with some final remarks.

II. Open Shortest Path First (OSPF) Protocol

OSPF is a link-state routing protocol where each router locally and dynamically computes the best route, according to some metric, the every reachable network prefix.

For this, each router leverages the following four structures:

- *Link State Database (LSDB)*: contains the local topology information of every router of the network, i.e. the global network topology.
- *Shortest Path Tree (SPT)*: is a tree formed by the shortest paths from the current router to all the other routers of the network. The SPT is computed from the LSDB through an algorithm called Shortest Path First (SPF).
- *Routing Information Base (RIB)*[1]: assigns to each network prefix the address of the router to which the packets, whose destination matches the prefix, should be sent to.
- *Forwarding Information Base (FIB)*[2]: assigns to each network prefix the current router's network interface from which the packets, whose destination matches the prefix, should be sent.

The OSPF protocol works as follows: each router periodically transmits a type of control packet, called HELLO packet, through each one of its interfaces, to discover links with their neighbors, i.e. determining their local topology.

Next, upon detecting a topology change (i.e. a new link or a link failure), routers broadcast their local topology information, through reliable flooding, inside a special packet called Link State Advertisement (LSA). Reliable flooding consists in transmitting a packet through every interface, excluding the one from which the packet was received[3], and ensuring that the routers at the other end of the link receive it, usually through the usage of acknowledgment (ACK) packets. Routers can also periodically broadcast LSAs (even when no topology changes occurred) to avoid existing incorrect information due to undetected memory or transmission errors.

Whenever a router receives an LSA, it updates its LSDB and floods the LSA. From the updated LSDB, the current router performs a two-way connectivity check on every pair of routers, verifying if both advertise each other. In the case this verification fails, i.e. only one of the routers advertise the other, the link between those routers is removed from the LSDB. Afterward, the router computes the new SPT from the LSDB, with itself as the root, determining the shortest paths to every destination. Those paths are then leveraged to update the RIB, assigning to each prefix the neighbor router, or routers, which belongs to the shortest path(s) between the current router and that prefix.

[1] also called routing table.

[2] also known as a forwarding table.

[3] In the case of the router that initiates the broadcast, the packet is transmitted through all interfaces

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Then, the RIB is utilized to update the FIB, assigning to each prefix the network interface(s) that connects the current router with the neighbor(s) router assigned to that prefix in the RIB.

Posteriorly, when a packet is received by a router, the router consults its FIB to determine through which network interface that packet should be forwarded to. For this, the router extracts the packet's destination address and matches it with the every network prefix contained in the FIB. The best match corresponds to the longest prefix found, that matches with the destination IP address. When several equal-cost routes exist to the same destination, the packets are identically distributed through those routes.

In OSPF, when the network is stable, since the routers leverage the same loop-free algorithm to compute the best paths, the protocol guarantees that every router computes the same path for every given packet and that that path is loop-free. However, when there are changes in the network's topology, it temporarily leads to some routers having their state updated while others remain with stale information, i.e. routers having different global information. This phenomenon is called inconsistent states and is caused due to the difficulty of all routers become aware of a topology update at the same time, since the propagation of topology changes across the networks is not instantaneous. To the time required to all the routers of the network to reach a new consistent state , upon a topology change, it's called convergence time. This convergence time between consistent states can be decomposed into: i) link failure detection time; ii) delays before originating new LSAs; iii) broadcast latency; iv) SPF computation time; and v) RIB and FIB computation time.

III. Network Configuration

In this section, we delve into our network configuration, describing the IP addresses assigned to each interface, either physical or virtual, the networks' prefixes, and the OSPF configurations.

A. Network Topology

The topology of our network is presented in Figure 1 and is organized into four zones: North, East, South, and West. Each LAN belongs to a zone or the intersection of two zones, being this information reflected in the label of the LAN's correspondent router. The network is formed by nine Cisco 3745 [2], which contain both switching and routing capabilities in the same machine. We simulated this network on the GNS3 [3] network simulator. Each link between the routers has the default speed of 100 Mbps since in GNS3 different speeds could not be simulated.

B. Router Interfaces Configuration

Each router has an associated number, from 1 to 9, being this number utilized to form the prefixes of their associated LANs as well as the multiple routers' addresses[4]. Thus, each

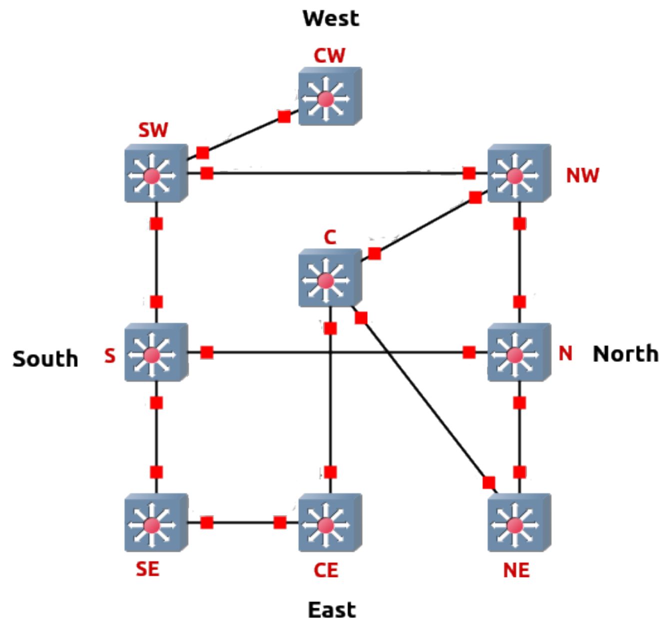

Fig. 1: Network Topology

LAN has a prefix of the form 192.168.X.0/24, being X the router's number, and, each LAN, is formed exclusively by the default VLAN, VLAN 1. Each router has a virtual interface, which we dub gateway interface, created on VLAN 1, with an assigned address corresponding to the first address of prefix of the LAN associated with the router, e.g. router C, which has the number 5, has the address 192.168.5.1 on the gateway interface. The routers' physical interfaces configured as switch ports are connected to this virtual interface. Additionally, each router also has a loopback interface, to provide a stable constant interface, with addresses of the form 192.168.0.X/24, where X is again the router's number.

For inter-router networks, i.e. networks which directly connect two routers with a point-to-point link, prefixes of the form 10.10.Y.0/24 are used, where Y is the number assigned to the link connecting the routers. On these networks, the interface of each connected router has an address of the form 10.10.Y.X, where Y is the link's number multiplied by 10 and X is the router's number. For instance, the link connecting the routers NW and N (link 1) forms the network 10.10.10.0/24, and NW's interface belonging to that network has the address 10.10.10.1, and N's interface belonging to that network has the address 10.10.10.2. Since in our case we are dealing with only nine routers, we decided to assigning prefixes of the form 10.10.Y.0/24, instead of prefixes of the form 10.10.Y.Z/30, to improve address readability, even though the first form wastes some addresses[5]. Since the routers all belong to the same autonomous system and this addresses are , later changing them to

This information is summarized in Table I for each router.

[4]With router's addresses we mean the addresses of all the router's physical or virtual interfaces.

[5]Which is not an issue in our current setup.

#	Label	Loopback	LAN prefix	Gateway	Interface	Type	Address	Connected
1	NW	192.168.0.1	192.168.1.0/24	192.168.1.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.10.1	N: f1/13
					f1/14	Routing	10.10.30.1	SW: f1/14
					f1/15	Routing	10.10.20.1	C: f1/15
2	N	192.168.0.2	192.168.2.0/24	192.168.2.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.30.2	NW: f1/13
					f1/14	Routing	10.10.50.2	NE: f1/14
					f1/15	Routing	10.10.40.2	S: f1/15
3	NE	192.168.0.3	192.168.3.0/24	192.168.3.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.60.3	C: f1/13
					f1/14	Routing	10.10.50.3	N: f1/14
					f1/15	Switching	-	-
4	CW	192.168.0.4	192.168.4.0/24	192.168.4.1	f1/0 - 14	Switching	-	-
					f1/15	Routing	10.10.70.4	SW: f1/15
5	C	192.168.0.5	192.168.5.0/24	192.168.5.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.60.5	NE: f1/13
					f1/14	Routing	10.10.80.5	CE: f1/14
					f1/15	Routing	10.10.20.5	NW: f1/15
6	CE	192.168.0.6	192.168.6.0/24	192.168.6.1	f1/0 -12	Switching	-	-
					f1/13	Routing	10.10.90.6	SE: f1/13
					f1/14	Routing	10.10.80.6	C: f1/14
					f1/15	Switching	-	-
7	SW	192.168.0.7	192.168.7.0/24	192.168.7.1	f1/0 -12	Switching	-	-
					f1/13	Routing	10.10.100.7	S: f1/13
					f1/14	Routing	10.10.30.7	NW: f1/14
					f1/15	Routing	10.10.70.7	CW: f1/15
8	S	192.168.0.8	192.168.8.0/24	192.168.8.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.100.8	SW: f1/13
					f1/14	Routing	10.10.110.8	SE: f1/14
					f1/15	Routing	10.10.40.8	N: f1/14
9	SE	192.168.0.9	192.168.9.0/24	192.168.9.1	f1/0 - 12	Switching	-	-
					f1/13	Routing	10.10.90.9	CE: f1/13
					f1/14	Routing	10.10.110.9	S: f1/14
					f1/15	Switching	-	-

TABLE I: Router Configured Addresses

C. OSPF Configuration

1) Process ID

Multiple instances of OSPF can be executed simultaneously on the same router, being each identified by a 16 bit unsigned integer, between 1 and 65535 (inclusive), called the process ID. This process ID is local to each router and thus, routers of the same network can have different OSPF process IDs. This can be set up with the following command:

```
R(config)# router ospf process-id
```

However, to organize the management of our network, we configured all the routers to run a single OSPF instance with the same process ID, which is equal to 10.

2) Router ID

To identify each router running OSPF, each has assigned a unique 32 bit unsigned integer called router ID. This ID is automatically selected as the largest IP address assigned to the router's interfaces, having loopback interfaces an higher priority in this selection i.e., the router ID will correspond to the largest IP address assigned to a loopback interface. However, if the selected IP address is removed from the interface or that interface goes down, the router selects a new router ID, which might difficult reasoning about and managing the network. Even though having a loopback interface mitigates this, it is still better to assign a static router ID to each router. Therefore, assigned to each router as its ID the IP assigned to its loopback interface[6]. This can be configured with the following command:

```
R(config-router)# router-id ip-address
```

3) Prefix Suppression

On a router, it is necessary to assign a unique IP address to each (routing) interface so that it can appear in the routing

[6]By statically defining the ID we guarantee that if the loopback interface is removed or its IP address is modified, the router ID remains the same. They are numerically the same number, however the ID will not change if the IP address does.

table and process IP packets. This necessity, leads to every point-to-point link between routers requiring an individual network, with at least 2 available IP addresses (excluding the .0 and the broadcast address). As stated before, for these networks we assigned prefixes of the form 10.10.X.0/24. This causes these networks be present at the routing tables of every router of the network, which can occupy several entries and thus increase the convergence time. However, there is no need for these networks to be know to other routers than the ones which have interfaces belonging to such networks. Therefore, these networks suppressed from the routing tables. There are two approaches to achieve this: OSPF prefix suppression and IP unnumbered interfaces.

On the one hand, OSPF prefix suppression prevents the propagation of these inter-router networks in LSAs. It can be applied to a single interface or globally, i.e., all interfaces simultaneously. When it is applied to a single interface, only the prefixes under that interface are suppressed. This feature can be enabled with the following commands, for global or single interface configuration respectively:

```
R(config)# prefix-suppression
R(config-if)# ip ospf prefix-suppression
```

Unfortunately, the Cisco model we are using does not have these commands available.

On the other hand, IP unnumbered interfaces allows enabling the processing of IP packets on an interface without an explicitly assigned IP address. For this, the unnumbered interface “borrows” an IP address from another interface, either physical or virtual, with a configured IP address. In this way, there are no IP addresses assigned to point-to-point links between routers, and thus there are no prefixes of inter-router links being propagated. This feature can be activated with the following command, on the interface without an assigned IP addressed to borrow an IP address from the provided interface:multi-point

```
R(config-if)# ip unnumbered type number
```

Unfortunately, IP unnumbered interfaces can only be configured on point-to-point interfaces and the Ciscos we are using only have Ethernet interfaces, which are point-to-multi-point, and thus not eligible for IP unnumbered.

Consequently, due to the limitations of the Ciscos we are unable to configure the suppression of inter-router networks.

4) Area Configuration

To decrease the amount of control traffic that circulates throughout the network, OSPF allows to create sub-sets of networks, called areas, each with its own topology, which is hidden from the remaining areas. Since our network is small, we defined a single area for OSPF. Thus, we defined all the routing interfaces, with IP addresses contained on the prefixes 192.168.0.0/16 and 10.10.0.0/16, to run OSPF and assigned them the area ID 0, by leveraging the command:

```
R(config-router)# network ip-address
                     wildcard-mask area area-id
```

5) OSPF Optimizations

In order to improve the convergence time of OSPF, we can modify its default configurations for performing computations. In order to choose the most suitable parameters, we performed an experiemtal evaluation, which is discussed in §**??**. These are the configurations that we found to be most relevant to modify:

a) Hello Interval

This timer corresponds to the time between consecutive HELLO packet transmissions on a given interface, and must be the same for pairs of connected interfaces. The smaller this value, the faster topological changes are detected, however, the more traffic overhead of control messages. The default value is 10 s, and can be configured with the following command:

```
R(config-if)# ip ospf hello-interval sec
```

b) Dead Interval

This timer corresponds to the time required to consider a neighbor as failed, after stopping to receive its’s HELLO packets. It should be a multiple of the Hello Interval and it also must be the same for pairs of connected interfaces. The smaller this value, the faster topological changes are detected, however it can lead to wrongly assuming a neighbor as failed. The default value is 40 s, and can be configured with the following command:

```
R(config-if)# ip ospf dead-interval sec
```

c) SPF Timers

This is a triple of timers of the form (spf-start, spf-hold, spf-max-wait), which control the time between consecutive SPF executions. spf-start corresponds to the first interval between the reception of a new LSA and the start of SPF; spf-hold and spf-max-wait correspond to the minimum and maximum, respectively, time between two consecutive SPF executions. The default values are (5000, 10000, 10000), and can be configured with the following command:

```
R(config-router)# timers throttle spf
           spf-start spf-hold spf-max-wait
```

d) Incremental SPF

Incremental SPF (or iSPF) consists in recomputing only the modified paths of the current SPT, instead of recomputing the new SPT from scratch, which leads to a smaller convergence time. The default value is desabled, and can be enabled with the following command:

```
R(config-router)# ispf
```

e) Link Cost

OSPF selects the best routes to destinations, as the routes with the lowest cost. The cost of a route corresponds to the sum of the costs of the routes’s constituent links. The cost of a link is computed by the router with the following formula:

$$Cost = \frac{\text{Reference bandwidth}}{\text{Interface bandwidth}}$$

The default reference bandwidth is 100 Mbps. Sometimes, it is presented to modify a link’s cost, for instance, to assign preferences in traffic flowing through or avoiding a given link. There are three ways of changing a link cost: change the reference bandwidth, change the interface bandwidth, or directly assigning a cost to the interface. Changing the reference bandwidth (in Mbps) can be done through the following command:

```
R(config-router)# auto-cost
                  reference-bandwidth value
```

The same reference bandwidth must be set on all routers, so that the results are consistent. Changing the interface bandwidth (in Mbps) can be done through the following command [7]:

```
R(config-if)# speed value
```

This change must be done in all interfaces belonging to the link. Finally, directly changing an interface cost can be done through the following command:

```
R(config-if)# ip ospf cost value
```

Again, this change must be done in all interfaces belonging to the link.

IV. Experimental Evaluation

In this section, we describe our experimental evaluation methods as well as the obtained results. We performed two types of measurements: muti-path routes and convergence time, which we describe in more detail next.

A. Multi-Path Routes

We decided to measure the multiplicity of minimal cost routes to measure how balanced the traffic on our network is. For this, we compared our previous scenario presented in §III-A, where all links have the same cost, with a second scenario, where some links have an higher cost, as shown in Figure 2. The link's labels are structured as X | Y, where X and Y represent the original cost and the new cost, respectively. The costs of the second scenario where configured by directly changing the interfaces' costs, instead of their bandwidth.

In our network, we detected several instances of multi-path routing, for both the original and the new topology, being this information summarized in Table II.

Routes	Default	New
x1	49	68
x2	19	1
x3	4	3
Total	72	72
W. Avg	1.38	1.10

TABLE II: Multi-Path Routes Distribution

In the table, the first column represents the multiplicity of routes, e.g. x2 means there are 2 alternative routes. The amount of double and triple routes, is superior in the case

[7]Unfortunately, in GNS3 different speeds cannot be simulated and thus this command has no effect.

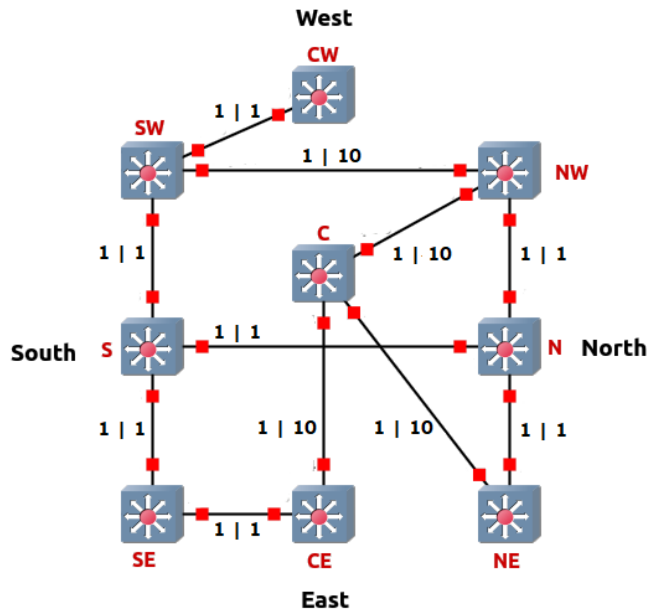

Fig. 2: Network Topology Costs

where all links have equal cost (Default scenario), with an average amount of alternative routes of 1.38, while the New scenario had an average of 1.10. Thus, the Default scenario provides a better distribution of the network's traffic, assuming all the LANs send approximately the same amount of packets to every other LAN, in a given period.

B. Convergence Time

In addition to the multiplicity of routes, we decided to measure the convergence time of OSPF upon topology changes.

We chose four OSPF configurations to evaluate, based on the experimental evalution performed in [4], which are summarized in Table III.

Label	Description
Default (DF)	Default OSPF configurations
Dead Interval (DI)	hello interval = 300 ms dead interval = 900 ms
SPF Timers (ST)	spf-start = 50 ms spf-hold = 200 ms spf-max = 5000 ms
iSPF (IS)	Incremental SPF enabled

TABLE III: Evaluated OSPF Configurations

For the measurements, we performed an approximation of the convergence time by leveraging the ping tool to send packets from one host of a LAN to a host of another LAN. Then, we performed a topology change which affected the route being used by those packets, and measured the elapsed time while the packets could not be forwarded. This information is provided by ICMP packets with the error "destination host unreachable". Each experiment was repeated 15 times, and the results were averaged, in order to minimize the impact of external interference, such as CPU scheduling, and obtain more consisted results. We studied two kinds topology changes: link failures and router failures.

1) Link Failures

In this type of experiments, we randomly selected a link between two routers which were part of the path the packets were traveling.

Unfortunately, due to problems with our simulation tool, the convergence time measurements could not be performed. See Appendix A.

2) Router Failures

In this type of experiments, we randomly selected a router which was part of the path the packets were traveling.

Unfortunately, due to problems with our simulation tool, the convergence time measurements could not be performed. See Appendix A.

V. Final Remarks

A. Final Considerations

In the lab guide of this project, the professor asked "why the authors of the paper you studied ([4]) had to resort to simulation to obtain the results they report?"

The answer to this question is that to perform an experimental evaluation on real networks of such magnitude (several tens of routers across very large distances), the authors either:

- Had to have enough funds to acquire the required hardware as well as the capacity to scatter it through very large distances.
- Had to have access to an already existing network of that dimensions, which is also challenging. Even in the case the authors could get access to such network, they could (or should) only leverage the network for experiments on periods of no traffic. This is due to the need of purposefully failing links and routers, to measure the convergence times, which leads to inconsistencies on the routing tables. Although this consistencies are temporary, this disrupts the usage of the network by its clients.

Furthermore, in a real network, the management and coordination of the experiments would also be a challenge to address. Therefore, due to the previous motives, resorting to simulation models is the most practical solution to conduct an experimental evaluation on very large networks.

B. Conclusion

Finally, in this project we configured a set of routers, each with its own LAN, to be inter-connected through IP routing in a WAN. For this, we used nine Cisco c3745, which have both switching and routing functionalities on the same device. To avoid statically defining each routing table entry of each router, we leveraged the OSPF dynamic routing protocol. We presented our network configurations, including the assigned IP addresses and prefixes, as well as the chosen OSPF parameters. Some of these parameters were experimentally evaluated, in a network simulator, in order to determine the best configurations to achieve better traffic distribution as well as lower convergence times. Unfortunately, due to problems with our simulation tool, the convergence time measurements could not be performed.

References

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[2] "Cisco 3745 Router Quick Start Guide," https://www.cisco.com/en/US/docs/routers/access/3700/3745/hardware/quick/guide/3745qsg.html, accessed: 18-04-2020.

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APPENDIX

A - TROUBLESHOOTING CONSIDERATIONS

During the experimental evaluation, we were able to correctly configure OSPF and ping any host on the network. This was our procedure: we defined a host I-5, connected to router CW with IP address 192.168.4.15, and a host I-2, connected to router NE with IP address 192.168.5.12. Then, we checked the route where the packets should be traveling, from I-5 to I-2. For this, we went to each router, starting with CW, and checked the routing tables:

```
CW# show ip route
O    192.168.5.0/24 [110/4] via 10.10.70.7, 00:03:06, FastEthernet1/15

SW# show ip route
O    192.168.5.0/24 [110/3] via 10.10.30.1, 00:00:13, FastEthernet1/14

NW# show ip route
O    192.168.5.0/24 [110/2] via 10.10.20.5, 00:01:34, FastEthernet1/15
```

From this, we confirmed the packets should be traveling through this route: I-5 $\longrightarrow$ CW $\longrightarrow$ SW $\longrightarrow$ NW $\longrightarrow$ C $\longrightarrow$ I-2. We then proceeded to ping I-2 from I-5, with an interval of 500 ms:

```
root@I-5˜# ping -i 0.5 -O 192.168.5.12
```

Up to this moment, everything was OK, i.e. the pings reached the destination.

Afterwards, we tried to shutdown some links to measure the convergence time of OSPF. Unfortunately, we encountered some problems. First, we selected interface f1/14 of SW to be shutdown:

```
NW# conf t
NW(config)# int f1/14
NW(config-if)# shutdown
NW(config-if)# end
NW#
*Mar  1 00:04:01.935: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
    from FULL to DOWN, Neighbor Down: Interface down or detached
*Mar  1 00:04:03.851: %LINK-5-CHANGED: Interface FastEthernet1/14, changed state to
    administratively down
*Mar  1 00:04:04.851: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/14,
    changed state to down
```

However, SOMETIMES, after shutting down an interface, another non-related interface of the same router “breaks”. For instance, shutting down interface f1/13 “breaks” interface f1/14. Example:

```
*Mar  1 00:12:43.999: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
    from FULL to INIT, 1-Way

NW# show ip ospf neighbor
192.168.0.7       1   INIT/DROTHER    00:00:33    10.10.30.7      FastEthernet1/14
```

We then later receive the following message:

```
*Mar  1 00:03:01.635: $%$OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.1 on FastEthernet1/14
     from FULL to DOWN, Neighbor Down: Dead timer expired
```

In the case the above step goes according to expected, it SOMETIMES happens later when we restore the interface with the command “no shutdown”. For instance, ”no shutdown” on interface f1/15, “breaks” interface f1/14.

In the case both of the previous problems did not occur, we also experienced high inconsistencies in convergence times, when breaking the SAME link several times (over different tries, after shutting down the emulation and even GNS3 itself). When shutting down an interface, the selection of a new route (without previous multi path routes) is fast and approximately 1 second, other times, more or less, 6 seconds and the worst time being approximately 12 seconds.

In spite of the previous problems, there were times where we managed to perform some successful tests. However, there was no consistency in results: sometimes it failed and sometimes it worked but with very different times. Therefore, we could not construct a plot to present the results. Next we present the full procedure.

First we shutdown the interface:

```
NW# conf t
NW(config)# int f1/14
NW(config-if)# shutdown
NW(config-if)# end
```

Next, we check, again, the routing tables of SW, to identify how the packet are now forwarded to reach C. Doing the same procedure as we did before shut-down we got the following paths:

I-5 $\longrightarrow$ CW $\longrightarrow$ SW $\longrightarrow$ S $\longrightarrow$ SE $\longrightarrow$ CE $\longrightarrow$ C $\longrightarrow$ I-2
I-5 $\longrightarrow$ CW $\longrightarrow$ SW $\longrightarrow$ S $\longrightarrow$ N $\longrightarrow$ NW $\longrightarrow$ C $\longrightarrow$ I-2
I-5 $\longrightarrow$ CW $\longrightarrow$ SW $\longrightarrow$ S $\longrightarrow$ N $\longrightarrow$ NE $\longrightarrow$ C $\longrightarrow$ I-2

We then waited for the dead timer notification on the adjacent routers:

```
*Mar  1 00:03:01.635: $%$OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.1 on FastEthernet1/14
    from FULL to DOWN, Neighbor Down: Dead timer expired
```

Next, we proceeded to re-enable the router interface with the command ”no shutdown”:

```
SW# conf t
SW(config)# int f1/14
SW(config-if)# no shutdown
SW(config-if)# end
SW#
*Mar  1 00:09:10.827: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
    from DOWN to INIT, Received Hello
*Mar  1 00:09:10.827: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
     from INIT to 2WAY, 2-Way Received
*Mar  1 00:09:10.831: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
     from 2WAY to EXSTART, AdjOK?
*Mar  1 00:09:13.683: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet1/14,
     changed state to up
*Mar  1 00:09:15.867: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
     from EXSTART to EXCHANGE, Negotiation Done
*Mar  1 00:09:15.963: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
     from EXCHANGE to LOADING, Exchange Done
*Mar  1 00:09:15.963: %OSPF-5-ADJCHG: Process 10, Nbr 192.168.0.7 on FastEthernet1/14
     from LOADING to FULL, Loading Done
```

For one last time, we then check the route the packets would take, and obtained the original path.

B - Ciscos Running Configurations

NW Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname NW
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.1 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
```

```
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
```

```
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to N
 no switchport
 ip address 10.10.10.1 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to SW
 no switchport
 ip address 10.10.30.1 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to C
 no switchport
 ip address 10.10.20.1 255.255.255.0
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.1.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.1
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C
```

```
************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

N Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname N
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
```

```
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.2 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
```

```
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to NW
 no switchport
 ip address 10.10.10.2 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to NE
 no switchport
 ip address 10.10.50.2 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to S
 no switchport
 ip address 10.10.40.2 255.255.255.0
 duplex full
 speed 100
!
```

```
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.2.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.2
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C

***************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
***************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
```

```
!
end
```

NE Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname NE
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
```

```
 ip address 192.168.0.3 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
```

```
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to C
 no switchport
 ip address 10.10.60.3 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to N
 no switchport
 ip address 10.10.50.3 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.3.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.3
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
```

```
banner exec ^C

**************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
**************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

CW Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname CW
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
```

```
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.4 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
```

```
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 duplex full
 speed 100
!
interface FastEthernet1/14
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to SW
 no switchport
 ip address 10.10.70.4 255.255.255.0
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.4.1 255.255.255.0
!
router ospf 10
```

```
 router-id 192.168.0.4
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C

***************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
***************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

C Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname C
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.5 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
```

```
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
```

```
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to NE
 no switchport
 ip address 10.10.60.1 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to CE
 no switchport
 ip address 10.10.80.5 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to NW
 no switchport
 ip address 10.10.20.5 255.255.255.0
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.5.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.5
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C
```

```
************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

CE Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname CE
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
```

```
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.6 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
```

```
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to SE
 no switchport
 ip address 10.10.90.6 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to C
 no switchport
 ip address 10.10.80.6 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.6.1 255.255.255.0
!
```

```
router ospf 10
 router-id 192.168.0.6
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C

****************************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
****************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

SW Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname SW
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.7 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
```

```
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
```

```
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to S
 no switchport
 ip address 10.10.100.7 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to NW
 no switchport
 ip address 10.10.30.7 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to CW
 no switchport
 ip address 10.10.70.7 255.255.255.0
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.7.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.7
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C
```

```
***********************************************************
This is a normal Router with a SW module inside (NM-16ESW)
It has been preconfigured with hard coded speed and duplex

To create vlans use the command "vlan database" from exec mode
After creating all desired vlans use "exit" to apply the config

To view existing vlans use the command "show vlan-switch brief"

Warning: You are using an old IOS image for this router.
Please update the IOS to enable the "macro" command!
***********************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

S Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname S
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
```

```
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.8 255.255.255.0
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
```

```
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to SW
 no switchport
 ip address 10.10.100.8 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to SE
 no switchport
 ip address 10.10.110.8 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 description Connection to N
 no switchport
 ip address 10.10.40.8 255.255.255.0
 duplex full
 speed 100
!
interface Vlan1
```

```
 description Virtual Interface on Vlan1
 ip address 192.168.8.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.8
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C

**************************************************************
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It has been preconfigured with hard coded speed and duplex

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**************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
```

```
end
```

SE Running Configuration

```
!
version 12.4
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
no service dhcp
!
hostname SE
!
boot-start-marker
boot-end-marker
!
!
no aaa new-model
memory-size iomem 5
no ip icmp rate-limit unreachable
ip cef
!
!
!
!
no ip domain lookup
ip auth-proxy max-nodata-conns 3
ip admission max-nodata-conns 3
!
!
!
!
!
!
!
!
!
!
!
!
!
!
!
vtp file nvram:vlan.dat

!
!
ip tcp synwait-time 5
!
!
!
!
!
interface Loopback1
 description Loopback Interface
 ip address 192.168.0.9 255.255.255.0
```

```
!
interface FastEthernet0/0
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet0/1
 description *** Unused for Layer2 EtherSwitch ***
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface FastEthernet1/0
 duplex full
 speed 100
!
interface FastEthernet1/1
 duplex full
 speed 100
!
interface FastEthernet1/2
 duplex full
 speed 100
!
interface FastEthernet1/3
 duplex full
 speed 100
!
interface FastEthernet1/4
 duplex full
 speed 100
!
interface FastEthernet1/5
 duplex full
 speed 100
!
interface FastEthernet1/6
 duplex full
 speed 100
!
interface FastEthernet1/7
 duplex full
 speed 100
!
interface FastEthernet1/8
 duplex full
 speed 100
!
interface FastEthernet1/9
 duplex full
 speed 100
!
interface FastEthernet1/10
 duplex full
 speed 100
```

```
!
interface FastEthernet1/11
 duplex full
 speed 100
!
interface FastEthernet1/12
 duplex full
 speed 100
!
interface FastEthernet1/13
 description Connection to CE
 no switchport
 ip address 10.10.90.9 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/14
 description Connection to S
 no switchport
 ip address 10.10.110.9 255.255.255.0
 duplex full
 speed 100
!
interface FastEthernet1/15
 duplex full
 speed 100
!
interface Vlan1
 description Virtual Interface on Vlan1
 ip address 192.168.9.1 255.255.255.0
!
router ospf 10
 router-id 192.168.0.9
 log-adjacency-changes detail
 network 10.10.0.0 0.0.255.255 area 0
 network 192.168.0.0 0.0.255.255 area 0
!
ip forward-protocol nd
!
!
no ip http server
no ip http secure-server
!
no cdp log mismatch duplex
!
!
!
control-plane
!
!
!
!
!
!
!
!
!
banner exec ^C
```

```
*****************************************************************
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*****************************************************************

^C
!
line con 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line aux 0
 exec-timeout 0 0
 privilege level 15
 logging synchronous
line vty 0 4
 login
!
!
end
```

A