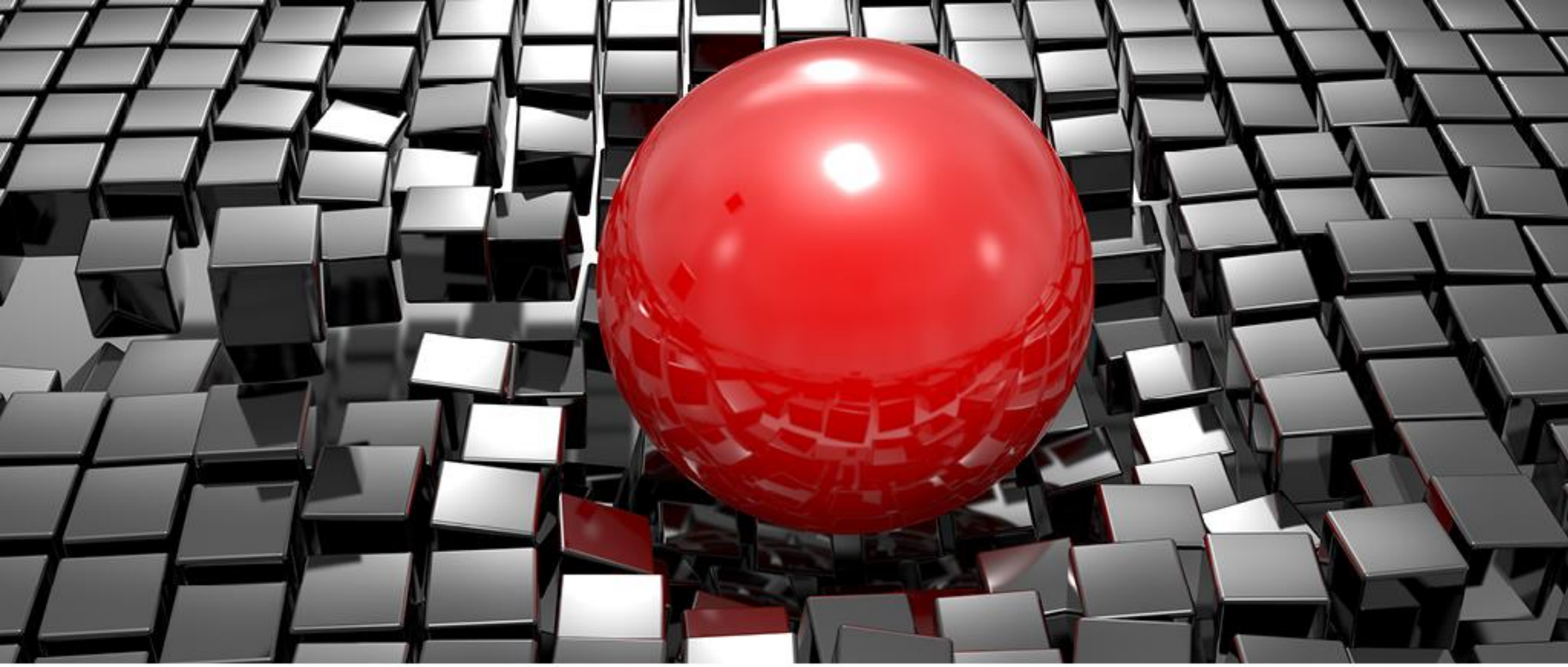

네트워크 지능화를 위한 Controller 분석

Mar, 2014

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table of contents

NAIM

Controller의 Flow Control Test 개요

Mar, 2014

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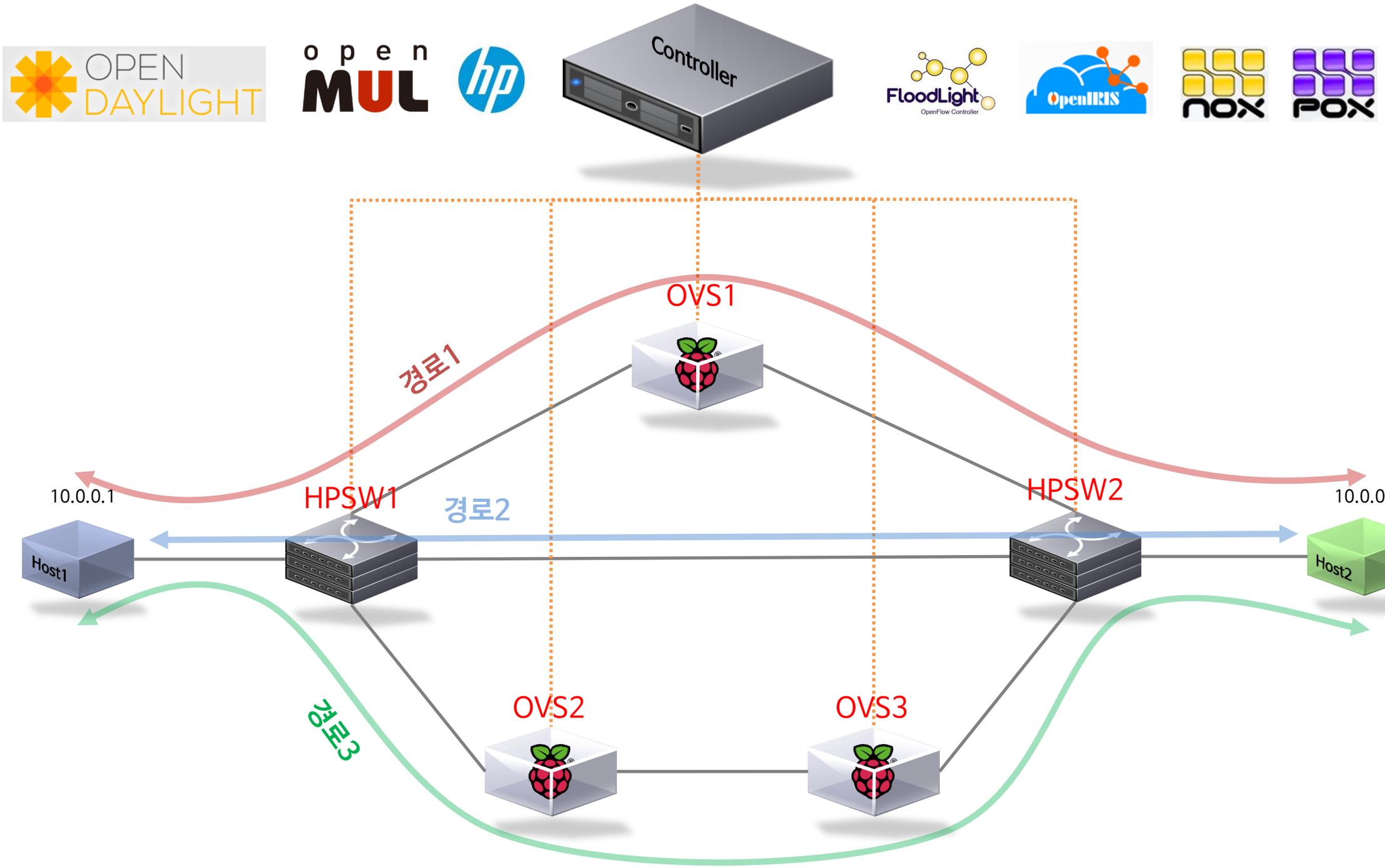
Rainbow Topology



Controller의 Flow Control Test 개요

- OpenSource Controller는 2014년 2월에 download한 버전을 설치하여 Test

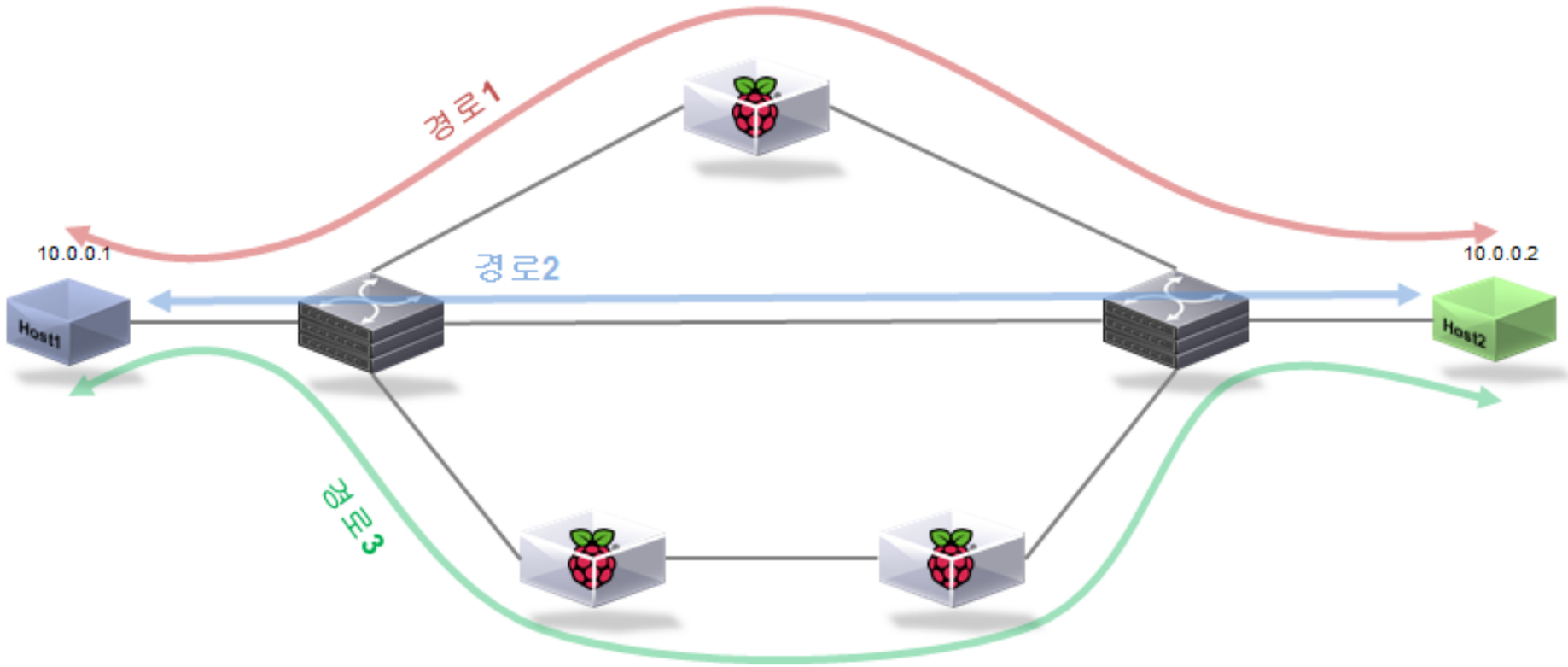
- 기존의 Mininet과 같은 에뮬레이터 환경에서 테스트한 Controller 분석 결과가 아니라 실제 환경에서 SDN을 연구하고 적용할 수 있는 Controller 분석 결과를 얻기 위한 Test

- 실환경에서의 실질적인 Controller 동작 비교를 통해 물리적 환경에 최적화된 Controller와 SDN Application 개발을 하기 위한 Test

- 이번 테스트 결과 자료는 네트워크 운영자 관점에서 실제 SDN 환경에 필요한 네트워크 기능들에 대해 각 Controller를 비교 분석

- 다른 관점에서는 각 Controller의 장단점이 다르게 분석될 수 있기 때문에 이번 테스트 결과가 Controller의 모든 것이라 판단할 수는 없음

Controller의 Flow Control Test 개요



- ❖ Redundant Network 구성 환경에서 각 Controller의 최적 경로 선택 비교
- ❖ 각 Controller 의 Flow Table 생성 결과 비교
- ❖ Data 전송 경로 fail 발생 시 Controller별 Failover 동작 비교

NAIM

Floodlight

Mar, 2014

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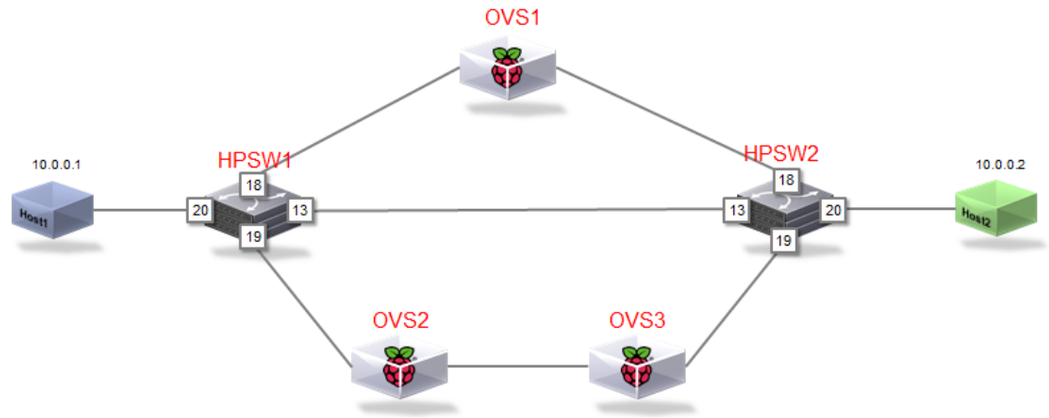
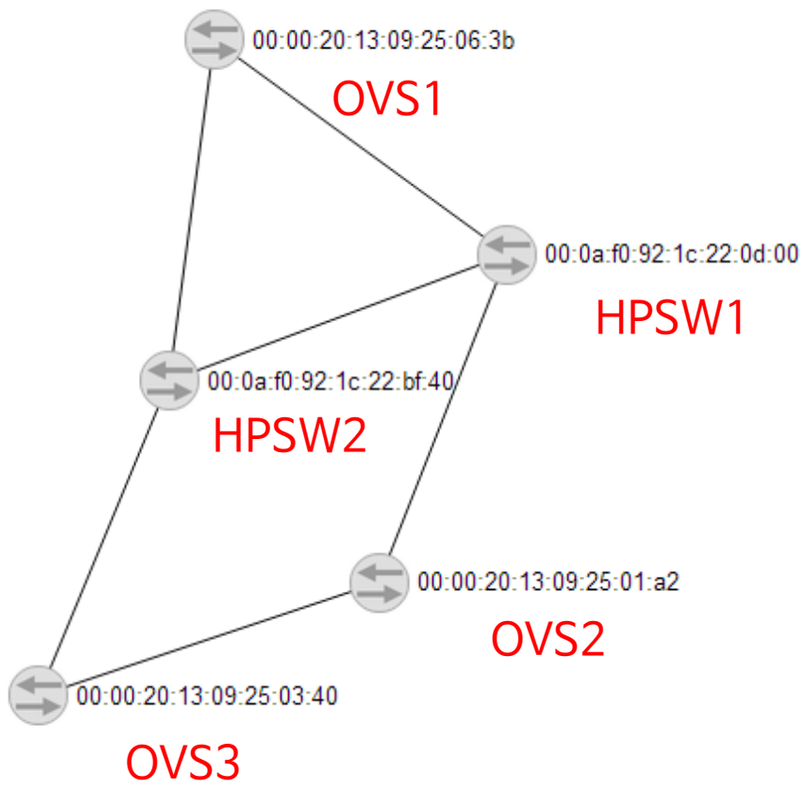
Floodlight Topology

Floodlight Dashboard Topology Switches Hosts

Live updates

Network Topology





Floodlight © Big Switch Networks, IBM, et. al. Powered by Backbone.js, Bootstrap, jQuery, D3.js, etc.

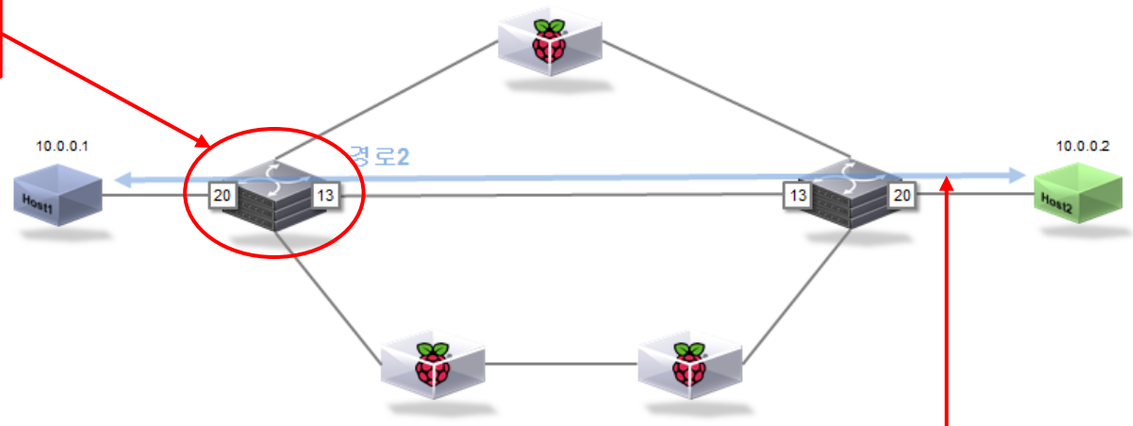
Floodlight의 Flow Table

Floodlight Dashboard Topology Switches Hosts

Live updates

Switch 00:0a:f0:92:1c:22:0d:00 /192.168.1.204

Connected since 2014년 2월 17일 오후 7:12:45
HP Networking
BTTF
VER 1.0
S/N: None



Ports (5)

#	Link Status	TX Bytes	RX Bytes	TX Pkts	RX Pkts	Dropped	Errors
19	UP 100 Mbps FDX	93800032	76488487	940881	735869	0	0
18	UP 100 Mbps FDX	116786189	585487829	1168597	986397	0	0
20	UP 100 Mbps FDX	54108022	13664314	591402	203949	0	0
65534 (local)	UP	0	0	0	0	0	0
13	UP 1 Gbps FDX	82369826	104865375	839720	1060084	0	0

Flows (2)

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
9007199254740992	0	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 13	155	15190	77 s	5 s
9007199254740992	0	port=13, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 20	157	15348	77 s	5 s

Floodlight © Big Switch Networks, IBM, et. al. Powered by Backbone.js, Bootstrap, jQuery, D3.js, etc.

HP Switch1의 Flow Table

```
HPSW1# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                        Ethernet Type     : Any
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : Any
  Target Protocol Address : Any
  IP Protocol   : Any                       IP ToS Bits       : Any
  Source Port   : Any                       Destination Port  : Any
 Attributes
  Priority      : 0                         Duration          : 15 seconds
  Hard Timeout  : 0 seconds                 Idle Timeout      : 5 seconds
  Byte Count    : 3038                      Packet Count      : 31
  Controller ID : 10                        Cookie            : 0x20000000000000
  Flow Location : Software
  Hardware Index      : NA
  Reason Code         : 15
  Reason Description : Rule cannot be accelerated in hardware
 Actions
    Output                  : 13

 Flow 2
 Match
  Incoming Port : 13                        Ethernet Type     : Any
  Source MAC    : b827eb-0d85f8             Destination MAC   : b827eb-1225e1
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : Any
  Target Protocol Address : Any
  IP Protocol   : Any                       IP ToS Bits       : Any
  Source Port   : Any                       Destination Port  : Any
 Attributes
  Priority      : 0                         Duration          : 15 seconds
  Hard Timeout  : 0 seconds                 Idle Timeout      : 5 seconds
  Byte Count    : 3196                      Packet Count      : 33
  Controller ID : 10                        Cookie            : 0x20000000000000
  Flow Location : Software
  Hardware Index      : NA
  Reason Code         : 15
  Reason Description : Rule cannot be accelerated in hardware
 Actions
    Output                  : 20

HPSW1#
```

HP Switch support

OpenFlow 1.3.1
in ProVision 15.14

V2 modules for 5400, 8200 and 3800, 2920 stackable switches

- **~ 4K rules**

HP 2920

- **~ 1K rules**

Specify or wildcard for match in hardware

Field Must be wildcarded, or Not included in rule

Must Program specific value

MATCH

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

IP (0x0800)

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

NOT IP, any other

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

2920 MATCH

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

IP (0x0800)

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

NOT IP, any other

Rx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

FORWARD ACTION

Additional actions permissible for flows matched above:
DROP, FLOOD (VLAN), NORMAL, OUT_PORT (1 or many)

SET ACTION

Add VLAN tag, Remove VLAN tag, Re-write VLAN tag
Rewrite src. or dst. MAC address

Setable Fields

Cannot alter Fields

Must set fields to specific value

Tx Interface	VLAN ID	VLAN priority	MAC Src	MAC Dst	Eth type	IP Src	IP Dst	IP Prot	IP ToS	TCP Src	TCP Dst

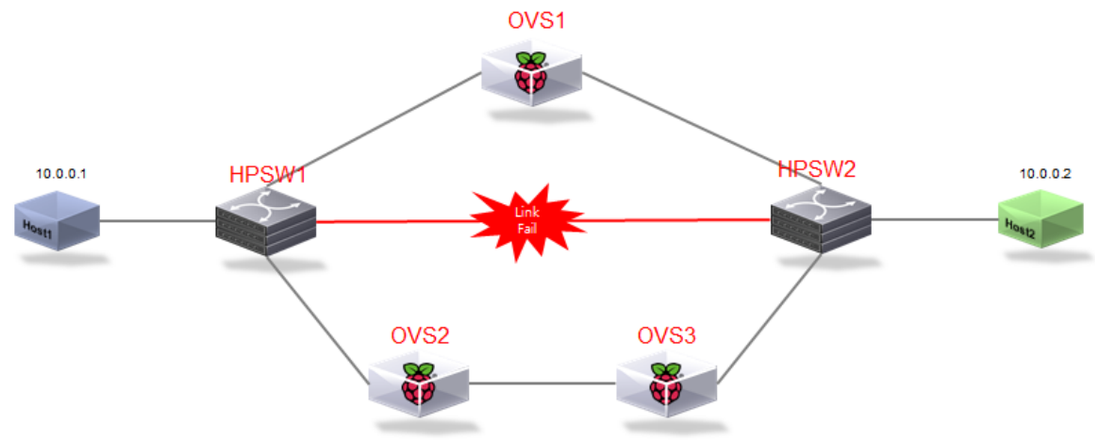
1 or multiple interfaces;
If no interface is specified, action is DROP

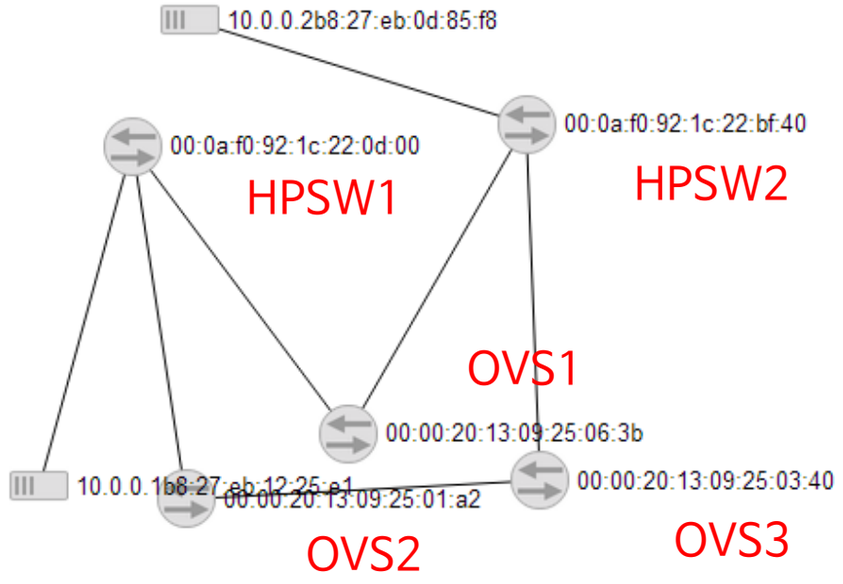
경로2 fail 시 Floodlight Topology

Floodlight Dashboard Topology Switches Hosts

Live updates

Network Topology





Floodlight © Big Switch Networks, IBM, et. al. Powered by Backbone.js, Bootstrap, jQuery, D3.js, etc.

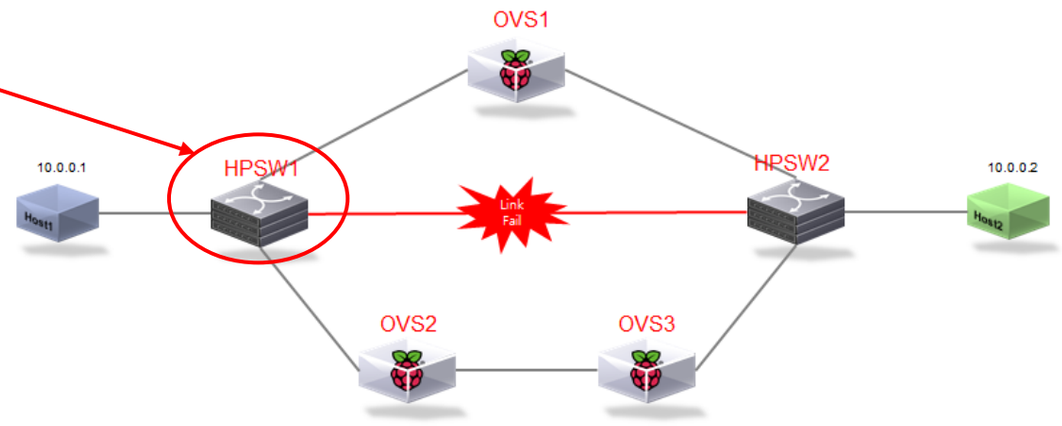
경로2 fail 시 Floodlight의 Flow Table

Floodlight Dashboard Topology Switches Hosts

Live updates

Switch 00:0a:f0:92:1c:22:0d:00 /192.168.1.204:62072

Connected since 2014년 2월 17일 오후 7:12:45
HP Networking
BTTF
VER 1.0
S/N: None



Ports (5)

#	Link Status	TX Bytes	RX Bytes	TX Pkts	RX Pkts	Dropped	Errors
19	UP 100 Mbps FDX	93801214	76490413	940890	735899	0	0
18	UP 100 Mbps FDX	116788907	585488219	1168630	986403	0	0
20	UP 100 Mbps FDX	54116686	13677886	591495	204091	0	0
65534 (local)	UP	0	0	0	0	0	0
13	DOWN	82375801	104871277	839778	1060141	0	0

Flows (2)

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
9007199254740992	0	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 13	155	15190	77 s	5 s
9007199254740992	0	port=13, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 20	157	15348	77 s	5 s

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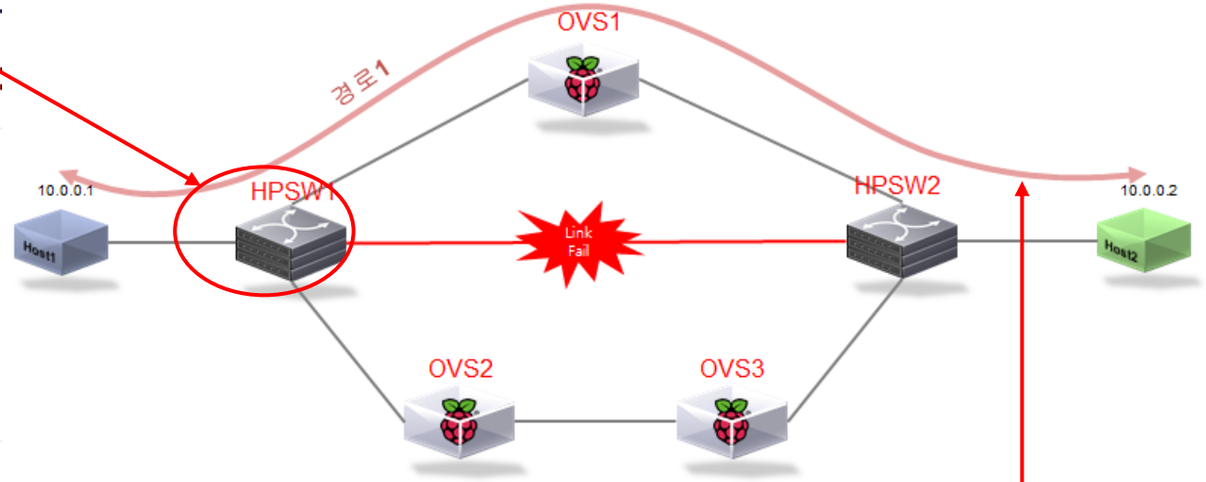
Floodlight Reboot 후 Flow Table

Floodlight Dashboard Topology Switches Hosts

Live updates

Switch 00:0a:f0:92:1c:22:0d:00 /192.168.1.204

Connected since 2014년 2월 17일 오후 7:16:55
HP Networking
BTTF
VER 1.0
S/N: None



Ports (5)

#	Link Status	TX Bytes	RX Bytes	TX Pkts	RX Pkts	Dropped	Errors
19	UP 100 Mbps FDX	93802773	76492926	940904	735938	0	0
18	UP 100 Mbps FDX	116805673	585502062	1168805	986542	0	0
20	UP 100 Mbps FDX	54133752	13696828	591674	204289	0	0
65534 (local)	UP	0	0	0	0	0	0
13	DOWN	82375801	104871277	839778	1060141	0	0

Flows (2)

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
9007199254740992	0	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 18	124	12114	61 s	5 s
9007199254740992	0	port=18, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 20	126	12272	61 s	5 s

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NAIM

HP Controller

Mar, 2014

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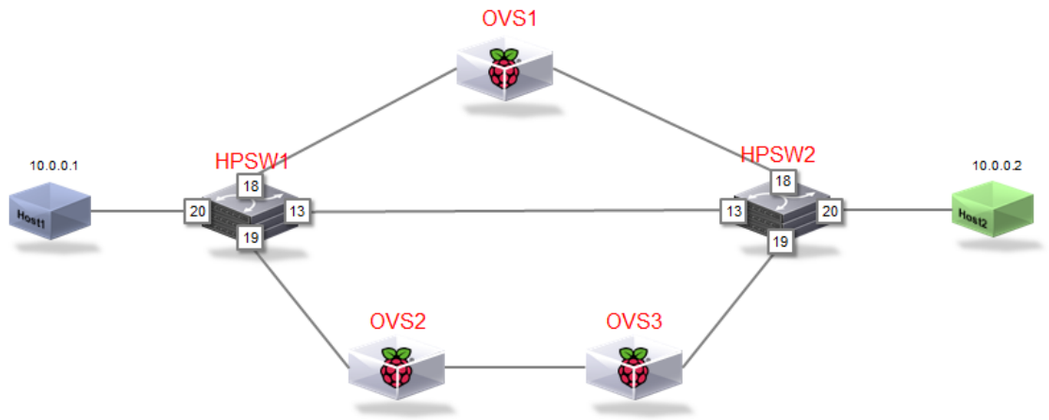
HP Controller Topology



HP VAN SDN Controller 2.0

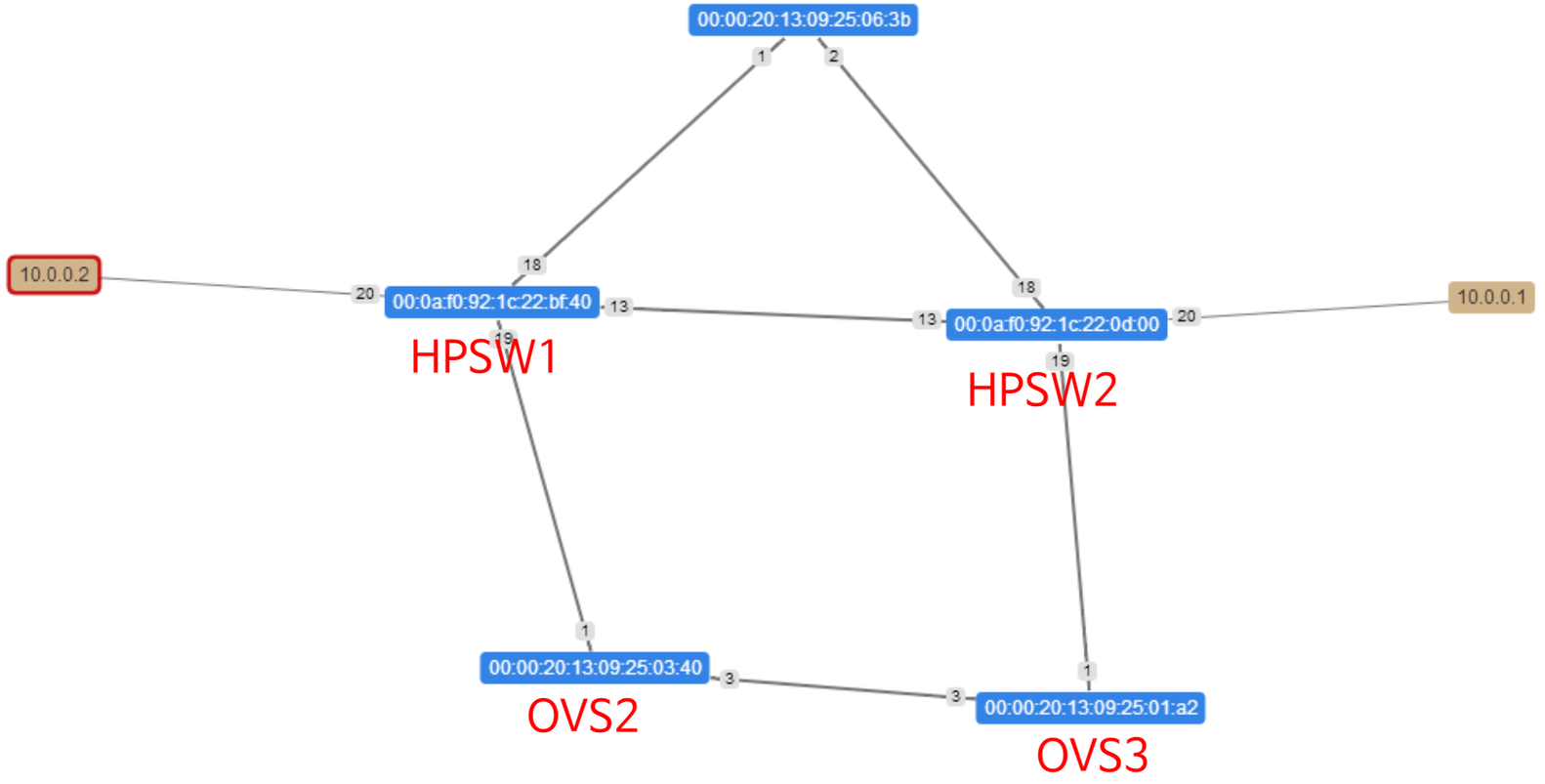
93 sdn

- General
  - Alerts
  - Applications
  - Configurations
  - Audit Log
  - Support Logs
  - OpenFlow Monitor
  - OpenFlow Topology
  - OpenFlow Trace

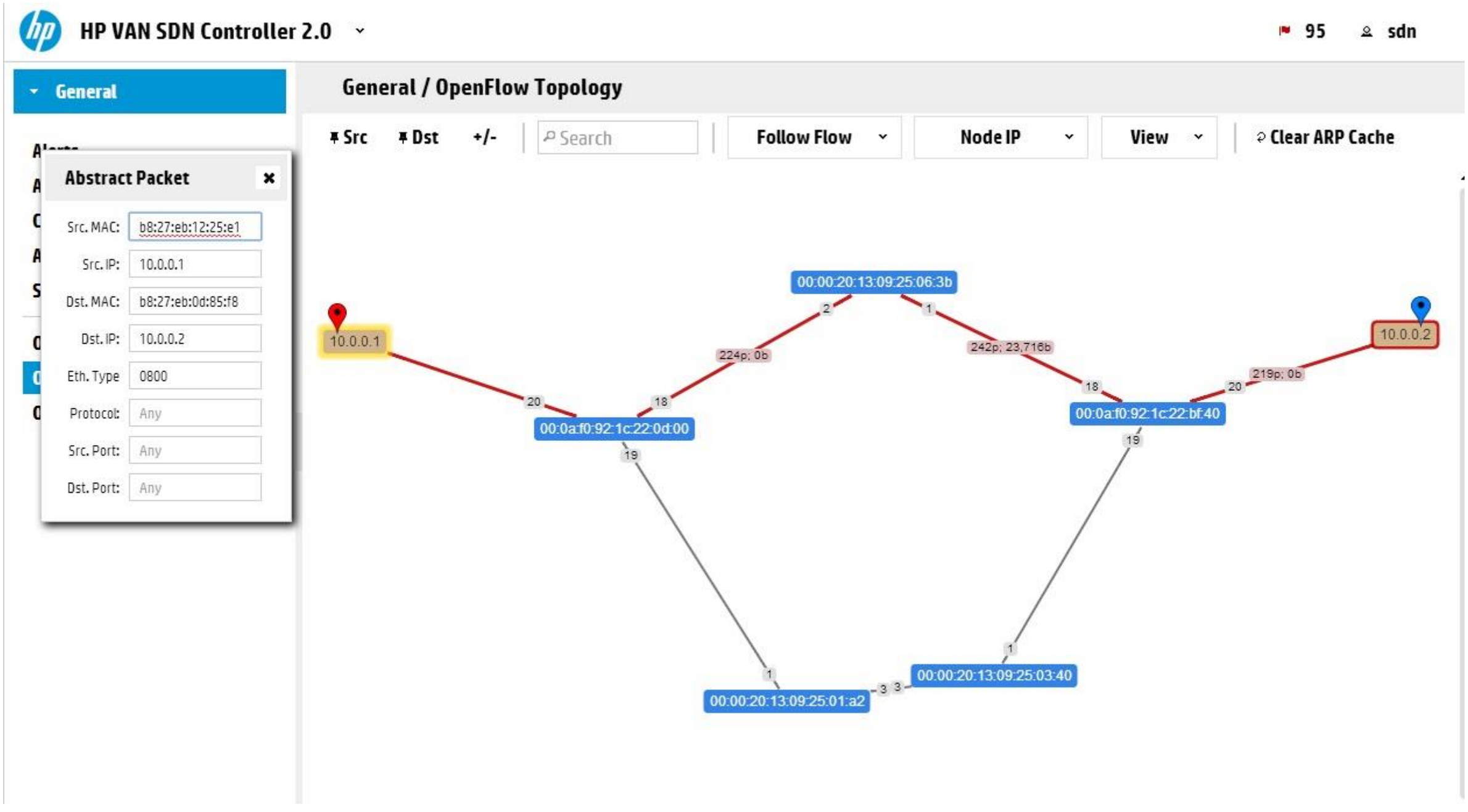
General / OpenFlow Topology

Src Dst +/- Search Shortest Path Node IP View Clear ARP Cache

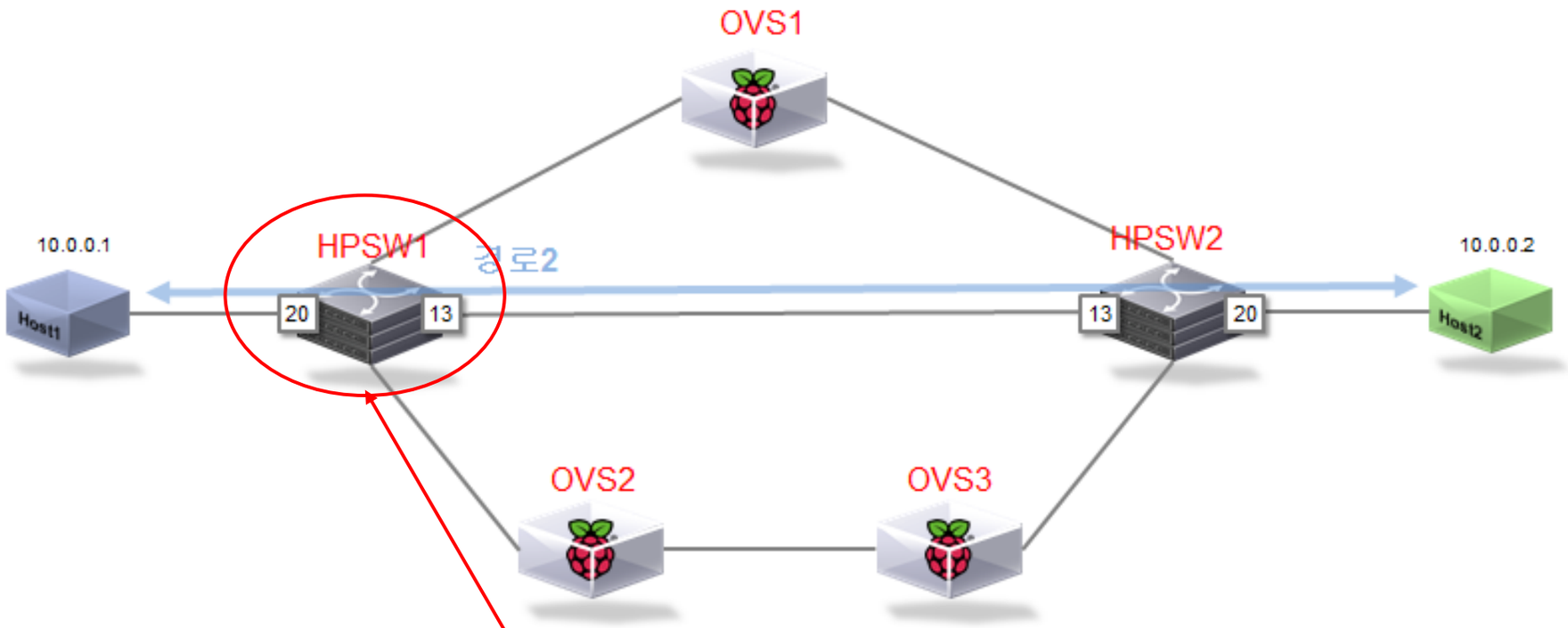
OVS1



HP Controller Topology



HP Controller의 Flow Table



HP VAN SDN Controller 2.0

- General
- Alerts
- Applications
- Configurations
- Audit Log
- Support Logs
- OpenFlow Monitor
- OpenFlow Topology
- OpenFlow Trace

Flows for Data Path ID: 00:0a:f0:92:1c:22:0d:00

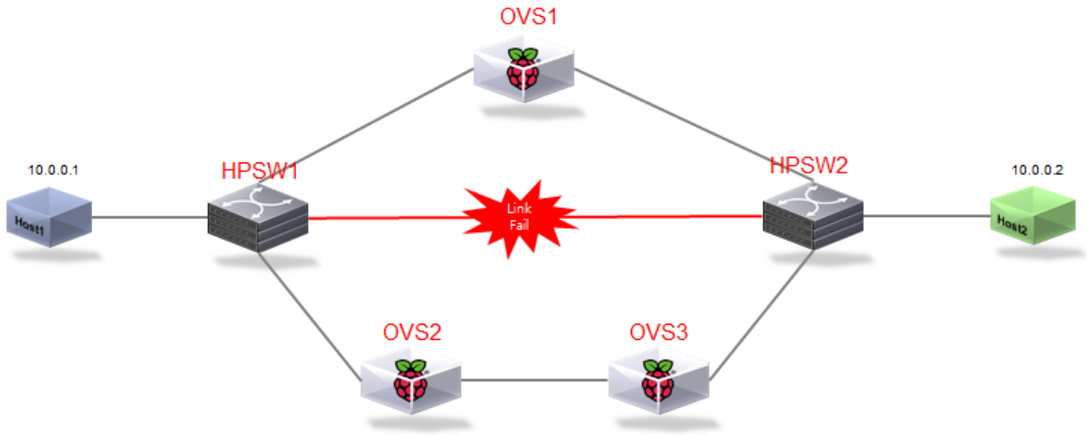
Summ

Table ID	Priority	Packets	Bytes	Matches	Actions/Instructions
n/a	29999	913	0	in_port: 20 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: ipv4	output: 13
n/a	29999	914	0	in_port: 13 eth_dst: b8:27:eb:12:25:e1 eth_src: b8:27:eb:0d:85:f8 eth_type: ipv4	output: 20

HP Switch1의 Flow Table

```
HP-3800-24G-2SFPP# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : Any                       VLAN priority     : Any
  Source Protocol Address : Any
  Target Protocol Address : Any
  IP Protocol   : Any                       IP ToS Bits       : Any
  Source Port   : Any                       Destination Port  : Any
 Attributes
  Priority      : 29999                     Duration          : 153 seconds
  Hard Timeout  : 0 seconds                 Idle Timeout      : 60 seconds
  Byte Count    : 0                         Packet Count      : 273
  Controller ID : 10                        Cookie            : 0x2328
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 13

 Flow 2
 Match
  Incoming Port : 13                        Ethernet Type     : IP
  Source MAC    : b827eb-0d85f8             Destination MAC   : b827eb-1225e1
  VLAN ID       : Any                       VLAN priority     : Any
  Source Protocol Address : Any
  Target Protocol Address : Any
  IP Protocol   : Any                       IP ToS Bits       : Any
  Source Port   : Any                       Destination Port  : Any
 Attributes
  Priority      : 29999                     Duration          : 153 seconds
  Hard Timeout  : 0 seconds                 Idle Timeout      : 60 seconds
  Byte Count    : 0                         Packet Count      : 274
  Controller ID : 10                        Cookie            : 0x2328
  Flow Location : Hardware
  Hardware Index      : 1
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 20

HP-3800-24G-2SFPP#
```

경로2 fail 시 HP Controller Topology



HP VAN SDN Controller 2.0

93 sdn

General

Alerts
Applications
Configurations
Audit Log
Support Logs

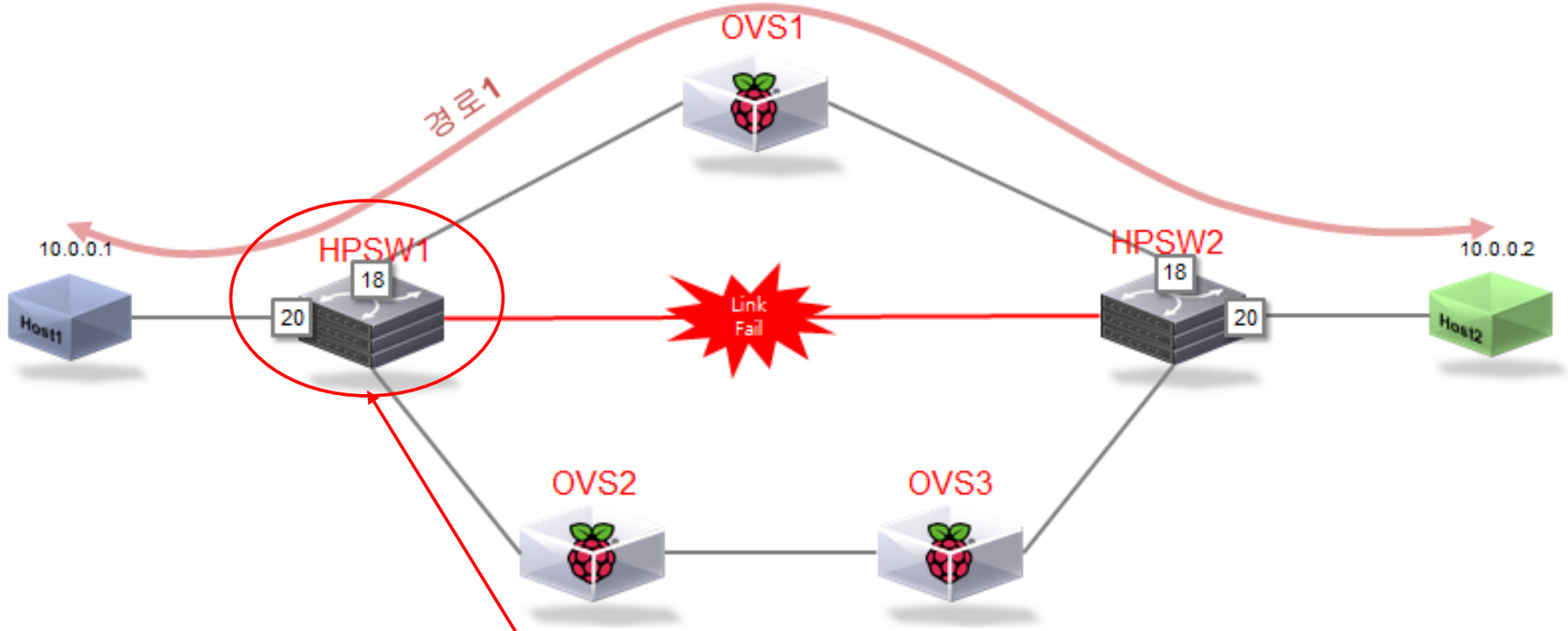
OpenFlow Monitor
OpenFlow Topology
OpenFlow Trace

General / OpenFlow Topology

Src Dst +/- Search Follow Flow Node IP View Clear ARP Cache

OVS1
00:00:20:13:09:25:06:3b
10.0.0.1
10.0.0.2
00:0a:f0:92:1c:22:0d:00
HPSW1
00:0a:f0:92:1c:22:bf:40
HPSW2
00:00:20:13:09:25:01:a2
OVS2
00:00:20:13:09:25:03:40
OVS3

경로2 fail 시 HP Controller의 Flow Table



HP VAN SDN Controller 2.0

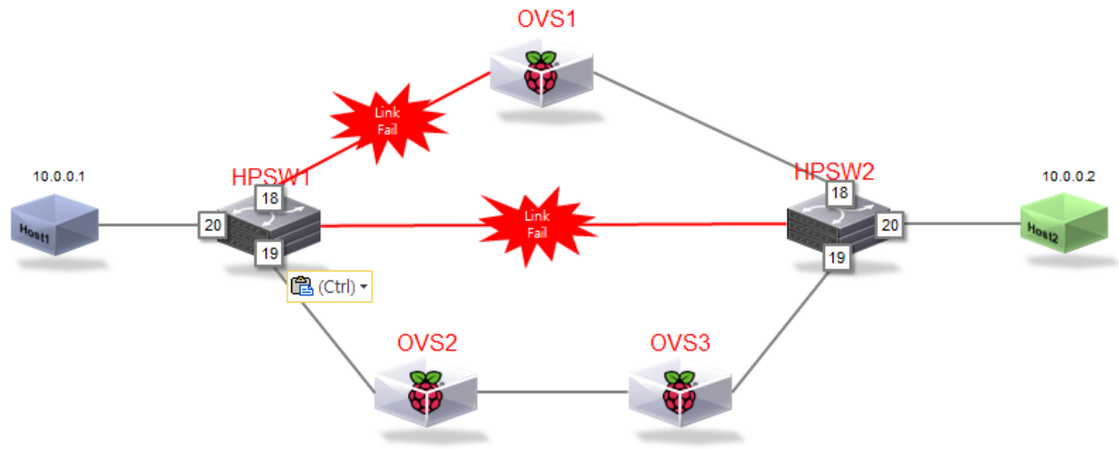
- General
- Alerts
- Applications
- Configurations
- Audit Log
- Support Logs
- OpenFlow Monitor
- OpenFlow Topology
- OpenFlow Trace

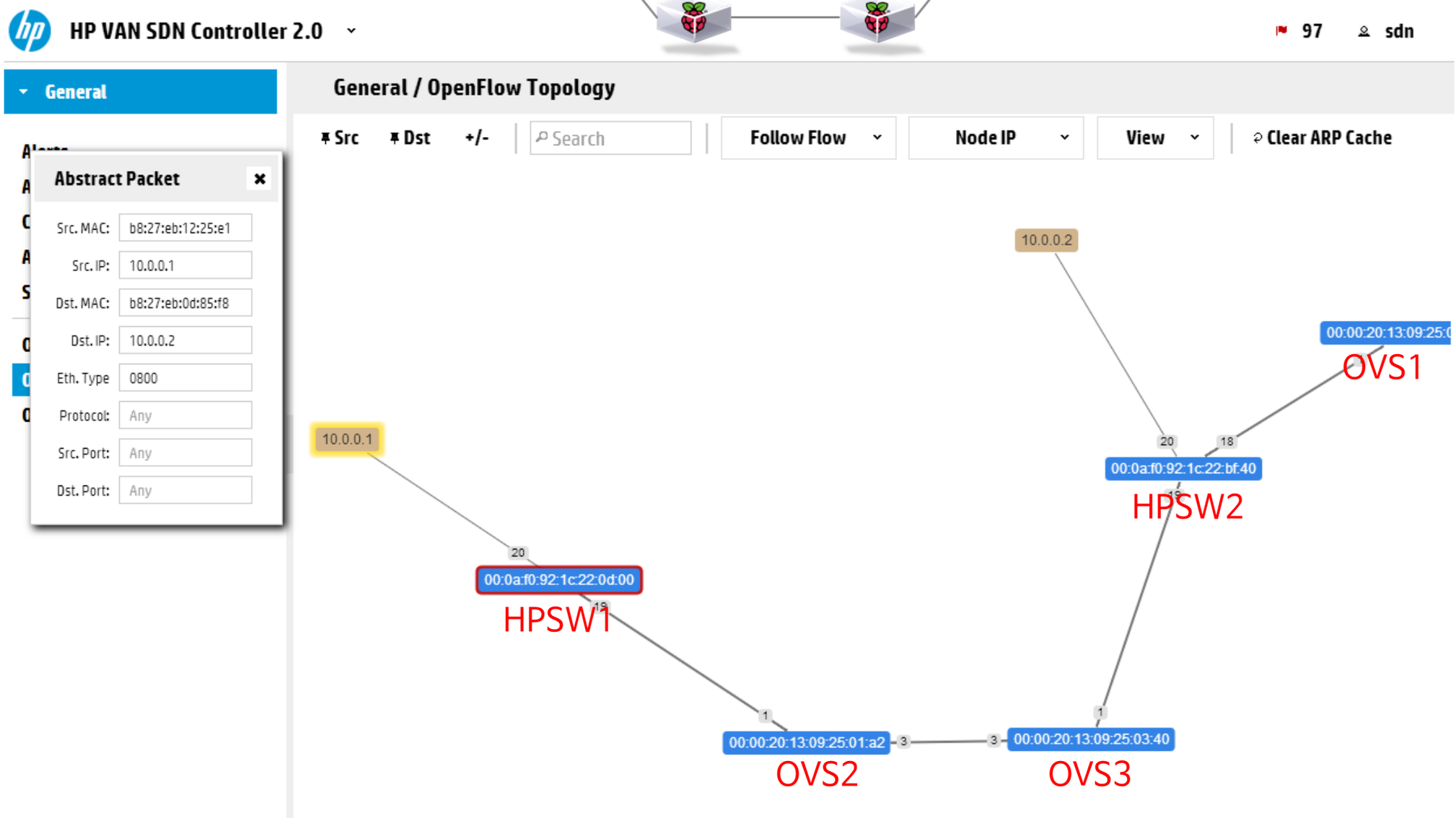
Flows for Data Path ID: 00:0a:f0:92:1c:22:0d:00

Sum

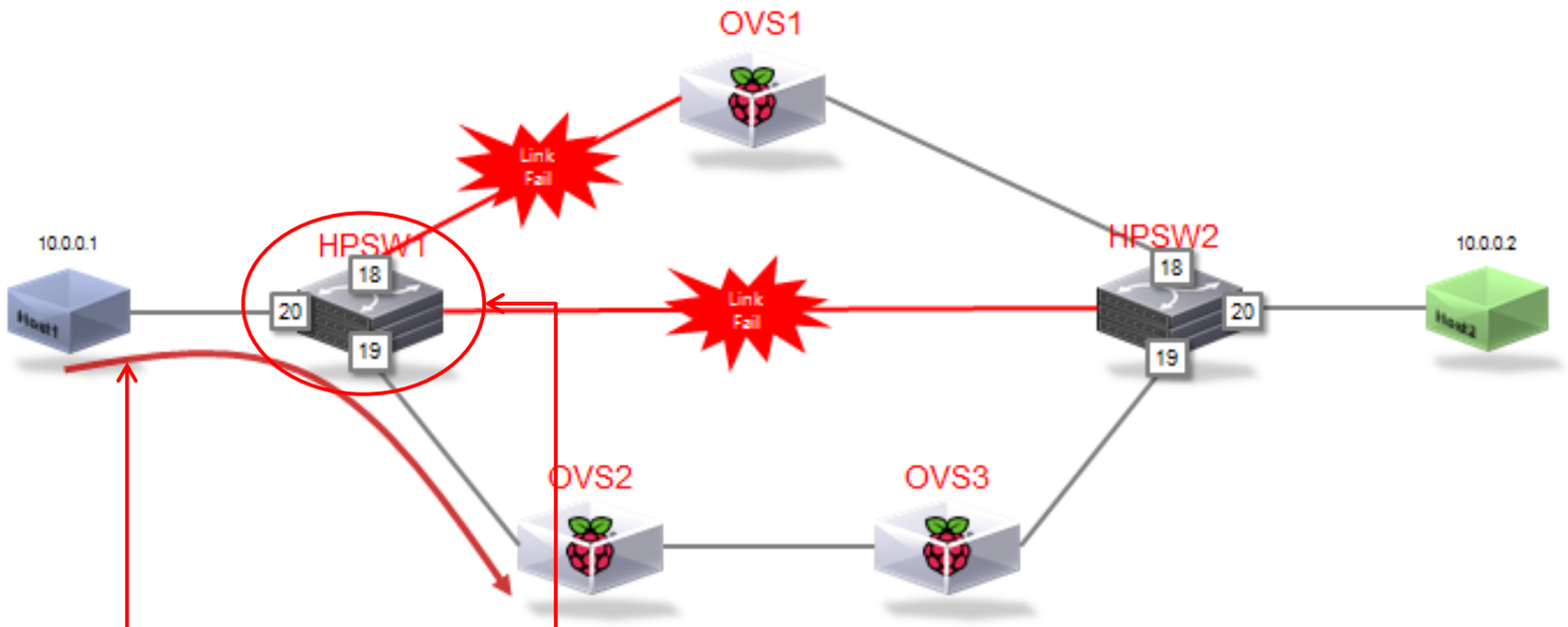
Table ID	Priority	Packets	Bytes	Matches	Actions/Instructions
n/a	29999	344	0	in_port: 20 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: ipv4	output: 18
n/a	29999	344	0	in_port: 18 eth_dst: b8:27:eb:12:25:e1 eth_src: b8:27:eb:0d:85:f8 eth_type: ipv4	output: 20

경로1,2 fail 시 HP Controller Topology





경로1,2 fail 시 HP Controller Flow Table



HP VAN SDN Controller 2.0

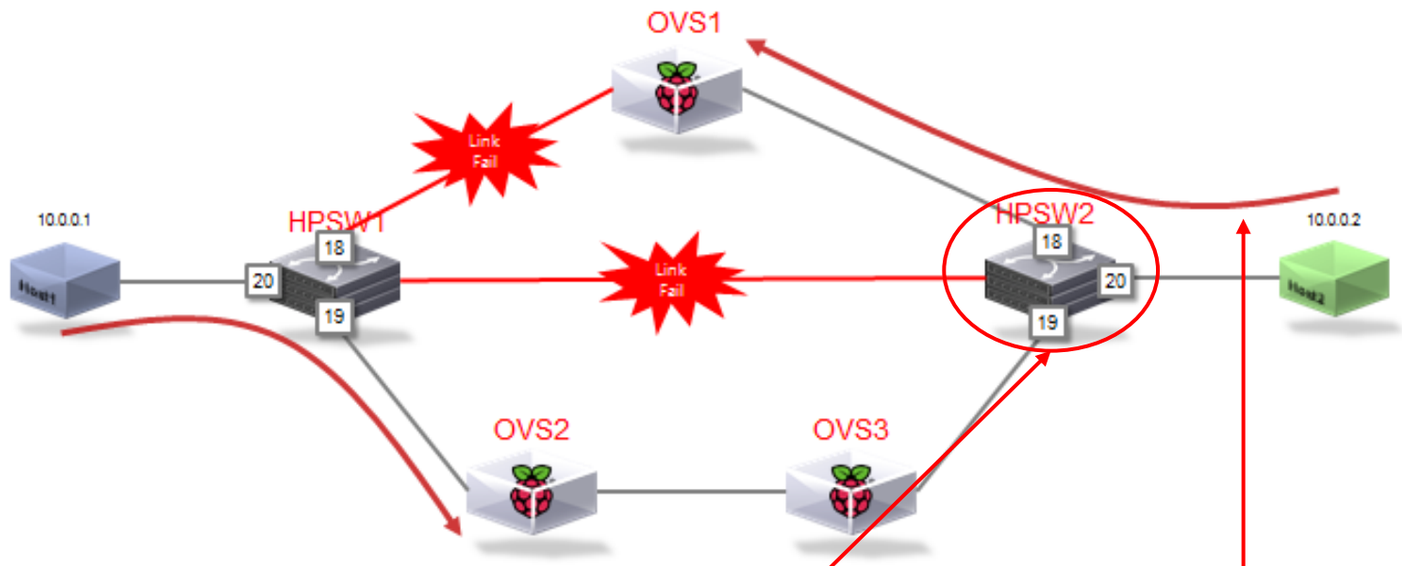
- General
- Alerts
- Applications
- Configurations
- Audit Log
- Support Logs
- OpenFlow Monitor
- OpenFlow Topology
- OpenFlow Trace

Flows for Data Path ID: 00:0a:f0:92:1c:22:0d:00

Summary | Ports

Table ID	Priority	Packets	Bytes	Matches	Actions/Instructions
n/a	29999	160	0	in_port: 20 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: ipv4	output: 19
n/a	29999	8	0	in_port: 20 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: arp	output: 19
n/a	29999	9	0	in_port: 19 eth_dst: b8:27:eb:12:25:e1 eth_src: b8:27:eb:0d:85:f8 eth_type: arp	output: 20

경로1,2 fail 시 HP Controller Flow Table



HP VAN SDN Controller 2.0

General

- Alerts
- Applications
- Configurations
- Audit Log
- Support Logs
- OpenFlow Monitor
- OpenFlow Topology
- OpenFlow Trace

Flows for Data Path ID: 00:0a:f0:92:1c:22:bf:40

Summary | Ports

Table ID	Priority	Packets	Bytes	Matches	Actions/Instructions
n/a	29999	17	0	in_port: 19 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: arp	output: 20
n/a	29999	1178	0	in_port: 20 eth_dst: b8:27:eb:12:25:e1 eth_src: b8:27:eb:0d:85:f8 eth_type: ipv4	output: 18 〈– Bug Flow
n/a	29999	278	0	in_port: 19 eth_dst: b8:27:eb:0d:85:f8 eth_src: b8:27:eb:12:25:e1 eth_type: ipv4	output: 20
n/a	29999	16	0	in_port: 20 eth_dst: b8:27:eb:12:25:e1 eth_src: b8:27:eb:0d:85:f8 eth_type: arp	output: 19

NAIM

OpenIRIS

Mar, 2014

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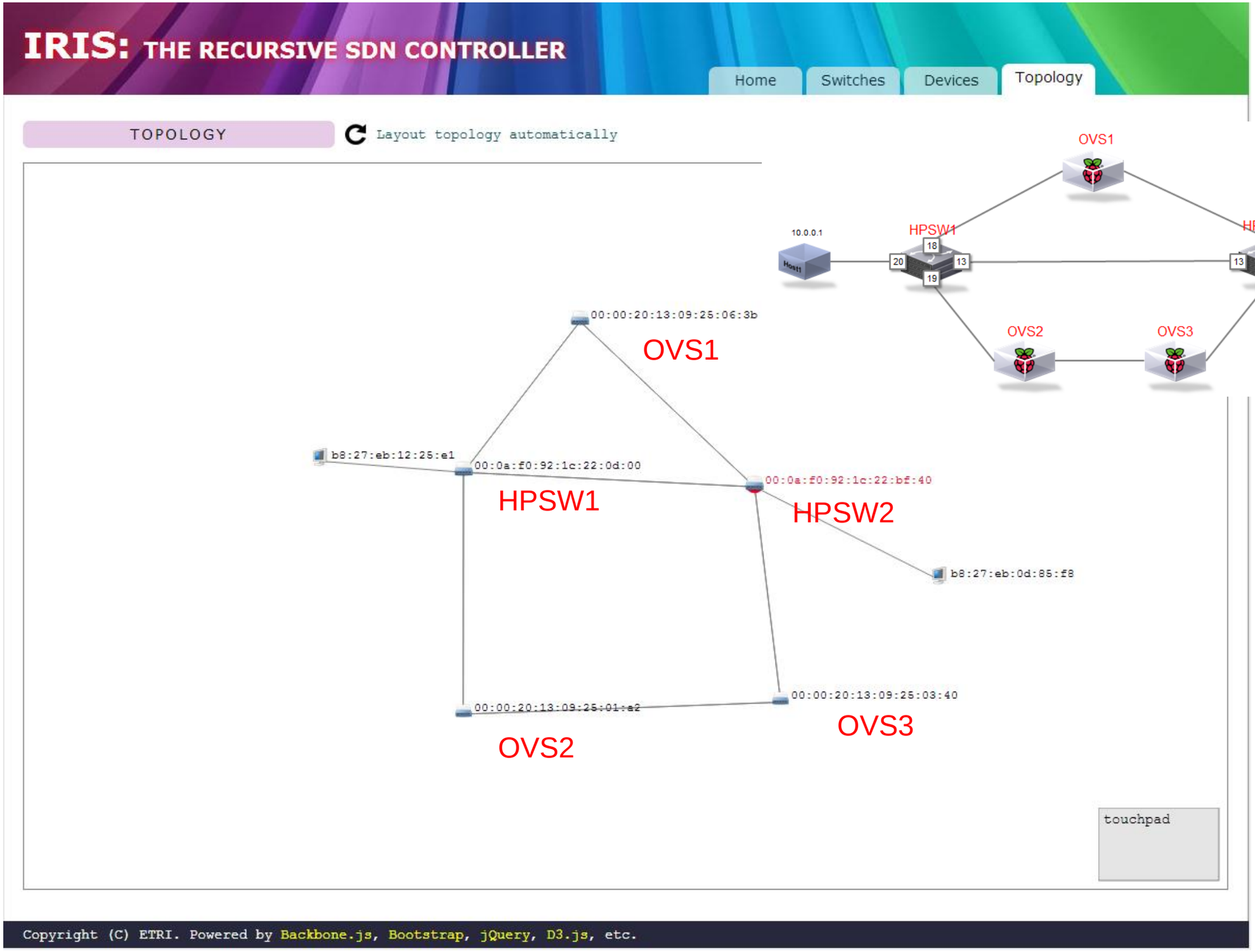
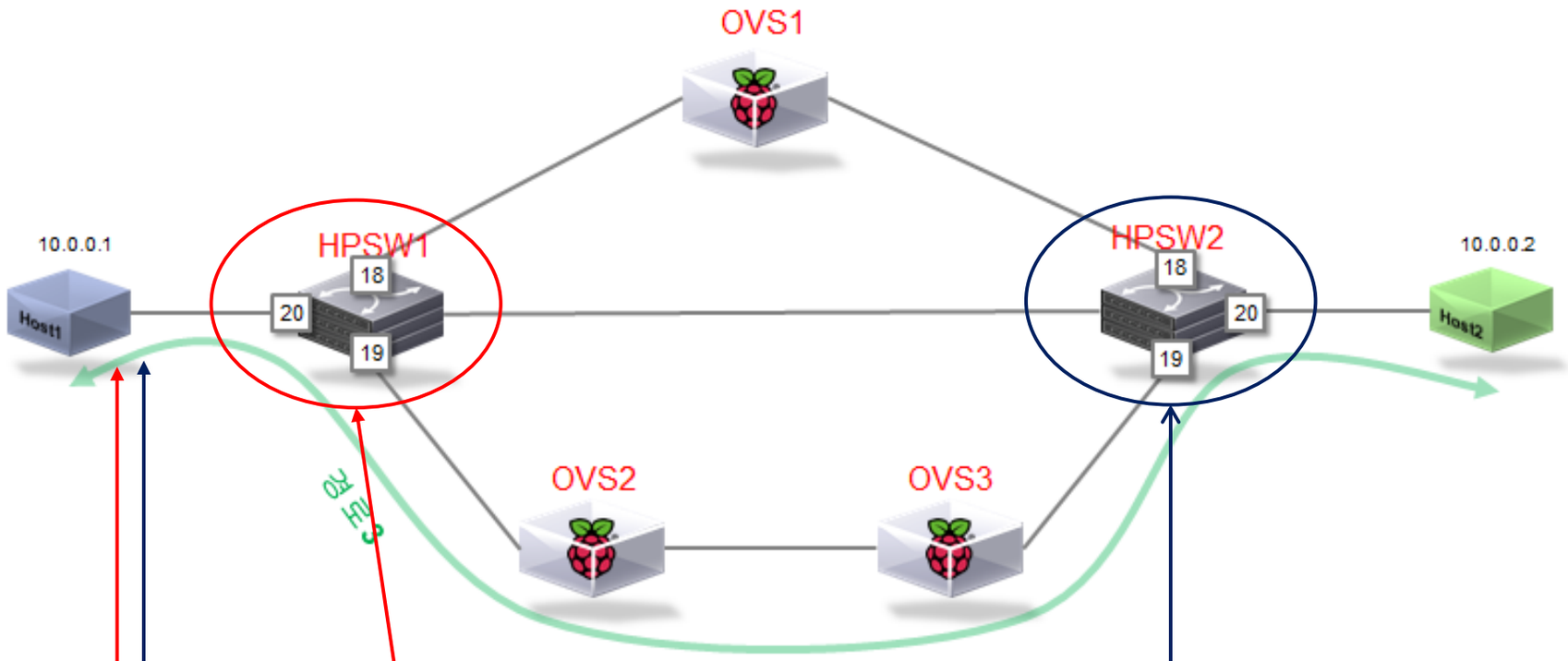
OpenIRIS Topology



OpenIRIS Flow Table



00:0a:f0:92:1c:22:0d:00 /192.168.1.204:54709 HP Networking 5 490 2 2014년 2월 17일 오후 4:26:16

Flow Records:

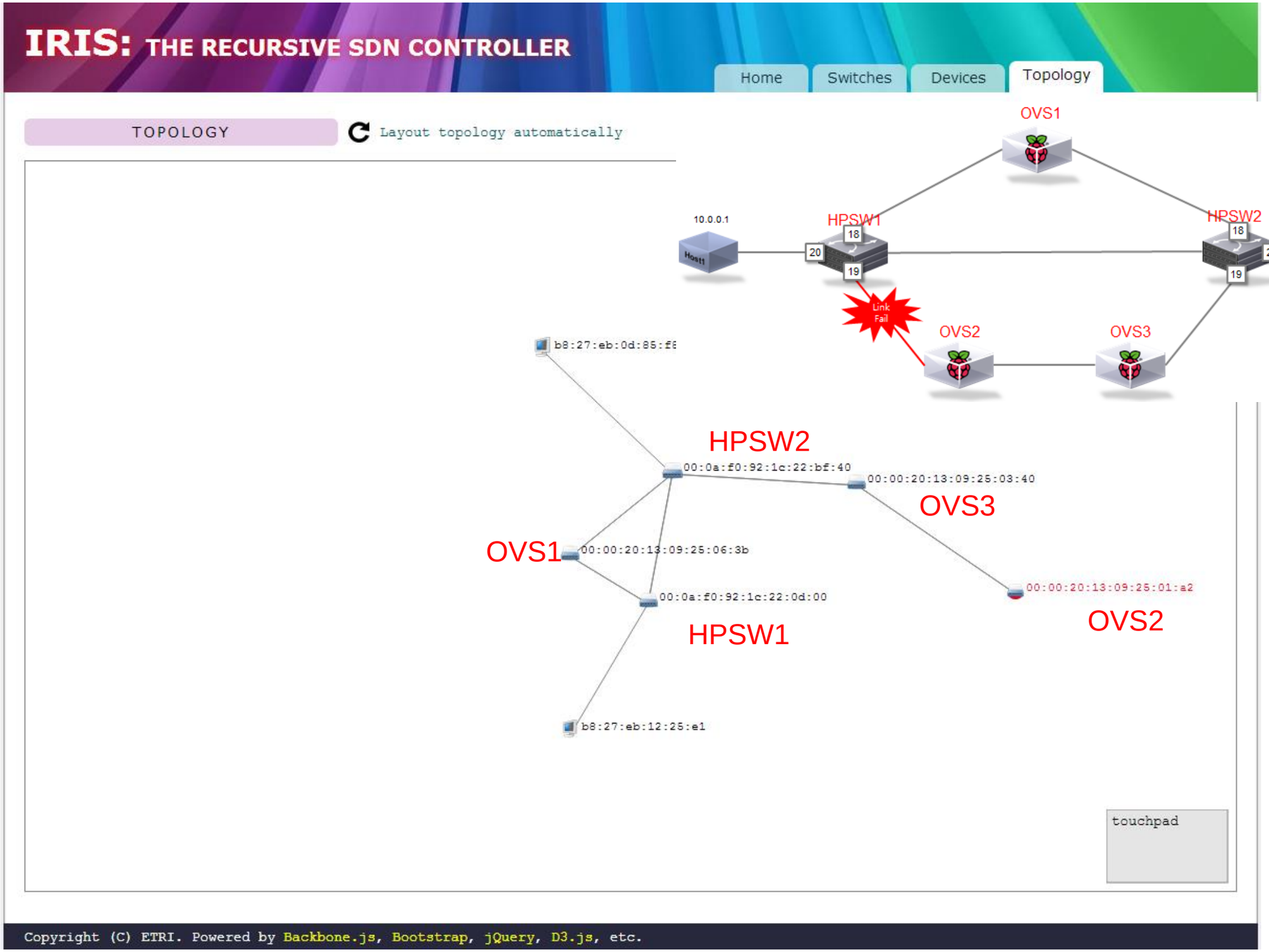
Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 19	34	3294	19s	5s
4503599627370496	100	port=19, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 20	32	3098	19s	5s

00:0a:f0:92:1c:22:bf:40 /192.168.1.205:55005 HP Networking 0 0 3 2014년 2월 17일 오후 4:26:46

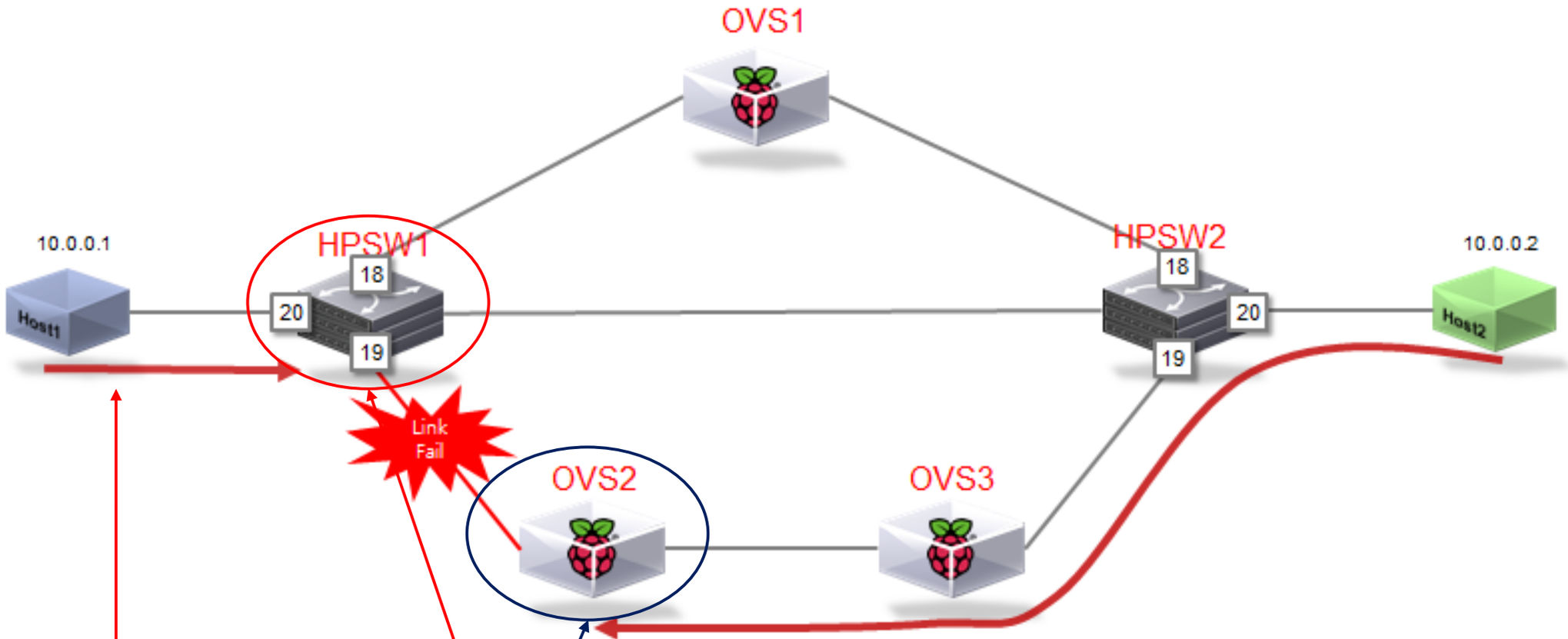
Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=19, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 20	29	2804	16s	5s
4503599627370496	100	port=20, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 19	30	2902	16s	5s

경로3 fail 시 OpenIRIS Topology



경로3 fail 시 OpenIRIS의 Flow Table



00:0a:f0:92:1c:22:0d:00 /192.168.1.204:54709 HP Networking 66 6468 1 2014년 2월 17일 오후 4:26:16

Flow Records:

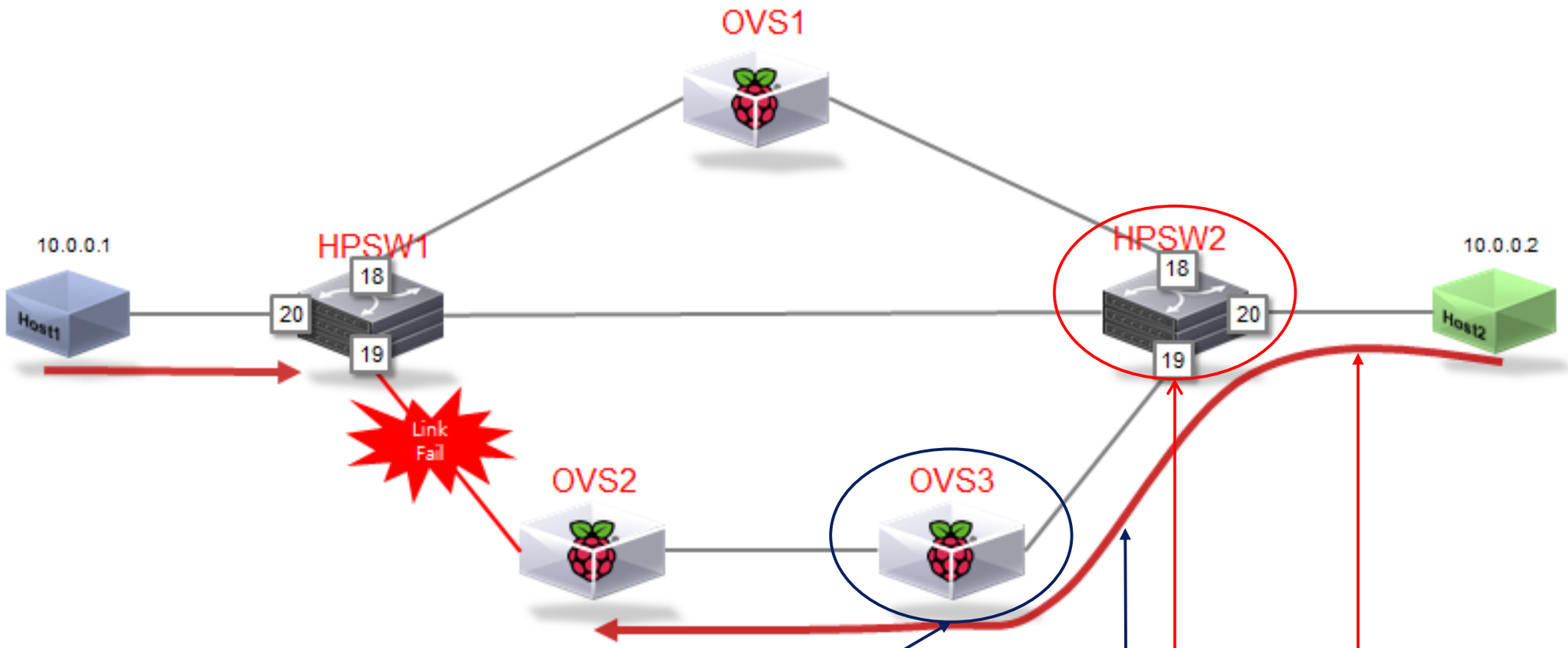
Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 19	70	6860	55s	5s

00:00:20:13:09:25:01:a2 /192.168.1.202:36556 Nicira, Inc. 66 6468 1 2014년 2월 17일 오후 4:25:44

Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=1, VLAN=-1, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 3	71	6882	53s	5s

경로3 fail 시 OpenIRIS의 Flow Table



00:0a:f0:92:1c:22:bf:40 /192.168.1.205:55005 HP Networking 67 6566 1 2014년 2월 17일 오후 4:26:46

Flow Records:

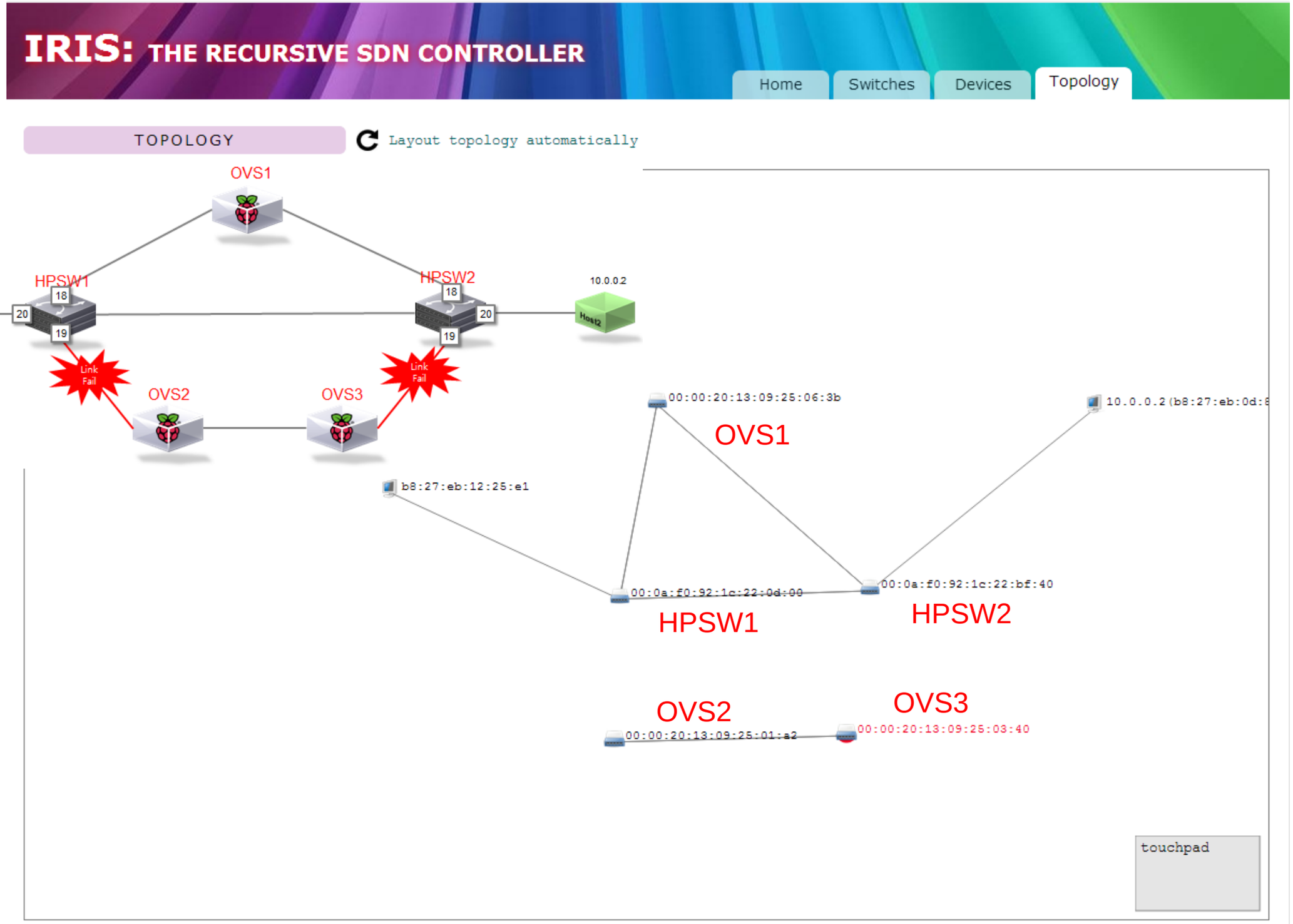
Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=20, VLAN=-1, prio=0, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 19	69	6724	56s	5s

00:00:20:13:09:25:03:40 /192.168.1.203:51206 Nicira, Inc. 67 6566 1 2014년 2월 17일 오후 4:25:44

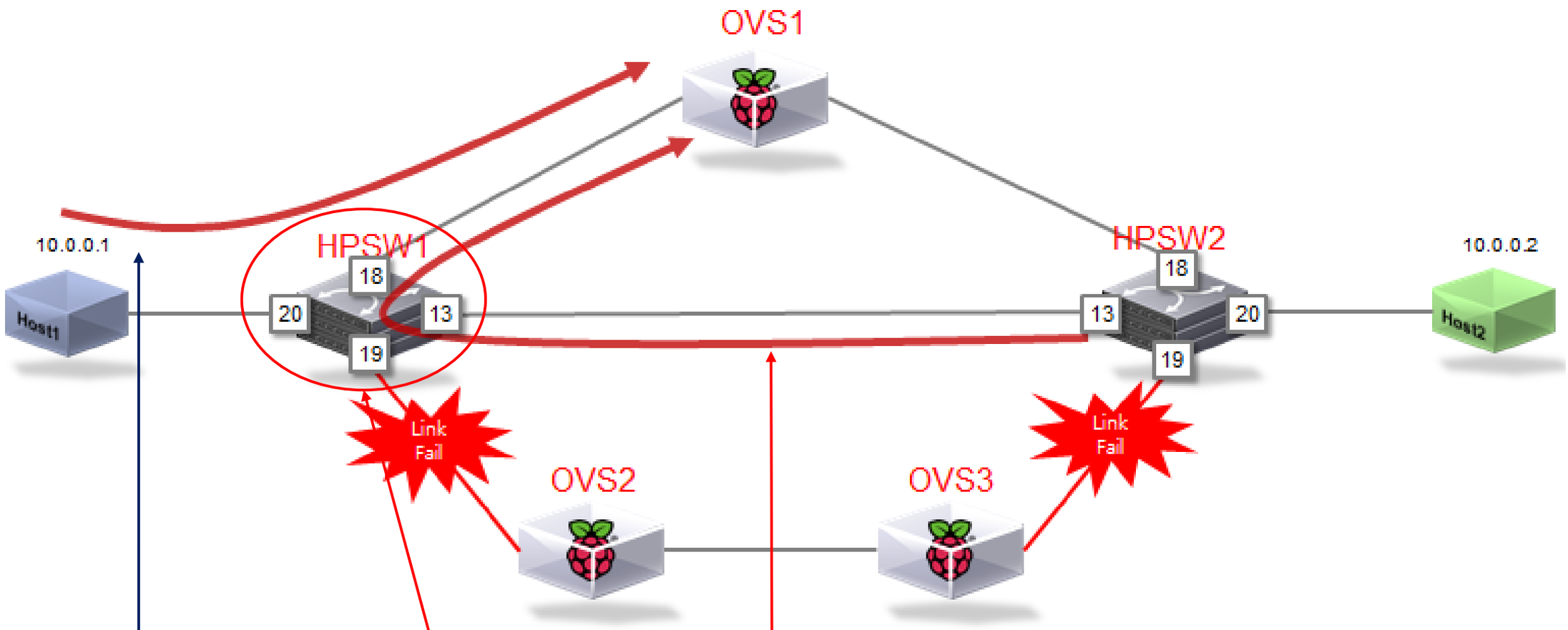
Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=1, VLAN=-1, src=b8:27:eb:0d:85:f8, dest=b8:27:eb:12:25:e1	output 3	73	7040	55s	5s

OpenIRIS Reboot 후 Topology



경로3 fail 시 OpenIRIS의 Flow Table

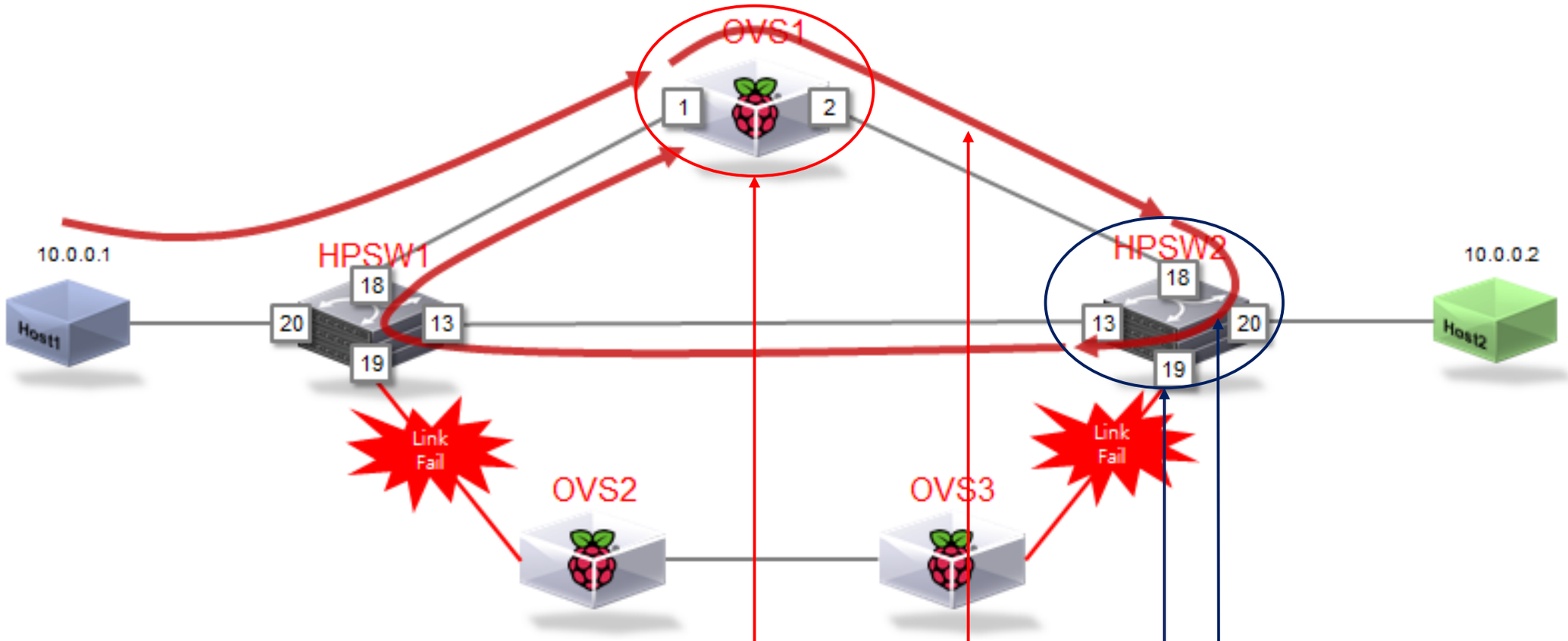


00:0a:f0:92:1c:22:0d:00 /192.168.1.204:56303 HP Networking 5577 371290 2 2014년 2월 17일 오후 4:40:11

Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=13, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 18	3668	252418	197s	5s
4503599627370496	100	port=20, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 18	2004	125978	199s	5s

경로3 fail 시 OpenIRIS의 Flow Table



00:00:20:13:09:25:06:3b /192.168.1.201:60257 Nicira, Inc. 5577 371290 1 2014년 2월 17일 오후 4:40:11

Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=1, VLAN=-1, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 2	5600	372708	196s	5s

00:0a:f0:92:1c:22:bf:40 /192.168.1.205:60204 HP Networking 5537 368624 1 2014년 2월 17일 오후 4:40:12

Flow Records:

Cookie	Priority	Match	Action	Packets	Bytes	Age	Timeout
4503599627370496	100	port=18, VLAN=-1, prio=0, src=b8:27:eb:12:25:e1, dest=b8:27:eb:0d:85:f8	output 13	5609	373894	197s	5s

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Mar, 2014

Erica Eun-Jung Lee

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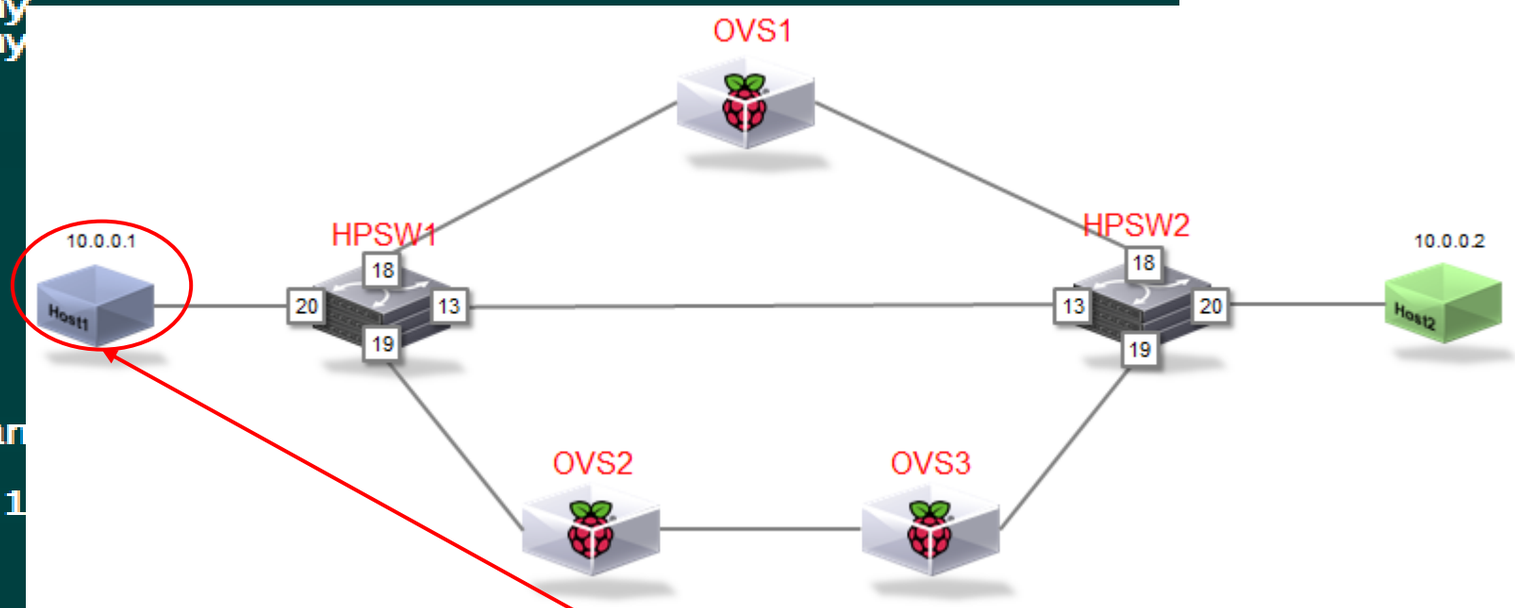
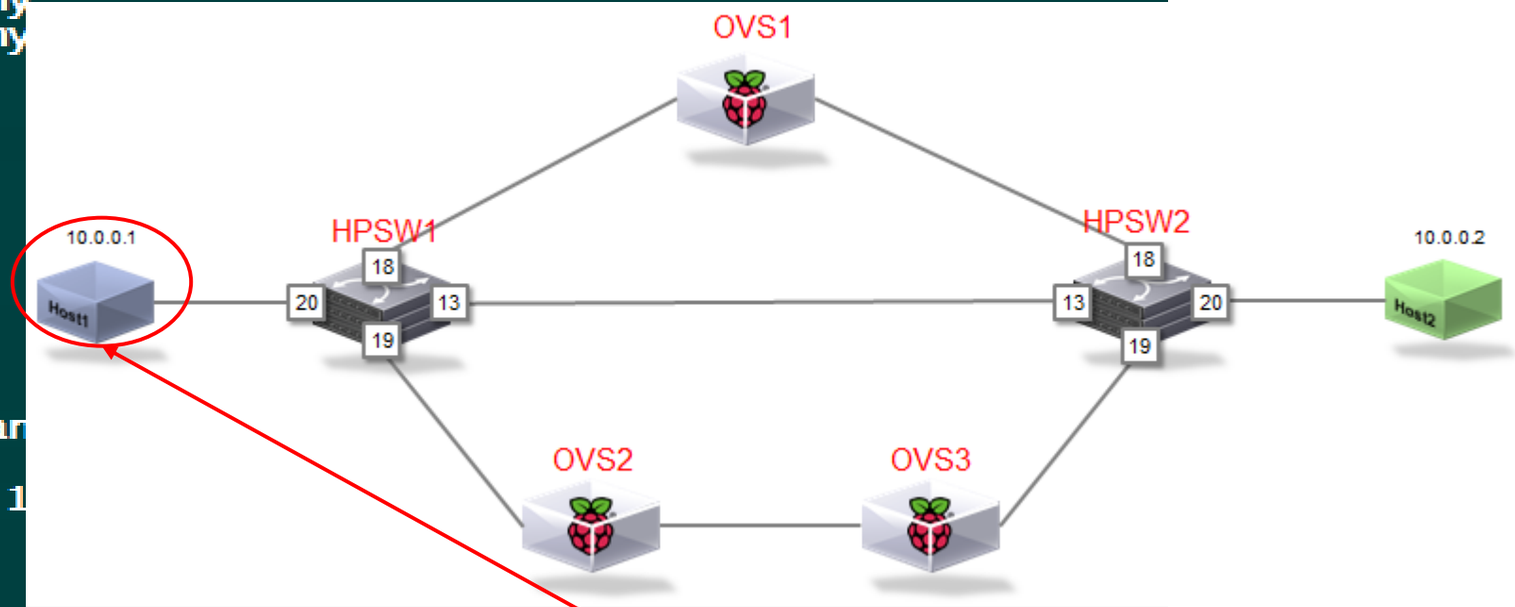
HP Switch1의 Flow Table

```
Flow 3
Match
 Incoming Port : Any                          Ethernet Type     : Any
 Source MAC    : Any                          Destination MAC   : b827eb-0d85f8
 VLAN ID       : Any                          VLAN priority     : Any
 Source Protocol Address : Any
 Target Protocol Address : Any
 IP Protocol   : Any
 Source Port   : Any
Attributes
 Priority      : 0
 Hard Timeout  : 20 seconds
 Byte Count    : 4998
 Controller ID : 10
 Flow Location : Software
 Hardware Index      : NA
 Reason Code         : 15
 Reason Description : Rule can
Actions
   Output                    : 1

Flow 4
Match
 Incoming Port : Any                          Ethernet Type     : Any
 Source MAC    : Any                          Destination MAC   : b827eb-1225e1
 VLAN ID       : Any                          VLAN priority     : Any
 Source Protocol Address : Any
 Target Protocol Address : Any
 IP Protocol   : Any                          IP ToS Bits       : Any
 Source Port   : Any                          Destination Port  : Any
Attributes
 Priority      : 0                            Duration          : 956295047 seconds
 Hard Timeout  : 0 seconds                    Idle Timeout      : 60 seconds
 Byte Count    : 43638                        Packet Count      : 695
 Controller ID : 10                           Cookie            : 0x0
 Flow Location : Software
 Hardware Index      : NA
 Reason Code         : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                    : 19
```

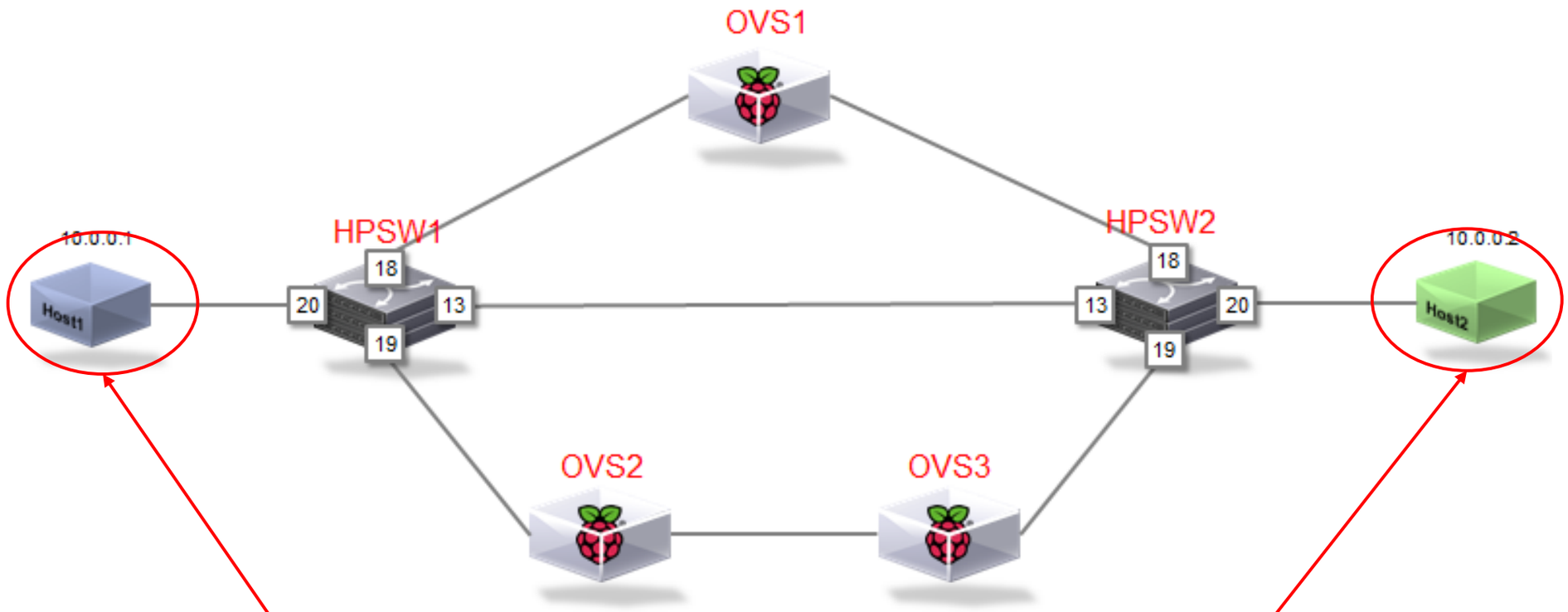


HP Switch1의 Flow Table2

```
Flow 3
Match
 Incoming Port : Any                          Ethernet Type     : Any
 Source MAC    : Any                          Destination MAC   : b827eb-0d85f8
 VLAN ID       : Any                          VLAN priority     : Any
 Source Protocol Address : Any
 Target Protocol Address : Any
 IP Protocol   : Any
 Source Port   : Any
Attributes
 Priority      : 0
 Hard Timeout  : 0 seconds
 Byte Count    : 109100
 Controller ID : 10
 Flow Location : Software
 Hardware Index      : NA
 Reason Code         : 15
 Reason Description : Rule car
Actions
   Output                    : 1

Flow 4
Match
 Incoming Port : Any                          Ethernet Type     : Any
 Source MAC    : Any                          Destination MAC   : b827eb-1225e1
 VLAN ID       : Any                          VLAN priority     : Any
 Source Protocol Address : Any
 Target Protocol Address : Any
 IP Protocol   : Any                          IP ToS Bits       : Any
 Source Port   : Any                          Destination Port  : Any
Attributes
 Priority      : 0                            Duration          : 956295828 seconds
 Hard Timeout  : 0 seconds                    Idle Timeout      : 60 seconds
 Byte Count    : 316114                       Packet Count      : 5026
 Controller ID : 10                           Cookie            : 0x0
 Flow Location : Software
 Hardware Index      : NA
 Reason Code         : 15
 Reason Description : Rule cannot be accelerated in hardware
Actions
   Output                    : 20
```



Host의 통신 상태



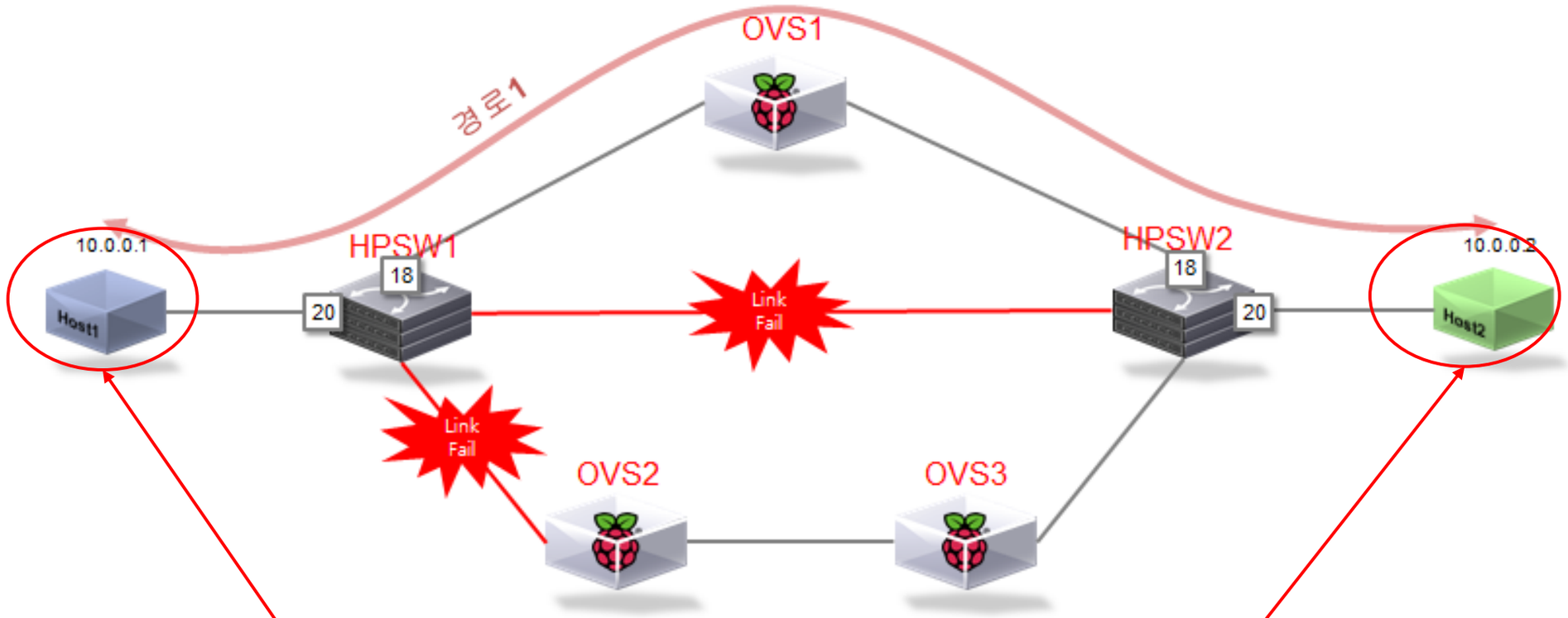

```
pi@raspberrypi: ~
File  Edit  Tabs  Help
From 10.0.0.1 icmp_seq=4 Destination Host Unreachable
From 10.0.0.1 icmp_seq=5 Destination Host Unreachable
From 10.0.0.1 icmp_seq=6 Destination Host Unreachable
From 10.0.0.1 icmp_seq=7 Destination Host Unreachable
From 10.0.0.1 icmp_seq=8 Destination Host Unreachable
From 10.0.0.1 icmp_seq=9 Destination Host Unreachable
From 10.0.0.1 icmp_seq=10 Destination Host Unreachable
From 10.0.0.1 icmp_seq=11 Destination Host Unreachable
From 10.0.0.1 icmp_seq=12 Destination Host Unreachable
From 10.0.0.1 icmp_seq=13 Destination Host Unreachable
From 10.0.0.1 icmp_seq=14 Destination Host Unreachable
From 10.0.0.1 icmp_seq=15 Destination Host Unreachable
From 10.0.0.1 icmp_seq=107 Destination Host Unreachable
From 10.0.0.1 icmp_seq=108 Destination Host Unreachable
From 10.0.0.1 icmp_seq=109 Destination Host Unreachable

64 bytes from 10.0.0.2: icmp_req=156 ttl=64 time=8.82 ms
64 bytes from 10.0.0.2: icmp_req=176 ttl=64 time=54.2 ms
```

〈- 통신이 불안정

```
pi@raspberrypi: ~
File  Edit  Tabs  Help
PING 10.0.0.1 (10.0.0.1) from 10.0.0.2 eth0: 56(84) bytes of data.
64 bytes from 10.0.0.1: icmp_req=92 ttl=64 time=10.8 ms
64 bytes from 10.0.0.1: icmp_req=94 ttl=64 time=14.1 ms
64 bytes from 10.0.0.1: icmp_req=98 ttl=64 time=50.2 ms
64 bytes from 10.0.0.1: icmp_req=136 ttl=64 time=30.1 ms
64 bytes from 10.0.0.1: icmp_req=144 ttl=64 time=14.3 ms
64 bytes from 10.0.0.1: icmp_req=145 ttl=64 time=56.1 ms
64 bytes from 10.0.0.1: icmp_req=146 ttl=64 time=35.1 ms
64 bytes from 10.0.0.1: icmp_req=150 ttl=64 time=9.76 ms
64 bytes from 10.0.0.1: icmp_req=156 ttl=64 time=12.1 ms
64 bytes from 10.0.0.1: icmp_req=161 ttl=64 time=20.8 ms
64 bytes from 10.0.0.1: icmp_req=169 ttl=64 time=11.5 ms
64 bytes from 10.0.0.1: icmp_req=189 ttl=64 time=32.8 ms
```

〈- 통신이 불안정

경로2,3 Fail 시 Host의 통신 상태



pi@raspberrypi: ~

File Edit Tabs Help

```
64 bytes from 10.0.0.2: icmp_req=1238 ttl=64 time=2.11 ms
64 bytes from 10.0.0.2: icmp_req=1239 ttl=64 time=2.24 ms
64 bytes from 10.0.0.2: icmp_req=1240 ttl=64 time=2.02 ms
64 bytes from 10.0.0.2: icmp_req=1241 ttl=64 time=2.34 ms
64 bytes from 10.0.0.2: icmp_req=1242 ttl=64 time=2.08 ms
64 bytes from 10.0.0.2: icmp_req=1243 ttl=64 time=2.08 ms
64 bytes from 10.0.0.2: icmp_req=1244 ttl=64 time=2.10 ms
64 bytes from 10.0.0.2: icmp_req=1245 ttl=64 time=43.0 ms
64 bytes from 10.0.0.2: icmp_req=1246 ttl=64 time=2.23 ms
64 bytes from 10.0.0.2: icmp_req=1247 ttl=64 time=2.28 ms
64 bytes from 10.0.0.2: icmp_req=1248 ttl=64 time=1.95 ms
64 bytes from 10.0.0.2: icmp_req=1249 ttl=64 time=2.05 ms
64 bytes from 10.0.0.2: icmp_req=1250 ttl=64 time=2.41 ms
64 bytes from 10.0.0.2: icmp_req=1251 ttl=64 time=2.45 ms
64 bytes from 10.0.0.2: icmp_req=1252 ttl=64 time=2.10 ms
64 bytes from 10.0.0.2: icmp_req=1253 ttl=64 time=2.09 ms
64 bytes from 10.0.0.2: icmp_req=1254 ttl=64 time=2.94 ms
64 bytes from 10.0.0.2: icmp_req=1255 ttl=64 time=2.14 ms
64 bytes from 10.0.0.2: icmp_req=1256 ttl=64 time=2.47 ms
64 bytes from 10.0.0.2: icmp_req=1257 ttl=64 time=2.20 ms
64 bytes from 10.0.0.2: icmp_req=1258 ttl=64 time=2.05 ms
64 bytes from 10.0.0.2: icmp_req=1259 ttl=64 time=2.26 ms
64 bytes from 10.0.0.2: icmp_req=1260 ttl=64 time=2.12 ms
```

pi@raspberrypi: ~

File Edit Tabs Help

```
64 bytes from 10.0.0.1: icmp_req=1237 ttl=64 time=2.21 ms
64 bytes from 10.0.0.1: icmp_req=1238 ttl=64 time=2.35 ms
64 bytes from 10.0.0.1: icmp_req=1239 ttl=64 time=2.13 ms
64 bytes from 10.0.0.1: icmp_req=1240 ttl=64 time=2.08 ms
64 bytes from 10.0.0.1: icmp_req=1241 ttl=64 time=2.25 ms
64 bytes from 10.0.0.1: icmp_req=1242 ttl=64 time=2.29 ms
64 bytes from 10.0.0.1: icmp_req=1243 ttl=64 time=2.20 ms
64 bytes from 10.0.0.1: icmp_req=1244 ttl=64 time=43.2 ms
64 bytes from 10.0.0.1: icmp_req=1245 ttl=64 time=2.03 ms
64 bytes from 10.0.0.1: icmp_req=1246 ttl=64 time=2.32 ms
64 bytes from 10.0.0.1: icmp_req=1247 ttl=64 time=2.39 ms
64 bytes from 10.0.0.1: icmp_req=1248 ttl=64 time=2.21 ms
64 bytes from 10.0.0.1: icmp_req=1249 ttl=64 time=2.27 ms
64 bytes from 10.0.0.1: icmp_req=1250 ttl=64 time=2.18 ms
64 bytes from 10.0.0.1: icmp_req=1251 ttl=64 time=2.38 ms
64 bytes from 10.0.0.1: icmp_req=1252 ttl=64 time=2.11 ms
64 bytes from 10.0.0.1: icmp_req=1253 ttl=64 time=2.82 ms
64 bytes from 10.0.0.1: icmp_req=1254 ttl=64 time=2.35 ms
64 bytes from 10.0.0.1: icmp_req=1255 ttl=64 time=2.12 ms
64 bytes from 10.0.0.1: icmp_req=1256 ttl=64 time=2.49 ms
64 bytes from 10.0.0.1: icmp_req=1257 ttl=64 time=2.21 ms
64 bytes from 10.0.0.1: icmp_req=1258 ttl=64 time=2.22 ms
64 bytes from 10.0.0.1: icmp_req=1259 ttl=64 time=2.11 ms
```

NAIM

NOX

Mar, 2014

Erica Eun-Jung Lee

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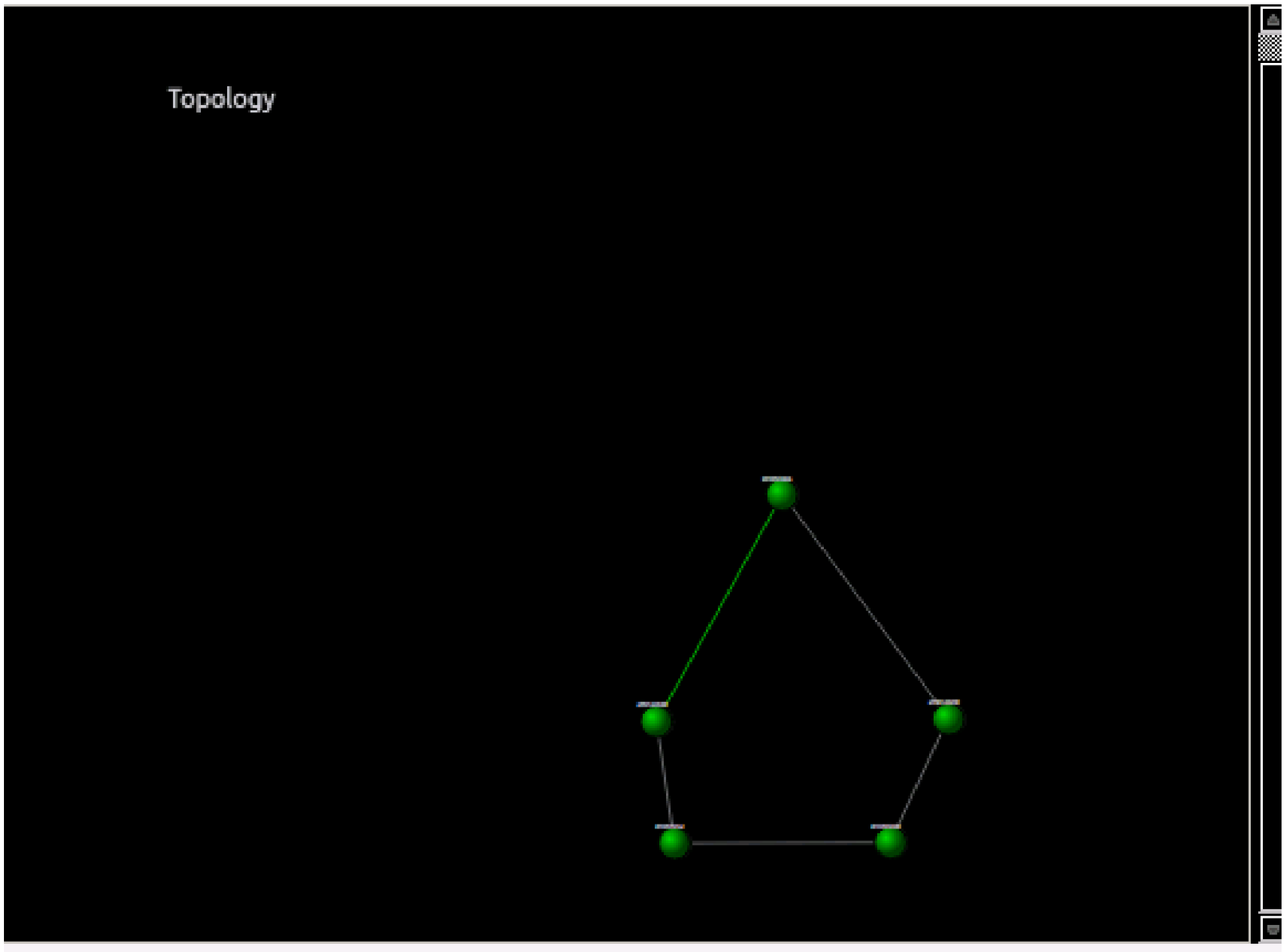
erica@naimnetworks.com

NOX Topology



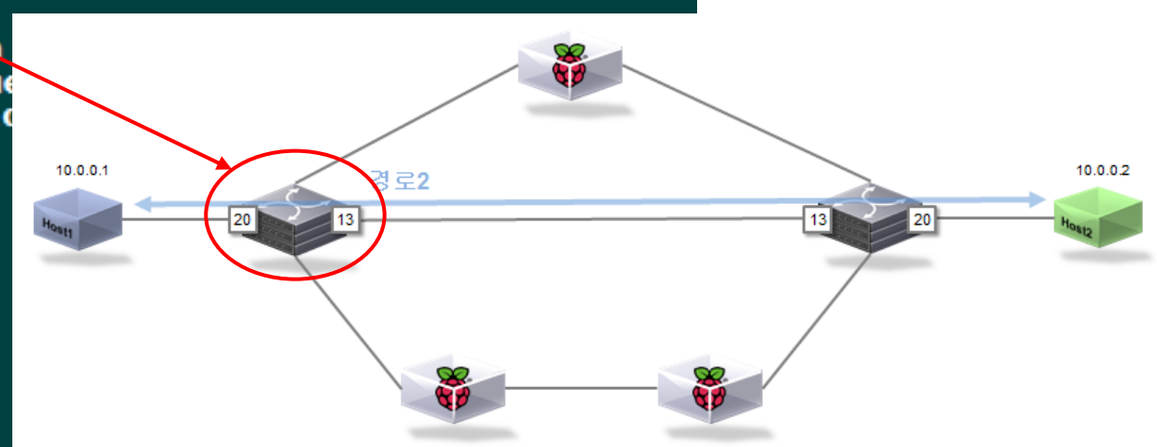
HP Switch1의 Flow Table

```
HPSW1# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 13                          Ethernet Type     : IP
  Source MAC    : b827eb-0d85f8               Destination MAC   : b827eb-1225e1
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.2/32
  Target Protocol Address : 10.0.0.1/32
  IP Protocol   : ICMP                        IP ToS Bits       : 0
  ICMP Type     : 8                           ICMP Code         : 0
 Attributes
  Priority      : 65535                       Duration
  Hard Timeout  : 0 seconds                   Idle Time
  Byte Count    : 0                           Packet Co
  Controller ID : 10                          Cookie
  Flow Location : Hardware
  Hardware Index      : 1
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 20

 Flow 2
 Match
  Incoming Port : 20                          Ethernet Type     : IP
  Source MAC    : b827eb-1225e1               Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                        IP ToS Bits       : 0
  ICMP Type     : 8                           ICMP Code         : 0
 Attributes
  Priority      : 65535                       Duration          : 4 seconds
  Hard Timeout  : 0 seconds                   Idle Timeout      : 5 seconds
  Byte Count    : 0                           Packet Count      : 1
  Controller ID : 10                          Cookie            : 0x59cf59a2b9f248c5
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 13
```



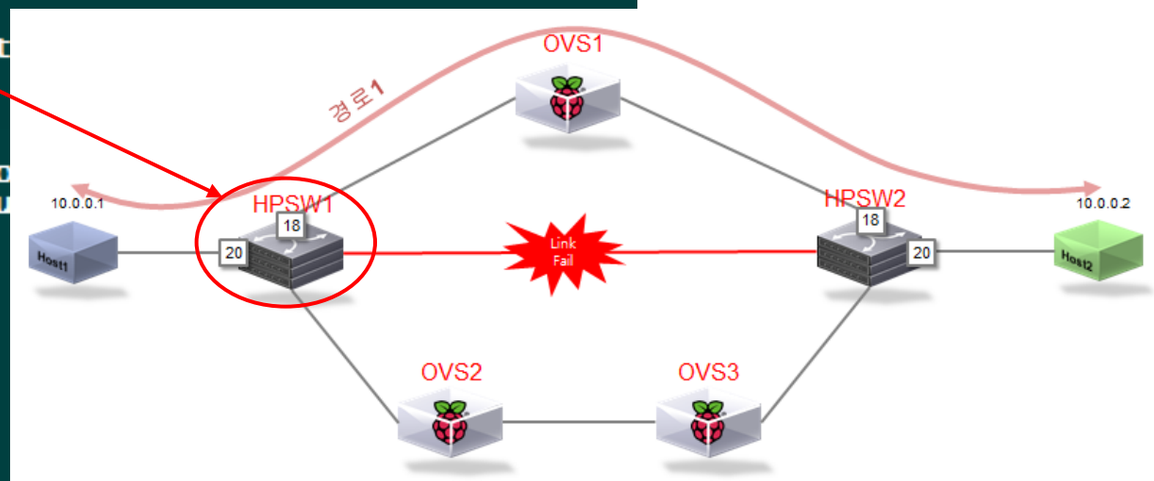
경로2 Fail 시 HP Switch1의 Flow Table

```
HPSW1(config)# int 13
HPSW1(eth-13)# disable
HPSW1(eth-13)# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                      IP ToS Bit
  ICMP Type     : 8                         ICMP Code
 Attributes
  Priority      : 65535                     Duration
  Hard Timeout  : 0 seconds                 Idle Timeo
  Byte Count    : 0                         Packet Cou
  Controller ID : 10                        Cookie
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 18

 Flow 2
 Match
  Incoming Port : 20                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                      IP ToS Bits       : 0
  ICMP Type     : 0                         ICMP Code         : 0
 Attributes
  Priority      : 65535                     Duration          : 3 seconds
  Hard Timeout  : 0 seconds                 Idle Timeout      : 5 seconds
  Byte Count    : 0                         Packet Count      : 1
  Controller ID : 10                        Cookie            : 0x7936dc124f099bf5
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 18
```



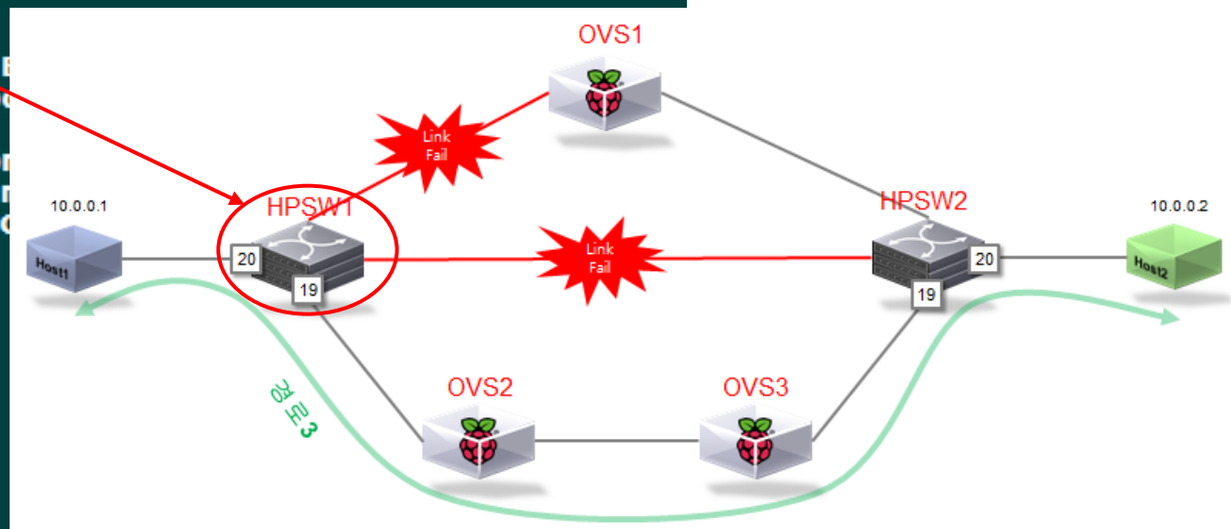
경로1,2 Fail 시 HPSW1의 Flow Table

```
HPSW1(config)# int 18
HPSW1(eth-18)# disable
HPSW1(eth-18)# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                          Ethernet Type     : IP
  Source MAC    : b827eb-1225e1               Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                        IP ToS
  ICMP Type     : 8                           ICMP Co
 Attributes
  Priority      : 65535                       Duratio
  Hard Timeout  : 0 seconds                   Idle Ti
  Byte Count    : 0                           Packet
  Controller ID : 10                          Cookie
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 19

 Flow 2
 Match
  Incoming Port : 20                          Ethernet Type     : IP
  Source MAC    : b827eb-1225e1               Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                        IP ToS Bits       : 0
  ICMP Type     : 0                           ICMP Code         : 0
 Attributes
  Priority      : 65535                       Duration          : 0 seconds
  Hard Timeout  : 0 seconds                   Idle Timeout      : 5 seconds
  Byte Count    : 0                           Packet Count      : 1
  Controller ID : 10                          Cookie            : 0x7936dc124f099bf5
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 19
```



NAIM

OpenDaylight Hydrogen

Mar, 2014

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OpenDaylight Hydrogen Topology

OPENDAYLIGHT Devices Flows Troubleshoot admin

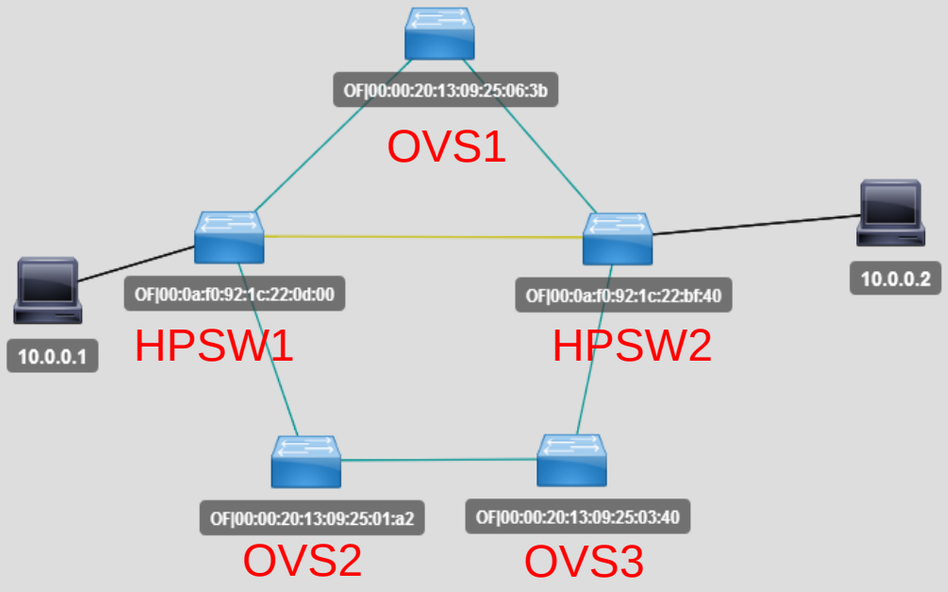
Existing Nodes

Existing Nodes

Search

Name	Node ID	Statistics
None	OF|00:0a:f0:92:1c:22:0d:00	Flows Ports
None	OF|00:00:20:13:09:25:06:3b	Flows Ports
None	OF|00:0a:f0:92:1c:22:bf:40	Flows Ports
None	OF|00:00:20:13:09:25:03:40	Flows Ports
None	OF|00:00:20:13:09:25:01:a2	Flows Ports

1-5 of 5 items Page 1 of 1



Uptime

Uptime

Search

Node	Node ID	Statistics
None	OF|00:0a:f0:92:1c:22:0d:00	Mon Feb 17 15:45:37 KST 2014
None	OF|00:00:20:13:09:25:06:3b	Mon Feb 17 15:38:37 KST 2014
None	OF|00:0a:f0:92:1c:22:bf:40	Mon Feb 17 15:45:45 KST 2014
None	OF|00:00:20:13:09:25:03:40	Mon Feb 17 15:38:37 KST 2014
None	OF|00:00:20:13:09:25:01:a2	Mon Feb 17 15:38:37 KST 2014

1-5 of 5 items Page 1 of 1

Flows

Flow Details

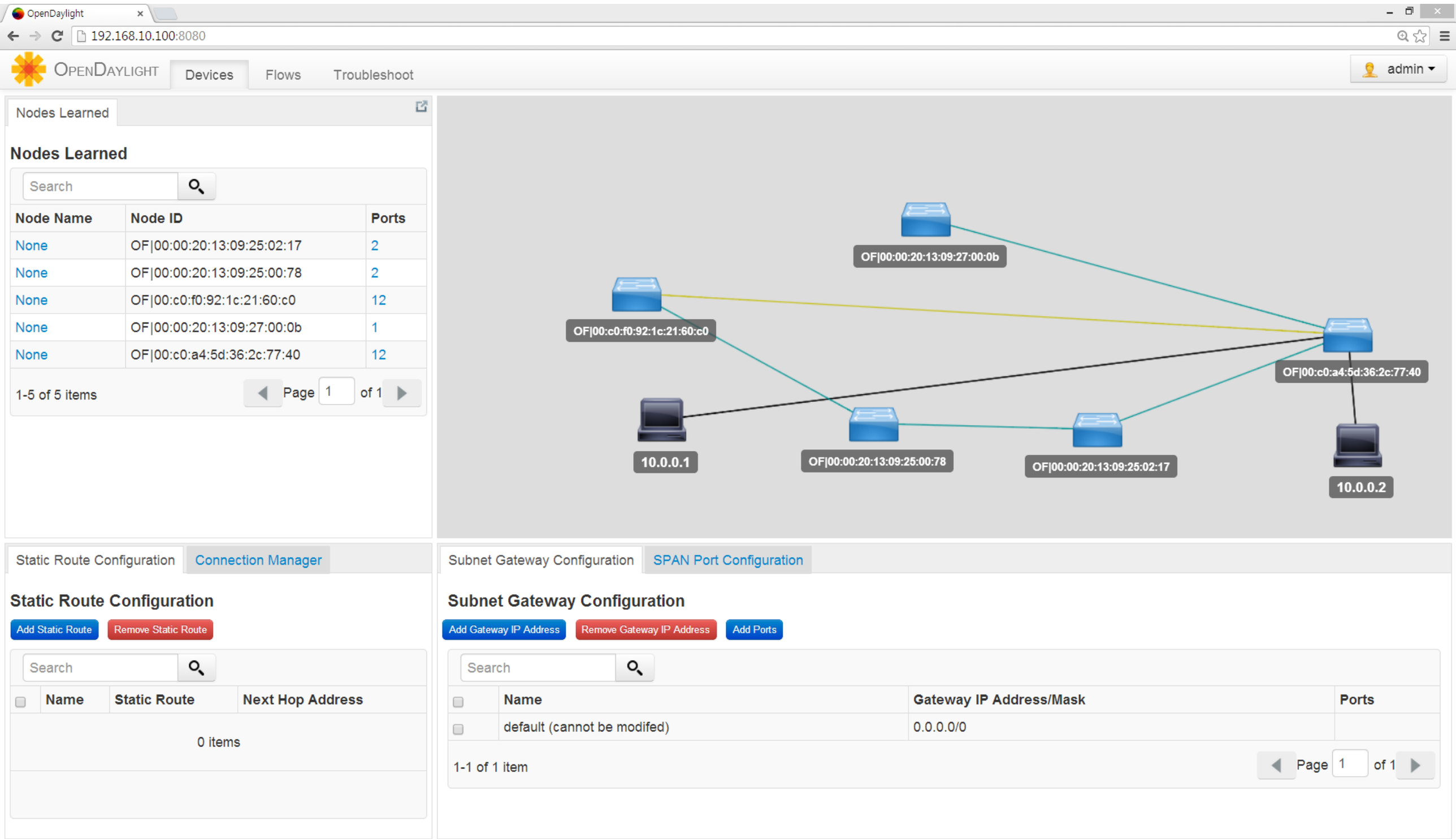
Refresh

Search

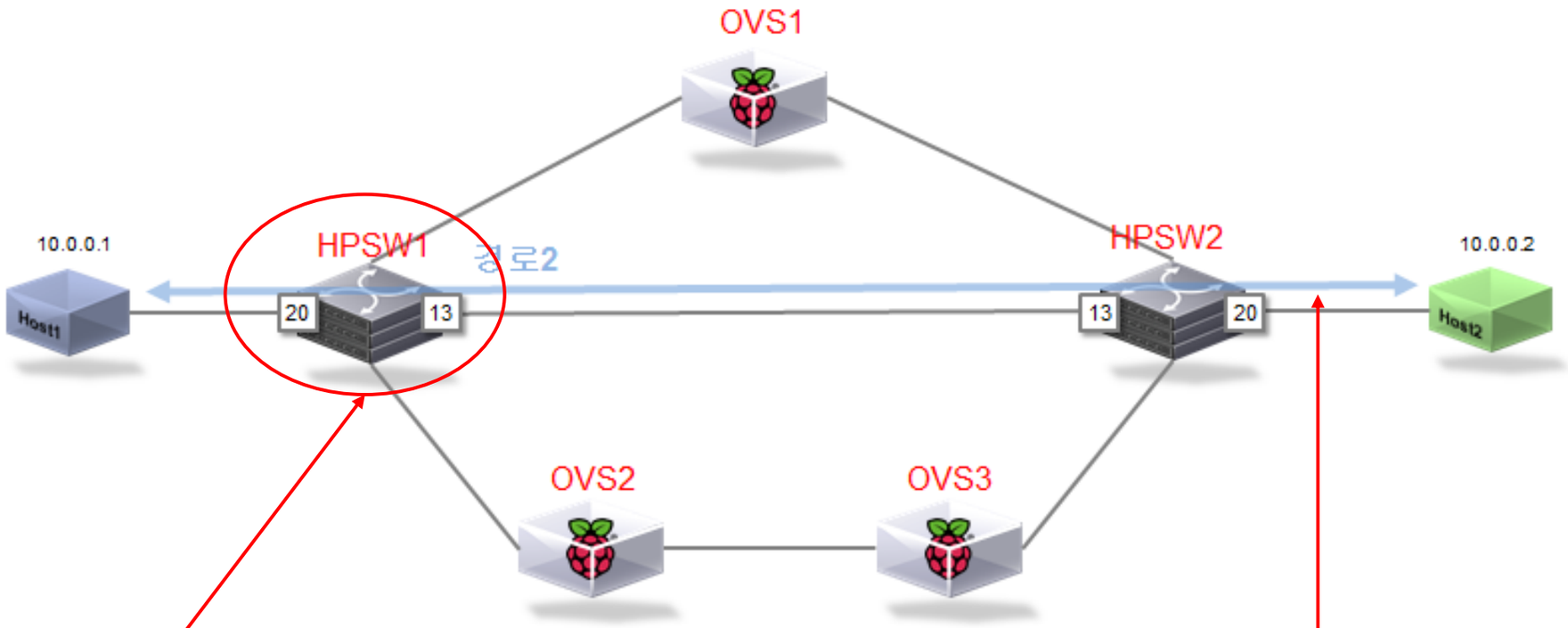
Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:00:20:13:09:25:01:a2	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|3	0	0	29	0	1
OF|00:00:20:13:09:25:01:a2	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	OUTPUT = OF|3	0	0	29	0	1

1-2 of 2 items Page 1 of 1

ODL Hydrogen Topology Bug



OpenDaylight Hydrogen Flow Table



Flows

Flow Details

Refresh

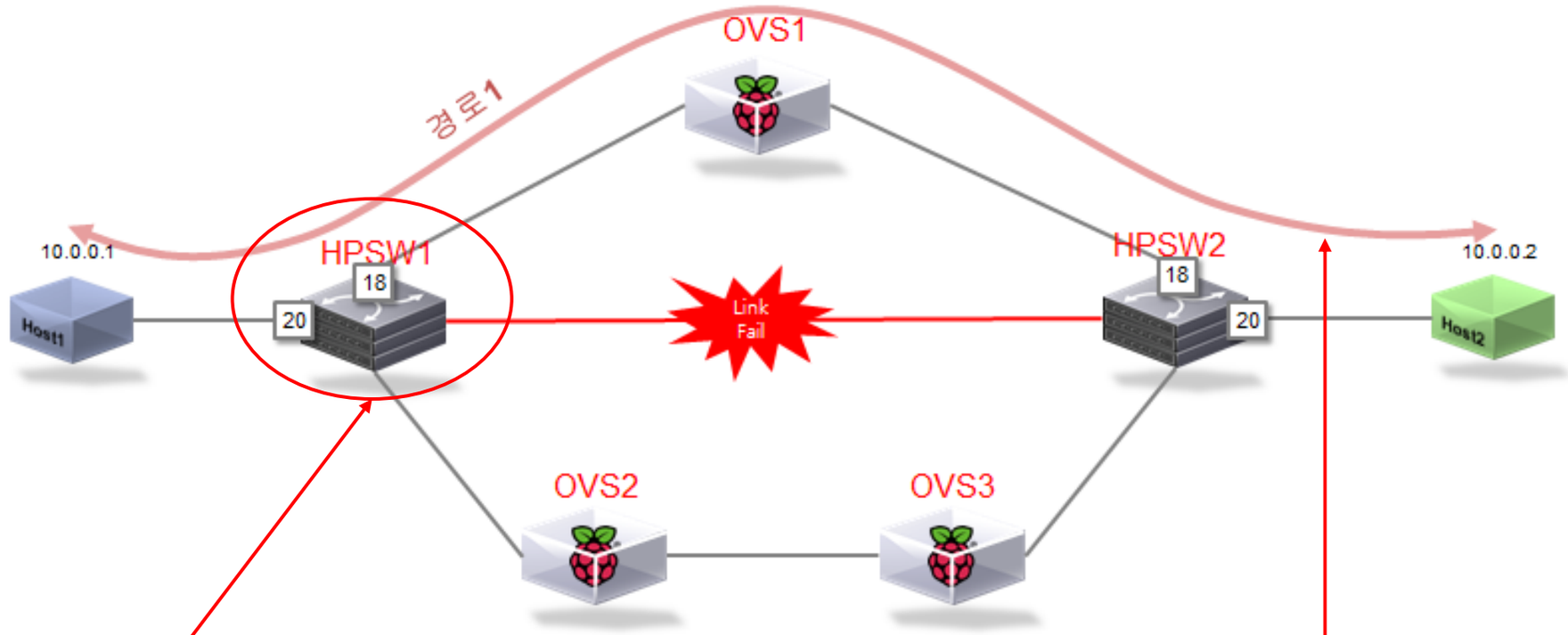
Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	SET_DL_DST = b8:27:eb:12:25:e1 OUTPUT = OF|20	0	142	86	0	1
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|13	0	142	86	0	1

1-2 of 2 items

Page 1 of 1

경로2 Fail 시 ODL Flow Table



Flows

Flow Details

Refresh

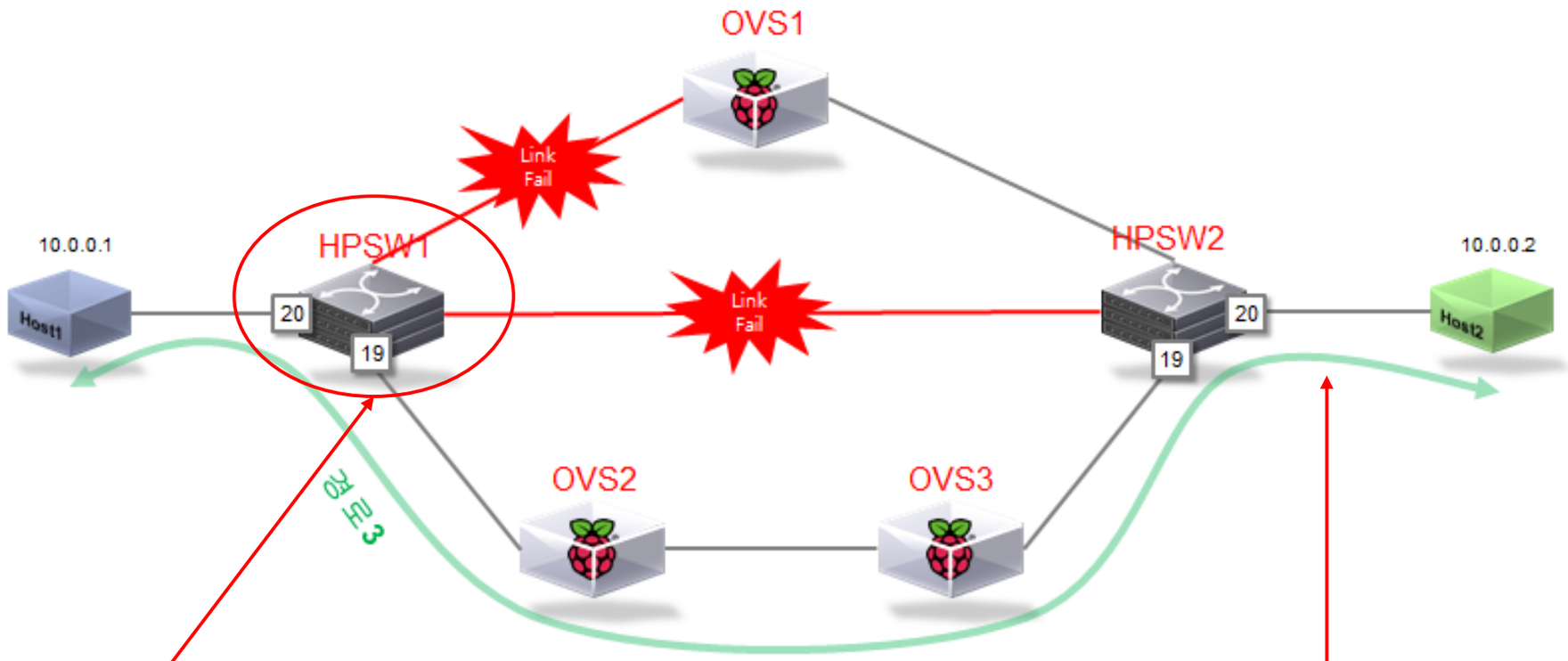
Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	SET_DL_DST = b8:27:eb:12:25:e1 OUTPUT = OF|20	0	382	196	0	1
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|18	0	8	196	0	1

1-2 of 2 items

Page 1 of 1

경로1,2 Fail 시 ODL Flow Table



Flows

Flow Details

Refresh

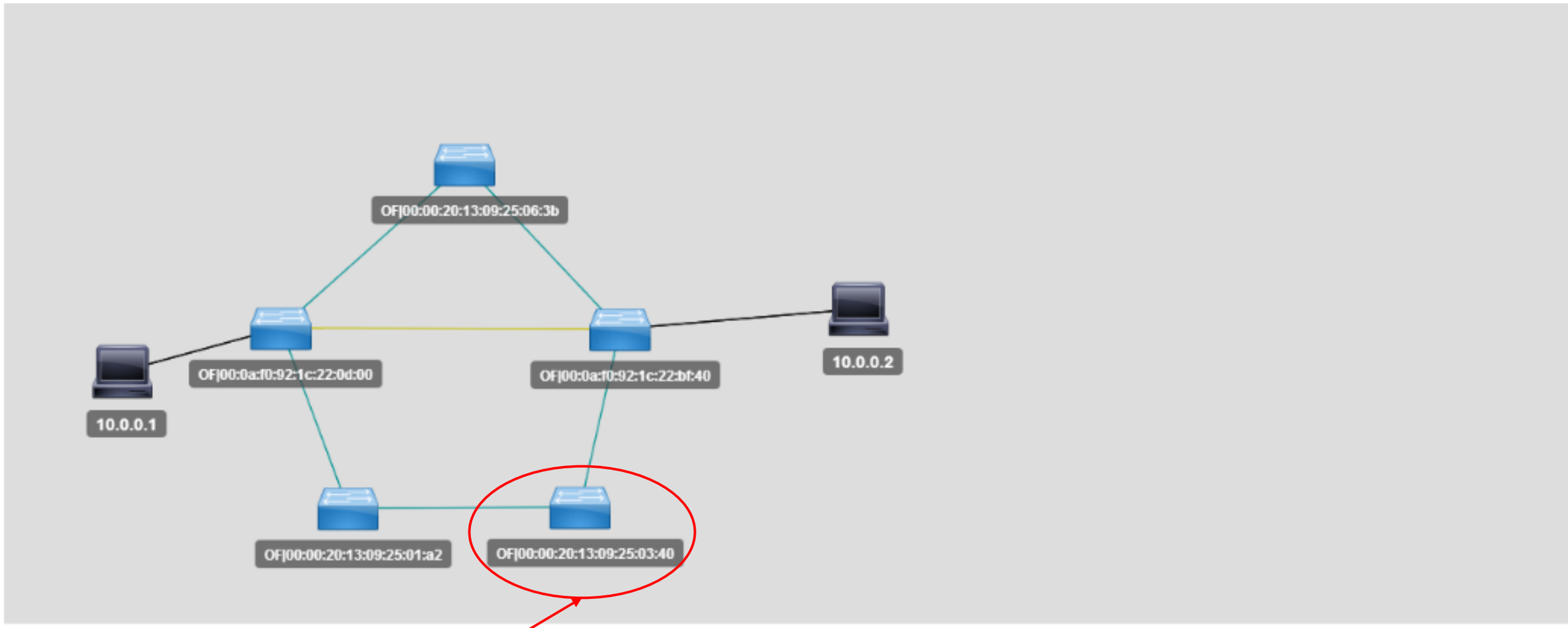
Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	SET_DL_DST = b8:27:eb:12:25:e1 OUTPUT = OF|20	0	742	386	0	1
OF|00:0a:f0:92:1c:22:0d:00	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|19	0	2	386	0	1

1-2 of 2 items

Page 1 of 1

OpenDaylight Hydrogen Flow Table



Flows

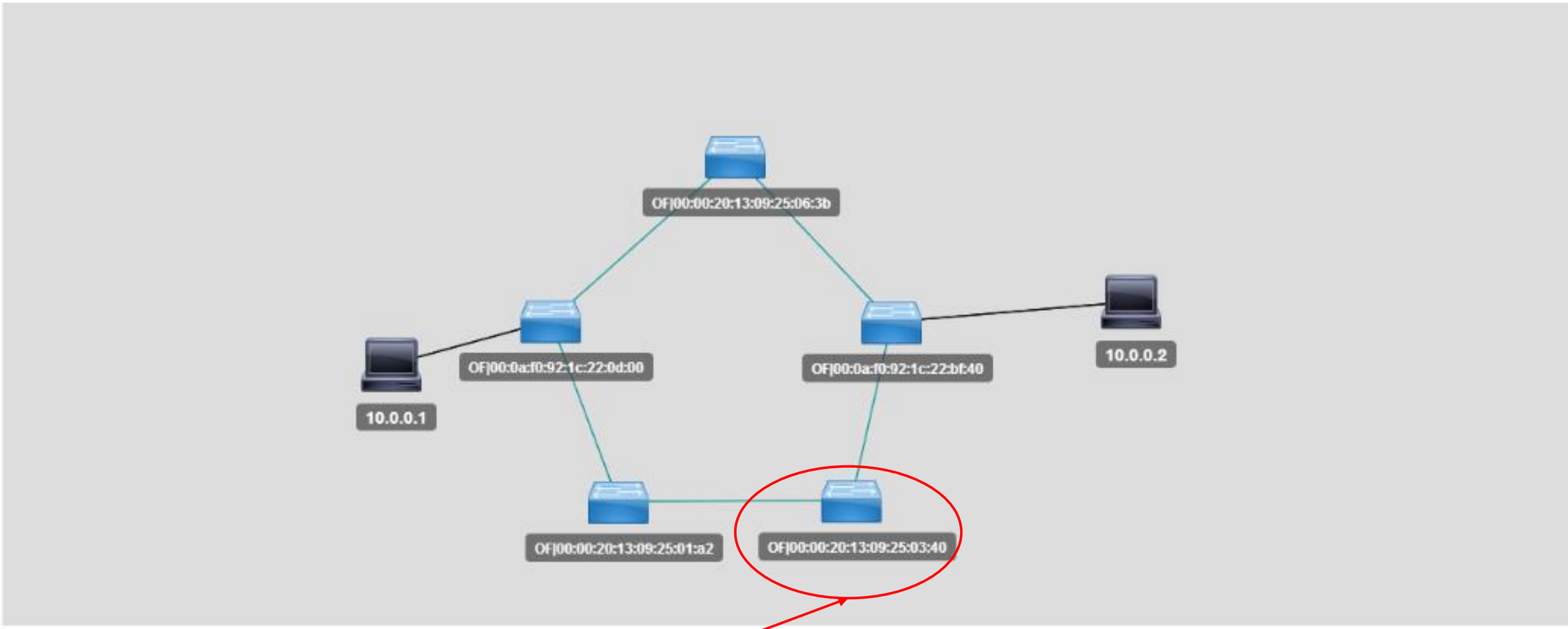
Flow Details

Refresh

Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|1	0	0	110	0	1
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	OUTPUT = OF|3	0	0	110	0	1

OpenDaylight Hydrogen Flow Table



Flows

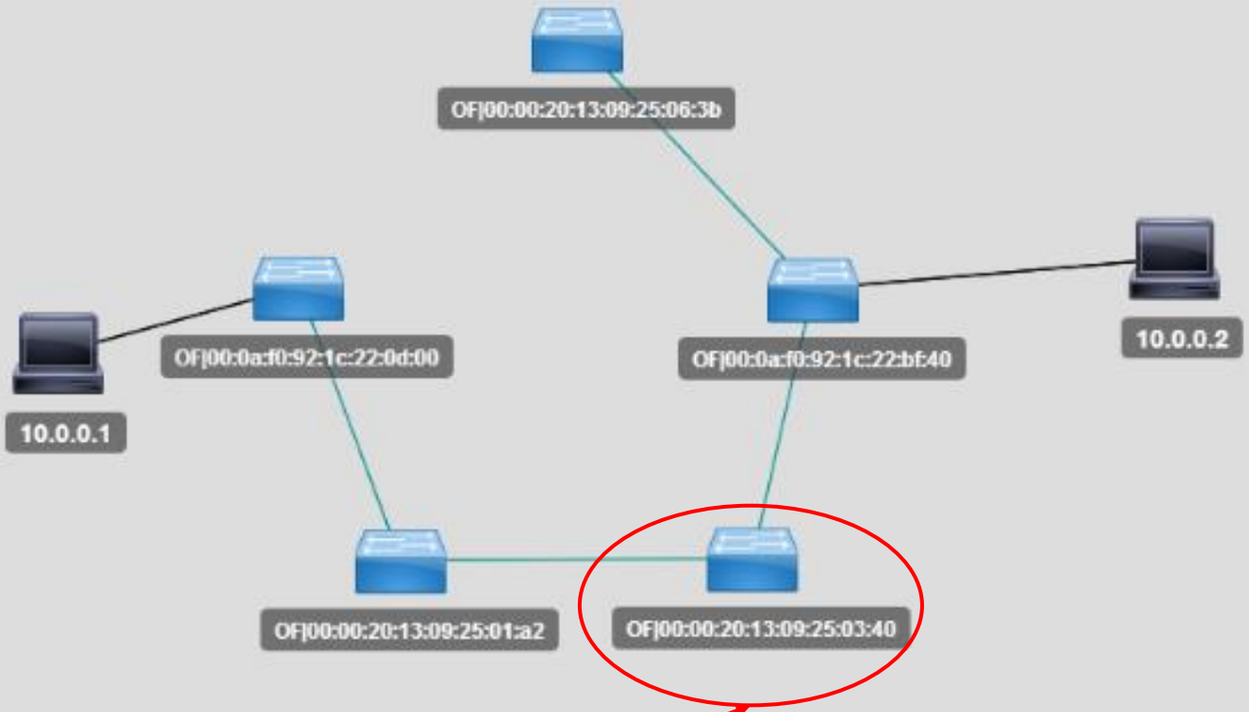
Flow Details

Refresh

Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|1	0	0	240	0	1
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	OUTPUT = OF|3	0	0	240	0	1

OpenDaylight Hydrogen Flow Table



Flows

Flow Details

Refresh

Search

Node	In Port	DL Src	DL Dst	DL Type	DL Vlan	NW Src	NW Dst	NW Proto	TP Src	TP Dst	Actions	Byte Count	Packet Count	Duration Seconds	Idle Timeout	Priority
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.2	*	*	*	OUTPUT = OF|1	11564	118	430	0	1
OF|00:00:20:13:09:25:03:40	*	*	*	IPv4	*	*	10.0.0.1	*	*	*	OUTPUT = OF|3	11564	118	430	0	1

NAIM

POX

Mar, 2014

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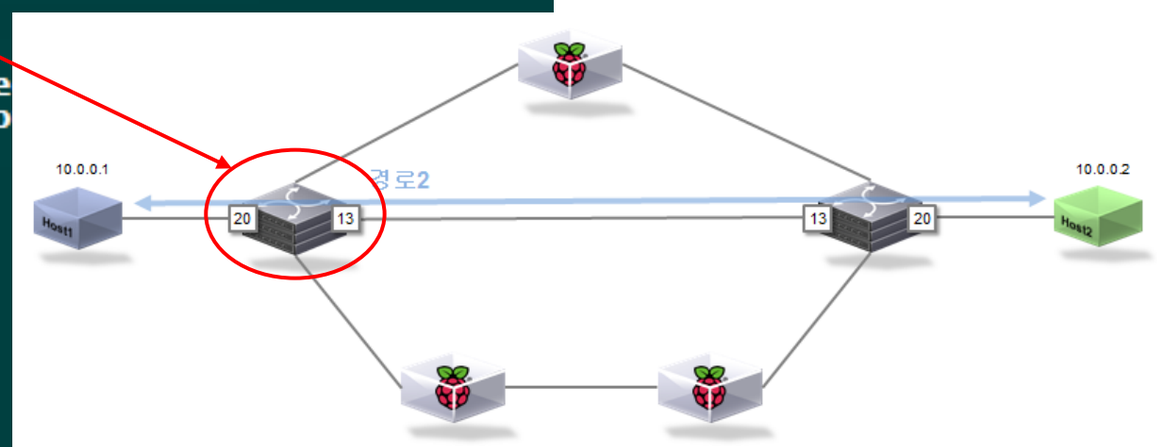
HP Switch1의 Flow Table

```
HPSW1# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                      IP ToS Bits       : 0
  ICMP Type     : 0                         ICMP Code         : 0
 Attributes
  Priority      : 65535                     Duration
  Hard Timeout  : 30 seconds                Idle Time
  Byte Count    : 0                         Packet Co
  Controller ID : 10                        Cookie
  Flow Location : Hardware
  Hardware Index      : 1
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 13

 Flow 2
 Match
  Incoming Port : 13                        Ethernet Type     : IP
  Source MAC    : b827eb-0d85f8             Destination MAC   : b827eb-1225e1
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.2/32
  Target Protocol Address : 10.0.0.1/32
  IP Protocol   : ICMP                      IP ToS Bits       : 0
  ICMP Type     : 8                         ICMP Code         : 0
 Attributes
  Priority      : 65535                     Duration          : 8 seconds
  Hard Timeout  : 30 seconds                Idle Timeout      : 10 seconds
  Byte Count    : 0                         Packet Count      : 1
  Controller ID : 10                        Cookie            : 0x0
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 20
```



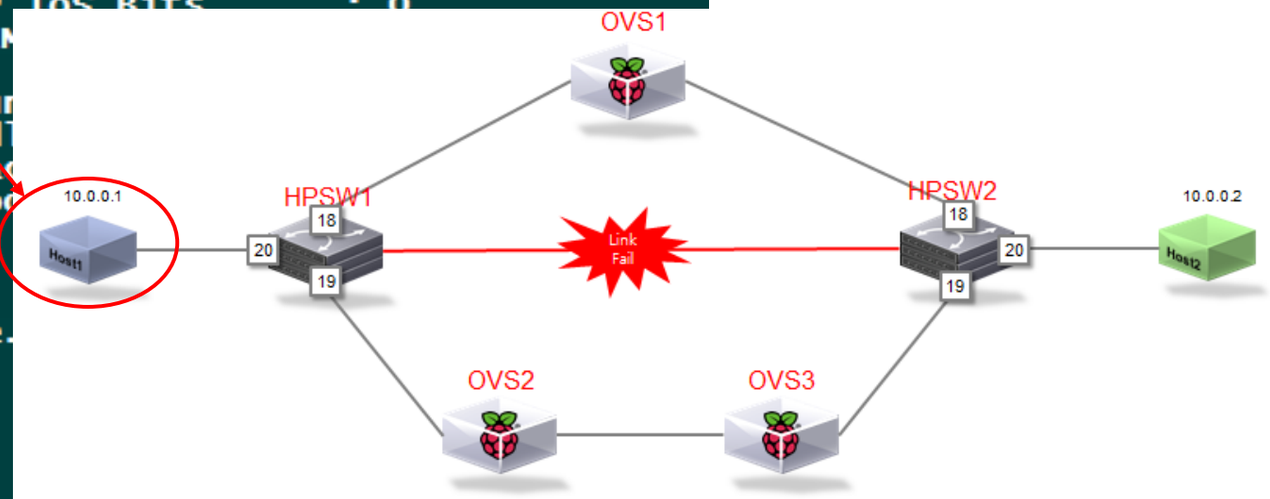
경로2 Fail 시 HP Switch1의 Flow Table

```
HPSW1(eth-13)# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 18                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                      IP ToS Bits       : 0
  ICMP Type     : 8                         ICM
 Attributes
  Priority      : 65535                     Dur
  Hard Timeout  : 30 seconds                Idl
  Byte Count    : 0                         Pac
  Controller ID : 10                        Coo
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 19

 Flow 2
 Match
  Incoming Port : 18                        Ethernet Type     : IP
  Source MAC    : b827eb-1225e1             Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                         VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                      IP ToS Bits       : 0
  ICMP Type     : 0                         ICMP Code         : 0
 Attributes
  Priority      : 65535                     Duration          : 6 seconds
  Hard Timeout  : 30 seconds                Idle Timeout      : 10 seconds
  Byte Count    : 0                         Packet Count      : 1
  Controller ID : 10                        Cookie            : 0x0
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                  : 19
```



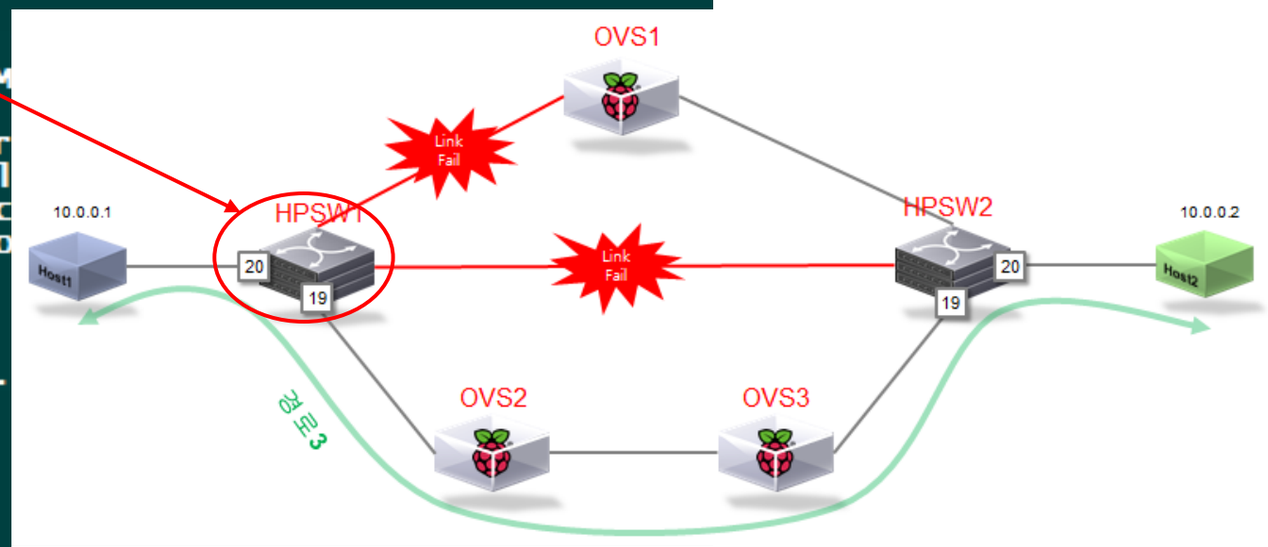
경로1,2 Fail 시 HPSW1의 Flow Table

```
HPSW1# sh openflow instance test flows

 OpenFlow Flow Table

 Flow 1
 Match
  Incoming Port : 20                          Ethernet Type     : IP
  Source MAC    : b827eb-1225e1               Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                        IP
  ICMP Type     : 0                           ICM
 Attributes
  Priority      : 65535                       Dur
  Hard Timeout  : 30 seconds                  Idl
  Byte Count    : 0                           Pac
  Controller ID : 10                          Coo
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 19

 Flow 2
 Match
  Incoming Port : 20                          Ethernet Type     : IP
  Source MAC    : b827eb-1225e1               Destination MAC   : b827eb-0d85f8
  VLAN ID       : 0                           VLAN Priority     : 0
  Source Protocol Address : 10.0.0.1/32
  Target Protocol Address : 10.0.0.2/32
  IP Protocol   : ICMP                        IP ToS Bits       : 0
  ICMP Type     : 8                           ICMP Code         : 0
 Attributes
  Priority      : 65535                       Duration          : 12 seconds
  Hard Timeout  : 30 seconds                  Idle Timeout      : 10 seconds
  Byte Count    : 0                           Packet Count      : 8
  Controller ID : 10                          Cookie            : 0x0
  Flow Location : Hardware
  Hardware Index      : 2
  Reason Code         : 12
  Reason Description : Rule is in hardware.
 Actions
    Output                    : 19
```



NAIM

Controller의 Flow Control 분석

Mar, 2014

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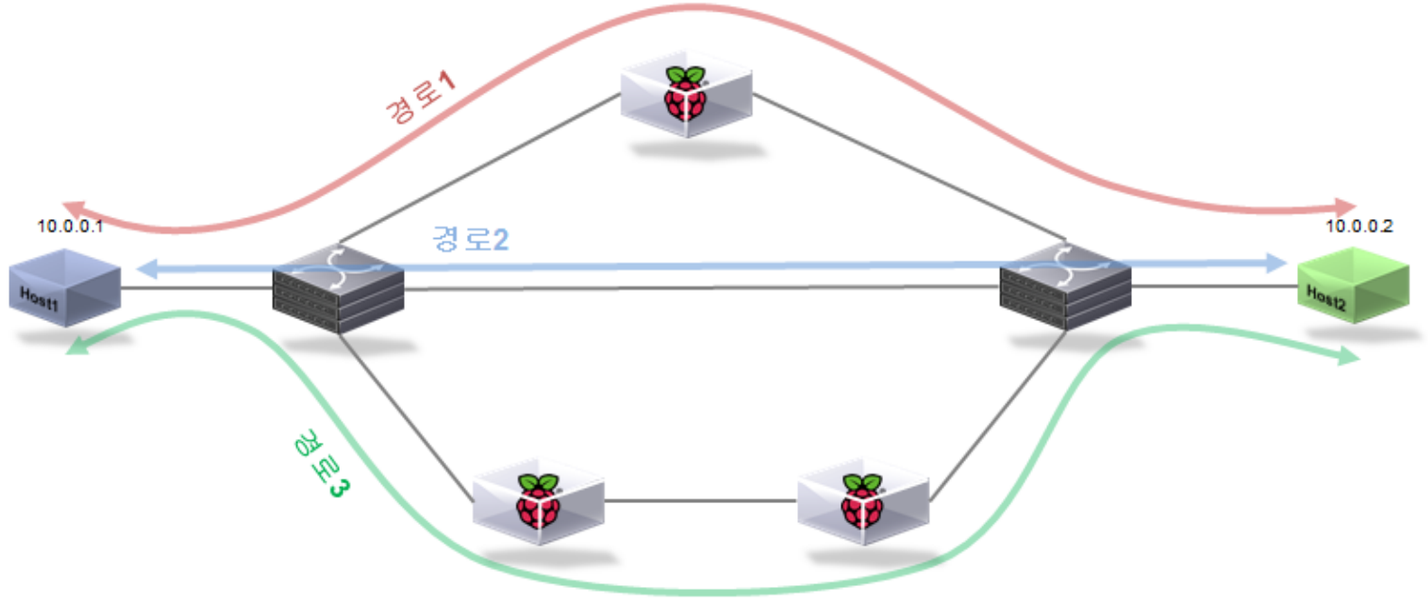
Controller의 Flow Control 분석



	FL	HP	OpenIRIS	Mul	NOX	ODL	POX
GUI	O	O	O	X	O(최소 정보 제공)	O(일부 버그)	X
최적 경로	경로2	경로2	경로3	-	경로2	경로2	경로2
기본 Flow Match field	in-port MAC	in-port eth_type MAC	in-port MAC	D-MAC	in-port eth_type MAC, IP Protocol	eth_type D-IP	in-port eth_type MAC, IP Protocol
HP Switch의 기본 Flow 처리	Software	Hardware	Software	Software	Hardwrare	Hardware	Hardware
Failover	수동(Reboot)	자동	수동(Reboot)	-	자동	자동	-
Failover Time	-	Fast	-	-	Normal	Fast	-
경로 재계산	Reboot 필요	일부 버그 경로 발생	Reboot 필요 일부 loop 발생	단일 경로만 통신 가능	O	O	단일 경로만 통신 가능

Thank you very much