### Hands-on Workshop on Open vSwitch and Software-defined Networking

Ali AlSabeh, Jorge Crichigno University of South Carolina http://ce.sc.edu/cyberinfra aalsabeh@email.sc.edu, jcrichigno@cec.sc.edu

WASTC 2021 virtual Faculty Development Weeks (vFDW) June 23, 2021



### Lab 6: Introduction to OpenFlow



# Lab 6: Introduction to OpenFlow

- The topology consists of an ONOS controller, an OVS device, and hosts h1 and h2
- The OVS switch is administered using the ovs-ofctl command line utility
- The lab demonstrates how to inspect OpenFlow messages exchanged between the ONOS controller and the OVS switch



# Adding Entries in the Flow Table

#### Adding flows to forward traffic from host h1 to host h2

5				root@admin: /ho	me/sdn
File	Actions	Edit	View	Help	
		г	oot@ad	min: /home/sdn 🛛 🖗	
root( root(	∂admin:/ ∂admin:/	/home /home	/sdn# /sdn#	ovs-ofctl add-flow s1 in_po	ort=1,actions=output:2

#### Adding flows to forward traffic from host h2 to host h1

I	• root@admin: /ho							n: /hom	e/sdn
	File	Actions	Edit	View	Help				
	root@admin: /home/sdn 🛛 🛞							$\otimes$	
٢	oot@	@admin:	/home	/sdn#	ovs-ofctl	add-flow	s1 i	in_por	t=1,actions=output:2
٢	oot@	@admin:	/home	/sdn#	<u>o</u> vs-ofctl	add-flow	s1 i	in_por	t=2,actions=output:1
٢	oot@	@admin:	/home	/sdn#					



## Capturing OpenFlow Messages

6	*Loopback: lo – ک ×									
File	e <u>E</u> dit <u>V</u> iew <u>G</u> o	<u>Capture</u> <u>A</u> nalyze	Statistics Telephony M	<u>(</u> ireless <u>T</u> ools <u>H</u> elp						
	🔳 🙇 🔘		। ९ 🗢 🏓 🖀 🗿	ें 🛓 📃 📃 🔍 २						
	openflow_v1			×	Expression +					
No.	Time	Source	Destination	Protocol Length Info	A					
	1277 3349,90786 1277 3340,00331 1279 3340,40852 1281 3340,42733 1283 3340,42741 1284 3340,42742 1286 3340,4322	127.0.0.1 78 127.0.0.1 41 127.0.0.1 41 127.0.0.1 19 127.0.0.1 39 127.0.0.1 96. 127.0.0.1	127.0.0.1 $127.0.0.1$ $127.0.0.1$ $127.0.0.1$ $127.0.0.1$ $127.0.0.1$ $127.0.0.1$	OpenF1         74         Type: 0           OpenF1         82         Type: 0           OpenF1         242         Type: 0           OpenF1         82         Type: 0           OpenF1         82         Type: 0           OpenF1         74         Type: 0           OpenF1         74         Type: 0           OpenF1         74         Type: 0           OpenF1         78         Type: 0	FPT_HELLO FPT_FEATURES_REPLY FPT_GET_CONFIG_REQUEST FPT_BARRIER_REPLY FPT_GET_CONFIG_REPLY FPT_GET_CONFIG_REPLY FPT_STATS_REQUEST					
4	1287 3340.43328	10 127.0.0.1	127.0.0.1	OpenF1 1134 Type: 0	FPT STATS REPLY					

0	penflow_v1					Expression	on +
No.	Time	Source	Destination	Protocol	Length Info		-
T	73 26.013171130	127.0.0.1	127.0.0.1	OpenF1	78 Type: OFP1	STATS REQUEST	
	74 26.013585493	127.0.0.1	127.0.0.1	OpenF1	16334 Type: OFP1	STATS REPLY	
1	76 26.402409764	e2:7d:8b:63:cf:59	Broadcast	OpenF1	126 Type: OFPT	F PACKET IN	
1	78 26.415998945	e2:7d:8b:63:cf:59	Broadcast	OpenF1	132 Type: OFPT	F PACKET OUT	
1	79 26.416212343	22:66:a9:a9:88:53	e2:7d:8b:63:cf:59	OpenF1	126 Type: OFP	PACKET IN	
1	80 26.417154061	22:66:a9:a9:88:53	e2:7d:8b:63:cf:59	OpenF1	132 Type: OFPT	F PACKET OUT	
1	81 26.417323024	10.0.0.1	10.0.0.2	OpenF1	182 Type: OFPT	F PACKET IN	
L.	82 26.421687260	10.0.0.1	10.0.0.2	OpenF1	188 Type: OFPT	PACKET_OUT	
4							



### Lab 8: Interconnection between legacy networks and SDN networks



# Lab 8: Interconnecting Legacy and SDN networks

- Two legacy networks connected to an SDN network
- The SDN network consists of switches controlled by an ONOS controller
- The ONOS controller interacts with an application referred to as SDN-IP
- SDN-IP allows the SDN network to i) exchange BGP information with an iBGP router; and ii) translates routing information to SDN flow rules



# Configuring BGP in Legacy Networks

#### Router r2



Hello, this is FRRouting (version 7.2-dev). Copyright 1996-2005 Kunihiro Ishiguro, et al.

admin# configure terminal admin(config)# router bgp 300 admin(config-router)# neighbor 192.168.13.1 remote-as 100 admin(config-router)# network 192.168.3.0/24 admin(config-router)# end admin#





# Configure BGP in SDN Network

Router r1					
X	"Host: r1"				
root@admin:/etc/router root@admin:/etc/router	s/rl# bgpd s/rl# vtysh				
Hello, this is FRRouti Copyright 1996-2005 Ku	ng (version 7.2-dev). nihiro Ishiguro, et al.				
admin# configure termi admin(config)# router	nal j bop 100				
admin(config-router)#	neighbor 192.168.12.2 remote-as	200			
admin(config-router)# admin(config-router)# admin(config-router)# admin(config-router)#	neighbor 192.168.13.2 remote-as neighbor 10.0.0.3 remote-as 100 neighbor 10.0.0.3 port 2000	300			



# **SDN-IP** Application

#### ONOS CLI – BGP neighbors

50 C			r	oot@admin: /home/sdn	/SDN_Labs/lab8	- 0 :
File	Actions	Edit	View	Help		
	ro	ot@ad	min: /ho	me/sdn/SDN_Labs/lab8	8	
GP ( Ref I tin Ref I tin Ref Ref I tin Ref I tin Ref Ref Tin Ref I tin Ref I tin Ref I tin Ref I tin Ref I tin Ref I	f@root neighbo mote ro me 180 mote AF NO cal ro 0 cal AF NO Octet A f@root	> bgp r is uter I/SAF uter I/SAF S Cap >	<u>-neigh</u> 192.10 ID 192 I IPv4 ID 10 I IPv4 abilit	bors 58.13.1, remote AS 2.168.13.1, IP /10.1 4 Unicast YES Multi .0.0.3 IP /10.0.0.1 4 Unicast YES Multi ty: Advertised Rece	100 local AS 100 0.0.1:48998, BGP v cast NO, IPv6 Unic 3:2000, BGP versio cast NO, IPv6 Unic ived	14:58:58 ersion 4, Hol ast NO Multic n 4, Hold tim ast NO Multic 14:59:00



## **SDN-IP** Application

#### ONOS CLI – advertised routes







## **SDN Network**

#### BGP table of router r1

X .	"Host: r1"	- 0 :
admin#	show ip route	
Codes:	K - kernel route, C - connected, S - static, R - RIP,	
	0 - OSPF, I - IS-IS, B - BGP, E - EIGRP, N - NHRP,	
	T - Table, v - VNC, V - VNC-Direct, A - Babel, D - SHARP,	
	F - PBR, f - OpenFabric,	
	> - selected route, * - FIB route, q - queued route, r - rejected	ed rou
e		
and the second date		
C>* 10	.0.0.0/24 is directly connected, r1-eth1, 00:29:16	
B>* 19	2.168.2.0/24 [20/0] via 192.168.12.2, r1-eth0, 00:06:57	
B>* 19	2.168.3.0/24 [20/0] via 192.168.13.2, r1-eth0, 00:06:56	
C>* 19	2.168.12.0/30 is directly connected, r1-eth0, 00:38:20	
C>* 19	2.168.13.0/30 is directly connected, r1-eth0, 00:38:20	
admin#		



### Flow Table of Switch s2 – BGP Advertisements

#### BGP advertisements between router r2 and router r1

					root@admi	n: /home/sdn/Sl	DN_Labs/lab8				- 5 ×
File	Actions	Edit	View	Help							
			Sh	ell No. 1	$\otimes$	root@admin:	/home/sdn/SDN_Labs/la	ab8	$\otimes$		
i nospr P_DST atTri	d=be000 oject.r :179], ger=nu	0456 net.i trea ull, u	03ee8, ntent, tment= metada	state=ADDED, selector=[IN DefaultTraffi ta=null}	bytes=0, packets=0, c _PORT:1, ETH_TYPE:ipv4 cTreatment{immediate=[	duration=160, 4, IP_PROTO:6 [OUTPUT:2], d	liveType=UNKNOWN , IPV4_SRC:192.168 eferred=[], transi	, priority= 8.12.2/32, ition=None,	1000, table] IPV4_DST:192 meter=[], c	[d=0, appId= 2.168.12.1/3 cleared=fals	org.o 2, TC e, St
i onos TCP_S StatT	d=be000 project RC:179] rigger	)0554 .net  , tr	f4e97, .inten eatmen . meta	state=ADDED, t, selector=[ t=DefaultTraf data=null}	<pre>bytes=236, packets=3, IN_PORT:1, ETH_TYPE:ip ficTreatment{immediate</pre>	, duration=16 ov4, IP_PROTO e=[OUTPUT:2],	0, liveType=UNKNON :6, IPV4_SRC:192.1 deferred=[], tran	WN, priorit 168.12.2/32 nsition=Nor	y=1000, tab] , IPV4_DST:1 e, meter=[],	leId=0, appI 192.168.12.1 , cleared=fa	d=org /32, lse,
inospro reatmo l, me	d=be000 oject.r ent=Def tadata=	05a9 net.i ault null	47c9e, ntent, Traffi }	state=ADDED, selector=[IN cTreatment{im	bytes=0, packets=0, c _PORT:1, ETH_TYPE:ipv4 mediate=[OUTPUT:2], de	duration=160, 4, IP_PROTO:1 eferred=[], t	liveType=UNKNOWN , IPV4_SRC:192.168 ransition=None, me	, priority= 8.12.2/32, eter=[], cl	1000, table] IPV4_DST:192 eared=false,	[d=0, appId= 2.168.12.1/3 , StatTrigge	org.o 2], t r=nul
i onos TCP D	d=be000 project	08d1	075d7, .inten eatmen	state=ADDED, t, selector=[ t=DefaultTraf	<pre>bytes=302, packets=4, IN_PORT:2, ETH_TYPE:ip ficTreatment{immediate</pre>	, duration=16 ov4, IP_PROTO >=[OUTPUT:1]	0, liveType=UNKNON :6, IPV4_SRC:192.1 deferred=[], trai	WN, priorit 168.12.1/32 psition=Nor	y=1000, tabl , IPV4_DST:1 e. meter=[]	leId=0, appI 192.168.12.2 	d=org /32, lse.



tatTrigger=null, metadata=null}

### Flow Table of Switch s1 – BGP Advertisements

#### BGP advertisements between router r2 and router r1

M.	root@admin: /l	nome/sdn/SDN_Labs/lab8 – v ×
File Actions Edit View	Help	
S	hell No. 1 🛞	root@admin: /home/sdn/SDN_Labs/lab8 🚳
id=be00004efa1d57 onosproject.net.inteni CP_DST:179], treatmeni tatTrigger=null, metad org.onosproject.net.iu 2, TCP_DST:179], treai e, StatTrigger=null, r id=be00008c740563 org.onosproject.net.iu 2, TCP_DST:179], treai e, StatTrigger=null, r	<pre>, state=ADDED, bytes=0, packets=0, dura t, selector=[IN_PORT:3, ETH_TYPE:ipv4, t=DefaultTrafficTreatment{immediate=[0l data=null} , state=ADDED, bytes=4077, packets=54, ntent, selector=[IN_PORT:2, ETH_TYPE:it ment=DefaultTrafficTreatment{immediate metadata=null} , state=ADDED, bytes=4077, packets=54, ntent, selector=[IN_PORT:1, ETH_TYPE:it ment=DefaultTrafficTreatment{immediate metadata=null}</pre>	<pre>ation=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId=org. IP_PROTO:6, IPV4_SRC:192.168.12.2/32, IPV4_DST:192.168.12.1/32, T JTPUT:1], deferred=[], transition=None, meter=[], cleared=false, S duration=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId= ov4, IP_PROTO:6, IPV4_SRC:192.168.13.2/32, IPV4_DST:192.168.13.1/3 e=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=fals duration=1620, liveType=UNKNOWN, priority=1000, tableId=0, appId= ov4, IP_PROTO:6, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12.2/3 e=[OUTPUT:3], deferred=[], transition=None, meter=[], cleared=fals</pre>



## Flow Table of Switch s2 – Entry for Network 3

#### Flow entry that handles traffic going network 3 (192.168.3.0/24)

-		root@admin: /home/sdn/SDN_Labs/lab8	- 0 ×
File Actions Edit	View Help		
	Shell No. 1	root@admin: /home/sdn/SDN_Labs/lab8	
2, TCP_DST:179], e, StatTrigger=n id=be0000904 onosproject.net.' treatment=Defaul ll, metadata=nul id=be0000cce' onosproject.net.' CP_SRC:179], tre tatTrigger=nul, id=be0000018 Id=org.onosproje t{immediate=[ETH etadata=nul]	<pre>treatment=DefaultTraff ull, metadata=null} 72872, state=ADDED, byte intent, selector=[IN_P00 tTrafficTreatment{immedi l} 9c6c2, state=ADDED, byte intent, selector=[IN_P00 atment=DefaultTrafficTre metadata=null} d5c50, state=ADDED, byte ct.net.intent, selector: _DST:F6:3D:44:EF:8F:53,</pre>	<pre>icTreatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], clean es=0, packets=0, duration=1855, liveType=UNKNOWN, priority=1000, tableId=0, app RT:2, ETH_TYPE:tpv4, IP_PROTO:1, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12 iate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=false, StatTri es=0, packets=0, duration=1855, liveType=UNKNOWN, priority=1000, tableId=0, app RT:2, ETH_TYPE:tpv4, IP_PROTO:6, IPV4_SRC:192.168.12.1/32, IPV4_DST:192.168.12 eatment{immediate=[OUTPUT:1], deferred=[], transition=None, meter=[], cleared=f es=164052, packets=1674, duration=1746, liveType=UNKNOWN, priority=220, tableId= [IN_PORT:1, ETH_TYPE:tpv4, IPV4_DST:192.168.3.0/24], treatment=DefaultTraffic OUTPUT:2], deferred=[], transition=None, meter=[], cleared=false, StatTrigger:</pre>	red=fals DId=org. .2/32], igger=nu DId=org. .2/32, T false, S J=0, app Freatmen =null, m

#### Actions :

- Change the MAC destination address to router r3 (r3-eth1)
- Forward through port 2

