

Hands-on Workshop on Open vSwitch and Software-defined Networking

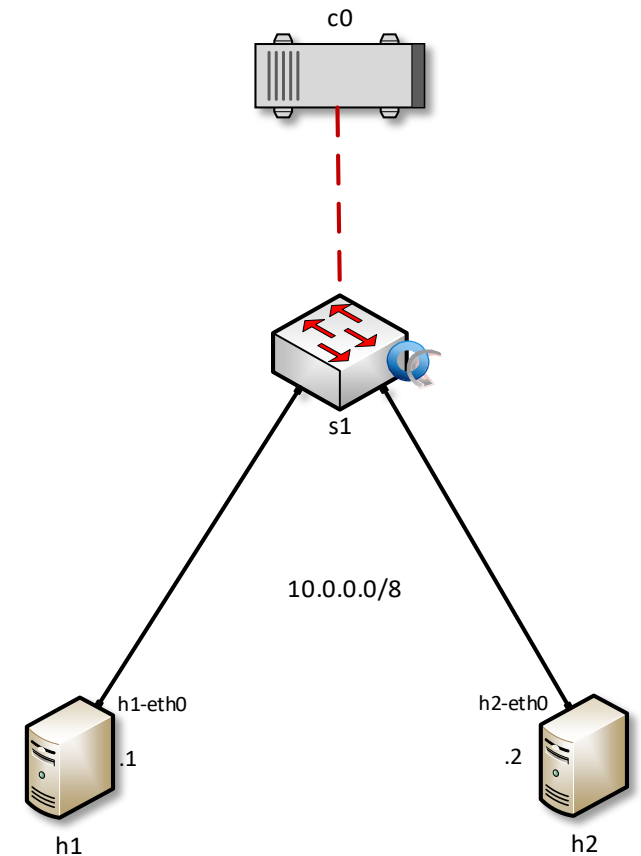
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Lab 6: Introduction to OpenFlow

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- The topology consists of an ONOS controller, an OVS device, and hosts h1 and h2
- The OVS switch is administered using the ovs-ofctl command line utility
- The lab demonstrates how to inspect OpenFlow messages exchanged between the ONOS controller and the OVS switch



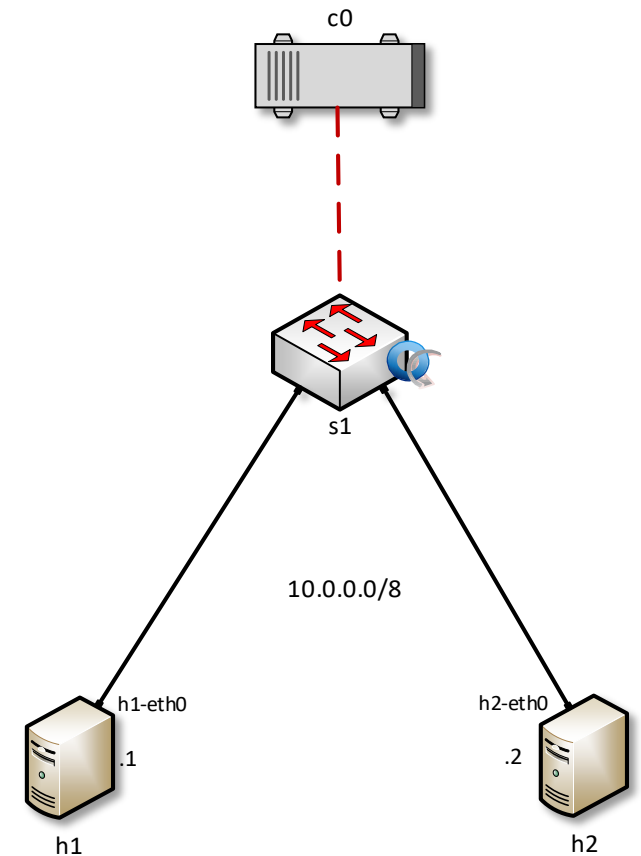
Adding Entries in the Flow Table

Adding flows to forward traffic from host h1 to host h2

```
root@admin: /home/sdn
File Actions Edit View Help
root@admin: /home/sdn
root@admin: /home/sdn# ovs-ofctl add-flow s1 in_port=1,actions=output:2
root@admin: /home/sdn#
```

Adding flows to forward traffic from host h2 to host h1

```
root@admin: /home/sdn
File Actions Edit View Help
root@admin: /home/sdn
root@admin: /home/sdn# ovs-ofctl add-flow s1 in_port=1,actions=output:2
root@admin: /home/sdn# ovs-ofctl add-flow s1 in_port=2,actions=output:1
root@admin: /home/sdn#
```



Capturing OpenFlow Messages

*Loopback: lo

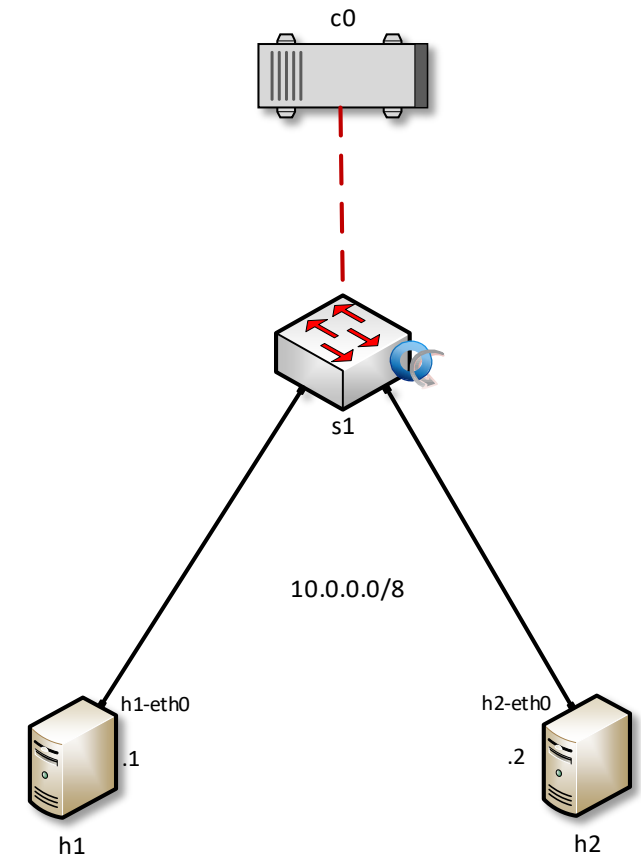
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

openflow_v1 Expression...

No.	Time	Source	Destination	Protocol	Length	Info
1275	3339.9078602...	127.0.0.1	127.0.0.1	OpenFl...	74	Type: OFPT_HELLO
1277	3340.0033178...	127.0.0.1	127.0.0.1	OpenFl...	82	Type: OFPT_FEATURES_REQUEST
1279	3340.4085241...	127.0.0.1	127.0.0.1	OpenFl...	242	Type: OFPT_FEATURES_REPLY
1281	3340.4273341...	127.0.0.1	127.0.0.1	OpenFl...	82	Type: OFPT_GET_CONFIG_REQUEST
1283	3340.4274119...	127.0.0.1	127.0.0.1	OpenFl...	74	Type: OFPT_BARRIER_REPLY
1284	3340.4274239...	127.0.0.1	127.0.0.1	OpenFl...	78	Type: OFPT_GET_CONFIG_REPLY
1286	3340.4332296...	127.0.0.1	127.0.0.1	OpenFl...	78	Type: OFPT_STATS_REQUEST
1287	3340.4332810...	127.0.0.1	127.0.0.1	OpenFl...	1134	Type: OFPT_STATS_REPLY

openflow_v1 Expression...

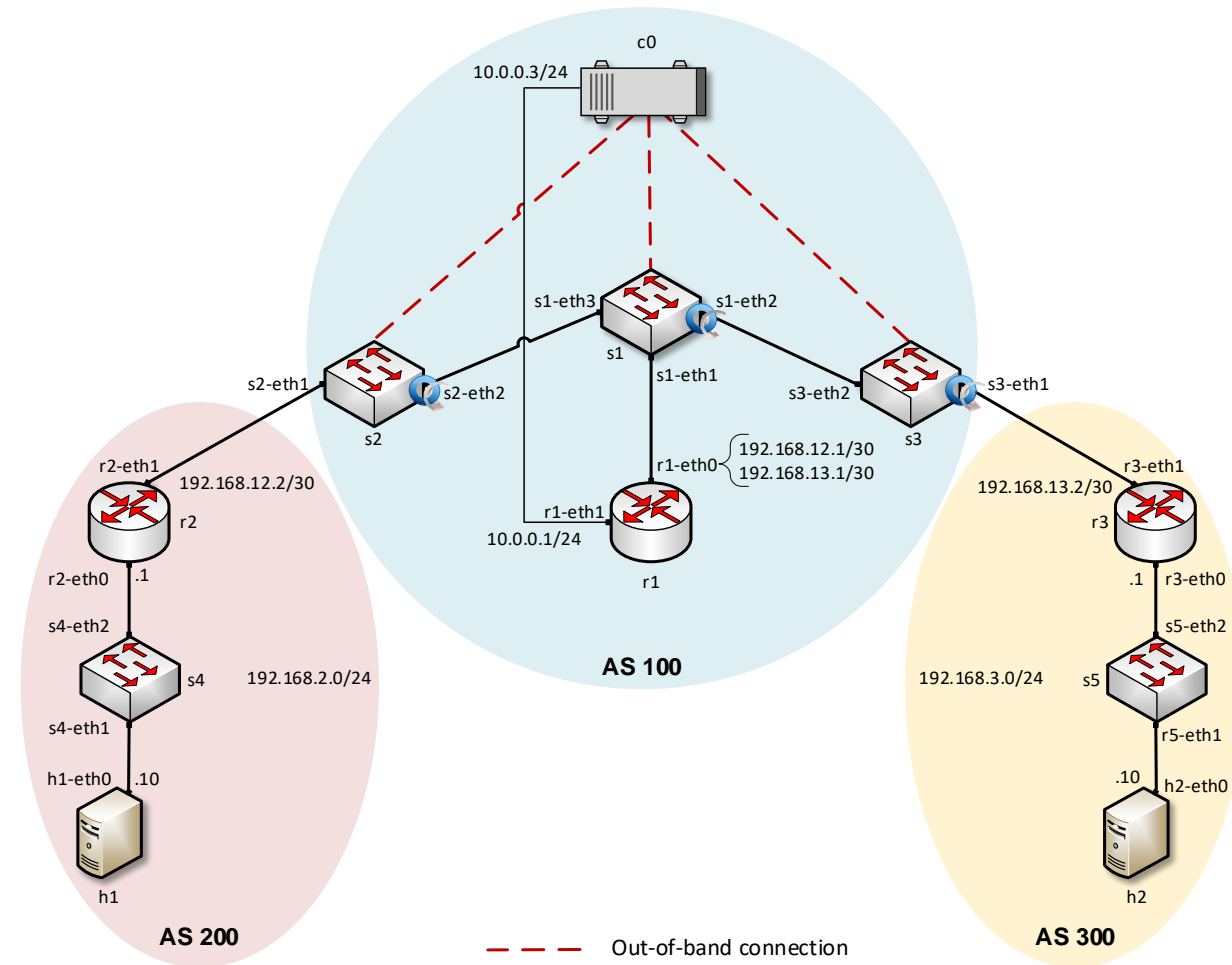
No.	Time	Source	Destination	Protocol	Length	Info
73	26.013171130	127.0.0.1	127.0.0.1	OpenFl...	78	Type: OFPT_STATS_REQUEST
74	26.013585493	127.0.0.1	127.0.0.1	OpenFl...	16334	Type: OFPT_STATS_REPLY
76	26.402409764	e2:7d:8b:63:cf:59	Broadcast	OpenFl...	126	Type: OFPT_PACKET_IN
78	26.415998945	e2:7d:8b:63:cf:59	Broadcast	OpenFl...	132	Type: OFPT_PACKET_OUT
79	26.416212343	22:66:a9:a9:88:53	e2:7d:8b:63:cf:59	OpenFl...	126	Type: OFPT_PACKET_IN
80	26.417154061	22:66:a9:a9:88:53	e2:7d:8b:63:cf:59	OpenFl...	132	Type: OFPT_PACKET_OUT
81	26.417323024	10.0.0.1	10.0.0.2	OpenFl...	182	Type: OFPT_PACKET_IN
82	26.421687260	10.0.0.1	10.0.0.2	OpenFl...	188	Type: OFPT_PACKET_OUT



Lab 8: Interconnection between legacy networks and SDN networks

Lab 8: Interconnecting Legacy and SDN networks

- Two legacy networks connected to an SDN network
- The SDN network consists of switches controlled by an ONOS controller
- The ONOS controller interacts with an application referred to as SDN-IP
- SDN-IP allows the SDN network to i) exchange BGP information with an iBGP router; and ii) translates routing information to SDN flow rules



Configuring BGP in Legacy Networks

Router r2

```
admin# exit
root@admin:/etc/routers/r2# bgpd
root@admin:/etc/routers/r2# vtysh

Hello, this is FRRouting (version 7.2-dev).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

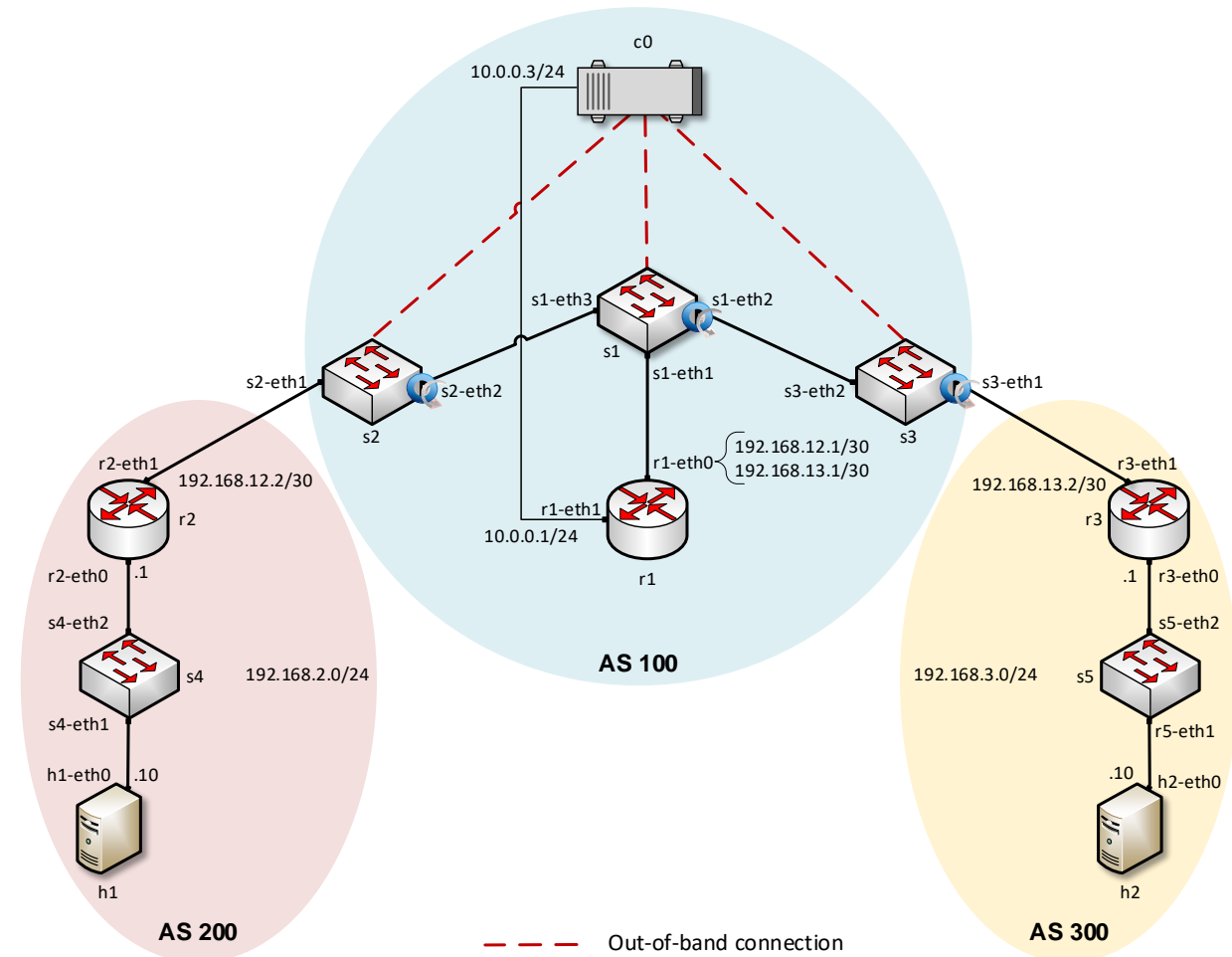
admin# configure terminal
admin(config)# router bgp 200
admin(config-router)# neighbor 192.168.12.1 remote-as 100
admin(config-router)# network 192.168.2.0/24
admin(config-router)#
```

Router r3

```
admin# exit
root@admin:/etc/routers/r3# bgpd
root@admin:/etc/routers/r3# vtysh

Hello, this is FRRouting (version 7.2-dev).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

admin# configure terminal
admin(config)# router bgp 300
admin(config-router)# neighbor 192.168.13.1 remote-as 100
admin(config-router)# network 192.168.3.0/24
admin(config-router)# end
admin#
```



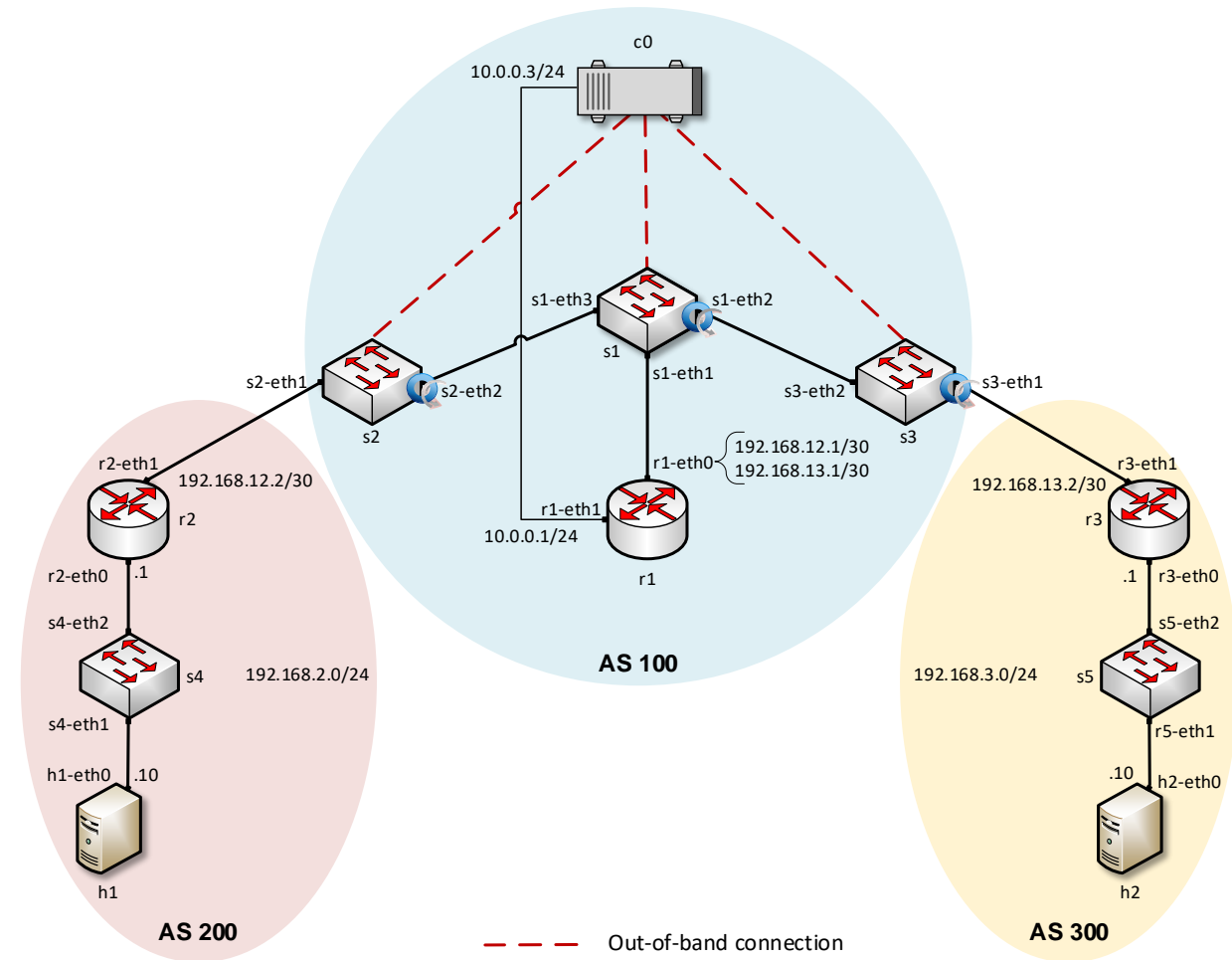
Configure BGP in SDN Network

Router r1

```
Host: r1
root@admin:/etc/routers/r1# bgpd
root@admin:/etc/routers/r1# vtysh

Hello, this is FRRouting (version 7.2-dev).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

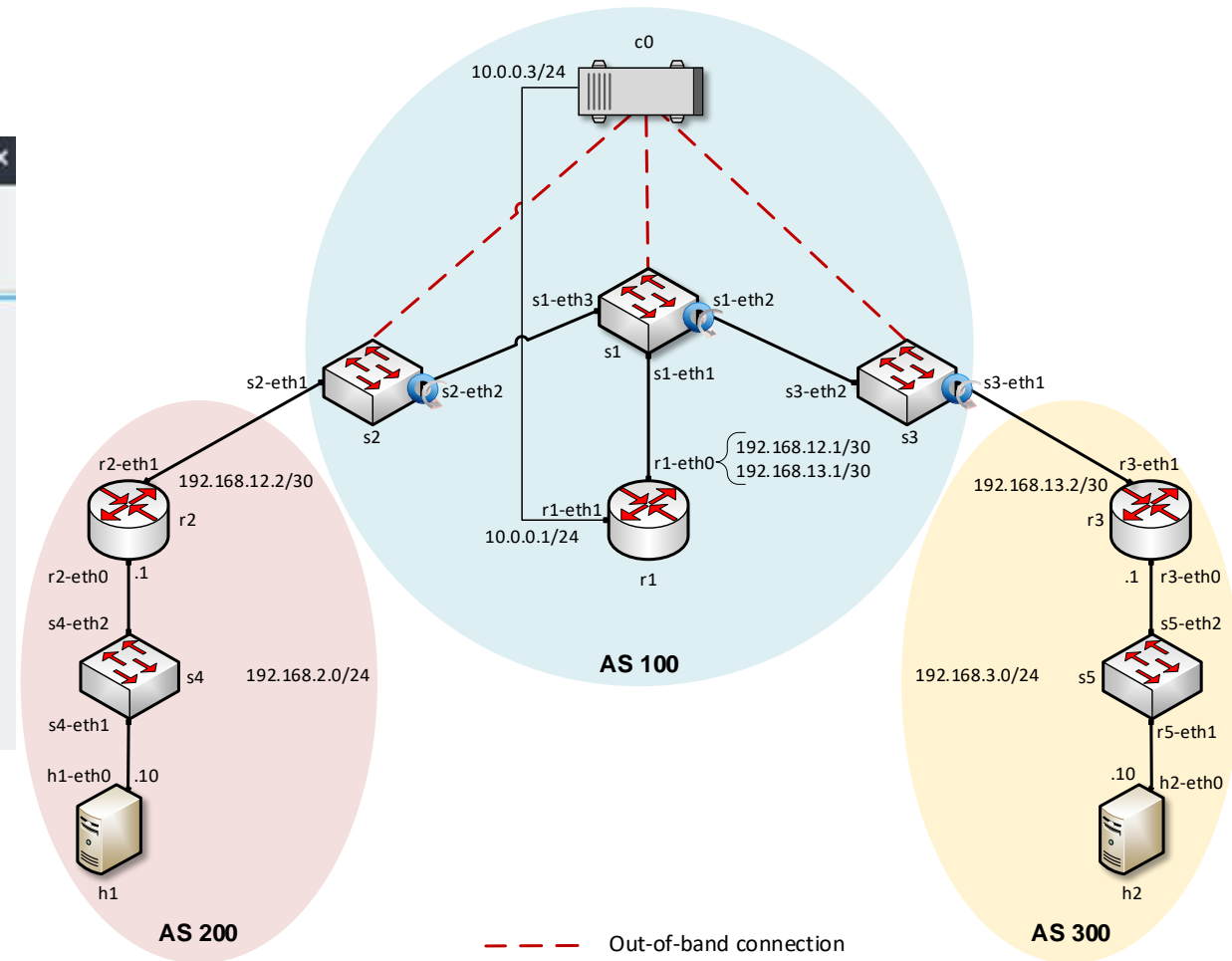
admin# configure terminal
admin(config)# router bgp 100
admin(config-router)# neighbor 192.168.12.2 remote-as 200
admin(config-router)# neighbor 192.168.13.2 remote-as 300
admin(config-router)# neighbor 10.0.0.3 remote-as 100
admin(config-router)# neighbor 10.0.0.3 port 2000
admin(config-router)#
```



SDN-IP Application

ONOS CLI – BGP neighbors

```
root@admin: /home/sdn/SDN_Labs/lab8
File Actions Edit View Help
root@admin: /home/sdn/SDN_Labs/lab8
karaf@root > bgp-neighbors 14:58:58
BGP neighbor is 192.168.13.1, remote AS 100 local AS 100
Remote router ID 192.168.13.1, IP /10.0.0.1:48998, BGP version 4, Hold time 180
Remote AFI/SAFI IPv4 Unicast YES Multicast NO, IPv6 Unicast NO Multicast NO
Local router ID 10.0.0.3 IP /10.0.0.3:2000, BGP version 4, Hold time 180
Local AFI/SAFI IPv4 Unicast YES Multicast NO, IPv6 Unicast NO Multicast NO
4 Octet AS Capability: Advertised Received
karaf@root > 14:59:00
```

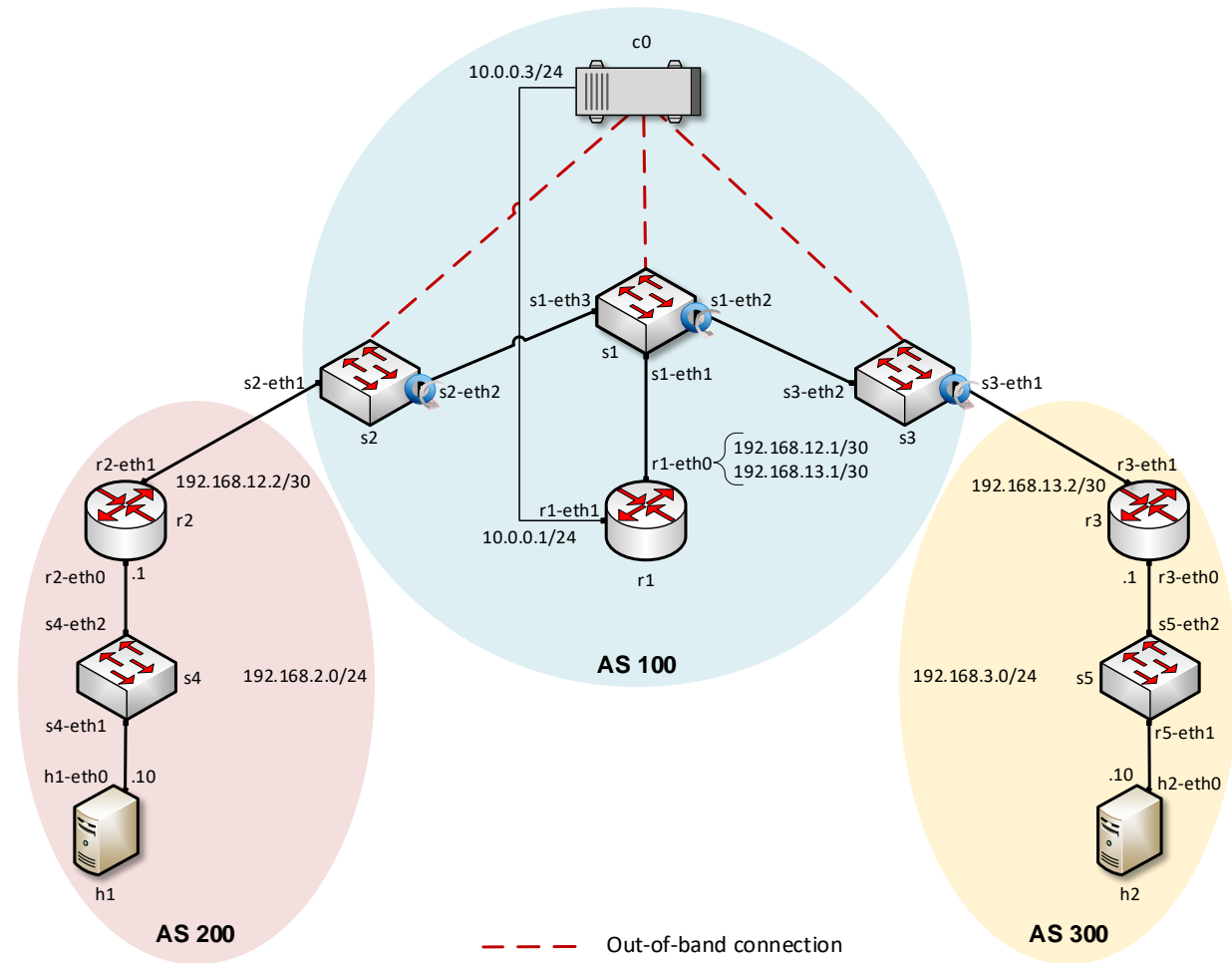


SDN-IP Application

ONOS CLI – advertised routes

```

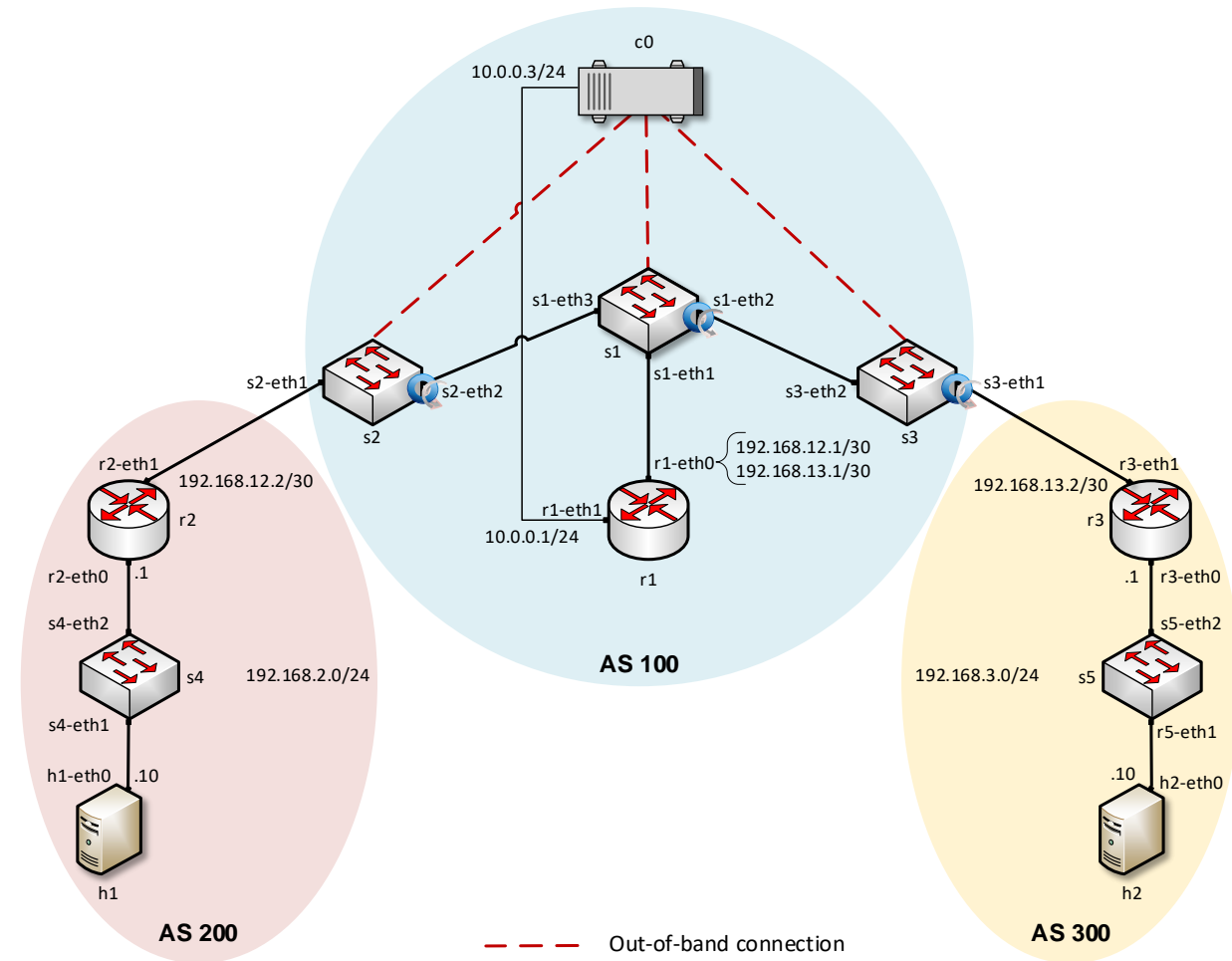
root@admin: /home/sdn/SDN_Labs/lab8
File Actions Edit View Help
root@admin: /home/sdn/SDN_Labs/lab8
karaf@root > routes
B: Best route, R: Resolved route
Table: ipv4
B R Network Next Hop Source (Node)
> * 192.168.2.0/24 192.168.12.2 BGP (172.17.0.2)
> * 192.168.3.0/24 192.168.13.2 BGP (172.17.0.2)
Total: 2
Table: ipv6
B R Network Next Hop Source (Node)
Total: 0
karaf@root >
  
```



SDN Network

BGP table of router r1

```
Host: r1
admin# show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP,
       O - OSPF, I - IS-IS, B - BGP, E - EIGRP, N - NHRP,
       T - Table, v - VNC, V - VNC-Direct, A - Babel, D - SHARP,
       F - PBR, f - OpenFabric,
       > - selected route, * - FIB route, q - queued route, r - rejected route
C>* 10.0.0.0/24 is directly connected, r1-eth1, 00:29:16
B>* 192.168.2.0/24 [20/0] via 192.168.12.2, r1-eth0, 00:06:57
B>* 192.168.3.0/24 [20/0] via 192.168.13.2, r1-eth0, 00:06:56
C>* 192.168.12.0/30 is directly connected, r1-eth0, 00:38:20
C>* 192.168.13.0/30 is directly connected, r1-eth0, 00:38:20
admin#
```

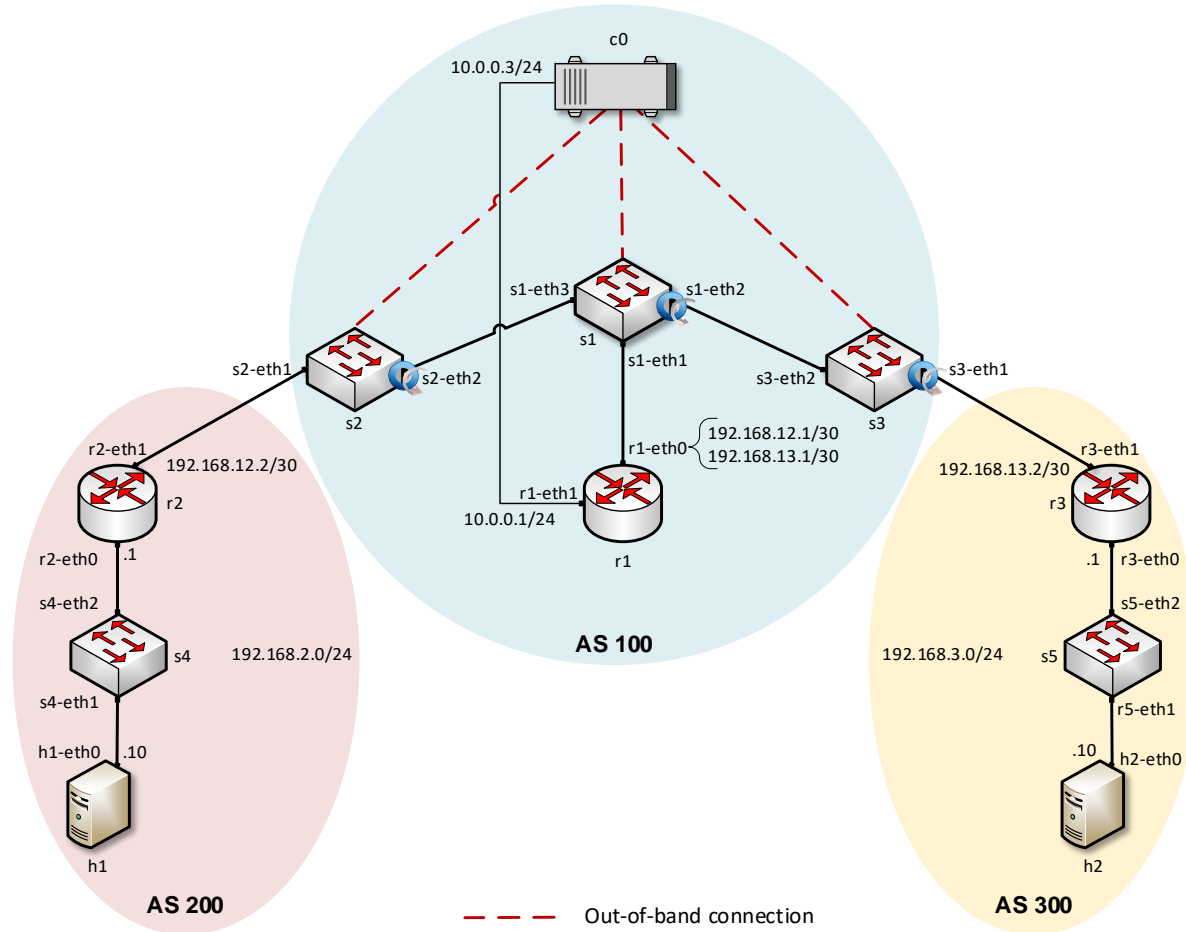


Flow Table of Switch s2 – BGP Advertisements

BGP advertisements between router r2 and router r1

```

root@admin: /home/sdn/SDN_Labs/lab8
File Actions Edit View Help
Shell No. 1
root@admin: /home/sdn/SDN_Labs/lab8
id=be000045603ee8, state=ADDED, bytes=0, packets=0, duration=160, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:1, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.2/32, IPV4_DST:192.168.12.1/32, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:2], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be0000554f4e97, state=ADDED, bytes=236, packets=3, duration=160, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:1, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.2/32, IPV4_DST:192.168.12.1/32, TCP_SRC:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:2], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be00005a947c9e, state=ADDED, bytes=0, packets=0, duration=160, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:1, ETH_TYPE:ipv4, IP_PROTO:1, IPV4_SRC:192.168.12.2/32, IPV4_DST:192.168.12.1/32], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:2], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be00008d1075d7, state=ADDED, bytes=302, packets=4, duration=160, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:2, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12.2/32, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
    
```

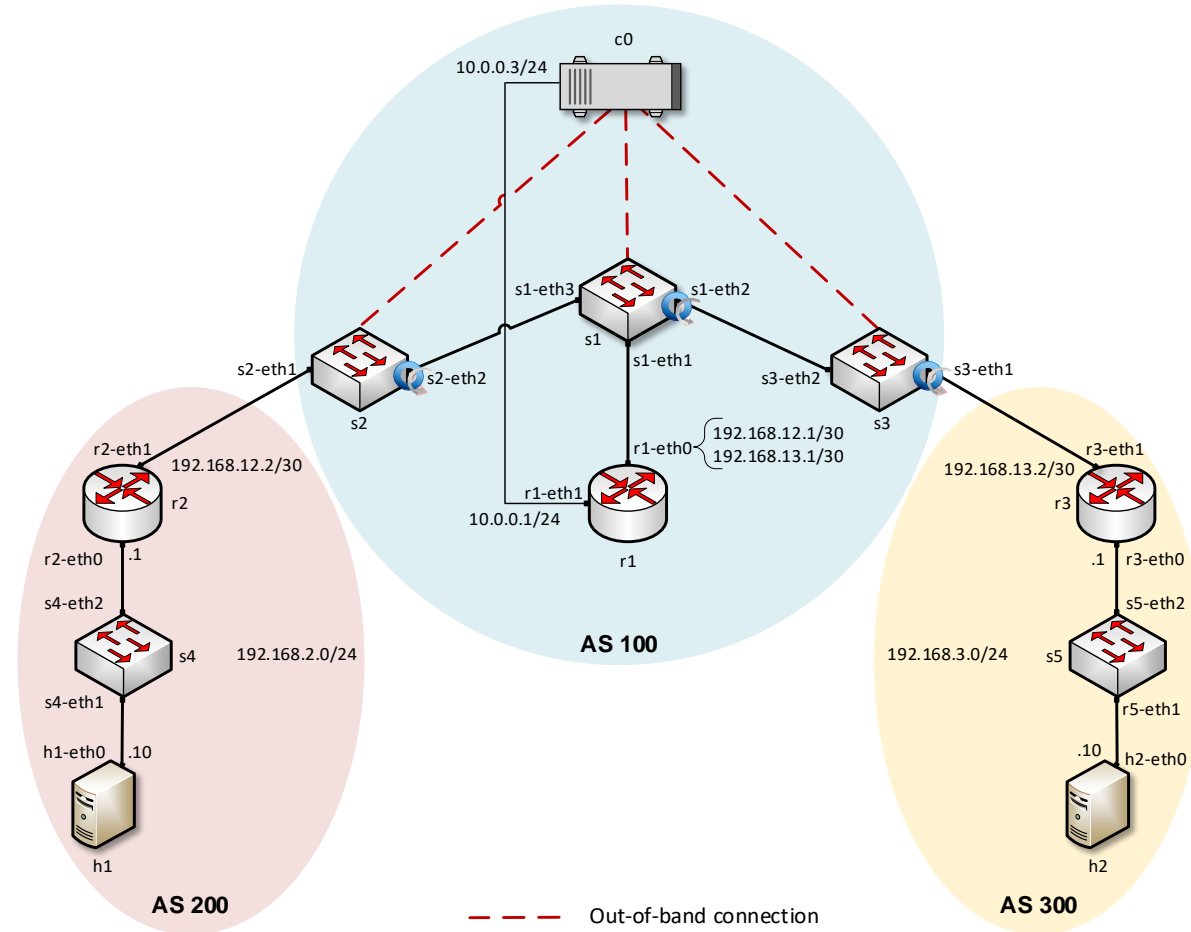


Flow Table of Switch s1 – BGP Advertisements

BGP advertisements between router r2 and router r1

```

root@admin: /home/sdn/SDN_Labs/lab8
File Actions Edit View Help
Shell No. 1 root@admin: /home/sdn/SDN_Labs/lab8
id=be00004efa1d57, state=ADDED, bytes=0, packets=0, duration=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:3, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.2/32, IPV4_DST:192.168.12.1/32, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be00006f02b188, state=ADDED, bytes=4077, packets=54, duration=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:2, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.13.2/32, IPV4_DST:192.168.13.1/32, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be00008c740563, state=ADDED, bytes=4077, packets=54, duration=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:1, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12.2/32, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:3], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
    
```



Flow Table of Switch s2 – Entry for Network 3

Flow entry that handles traffic going network 3 (192.168.3.0/24)

```

root@admin: /home/sdn/SDN_Labs/lab8
File Actions Edit View Help
Shell No. 1 root@admin: /home/sdn/SDN_Labs/lab8
2, TCP_DST:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be000090472872, state=ADDED, bytes=0, packets=0, duration=1855, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:2, ETH_TYPE:ipv4, IP_PROTO:1, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12.2/32], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be0000cce9c6c2, state=ADDED, bytes=0, packets=0, duration=1855, liveType=UNKNOWN, priority=1000, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:2, ETH_TYPE:ipv4, IP_PROTO:6, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12.2/32, TCP_SRC:179], treatment=DefaultTrafficTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
id=be0000018d5c50, state=ADDED, bytes=164052, packets=1674, duration=1746, liveType=UNKNOWN, priority=220, tableId=0, appId=org.onosproject.net.intent, selector=[IN_PORT:1, ETH_TYPE:ipv4, IPV4_DST:192.168.3.0/24], treatment=DefaultTrafficTreatment{immediate=[ETH_DST:F6:3D:44:EF:8F:53, OUTPUT:2], deferred=[], transition=None, meter=[], cleared=false, StatTrigger=null, metadata=null}
    
```

Actions :

- Change the MAC destination address to router r3 (r3-eth1)
- Forward through port 2

