Software-Defined Networks

Lab 2
GNS3 – Mininet Integration & Hardware

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Summary

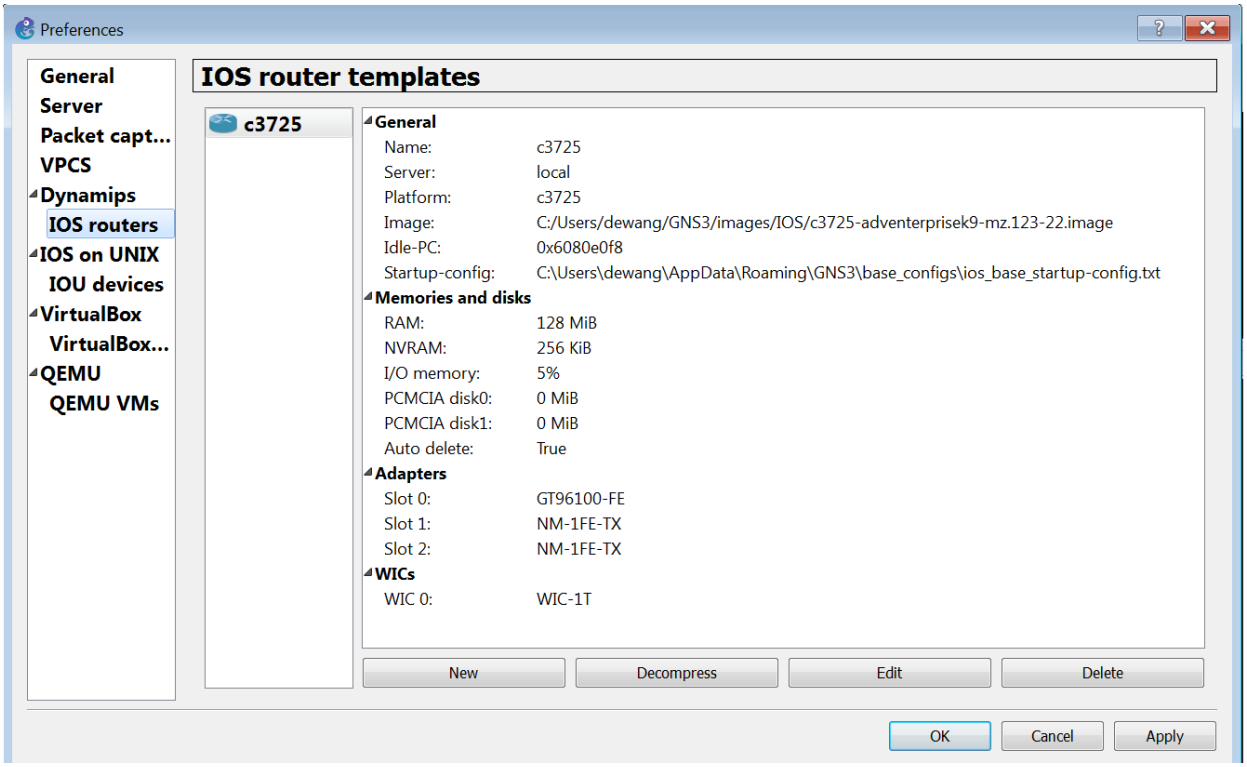
The real world currently encompasses proprietary devices from vendors such as Cisco, Juniper, Brocade, and Arista. The world is moving from these traditional networks to a software-defined one. However, this transition is slow and requires a hybrid approach before phasing out the traditional hardware. This lab acquaints you with virtual and physical hardware, as well as traditional and SDN using GNS3, networking hardware, and Mininet in a hybrid topology. Please use this lab as a base to develop much more complex topologies to demonstrate a traditional and SDN hybrid network.

Part 1: GNS3 – Mininet Integration

Objective 1 – Install GNS3

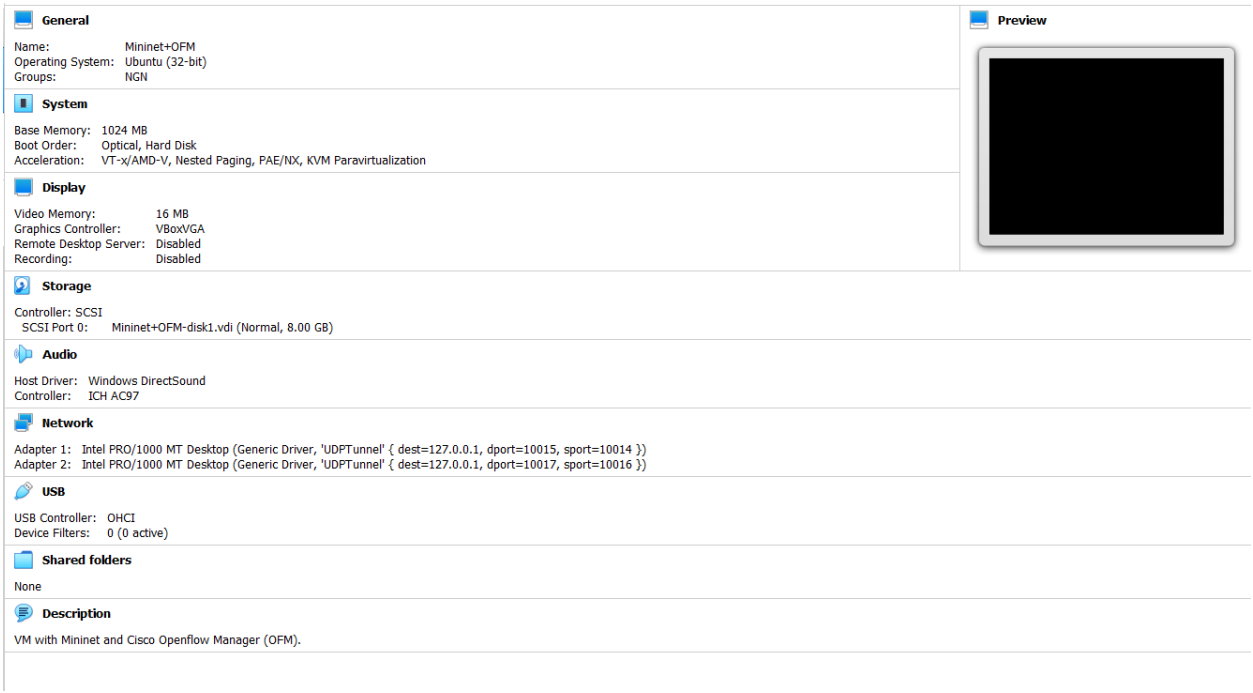
1. Visit http://gns3.com/ and download the latest version of GNS3 available.
2. Make sure you have an IOS image to be used in your router. If not, then please download the following image by searching on web:

3. Add the IOS image to the list of images in GNS3 as shown below: **[5 points]**

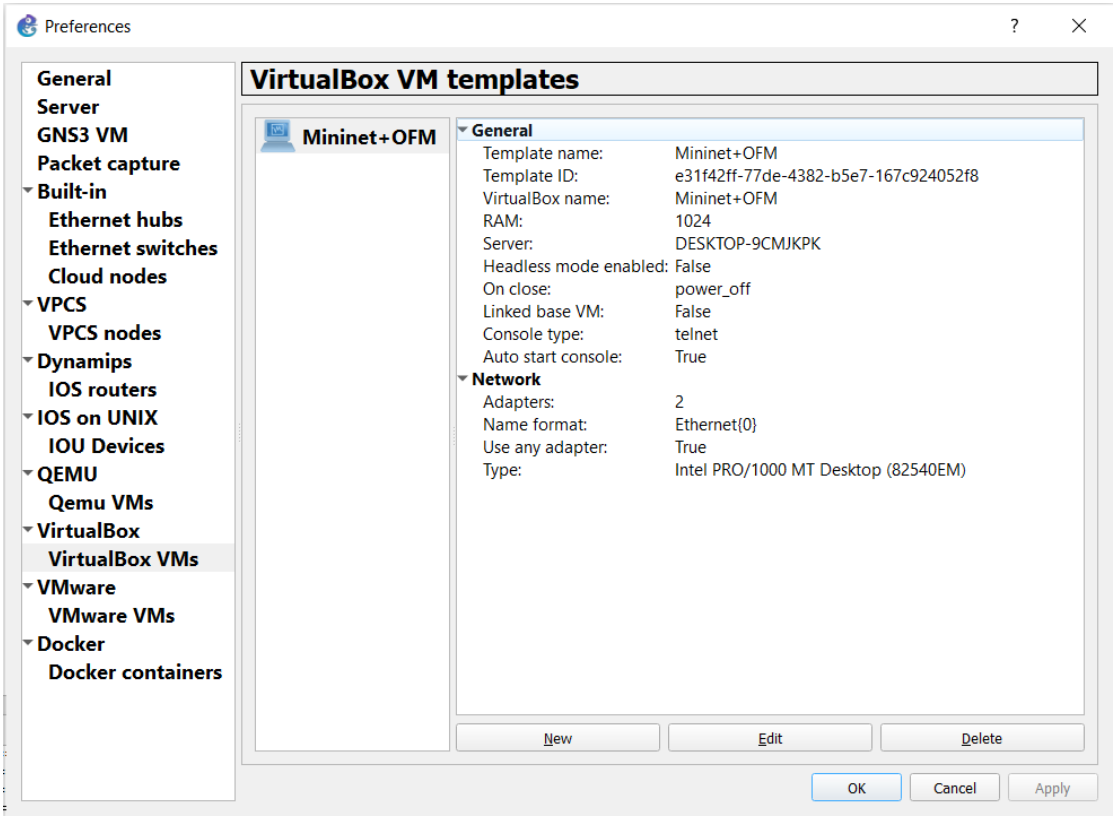


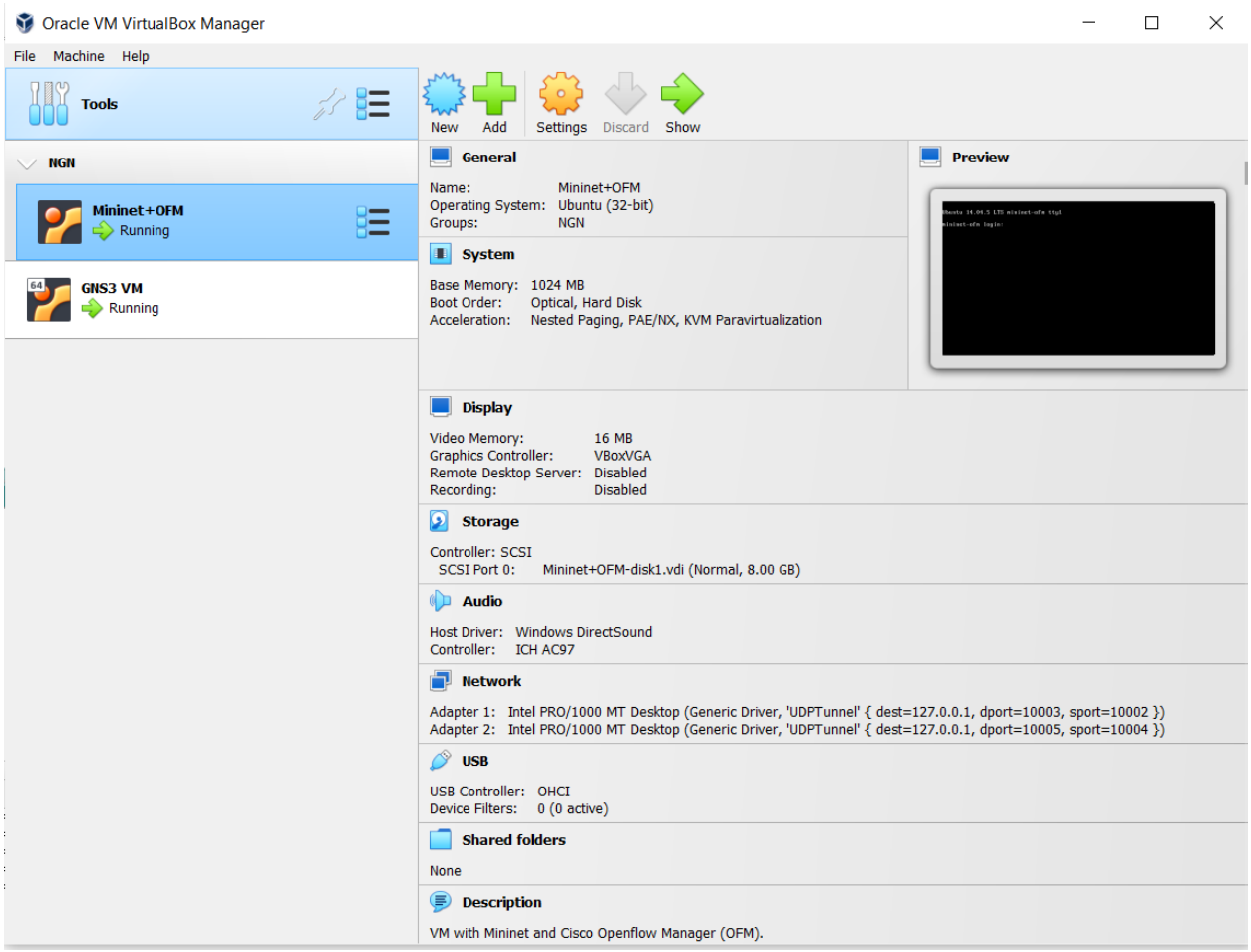
Objective 2 - Integrating Mininet with VirtualBox

1. Configure two network interfaces as 'Not Attached' for the Mininet+OFM VM.



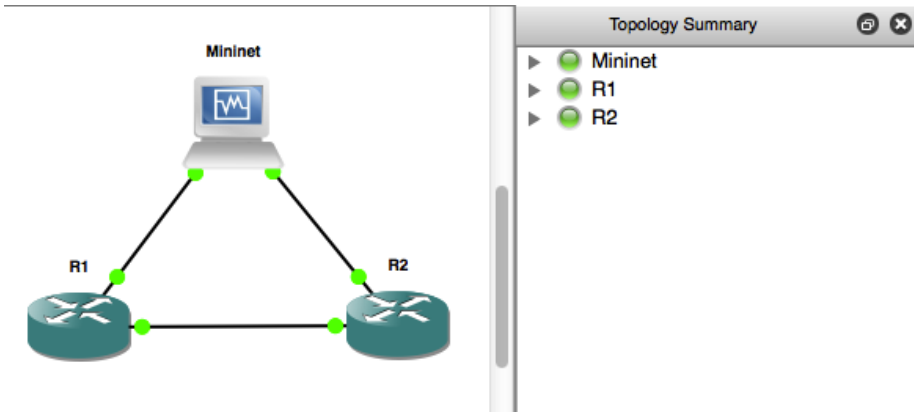
2. Add Mininet VM and enable console support for it by going to **Edit > Preferences > VirtualBox > New** in GNS3. Paste the screenshot after successfully adding the Mininet VM in VirtualBox by going to **Edit > Preferences > VirtualBox**. **[10 points]**

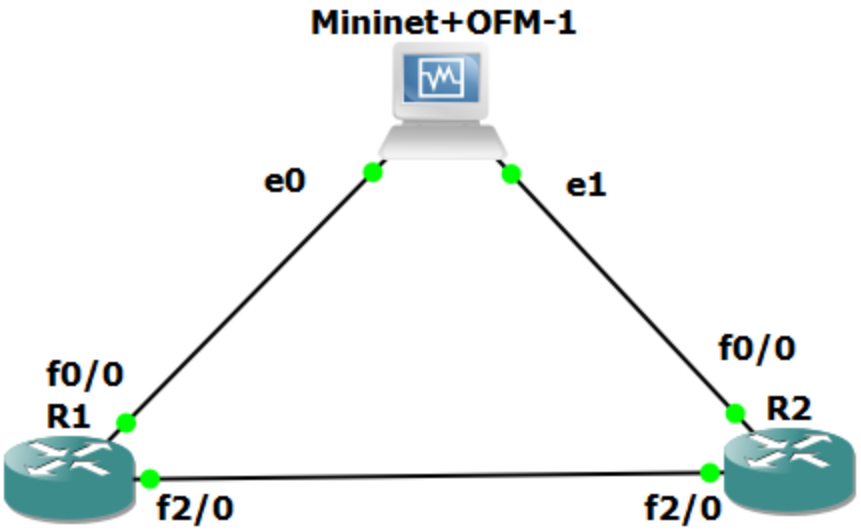




Objective 3 - Topology Creation and Achieving Connectivity

1. Create the topology in GNS3 as shown **[10 points]**





2. Start all the devices and add IP addresses to the interfaces of R1 and R2 such that the ones connecting Mininet are in 10.0.0.0/24 network excluding 10.0.0.1 and 10.0.0.2 (which will be used for end hosts inside Mininet VM) and the link connecting R1 and R2 in the 20.0.0.0/24 network.Use Cisco CLI to configure interfaces of routers. Issue the appropriate Cisco CLI command to indicate all the router IP addresses and interface status. **[10 points]**

```
mininet> py h1.IP()
10.0.0.1
mininet> py h2.IP()
10.0.0.2
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
s1 lo:  s1-eth1:h1-eth0 s1-eth2:h2-eth0
c0
mininet>
```

```
R1#sh ip int br
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            10.0.0.10       YES manual up                    up
Serial0/0                  unassigned      YES unset  administratively down down
FastEthernet0/1            unassigned      YES unset  administratively down down
Serial0/1                  unassigned      YES unset  administratively down down
Serial0/2                  unassigned      YES unset  administratively down down
Serial0/3                  unassigned      YES unset  administratively down down
FastEthernet1/0            unassigned      YES unset  administratively down down
FastEthernet2/0            20.0.0.1        YES manual up                    up
R1#
```

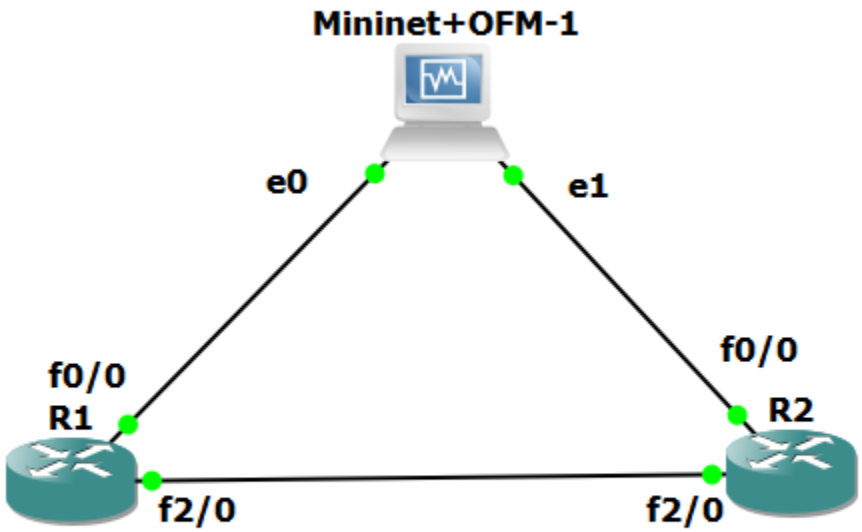
```
R2#sh ip int br
Interface                  IP-Address      OK? Method Status                Protocol
FastEthernet0/0            10.0.0.11       YES manual up                    up
Serial0/0                  unassigned      YES unset  administratively down down
FastEthernet0/1            unassigned      YES unset  administratively down down
Serial0/1                  unassigned      YES unset  administratively down down
Serial0/2                  unassigned      YES unset  administratively down down
Serial0/3                  unassigned      YES unset  administratively down down
FastEthernet1/0            unassigned      YES unset  administratively down down
FastEthernet2/0            20.0.0.2        YES manual up                    up
R2#
```

3. Initialize the default Mininet network topology using **sudo mn** and bind the interfaces to the actual physical interfaces using following two commands:

   Mininet> py s1.attach('eth0')

   Mininet> py s1.attach('eth1')

   a. Paste the screenshot of the topology created in Mininet **[20 points]**



2. Check for full connectivity by pinging R2 from R1. Paste the screenshot of the ping command **[10 points]**

```
R2#ping 10.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/10/16 ms
R2#ping 10.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/8/12 ms
```

```
R1#ping 10.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/10/20 ms
R1#ping 10.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/10/16 ms
R1#
```

```
R1#ping 20.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/9/12 ms
R1#
```

```
R2#ping 20.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 12/19/28 ms
R2#
```

3. Enable ARP debugging on the routers to check the MAC address and IP mapping learned. Achieve router end-to-end connectivity. Paste the screenshot of the ARP debug results seen after executing ARP debugging on R1 and R2, that indicates the virtual hosts MAC addresses. **[10 points]**

```
R1#ping 10.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 8/12/16 ms
R1#ping 10.0.0.2
*Mar  1 02:31:45.683: IP ARP: rcvd req src 10.0.0.1 2a42.a2bf.2869, dst 10.0.0.10 FastEthernet0/0
*Mar  1 02:31:45.687: IP ARP: sent rep src 10.0.0.10 c201.0c88.0000,
                 dst 10.0.0.1 2a42.a2bf.2869 FastEthernet0/0
R1#ping 10.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/10/20 ms
R1#
*Mar  1 02:31:59.247: IP ARP: rcvd req src 10.0.0.2 86e3.a019.1279, dst 10.0.0.10 FastEthernet0/0
*Mar  1 02:31:59.247: IP ARP: sent rep src 10.0.0.10 c201.0c88.0000,
                 dst 10.0.0.2 86e3.a019.1279 FastEthernet0/0
R1#
```

```
R2#ping 10.0.0.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/9/20 ms
R2#
*Mar  1 02:29:22.743: IP ARP: rcvd req src 10.0.0.1 2a42.a2bf.2869, dst 10.0.0.11 FastEthernet0/0
*Mar  1 02:29:22.743: IP ARP: sent rep src 10.0.0.11 c202.3850.0000,
                 dst 10.0.0.1 2a42.a2bf.2869 FastEthernet0/0
R2#ping 10.0.0.2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/8/16 ms
R2#
*Mar  1 02:29:37.919: IP ARP: rcvd req src 10.0.0.2 86e3.a019.1279, dst 10.0.0.11 FastEthernet0/0
*Mar  1 02:29:37.919: IP ARP: sent rep src 10.0.0.11 c202.3850.0000,
                 dst 10.0.0.2 86e3.a019.1279 FastEthernet0/0
```

Objective 4 – Report Questions

1. Why do you think this lab is relevant for SDN? (*Think critically about virtualization, traditional networks, hybrid networks, etc.)* **[5 points]**

Integrating Mininet with GNS3 allows us to create topology in GNS3 and route as required based on the controller decisions configured in the Mininet.

However, if we were to consider GNS3 as a set of actual physical networking components and Mininet networking devices as virtualized components, we can achieve extreme availability. We can write apps to monitor traffic on the actual physical networking components and spun more

networking components in a virtualized environment, depending on the traffic received, allowing us to scale up and scale down as per the requirements of the traffic.

Thus, SDN can allow us to scale into the cloud when the in house Datacenter is running at capacity, by spinning more instances of network components in the cloud.

Additionally, we can also use this as a hybrid model of SDN where certain components in GNS3 and Mininet are performing networking using traditional protocols and others are using Controllers to make decisions.

Part – II: Installing OVS in GNS3

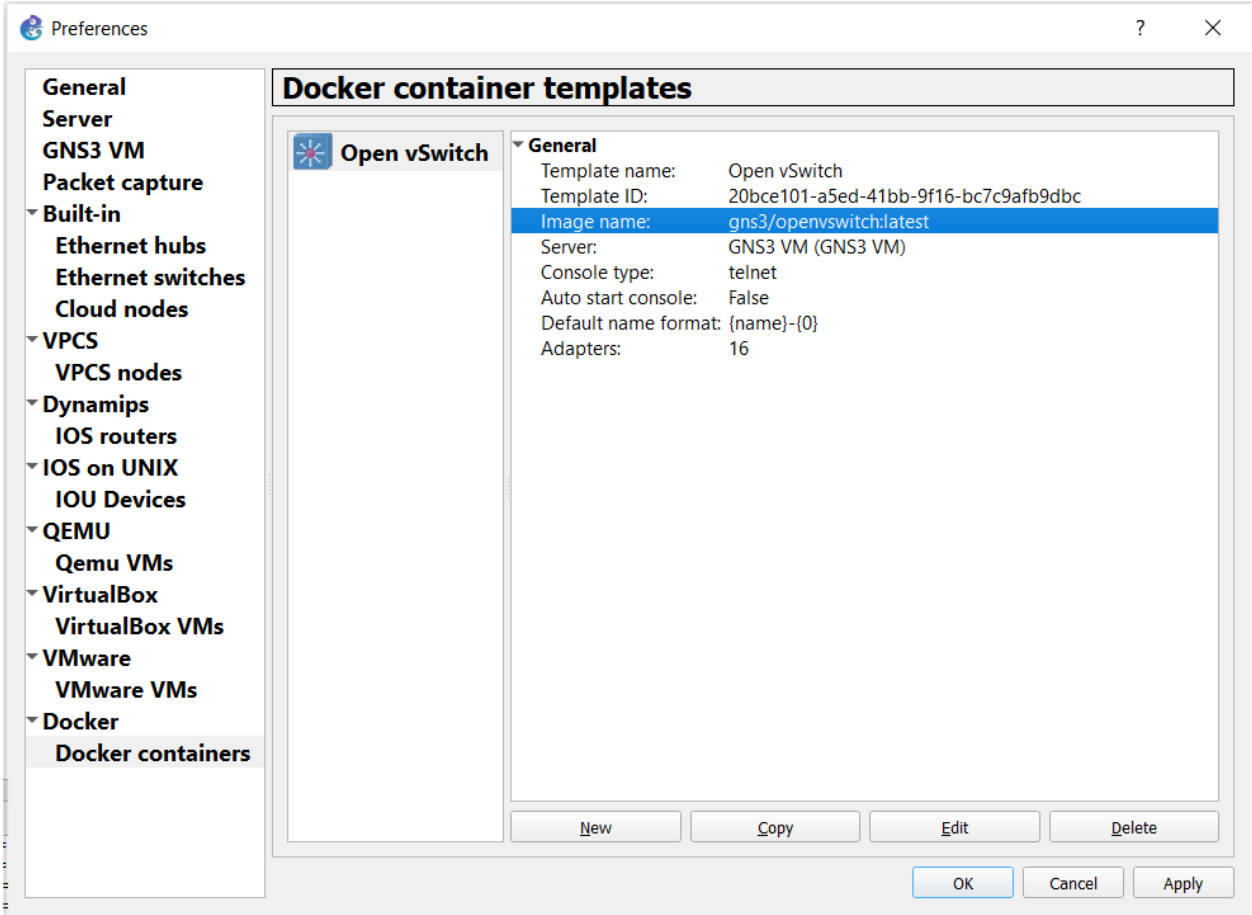
Objective 1 – Add Open vSwitch (OVS) in GNS3

1. Add OVS appliance in GNS3 using the link: https://gns3.com/marketplace/appliances/open-vswitch.

2. If there are issues installing the appliance, configure it to use the local GNS3 VM, which can be downloaded from: https://github.com/GNS3/gns3-gui/releases/download/v2.0.2/GNS3.VM.VirtualBox.2.0.2.zip

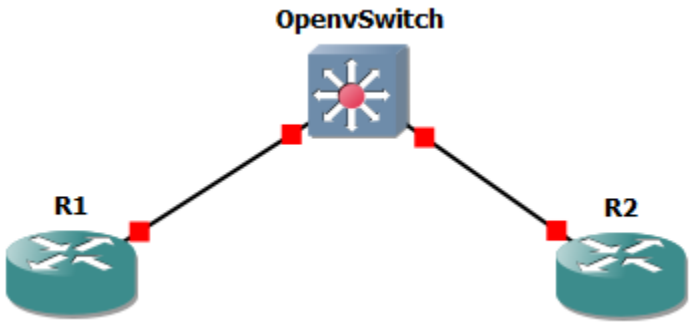
3. Paste the screenshot of the current version of Open vSwitch from its console window. **[10 points]**

```
/ # ovs-v
ovs-vlan-test  ovs-vsctl      ovs-vswitchd
/ # ovs-vswitchd --version
ovs-vswitchd (Open vSwitch) 2.17.6
/ #
```



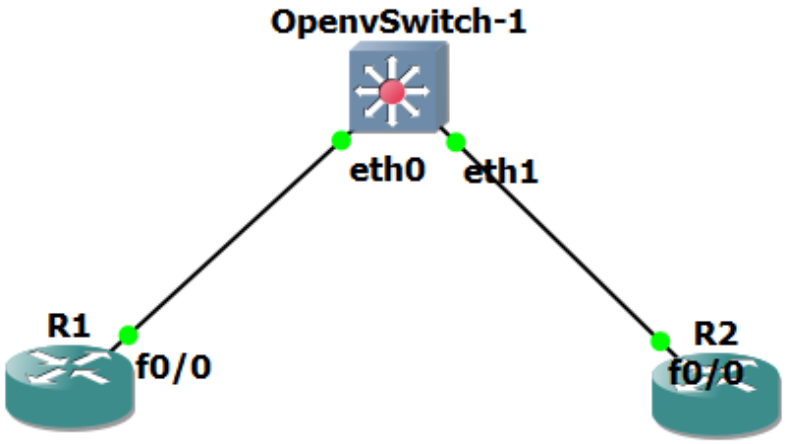
Objective 2 - Topology Creation and Achieving Connectivity

1. Create the topology in GNS3 as shown-



2. Assign static IP addresses to R1 and R2 in the same network.
   Can you ping between R1 and R2 connected to the two OVS ports?

   Explain why this would or wouldn't work, and provide a screenshot from OVS that supports your decision [**20 points**]



Below are the MAC addresses of R1 and R2 as highlighted for interface **f0/0**

```
R1#sh int f0/0
FastEthernet0/0 is up, line protocol is up
  Hardware is Gt96k FE, address is c201.0820.0000 (bia c201.0820.0000)
  Internet address is 10.0.0.10/24
  MTU 1500 bytes, BW 10000 Kbit/sec, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Half-duplex, 10Mb/s, 100BaseTX/FX
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input 01:01:54, output 00:00:07, output hang never
  Last clearing of "show interface" counters never
```

```
R2#sh int f0/0
FastEthernet0/0 is up, line protocol is up
  Hardware is Gt96k FE, address is c202.0843.0000 (bia c202.0843.0000)
  Internet address is 10.0.0.11/24
  MTU 1500 bytes, BW 10000 Kbit/sec, DLY 1000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
```

We can check the interface mapping inside the OVS, to check to which bridge interface eth0 and eth1 are connected.

```
/var/log # ovs-vsctl show
01ac989d-5ded-47d6-8b0a-9e8c80a02172
    Bridge br1
        datapath_type: netdev
        Port br1
            Interface br1
                type: internal
    Bridge br3
        datapath_type: netdev
        Port br3
            Interface br3
                type: internal
    Bridge br0
        datapath_type: netdev
        Port eth0
            Interface eth0
        Port eth13
            Interface eth13
        Port eth7
            Interface eth7
        Port eth9
            Interface eth9
        Port eth4
            Interface eth4
        Port eth8
            Interface eth8
        Port eth6
            Interface eth6
        Port eth10
            Interface eth10
        Port eth12
            Interface eth12
        Port eth2
            Interface eth2
        Port eth15
            Interface eth15
        Port eth3
            Interface eth3
        Port br0
            Interface br0
                type: internal
        Port eth5
            Interface eth5
        Port eth1
            Interface eth1
        Port eth11
```

From the above screenshot, eth0 and eth1 → connected to bridge0

Now, we can check which flows are present for bridge0

```
/var/log # ovs-ofctl dump-flows br0
 cookie=0x0, duration=9050.531s, table=0, n_packets=2168, n_bytes=220542, priority=0 actions=NORMAL
/var/log #
```

As we can observe, there exists a default flow even before the traffic is initiated, where **action=NORMAL, which indicates the switch will behave like a normal L2 switch.**
Ping would work from R1 to R2 because regular switching is performed. We can check the MAC address table that is populated.

```
/var/log # ovs-appctl fdb/show br0
 port  VLAN  MAC                Age
    1     0  c2:01:08:20:00:00    8
    2     0  c2:02:08:43:00:00    8
/var/log #
```

Port1 and Port2 mapping to the virtual interface can be found using the below command.

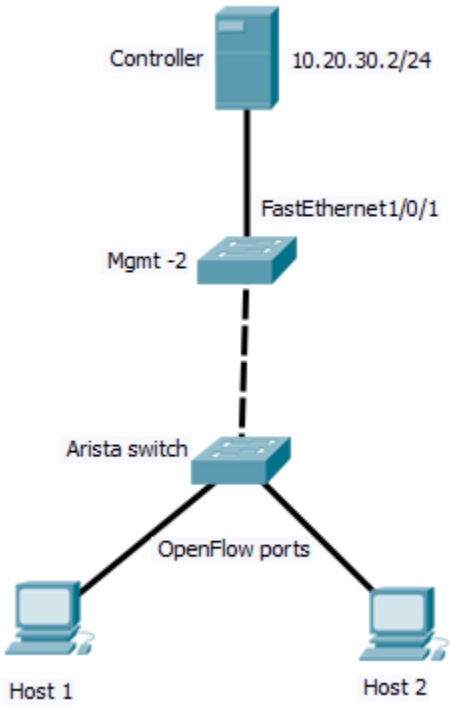
```
/var/log # ovs-ofctl show br0
OFPT_FEATURES_REPLY (xid=0x2): dpid:0000e2d047b3b54d
n_tables:254, n_buffers:0
capabilities: FLOW_STATS TABLE_STATS PORT_STATS QUEUE_STATS ARP_MATCH_IP
actions: output enqueue set_vlan_vid set_vlan_pcp strip_vlan mod_dl_src mod_dl_dst mod_nw_src mod_nw_dst mod_nw_tos mod_tp_src mod_tp_dst
 1(eth0): addr:4e:7c:8b:18:55:e9
     config:     0
     state:      0
     current:    10MB-FD COPPER
     speed: 10 Mbps now, 0 Mbps max
 2(eth1): addr:4a:04:68:ff:2f:93
     config:     0
     state:      0
     current:    10MB-FD COPPER
     speed: 10 Mbps now, 0 Mbps max
```

Ping works because the OVS switch uses regular switching operation and transparent bridges do not require any configuration. There is no controller, thus the default flow is used, **action=NORMAL** which causes the switch to learn MAC address, perform flooding and thus ping packets work.

PART – III: Connecting hardware switches to external controller

Objective 1 – Connect Arista switch to an SDN controller

1. Each team will use one Arista switch for this objective. You can console into the Arista switch to access its CLI. [Login: admin]
2. Connect the Arista switch to an external SDN controller.



   a. The controller IP is 192.168.1.7/24 :6633 and it connected to the 'Mgmt - 2' switch on FastEthernet1/0/1. (Don't change any config on this port)
   b. Connect two laptops to two ports on the Arista switch. Assign static IP's to the 2 laptops connected in another subnet (apart from 192.168.100.0/24 and 10.20.30.0/24).
   c. Follow the 'Lab Devices-Arista-SFP' document on Canvas to activate 10G ports.
   d. Follow Arista documentation instructions to activate OpenFlow ports on the hardware. [https://www.arista.com/en/um-eos/eos-section-47-3-openflow-configuration#ww1141650]

e. To connect to the controller, connect one free port on the Arista switch to any of the Gig ports on the 'Mgmt - 2' switch.

f. Make 2 new VLAN's on Arista - one for the traditional port connecting to the management switch, and another for the two OpenFlow ports connected to your laptops.

g. Assign an IP to the traditional VLAN interface as: 10.20.30.20X/24 where X is your team number (for example, team 5 will assign 10.20.30.205/24).

h. List all the commands needed in the Arista switch to connect to the controller; indicate in the switch that it is connected to the controller via the OpenFlow channel. [**25 points**]

Openflow Commands -

```
NGN-Arista-4(config)#sh run sec openflow
vlan 200
   name openflow
!
openflow
   bind mode vlan
   bind vlan 200
   no shutdown
   controller tcp:192.168.1.7:6633
```

Arista switch connected to controller -

```
NGN-Arista-4(config)#sh openflow
OpenFlow configuration: Enabled
DPID: 0x0000001c73588ab5
Description: NGN-Arista-4
Controllers:
  configured: 192.168.1.7:6633
  connected:
    192.168.1.7:6633
      negotiated version: Version 1.0
  connection count: 1
  keepalive period: 10 sec
Flow table state: Enabled
Flow table profile: full-match
Forwarding pipeline: flow
Bind mode: bindModeVlan
  VLANs: 200
  native VLAN: 200
IP routing state: Disabled
Shell command execution: Disabled
Total matched: 118 packets
```

4. Ping between two hosts connected to the Arista switch; show the success/failure of the ping, and the corresponding flow table on the switch. [**25 points**]

Host1 - **21.21.21.1/24**

```
Ethernet adapter Ethernet 4:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::53d:9883:ac66:9d13%59
   IPv4 Address. . . . . . . . . . . : 21.21.21.1
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
```

Host2 -

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::e4b9:4a0b:4162:943b%5
   IPv4 Address. . . . . . . . . . . : 21.21.21.2
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
```

Successful Ping -

```
C:\Users\kiran>ping 21.21.21.2

Pinging 21.21.21.2 with 32 bytes of data:
Reply from 21.21.21.2: bytes=32 time=9ms TTL=128
Reply from 21.21.21.2: bytes=32 time<1ms TTL=128
Reply from 21.21.21.2: bytes=32 time<1ms TTL=128
Reply from 21.21.21.2: bytes=32 time<1ms TTL=128

Ping statistics for 21.21.21.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 9ms, Average = 2ms
```

Openflow Table - **(Before Ping)**

```
NGN-Arista-4(config)#sh openflow flows
Flow __default__:
  priority: -1
  cookie: 0 (0x0)
  match:
  actions:
    output to controller
  matched: 13 packets, 2759 bytes
```

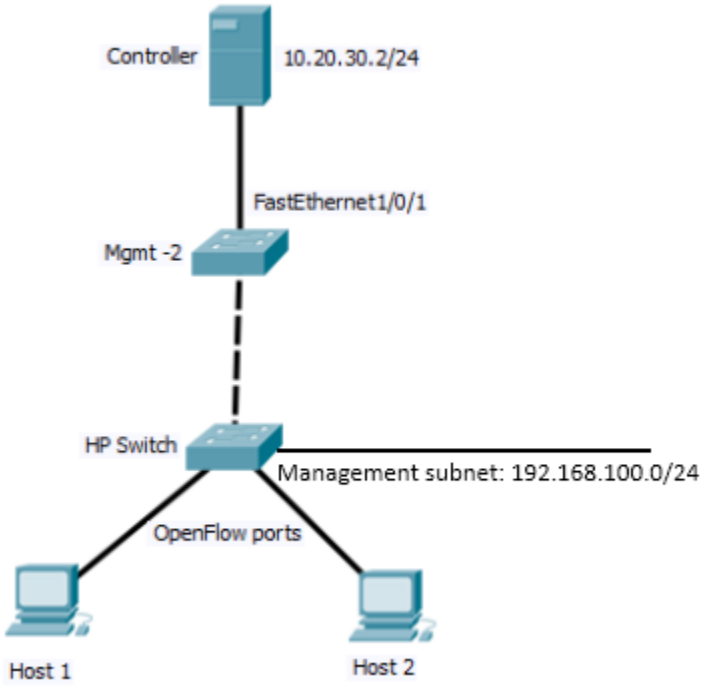
Openflow Table - **(After Ping)**

```
NGN-Arista-4(config)#sh openflow flows
Flow flow0000000000000000003:
  priority: 32768
  cookie: 0 (0x0)
  match:
    ingress interface:
        Et19
    source Ethernet address: 5c:26:0a:24:8f:a0/ff:ff:ff:ff:ff:ff
    destination Ethernet address: 00:0a:cd:41:a7:1f/ff:ff:ff:ff:ff:ff
  actions:
    output interfaces:
        Et18
  matched: 4 packets, 298 bytes
Flow flow0000000000000000002:
  priority: 32768
  cookie: 0 (0x0)
  match:
    ingress interface:
        Et18
    source Ethernet address: 00:0a:cd:41:a7:1f/ff:ff:ff:ff:ff:ff
    destination Ethernet address: 5c:26:0a:24:8f:a0/ff:ff:ff:ff:ff:ff
  actions:
    output interfaces:
        Et19
  matched: 4 packets, 298 bytes
Flow __default__:
  priority: -1
  cookie: 0 (0x0)
  match:
  actions:
    output to controller
  matched: 110 packets, 17291 bytes
```

Objective 2 – Connect HP switch to an SDN controller

1. Each team will use 1 HP switch from Switch 2 (192.168.100.2) , Switch 3 (192.168.100.3) or Switch 7(192.168.100.7) for this objective.
2. Use the IP's provided to connect to the switch. Connect your workstation to the patch panel outside the Data Center in the panel labelled 'NGN – Levi Perigo'. Then connect the corresponding port on the patch panel inside the data center to your HP switch on any port. Assign an IP in the range 192.168.100.100-200/24 to your workstation. To access the switch, Telnet on port 23 from your workstation to your HP switch IP. Do not change any configurations for Vlan 1, otherwise you will lose access to the switch.

3. Connect the HP switch to an external SDN controller.



i. The controller IP is 192.168.1.7/24 :6633 and it connected to the 'Mgmt - 2' switch on FastEthernet1/0/1.

j. Connect two laptops to two free ports on the HP switch. Assign static IP's to the 2 laptops connected in another subnet (apart from 192.168.100.0/24 and 10.20.30.0/24).

k. Follow HP documentation instructions to activate OpenFlow ports on the hardware. [https://support.hpe.com/hpsc/doc/public/display?sp4ts.oid=1839466&docLocale=en_US&docId=emr_na-c04777809]

l. To connect to the controller, connect one free port on the HP switch to any of the FastEthernet ports 4-48 on the 'Mgmt - 2' switch.

m. Make 2 new VLAN's on HP - one for the traditional port connecting to the management switch, and another for the two OpenFlow ports connected to your laptops. (Note: these VLANs are in addition to the 192.168.100.0 subnet on management VLAN 1, which is just to manage the switch - the management VLAN doesn't have anything to do with OpenFlow or the lab, it is just to access the HP CLI for configuration purposes.)

```
hpswitch# show vlan 100

 Status and Counters - VLAN Information - VLAN 100

  VLAN ID : 100
  Name : Management
  Status : Port-based
  Voice : No
  Jumbo : No
  Private VLAN : none
  Associated Primary VID : none
  Associated Secondary VIDs : none

  Port Information Mode     Unknown VLAN Status
  --------------- -------- ------------ ----------
  1               Untagged Learn        Up


hpswitch# show vlan 200

 Status and Counters - VLAN Information - VLAN 200

  VLAN ID : 200
  Name : OpenFlow
  Status : Port-based
  Voice : No
  Jumbo : No
  Private VLAN : none
  Associated Primary VID : none
  Associated Secondary VIDs : none

  Port Information Mode     Unknown VLAN Status
  --------------- -------- ------------ ----------
  23              Untagged Learn        Up
  24              Untagged Learn        Up
```

n. List all the commands needed in the HP switch to connect to the controller; indicate in the switch that it is connected to the controller via the OpenFlow channel. [**25 points**]

Commands to configure Controller -

```
hpswitch# sh run | b open
openflow
   controller-id 1 ip 192.168.1.7 controller-interface vlan 100
   instance "vlan200"
      member vlan 200
      controller-id 1
      version 1.3
      enable
      exit
   enable
   exit
```

Connectivity to the controller -

```
hpswitch# sh openflow instance vlan200

 Configured OF Version          : 1.3
 Negotiated OF Version          : 1.0
 Instance Name                  : vlan200
 Data-path Description          : vlan200
 Administrator Status           : Enabled
 Member List                    : VLAN 200
 Pipeline Model                 : Standard Match
 Listen Port                    : None
 Operational Status             : Up
 Operational Status Reason      : NA
 Datapath ID                    : 00c80017a47f2100
 Mode                           : Active
 Flow Location                  : Hardware and Software
 No. of Hardware Flows          : 0
 No. of Software Flows          : 2
 Hardware Rate Limit            : 0 kbps
 Software Rate Limit            : 100 pps
 Conn. Interrupt Mode           : Fail-Secure
 Maximum Backoff Interval       : 60 seconds
 Probe Interval                 : 10 seconds
 Hardware Table Miss Count      : NA
 No. of Software Flow Tables    : 1
 Egress Only Ports              : None
 Table Model                    : Single Table
 Source MAC Group Table         : Disabled
 Destination MAC Group Table    : Disabled

 Controller Id Connection Status Connection State Secure Role
 ------------- ----------------- ---------------- ------ ------
 1             Connected         Active           No     Equal
```

4. Ping between two hosts connected to the HP switch; show the success/failure of the ping, and the corresponding flow table on the switch. [**25 points**]

Host1 -

```
Ethernet adapter Ethernet 4:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : ASIX AX88179 USB 3.0 to Gigabit Ethernet Adapter #2
   Physical Address. . . . . . . . . : 00-0A-CD-41-A7-1F
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::53d:9883:ac66:9d13%59(Preferred)
   IPv4 Address. . . . . . . . . . . : 21.21.21.1(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
   DHCPv6 IAID . . . . . . . . . . . : 989858509
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-2C-97-52-3D-D4-81-D7-A7-E6-F4
   DNS Servers . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                       fec0:0:0:ffff::2%1
                                       fec0:0:0:ffff::3%1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Host2 -

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) 82577LM Gigabit Network Connection
   Physical Address. . . . . . . . . : 5C-26-0A-24-8F-A0
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::e4b9:4a0b:4162:943b%5(Preferred)
   IPv4 Address. . . . . . . . . . . : 21.21.21.2(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
   DHCPv6 IAID . . . . . . . . . . . : 89925130
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-28-8D-03-04-5C-26-0A-24-8F-A0
   DNS Servers . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                       fec0:0:0:ffff::2%1
                                       fec0:0:0:ffff::3%1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

```
C:\Users\kiran>ping 21.21.21.2

Pinging 21.21.21.2 with 32 bytes of data:
Reply from 21.21.21.2: bytes=32 time=1ms TTL=128
Reply from 21.21.21.2: bytes=32 time=1ms TTL=128
Reply from 21.21.21.2: bytes=32 time=1ms TTL=128
Reply from 21.21.21.2: bytes=32 time=1ms TTL=128

Ping statistics for 21.21.21.2:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 1ms, Average = 1ms
```

Flow Table - Output of - # show openflow instance vlan200 flows

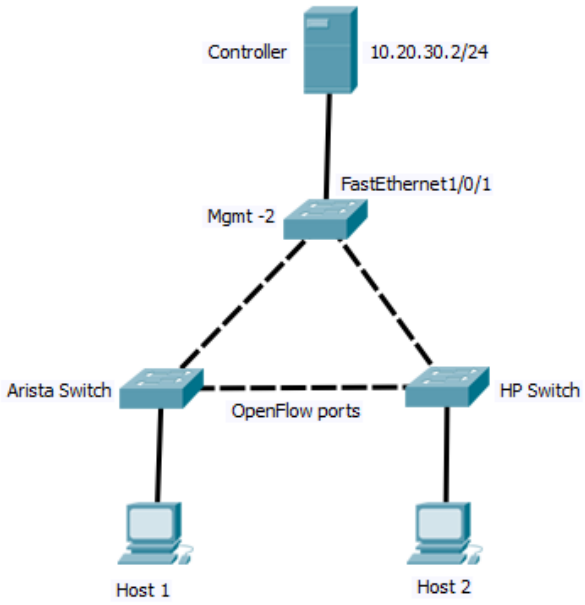
```
OpenFlow Flow Table

Flow 1
Match
 Incoming Port : 24                    Ethernet Type    : Any
 Source MAC    : 5c260a-248fa0         Destination MAC  : 000acd-41a71f
 Destination MAC Mask : 000000-000000
 VLAN ID       : Any                   VLAN Priority    : Any
 Source IP Address      : Any
 Destination IP Address : Any
 IP Protocol   : Any                   IP ToS Bits      : Any
 Source Port   : Any                   Destination Port : Any
Attributes
 Priority      : 32768                 Duration         : 1457 seconds
 Hard Timeout  : 0 seconds             Idle Timeout     : 0 seconds
 Byte Count    : 5552                  Packet Count     : 61
 Controller ID : 1                     Cookie           : 0x0
 Flow Location : Software
 Hardware Index: NA
 Reason Code        : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                  : 23

Flow 2
Match
 Incoming Port : 23                    Ethernet Type    : Any
 Source MAC    : 000acd-41a71f         Destination MAC  : 5c260a-248fa0
 Destination MAC Mask : 000000-000000
 VLAN ID       : Any                   VLAN Priority    : Any
 Source IP Address      : Any
 Destination IP Address : Any
 IP Protocol   : Any                   IP ToS Bits      : Any
 Source Port   : Any                   Destination Port : Any
Attributes
 Priority      : 32768                 Duration         : 1453 seconds
 Hard Timeout  : 0 seconds             Idle Timeout     : 0 seconds
 Byte Count    : 2114                  Packet Count     : 28
 Controller ID : 1                     Cookie           : 0x0
 Flow Location : Software
 Hardware Index: NA
 Reason Code        : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                  : 24
```

Objective 3 – Connect Arista to HP switch

1. Connect the Arista switch to the HP switch –



2. Provide screenshots from the OVS and HP switch showing the OpenFlow configurations and controller connectivity via the OpenFlow channel. [**20 points**]

Arista switch connectivity to controller

```
NGN-Arista-4(config)#sh openflow
OpenFlow configuration: Enabled
DPID: 0x0000001c73588ab5
Description: NGN-Arista-4
Controllers:
  configured: 192.168.1.7:6633
  connected:
    192.168.1.7:6633
      negotiated version: Version 1.0
  connection count: 15
  keepalive period: 10 sec
Flow table state: Enabled
Flow table profile: full-match
Forwarding pipeline: flow
Bind mode: bindModeVlan
  VLANs: 200
  native VLAN: 200
IP routing state: Disabled
Shell command execution: Disabled
Total matched: 5063 packets
```

OpenFlow config Arista switch -

```
interface Ethernet17
   description Connection To HP
   speed forced 1000full
   switchport access vlan 200
!
interface Ethernet18
   description AristaPC
   speed forced 1000full
   switchport access vlan 200
!
interface Ethernet19
   speed forced 1000full
!
interface Ethernet20
   speed forced 1000full
!
interface Management1
   description To-Controller
   ip address 192.168.1.19/24
!
ip routing
!
openflow
   bind mode vlan
   bind vlan 200
   no shutdown
   controller tcp:192.168.1.7:6633
!
!
end
NGN-Arista-4(config)#
```

OpenFlow Config HP switch-

```
openflow
   controller-id 1 ip 192.168.1.7 controller-interface vlan 100
   instance "vlan200"
      member vlan 200
      controller-id 1
      version 1.3
      enable
      exit
   enable
   exit
vlan 1
   name "DEFAULT_VLAN"
   no untagged 2,17-18,24
   untagged 1,3-16,19-23
   no ip address
   exit
vlan 4
   name "telnet"
   untagged 24
   ip address 10.10.10.1 255.255.255.0
   exit
vlan 100
   name "managementController"
   untagged 2
   ip address 192.168.1.20 255.255.255.0
   exit
vlan 200
   name "openflow"
   untagged 17-18
   no ip address
   exit

hpswitch(config)#
```

HP switch connection to Openflow

```
hpswitch# sh openflow instance vlan200

 Configured OF Version         : 1.3
 Negotiated OF Version         : 1.0
 Instance Name                 : vlan200
 Data-path Description         : vlan200
 Administrator Status          : Enabled
 Member List                   : VLAN 200
 No. of Software Flow Tables   : 1
 Pipeline Model                : Standard Match
 Listen Port                   : None
 Operational Status            : Up
 Operational Status Reason     : NA
 Datapath ID                   : 00c8001c2e981280
 Mode                          : Active
 Flow Location                 : Hardware and Software
 No. of Hardware Flows         : 0
 No. of Software Flows         : 2
 Hardware Rate Limit           : 0 kbps
 Software Rate Limit           : 100 pps
 Conn. Interrupt Mode          : Fail-Secure
 Maximum Backoff Interval      : 60 seconds
 Probe Interval                : 10 seconds
 Hardware Table Miss Count     : NA
 Egress Only Ports             : 1,3-16,19-24
 Table Model                   : Single Table
 Source MAC Group Table        : Disabled
 Destination MAC Group Table   : Disabled

 Controller Id Connection Status Connection State Secure Role
 ------------- ----------------- ---------------- ------ ------
 1             Connected         Active           No     Equal

hpswitch#
```

3. Ping between the two hosts; show the success/failure of the ping, and the corresponding flow tables on the switches. [**20 points**]

Host1 -

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) 82577LM Gigabit Network Connection
   Physical Address. . . . . . . . . : 5C-26-0A-24-8F-66
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::debc:dd65:d405:98ee%11(Preferred)
   IPv4 Address. . . . . . . . . . . : 21.21.21.2(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
   DHCPv6 IAID . . . . . . . . . . . : 157033994
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-28-8E-4C-C4-5C-26-0A-24-8F-66
   DNS Servers . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                       fec0:0:0:ffff::2%1
                                       fec0:0:0:ffff::3%1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Host2 -

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) 82577LM Gigabit Network Connection
   Physical Address. . . . . . . . . : 5C-26-0A-24-8D-7A
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::87ad:2e4a:a336:d888%17(Preferred)
   IPv4 Address. . . . . . . . . . . : 21.21.21.1(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . :
   DHCPv6 IAID . . . . . . . . . . . : 291251722
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-28-8E-3E-A0-5C-26-0A-24-8D-7A
   DNS Servers . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                       fec0:0:0:ffff::2%1
                                       fec0:0:0:ffff::3%1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Arista Switch Flow Table -

```
NGN-Arista-4(config)#sh openflow flows
Flow flow0000000000000000006:
  priority: 32768
  cookie: 0 (0x0)
  match:
    ingress interface:
        Et17
    source Ethernet address: 5c:26:0a:24:8f:66/ff:ff:ff:ff:ff:ff
    destination Ethernet address: 5c:26:0a:24:8d:7a/ff:ff:ff:ff:ff:ff
  actions:
    output interfaces:
        Et18
  matched: 4 packets, 298 bytes
Flow flow0000000000000000005:
  priority: 32768
  cookie: 0 (0x0)
  match:
    ingress interface:
        Et18
    source Ethernet address: 5c:26:0a:24:8d:7a/ff:ff:ff:ff:ff:ff
    destination Ethernet address: 5c:26:0a:24:8f:66/ff:ff:ff:ff:ff:ff
  actions:
    output interfaces:
        Et17
  matched: 5 packets, 376 bytes
Flow flow0000000000000000004:
  priority: 32768
  cookie: 0 (0x0)
  match:
    ingress interface:
        Et17
    source Ethernet address: 00:1c:73:7a:0b:60/ff:ff:ff:ff:ff:ff
    destination Ethernet address: ac:a0:16:0c:07:b1/ff:ff:ff:ff:ff:ff
  actions:
    output interfaces:
        Et17
  matched: 1 packets, 64 bytes
Flow __default__:
  priority: -1
  cookie: 0 (0x0)
  match:
  actions:
    output to controller
  matched: 4856 packets, 826183 bytes
NGN-Arista-4(config)#
```

HP switch Flow Table

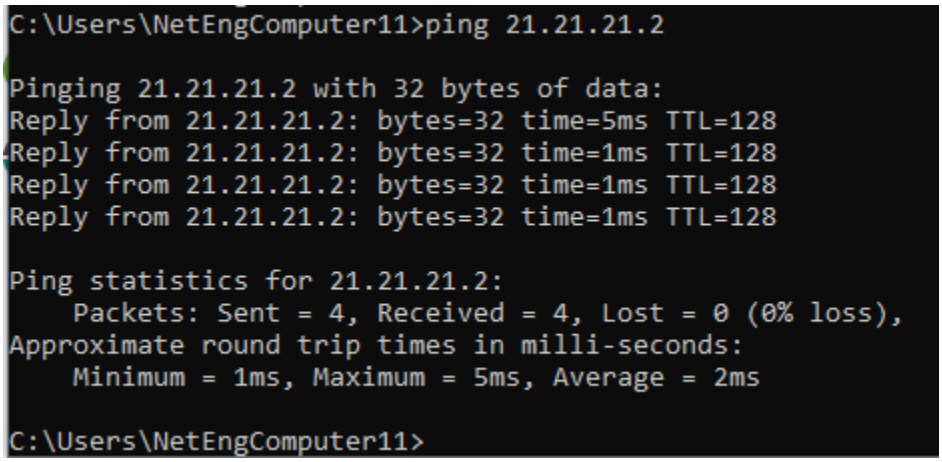
```
OpenFlow Flow Table

Flow 1
Match
 Incoming Port : 17                    Ethernet Type    : Any
 Source MAC    : 5c260a-248d7a         Destination MAC  : 5c260a-248f66
 Destination MAC Mask : 000000-000000
 VLAN ID       : Any                   VLAN Priority    : Any
 Source IP Address      : Any
 Destination IP Address : Any
 IP Protocol   : Any                   IP ToS Bits      : Any
 Source Port   : Any                   Destination Port : Any
Attributes
 Priority      : 32768                 Duration         : 404 seconds
 Hard Timeout  : 0 seconds             Idle Timeout     : 0 seconds
 Byte Count    : 356                   Packet Count     : 5
 Controller ID : 1                     Cookie           : 0x0
 Flow Location : Software
 Hardware Index: NA
 Reason Code        : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                : 18

Flow 2
Match
 Incoming Port : 18                    Ethernet Type    : Any
 Source MAC    : 5c260a-248f66         Destination MAC  : 5c260a-248d7a
 Destination MAC Mask : 000000-000000
 VLAN ID       : Any                   VLAN Priority    : Any
 Source IP Address      : Any
 Destination IP Address : Any
 IP Protocol   : Any                   IP ToS Bits      : Any
 Source Port   : Any                   Destination Port : Any
Attributes
 Priority      : 32768                 Duration         : 404 seconds
 Hard Timeout  : 0 seconds             Idle Timeout     : 0 seconds
 Byte Count    : 282                   Packet Count     : 4
 Controller ID : 1                     Cookie           : 0x0
 Flow Location : Software
 Hardware Index: NA
 Reason Code        : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                : 17

hpswitch(config)#
```

Ping -



Total - _____ / 285