Hands-On SDN

Block Course – Winter 2016/17

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Where we are now

You have now learned about:

•SDN basic principles

- Basic concepts (CP/DP separation etc.)
- De-facto standard interfaces (OpenFlow)
- Controllers (NOX, POX, …)
- Virtualization (FlowVisor)

Where we want to go

You have now learned about:

•SDN basic principles

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- Virtualization (FlowVisor)

• **Put the stuff learned into practice:**

- Implement OpenFlow?
- Implement controllers?
- Implement FlowVisor?

- Rather: *learn how to use and program them!*
  - Hands-on work on state-of-the-art tools

How can we get there?

- Luckily, implementations are available.
  - Switches implementing OF
  - Controllers implementing OF

- So, how do we run them?
  - We don‘t have a hardware testbed at hand
  - We don‘t have access to a production network
  - We may want to test different things on different network topologies
  - Simulation?

Emulation of Networks

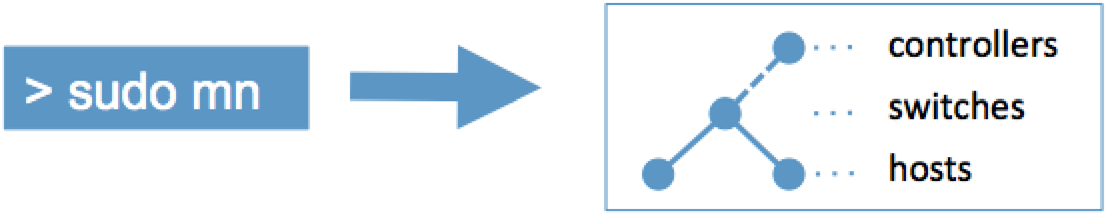
- Network emulation means to run unmodified code interactively on virtual hardware

- Huge benefit:
  - Can actually port our applications seamlessly to hardware

- Challenges:
  - Scalability: need to model hosts, switches, links, controllers, …
  - Ease-of-Use: easily allow to create different topologies with varying parameters
  - Accuracy: results have to match results obtained from running same experiment on hardware

Enter Mininet

"Mininet creates a **realistic virtual network**, running **real kernel, switch and application code**, on a single machine (VM, cloud or native), in seconds, with a single command"[1]



[1] mininet.org

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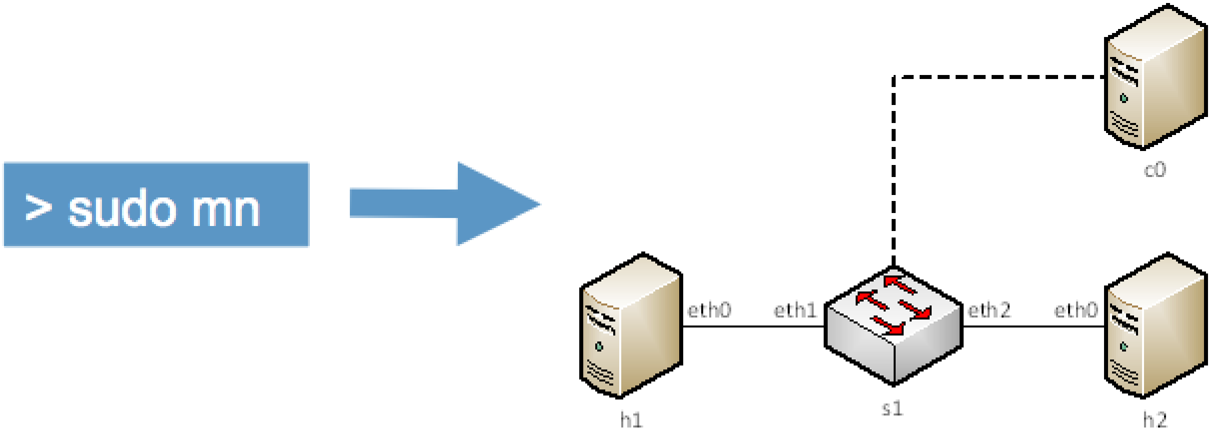


[1] mininet.org

Enter Mininet

Mininet offers CLI & API to interact with the network

(see demo)

Customize Topologies

Mininet is not limited to the very basic setup

(see demo)

Customize Topologies

```
from mininet.topo import Topo
class MyTopo( Topo ):
    "Simple topology example."

    def __init__( self ):
    "Create custom topo."

        # Initialize topology
        Topo.__init__( self )

        # Add hosts and switches
        leftHost = self.addHost( 'h1' )
        rightHost = self.addHost( 'h2' )
        leftSwitch = self.addSwitch( 's3' )
        rightSwitch = self.addSwitch( 's4' )

        # Add links
        self.addLink( leftHost, leftSwitch )
        self.addLink( leftSwitch, rightSwitch )
        self.addLink( rightSwitch, rightHost )

topos = { 'mytopo': ( lambda: MyTopo() ) }
```

Customize Switches and Controllers

You can connect different switches and controllers

(see demo)

Bring Links Up/Down

Change the topology at runtime

(see demo)

Use of Wireshark

We can use Wireshark to debug our network

(see demo)

Limitations?

Limited by single system resources

Limited to Linux kernel (e.g., portability to Windows?)

Limited to real-time

NOTE:

Afternoon lecture today 1 hour later! Starts at 3.15pm!

Exercise!

Time for Exercises 5a and 5b

Custom Topologies with Mininet Python API

Mininet offers some topologies!

Eg: single switch, linear, tree

What if you want to replicate your very own production network?

Create a custom topology!

Low-level API: Nodes and Links

```
h1 = Host( 'h1' )
h2 = Host( 'h2' )
s1 = OVSSwitch( 's1', inNamespace=False )
c0 = Controller( 'c0', inNamespace=False )
Link( h1, s1 )
Link( h2, s1 )
h1.setIP( '10.1/8' )
h2.setIP( '10.2/8' )
c0.start()
s1.start( [ c0 ] )
print h1.cmd( 'ping -c1', h2.IP() )
s1.stop()
c0.stop()
```

Mid-level API: Network Object

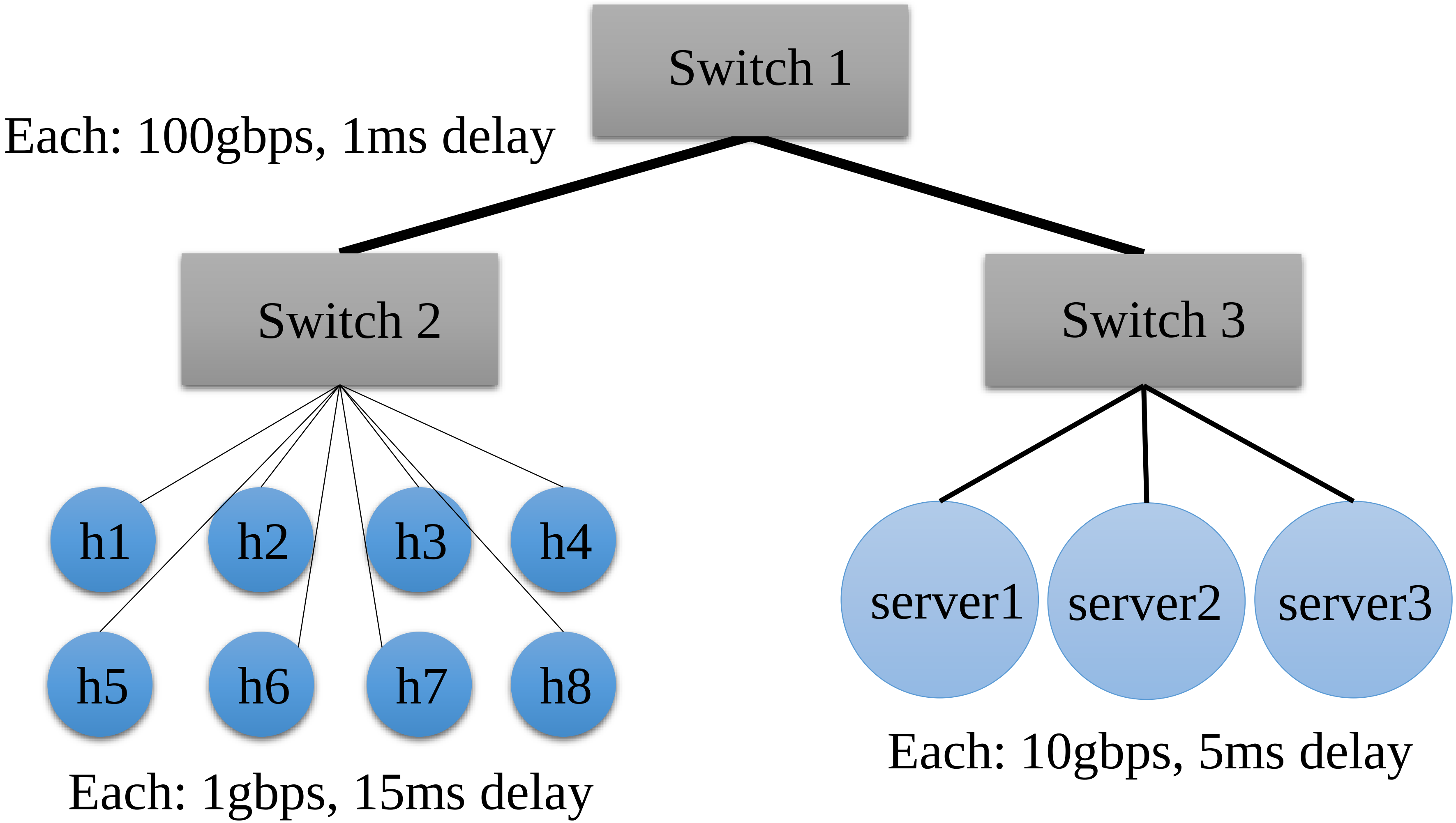
```
net = Mininet()
h1 = net.addHost( 'h1' )
h2 = net.addHost( 'h2' )
s1 = net.addSwitch( 's1' )
c0 = net.addController( 'c0' )
net.addLink( h1, s1 )
net.addLink( h2, s1 )
net.start()
print h1.cmd( 'ping -c1', h2.IP() )
CLI( net )
net.stop()
```

High-level API: Topology templates

```
class SingleSwitchTopo( Topo ):
    "Single Switch Topology"
    def __init__( self, count=1):
        Topo.__init__(self)
        hosts = [ self.addHost( 'h%d' % i )
                  for i in range( 1, count + 1 ) ]
        s1 = self.addSwitch( 's1' )
        for h in hosts:
            self.addLink( h, s1 )

topos = {'topo' : (lambda: SingleSwitchTopo())}
```

Example Topology – Research Lab



Example Topology – Research Lab

```python
#!/usr/bin/python
from mininet.topo import Topo

class ResearchLab ( Topo ):
  """"Research Lab Topology"""
  def __init__( self ):

    Topo.__init__(self)
    testbedhosts = [ self.addHost( 'h%d' % i ) for i in range( 1, 9) ]
    simservers = [self.addHost( 'sim%d' % i ) for i in range( 1, 4) ]
    s1 = self.addSwitch( 's1' ) # TOR switch
    s2 = self.addSwitch( 's2' ) # Testbed switch
    s3 = self.addSwitch( 's3' ) # Server switch

    for h in testbedhosts:
      self.addLink( h, s2 , bw=1, delay='15ms')

    for srv in simservers:
      self.addLink( srv,s3, bw=10, delay='1ms')

    self.addLink(s2, s1, bw=100)
    self.addLink(s3, s1, bw=100)

topos = { 'rlab' : (lambda: ResearchLab() ) }
```

```
sudo mn
--custom rlab.py
--topo rlab
--link=tc
```

The POX Controller

- Invoke with: ./pox.py [options] <component>

- <options> can be:
  - --verbose : display debugging info
  - --no-openflow: do not automatically listen for OpenFlow connections

- <components> are the real meat!
  - There are some basic components we will use for this class
  - Intention: developers will build their own components

The POX Controller - Components

- Some stock components:
  - py
  - forwarding.hub
  - forwarding.l2_learning
  - forwarding.l2_pairs
  - forwarding…..

./pox.py forwarding.l2_learning ?

  - openflow.webservice
    - Creates a webinterface to interact with OpenFlow

  - openflow.of_01
    - Communicates with OpenFlow 1.0 switches

The POX Controller - Components

- Developing your own components:
  - https://openflow.stanford.edu/display/ONL/POX+Wiki#POXWiki-DevelopingyourownComponents

- In general: POX wiki a good place to look for help
  - https://openflow.stanford.edu/display/ONL/POX+Wiki

POX APIs

- When writing or modifying components (you will do the latter in this course), POX offers some helpful API.
  - E.g.: API for packet handling: **`pox.lib.packet`**

Example: Get L2 source and destination from a packet

```
def _handle_PacketIn(self, event):
        packet = event.parsed # POX is based on events!
        src_of_packet = packet.src #returns an EthAddr
        dst_of_packet = packet.dst #also returns an EthAddr
```

POX APIs

- When writing or modifying components (you will do the latter in this course), POX offers some helpful API.
  - E.g.: API for packet handling: **pox.lib.packet**

Example: Get source IP from a packet

```
def _handle_PacketIn(self, event):
      "check if packet is an IP packet"
      packet = event.parsed
      ip = packet.find('ipv4') #check if packet is IP
      if ip is None: #packet is not IP
            return
      print "Source IP: ", ip.srcip
```

POX and Openflow

- Up front: Best to read POX wiki:
  - https://openflow.stanford.edu/display/ONL/POX+Wiki#POXWiki-OpenFlowinPOX
- Usually, switches connect to POX automatically via OpenFlow
  - Exception: `no-openflow` option (see previous slides)
- So – how do we communicate with them?

Coding in POX – Connection Elements

- Upon connecting to POX, a switch is associated with a `Connection` object
- Use that object's `send()` method to send messages to the switch
- `Connection` object will raise events on the corresponding switch
  - Create **event handlers** for events you are interested in

In Practice

- Launch our component.
- Add one event listener for PacketIn

```
from pox.core import core
import pox.openflow.libopenflow_01 as of

log = core.getLogger()

def launch ():
    “Starts the Component“
    core.openflow.addListenerByName("PacketIn",
                    _handle_packetin)

    log.info("Switch running.")
```

In Practice

- Write packet handler (here: flood packet)

```
def _handle_packetin (event):
    “Handle PacketIn“
    packet = event.parsed
    send_packet(event, of.OFPP_ALL) #broadcast

    log.debug("Broadcasting %s.%i -> %s.%i" %
               (packet.src, event.ofp.in_port,
               packet.dst, of.OFPP_ALL))
```

In Practice

- Write send_packet method (simplified)

```
def send_packet (event, dst_port):
    "Instructs switch to send packet via dst_port"
     msg = of.ofp_packet_out(in_port=event.ofp.in_port)
     msg.data = event.ofp.data
     msg.actions.append(of.ofp_action_output(port = dst_port))

     event.connection.send(msg)
```

In Practice

- Code on previous slides implemented a hub behaviour

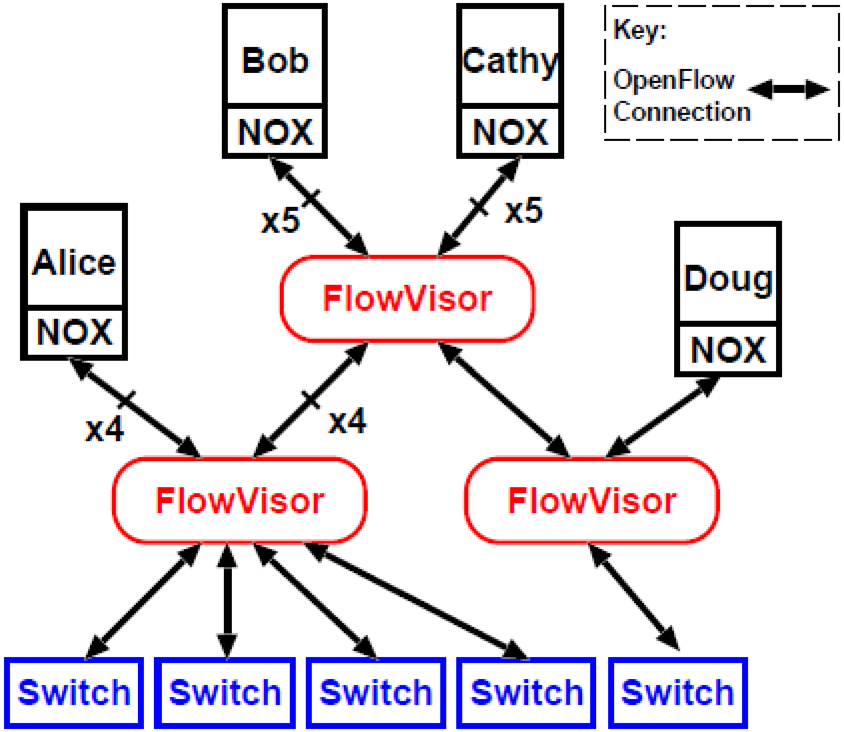
- Exercise: modify hub behaviour to learning switch behaviour

Exercise!

Time for Exercise 6

FlowVisor

- Exercise 5: You have already installed FlowVisor
- Recall: FlowVisor is an extra layer between controllers and switches



FlowVisor

- Basic procedure:
  - Create and start your network topology with Mininet
  - Connect Flowvisor to switches on standard port
  - Slice network with Flowvisor
  - Connect Controllers to Flowvisor slices

FlowVisor

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Connecting FlowVisor

- FlowVisor operates outside of Mininet!

```
$ sudo /etc/init.d/flowvisor start
```

(see demo)

- Afterwards: use flowvisor control (command: `fvctl`) to slice

Slicing the Network with FlowVisor

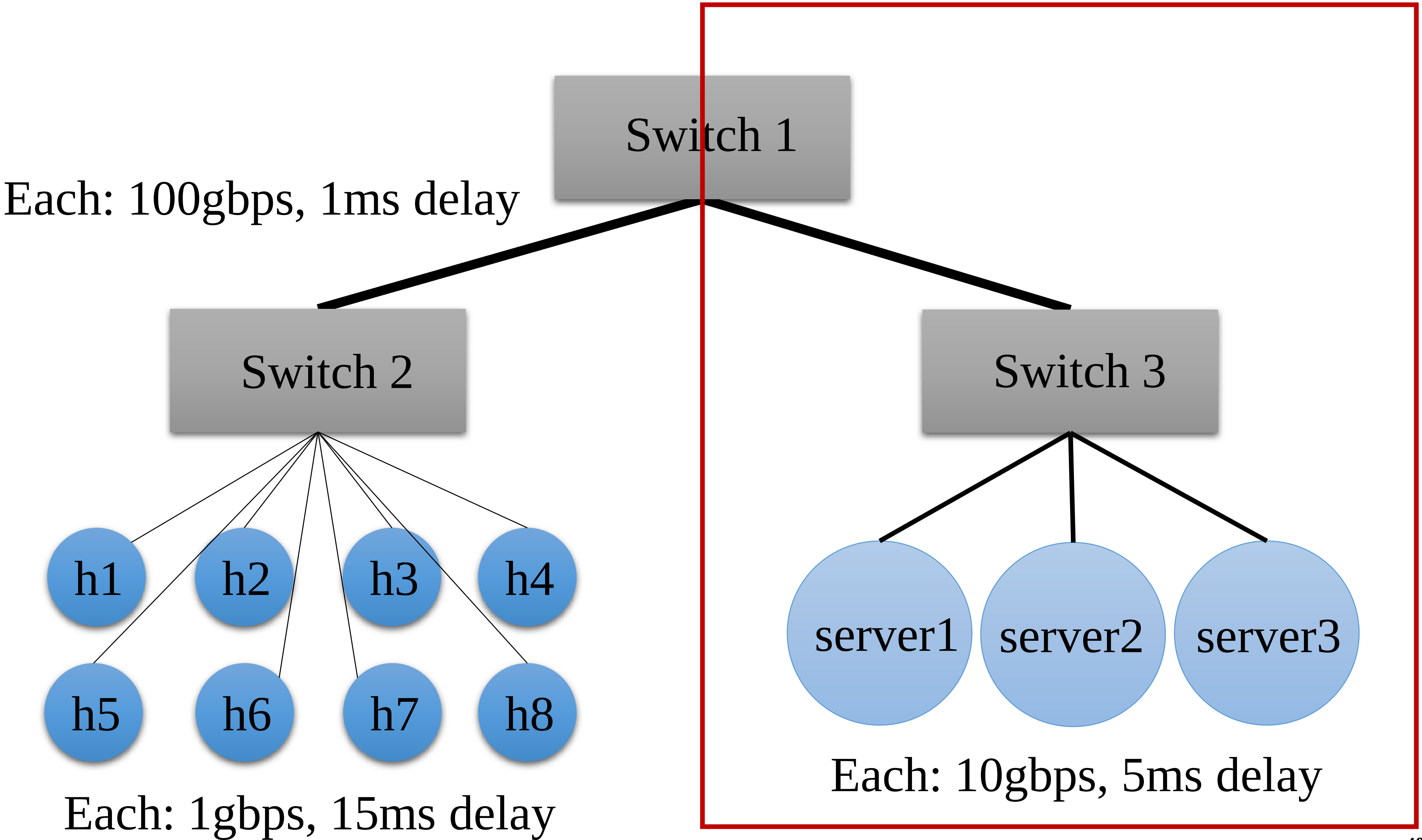
- First: enable topology controller

```
$ fvctl –f /dev/null set-config --enable-topo-ctrl
$ sudo /etc/init.d/flowvisor restart
```

(see demo)

- -f /dev/null option: -f points to pwd file – in our case: empty pw

Let's slice the research lab



Slicing the Network with FlowVisor

- Want to create slice for servers. Have a look at topology:

```
$ fvctl –f /dev/null list-slices
$ fvctl –f /dev/null list-flowspace
$ fvctl –f /dev/null list-datapaths
$ fvctl –f /dev/null list-links
```

(see demo)

Slicing the Network with FlowVisor

- Add slices with

```
fvctl add-slice [options] <slicename>
                <controller-url> <admin-email>
```

```
$ fvctl –f /dev/null add-slice servers
                    tcp:localhost:10001 admin@servers
```

(see demo)

Add Flowspaces

- Add flowspaces with

```
fvctl add-flowspace [options] <flowspace-name> <dpid>
                      <priority> <match> <slice-perm>
```

```
$ fvctl –f /dev/null add-flowspace switch1-port2
                    1 1 in_port=2 servers=7
```

- Permissions: Bitmask
  - `1=DELEGATE, 2=READ, 4=WRITE`

(see demo)

Connect Controllers

- Start controller and connect to FlowVisor

(see demo)

Test Slicing

- Servers should be able to ping each other, but not any hosts

(see demo)

Exercise!

Time for Exercise 7