Scenario 1

Installation rules: we implemented self-learning function in switch. When the destination is unknown, the switch will broadcast or flooding the ethernet frames to all ports. And the switch will learn the source port, matching the MAC address and port number. Once the MAC to port mapping is learnt by the controller for a switch port, it will install OpenFlow rules in the switch so that subsequent packets should not come to the controller, and directly sent to the port.

h1 ping h2:

```
mininet> h1 ping -c1 h2
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=0.161 ms

--- 10.0.0.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.161/0.161/0.161/0.000 ms
```

```
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:01 to ff:ff:ff:ff:ff:ff
DEBUG:switch:Switch dpid 1: learns port 1 as source port
DEBUG:switch:Switch dpid 1: flooding
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:02 to 00:00:00:00:00:01
DEBUG:switch:Switch dpid 1: learns port 2 as source port
DEBUG:switch:Switch dpid 1: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 1: adding flow from src 00:00:00:00:00:02 to dst 00:00:00:00:00:01, port 1
```

Pingall:

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

```
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:01 to ff:ff:ff:ff:ff:ff
DEBUG:switch:Switch dpid 1: flooding
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:03 to 00:00:00:00:00:01
DEBUG:switch:Switch dpid 1: learns port 3 as source port
DEBUG:switch:Switch dpid 1: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 1: adding flow from src 00:00:00:00:00:03 to dst 00:00:00:00:00:01, port 1
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:01 to 00:00:00:00:00:03
DEBUG:switch:Switch dpid 1: sending packet to port 3
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 1: adding flow from src 00:00:00:00:00:01 to dst 00:00:00:00:00:03, port 3
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:02 to ff:ff:ff:ff:ff:ff
DEBUG:switch:Switch dpid 1: flooding
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:03 to 00:00:00:00:00:02
DEBUG:switch:Switch dpid 1: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 1: adding flow from src 00:00:00:00:00:03 to dst 00:00:00:00:00:02, port 2
DEBUG:misc.controller_1:DPID 1 dealing with packets from 00:00:00:00:00:02 to 00:00:00:00:00:03
DEBUG:switch:Switch dpid 1: sending packet to port 3
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 1: adding flow from src 00:00:00:00:00:02 to dst 00:00:00:00:00:03, port 3
```

Scenario 2

Installation rules of router: When the host wants to send a packet to an address with unknow next hop, the host will firstly send an ARP request, and the router will reply the next hop's MAC address to the host. Then the host will send the packet to that address. In another network, similarly, when the router doesn't know the MAC address of destination, it will request an ARP reply first, getting the output port. Then the packet will be sent to the right port.

h1 ping h2:

```
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 10.0.0.2 to MAC 00:00:00:00:00:01
DEBUG:router:dpid 1: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
11
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 20.0.0.2
DEBUG:router:dpid 1: packet from 10.0.0.2 to 20.0.0.2 is unknown for MAC of nexthop 20.0.0.2, adding
to ArpWait
DEBUG:router:dpid 1: port 2, sending ARP request for IP 20.0.0.2 from 20.0.0.1
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 20.0.0.2 to MAC 00:00:00:00:00:02
DEBUG:router:dpid 1: process ARP wait packet for IP 20.0.0.2
DEBUG:router:dpid 1: send wait ARP packet, destIP: 20.0.0.2, destMAC: 00:00:00:00:00:02, output port:
 2
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 2, from 20.0.0.2 to 10.0.0.2
DEBUG:router:dpid 1: packet from 20.0.0.2 to 10.0.0.2 sent to port 1
```

```
mininet> h1 ping h2
PING 20.0.0.2 (20.0.0.2) 56(84) bytes of data.
64 bytes from 20.0.0.2: icmp_seq=1 ttl=64 time=42.2 ms
64 bytes from 20.0.0.2: icmp_seq=2 ttl=64 time=17.1 ms
^C
--- 20.0.0.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1000ms
rtt min/avg/max/mdev = 17.132/29.706/42.281/12.575 ms
```

Pingall

```
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 20.0.0.2
DEBUG:router:dpid 1: packet from 10.0.0.2 to 20.0.0.2 sent to port 2
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 2, replying for ARP from 20.0.0.2: mac for IP 20.0.0.1 is 02:00:de:ad:be:
12
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 30.0.0.2
DEBUG:router:dpid 1: packet from 10.0.0.2 to 30.0.0.2 is unknown for MAC of nexthop 30.0.0.2, adding
to ArpWait
DEBUG:router:dpid 1: port 3, sending ARP request for IP 30.0.0.2 from 30.0.0.1
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 30.0.0.2 to MAC 00:00:00:00:00:03
DEBUG:router:dpid 1: process ARP wait packet for IP 30.0.0.2
DEBUG:router:dpid 1: send wait ARP packet, destIP: 30.0.0.2, destMAC: 00:00:00:00:00:03, output port:
 3
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 2, from 20.0.0.2 to 30.0.0.2
DEBUG:router:dpid 1: packet from 20.0.0.2 to 30.0.0.2 sent to port 3
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 30.0.0.2
DEBUG:router:dpid 1: packet from 10.0.0.2 to 30.0.0.2 sent to port 3
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
11
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 2, replying for ARP from 20.0.0.2: mac for IP 20.0.0.1 is 02:00:de:ad:be:
12
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 3, replying for ARP from 30.0.0.2: mac for IP 30.0.0.1 is 02:00:de:ad:be:
13
```

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

Iperf h1 h2

```
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
.....*** Results: ['33.7 Gbits/sec', '33.7 Gbits/sec']
```

H1 ping 10.0.0.1

```
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 10.0.0.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 1: reply ping from 10.0.0.2 to 10.0.0.1
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
11
```

```
mininet> h1 ping -c1 10.0.0.1
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=5.53 ms

--- 10.0.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 5.535/5.535/5.535/0.000 ms
```

H1 ping 20.0.0.1

```
mininet> h1 ping -c1 20.0.0.1
PING 20.0.0.1 (20.0.0.1) 56(84) bytes of data.
64 bytes from 20.0.0.1: icmp_seq=1 ttl=64 time=11.7 ms

--- 20.0.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 11.724/11.724/11.724/0.000 ms
```

```
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 20.0.0.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 1: reply ping from 10.0.0.2 to 20.0.0.1
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
11
```

H1 ping 30.0.0.1

```
mininet> h1 ping -c1 30.0.0.1
PING 30.0.0.1 (30.0.0.1) 56(84) bytes of data.
64 bytes from 30.0.0.1: icmp_seq=1 ttl=64 time=34.4 ms

--- 30.0.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 34.402/34.402/34.402/0.000 ms
```

```
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 10.0.0.2 to 30.0.0.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 1: reply ping from 10.0.0.2 to 30.0.0.1
DEBUG:misc.controller_2:DPID 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
11
```

Scenario 3

rules installation in routers: The routers store all the pair and entries and IP addresses in the routing table. When the host wants to send a packet to an address with unknow next hop, the host will firstly send an ARP request, and the router will reply the next hop's MAC address to the host. Then the host will send the packet to that address. In another network, similarly, when the router doesn't know the MAC address of destination, it will request an ARP reply first, getting the output port. Then the packet will be sent to the right port.

rules installation in switches: When the host wants to send an ethernet frame with unknown destination, it will flood to every other port, and learn the mapping of port number and MAC address, storing it in the forwarding table..

H9 ping h10

```
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: sending packet to port 3
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow for dst 00:00:00:00:00:02, port 3
```

```
mininet> h9 ping -c1 h10
PING 172.17.16.3 (172.17.16.3) 56(84) bytes of data.
64 bytes from 172.17.16.3: icmp_seq=1 ttl=64 time=0.335 ms

--- 172.17.16.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.335/0.335/0.335/0.000 ms
```

H9 ping h12

```
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:
ad:be:11
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 10.0.0.2
DEBUG:router:dpid 1: packet from 172.17.16.2 to 10.0.0.2 is unknown for MAC of nexthop 192.168.0.2, a
dding to ArpWait
DEBUG:router:dpid 1: port 2, sending ARP request for IP 192.168.0.2 from 192.168.0.1
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 192.168.0.1 to MAC 02:00:de:ad:be:12
DEBUG:router:dpid 2: inport 3, replying for ARP from 192.168.0.1: mac for IP 192.168.0.2 is 02:00:de:
ad:be:23
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 192.168.0.2 to MAC 02:00:de:ad:be:23
DEBUG:router:dpid 1: process ARP wait packet for IP 192.168.0.2
DEBUG:router:dpid 1: send wait ARP packet, destIP: 192.168.0.2, destMAC: 02:00:de:ad:be:23, output po
rt: 2
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 3, from 172.17.16.2 to 10.0.0.2
DEBUG:router:dpid 2: packet from 172.17.16.2 to 10.0.0.2 is unknown for MAC of nexthop 10.0.0.2, addi
ng to ArpWait
DEBUG:router:dpid 2: port 1, sending ARP request for IP 10.0.0.2 from 10.0.0.1
DEBUG:misc.controller_3:Switch 5 dealing with packets
DEBUG:switch:Switch dpid 5: learns port 1 as source port
DEBUG:switch:Switch dpid 5: flooding
DEBUG:misc.controller_3:Switch 5 dealing with packets
DEBUG:switch:Switch dpid 5: learns port 2 as source port
DEBUG:switch:Switch dpid 5: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 5: adding flow for dst 02:00:de:ad:be:21, port 1
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 10.0.0.2 to MAC 00:00:00:00:00:04
DEBUG:router:dpid 2: process ARP wait packet for IP 10.0.0.2
DEBUG:router:dpid 2: send wait ARP packet, destIP: 10.0.0.2, destMAC: 00:00:00:00:00:04, output port:
 1
DEBUG:misc.controller_3:Switch 5 dealing with packets
DEBUG:switch:Switch dpid 5: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 5: adding flow for dst 00:00:00:00:00:04, port 2
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 1, from 10.0.0.2 to 172.17.16.2
DEBUG:router:dpid 2: packet from 10.0.0.2 to 172.17.16.2 sent to port 3
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 2, from 10.0.0.2 to 172.17.16.2
DEBUG:router:dpid 1: packet from 10.0.0.2 to 172.17.16.2 sent to port 1
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:
```

```
mininet> h9 ping -c1 h12
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=89.7 ms

--- 10.0.0.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 89.745/89.745/89.745/0.000 ms
mininet>
```

H9 ping h15

```
ADEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 10.0.0.130
DEBUG:router:dpid 1: packet from 172.17.16.2 to 10.0.0.130 sent to port 2
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 3, from 172.17.16.2 to 10.0.0.130
DEBUG:router:dpid 2: packet from 172.17.16.2 to 10.0.0.130 is unknown for MAC of nexthop 10.0.0.130, adding to ArpWait
DEBUG:router:dpid 2: port 2, sending ARP request for IP 10.0.0.130 from 10.0.0.129
DEBUG:misc.controller_3:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: learns port 1 as source port
DEBUG:switch:Switch dpid 6: flooding
DEBUG:misc.controller_3:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: learns port 2 as source port
DEBUG:switch:Switch dpid 6: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow for dst 02:00:de:ad:be:22, port 1
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 10.0.0.130 to MAC 00:00:00:00:00:07
DEBUG:router:dpid 2: process ARP wait packet for IP 10.0.0.130
DEBUG:router:dpid 2: send wait ARP packet, destIP: 10.0.0.130, destMAC: 00:00:00:00:00:07, output port: 2
DEBUG:misc.controller_3:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow for dst 00:00:00:00:00:07, port 2
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: inport 2, replying for ARP from 10.0.0.130: mac for IP 10.0.0.129 is 02:00:de:ad:be:22
```

```
mininet> h9 ping -c1 h15
PING 10.0.0.130 (10.0.0.130) 56(84) bytes of data.
64 bytes from 10.0.0.130: icmp_seq=1 ttl=64 time=94.3 ms

--- 10.0.0.130 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 94.391/94.391/94.391/0.000 ms
```

H9 ping h18

```
mininet> h9 ping -c1 h18
PING 20.0.0.2 (20.0.0.2) 56(84) bytes of data.
64 bytes from 20.0.0.2: icmp_seq=1 ttl=64 time=105 ms

--- 20.0.0.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 105.952/105.952/105.952/0.000 ms
```

```
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 20.0.0.2
DEBUG:router:dpid 1: packet from 172.17.16.2 to 20.0.0.2 is unknown for MAC of nexthop 192.168.0.6, adding to ArpWait
DEBUG:router:dpid 1: port 3, sending ARP request for IP 192.168.0.6 from 192.168.0.5
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: adds arpTable IP 192.168.0.5 to MAC 02:00:de:ad:be:13
DEBUG:router:dpid 3: inport 3, replying for ARP from 192.168.0.5: mac for IP 192.168.0.6 is 02:00:de:ad:be:33
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 192.168.0.6 to MAC 02:00:de:ad:be:33
DEBUG:router:dpid 1: process ARP wait packet for IP 192.168.0.6
DEBUG:router:dpid 1: send wait ARP packet, destIP: 192.168.0.6, destMAC: 02:00:de:ad:be:33, output port: 3
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 172.17.16.2 to 20.0.0.2
DEBUG:router:dpid 3: packet from 172.17.16.2 to 20.0.0.2 is unknown for MAC of nexthop 20.0.0.2, adding to ArpWait
DEBUG:router:dpid 3: port 1, sending ARP request for IP 20.0.0.2 from 20.0.0.1
DEBUG:misc.controller_3:Switch 7 dealing with packets
DEBUG:switch:Switch dpid 7: learns port 1 as source port
DEBUG:switch:Switch dpid 7: flooding
DEBUG:misc.controller_3:Switch 7 dealing with packets
DEBUG:switch:Switch dpid 7: learns port 2 as source port
DEBUG:switch:Switch dpid 7: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 7: adding flow for dst 02:00:de:ad:be:31, port 1
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: adds arpTable IP 20.0.0.2 to MAC 00:00:00:00:00:0a
DEBUG:router:dpid 3: process ARP wait packet for IP 20.0.0.2
DEBUG:router:dpid 3: send wait ARP packet, destIP: 20.0.0.2, destMAC: 00:00:00:00:00:0a, output port: 1
DEBUG:misc.controller_3:Switch 7 dealing with packets
DEBUG:switch:Switch dpid 7: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 7: adding flow for dst 00:00:00:00:00:0a, port 2
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 1, from 20.0.0.2 to 172.17.16.2
DEBUG:router:dpid 3: packet from 20.0.0.2 to 172.17.16.2 sent to port 3
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: inport 1, replying for ARP from 20.0.0.2: mac for IP 20.0.0.1 is 02:00:de:ad:be:31
```

H9 ping h21

```
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 20.0.0.130
DEBUG:router:dpid 1: packet from 172.17.16.2 to 20.0.0.130 sent to port 3
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 172.17.16.2 to 20.0.0.130
DEBUG:router:dpid 3: packet from 172.17.16.2 to 20.0.0.130 is unknown for MAC of nexthop 20.0.0.130, adding to ArpWait
DEBUG:router:dpid 3: port 2, sending ARP request for IP 20.0.0.130 from 20.0.0.129
DEBUG:misc.controller_3:Switch 8 dealing with packets
DEBUG:switch:Switch dpid 8: learns port 1 as source port
DEBUG:switch:Switch dpid 8: flooding
DEBUG:misc.controller_3:Switch 8 dealing with packets
DEBUG:switch:Switch dpid 8: learns port 2 as source port
DEBUG:switch:Switch dpid 8: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 8: adding flow for dst 02:00:de:ad:be:32, port 1
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: adds arpTable IP 20.0.0.130 to MAC 00:00:00:00:00:0d
DEBUG:router:dpid 3: process ARP wait packet for IP 20.0.0.130
DEBUG:router:dpid 3: send wait ARP packet, destIP: 20.0.0.130, destMAC: 00:00:00:00:00:0d, output port: 2
DEBUG:misc.controller_3:Switch 8 dealing with packets
DEBUG:switch:Switch dpid 8: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 8: adding flow for dst 00:00:00:00:00:0d, port 2
DEBUG:misc.controller_3:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: inport 2, replying for ARP from 20.0.0.130: mac for IP 20.0.0.129 is 02:00:de:ad:be:32
```

```
mininet> h9 ping -c1 h21
PING 20.0.0.130 (20.0.0.130) 56(84) bytes of data.
64 bytes from 20.0.0.130: icmp_seq=1 ttl=64 time=100 ms

--- 20.0.0.130 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 100.955/100.955/100.955/0.000 ms
mininet>
```

Pingall

```
mininet> pingall
*** Ping: testing ping reachability
h9 → h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h10 → h9 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h11 → h9 h10 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h12 → h9 h10 h11 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h13 → h9 h10 h11 h12 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h14 → h9 h10 h11 h12 h13 h15 h16 h17 h18 h19 h20 h21 h22 h23
h15 → h9 h10 h11 h12 h13 h14 h16 h17 h18 h19 h20 h21 h22 h23
h16 → h9 h10 h11 h12 h13 h14 h15 h17 h18 h19 h20 h21 h22 h23
h17 → h9 h10 h11 h12 h13 h14 h15 h16 h18 h19 h20 h21 h22 h23
h18 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h19 h20 h21 h22 h23
h19 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h20 h21 h22 h23
h20 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h21 h22 h23
h21 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h22 h23
h22 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h23
h23 → h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22
*** Results: 0% dropped (210/210 received)
```

h9 ping 172.17.16.1

```
mininet> h9 ping -c1 172.17.16.1
PING 172.17.16.1 (172.17.16.1) 56(84) bytes of data.
64 bytes from 172.17.16.1: icmp_seq=1 ttl=64 time=35.4 ms

--- 172.17.16.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 35.456/35.456/35.456/0.000 ms
```

```
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 172.17.16.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 1: reply ping from 172.17.16.2 to 172.17.16.1
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

h9 ping 10.0.0.1

```
EBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 10.0.0.1
DEBUG:router:dpid 1: packet from 172.17.16.2 to 10.0.0.1 sent to port 2
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 3, from 172.17.16.2 to 10.0.0.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 2: reply ping from 172.17.16.2 to 10.0.0.1
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

```
mininet> h9 ping -c1 10.0.0.1
PING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_seq=1 ttl=64 time=27.5 ms

--- 10.0.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 27.587/27.587/27.587/0.000 ms
```

h9 ping 10.0.0.129

```
mininet> h9 ping -c1 10.0.0.129
PING 10.0.0.129 (10.0.0.129) 56(84) bytes of data.
64 bytes from 10.0.0.129: icmp_seq=1 ttl=64 time=34.7 ms

--- 10.0.0.129 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 34.710/34.710/34.710/0.000 ms
```

```
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 10.0.0.129
DEBUG:router:dpid 1: packet from 172.17.16.2 to 10.0.0.129 sent to port 2
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 3, from 172.17.16.2 to 10.0.0.129
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 2: reply ping from 172.17.16.2 to 10.0.0.129
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

h9 ping 20.0.0.1

```
mininet> h9 ping -c1 20.0.0.1
PING 20.0.0.1 (20.0.0.1) 56(84) bytes of data.
64 bytes from 20.0.0.1: icmp_seq=1 ttl=64 time=7.91 ms

--- 20.0.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 7.916/7.916/7.916/0.000 ms
```

```
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 20.0.0.1
DEBUG:router:dpid 1: packet from 172.17.16.2 to 20.0.0.1 sent to port 3
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 172.17.16.2 to 20.0.0.1
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 3: reply ping from 172.17.16.2 to 20.0.0.1
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

h9 ping 20.0.0.129

```
mininet> h9 ping -c1 20.0.0.129
PING 20.0.0.129 (20.0.0.129) 56(84) bytes of data.
64 bytes from 20.0.0.129: icmp_seq=1 ttl=64 time=35.8 ms

--- 20.0.0.129 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 35.882/35.882/35.882/0.000 ms
mininet>
```

```
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 20.0.0.129
DEBUG:router:dpid 1: packet from 172.17.16.2 to 20.0.0.129 sent to port 3
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 172.17.16.2 to 20.0.0.129
DEBUG:router:ICMP packet comes to router
DEBUG:router:dpid 3: reply ping from 172.17.16.2 to 20.0.0.129
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

h9 ping 8.8.8.8

```
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 8.8.8.8
DEBUG:router:dpid 1: packet from 172.17.16.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 8.8.8.8
DEBUG:router:dpid 1: packet from 172.17.16.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 8.8.8.8
DEBUG:router:dpid 1: packet from 172.17.16.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 8.8.8.8
DEBUG:router:dpid 1: packet from 172.17.16.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

```
mininet>
mininet> h9 ping 8.8.8.8
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
From 8.8.8.8 icmp_seq=1 Destination Net Unreachable
From 8.8.8.8 icmp_seq=2 Destination Net Unreachable
From 8.8.8.8 icmp_seq=3 Destination Net Unreachable
From 8.8.8.8 icmp_seq=4 Destination Net Unreachable
^C
--- 8.8.8.8 ping statistics ---
4 packets transmitted, 0 received, +4 errors, 100% packet loss, time 3005ms
```

h12 ping 8.8.8.8

```
mininet> h12 ping 8.8.8.8
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
From 8.8.8.8 icmp_seq=1 Destination Net Unreachable
From 8.8.8.8 icmp_seq=2 Destination Net Unreachable
^C
--- 8.8.8.8 ping statistics ---
2 packets transmitted, 0 received, +2 errors, 100% packet loss, time 1001ms
```

```
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 1, from 10.0.0.2 to 8.8.8.8
DEBUG:router:dpid 2: packet from 10.0.0.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 1, from 10.0.0.2 to 8.8.8.8
DEBUG:router:dpid 2: packet from 10.0.0.2 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 2 dealing with packets
DEBUG:router:dpid 2: inport 1, replying for ARP from 10.0.0.2: mac for IP 10.0.0.1 is 02:00:de:ad:be:21
```

h21 ping 8.8.8.8

```
mininet> h21 ping 8.8.8.8
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data.
From 8.8.8.8 icmp_seq=1 Destination Net Unreachable
From 8.8.8.8 icmp_seq=2 Destination Net Unreachable
From 8.8.8.8 icmp_seq=3 Destination Net Unreachable
^C
--- 8.8.8.8 ping statistics ---
3 packets transmitted, 0 received, +3 errors, 100% packet loss, time 2004ms
```

```
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 2, from 20.0.0.130 to 8.8.8.8
DEBUG:router:dpid 3: packet from 20.0.0.130 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 2, from 20.0.0.130 to 8.8.8.8
DEBUG:router:dpid 3: packet from 20.0.0.130 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 2, from 20.0.0.130 to 8.8.8.8
DEBUG:router:dpid 3: packet from 20.0.0.130 to 8.8.8.8 is unreachable
DEBUG:misc.controller_3:Router 3 dealing with packets
DEBUG:router:dpid 3: inport 2, replying for ARP from 20.0.0.130: mac for IP 20.0.0.129 is 02:00:de:ad:be:32
```

iperf h9 h12

```
mininet> iperf h9 h12
*** Iperf: testing TCP bandwidth between h9 and h12
.*** Results: ['26.4 Gbits/sec', '26.5 Gbits/sec']
```

iperf h9 h15

```
mininet> iperf h9 h15
*** Iperf: testing TCP bandwidth between h9 and h15
*** Results: ['28.8 Gbits/sec', '28.9 Gbits/sec']
```

iperf h9 h18

```
mininet> iperf h9 h18
*** Iperf: testing TCP bandwidth between h9 and h18
.*** Results: ['20.0 Gbits/sec', '20.0 Gbits/sec']
```

iperf h9 h21

```
mininet> iperf h9 h21
*** Iperf: testing TCP bandwidth between h9 and h21
*** Results: ['19.8 Gbits/sec', '19.9 Gbits/sec']
```

Scenario 3b

Installation rules of router: To block all communications with h12, in the controller, the router 2 will identify whether the destination or source address of the packet is h12. If yes, the packet will be dropped. To implement the secure server h17, in router 2, we set the priority of blocking all packets whose destination is h17 lower than the priority of allowing packets to h17, but higher than the default priority.

In switch, we block all the frame to h12 and h17.

H12 ping h14

```
DEBUG:misc.controller_3b:Switch 5 dealing with packets
DEBUG:switch:Switch dpid 5: learns port 2 as source port
DEBUG:switch:Switch dpid 5: flooding
DEBUG:misc.controller_3b:Installing additional rules
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 10.0.0.2 to MAC 00:00:00:00:00:04
DEBUG:misc.controller_3b:Switch 5 dealing with packets
DEBUG:switch:Switch dpid 5: learns port 4 as source port
DEBUG:switch:Switch dpid 5: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 5: adding flow from src 00:00:00:00:00:06 to dst 00:00:00:00:00:04, port 2
```

```
mininet> h12 ping -c1 h14
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.

--- 10.0.0.4 ping statistics ---
1 packets transmitted, 0 received, 100% packet loss, time 0ms
```

H10 ping h12

```
mininet> h10 ping -c1 h12
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.

--- 10.0.0.2 ping statistics ---
1 packets transmitted, 0 received, 100% packet loss, time 0ms
```

```
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.3 to 10.0.0.2
DEBUG:router:dpid 1: packet from 172.17.16.3 to 10.0.0.2 is unknown for MAC of nexthop 192.168.0.2, adding to ArpWait
DEBUG:router:dpid 1: port 2, sending ARP request for IP 192.168.0.2 from 192.168.0.1
DEBUG:misc.controller_3b:Installing additional rules
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 192.168.0.1 to MAC 02:00:de:ad:be:12
DEBUG:router:dpid 2: inport 3, replying for ARP from 192.168.0.1: mac for IP 192.168.0.2 is 02:00:de:ad:be:23
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 192.168.0.2 to MAC 02:00:de:ad:be:23
DEBUG:router:dpid 1: process ARP wait packet for IP 192.168.0.2
DEBUG:router:dpid 1: send wait ARP packet, destIP: 192.168.0.2, destMAC: 02:00:de:ad:be:23, output port: 2
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.3 to 10.0.0.2
DEBUG:router:dpid 1: packet from 172.17.16.3 to 10.0.0.2 sent to port 2
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 172.17.16.3 to MAC 00:00:00:00:00:02
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.3: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: learns port 1 as source port
DEBUG:switch:Switch dpid 4: sending packet to port 3
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 02:00:de:ad:be:11 to dst 00:00:00:00:00:02, port 3
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 00:00:00:00:00:02 to dst 02:00:de:ad:be:11, port 1
```

H12 ping h12

```
mininet> h12 ping -c1 h12
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=0.013 ms

--- 10.0.0.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.013/0.013/0.013/0.000 ms
```

Iperf h16 h12

```
DEBUG:misc.controller_3b:Installing additional rules
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: inport 2, replying for ARP from 10.0.0.131: mac for IP 10.0.0.129 is 02:00:de:ad:be:22
```

```
mininet> iperf h16 h12
*** Iperf: testing TCP bandwidth between h16 and h12
```

H9 ping h17

```
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: learns port 2 as source port
DEBUG:switch:Switch dpid 4: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 00:00:00:00:00:01 to dst 02:00:de:ad:be:11, port 1
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 1, from 172.17.16.2 to 10.0.0.132
DEBUG:router:dpid 1: packet from 172.17.16.2 to 10.0.0.132 sent to port 2
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: learns port 1 as source port
DEBUG:switch:Switch dpid 6: flooding
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 172.17.16.2 to MAC 00:00:00:00:00:01
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.2: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 02:00:de:ad:be:11 to dst 00:00:00:00:00:01, port 2
```

```
mininet> h9 ping -c1 h17
PING 10.0.0.132 (10.0.0.132) 56(84) bytes of data.

--- 10.0.0.132 ping statistics ---
1 packets transmitted, 0 received, 100% packet loss, time 0ms
```

H17 ping h14

```
mininet> h17 ping -c1 h14
PING 10.0.0.4 (10.0.0.4) 56(84) bytes of data.

--- 10.0.0.4 ping statistics ---
1 packets transmitted, 0 received, 100% packet loss, time 0ms
```

```
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: learns port 4 as source port
DEBUG:switch:Switch dpid 6: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow from src 00:00:00:00:00:09 to dst 02:00:de:ad:be:22, port 1
DEBUG:misc.controller_3b:Installing additional rules
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 10.0.0.132 to MAC 00:00:00:00:00:09
DEBUG:router:dpid 2: inport 2, replying for ARP from 10.0.0.132: mac for IP 10.0.0.129 is 02:00:de:ad:be:22
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: sending packet to port 4
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow from src 02:00:de:ad:be:22 to dst 00:00:00:00:00:09, port 4
```

Iperf h17 h18

```
mininet> iperf h17 h18
*** Iperf: testing TCP bandwidth between h17 and h18
*** Results: ['28.0 Gbits/sec', '27.9 Gbits/sec']
```

```
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
DEBUG:misc.controller_3b:Router 3 dealing with packets
DEBUG:router:dpid 3: ipv4 packet inport 3, from 10.0.0.132 to 20.0.0.2
DEBUG:router:dpid 3: packet from 10.0.0.132 to 20.0.0.2 sent to port 1
```

Iperf h17 h15

```
DEBUG:switch:Switch dpid 6: flooding
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: learns port 2 as source port
DEBUG:switch:Switch dpid 6: sending packet to port 4
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow from src 00:00:00:00:00:07 to dst 00:00:00:00:00:09, port 4
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: adds arpTable IP 10.0.0.132 to MAC 00:00:00:00:00:09
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow from src 00:00:00:00:00:09 to dst 00:00:00:00:00:07, port 2
```

```
mininet> iperf h17 h15
*** Iperf: testing TCP bandwidth between h17 and h15
```

Iperf h17 h11

```
DEBUG:misc.controller_3b:Switch 6 dealing with packets
DEBUG:switch:Switch dpid 6: sending packet to port 2
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 6: adding flow from src 00:00:00:00:00:09 to dst 00:00:00:00:00:07, port 2
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: ipv4 packet inport 2, from 10.0.0.132 to 172.17.16.4
DEBUG:router:dpid 2: packet from 10.0.0.132 to 172.17.16.4 sent to port 3
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 2, from 10.0.0.132 to 172.17.16.4
DEBUG:router:dpid 1: packet from 10.0.0.132 to 172.17.16.4 is unknown for MAC of nexthop 172.17.16.4, adding to ArpWait
DEBUG:router:dpid 1: port 1, sending ARP request for IP 172.17.16.4 from 172.17.16.1
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: learns port 1 as source port
DEBUG:switch:Switch dpid 4: flooding
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: learns port 4 as source port
DEBUG:switch:Switch dpid 4: sending packet to port 1
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 00:00:00:00:00:03 to dst 02:00:de:ad:be:11, port 1
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: adds arpTable IP 172.17.16.4 to MAC 00:00:00:00:00:03
DEBUG:router:dpid 1: process ARP wait packet for IP 172.17.16.4
DEBUG:router:dpid 1: send wait ARP packet, destIP: 172.17.16.4, destMAC: 00:00:00:00:00:03, output port: 1
DEBUG:misc.controller_3b:Switch 4 dealing with packets
DEBUG:switch:Switch dpid 4: sending packet to port 4
DEBUG:switch:Installing flow...
DEBUG:switch:Switch dpid 4: adding flow from src 02:00:de:ad:be:11 to dst 00:00:00:00:00:03, port 4
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: ipv4 packet inport 2, from 10.0.0.132 to 172.17.16.4
DEBUG:router:dpid 1: packet from 10.0.0.132 to 172.17.16.4 sent to port 1
DEBUG:misc.controller_3b:Router 2 dealing with packets
DEBUG:router:dpid 2: inport 2, replying for ARP from 10.0.0.132: mac for IP 10.0.0.129 is 02:00:de:ad:be:22
DEBUG:misc.controller_3b:Router 1 dealing with packets
DEBUG:router:dpid 1: inport 1, replying for ARP from 172.17.16.4: mac for IP 172.17.16.1 is 02:00:de:ad:be:11
```

Ping all

```
mininet> pingall
*** Ping: testing ping reachability
h9 → h10 h11 X h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h10 → h9 h11 X h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h11 → h9 h10 X h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23
h12 → X X X X X X X X X X X X X
h13 → h9 h10 h11 X h14 h15 h16 X h18 h19 h20 h21 h22 h23
h14 → h9 h10 h11 X h13 h15 h16 X h18 h19 h20 h21 h22 h23
h15 → h9 h10 h11 X h13 h14 h16 X h18 h19 h20 h21 h22 h23
h16 → h9 h10 h11 X h13 h14 h15 X h18 h19 h20 h21 h22 h23
h17 → h9 h10 h11 X X X X X h18 X X X X X
h18 → h9 h10 h11 X h13 h14 h15 h16 h17 h19 h20 h21 h22 h23
h19 → h9 h10 h11 X h13 h14 h15 h16 X h18 h20 h21 h22 h23
h20 → h9 h10 h11 X h13 h14 h15 h16 X h18 h19 h21 h22 h23
h21 → h9 h10 h11 X h13 h14 h15 h16 X h18 h19 h20 h22 h23
h22 → h9 h10 h11 X h13 h14 h15 h16 X h18 h19 h20 h21 h23
h23 → h9 h10 h11 X h13 h14 h15 h16 X h18 h19 h20 h21 h22
*** Results: 21% dropped (164/210 received)
```