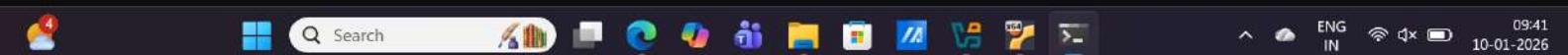


Q1.

A startup incubator wants fine-grained control over which teams can access shared build servers. You are asked to design an SDN-based solution using Mininet and a Ryu controller. You must infer a suitable topology, implement flow rules to restrict or allow communication, handle dynamic rule insertion/removal, and justify all design decisions. Demonstrate the behavior using Mininet commands and flow table inspection.

```
mininet@mininet-vm:~$ sudo mn --topo single,3 --mac --switch ovsk --controller remote
*** Creating network
*** Adding controller
Connecting to remote controller at 127.0.0.1:6653
*** Adding hosts:
h1 h2 h3
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1) (h3, s1)
*** Configuring hosts
h1 h2 h3
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
h3 h3-eth0:s1-eth3
s1 lo: s1-eth1:h1-eth0 s1-eth2:h2-eth0 s1-eth3:h3-eth0
c0
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2 h3
h2 -> h1 h3
h3 -> h1 h2
*** Results: 0% dropped (6/6 received)
mininet> |
```

```
mininet@mininet-vm:~$ ryu-manager ryu.app.simple_switch_13
loading app ryu.app.simple_switch_13
loading app ryu.controller.ofp_handler
instantiating app ryu.app.simple_switch_13 of SimpleSwitch13
instantiating app ryu.controller.ofp_handler of OFPHandler
packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1
packet in 1 00:00:00:00:00:02 00:00:00:00:00:01 2
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:01
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:01
packet in 1 00:00:00:00:00:01 00:00:00:00:00:02 1
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02
packet in 1 00:00:00:00:00:01 ff:ff:ff:ff:ff:ff 1
packet in 1 00:00:00:00:00:03 00:00:00:00:00:01 3
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01
packet in 1 00:00:00:00:00:01 00:00:00:00:00:03 1
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03
packet in 1 00:00:00:00:00:02 ff:ff:ff:ff:ff:ff 2
packet in 1 00:00:00:00:00:03 00:00:00:00:00:02 3
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:02
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:02
packet in 1 00:00:00:00:00:02 00:00:00:00:00:03 2
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:03
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:03
|
```



```
mininet@mininet-vm:~$ sudo ovs-ofctl add-flow s1 \
> "priority=100,ip,nw_src=10.0.0.1,nw_dst=10.0.0.3,actions=output:3"
mininet@mininet-vm:~$ sudo ovs-ofctl add-flow s1 \
> "priority=200,ip,nw_src=10.0.0.2,nw_dst=10.0.0.3,actions=drop"
```

```
mininet> h1 ping h3
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=0.386 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.077 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.097 ms
64 bytes from 10.0.0.3: icmp_seq=4 ttl=64 time=0.138 ms
64 bytes from 10.0.0.3: icmp_seq=5 ttl=64 time=0.080 ms
64 bytes from 10.0.0.3: icmp_seq=6 ttl=64 time=0.114 ms
64 bytes from 10.0.0.3: icmp_seq=7 ttl=64 time=0.080 ms
64 bytes from 10.0.0.3: icmp_seq=8 ttl=64 time=0.113 ms
64 bytes from 10.0.0.3: icmp_seq=9 ttl=64 time=0.079 ms
^C
--- 10.0.0.3 ping statistics ---
9 packets transmitted, 9 received, 0% packet loss, time 8177ms
rtt min/avg/max/mdev = 0.077/0.129/0.386/0.092 ms
mininet> h2 ping h3
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
^C
--- 10.0.0.3 ping statistics ---
139 packets transmitted, 0 received, 100% packet loss, time 141306ms

mininet> |
```

```
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s1
cookie=0x0, duration=363.351s, table=0, n_packets=9, n_bytes=882, priority=100, ip,nw_src=10.0.0.1,nw_dst=10.0.0.3 actions=output:"s1-eth3"
cookie=0x0, duration=318.228s, table=0, n_packets=139, n_bytes=13622, priority=200, ip,nw_src=10.0.0.2,nw_dst=10.0.0.3 actions=drop
cookie=0x0, duration=703.606s, table=0, n_packets=3, n_bytes=238, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
cookie=0x0, duration=703.600s, table=0, n_packets=2, n_bytes=140, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"
cookie=0x0, duration=703.582s, table=0, n_packets=14, n_bytes=1204, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
cookie=0x0, duration=703.577s, table=0, n_packets=4, n_bytes=224, priority=1,in_port="s1-eth1",dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"
cookie=0x0, duration=703.550s, table=0, n_packets=7, n_bytes=406, priority=1,in_port="s1-eth3",dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:02 actions=output:"s1-eth2"
cookie=0x0, duration=703.546s, table=0, n_packets=6, n_bytes=308, priority=1,in_port="s1-eth2",dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:03 actions=output:"s1-eth3"
cookie=0x0, duration=723.070s, table=0, n_packets=9, n_bytes=546, priority=0 actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl del-flows s1 nw_src=10.0.0.2,nw_dst=10.0.0.3
2026-01-10T04:22:24Z|00001|ofp_match|INFO|normalization changed ofp_match, details:
2026-01-10T04:22:24Z|00002|ofp_match|INFO| pre: nw_src=10.0.0.2,nw_dst=10.0.0.3
2026-01-10T04:22:24Z|00003|ofp_match|INFO|post:
mininet@mininet-vm:~$ |
```

```
mininet> h2 ping h3
PING 10.0.0.3 (10.0.0.3) 56(84) bytes of data.
64 bytes from 10.0.0.3: icmp_seq=1 ttl=64 time=13.4 ms
64 bytes from 10.0.0.3: icmp_seq=2 ttl=64 time=0.385 ms
64 bytes from 10.0.0.3: icmp_seq=3 ttl=64 time=0.078 ms
64 bytes from 10.0.0.3: icmp_seq=4 ttl=64 time=0.189 ms
64 bytes from 10.0.0.3: icmp_seq=5 ttl=64 time=0.070 ms
64 bytes from 10.0.0.3: icmp_seq=6 ttl=64 time=0.116 ms
^C
--- 10.0.0.3 ping statistics ---
6 packets transmitted, 6 received, 0% packet loss, time 5080ms
rtt min/avg/max/mdev = 0.070/2.367/13.364/4.919 ms
mininet> |
```

Q2.

The SOC team needs periodic snapshots of flow statistics. Without prior knowledge of the topology, use Ryu REST APIs to extract all possible network information. Identify switches, links, hosts, and flow statistics. Explain how each API endpoint contributes to network visibility and validation.

```
mininet@mininet-vm:~$ ryu-manager ryu.app.ofctl_rest ryu.app.rest_topology ryu.app.simple_switch_13
loading app ryu.app.ofctl_rest
loading app ryu.app.rest_topology
loading app ryu.app.simple_switch_13
loading app ryu.controller.ofp_handler
loading app ryu.topology.switches
loading app ryu.controller.ofp_handler
instantiating app None of DPSet
creating context dpset
creating context wsgi
instantiating app ryu.app.ofctl_rest of RestStatsApi
instantiating app ryu.app.rest_topology of TopologyAPI
instantiating app ryu.app.simple_switch_13 of SimpleSwitch13
instantiating app ryu.controller.ofp_handler of OFPHandler
instantiating app ryu.topology.switches of Switches
(1414) wsgi starting up on http://0.0.0.0:8080
```

```
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2 h3
h2 -> h1 h3
h3 -> h1 h2
*** Results: 0% dropped (6/6 received)
mininet> |
```

```
mininet@mininet-vm: ~ X mininet@mininet-vm: ~ X | mininet@mininet-vm: ~ X | mininet@mininet-vm: ~ X + - x

Install the latest PowerShell for new features and improvements! https://aka.ms/PSWindows

PS C:\Users\nirma> ssh mininet@10.130.59.177
mininet@10.130.59.177's password:
Welcome to Ubuntu 20.04.6 LTS (GNU/Linux 5.4.0-216-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/pro
New release '22.04.5 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Fri Jan  9 20:41:25 2026 from 10.130.59.4
mininet@mininet-vm:~$ curl http://localhost:8080/v1.0/topology/switches
[{"dpid": "0000000000000002", "ports": []}, {"dpid": "0000000000000001", "ports": [{"dpid": "0000000000000001", "port_no": "00000001", "hw_addr": "da:26:26:a0:cd:f7", "name": "s1-eth1"}, {"dpid": "0000000000000001", "port_no": "00000002", "hw_addr": "06:8a:8c:e7:46:63", "name": "s1-eth2"}, {"dpid": "0000000000000001", "port_no": "00000003", "hw_addr": "6a:43:cb:6a:36:32", "name": "s1-eth3"}]]
mininet@mininet-vm:~$ curl http://localhost:8080/v1.0/topology/hosts
[{"mac": "00:00:00:00:00:01", "ipv4": ["10.0.0.1"], "ipv6": [], "port": {"dpid": "0000000000000001", "port_no": "00000001", "hw_addr": "da:26:26:a0:cd:f7", "name": "s1-eth1"}, {"mac": "00:00:00:00:00:02", "ipv4": ["10.0.0.2"], "ipv6": [], "port": {"dpid": "0000000000000001", "port_no": "00000002", "hw_addr": "06:8a:8c:e7:46:63", "name": "s1-eth2"}, {"mac": "00:00:00:00:00:03", "ipv4": ["10.0.0.3"], "ipv6": [], "port": {"dpid": "0000000000000001", "port_no": "00000003", "hw_addr": "6a:43:cb:6a:36:32", "name": "s1-eth3"}]]
mininet@mininet-vm:~$ curl http://localhost:8080/linkscurl http://localhost:8080/v1.0/topology/links
<html>
<head>
<title>404 Not Found</title>
</head>
<body>
<h1>404 Not Found</h1>
The resource could not be found.<br /><br />
</body>
</html>[]
mininet@mininet-vm:~$ curl http://localhost:8080/stats/switches
```



```
mininet@mininet-vm:~$ curl http://localhost:8080/stats/switches
[2, 1]mininet@mininet-vm:$
mininet@mininet-vm:$ curl http://localhost:8080/stats/flow/1
{"1": [{"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 854, "duration_sec": 1461, "duration_nsec": 10000000, "packet_count": 11, "length": 104, "flags": 0, "actions": ["OUTPUT:3"], "match": {"in_port": 2, "dl_src": "00:00:00:00:00:02", "dl_dst": "00:00:00:00:00:03"}, "table_id": 0}, {"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 854, "duration_sec": 1461, "duration_nsec": 16100000, "packet_count": 11, "length": 104, "flags": 0, "actions": ["OUTPUT:2"], "match": {"in_port": 3, "dl_src": "00:00:00:00:00:03", "dl_dst": "00:00:00:00:00:02"}, "table_id": 0}, {"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 182, "duration_sec": 370, "duration_nsec": 67800000, "packet_count": 3, "length": 104, "flags": 0, "actions": ["OUTPUT:1"]}, {"match": {"in_port": 2, "dl_src": "00:00:00:00:00:02", "dl_dst": "00:00:00:00:00:01"}, "table_id": 0}, {"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 182, "duration_sec": 370, "duration_nsec": 66100000, "packet_count": 3, "length": 104, "flags": 0, "actions": ["OUTPUT:1"]}, {"match": {"in_port": 3, "dl_src": "00:00:00:00:00:03", "dl_dst": "00:00:00:00:00:01"}, "table_id": 0}, {"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 182, "duration_sec": 370, "duration_nsec": 64800000, "packet_count": 3, "length": 104, "flags": 0, "actions": ["OUTPUT:2"]}, {"match": {"in_port": 1, "dl_src": "00:00:00:00:00:01", "dl_dst": "00:00:00:00:00:02"}, "table_id": 0}, {"priority": 1, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 84, "duration_sec": 370, "duration_nsec": 62500000, "packet_count": 2, "length": 104, "flags": 0, "actions": ["OUTPUT:3"]}, {"match": {"in_port": 1, "dl_src": "00:00:00:00:00:01", "dl_dst": "00:00:00:00:00:03"}, "table_id": 0}, {"priority": 0, "cookie": 0, "idle_timeout": 0, "hard_timeout": 0, "byte_count": 1232, "duration_sec": 522, "duration_nsec": 573000000, "packet_count": 16, "length": 80, "flags": 0, "actions": ["OUTPUT:CONTROLLER"]}, {"match": {}, "table_id": 0}]}mininet@mininet-vm:$
mininet@mininet-vm:$ curl http://localhost:8080/stats/port/1
{"1": [{"rx_packets": 27, "tx_packets": 28, "rx_bytes": 2086, "tx_bytes": 2128, "rx_dropped": 0, "tx_dropped": 0, "rx_errors": 0, "tx_errors": 0, "rx_frame_err": 0, "rx_over_err": 0, "rx_crc_err": 0, "collisions": 0, "duration_sec": 2262, "duration_nsec": 626000000, "port_no": 1}, {"rx_packets": 0, "tx_packets": 0, "rx_bytes": 0, "tx_bytes": 0, "rx_dropped": 5, "tx_dropped": 0, "rx_errors": 0, "tx_errors": 0, "rx_frame_err": 0, "rx_over_err": 0, "rx_crc_err": 0, "collisions": 0, "duration_sec": 4333, "duration_nsec": 568000000, "port_no": "LOCAL"}, {"rx_packets": 167, "tx_packets": 30, "rx_bytes": 15582, "tx_bytes": 2100, "rx_dropped": 0, "tx_dropped": 0, "rx_errors": 0, "tx_errors": 0, "rx_frame_err": 0, "rx_over_err": 0, "rx_crc_err": 0, "collisions": 0, "duration_sec": 2262, "duration_nsec": 626000000, "port_no": 2}, {"rx_packets": 39, "tx_packets": 41, "rx_bytes": 2926, "tx_bytes": 3066, "rx_dropped": 0, "tx_dropped": 0, "rx_errors": 0, "tx_errors": 0, "rx_frame_err": 0, "rx_over_err": 0, "rx_crc_err": 0, "collisions": 0, "duration_sec": 2262, "duration_nsec": 418000000, "port_no": 3}]}mininet@mininet-vm:$
mininet@mininet-vm:$ curl http://localhost:8080/stats/aggregateflow/1
mininet@mininet-vm:$ |
```



```
mininet@mininet-vm:~$ ryu-manager ryu.app.ofctl_rest ryu.app.rest_topology ryu.app.simple_switch_13
loading app ryu.app.ofctl_rest
loading app ryu.app.rest_topology
loading app ryu.app.simple_switch_13
loading app ryu.controller.ofp_handler
loading app ryu.topology.switches
loading app ryu.controller.ofp_handler
instantiating app None of DPSet
creating context dpset
creating context wsgi
instantiating app ryu.app.ofctl_rest of RestStatsApi
instantiating app ryu.app.rest_topology of TopologyAPI
instantiating app ryu.app.simple_switch_13 of SimpleSwitch13
instantiating app ryu.controller.ofp_handler of OFPHandler
instantiating app ryu.topology.switches of Switches
(1414) wsgi starting up on http://0.0.0.0:8080
packet in 1 00:00:00:00:00:01 00:00:00:00:00:02 1
packet in 1 00:00:00:00:00:02 00:00:00:00:00:01 2
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:01
add unicast flow from 00:00:00:00:00:02 port 2 to 00:00:00:00:00:01
packet in 1 00:00:00:00:00:01 00:00:00:00:00:03 1
packet in 1 00:00:00:00:00:03 00:00:00:00:00:01 3
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01
packet in 1 00:00:00:00:00:01 00:00:00:00:00:02 1
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02
packet in 1 00:00:00:00:00:01 00:00:00:00:00:03 1
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03
(1414) accepted ('127.0.0.1', 39752)
127.0.0.1 - - [09/Jan/2026 20:41:36] "GET /v1.0/topology/switches HTTP/1.1" 200 505 0.017234
(1414) accepted ('127.0.0.1', 33062)
127.0.0.1 - - [09/Jan/2026 20:42:49] "GET /v1.0/topology/switches HTTP/1.1" 200 505 0.004933
(1414) accepted ('127.0.0.1', 33570)
127.0.0.1 - - [09/Jan/2026 20:43:04] "GET /v1.0/topology/hosts HTTP/1.1" 200 637 0.000650
(1414) accepted ('127.0.0.1', 36832)
```

```
mininet@mininet-vm: ~      mininet@mininet-vm: ~      mininet@mininet-vm: ~      mininet@mininet-vm: ~      mininet@mininet-vm: ~  
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01  
add unicast flow from 00:00:00:00:00:03 port 3 to 00:00:00:00:00:01  
packet in 1 00:00:00:00:00:01 00:00:00:00:00:02 1  
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02  
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:02  
packet in 1 00:00:00:00:00:01 00:00:00:00:00:03 1  
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03  
add unicast flow from 00:00:00:00:00:01 port 1 to 00:00:00:00:00:03  
(1414) accepted ('127.0.0.1', 39752)  
127.0.0.1 -- [09/Jan/2026 20:41:36] "GET /v1.0/topology/switches HTTP/1.1" 200 505 0.017234  
(1414) accepted ('127.0.0.1', 33062)  
127.0.0.1 -- [09/Jan/2026 20:42:49] "GET /v1.0/topology/switches HTTP/1.1" 200 505 0.004933  
(1414) accepted ('127.0.0.1', 33570)  
127.0.0.1 -- [09/Jan/2026 20:43:04] "GET /v1.0/topology/hosts HTTP/1.1" 200 637 0.000650  
(1414) accepted ('127.0.0.1', 36832)  
127.0.0.1 -- [09/Jan/2026 20:43:38] "GET /v1.0/topology/linkscurl HTTP/1.1" 404 278 0.000703  
127.0.0.1 -- [09/Jan/2026 20:43:38] "GET /v1.0/topology/links HTTP/1.1" 200 109 0.003685  
(1414) accepted ('127.0.0.1', 40686)  
127.0.0.1 -- [09/Jan/2026 20:43:52] "GET /stats/switches HTTP/1.1" 200 113 0.000468  
(1414) accepted ('127.0.0.1', 37902)  
127.0.0.1 -- [09/Jan/2026 20:44:08] "GET /stats/flow/1 HTTP/1.1" 200 2219 0.012694  
(1414) accepted ('127.0.0.1', 33636)  
Invalid dpid: 1curl  
Traceback (most recent call last):  
  File "/usr/local/lib/python3.8/dist-packages/ryu/app/ofctl_rest.py", line 199, in wrapper  
    dp = self.dpset.get(int(str(dpid), 0))  
ValueError: invalid literal for int() with base 0: '1curl'  
127.0.0.1 -- [09/Jan/2026 20:45:58] "GET /stats/port/1curl HTTP/1.1" 400 124 0.013569  
127.0.0.1 -- [09/Jan/2026 20:45:58] "GET /stats/port/1 HTTP/1.1" 200 1217 0.008600  
(1414) accepted ('127.0.0.1', 47970)  
127.0.0.1 -- [09/Jan/2026 20:46:45] "GET /stats/switches HTTP/1.1" 200 113 0.000497  
(1414) accepted ('127.0.0.1', 54576)  
127.0.0.1 -- [09/Jan/2026 20:47:02] "GET /stats/flow/1 HTTP/1.1" 200 2219 0.011592  
(1414) accepted ('127.0.0.1', 54332)  
127.0.0.1 -- [09/Jan/2026 20:47:14] "GET /stats/port/1 HTTP/1.1" 200 1217 0.006822  
(1414) accepted ('127.0.0.1', 45122)  
127.0.0.1 -- [09/Jan/2026 20:47:32] "GET /stats/aggregateflow/1 HTTP/1.1" 200 174 0.003820
```

