

CS5113: Network Engineering

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Tentative Course Schedule

Week 01: Orientation & VM related instructions

Week 02: Revisiting Basics through Linux Network Commands & Scripts

Week 03: Network Topology (IPv4/IPv6 addressing and VLAN)

Week 04: Configuring Open Software Router (VyOS)

Week 05: Interconnecting Routers using Static Routing

Week 06: Intra-AS Routing Protocols (OSPF)

Week 07: Inter-AS Routing Protocol (BGP)

Week 08: Introduction to Software Defined Networking

Week 09: Project Orientation

Week 10: Benchmarking, Monitoring and Trouble Shooting in Networks

Week 11: Managing Firewalls

Week 12: Designing Enterprise Networks and Summary

Week 13: Security (Managing Firewalls)

Week 14: Covering up left-over topics

Week 15: Project Evaluation

Outline of This Week

- What is routing protocol?
- What is OSPF?
- Let's touch OSPF, a dynamic routing protocol
 - Simplest configuration
 - Path control
 - Failure recovery

Brief Overview on Routing Protocol Open Shortest Path First (OSPF)

Routing Protocol

- Mechanism to exchange routing information among routers
 - Algorithms and Metric are different among protocols
 - Distance Vector / Hop Count / RIP
 - Link State / Link Cost / OSPF
 - Path Vector / Path Length / BGP

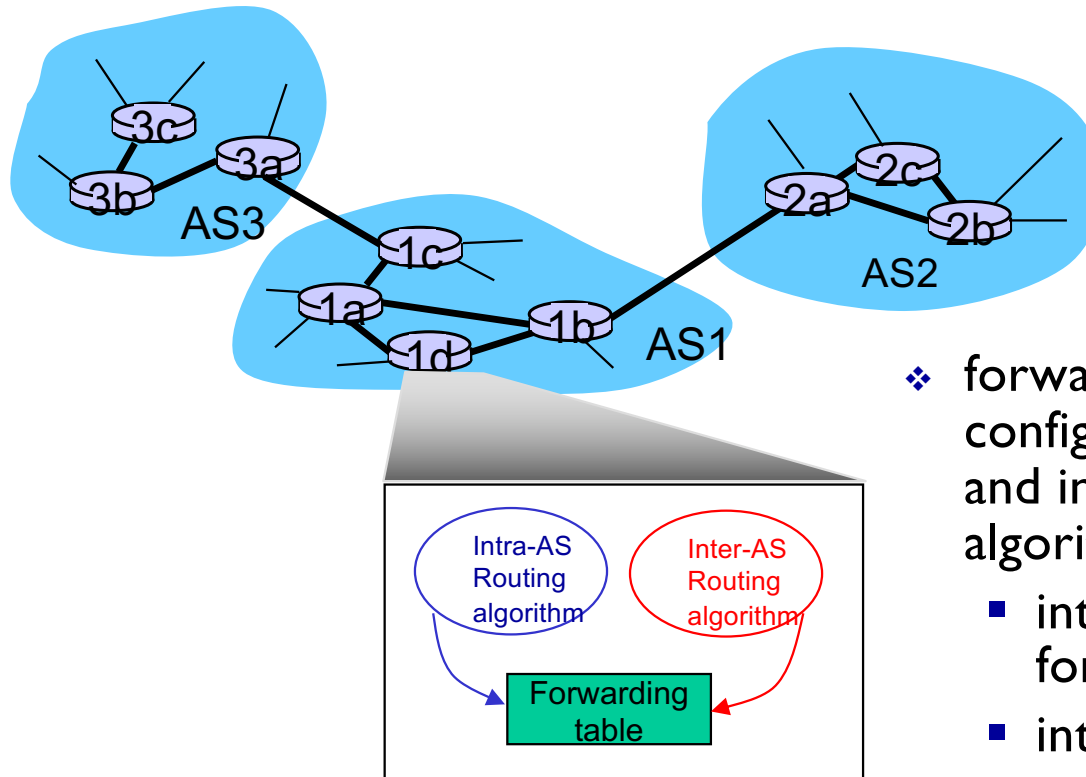
Hierarchical routing

- ❖ aggregate routers into regions, “**autonomous systems**” (AS)
- ❖ routers in same AS run same routing protocol
 - “**intra-AS**” routing protocol
 - routers in different AS can run different intra-AS routing protocol

gateway router:

- ❖ at “edge” of its own AS
- ❖ has link to router in another AS

Interconnected ASes



- ❖ forwarding table configured by both intra- and inter-AS routing algorithm
 - intra-AS sets entries for internal dests
 - inter-AS & intra-AS sets entries for external dests

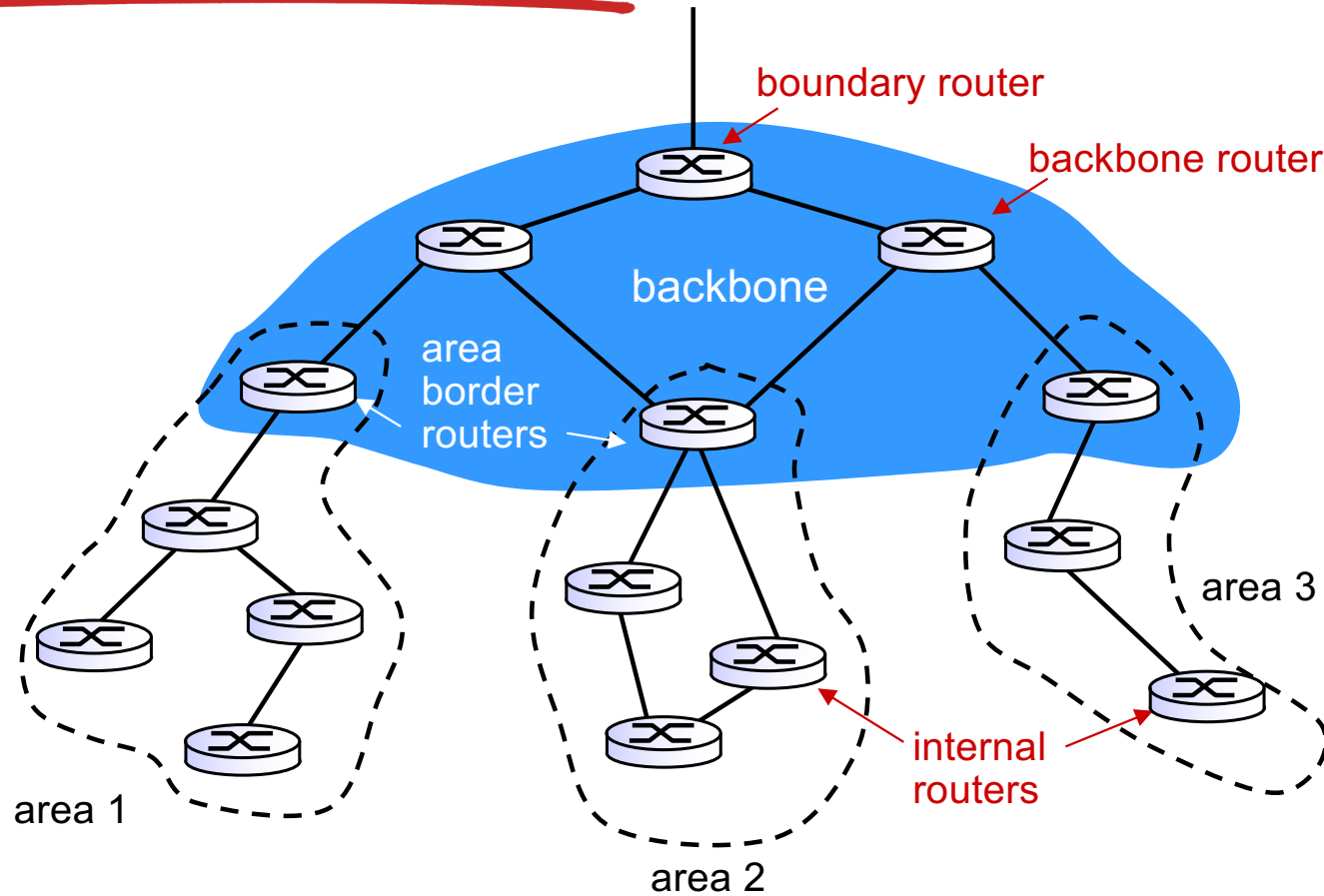
OSPF (Open Shortest Path First)

- ❖ “open”: publicly available
- ❖ uses link state algorithm
 - LS packet dissemination
 - topology map at each node
 - route computation using Dijkstra's algorithm
- ❖ OSPF advertisement carries one entry per neighbor
- ❖ advertisements flooded to *entire* AS
 - carried in OSPF messages directly over IP (rather than TCP or UDP)
- ❖ *IS-IS routing* protocol: nearly identical to OSPF

OSPF “advanced” features (not in RIP)

- *security*: all OSPF messages authenticated (to prevent malicious intrusion)
- **multiple** same-cost **paths** allowed (only one path in RIP)
- for each link, multiple cost metrics for different **TOS** (e.g., satellite link cost set “low” for best effort ToS; high for real time ToS)
- integrated uni- and **multicast** support:
 - Multicast OSPF (MOSPF) uses same topology data base as OSPF
- **hierarchical** OSPF in large domains.

Hierarchical OSPF



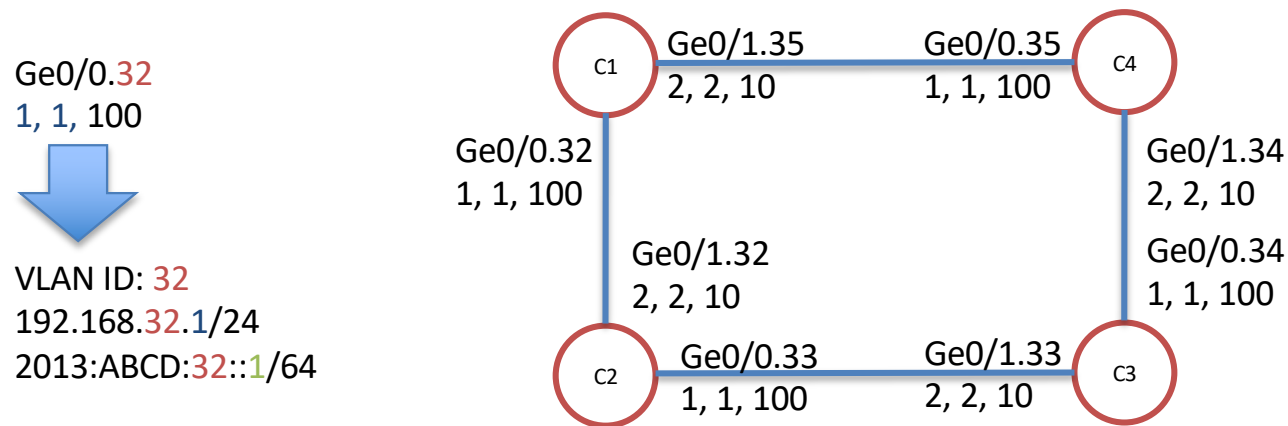
Hierarchical OSPF

- *two-level hierarchy*: local area, backbone.
 - link-state advertisements only in area
 - each nodes has detailed area topology; only know direction (shortest path) to nets in other areas.
- *area border routers*: “summarize” distances to nets in own area, advertise to other Area Border routers.
- *backbone routers*: run OSPF routing limited to backbone.
- *boundary routers*: connect to other AS' s.

Configuring OSPF on Cisco Routers

Starting from a Small Network with Cisco Routers

- Design
 - All networks will join a single area 0 (Backbone)
 - Packets will go clock-wise on the topology
 - In the case of link-down, path will switch to the alternative one



Basic Configuration

- Configure host name
- Configure NICs
 - Create Virtual I/F and specify VLAN ID
 - Configure IPv4/v6 address
 - No shutdown
- Check that your router can ping to the next routers

Configuring OSPFv2 for IPv4 (1/x)

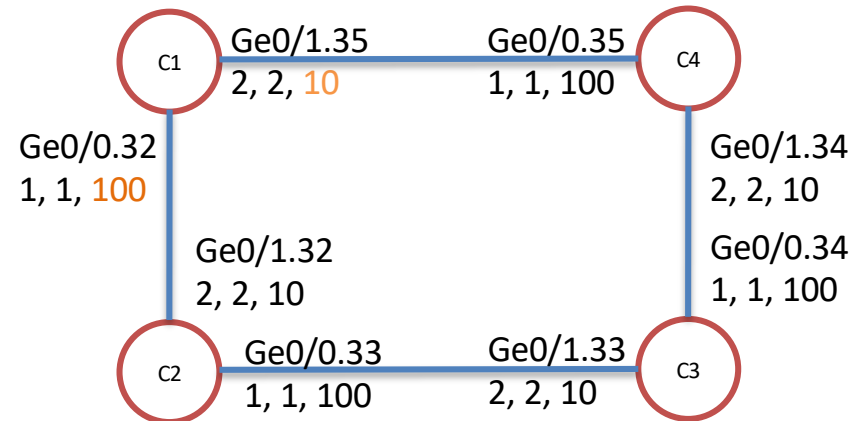
- Enable OSPF and specifying the prefixes that join to the area 0 (backbone)

```
(config)# router ospf 5113
(config-router)# network 192.168.0.0 0.0.3.255 area 0
(config-router)# network 192.168.4.0 0.0.3.255 area 0
(config-router)# network 192.168.8.0 0.0.3.255 area 0
(config-router)# network 192.168.12.0 0.0.3.255 area 0
(config-router)# network 192.168.32.0 0.0.3.255 area 0
```

Configuring OSPFv2 for IPv4 (2/x)

- Set cost on each I/F
(to make traffic go clock-wise)

```
(config)# interface GigabitEthernet0/0.32
(config-subif)# ip ospf cost 100
(config-subif)# exit
(config)# interface GigabitEthernet0/1.35
(config-subif)# ip ospf cost 10
(config-subif)# exit
```



Configuring OSPFv2 for IPv4 (3/x)

- Check the neighbors, Designated Router (DR) and Backup DR

```
# show ip ospf neighbor
```

- Check the routing table
 - Which route is learned from OSPF?
 - What are others?

```
# show ip route
```

Configuring OSPFv3 for IPv6 (1/x)

- Enable OSPF

```
(config)# ipv6 unicast routing
```

- No need to specify the prefixes that join to the specific an area

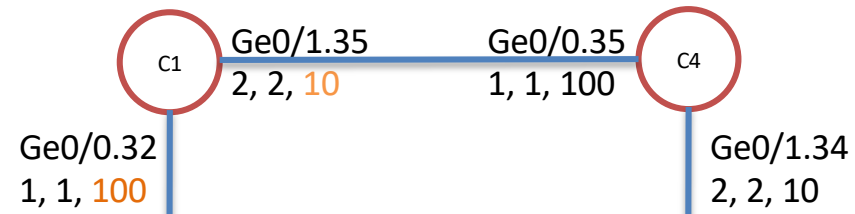
```
(config)# ipv6 router ospf 5113
```

```
(config-router)# exit
```

Configuring OSPFv3 for IPv6 (2/x)

- Set OSPF process, area and cost on each I/F (to make traffic go clock-wise)

```
(config)# interface GigabitEthernet0/0.32
(config-subif)# ipv6 ospf 5113 area 0
(config-subif)# ipv6 ospf cost 100
(config-subif)# exit
(config)# interface GigabitEthernet0/1.35
(config-subif)# ipv6 ospf 5113 area 0
(config-subif)# ipv6 ospf cost 10
(config-subif)# exit
```



Configuring OSPFv3 for IPv6 (3/x)

- Check the neighbors, Designated Router (DR) and Backup DR

```
# show ipv6 ospf neighbor
```

- Check the routing table
 - Which is learned from OSPF?
 - What are others?

```
# show ipv6 route
```

Checking OSPF More on Cisco

- show ip protocols
- show ip ospf
- show ip ospf interface
- show ip ospf database self-originate
- show ip route ospf
- show ipv6 protocols
- show ipv6 ospf
- show ipv6 ospf interface
- show ipv6 ospf database self-originate
- and more...

IPv4 Routing Table on Cisco

```
Dynamips(2): R2, Console port
om FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
C2#
C2#show ip os
C2#show ip rou
C2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

O    192.168.24.0/24 [110/2] via 192.168.21.1, 00:01:19, GigabitEthernet1/0
C    192.168.21.0/24 is directly connected, GigabitEthernet1/0
O    192.168.23.0/24 [110/2] via 192.168.22.2, 00:01:19, GigabitEthernet2/0
C    192.168.22.0/24 is directly connected, GigabitEthernet2/0
O    192.168.0.0/24 [110/202] via 192.168.21.1, 00:01:19, GigabitEthernet1/0
O    192.168.1.0/24 [110/2] via 192.168.21.1, 00:01:19, GigabitEthernet1/0
O    192.168.2.0/24 [110/2] via 192.168.21.1, 00:01:19, GigabitEthernet1/0
O    192.168.3.0/24 [110/102] via 192.168.21.1, 00:01:19, GigabitEthernet1/0
C2#
```

IPv6 Routing Table on Cisco

```
Dynamips(2): R2, Console port
C2#show ipv6 route
IPv6 Routing Table - 12 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
O  2013:ABCD::/64 [110/400]
   via FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
O  2013:ABCD:1::/64 [110/110]
   via FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
O  2013:ABCD:2::/64 [110/200]
   via FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
O  2013:ABCD:3::/64 [110/300]
   via FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
C  2013:ABCD:21::/64 [0/0]
   via ::, GigabitEthernet1/0
L  2013:ABCD:21::2/128 [0/0]
   via ::, GigabitEthernet1/0
C  2013:ABCD:22::/64 [0/0]
   via ::, GigabitEthernet2/0
L  2013:ABCD:22::1/128 [0/0]
   via ::, GigabitEthernet2/0
O  2013:ABCD:23::/64 [110/110]
   via FE80::C803:CFF:FE01:1C, GigabitEthernet2/0
O  2013:ABCD:24::/64 [110/110]
   via FE80::C801:CFF:FE01:1C, GigabitEthernet1/0
L  FE80::/10 [0/0]
   via ::, Null0
L  FE80::/48 [0/0]
```

Points to Check

- Use traceroute for checking normal path
- What happens if one router is disconnected? How long did it take to recover?
- What happens if you change “Hello Interval” to smaller number on the interface?

Configure OSPF on VyOS Routers

4 Cs + 11 Vs in Area 0

ethX.2
1, 1, 100



For VyOS

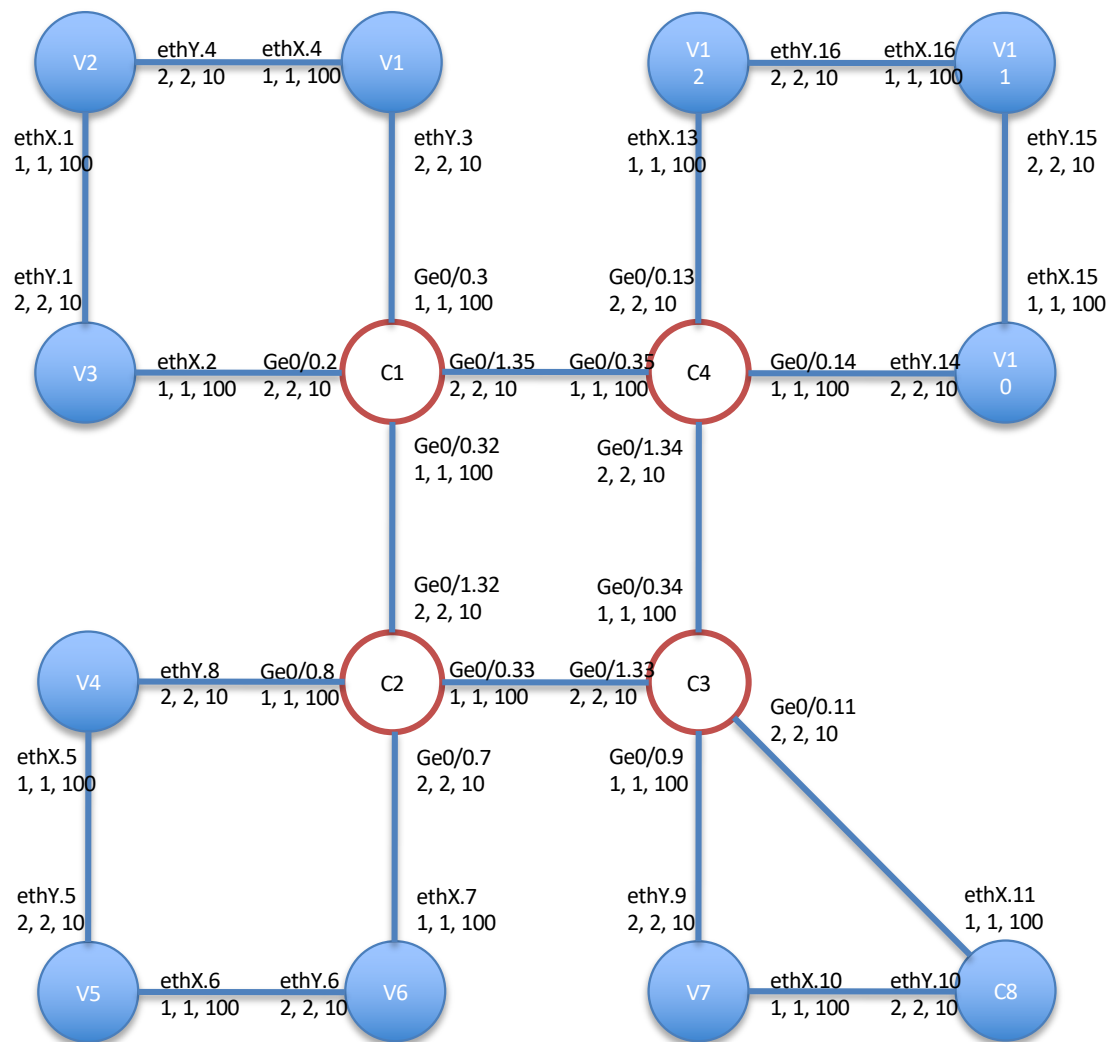
VLAN ID: 2

3rd Octet/Group = VLAN ID - 1

192.168.1.1/24

2013:ABCD:1::1/64

OSPF Cost: 100



Configuring OSPF for IPv4 (1/x)

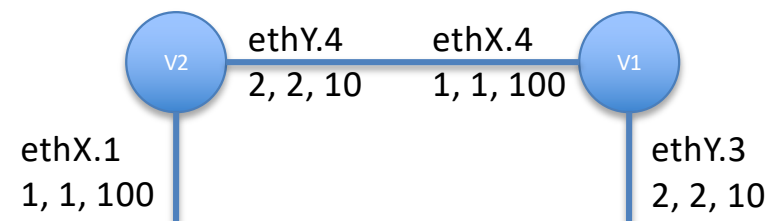
- Enable OSPF and specify the prefixes that join to the area 0 (backbone)

```
# set protocols ospf area 0 network 192.168.0.0/22
# set protocols ospf area 0 network 192.168.4.0/22
# set protocols ospf area 0 network 192.168.8.0/22
# set protocols ospf area 0 network 192.168.12.0/22
# set protocols ospf area 0 network 192.168.32.0/22
```

Configuring OSPF for IPv4 (2/x)

- Set cost on each I/F
(to make traffic go clock-wise)

```
# set interfaces ethernet ethX ip ospf cost 100
# set interfaces ethernet ethY ip ospf cost 10
# commit
# save
```



Configuring OSPF for IPv4 (3/x)

- Check the neighbors, Designated Router (DR) and Backup DR

```
$ show ip ospf neighbor
```

- Check the routing table
 - Which route is learned from OSPF?
 - What are others?

```
$ show ip route
```

- Check the connectivity using ping/traceroute

Configuring OSPF for IPv6 (1/x)

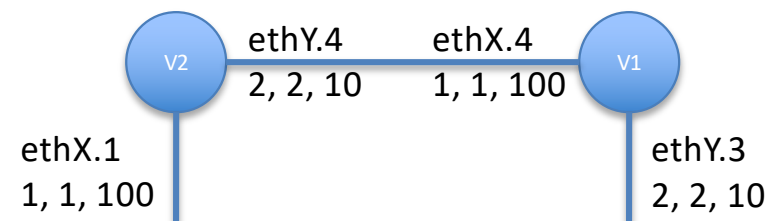
- No need to specify the prefixes that join to the specific an area
- Specify area and interface to speak OSPF

```
# set protocols ospfv3 area 0.0.0.0 interface ethX
# set protocols ospfv3 area 0.0.0.0 interface ethY
# commit
# save
```

Configuring OSPF for IPv6 (2/x)

- Set cost on each I/F (to make traffic go clock-wise)

```
# set interfaces ethernet ethX ipv6 ospfv3 cost 100
# set interfaces ethernet ethY ipv6 ospfv3 cost 10
# commit
# save
```



Configuring OSPF for IPv6 (3/x)

- Check the neighbors, Designated Router (DR) and Backup DR

```
$ show ipv6 ospfv3 neighbor
```

- Check the routing table
 - Which is learned from OSPF?
 - What are others?

```
$ show ipv6 route
```

- Check the connectivity using ping6/traceroute6

Checking OSPF More on VyOS

- `show ip ospf interface`
- `show ip ospf database self-originated`
- `show ip ospf route`
- `show ipv6 ospfv3 interface`
- `show ipv6 ospfv3 linkstate`
- `show ipv6 ospfv3 database self-originated`
- `show ipv6 ospfv3 route`
- and more...

IPv4 Routing Table on VyOS

```
QEMU7
vyatta@vyatta:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
O  192.168.0.0/24 [110/10] is directly connected, eth1, 00:12:29
C>* 192.168.0.0/24 is directly connected, eth1
O  192.168.1.0/24 [110/31] via 192.168.0.1, 00:12:21
C>* 192.168.1.0/24 is directly connected, eth2
O>* 192.168.2.0/24 [110/30] via 192.168.0.1, eth1, 00:12:21
O>* 192.168.3.0/24 [110/20] via 192.168.0.1, eth1, 00:12:21
O>* 192.168.21.0/24 [110/31] via 192.168.0.1, eth1, 00:12:21
O>* 192.168.22.0/24 [110/32] via 192.168.0.1, eth1, 00:12:21
O>* 192.168.23.0/24 [110/32] via 192.168.0.1, eth1, 00:12:21
O>* 192.168.24.0/24 [110/31] via 192.168.0.1, eth1, 00:12:21
vyatta@vyatta:~$
```

IPv6 Routing Table on VyOS

```
QEMU7
vyatta@vyatta:~$ show ipv6 route
Codes: K - kernel route, C - connected, S - static, R - RIPng, O - OSPFv3,
       I - ISIS, B - BGP, * - FIB route.

C>* ::1/128 is directly connected, lo
O  2013:abcd::/64 [110/10] is directly connected, eth1, 00:12:48
C>* 2013:abcd::/64 is directly connected, eth1
O  2013:abcd:1::/64 [110/40] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:43
C>* 2013:abcd:1::/64 is directly connected, eth2
O>* 2013:abcd:2::/64 [110/30] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
O>* 2013:abcd:3::/64 [110/20] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
O>* 2013:abcd:21::/64 [110/130] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
O>* 2013:abcd:22::/64 [110/60] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
O>* 2013:abcd:23::/64 [110/50] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
O>* 2013:abcd:24::/64 [110/40] via fe80::2ab:2eff:fee1:2a01, eth1, 00:12:44
C * fe80::/64 is directly connected, eth1
C>* fe80::/64 is directly connected, eth2
vyatta@vyatta:~$
```