Software Defined Networking Security

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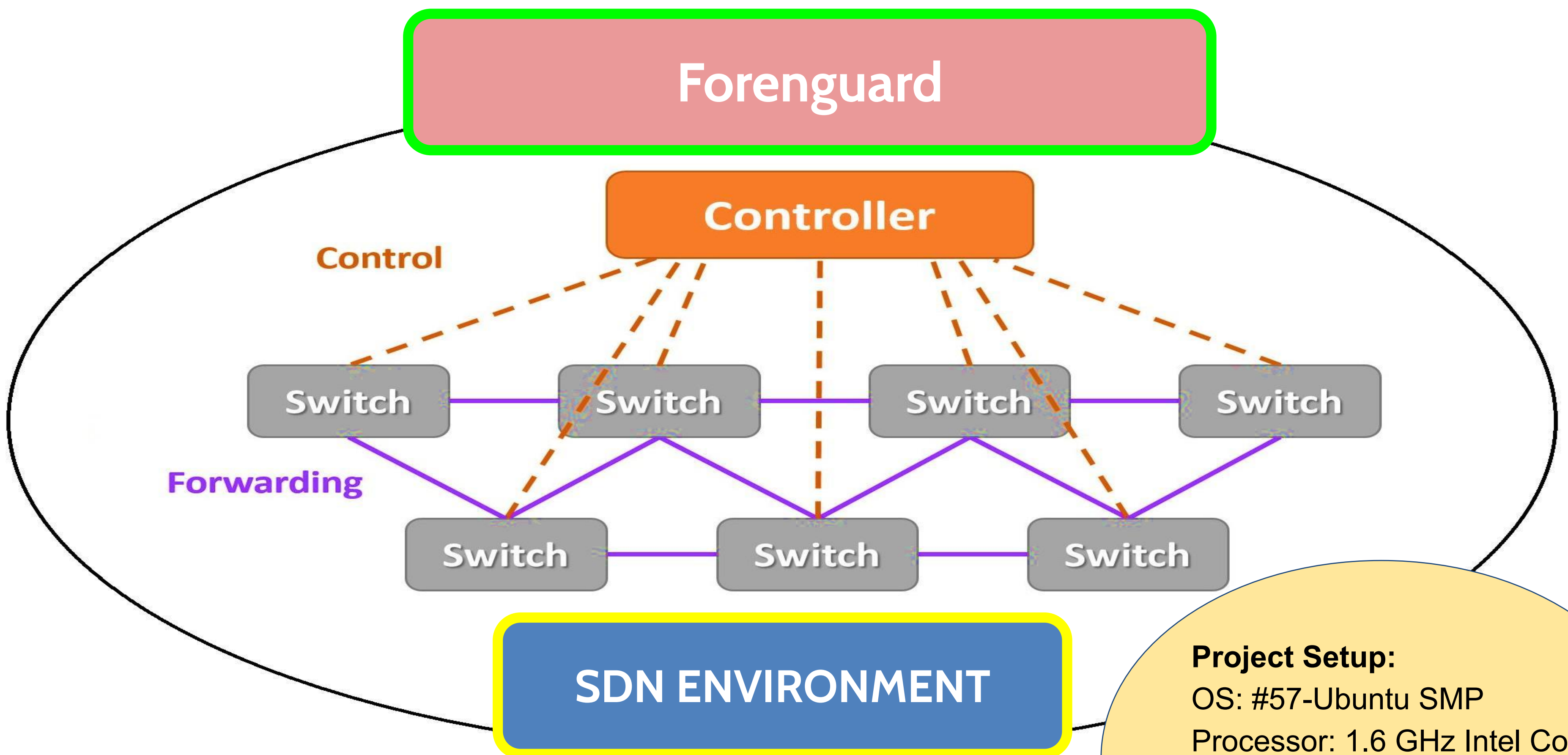


Project Setup:
OS: #57-Ubuntu SMP
Processor: 1.6 GHz Intel Core i5
Memory: 8 GB 1867 MHz DDR3
Tools used: ForenGuard
MongoDB
ODL Controller

Introduction

What is SDN? Software Defined Networking is an modern computer network architecture which defines how a networking and computing system can be built using a combination of open, software-based technologies and commodity networking hardware that separate the SDN control plane and the SDN data plane of the networking stack.

Before SDN/Traditional Networking? In traditional networking, the switch does not have programmability, the rules cannot be changed dynamically. In SDN, the switch is connected to a controller, which controls the actions of the switch. The controller can be programmed dynamically to control the switch.

Advantages of SDN

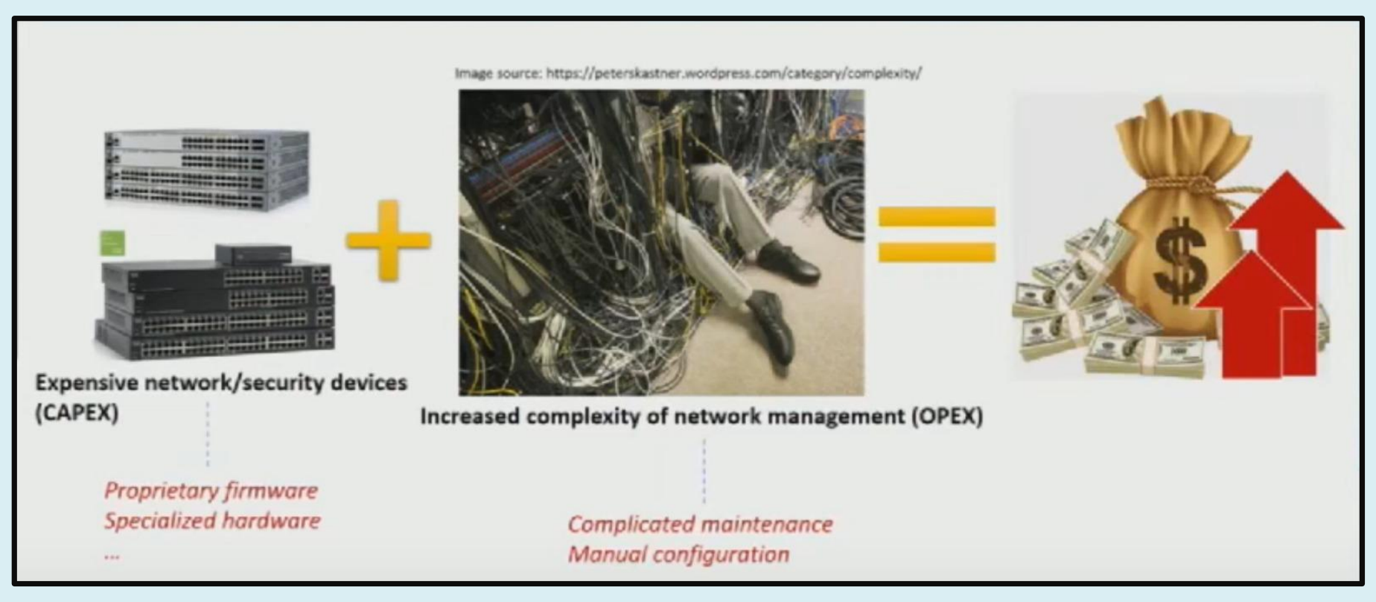
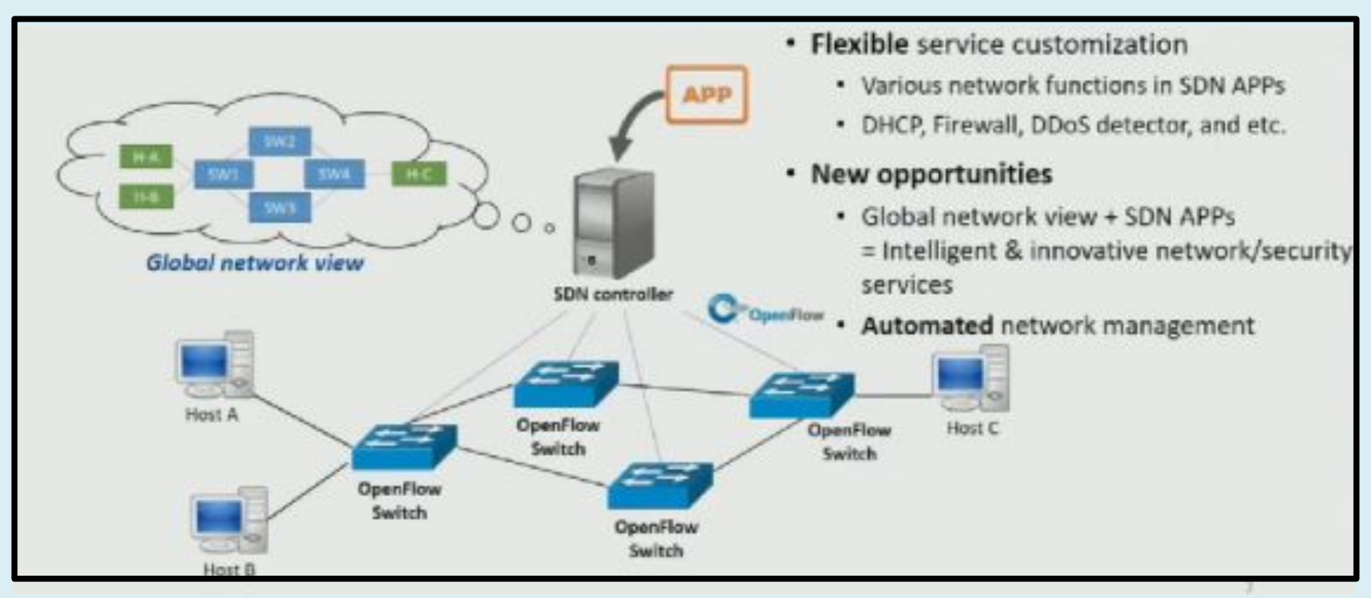


Image source: https://peterskastner.wordpress.com/category/complexity/
Expensive network/security devices (CAPEX)
Proprietary firmware
Specialized hardware
...
Increased complexity of network management (OPEX)
Complicated maintenance
Manual configuration

- ❑ In a month from now, there will be over 50 billion devices connected to the internet because of this our network will need to be scaled at a much larger rate.


Flexible service customization
Various network functions in SDN APPs
DHCP, Firewall, DDoS detector, and etc.
New opportunities
Global network view + SDN APPs = Intelligent & innovative network/security services
Automated network management
APP
Global network view
SDN controller
OpenFlow
Host A
Host B
Host C
OpenFlow Switch
OpenFlow Switch
OpenFlow Switch
OpenFlow Switch

- ❑ SDN grants the ability to manage a network from a centralized perspective.
- ❑ SDN virtualizes both the data and control planes allowing the user to provision physical and virtual elements from one location.
- ❑ SDN gives the user more scalability providing the ability to provision resources at will you can change your network infrastructure at a moment's notice.

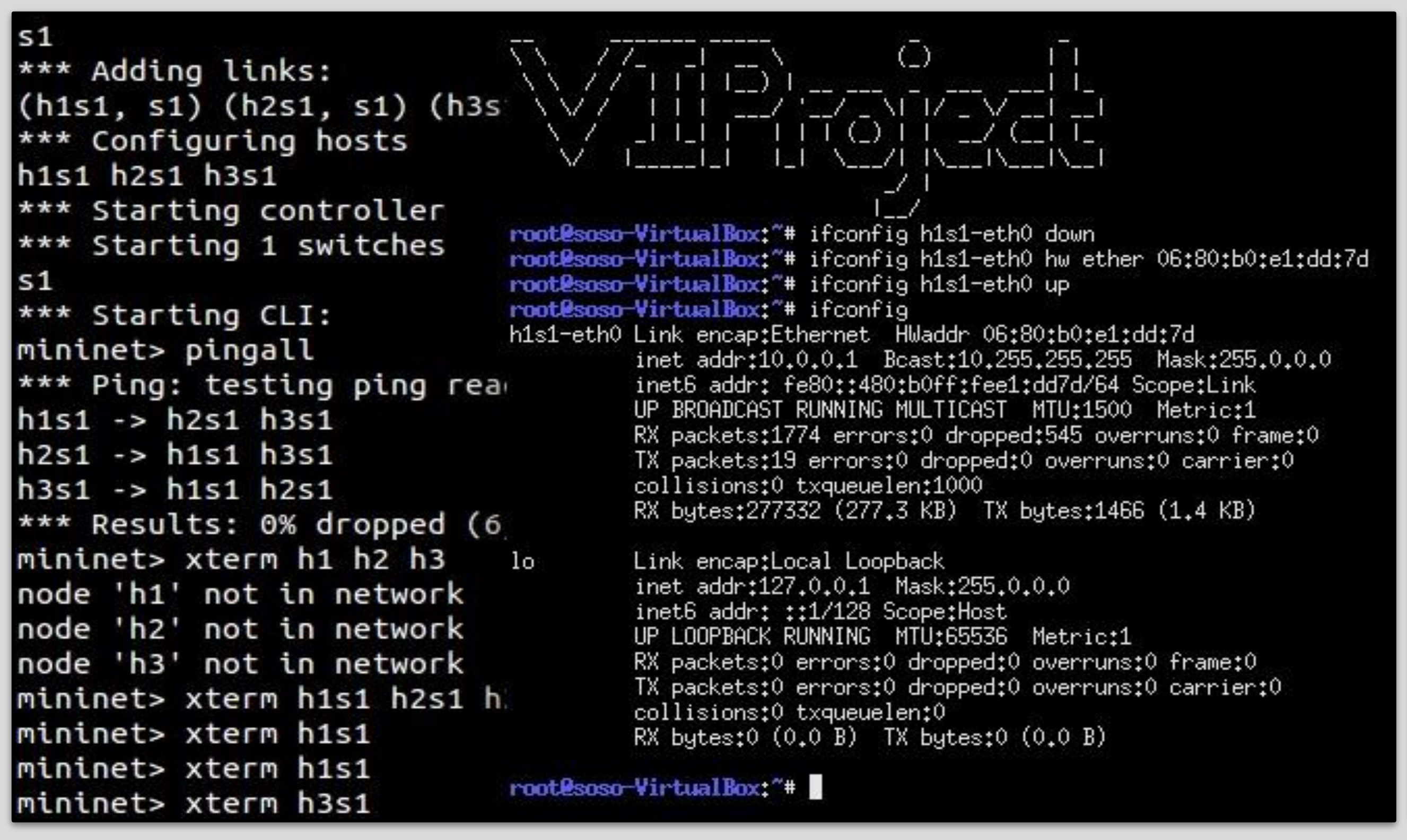
Disadvantages of SDN

- ❑ Increased complexity which allows hackers to control network operations in arbitrary ways, confuse or blind the defenders, and create inconsistencies
- ❑ Inability to directly manage individual devices, leading to increased maintenance.
- ❑ Increased latency due to infrastructure being virtualized.

Leading SDN Market Players:

- ❑ Cisco Systems Inc.
- ❑ IBM Corporation
- ❑ Hewlett Packard Enterprise
- ❑ VMware
- ❑ Juniper Networks
- ❑ Huawei Technologies Co. Ltd.

Environment Setup

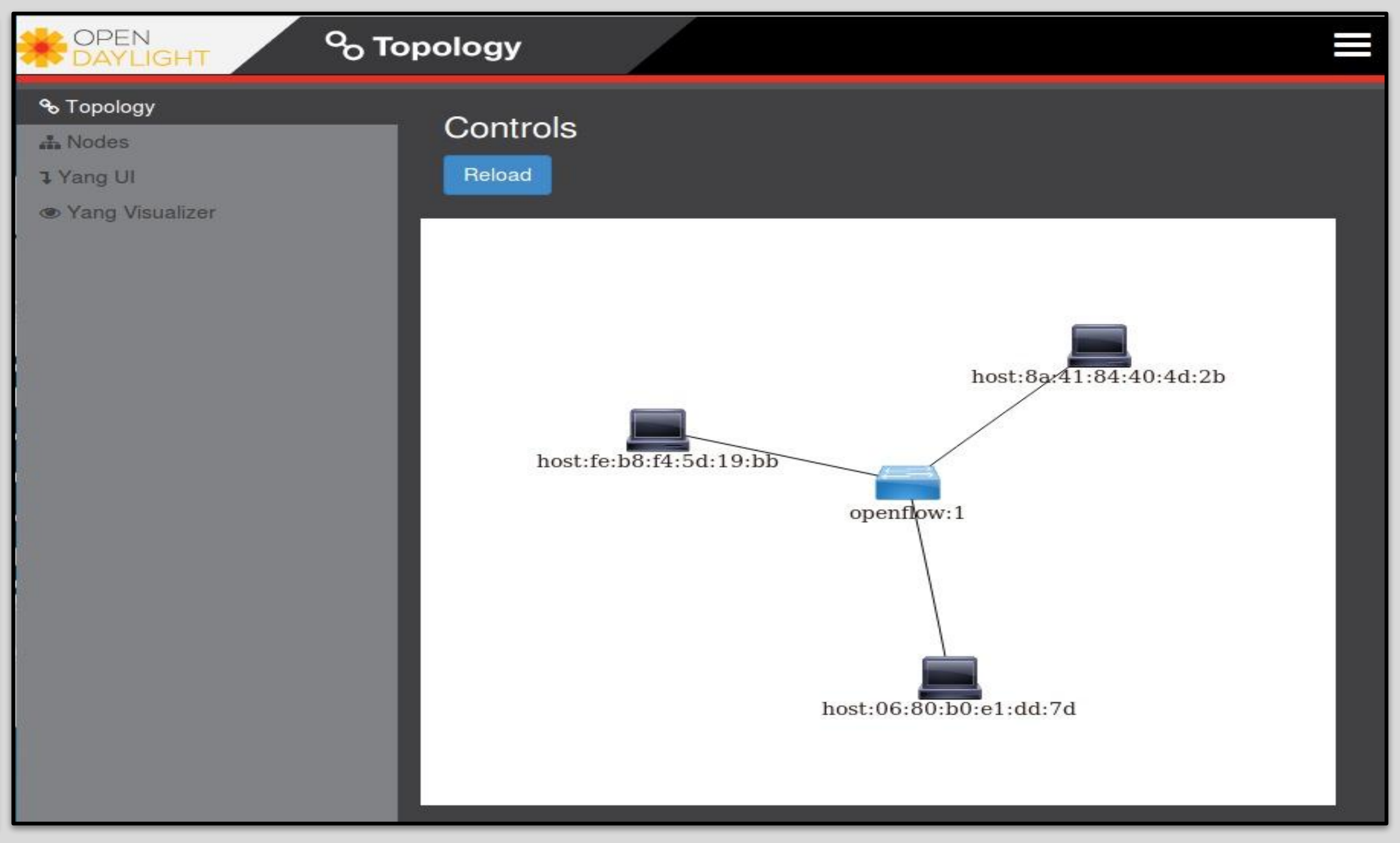


```
s1
*** Adding links:
(h1s1, s1) (h2s1, s1) (h3s
*** Configuring hosts
h1s1 h2s1 h3s1
*** Starting controller
*** Starting 1 switches
s1
*** Starting CLI:
mininet> pingall
*** Ping: testing ping rea
h1s1 -> h2s1 h3s1
h2s1 -> h1s1 h3s1
h3s1 -> h1s1 h2s1
*** Results: 0% dropped (6
mininet> xterm h1 h2 h3
node 'h1' not in network
node 'h2' not in network
node 'h3' not in network
mininet> xterm h1s1 h2s1 h
mininet> xterm h1s1
mininet> xterm h1s1
mininet> xterm h3s1
```

```
root@soso-VirtualBox:~# ifconfig h1s1-eth0 down
root@soso-VirtualBox:~# ifconfig h1s1-eth0 hw ether 06:80:b0:e1:dd:7d
root@soso-VirtualBox:~# ifconfig h1s1-eth0 up
root@soso-VirtualBox:~# ifconfig
h1s1-eth0 Link encap:Ethernet  HWaddr 06:80:b0:e1:dd:7d
          inet addr:10.0.0.1  Bcast:10.255.255.255  Mask:255.0.0.0
          inet6 addr: fe80::480:b0ff:fee1:dd7d/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1774 errors:0 dropped:545 overruns:0 frame:0
          TX packets:19 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:277332 (277.3 KB)  TX bytes:1466 (1.4 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@soso-VirtualBox:~# 
```



Implementation

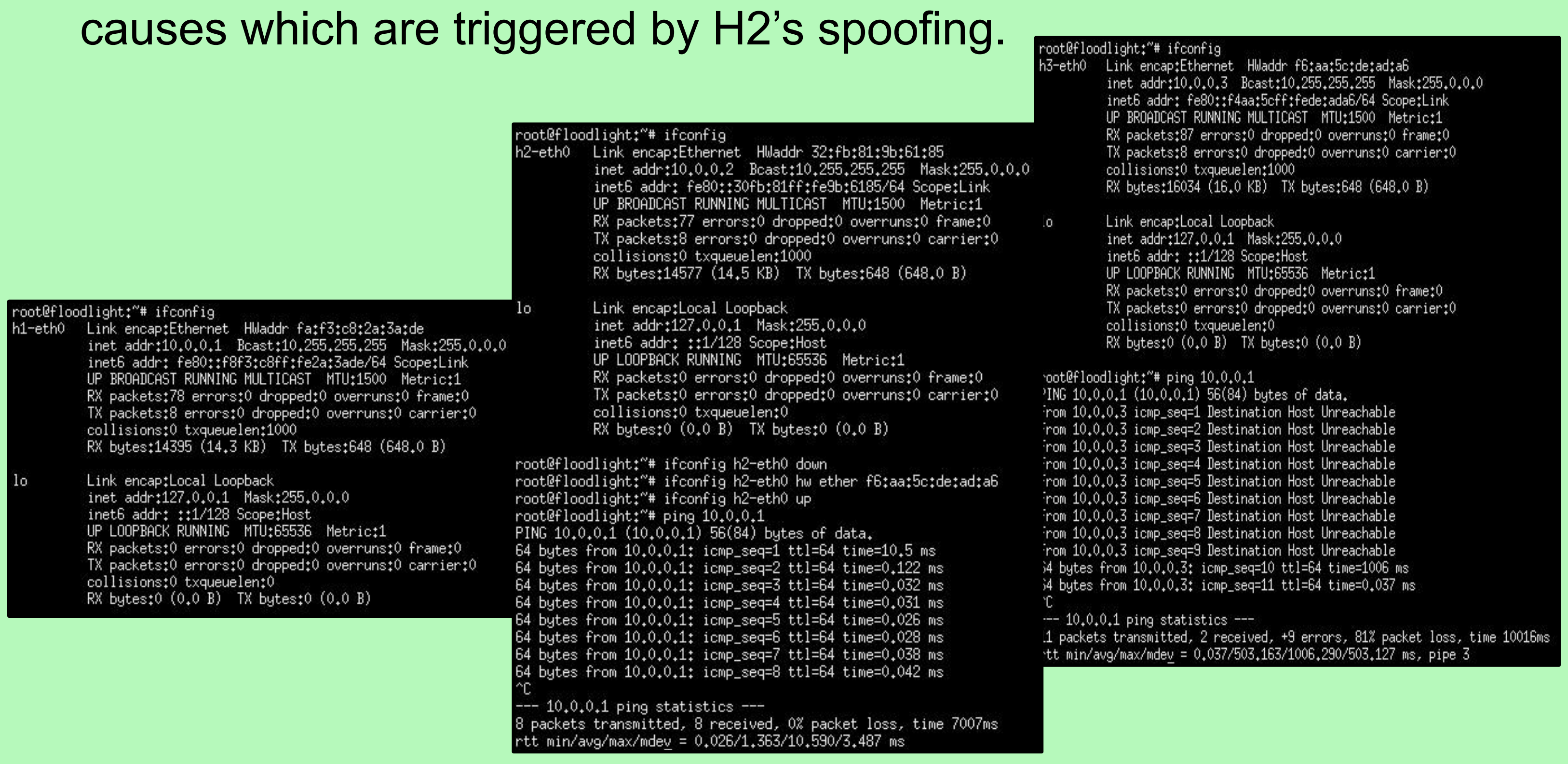
```
OFSwitchBase
DPID[00:00:00:00:00:00:00:02]:
-> Receive Event OFPacketInVer13
-> Init Function
processPacketInMessage
-> Init Function addToPortMap
-> Write Variable
macVlanToSwitchPortMap -254649434
-> Return Function addToPortMap
-> Init Function getFromPortMap
-> Read Variable
macVlanToSwitchPortMap -517582621
-> Return Function getFromPortMap
-> Init Function pushPacket
-> Return Function pushPacket
-> Init Function writeFlowMod
-> send Message FLOW_MOD
-> Return Function writeFlowMod
-> Init Function writeFlowMod
-> send Message FLOW_MOD
-> Return Function writeFlowMod
-> Return Function
processPacketInMessage
-> Return Function receive
```

```
OFSwitchBase
DPID[00:00:00:00:00:00:00:02]:
-> Receive Event
OFPacketInVer13
-> Init Function
processPacketInMessage
-> Init Function addToPortMap
-> Write Variable
macVlanToSwitchPortMap
-517582621
-> Return Function addToPortMap
-> Init Function getFromPortMap
-> Read Variable
macVlanToSwitchPortMap null
-> Return Function
getFromPortMap
-> Init Function
writePacketOutForPacketIn
-> Return Function
writePacketOutForPacketIn
-> Return Function
processPacketInMessage
-> Return Function receive
```

```
OFSwitchBase
DPID[00:00:00:00:00:00:00:01]:
-> Receive Event OFPacketInVer13
-> Init Function
processPacketInMessage
-> Init Function addToPortMap
-> Write Variable
macVlanToSwitchPortMap -517582622
-> Return Function addToPortMap
-> Init Function getFromPortMap
-> Read Variable
macVlanToSwitchPortMap -254649433
-> Return Function getFromPortMap
-> Init Function pushPacket
-> Return Function pushPacket
-> Init Function writeFlowMod
-> send Message FLOW_MOD
-> Return Function writeFlowMod
-> Init Function writeFlowMod
-> send Message FLOW_MOD
-> Return Function writeFlowMod
-> Return Function
processPacketInMessage
-> Return Function receive
```

```
OFSwitchBase
DPID[00:00:00:00:00:00:00:01]:
-> Receive Event
OFPacketInVer13
-> Init Function
processPacketInMessage
-> Init Function addToPortMap
-> Write Variable
macVlanToSwitchPortMap
-254649433
-> Return Function addToPortMap
-> Init Function getFromPortMap
-> Read Variable
macVlanToSwitchPortMap null
-> Return Function
getFromPortMap
-> Init Function
writePacketOutForPacketIn
-> Return Function
writePacketOutForPacketIn
-> Return Function
processPacketInMessage
-> Return Function receive
```

- ❑ Setup the environment using OpenDayLight SDN Controller
- ❑ Start mongodb to collect and store data from mininet
- ❑ Create a three-switch topology using mininet and openflow protocol
- ❑ Prepare for the MAC spoofing attack within node H1,H2, and H3
- ❑ Check all three hosts network configuration
- ❑ H2 is spoofing H3's MAC address then pings to H1
- ❑ At the same time, H3 cannot make the connection with H1 anymore
- ❑ ForenGuard is able to diagnose why H3 lost connection with H1.
- ❑ By checking the diagnosis results, there are four events that are the root causes which are triggered by H2's spoofing.



```
root@floodlight:~# ifconfig
h1-eth0   Link encap:Ethernet  HWaddr fa:f3:c8:2a:3a:de
          inet addr:10.0.0.1  Bcast:10.255.255.255  Mask:255.0.0.0
          inet6 addr: fe80::f8f3:c8ff:fe2a:3ade/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:78 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:14395 (14.3 KB)  TX bytes:648 (648.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)
```

```
root@floodlight:~# ifconfig
h2-eth0   Link encap:Ethernet  HWaddr 32:fb:81:9b:61:85
          inet addr:10.0.0.2  Bcast:10.255.255.255  Mask:255.0.0.0
          inet6 addr: fe80::30fb:81ff:fe9b:6185/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:77 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:14577 (14.5 KB)  TX bytes:648 (648.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@floodlight:~# ifconfig h2-eth0 down
root@floodlight:~# ifconfig h2-eth0 hw ether f6:aa:5c:de:ad:a6
root@floodlight:~# ifconfig h2-eth0 up
root@floodlight:~# ping 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=10.5 ms
64 bytes from 10.0.0.1: icmp_seq=2 ttl=64 time=0.122 ms
64 bytes from 10.0.0.1: icmp_seq=3 ttl=64 time=0.032 ms
64 bytes from 10.0.0.1: icmp_seq=4 ttl=64 time=0.031 ms
64 bytes from 10.0.0.1: icmp_seq=5 ttl=64 time=0.026 ms
64 bytes from 10.0.0.1: icmp_seq=6 ttl=64 time=0.028 ms
64 bytes from 10.0.0.1: icmp_seq=7 ttl=64 time=0.038 ms
64 bytes from 10.0.0.1: icmp_seq=8 ttl=64 time=0.042 ms
^C
--- 10.0.0.1 ping statistics ---
8 packets transmitted, 8 received, 0% packet loss, time 7007ms
rtt min/avg/max/mdev = 0.026/1.363/10.590/3.487 ms
```

```
root@floodlight:~# ifconfig
h3-eth0   Link encap:Ethernet  HWaddr f6:aa:5c:de:ad:a6
          inet addr:10.0.0.3  Bcast:10.255.255.255  Mask:255.0.0.0
          inet6 addr: fe80::f4aa:5cff:fede:ada6/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:87 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:16034 (16.0 KB)  TX bytes:648 (648.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

oot@floodlight:~# ping 10.0.0.1
ING 10.0.0.1 (10.0.0.1) 56(84) bytes of data.
rom 10.0.0.3 icmp_seq=1 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=2 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=3 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=4 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=5 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=6 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=7 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=8 Destination Host Unreachable
rom 10.0.0.3 icmp_seq=9 Destination Host Unreachable
4 bytes from 10.0.0.3: icmp_seq=10 ttl=64 time=1006 ms
4 bytes from 10.0.0.3: icmp_seq=11 ttl=64 time=0.037 ms
C
-- 10.0.0.1 ping statistics ---
1 packets transmitted, 2 received, +9 errors, 81% packet loss, time 10016ms
tt min/avg/max/mdev = 0.037/503.163/1006.290/503.127 ms, pipe 3
```

Future work

- ❑ Try to install malicious applications on the SDN controller to gain control of the network.
- ❑ Find ways to defend against incoming attacks (ex: using DELTA).

Acknowledgements

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