Lab 1 Tutorial

Aim

> 1. 使用 Mininet 的Python API搭建 k=4 的 fat tree 拓扑；
> 2. 使用 pingall 查看各主机之间的连通情况;
> 3. 若主机之间未连通，分析原因并解决（使用 wireshark 抓包分析）
> 4. 若主机连通，分析数据包的路径（ovs-appctl fdb/show 查看MAC表）
> 5. 不可以使用controller

Reference

- Mininet
- OpenVSwitch
- WireShark

Part 1 实验环境搭建

方式1：

- 使用 virtual box 镜像搭建 虚拟机软件 virtual box ， 可在官网查询
- 本实验提供 virtual box 虚拟机的镜像文件 （ sdn_exp_2023.ova ） 已配置 Mininet 和 Ryu
- 环境搭建步骤如下： 安装 virtual box 导入镜像文件 sdn_exp_2023.ova （ root 账户密码并未设置，需要的同学可以参考 sudo passwd root 指令）

方式2：

- 使用 VMWare 镜像搭建 虚拟机软件 VMWare， 可在官网自行下载
- 本实验也提供 VMWare 虚拟机镜像文件 （ sdn_exp_2023_vmware ）， 已配置 Mininet 和 Ryu 。
- 环境搭建步骤如下：
  - 安装 VMWare
  - 导入镜像文件 sdn_exp_2023_vmware （密码 sdn ）

方式3：
源码安装

```bash
# 参考视频
# `Workstaion`和`Ubuntu`的安装：https://www.bilibili.com/video/BV1ng4y1z77g
# SDN环境搭建（`Mininet`）：https://www.bilibili.com/video/BV1nC4y1x7Z8

# 安装mininet
git clone https://github.com/mininet/mininet.git
cd mininet/util
sudo ./install.sh -n3v

# 安装wireshark
sudo add-apt-repository ppa:wireshark-dev/stable
sudo apt update
sudo apt install wireshark
```

说明：
针对 Apple Silicon

- 本质上安装任一Linux虚拟机都可以使用
  - VMware
  - VirtualBox
  - Parallels Desktop
  - ...
- 但是Orbstack不行！
  - 它轻量化，既可以开docker也可以开vm
  - 它的linux虚拟机内核没有支持openvswitch
  - 除非你手动编译内核 :)
- 具体问题详见笔者在mininet-github中提出的issue

Part 2 实验工具介绍

2.1 三板斧

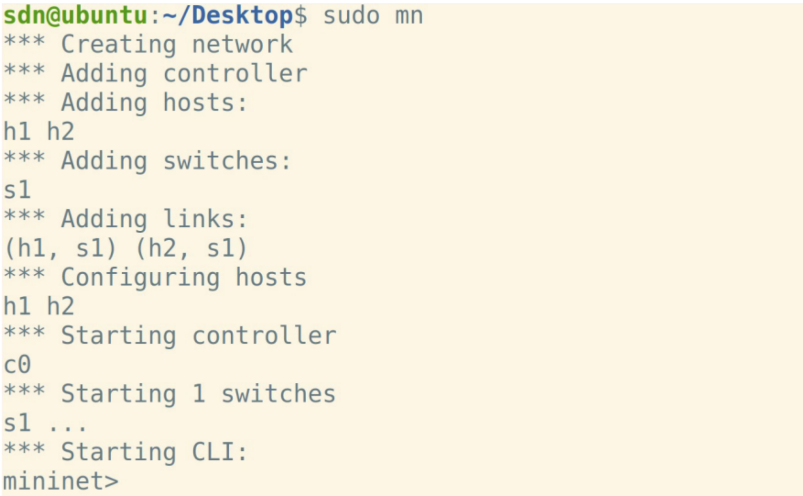
- mininet：用来在单台计算机上创建一个包含多台网络设备的虚拟网络
- Open vSwitch : Mininet 中使用的虚拟交换机
- WireShark : 抓包工具

2.2 Mininet

- 启动

SHELL

```
# shell prompt
mn -h        # 查看mininet命令中的各个选项
sudo mn -c # 不正确退出时清理mininet
sudo mn     # 创建默认拓扑，两个主机h1、h2连接到同一交换机s1
```

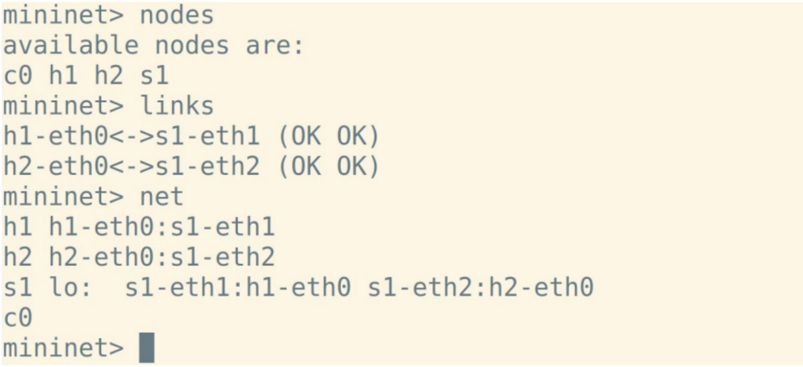


```
sdn@ubuntu:~/Desktop$ sudo mn
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet>
```

- 常用命令

SHELL

```
# inputs in Mininet CLI
nodes
links
net  # show the whole network topo now
dump  # show the detailed information of current net-topo
xterm h1  # open a Terminal Simulator for node-h1
sh [CMD]  #
h1 ping -c3 h2  # h1 send PING to h2 for 3 times
ping all  # PING in every node-pair
h1 ifconfig  # lookup the Interface and configuration of h1
h1 arp  # lookup the ARP map of h1
link s1 h1 down/up  # disconnect/connect the link between s1 and h1
exit # exit the mininet CLI
```



```
mininet> nodes
available nodes are:
c0 h1 h2 s1
mininet> links
h1-eth0<->s1-eth1 (OK OK)
h2-eth0<->s1-eth2 (OK OK)
mininet> net
h1 h1-eth0:s1-eth1
h2 h2-eth0:s1-eth2
s1 lo:  s1-eth1:h1-eth0 s1-eth2:h2-eth0
c0
mininet>
```

2.3 创建拓扑

CLI 创建

原始版，详见Lecture 4内容

```shell
sudo mn --mac --topo=tree,m,m
```

- --mac 指定mac地址从1开始递增，而不是无序的mac，方便观察
- --topo 指定拓扑参数，可选用single和linear等参数

自建拓扑 - Method1

- 用 Mininet Python API 创建自定义拓扑
- 通过命令行运行 pwd = 'mininet/custom/topo-2sw-2host.py'

PYTHON

```python
from mininet.topo
import Topo
class MyTopo( Topo ):
    "Simple topology example."
    def build( self ):
        "Create custom topo."
        # 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() ) }
```

运行

SHELL

```shell
mn> cd ~/sdn/mininet/custom
mn> sudo mn --custom topo-2sw-2host.py --topo mytopo --controller=none
```

自建拓扑 - Method2

```python
# sudo python topo_recommend.py
from mininet.topo import Topo
from mininet.net import Mininet
from mininet.cli import CLI
from mininet.log import setLogLevel

class S1H2(Topo):
    def build(self):
        s1 = self.addSwitch('s1')
        h1 = self.addHost('h1')
        h2 = self.addHost('h2')

        self.addLink(s1, h1)
        self.addLink(s1, h2)

    def run():
        topo = S1H2()
        net = Mininet(topo)
        net.start()
        CLI(net)
        net.stop()

if __name__ == '__main__':
    setLogLevel('info') # output, info, debug
    run()
```

运行

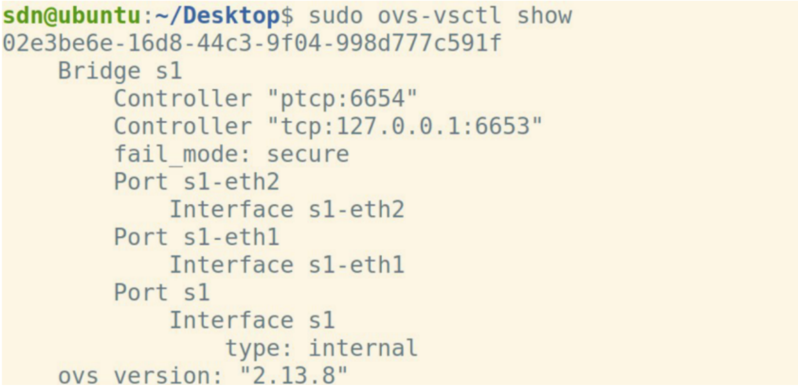
```shell
sudo python topo_recommend.py
```

2.4 OpenVSwitch (OVS)

查看交换机基本信息

```shell
su
mn
ovs-vsctl show
```

- **ovs-vsctl** 命令允许查看、修改和管理 OVS 的配置，包括网桥、端口、控制器、流表等
- **show** 参数指示该命令显示当前 OVS 的配置信息
- vsctl 的全称是 "Virtual Switch Control"



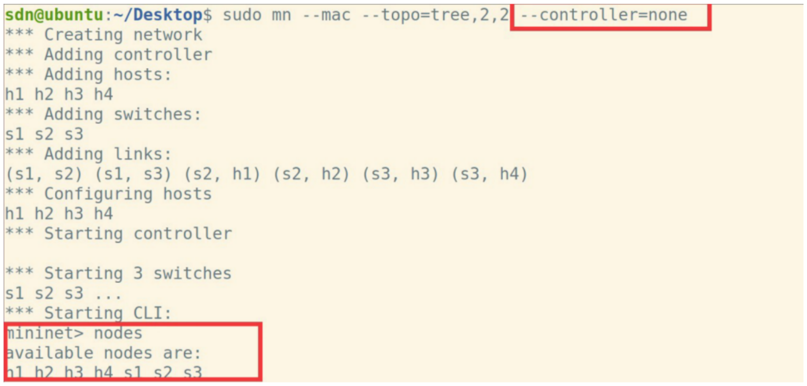
```
sdn@ubuntu:~/Desktop$ sudo ovs-vsctl show
02e3be6e-16d8-44c3-9f04-998d777c591f
    Bridge s1
        Controller "ptcp:6654"
        Controller "tcp:127.0.0.1:6653"
        fail_mode: secure
        Port s1-eth2
            Interface s1-eth2
        Port s1-eth1
            Interface s1-eth1
        Port s1
            Interface s1
                type: internal
    ovs_version: "2.13.8"
```

生成树协议

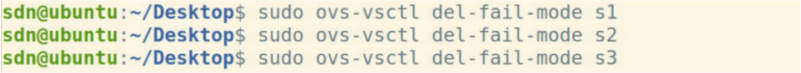
```shell
ovs-vsctl set bridge s1 stp_enable=true # open "STP" for Sw.s1
ovs-vsctl get bridge s1 stp_enable # check if STP is open for s1
ovs-vsctl list bridge # 列出所有 OVS 网桥及其相关信息
```

查看mac表

- 启动mininet，记得要禁用控制器，否则MAC表可能学习不到内容
- 对每个Switch执行**ovs-vsctl del-fail-mode Node_Name**，否则MAC表仍可能学不到内容
- **pingall**令所有主机发送数据包，防止“沉默主机”现象
- **ovs-appctl fdb/show Node_Name**查看每个节点的MAC表



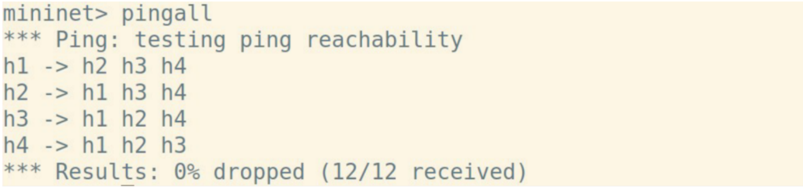
```
sdn@ubuntu:~/Desktop$ sudo mn --mac --topo=tree,2,2 --controller=none
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4
*** Adding switches:
s1 s2 s3
*** Adding links:
(s1, s2) (s1, s3) (s2, h1) (s2, h2) (s3, h3) (s3, h4)
*** Configuring hosts
h1 h2 h3 h4
*** Starting controller

*** Starting 3 switches
s1 s2 s3 ...
*** Starting CLI:
mininet> nodes
available nodes are:
h1 h2 h3 h4 s1 s2 s3
```



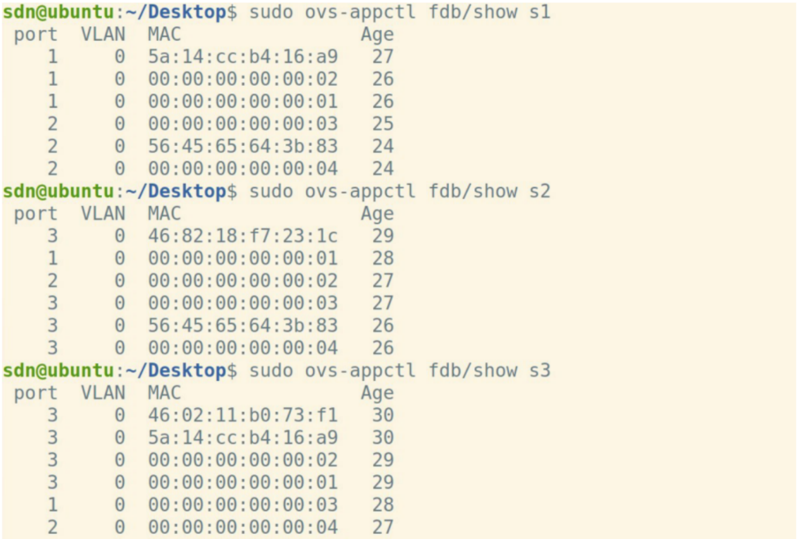
```
sdn@ubuntu:~/Desktop$ sudo ovs-vsctl del-fail-mode s1
sdn@ubuntu:~/Desktop$ sudo ovs-vsctl del-fail-mode s2
sdn@ubuntu:~/Desktop$ sudo ovs-vsctl del-fail-mode s3
```

del-fail-mode XXX:

> 该选项表示“删除先前设置的故障模式”，以允许交换机重新恢复到默认行为或者进行新的配置



```
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2 h3 h4
h2 -> h1 h3 h4
h3 -> h1 h2 h4
h4 -> h1 h2 h3
*** Results: 0% dropped (12/12 received)
```



```
sdn@ubuntu:~/Desktop$ sudo ovs-appctl fdb/show s1
 port  VLAN  MAC                Age
    1     0  5a:14:cc:b4:16:a9   27
    1     0  00:00:00:00:00:02   26
    1     0  00:00:00:00:00:01   26
    2     0  00:00:00:00:00:03   25
    2     0  56:45:65:64:3b:83   24
    2     0  00:00:00:00:00:04   24
sdn@ubuntu:~/Desktop$ sudo ovs-appctl fdb/show s2
 port  VLAN  MAC                Age
    3     0  46:82:18:f7:23:1c   29
    1     0  00:00:00:00:00:01   28
    2     0  00:00:00:00:00:02   27
    3     0  00:00:00:00:00:03   27
    3     0  56:45:65:64:3b:83   26
    3     0  00:00:00:00:00:04   26
sdn@ubuntu:~/Desktop$ sudo ovs-appctl fdb/show s3
 port  VLAN  MAC                Age
    3     0  46:02:11:b0:73:f1   30
    3     0  5a:14:cc:b4:16:a9   30
    3     0  00:00:00:00:00:02   29
    3     0  00:00:00:00:00:01   29
    1     0  00:00:00:00:00:03   28
    2     0  00:00:00:00:00:04   27
```

ovs-appctl fdb/show XXX:

> 显示指定网桥的转发数据库（FDB）内容
>
> - XXX: 网桥的名称or标识符
> - FDB：是一个表，存放的是 *MAC地址和与之关联的端口* 信息

2.5 WireShark

- 抓交换机的packet
  - **sudo wireshark**，并选择相应的端口
- 抓主机的packet
  - 在mininet CLI中执行**xterm h1**，打开host1的终端
- 在h1终端里运行wireshark

Part 3 实验解析

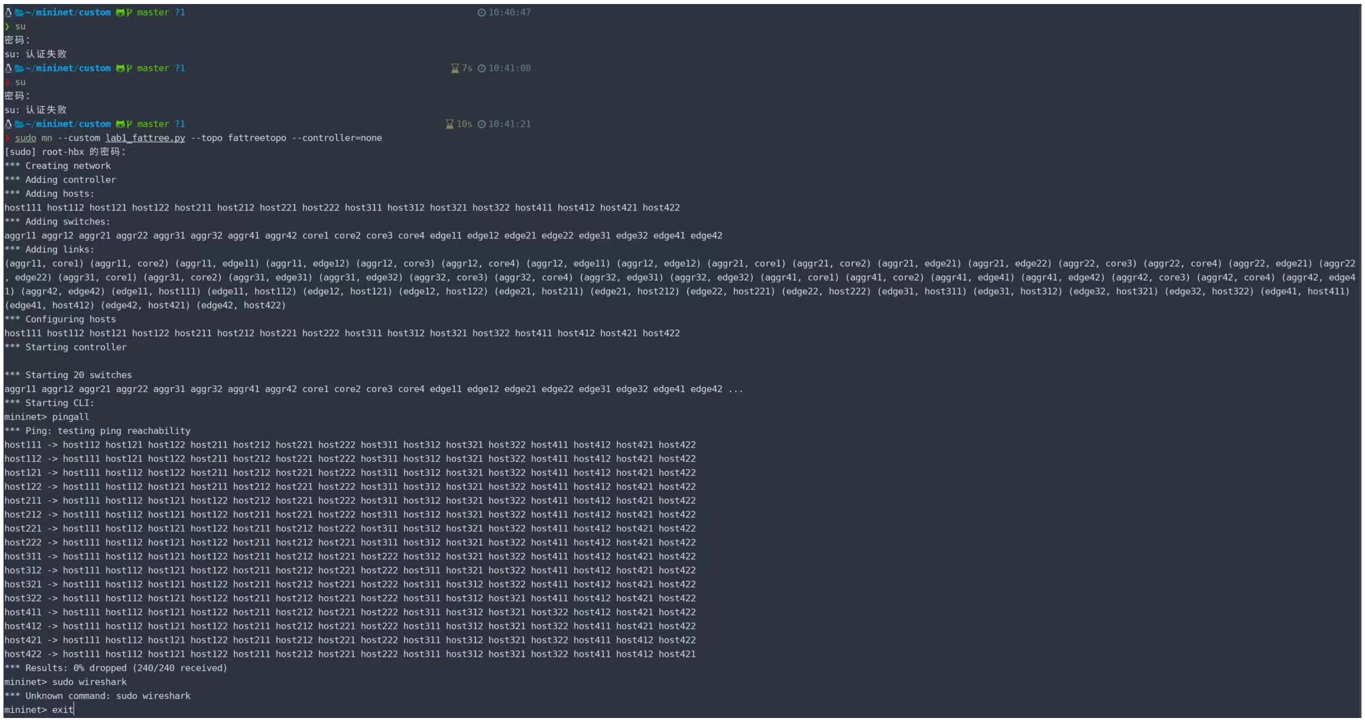
> 我的实验环境
>
> - Linux Ubuntu 22.04LTS 物理机

3.1 实验代码

```python
from mininet.topo import Topo
from mininet.net import Mininet
from mininet.cli import CLI
from mininet.log import setLogLevel

'''
Tutorial
- I prefer to use Method 1, which is to build the Fat-Tree topology via "Mininet Python API" and use CLI to run
- pwd:  ~/mininet/custom/lab1_fattree.py
- When you run the script, you should use the orders below:
    > cd ~/sdn/mininet/custom
    > sudo mn --custom lab1_fattree.py --topo fattreetopo --controller=none

'''


class FatTree(Topo):
    # offer the configuration of Fat-Tree
    def build(self, k=4):
        # total number in this topology
        self.k = k
        self.pods = k
        self.aggrSw = self.pods * (k // 2)
        self.edgeSw = self.pods * (k // 2)
        self.coreSw = (k // 2) ** 2
        # host number in each pod
        self.PodHost = (k // 2) ** 2

        # utilize the arguments above to build topo
        self.addCoreSw()
        self.addAggrSw()
        self.addEdgeSw()
        self.addHosts()
        self.setLink()

    def addCoreSw(self):
        for sw in range(self.coreSw):
            self.addSwitch('core{}'.format(sw + 1),
                         failMode='standalone', stp=True)
        # coreSw is identified by its own ID, which means it can be presented as 1 element turple
    def addAggrSw(self):
        for pod in range(self.pods):
            for sw in range(self.k // 2):
                self.addSwitch('aggr{}{}'.format(pod + 1, sw + 1),
                             failMode='standalone', stp=True)
        # aggrSw have to be presented as (pod, sw) in turple

    def addEdgeSw(self):
        for pod in range(self.pods):
            for sw in range(self.k // 2):
                self.addSwitch('edge{}{}'.format(pod + 1, sw + 1),
                             failMode='standalone', stp=True)
        # edgeSw have to be presented as (pod, sw) in turple

    def addHosts(self):
        for pod in range(self.pods):
            for sw in range(self.k // 2):
                for hst in range(self.k // 2):
                    self.addHost('host{}{}{}'.format(pod + 1, sw + 1, hst + 1),
                               failMode='standalone', stp=True)
        # host have to be presented as (pod, sw, hst) in turple

    def setLink(self):
        for pod in range(self.pods):
            # aggrSw → coreSw
            for aggr in range(self.k // 2):
                for core in range(self.k // 2):
                    self.addLink('aggr{}{}'.format(pod + 1, aggr + 1),
                               'core{}'.format(core + aggr * (self.k // 2) + 1))
                    # For coreSw is identified by its own ID

            # aggrSw → edgeSw
            for aggr in range(self.k // 2):
                for edge in range(self.k // 2):
                    self.addLink('aggr{}{}'.format(pod + 1, aggr + 1),
                               'edge{}{}'.format(pod + 1, edge + 1))

            # edgeSw → host
            for edge in range(self.k // 2):
                for hst in range(self.k // 2):
                    self.addLink('edge{}{}'.format(pod + 1, edge + 1),
                               'host{}{}{}'.format(pod + 1, edge + 1, hst + 1))
```

```
topos = { 'fattreetopo': ( lambda: FatTree() ) }
```

3.2 实验结果



```
~/mininet/custom  master ?1                                              10:40:47
❯ su
密码：
su: 认证失败
~/mininet/custom  master ?1                                          7s  10:41:08
❯ su
密码：
su: 认证失败
~/mininet/custom  master ?1                                         10s  10:41:21
❯ sudo mn --custom lab1_fattree.py --topo fattreetopo --controller=none
[sudo] root-hbx 的密码：
*** Creating network
*** Adding controller
*** Adding hosts:
host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
*** Adding switches:
aggr11 aggr12 aggr21 aggr22 aggr31 aggr32 aggr41 aggr42 core1 core2 core3 core4 edge11 edge12 edge21 edge22 edge31 edge32 edge41 edge42
*** Adding links:
(aggr11, core1) (aggr11, core2) (aggr11, edge11) (aggr11, edge12) (aggr12, core3) (aggr12, core4) (aggr12, edge11) (aggr12, edge12) (aggr21, core1) (aggr21, core2) (aggr21, edge21) (aggr21, edge22) (aggr22, core3) (aggr22, core4) (aggr22, edge21) (aggr22
, edge22) (aggr31, core1) (aggr31, core2) (aggr31, edge31) (aggr31, edge32) (aggr32, core3) (aggr32, core4) (aggr32, edge31) (aggr32, edge32) (aggr41, core1) (aggr41, core2) (aggr41, edge41) (aggr41, edge42) (aggr42, core3) (aggr42, core4) (aggr42, edge4
1) (aggr42, edge42) (edge11, host111) (edge11, host112) (edge12, host121) (edge12, host122) (edge21, host211) (edge21, host212) (edge22, host221) (edge22, host222) (edge31, host311) (edge31, host312) (edge32, host321) (edge32, host322) (edge41, host411)
(edge41, host412) (edge42, host421) (edge42, host422)
*** Configuring hosts
host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
*** Starting controller

*** Starting 20 switches
aggr11 aggr12 aggr21 aggr22 aggr31 aggr32 aggr41 aggr42 core1 core2 core3 core4 edge11 edge12 edge21 edge22 edge31 edge32 edge41 edge42 ...
*** Starting CLI:
mininet> pingall
*** Ping: testing ping reachability
host111 -> host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host112 -> host111 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host121 -> host111 host112 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host122 -> host111 host112 host121 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host211 -> host111 host112 host121 host122 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host212 -> host111 host112 host121 host122 host211 host221 host222 host311 host312 host321 host322 host411 host412 host421 host422
host221 -> host111 host112 host121 host122 host211 host212 host222 host311 host312 host321 host322 host411 host412 host421 host422
host222 -> host111 host112 host121 host122 host211 host212 host221 host311 host312 host321 host322 host411 host412 host421 host422
host311 -> host111 host112 host121 host122 host211 host212 host221 host222 host312 host321 host322 host411 host412 host421 host422
host312 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host321 host322 host411 host412 host421 host422
host321 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host322 host411 host412 host421 host422
host322 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host411 host412 host421 host422
host411 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host412 host421 host422
host412 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host421 host422
host421 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host422
host422 -> host111 host112 host121 host122 host211 host212 host221 host222 host311 host312 host321 host322 host411 host412 host421
*** Results: 0% dropped (240/240 received)
mininet> sudo wireshark
*** Unknown command: sudo wireshark
mininet> exit
```

the pingall is successful