Lab1——Mininet

（一）搭建 Fat Tree 网络拓扑（k=2）

```
test@sdnexp:~/Desktop$ sudo python FatTree.py
*** Creating network
*** Adding hosts:
H1 H2
*** Adding switches:
AS1 AS2 CS1 ES1 ES2
*** Adding links:
(AS1, ES1) (AS2, ES2) (CS1, AS1) (CS1, AS2) (ES1, H1) (ES2, H2)
*** Configuring hosts
H1 H2
*** Starting controller

*** Starting 5 switches
AS1 AS2 CS1 ES1 ES2 ...
*** Starting CLI:
mininet> links
AS1-eth2<->ES1-eth1 (OK OK)
AS2-eth2<->ES2-eth1 (OK OK)
CS1-eth1<->AS1-eth1 (OK OK)
CS1-eth2<->AS2-eth1 (OK OK)
ES1-eth2<->H1-eth0 (OK OK)
ES2-eth2<->H2-eth0 (OK OK)
mininet> pingall
*** Ping: testing ping reachability
H1 -> X
H2 -> X
*** Results: 100% dropped (0/2 received)
```

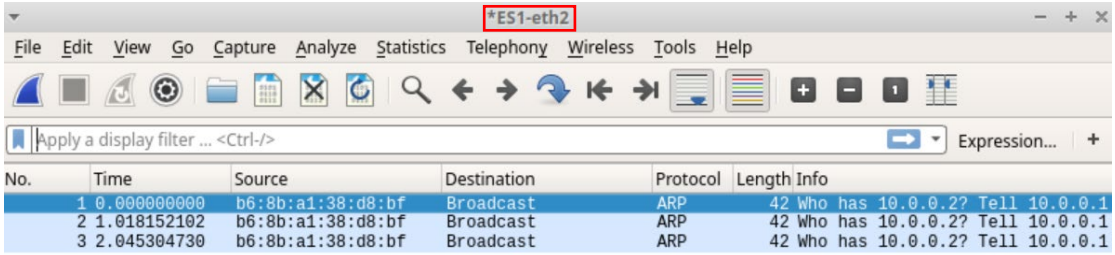
搭建完拓扑后，两主机无法 ping 通。

运行命令：H1 ping -c3 H2。

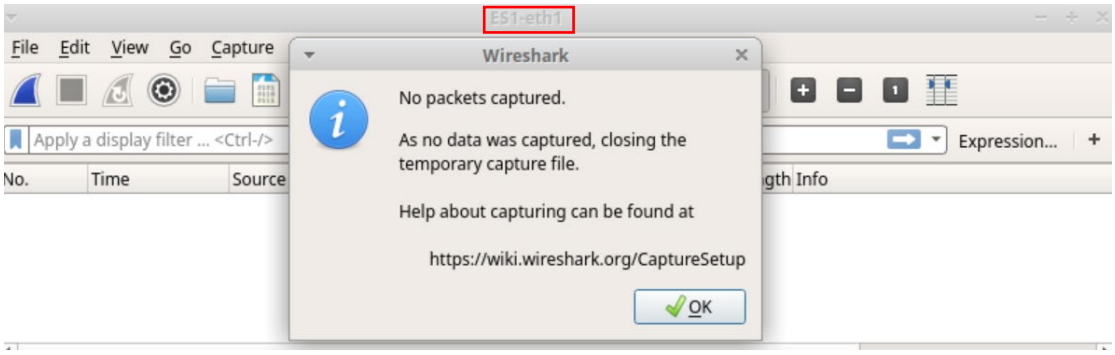
```
mininet> H1 ping -c3 H2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
From 10.0.0.1 icmp_seq=1 Destination Host Unreachable
From 10.0.0.1 icmp_seq=2 Destination Host Unreachable
From 10.0.0.1 icmp_seq=3 Destination Host Unreachable

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 0 received, +3 errors, 100% packet loss, time 2045ms
pipe 3
```

同时，使用 wireshark 抓包，分析与 H1 相连的交换机两端口的数据包。

ES1 与 H1 相连的端口捕获了 H1 发送的 3 个 ARP 请求报文：



ES1 与 AS1 相连的端口没有捕获到任何报文：



这说明交换机在收到主机发来的数据包后并没有将其转发出去，因而两主机无法 ping 通。

在终端输入 sudo ovs-vsctl show，查看交换机的基本信息：

```
Bridge "ES1"
    fail_mode: secure
    Port "ES1"
        Interface "ES1"
            type: internal
    Port "ES1-eth1"
        Interface "ES1-eth1"
    Port "ES1-eth2"
        Interface "ES1-eth2"
```

查阅资料后发现：fail_mode 是故障模式，意思是 SDN 控制器故障时，交换机未连接控制器时的模式（本实验中禁用了控制器）。在 secure 状态下，交换机按照原来流表继续转发，而无法进行 mac 自学习，故交换机 ES1 在收到主机 H1 发来的数据包后无法对其进行相应处理。

参考链接：[OpenvSwitch 系列之五 网桥特性功能配置]

解决方法：对每个交换机执行 sudo ovs-vsctl del-fail-mode xx

执行完相应指令后，两主机成功 ping 通：

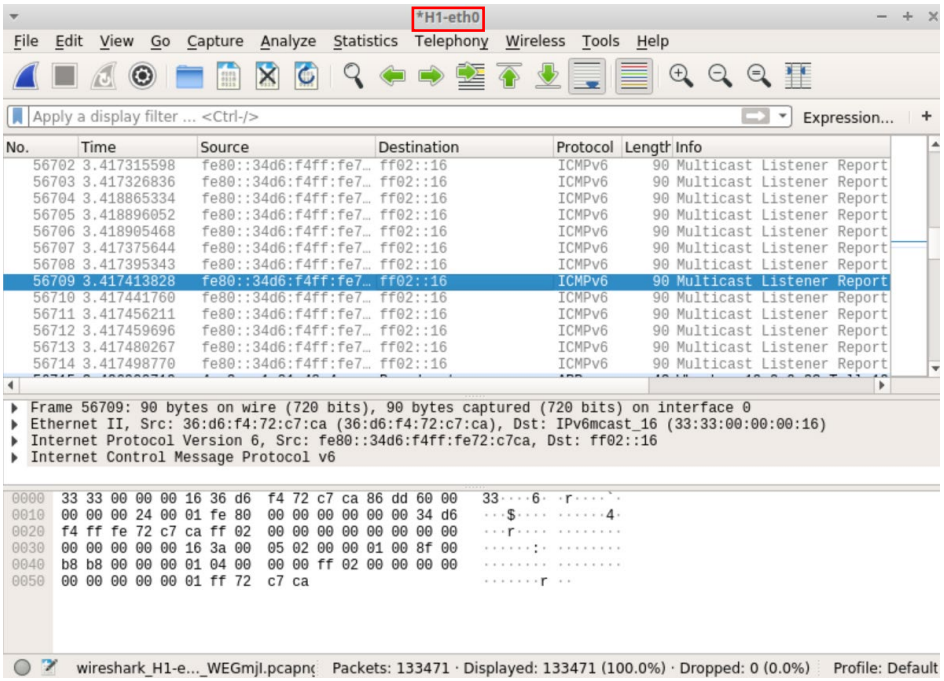
```
mininet> pingall
*** Ping: testing ping reachability
H1 -> H2
H2 -> H1
*** Results: 0% dropped (2/2 received)
```

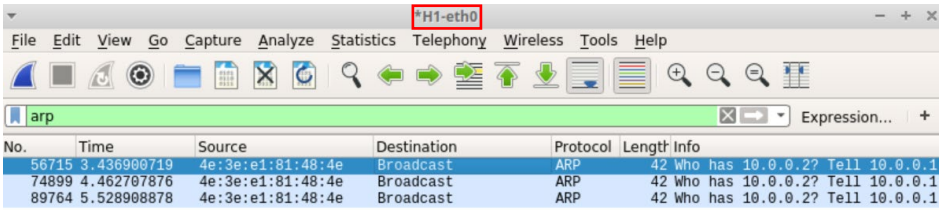
（二）搭建 Fat Tree 网络拓扑（k=4）

```
test@sdnexp:~/Desktop$ sudo python FatTree.py
*** Creating network
*** Adding hosts:
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
*** Adding switches:
AS1 AS2 AS3 AS4 AS5 AS6 AS7 AS8 CS1 CS2 CS3 CS4 ES1 ES2 ES3 ES4 ES5 ES6 ES7 ES8
*** Adding links:
(AS1, ES1) (AS1, ES2) (AS2, ES1) (AS2, ES2) (AS3, ES3) (AS3, ES4) (AS4, ES3) (AS4, ES4)
(AS5, ES5) (AS5, ES6) (AS6, ES5) (AS6, ES6) (AS7, ES7) (AS7, ES8) (AS8, ES7) (AS8, ES8)
(CS1, AS1) (CS1, AS3) (CS1, AS5) (CS1, AS7) (CS2, AS1) (CS2, AS3) (CS2, AS5) (CS2, AS7)
(CS3, AS2) (CS3, AS4) (CS3, AS6) (CS3, AS8) (CS4, AS2) (CS4, AS4) (CS4, AS6) (CS4, AS8)
(ES1, H1) (ES1, H2) (ES2, H3) (ES2, H4) (ES3, H5) (ES3, H6) (ES4, H7) (ES4, H8) (ES5, H9
) (ES5, H10) (ES6, H11) (ES6, H12) (ES7, H13) (ES7, H14) (ES8, H15) (ES8, H16)
*** Configuring hosts
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
*** Starting controller

*** Starting 20 switches
AS1 AS2 AS3 AS4 AS5 AS6 AS7 AS8 CS1 CS2 CS3 CS4 ES1 ES2 ES3 ES4 ES5 ES6 ES7 ES8 ...
```

```
*** Starting CLI:
mininet> pingall
*** Ping: testing ping reachability
H1 -> X X X X X X X X X X X X X X X
H2 -> X X X X X X X X X X X X X X X
H3 -> X X X X X X X X X X X X X X X
H4 -> X X X X X X X X X X X X X X X
H5 -> X X X X X X X X X X X X X X X
H6 -> X X X X X X X X X X X X X X X
H7 -> X X X X X X X X X X X X X X X
H8 -> X X X X X X X X X X X X X X X
H9 -> X X X X X X X X X X X X X X X
H10 -> X X X X X X X X X X X X X X X
H11 -> X X X X X X X X X X X X X X X
H12 -> X X X X X X X X X X X X X X X
H13 -> X X X X X X X X X X X X X X X
H14 -> X X X X X X X X X X X X X X X
H15 -> X X X X X X X X X X X X X X X
H16 -> X X X X X X X X X X X X X X X
*** Results: 100% dropped (0/240 received)
```

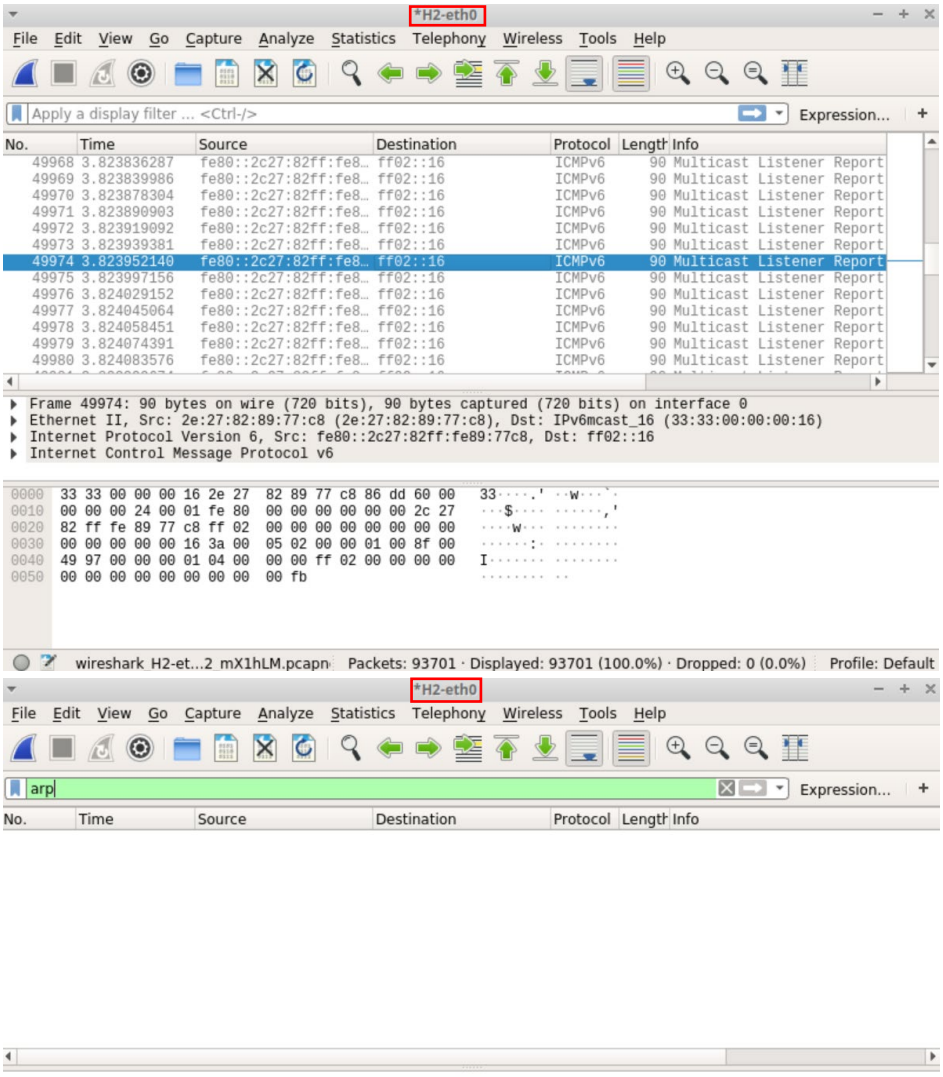
按照（一）中方法删除每个交换机的 fail_mode 后，主机间仍无法 ping 通。同样，运行命令 H1 ping -c3 H2， 并使用 wireshark 对主机 H1 进行抓包：





可以发现，主机 H1 发出的 ARP 请求报文被“淹没”在了大量的 ICMPv6 报文中（总共有 13.3 万多个）。

使用 wireshark 对主机 H2 进行抓包：



可以发现，主机 H2 也被大量的 ICMPv6 报文“淹没”，甚至连 ARP 应答报文都没有发出。

对比 k=4 和 k=2 两种网络拓扑，最大的不同应该是 k=4 的拓扑中出现了环路。这时，用来探测网络连接、更新路由等信息的数据包就可能形成广播风暴，让网络处于极度拥塞的状态。

解决方法：为每一个交换机开启生成树协议，避免数据包在一个环上来回转

发（sudo ovs-vsctl set bridge xx stp_enable=true）。

执行完相应指令后，等待一段时间，所有主机都能成功 ping 通：

```
mininet> pingall
*** Ping: testing ping reachability
H1 -> H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H2 -> H1 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H3 -> H1 H2 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H4 -> H1 H2 H3 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H5 -> H1 H2 H3 H4 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H6 -> H1 H2 H3 H4 H5 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16
H7 -> H1 H2 H3 H4 H5 H6 H8 H9 H10 H11 H12 H13 H14 H15 H16
H8 -> H1 H2 H3 H4 H5 H6 H7 H9 H10 H11 H12 H13 H14 H15 H16
H9 -> H1 H2 H3 H4 H5 H6 H7 H8 H10 H11 H12 H13 H14 H15 H16
H10 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H11 H12 H13 H14 H15 H16
H11 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H12 H13 H14 H15 H16
H12 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H13 H14 H15 H16
H13 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H14 H15 H16
H14 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H15 H16
H15 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H16
H16 -> H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15
*** Results: 0% dropped (240/240 received)
```

（三）分析数据包的路径

以 H1 ping -c3 H8 为例：

由于主机 H1 与交换机 ES1 直接相连，故先查询 ES1 的 MAC 表：

```
test@sdnexp:~$ sudo ovs-appctl fdb/show ES1
 port  VLAN  MAC                Age
    4     0  00:00:00:00:00:02  249
    2     0  00:00:00:00:00:0f  249
    2     0  00:00:00:00:00:0d  249
    3     0  00:00:00:00:00:01  233
    2     0  00:00:00:00:00:0e  233
    2     0  00:00:00:00:00:0b   69
    2     0  00:00:00:00:00:04   53
    2     0  00:00:00:00:00:08   53
    2     0  00:00:00:00:00:09   53
```

发现出口为 port 2，即转发到交换机 AS2，其 MAC 表为：

```
test@sdnexp:~$ sudo ovs-appctl fdb/show AS2
 port  VLAN  MAC                Age
    3     0  00:00:00:00:00:01  265
    1     0  00:00:00:00:00:0e  265
    1     0  00:00:00:00:00:0b  101
    4     0  00:00:00:00:00:04   85
    1     0  00:00:00:00:00:08   85
    1     0  00:00:00:00:00:09   85
```

发现出口为 port 1，即转发到交换机 CS3，其 MAC 表为：

```
test@sdnexp:~$ sudo ovs-appctl fdb/show CS3
 port  VLAN  MAC                Age
    4     0  00:00:00:00:00:0e  294
    3     0  00:00:00:00:00:0b  130
    2     0  00:00:00:00:00:08  114
    3     0  00:00:00:00:00:09  114
```

发现出口为 port 2，即转发到交换机 AS4，其 MAC 表为：

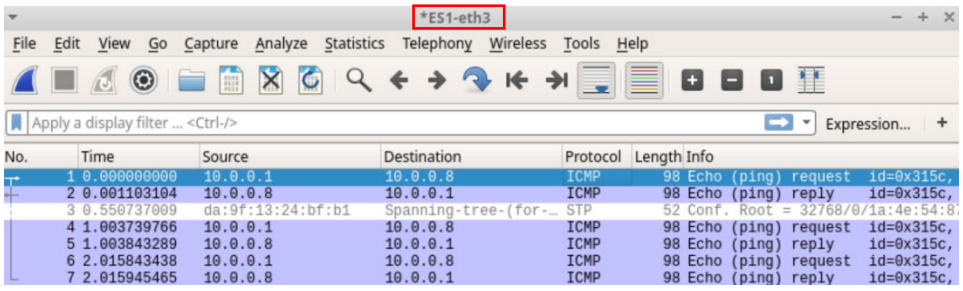
```
test@sdnexp:~$ sudo ovs-appctl fdb/show AS4
 port  VLAN  MAC                Age
    1     0  00:00:00:00:00:0b  173
    4     0  00:00:00:00:00:08  157
    1     0  00:00:00:00:00:09  157
```

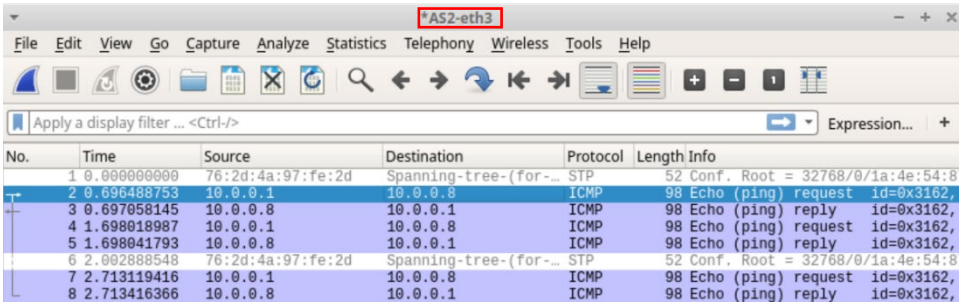
发现出口为 port 4，即转发到交换机 ES4，其 MAC 表为：

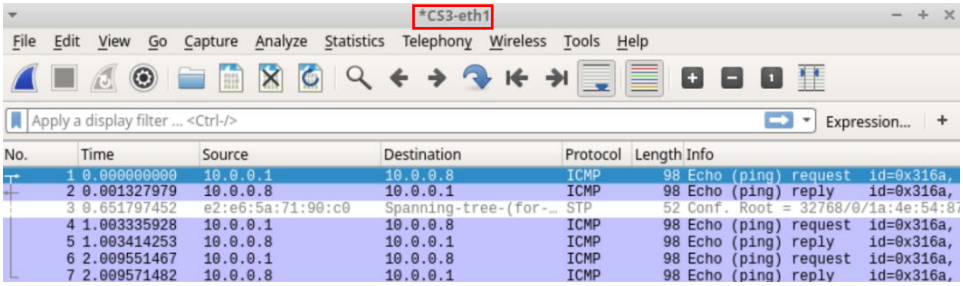
```
test@sdnexp:~$ sudo ovs-appctl fdb/show ES4
 port  VLAN  MAC                Age
    2     0  00:00:00:00:00:0b  195
    4     0  00:00:00:00:00:08  179
    2     0  00:00:00:00:00:09  179
```

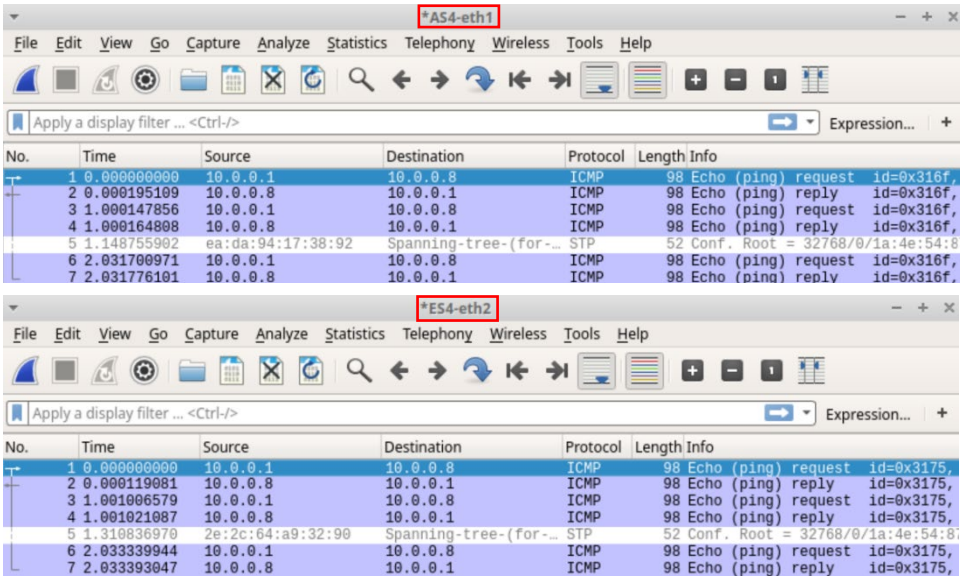
发现出口为 port 4，即转发到主机 H8。

通过 wireshark 抓包也可以进行验证：









故其转发路径为 H1->ES1->AS2->CS3->AS4->ES4->H8。

（四）源代码

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

class FatTree(Topo):

    def __init__(self, k, **opts):

        super(FatTree, self).__init__(**opts)

        CoreSwitches = [self.addSwitch('CS'+str(i+1)) for i in
range((k/2)**2)]
        AggrSwitches = [self.addSwitch('AS'+str(i+1)) for i in
range((k/2)*k)]
        EdgeSwitches = [self.addSwitch('ES'+str(i+1)) for i in
range((k/2)*k)]
        Host = [self.addHost('H'+str(i+1)) for i in range((k**3)/4)]

        # Create Link between Core and Aggregation
        for i in range((k/2)**2):
            for j in range(k):
                self.addLink(CoreSwitches[i],
AggrSwitches[i//(k/2)+j*(k/2)])
```

```
        # Create Link between Aggregation and Edge
        for i in range((k/2)*k):
            for j in range(k/2):
                self.addLink(AggrSwitches[i],
EdgeSwitches[i//(k/2)*(k/2)+j])

        # Create Link between Edge and Host
        for i in range((k/2)*k):
            for j in range(k/2):
                self.addLink(EdgeSwitches[i], Host[i*(k/2)+j])


def run(k=2):
    topo = FatTree(k)
    net = Mininet(topo=topo, controller=None, autoSetMacs=True)

    net.start()

    for i in range((k/2)**2):
        os.system('sudo ovs-vsctl set bridge CS' + str(i+1) + '
stp_enable=true')
        os.system('sudo ovs-vsctl del-fail-mode CS' + str(i+1))
    for i in range((k/2)*k):
        os.system('sudo ovs-vsctl set bridge AS' + str(i+1) + '
stp_enable=true')
        os.system('sudo ovs-vsctl del-fail-mode AS' + str(i+1))
    for i in range((k/2)*k):
        os.system('sudo ovs-vsctl set bridge ES' + str(i+1) + '
stp_enable=true')
        os.system('sudo ovs-vsctl del-fail-mode ES' + str(i+1))

    CLI(net)
    net.stop()

if __name__ == '__main__':
    setLogLevel('info')
    run(4)
```