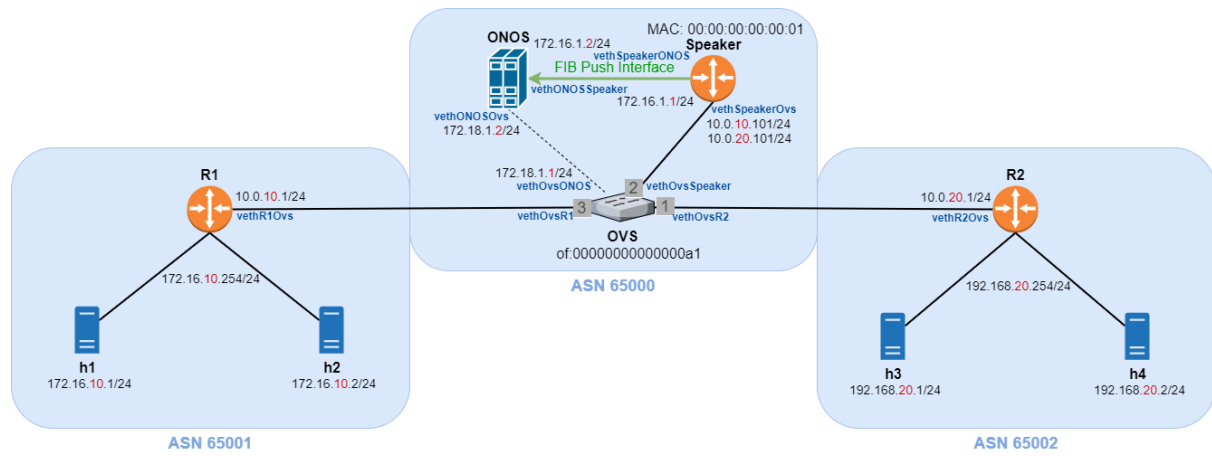


1. Show topology with IP addresses, interfaces and ASNs



2. Capture BGP packets (sent/received) on Speaker-OVS link sent and received (10.0.10.1 ⇔ 10.0.10.101)

No.	Time	Source	Destination	Protocol	Length	Info
5	0.462476367	10.0.10.1	10.0.10.101	BGP	85	KEEPALIVE Message
6	0.462485592	10.0.10.101	10.0.10.1	TCP	66	47110 → 179 [ACK] Seq=1 Ack=20 Win=502 Len=0 TSval=1619154050 TSecr=1724922535
7	0.462529187	10.0.10.101	10.0.10.1	BGP	85	KEEPALIVE Message
8	0.516046937	10.0.10.1	10.0.10.101	TCP	66	179 → 47110 [ACK] Seq=20 Ack=20 Win=508 Len=0 TSval=1724922588 TSecr=1619154050

Frame 5: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface 0

Interface id: 0 (vethSpeakerOvs)
Interface name: vethSpeakerOvs
Encapsulation type: Ethernet (1)
Arrival Time: Jan 7, 2022 17:02:41.457489434 UTC
[Time shift for this packet: 0.000000000 seconds]
Epoch Time: 1641574961.457489434 seconds
[Time delta from previous captured frame: 0.417487450 seconds]
[Time delta from previous displayed frame: 0.000000000 seconds]
[Time since reference or first frame: 0.462476367 seconds]
Frame Number: 5
Frame Length: 85 bytes (680 bits)
Capture Length: 85 bytes (680 bits)
[Frame is marked: False]
[Frame is ignored: False]
[Protocols in frame: eth:ethertype:ip:tcp:bgp]
[Coloring Rule Name: Routing]
[Coloring Rule String: hsrp || eigrp || ospf || bgp || cdp || vrrp || carp || gvrp || igmp || ismp]
Ethernet II, Src: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5), Dst: 00:00:00:00:00:01 (00:00:00:00:00:01)
Destination: 00:00:00:00:00:01 (00:00:00:00:00:01)
...0. = LG bit: Globally unique address (factory default)
...0. = IG bit: Individual address (unicast)
Source: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5)
Address: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5)
...1. = LG bit: Locally administered address (this is NOT the factory default)
...0. = IG bit: Individual address (unicast)
Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 10.0.10.1, Dst: 10.0.10.101
0100 ... = Version: 4
...0101 = Header Length: 20 bytes (5)
Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
Total Length: 71
Identification: 0x1892 (6290)
Flags: 0x4000, Don't fragment
Time to live: 255
Protocol: TCP (6)
Header checksum: 0x39f9 [validation disabled]
[Header checksum status: Unverified]
Source: 10.0.10.1
Destination: 10.0.10.101
Transmission Control Protocol, Src Port: 179, Dst Port: 47110, Seq: 1, Ack: 1, Len: 5
Border Gateway Protocol - KEEPALIVE Message
Marker: ffffffffffffffffffffffffffff
Length: 19
Type: KEEPALIVE Message (4)

No.	Time	Source	Destination	Protocol	Length	Info
5	0.462476367	10.0.10.1	10.0.10.101	BGP	85	KEEPALIVE Message
6	0.462485592	10.0.10.101	10.0.10.1	TCP	66	47110 → 179 [ACK] Seq=1 Ack=20 Win=502 Len=0 TSval=1619154050 TSecr=1724922535
7	0.462529187	10.0.10.101	10.0.10.1	BGP	85	KEEPALIVE Message
8	0.516046937	10.0.10.1	10.0.10.101	TCP	66	179 → 47110 [ACK] Seq=20 Ack=20 Win=508 Len=0 TSval=1724922588 TSecr=1619154050

Frame 7: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface 0

Interface id: 0 (vethSpeakerOvs)
Interface name: vethSpeakerOvs
Encapsulation type: Ethernet (1)
Arrival Time: Jan 7, 2022 17:02:41.457542254 UTC
[Time shift for this packet: 0.000000000 seconds]
Epoch Time: 1641574961.457542254 seconds
[Time delta from previous captured frame: 0.000043595 seconds]
[Time delta from previous displayed frame: 0.000043595 seconds]
[Time since reference or first frame: 0.462529187 seconds]
Frame Number: 7
Frame Length: 85 bytes (680 bits)
Capture Length: 85 bytes (680 bits)
[Frame is marked: False]
[Frame is ignored: False]
[Protocols in frame: eth:ethertype:ip:tcp:bgp]
[Coloring Rule Name: Routing]
[Coloring Rule String: hsrp || eigrp || ospf || bgp || cdp || vrrp || carp || gvrp || igmp || ismp]
Ethernet II, Src: 00:00:00:00:00:01 (00:00:00:00:00:01), Dst: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5)
Destination: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5)
Address: 3a:dd:95:56:8f:e5 (3a:dd:95:56:8f:e5)
...1. = LG bit: Locally administered address (this is NOT the factory default)
...0. = IG bit: Individual address (unicast)
Source: 00:00:00:00:00:01 (00:00:00:00:00:01)
Address: 00:00:00:00:00:01 (00:00:00:00:00:01)
...0. = LG bit: Globally unique address (factory default)
...0. = IG bit: Individual address (unicast)
Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 10.0.10.1, Dst: 10.0.10.1
0100 ... = Version: 4
...0101 = Header Length: 20 bytes (5)
Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
Total Length: 71
Identification: 0x40d2 (16594)
Flags: 0x4000, Don't fragment
Time to live: 255
Protocol: TCP (6)
Header checksum: 0x11b9 [validation disabled]
[Header checksum status: Unverified]
Source: 10.0.10.1
Destination: 10.0.10.1
Transmission Control Protocol, Src Port: 47110, Dst Port: 179, Seq: 1, Ack: 20, Len: 19
Border Gateway Protocol - KEEPALIVE Message
Marker: ffffffffffffffffffffffffffff
Length: 19
Type: KEEPALIVE Message (4)

sent and received (10.0.20.1 ⇔ 10.0.20.101)

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.20.1	10.0.20.101	BGP	65	KEEPALIVE Message
2	0.000019424	10.0.20.101	10.0.20.1	TCP	66	179 → 40540 [ACK] Seq=1 Ack=20 Win=509 Len=0 TSval=2922809307 TSecr=2204472482
3	0.001699207	10.0.20.101	10.0.20.1	BGP	85	KEEPALIVE Message
4	0.04498917	10.0.20.1	10.0.20.101	TCP	66	40540 → 179 [ACK] Seq=20 Ack=20 Win=502 Len=0 TSval=2204472527 TSecr=2922809309

▼ Frame 1: 85 bytes captured (680 bits) on interface 0

- Interface id: 0 (vethSpeaker0vs)
- Interface name: vethSpeaker0vs
- Encapsulation type: Ethernet (1)
- Arrival Time: Jan 7, 2022 17:02:40.995013067 UTC
- [Time shift for this packet: 0.00000000 seconds]
- Epoch Time: 1641574960.995013067 seconds
- [Time delta from previous captured frame: 0.000000000 seconds]
- [Time delta from previous displayed frame: 0.000000000 seconds]
- [Time since reference or first frame: 0.000000000 seconds]
- Frame Number: 1
- Frame Length: 85 bytes (680 bits)
- Capture Length: 85 bytes (680 bits)
- [Frame is marked: False]
- [Frame is ignored: False]
- [Protocols in frame: eth:ethertype:ip:tcp:bgp]
- [Coloring Rule Name: Routing]
- [Coloring Rule String: bgp || ospf || bgp || cdp || vrrp || carp || gvrp || igmp || ismp]

▼ Ethernet II, Src: 02:70:73:b5:27:59 (02:70:73:b5:27:59), Dst: 00:00:00:00:00:01 (00:00:00:00:00:01)

- Destination: 00:00:00:00:00:01 (00:00:00:00:00:01)
 - Address: 00:00:00:00:00:01 (00:00:00:00:00:01)
 - ...0 = LG bit: Globally unique address (factory default)
 - ...0 = IG bit: Individual address (unicast)
- Source: 02:70:73:b5:27:59 (02:70:73:b5:27:59)
 - Address: 02:70:73:b5:27:59 (02:70:73:b5:27:59)
 - ...1 = LG bit: Locally administered address (this is NOT the factory default)
 - ...0 = IG bit: Individual address (unicast)
 - Type: IPv4 (0x0800)

▼ Internet Protocol Version 4, Src: 10.0.20.1, Dst: 10.0.20.101

- 0100 ... = Version: 4
- 0101 = Header Length: 20 bytes (5)
- Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
- Total Length: 71
- Identification: 0xd8a7 (55463)
- Flags: 0x4000, Don't fragment
- Time to live: 255
- Protocol: TCP (6)
- Header checksum: 0x65e3 [validation disabled]
- [Header checksum status: Unverified]
- Source: 10.0.20.1
- Destination: 10.0.20.101

► Transmission Control Protocol, Src Port: 40540, Dst Port: 179, Seq: 1, Ack: 1, Len: 19

► Border Gateway Protocol - KEEPALIVE Message

- Marker: ffffffff...
- Length: 19
- Type: KEEPALIVE Message (4)

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.20.1	10.0.20.101	BGP	85	KEEPA L I V E Message
2	0.000010424	10.0.20.101	10.0.20.1	TCP	66	179 → 40540 [ACK] Seq=1 Ack=20 Win=509 Len=0 TSval=2922809307 TSecr=2204472482
3	0.001699207	10.0.20.101	10.0.20.1	BGP	85	KEEPA L I V E Message
4	0.044988917	10.0.20.1	10.0.20.101	TCP	66	40540 → 179 [ACK] Seq=20 Ack=20 Win=502 Len=0 TSval=2204472527 TSecr=2922809309

Frame 3: 85 bytes on wire (680 bits) 85 bytes captured (680 bits) on interface 0

- Interface id: 0 (vethSpeaker0vs)
 - Interface name: vethSpeaker0vs
 - Encapsulation type: Ethernet (1)
 - Arrival Time: Jan 7, 2022 17:02:40.996712274 UTC
 - [Time shift for this packet: 0.000000000 seconds]
 - Epoch Time: 1641574960.996712274 seconds
 - [Time delta from previous captured frame: 0.001688783 seconds]
 - [Time delta from previous displayed frame: 0.001688783 seconds]
 - [Time since reference or first frame: 0.001699207 seconds]
 - Frame Number: 3
 - Frame Length: 85 bytes (680 bits)
 - Capture Length: 85 bytes (680 bits)
 - [Frame is marked: False]
 - [Frame is ignored: False]
 - [Protocols in frame: eth:ethertype:ip:tcp:bgp]
 - [Coloring Rule Name: Routing]
 - [Coloring Rule String: hqhp-ll-bgp-ll-cdp-ll-vrrp-ll-carp-ll-ovpn-ll-icmp-ll-igmp]
- Ethernet II, Src: 00:00:00:00:00:01 (00:00:00:00:00:01), Dst: 02:70:73:b5:27:59 (02:70:73:b5:27:59)
 - Destination: 02:70:73:b5:27:59 (02:70:73:b5:27:59)
 - Address: 02:70:73:b5:27:59 (02:70:73:b5:27:59)
 -1. = LG bit: Locally administered address (this is NOT the factory default)
 -0. = IG bit: Individual address (unicast)
 - Source: 00:00:00:00:00:01 (00:00:00:00:00:01)
 - Address: 00:00:00:00:00:01 (00:00:00:00:00:01)
 -0. = LG bit: Globally unique address (factory default)
 -0. = IG bit: Individual address (unicast)
 - Type: IPv4 (0x0800)
- Internet Protocol Version 4, Src: 10.0.20.101, Dst: 10.0.20.1
 - 0100 = Version: 4
 - ... 0101 = Header Length: 20 bytes (5)
 - Differentiated Services Field: 0xc0 (DSCP: CS6, ECN: Not-ECT)
 - Total Length: 71
 - Identification: 0x8d94 (36244)
 - Flags: 0x4000, Don't fragment
 - Time to live: 255
 - Protocol: TCP (6)
 - Header checksum: 0xb0f6 [validation disabled]
 - [Header checksum status: Unverified]
 - Source: 10.0.20.101
 - Destination: 10.0.20.1
- Transmission Control Protocol, Src Port: 179, Dst Port: 40540, Seq: 1, Ack: 20, Len: 19
- Border Gateway Protocol - KEEPA L I V E Message
 - Marker: ffffffff
 - Length: 19
 - Type: KEEPA L I V E Message (4)

3. Telnet zebra and bgpd daemons on Speaker and show BGP summary routes

```
/home/q/G/final-project docker exec -it Speaker bash ✓ root@SDN-NFV 12:48:53 朝
root@1b6401fbfeca:/# telnet localhost 2601
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.24.1).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification                                     zebra (ip route)

Password:
Speakerzebra> show ip route bgp
Codes: K - kernel route, C - connected, S - static, R - RIP,
       O - OSPF, I - IS-IS, B - BGP, P - PIM, A - Babel,
       > - selected route, * - FIB route

B>* 172.16.10.0/24 [20/0] via 10.0.10.1, vethSpeakerOvs, 00:10:46
B>* 192.168.20.0/24 [20/0] via 10.0.20.1, vethSpeakerOvs, 00:10:50
Speakerzebra> exit
Connection closed by foreign host.
root@1b6401fbfeca:/# telnet localhost 2605
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.24.1).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification                                     bgpd (ip summary)

Password:
SpeakerBGP> show ip bgp summary
BGP router identifier 10.0.10.101, local AS number 65000
RIB entries 5, using 560 bytes of memory
Peers 2, using 9136 bytes of memory

Neighbor      V      AS MsgRcvd MsgSent   TblVer  InQ  OutQ Up/Down  State/PfxRcd
10.0.10.1      4 65001   1255   1262     0    0    0 00:11:32      1
10.0.20.1      4 65002   1255   1263     0    0    0 00:11:36      1

Total number of neighbors 2
```

4. Show command "routes" result in ONOS CLI

```
/home/g/G/final-project docker exec -it ONOS bash
root@901aebaaba7f:~/onos# ssh -p 8101 karaf@localhost
Password authentication
Password:
Welcome to Open Network Operating System (ONOS)!

  ONOS

Documentation: wiki.onosproject.org
Tutorials:    tutorials.onosproject.org
Mailing lists: lists.onosproject.org

Come help out! Find out how at: contribute.onosproject.org

Hit '<tab>' for a list of available commands
and '[cmd] --help' for help on a specific command.
Hit '<ctrl-d>' or type 'logout' to exit ONOS session.

karaf@root > routes
B: Best route, R: Resolved route

Table: ipv4
B R Network Next Hop Source (Node)
> * 172.16.10.0/24 10.0.10.1 FPM (172.17.0.2)
> * 192.168.20.0/24 10.0.20.1 FPM (172.17.0.2)
Total: 2

Table: ipv6
B R Network Next Hop Source (Node)
Total: 0
```

5. h1 can ping h4 successfully (show result with screenshot)

According to question1, here the pictures show the h1 and h2 ip addresses.



```
/home/g/G/final-project docker exec -it h1 bash
root@9c6562deb460:/# ping 192.168.20.2 -c 3
PING 192.168.20.2 (192.168.20.2) 56(84) bytes of data.
64 bytes from 192.168.20.2: icmp_seq=1 ttl=62 time=4.03 ms
64 bytes from 192.168.20.2: icmp_seq=2 ttl=62 time=0.083 ms
64 bytes from 192.168.20.2: icmp_seq=3 ttl=62 time=0.069 ms

--- 192.168.20.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2007ms
rtt min/avg/max/mdev = 0.069/1.394/4.031/1.864 ms
root@9c6562deb460:/#
```

6. Write down what you have learned or solved

I had trouble when I tried to implement the example scenario. I can't let Speaker and Router learn each route from bgp after activating ONOS apps. I retried lots of times, but I can't figure out what step I did wrong. After describing my trouble to TA, TA gives me some excellent debug ways and other suggestions, and then I figure out my mistakes of incorrect configuration(typo). I really appreciate TA. Thanks a lot.

Not only above mentioned, I also learned how to add ip links on linux os device, and assign mac address to the link interface. And I can know how to check interfaces already connect to each other by using "ip a | grep veth". Also, I can understand how to set the network configuration of a soft router, and let OVS switch added flow rules through ONOS control. It seems like I learned more knowledge about SDN, even though I'm still a beginner in the SDN world, it is meaningful to me.