Software Defined Networking Assignment 04

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Task1

Start the mininet and controller

Perform `sh task41.sh` to install flow entries for naive routing.

Run `Pingall` to test the connectivity between all hosts.

```
mininet> pingall
*** Ping: testing ping reachability
pub1 -> sub1 sub2 sub3 sub4
sub1 -> pub1 sub2 sub3 sub4
sub2 -> pub1 sub1 sub3 sub4
sub3 -> pub1 sub1 sub2 sub4
sub4 -> pub1 sub1 sub2 sub3
```

Compile the subscriber application (.java) into a bytecode file (.class).

```
student@sdnfp04:~/ex4$ javac Subscriber.java
```

Case 1: all received datagrams are unfiltered by the application.

On sub1, run `java Subscriber l 50001 1 500 nofilter gt`
On sub2, run `java Subscriber l 50002 1 500 nofilter gt`
On sub3, run `java Subscriber l 50003 0 30 nofilter le`
On sub4, run `java Subscriber l 50004 0 136 nofilter gt`
On pub1, run `~/ex4/publish`.


```
root@sdnfp04:~# ~/ex4/publish
Publishing 2000000 measurements from /home/student/ex4/measurements.csv
[################################################] done
```

Output: compared with 2 million measurements sent from pub1,only 1/10 datagrams received by each subscriber, this is because UDP is a connectionless protocol and the reliability of delivery cannot be guaranteed.

```
"Node: sub1"                    - □ x
1997098,1377987600,3,0,8,4,32
1997099,1377987600,0,0,12,5,32
1997100,1377987600,0,1,12,5,32
1997101,1377987600,0,1,4,5,32
^CShouting down ...
Unfiltered match: Total received count:220057, max: 762, min: 0
Filtered match: Total received count:0, max: -2147483648, min: 2147483647
root@sdnfp04:~/ex4# []
```

```
"Node: sub2"                    - □
1992370,1377987597,8,1,2,1,24
1992371,1377987597,0,1,1,2,24
1992372,1377987597,0,0,1,2,24
1992373,1377987597,0,1,2,2,24
^CShouting down ...
Unfiltered match: Total received count:221459, max: 671, min: 0
Filtered match: Total received count:0, max: -2147483648, min: 2147483647
root@sdnfp04:~/ex4# []
```

```
"Node: sub3"                    - □ x
1997389,1377987600,0,0,5,10,4
1997390,1377987600,0,1,5,10,4
1997391,1377987600,0,1,1,11,4
1997392,1377987600,0,0,1,11,4
^CShouting down ...
Unfiltered match: Total received count:298812, max: 762, min: 0
Filtered match: Total received count:0, max: -2147483648, min: 2147483647
```

```
"Node: sub4"                    - □
1999997,1377987602,0,1,5,1,25
1999998,1377987602,2,0,5,1,25
1999999,1377987602,0,1,4,2,25
2000000,1377987602,0,0,4,2,25
^CShouting down ...
Unfiltered match: Total received count:279793, max: 762, min: 0
Filtered match: Total received count:0, max: -2147483648, min: 2147483647
```

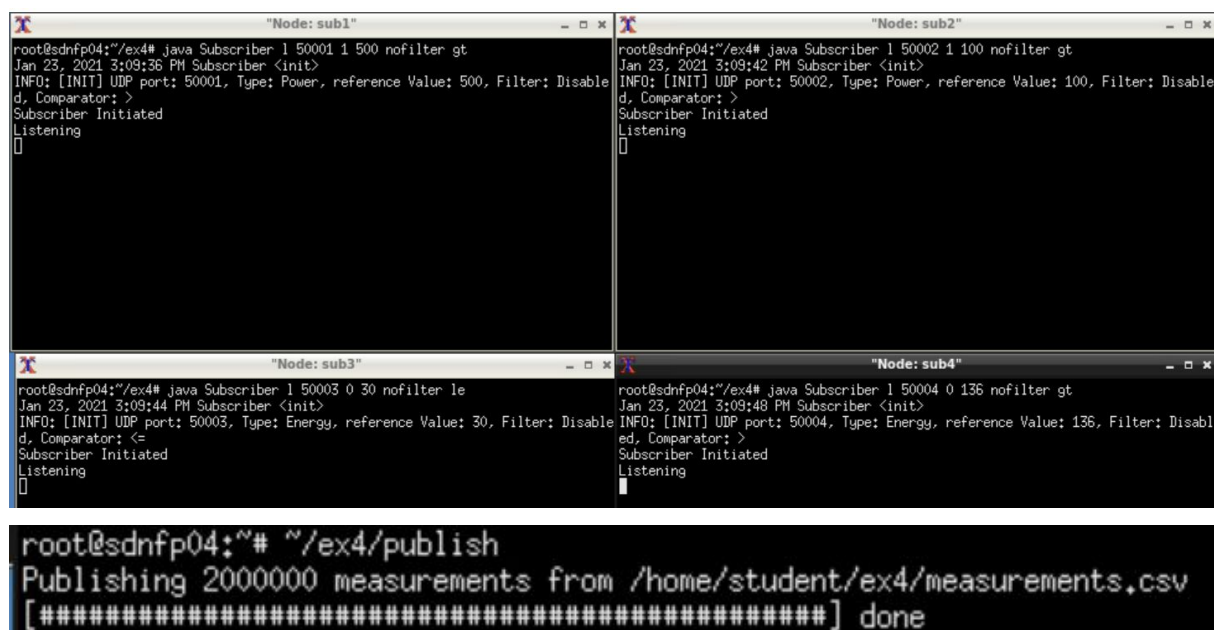Case 2: all received datagrams are filtered by the application.

On sub1, run `java Subscriber l 50001 1 500 filter gt`

On sub2, run `java Subscriber l 50002 1 100 filter gt`

On sub3, run `java Subscriber l 50003 0 30 filter ls`

On sub4, run `java Subscriber l 50004 0 136 filter gt`

On pub1, run `~/ex4/publish`.


```
"Node: sub1"                    - □ x
root@sdnfp04:~/ex4# java Subscriber l 50001 1 500 filter gt
Jan 23, 2021 3:11:34 PM Subscriber <init>
INFO: [INIT] UDP port: 50001, Type: Power, reference Value: 500, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
[]
```

```
"Node: sub2"                    - □ x
root@sdnfp04:~/ex4# java Subscriber l 50002 1 100 filter gt
Jan 23, 2021 3:11:39 PM Subscriber <init>
INFO: [INIT] UDP port: 50002, Type: Power, reference Value: 100, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
[]
```

```
"Node: sub3"                    - □ x
root@sdnfp04:~/ex4# java Subscriber l 50003 0 30 filter le
Jan 23, 2021 3:11:44 PM Subscriber <init>
INFO: [INIT] UDP port: 50003, Type: Energy, reference Value: 30, Filter: Enabled
, Comparator: <=
Subscriber Initiated
Listening
[]
```

```
"Node: sub4"                    - □ x
root@sdnfp04:~/ex4# java Subscriber l 50004 0 136 filter gt
Jan 23, 2021 3:11:50 PM Subscriber <init>
INFO: [INIT] UDP port: 50004, Type: Energy, reference Value: 136, Filter: Enable
d, Comparator: >
Subscriber Initiated
Listening
[]
```

Output: the number of received datagrams by each subscriber (around 1.5 million) increases significantly in comparison with unfiltered case (only 20 thousand) .


```
"Node: sub1"                    - □ x
1998711,1377987601,563,1,2,2,32
1998761,1377987601,585,1,1,8,32
1998771,1377987601,507,1,10,1,33
1999243,1377987601,627,1,1,3,6
^CShouting down ...
Unfiltered match: Total received count:1801975, max: 762, min: 0
Filtered match: Total received count:4124, max: 762, min: 501
root@sdnfp04:~/ex4# []
```

```
"Node: sub2"                    - □ x
1999291,1377987601,347,1,1,6,7
1999293,1377987601,401,1,10,7,7
1999333,1377987601,244,1,3,2,8
1999359,1377987601,185,1,9,1,9
^CShouting down ...
Unfiltered match: Total received count:1374213, max: 762, min: 0
Filtered match: Total received count:47264, max: 762, min: 101
root@sdnfp04:~/ex4# []
```

```
"Node: sub3"                    - □ x
1998532,1377987601,3,0,4,14,28
1998541,1377987601,2,0,3,15,28
1998545,1377987601,2,0,7,15,28
1998548,1377987601,3,0,4,16,28
^CShouting down ...
Unfiltered match: Total received count:1213447, max: 762, min: 0
Filtered match: Total received count:446010, max: 11, min: 0
```

```
"Node: sub4"                    - □ x
1998274,1377987601,173,0,3,2,23
1998310,1377987601,173,0,10,3,24
1998312,1377987601,173,0,11,3,24
1998324,1377987601,173,0,2,4,24
^CShouting down ...
Unfiltered match: Total received count:1497251, max: 762, min: 0
Filtered match: Total received count:50681, max: 174, min: 173
```

Task2

The type and measurement value have been encoded in the destination IP address, so we can use destination IP as match to realize content-based routing.

Comparator	Reference value	match	action
>	100	230.0.0.0/26	Drop the value below the next smaller powers of two of the reference value. Drop the value between 0-63
<	100	230.0.0.0/25	Pass the value below the next greater powers of two of the reference value. Pass the value between 0-127

Perform `sh task42.sh` to install flow entries for content-based routing. Unnecessary measurements have been dropped by S1, then S2 divides the passed measurements and delivers them to corresponding subscribers. S3 just forwards the filtered flows to sub2.

On sub1, run `java Subscriber l 50001 1 500 filter gt`
On sub2, run `java Subscriber l 50002 1 100 filter gt`
On sub3, run `java Subscriber l 50003 0 30 filter lt`
On sub4, run `java Subscriber l 50004 0 136 filter gt`
On pub1, run `~/ex4/publish`.

```
"Node: sub1"                                    _ □ x
root@sdnfp04:~/ex4# java Subscriber 1 50001 1 500 filter gt
Jan 24, 2021 10:26:22 PM Subscriber <init>
INFO: [INIT] UDP port: 50001, Type: Power, reference Value: 500, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
```

```
"Node: sub2"                                    _ □ x
root@sdnfp04:~/ex4# java Subscriber 1 50002 1 100 filter gt
Jan 24, 2021 10:26:24 PM Subscriber <init>
INFO: [INIT] UDP port: 50002, Type: Power, reference Value: 100, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
```

```
"Node: sub3"                                    _ □ x
root@sdnfp04:~/ex4# java Subscriber 1 50003 0 30 filter lt
Jan 24, 2021 10:26:26 PM Subscriber <init>
INFO: [INIT] UDP port: 50003, Type: Energy, reference Value: 30, Filter: Enabled
, Comparator: <=
Subscriber Initiated
Listening
```

```
"Node: sub4"                                    _ □ x
root@sdnfp04:~/ex4# java Subscriber 1 50004 0 136 filter gt
Jan 24, 2021 10:26:44 PM Subscriber <init>
INFO: [INIT] UDP port: 50004, Type: Energy, reference Value: 136, Filter: Enable
d, Comparator: >
Subscriber Initiated
Listening
```

Output
Explanation:

	Type 1	Type 0
S1	drops 230.1.0.0-230.1.0.63 and let the rest (>230.1.0.63) pass.	drops 230.0.0.32-230.0.0.127 and let the rest pass
S2	forwards 230.1.0.63-230.1.0.255 to sub2 and the rest (>230.1.0.255) will be forwarded to both sub1 and sub2.	forwards the 230.0.01-230.0.0.31 to su3 and the rest (>230.0.0.127) to sub4
S3	S2 has filtered out, so s3 just forwards the measurements to sub2.	

So the minimum value received by sub1 is 256 and the minimum value received by sub2 is 63.

```
         "Node: sub1"                    _ □ x          "Node: sub2"                    _ □ x
1992971,1377987597,639,1,1,3,6                  1995559,1377987599,500,1,1,4,28
1994767,1377987599,551,1,7,1,13                 1995561,1377987599,467,1,12,4,28
1995593,1377987599,516,1,10,9,28                1995581,1377987599,138,1,9,6,28
1995703,1377987599,545,1,2,2,32                 1995593,1377987599,516,1,10,9,28
1995747,1377987599,503,1,0,7,32                 1995601,1377987599,255,1,9,9,28
1995755,1377987599,593,1,1,8,32                 1995617,1377987599,228,1,0,1,29
1995763,1377987599,515,1,10,1,33                1995621,1377987599,127,1,2,1,29
1996225,1377987599,648,1,1,3,6                  1995633,1377987599,479,1,9,0,3
1997745,1377987601,552,1,7,1,13                 1995635,1377987599,376,1,0,1,3
1998603,1377987601,516,1,10,9,28                1995673,1377987599,412,1,6,0,32
1998631,1377987601,507,1,9,0,3                  1995703,1377987599,545,1,2,2,32
1998711,1377987601,563,1,2,2,32                 1995709,1377987599,113,1,2,3,32
1998761,1377987601,585,1,1,8,32                 1995725,1377987599,306,1,7,4,32
1998771,1377987601,507,1,10,1,33                1995747,1377987599,503,1,0,7,32
1999243,1377987601,627,1,1,3,6                  1995755,1377987599,593,1,1,8,32
^CShouting down ...                             ^CShouting down ...
Unfiltered match: Total received count:32749, max: 762, min: 256   Unfiltered match: Total received count:82676, max: 762, min: 64
Filtered match: Total received count:4369, max: 762, min: 501       Filtered match: Total received count:69368, max: 762, min: 101
root@sdnfp04:~/ex4# []                          root@sdnfp04:~/ex4# []

         "Node: sub3"                    _ □ x          "Node: sub4"                    _ □ x
1999968,1377987602,0,0,7,0,24                   1995402,1377987599,173,0,1,3,26
1999970,1377987602,2,0,3,1,24                   1995408,1377987599,173,0,6,3,26
1999971,1377987602,0,0,0,2,24                   1995414,1377987599,173,0,9,4,26
1999974,1377987602,2,0,4,3,24                   1995444,1377987599,173,0,5,5,27
1999976,1377987602,2,0,8,3,24                   1995462,1377987599,173,0,0,9,27
1999978,1377987602,3,0,0,4,24                   1995480,1377987599,173,0,6,0,28
1999979,1377987602,0,0,3,4,24                   1995492,1377987599,173,0,1,10,28
1999982,1377987602,0,0,2,5,24                   1995496,1377987599,173,0,6,10,28
1999984,1377987602,0,0,0,6,24                   1995506,1377987599,173,0,5,12,28
1999985,1377987602,0,0,4,6,24                   1995520,1377987599,173,0,3,14,28
1999988,1377987602,3,0,1,0,25                   1995528,1377987599,173,0,2,15,28
1999990,1377987602,3,0,2,0,25                   1995550,1377987599,173,0,6,2,28
1999992,1377987602,0,0,1,1,25                   1995560,1377987599,174,0,1,4,28
1999994,1377987602,2,0,2,1,25                   1995562,1377987599,174,0,12,4,28
1999995,1377987602,0,0,4,1,25                   1995582,1377987599,173,0,9,6,28
1999998,1377987602,2,0,5,1,25                   1995594,1377987599,174,0,10,9,28
2000000,1377987602,0,0,4,2,25                   1995602,1377987599,173,0,9,9,28
^CShouting down ...                             ^CShouting down ...
Unfiltered match: Total received count:255777, max: 11, min: 0    Unfiltered match: Total received count:68418, max: 174, min: 173
Filtered match: Total received count:255777, max: 11, min: 0       Filtered match: Total received count:68418, max: 174, min: 173
root@sdnfp04:~/ex4# []                          root@sdnfp04:~/ex4# []
```

Task3

Start the controller: `/opt/floodlight/floodlight-noforwarding.sh`

Start the mininet: `sudo ~/ex4/mininet4.py`

Perform `sh task43.sh` to install routes for IP-packets and run `dpctl dump-flows` to check the initial routes, then close the controller.


```
mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------------
cookie=0xa0000053156c9b, duration=2.455s, table=0, n_packets=0, n_bytes=0, priority=2,arp,arp_tpa=10.1.0.1,arp_op=2 actions=output:"s1-eth2"
cookie=0xa000054301235, duration=2.439s, table=0, n_packets=0, n_bytes=0, priority=2,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s1-eth3"
cookie=0xafffffb2bbdc24, duration=2.412s, table=0, n_packets=0, n_bytes=0, priority=2,ip,nw_dst=10.10.10.10 actions=output:"s1-eth3"
cookie=0xa000003fee90a3, duration=2.392s, table=0, n_packets=0, n_bytes=0, priority=2,ip,nw_dst=10.1.0.1 actions=output:"s1-eth2"
cookie=0xa000004f62261f, duration=2.468s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa0000067879969, duration=2.423s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_op=2 actions=output:"s1-eth1"
cookie=0xa000003ff09a5e, duration=2.385s, table=0, n_packets=0, n_bytes=0, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s1-eth1"
cookie=0x0, duration=211.540s, table=0, n_packets=74, n_bytes=8292, priority=0 actions=CONTROLLER:65535
*** s2 ------------------------------------------------------------------------
cookie=0xa000000b0d17da, duration=2.371s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa000003c954e4f, duration=2.357s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth1"
cookie=0xa000003e435370, duration=2.344s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"
cookie=0xa000003e435371, duration=2.331s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth2"
cookie=0xa000003e435372, duration=2.315s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth4"
cookie=0xa000003e435373, duration=2.302s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth5"
cookie=0xafffffd26b9f66, duration=2.289s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s2-eth1"
cookie=0xa0000060a11945, duration=2.275s, table=0, n_packets=0, n_bytes=0, priority=1,ip,nw_dst=10.10.10.10 actions=output:"s2-eth1"
cookie=0x0, duration=211.518s, table=0, n_packets=94, n_bytes=8878, priority=0 actions=CONTROLLER:65535
*** s3 ------------------------------------------------------------------------
cookie=0xa00000513a8c1f, duration=2.251s, table=0, n_packets=0, n_bytes=0, priority=2,arp,arp_tpa=10.1.1.2,arp_op=2 actions=output:"s3-eth2"
cookie=0xa000000f19b5ee, duration=2.225s, table=0, n_packets=0, n_bytes=0, priority=2,ip,nw_dst=10.1.1.2 actions=output:"s3-eth2"
cookie=0xafffffc6b80995, duration=2.265s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa000001a236c2f, duration=2.238s, table=0, n_packets=0, n_bytes=0, priority=1,arp,arp_op=2 actions=output:"s3-eth1"
cookie=0xafffff9912e1cc, duration=2.213s, table=0, n_packets=0, n_bytes=0, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s3-eth1"
cookie=0x0, duration=211.503s, table=0, n_packets=44, n_bytes=4214, priority=0 actions=CONTROLLER:65535
```

Run `Task43.launch` to start our module on eclipse.

On task33.properties file, change the configuration below to keep the pre-installed flow entries on switches.

```
50 net.floodlightcontroller.core.internal.OFSwitchManager.clearTablesOnInitialHandshakeAsMaster=NO
51 net.floodlightcontroller.core.internal.OFSwitchManager.clearTablesOnEachTransitionToMaster=NO
```

Control Logic:
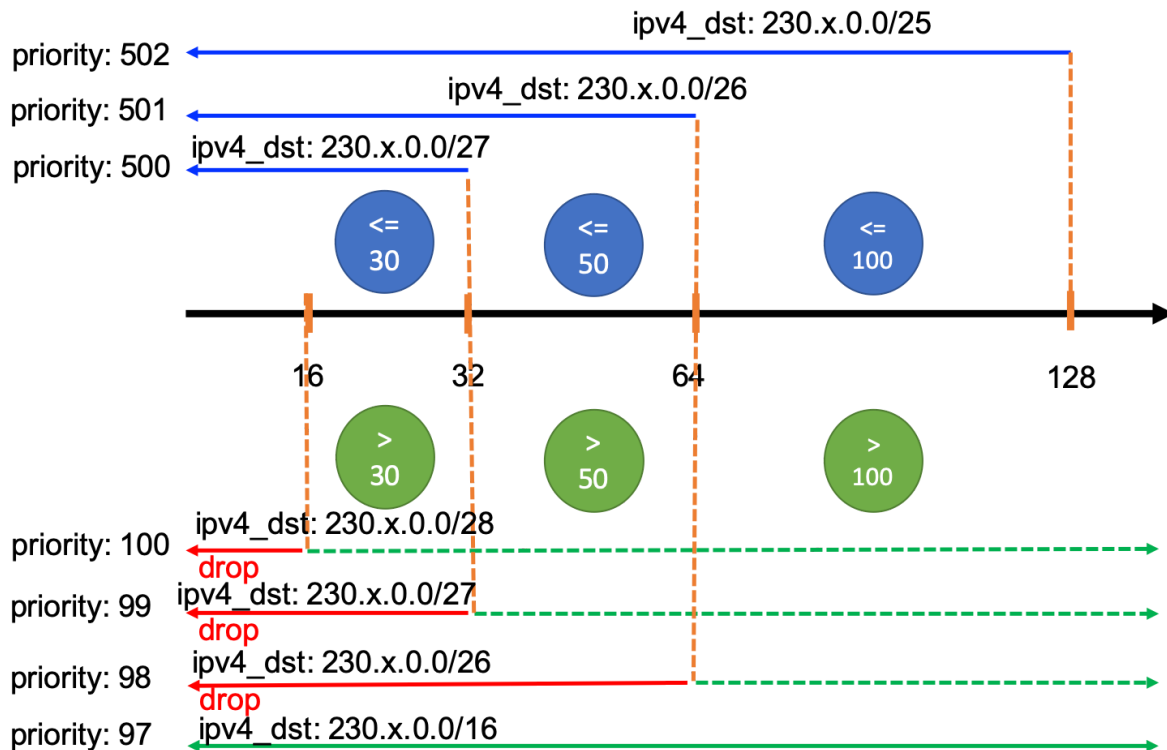
Our Control Logic Implementation is similar to that of task2. As in the picture above, we seperate flow into 4 categories according to their type and comparator. Then based on the category, we create 4 lists to maintain the order of subscription. We used priority and subnet mask for filtering and forwarding the flows. One thing worth noticing is that <= need to be taken to the ceiling while > with the floor to avoid flow missing. The <= has higher priority over > for the same reason.

Send POST request:

Run `java Subscriber p [name] [udp_port] [type] [reference_value] [isFilter] [isGreater]` for example:

On sub1, run `java Subscriber p sub1 50001 1 150 filter gt`
On sub2, run `java Subscriber p sub2 50002 1 100 filter lt`
On sub3, run `java Subscriber p sub3 50003 0 1 filter lt`
On sub4, run `java Subscriber p sub4 50004 0 50 filter gt`

```
"Node: sub1"                                           _ □ x
root@sdnfp04:~# cd ex4
root@sdnfp04:~/ex4# java Subscriber p sub1 50001 1 150 filter gt
Executing... curl -X POST -d {"udp_port":"50001","type":"1","filter_enable":"tru
e","reference_value":"150","is_greater":"true"} http://10.10.10.10:8080/subscrip
tions/sub1/json
{"status":"Successfully added new subscription sub1"}
root@sdnfp04:~/ex4# []
```

```
"Node: sub2"                                           _ □ x
root@sdnfp04:~# cd ex4
root@sdnfp04:~/ex4# java Subscriber p sub2 50002 1 100 filter lt
Executing... curl -X POST -d {"udp_port":"50002","type":"1","filter_enable":"tru
e","reference_value":"100","is_greater":"false"} http://10.10.10.10:8080/subscri
ptions/sub2/json
{"status":"Successfully added new subscription sub2"}
root@sdnfp04:~/ex4# []
```

```
"Node: sub4"                                           _ □ x
root@sdnfp04:~/ex4# java Subscriber p sub3 50003 0 1 filter lt
Executing... curl -X POST -d {"udp_port":"50003","type":"0","filter_enable":"tru
e","reference_value":"1","is_greater":"false"} http://10.10.10.10:8080/subscript
ions/sub3/json
{"status":"Successfully added new subscription sub3"}
root@sdnfp04:~/ex4# []
```

```
"Node: sub3"                                           _ □ x
root@sdnfp04:~# cd ex4
root@sdnfp04:~/ex4# java Subscriber p sub4 50004 0 50 filter gt
Executing... curl -X POST -d {"udp_port":"50004","type":"0","filter_enable":"tru
e","reference_value":"50","is_greater":"true"} http://10.10.10.10:8080/subscript
ions/sub4/json
{"status":"Successfully added new subscription sub4"}
root@sdnfp04:~/ex4# █
```

Check the installed flows

```
mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------
 cookie=0x0, duration=157.013s, table=0, n_packets=0, n_bytes=0, priority=100,ip,nw_dst=230.1.0.0/25 actions=drop
 cookie=0x0, duration=122.596s, table=0, n_packets=0, n_bytes=0, priority=500,ip,nw_dst=230.1.0.0/25 actions=output:"s1-eth1"
 cookie=0x0, duration=62.672s, table=0, n_packets=0, n_bytes=0, priority=500,ip,nw_dst=230.0.0.0/31 actions=output:"s1-eth1"
 cookie=0x0, duration=38.646s, table=0, n_packets=0, n_bytes=0, priority=100,ip,nw_dst=230.0.0.0/27 actions=drop
 cookie=0x0, duration=157.012s, table=0, n_packets=0, n_bytes=0, priority=99,ip,nw_dst=230.1.0.0/16 actions=output:"s1-eth1"
 cookie=0x0, duration=38.646s, table=0, n_packets=0, n_bytes=0, priority=99,ip,nw_dst=230.0.0.0/16 actions=output:"s1-eth1"
 cookie=0xa0000053156c9b, duration=624.836s, table=0, n_packets=0, n_bytes=0, priority=2,arp,arp_tpa=10.1.0.1,arp_op=2 actions=output:"s1-eth2"
 cookie=0xa0000054301235, duration=624.820s, table=0, n_packets=4, n_bytes=168, priority=2,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s1-eth3"
 cookie=0xaffffffb2bbdc24, duration=624.793s, table=0, n_packets=24, n_bytes=2699, priority=2,ip,nw_dst=10.10.10.10 actions=output:"s1-eth3"
 cookie=0xa000003fee90a3, duration=624.773s, table=0, n_packets=0, n_bytes=0, priority=2,ip,nw_dst=10.1.0.1 actions=output:"s1-eth2"
 cookie=0xa0000004f62261f, duration=624.849s, table=0, n_packets=8, n_bytes=336, priority=1,arp,arp_op=1 actions=FLOOD
 cookie=0xa0000067879969, duration=624.804s, table=0, n_packets=4, n_bytes=168, priority=1,arp,arp_op=2 actions=output:"s1-eth1"
 cookie=0xa000003ff09a5e, duration=624.766s, table=0, n_packets=16, n_bytes=3076, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s1-eth1"
 cookie=0x0, duration=375.397s, table=0, n_packets=29, n_bytes=2160, priority=0 actions=CONTROLLER:65535

*** s2 ------------------------------------------------------------
 cookie=0x0, duration=122.598s, table=0, n_packets=0, n_bytes=0, priority=500,udp,nw_dst=230.1.0.0/25 actions=mod_nw_dst:10.1.1.2,mod_tp_dst:50002,output:"s2-eth2"
 cookie=0x0, duration=62.675s, table=0, n_packets=0, n_bytes=0, priority=500,udp,nw_dst=230.0.0.0/31 actions=mod_nw_dst:10.1.1.4,mod_tp_dst:50003,output:"s2-eth5"
 cookie=0x0, duration=157.010s, table=0, n_packets=0, n_bytes=0, priority=100,udp,nw_dst=230.1.0.0/16 actions=mod_nw_dst:10.1.1.1,mod_tp_dst:50001,output:"s2-eth3"
 cookie=0x0, duration=38.649s, table=0, n_packets=0, n_bytes=0, priority=100,udp,nw_dst=230.0.0.0/16 actions=mod_nw_dst:10.1.1.3,mod_tp_dst:50004,output:"s2-eth4"
 cookie=0xa000000b0d17da, duration=624.752s, table=0, n_packets=8, n_bytes=336, priority=1,arp,arp_op=1 actions=FLOOD
 cookie=0xa000003c954e4f, duration=624.738s, table=0, n_packets=0, n_bytes=0, priority=1,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth1"
 cookie=0xa000003e435370, duration=624.725s, table=0, n_packets=5, n_bytes=811, priority=1,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"
 cookie=0xa000003e435371, duration=624.712s, table=0, n_packets=5, n_bytes=811, priority=1,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth2"
 cookie=0xa000003e435372, duration=624.696s, table=0, n_packets=5, n_bytes=811, priority=1,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth4"
 cookie=0xa000003e435373, duration=624.683s, table=0, n_packets=5, n_bytes=811, priority=1,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth5"
 cookie=0xaffffffd26b9f66, duration=624.670s, table=0, n_packets=4, n_bytes=168, priority=1,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s2-eth1"
 cookie=0xa0000060a11945, duration=624.656s, table=0, n_packets=24, n_bytes=2699, priority=1,ip,nw_dst=10.10.10.10 actions=output:"s2-eth1"
 cookie=0x0, duration=375.424s, table=0, n_packets=59, n_bytes=4408, priority=0 actions=CONTROLLER:65535

*** s3 ------------------------------------------------------------
 cookie=0xa00000513a8c1f, duration=624.632s, table=0, n_packets=1, n_bytes=42, priority=2,arp,arp_tpa=10.1.1.2,arp_op=2 actions=output:"s3-eth2"
 cookie=0xa000000f19b5ee, duration=624.606s, table=0, n_packets=4, n_bytes=769, priority=2,ip,nw_dst=10.1.1.2 actions=output:"s3-eth2"
 cookie=0xaffffffc6b80995, duration=624.646s, table=0, n_packets=8, n_bytes=336, priority=1,arp,arp_op=1 actions=FLOOD
 cookie=0xa000001a236c2f, duration=624.619s, table=0, n_packets=1, n_bytes=42, priority=1,arp,arp_op=2 actions=output:"s3-eth1"
 cookie=0xaffffff9912e1cc, duration=624.594s, table=0, n_packets=6, n_bytes=676, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s3-eth1"
 cookie=0x0, duration=38.652s, table=0, n_packets=0, n_bytes=0, priority=0,ip,nw_dst=230.0.0.0/8 actions=output:"s3-eth2"
 cookie=0x0, duration=375.428s, table=0, n_packets=29, n_bytes=2165, priority=0 actions=CONTROLLER:65535
```

sub1 to sub4 listen on the measurements they have subscribed

```
"Node: sub1"                                          _ □ x
root@sdnfp04:~/ex4# java Subscriber l 50001 1 150 filter gt
Jan 25, 2021 11:37:02 AM Subscriber <init>
INFO: [INIT] UDP port: 50001, Type: Power, reference Value: 150, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
[]
```

```
"Node: sub2"                                          _ □ x
root@sdnfp04:~/ex4# java Subscriber l 50002 1 100 filter lt
Jan 25, 2021 11:37:11 AM Subscriber <init>
INFO: [INIT] UDP port: 50002, Type: Power, reference Value: 100, Filter: Enabled
, Comparator: <=
Subscriber Initiated
Listening
[]
```

```
"Node: sub3"                                          _ □ x
root@sdnfp04:~/ex4# java Subscriber l 50003 0 1 filter lt
Jan 25, 2021 11:37:19 AM Subscriber <init>
INFO: [INIT] UDP port: 50003, Type: Energy, reference Value: 1, Filter: Enabled,
 Comparator: <=
Subscriber Initiated
Listening
[]
```

```
"Node: sub4"                                          _ □ x
root@sdnfp04:~/ex4# java Subscriber l 50004 0 50 filter gt
Jan 25, 2021 11:37:29 AM Subscriber <init>
INFO: [INIT] UDP port: 50004, Type: Energy, reference Value: 50, Filter: Enabled
, Comparator: >
Subscriber Initiated
Listening
[]
```

```
"Node: sub1"                                         "Node: sub2"
1998967,1377987601,169,1,8,7,37                      1999871,1377987602,0,1,2,4,21
1999011,1377987601,281,1,2,9,38                      1999873,1377987602,0,1,3,4,21
1999045,1377987601,409,1,1,13,39                     1999876,1377987602,0,1,4,4,21
1999067,1377987601,335,1,6,2,39                      1999877,1377987602,0,1,5,4,21
1999097,1377987601,436,1,6,6,39                      1999879,1377987602,0,1,8,4,21
1999141,1377987601,173,1,0,11,4                      1999881,1377987602,0,1,1,5,21
1999155,1377987601,213,1,10,13,4                     1999884,1377987602,0,1,2,5,21
1999177,1377987601,177,1,3,4,4                       1999885,1377987602,0,1,3,5,21
1999193,1377987601,447,1,1,7,4                       1999887,1377987602,0,1,2,6,21
1999231,1377987601,214,1,4,0,6                       1999890,1377987602,0,1,4,6,21
1999243,1377987601,627,1,1,3,6                       1999989,1377987602,0,1,2,0,25
1999289,1377987601,285,1,4,4,7                       1999991,1377987602,0,1,1,1,25
1999291,1377987601,347,1,1,6,7                       1999993,1377987602,0,1,2,1,25
1999293,1377987601,401,1,10,7,7                      1999996,1377987602,0,1,4,1,25
1999333,1377987601,244,1,3,2,8                       1999997,1377987602,0,1,5,1,25
1999359,1377987601,185,1,9,1,9                       1999999,1377987602,0,1,4,2,25
^CShouting down ...                                  ^CShouting down ...
Unfiltered match: Total received count:58311, max: 762, min: 128   Unfiltered match: Total received count:228516, max: 127, min: 0
Filtered match: Total received count:54163, max: 762, min: 151      Filtered match: Total received count:226828, max: 100, min: 0
root@sdnfp04:~/ex4#                                  root@sdnfp04:~/ex4#

"Node: sub4"                                         "Node: sub3"
1989542,1377987596,0,0,0,15,14                       1998784,1377987601,68,0,8,1,33
1989554,1377987596,0,0,1,16,14                       1998788,1377987601,173,0,1,10,33
1989560,1377987596,0,0,0,17,14                       1998790,1377987601,68,0,6,10,33
1989562,1377987596,0,0,3,2,14                        1998792,1377987601,173,0,0,11,33
1989563,1377987596,0,0,4,2,14                        1998798,1377987601,174,0,5,11,33
1989580,1377987596,0,0,3,5,14                        1998808,1377987601,68,0,1,3,33
1989591,1377987596,0,0,5,6,14                        1998812,1377987601,173,0,5,3,33
1989596,1377987596,0,0,7,6,14                        1998822,1377987601,68,0,2,5,33
1989599,1377987596,0,0,2,7,14                        1998834,1377987601,68,0,5,8,33
1989610,1377987596,0,0,2,8,14                        1998838,1377987601,68,0,2,9,33
1989626,1377987596,0,0,6,9,14                        1998840,1377987601,173,0,5,9,33
1989632,1377987596,0,0,10,0,15                       1998844,1377987601,68,0,2,0,34
1989634,1377987596,0,0,11,0,15                       1998850,1377987601,68,0,2,2,34
1989640,1377987596,0,0,2,0,15                        1998852,1377987601,68,0,4,2,34
1989645,1377987596,0,0,9,0,15                        1998858,1377987601,68,0,3,5,34
^CShouting down ...                                  ^CShouting down ...
Unfiltered match: Total received count:157880, max: 0, min: 0      Unfiltered match: Total received count:170690, max: 174, min: 35
Filtered match: Total received count:157880, max: 0, min: 0        Filtered match: Total received count:114027, max: 174, min: 68
root@sdnfp04:~/ex4#                                  root@sdnfp04:~/ex4#
```

Send Delete request:

Run `java Subscriber d [name]`
Delete subscription for sub1:

```
root@sdnfp04:~/ex4# java Subscriber d sub1
Executing... curl -X DELETE http://10.10.10.10:8080/subscriptions/sub1/json
{"status":"Successfully deleted subscription sub1"}
```

```
"Node: sub1"                                         "Node: sub2"
root@sdnfp04:~/ex4# java Subscriber l 50001 1 150 filter gt   1999965,1377987602,0,1,1,0,24
Jan 25, 2021 11:47:59 AM Subscriber <init>           1999967,1377987602,0,1,7,0,24
INFO: [INIT] UDP port: 50001, Type: Power, reference Value: 150, Filter: Enabled   1999969,1377987602,0,1,3,1,24
, Comparator: >                                      1999972,1377987602,0,1,0,2,24
Subscriber Initiated                                 1999973,1377987602,0,1,4,3,24
Listening                                            1999975,1377987602,0,1,8,3,24
                                                     1999977,1377987602,0,1,0,4,24
                                                     1999980,1377987602,0,1,3,4,24
                                                     1999981,1377987602,0,1,2,5,24
                                                     1999983,1377987602,0,1,0,6,24
                                                     1999986,1377987602,0,1,4,6,24
                                                     1999987,1377987602,0,1,1,0,25
                                                     1999989,1377987602,0,1,2,0,25
                                                     1999991,1377987602,0,1,1,1,25
                                                     1999993,1377987602,0,1,2,1,25
                                                     1999996,1377987602,0,1,4,1,25
                                                     ^CShouting down ...
                                                     Unfiltered match: Total received count:300478, max: 127, min: 0
                                                     Filtered match: Total received count:298279, max: 100, min: 0
                                                     root@sdnfp04:~/ex4#

"Node: sub3"                                         "Node: sub4"
1999949,1377987602,0,0,1,0,23                        1997704,1377987601,173,0,9,2,11
1999954,1377987602,0,0,3,0,23                        1997714,1377987601,173,0,2,0,12
1999955,1377987602,0,0,0,1,23                        1997728,1377987601,68,0,4,2,12
1999958,1377987602,0,0,4,1,23                        1997738,1377987601,68,0,1,0,13
1999961,1377987602,0,0,1,3,23                        1997744,1377987601,173,0,2,1,13
1999963,1377987602,0,0,6,3,23                        1997746,1377987601,174,0,7,1,13
1999968,1377987602,0,0,7,0,24                        1997758,1377987601,173,0,3,10,14
1999971,1377987602,0,0,0,2,24                        1997774,1377987601,173,0,4,12,14
1999979,1377987602,0,0,3,4,24                        1997778,1377987601,173,0,7,12,14
1999982,1377987602,0,0,2,5,24                        1997780,1377987601,174,0,1,13,14
1999984,1377987602,0,0,0,6,24                        1997788,1377987601,68,0,3,14,14
1999985,1377987602,0,0,4,6,24                        1997790,1377987601,68,0,4,14,14
1999992,1377987602,0,0,1,1,25                        1997796,1377987601,173,0,1,15,14
1999995,1377987602,0,0,4,1,25                        1997800,1377987601,68,0,5,15,14
2000000,1377987602,0,0,4,2,25                        1997802,1377987601,68,0,6,15,14
^CShouting down ...                                  ^CShouting down ...
Unfiltered match: Total received count:195581, max: 0, min: 0      Unfiltered match: Total received count:185563, max: 174, min: 35
Filtered match: Total received count:195581, max: 0, min: 0        Filtered match: Total received count:123167, max: 174, min: 68
root@sdnfp04:~/ex4#                                  root@sdnfp04:~/ex4#
```

Check the installed flows, we can see the route for sub1 (type1, value>150) has been deleted.

```
*** s1 --------------------------------------------------------------
cookie=0x0, duration=576.614s, table=0, n_packets=0, n_bytes=0, priority=500,ip,nw_dst=230.1.0.0/25 actions=output:"s1-eth1"
cookie=0x0, duration=544.334s, table=0, n_packets=0, n_bytes=0, priority=500,ip,nw_dst=230.0.0.0/31 actions=output:"s1-eth1"
cookie=0x0, duration=510.103s, table=0, n_packets=0, n_bytes=0, priority=100,ip,nw_dst=230.0.0.0/27 actions=drop
cookie=0x0, duration=510.102s, table=0, n_packets=0, n_bytes=0, priority=99,ip,nw_dst=230.0.0.0/16 actions=output:"s1-eth1"
cookie=0xa0000053156c9b, duration=2844.407s, table=0, n_packets=4, n_bytes=168, priority=2,arp,arp_tpa=10.1.0.1,arp_op=2 actions=output:"s1-eth2"
cookie=0xa0000054301235, duration=2844.390s, table=0, n_packets=14, n_bytes=588, priority=2,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s1-eth3"
cookie=0xafffffb2bbdc24, duration=2844.357s, table=0, n_packets=19, n_bytes=798, priority=2,ip,nw_dst=10.10.10.10 actions=output:"s1-eth3"
cookie=0xa000003fee90a3, duration=2844.343s, table=0, n_packets=8, n_bytes=784, priority=2,ip,nw_dst=10.1.0.1 actions=output:"s1-eth2"
cookie=0xa000004f62261f, duration=2844.428s, table=0, n_packets=49, n_bytes=2058, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa0000067879969, duration=2844.373s, table=0, n_packets=19, n_bytes=798, priority=1,arp,arp_op=2 actions=output:"s1-eth1"
cookie=0xa000003ff09a5e, duration=2844.329s, table=0, n_packets=77, n_bytes=14481, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s1-eth1"
cookie=0x0, duration=911.747s, table=0, n_packets=65, n_bytes=4860, priority=0 actions=CONTROLLER:65535
*** s2 --------------------------------------------------------------
cookie=0x0, duration=576.618s, table=0, n_packets=0, n_bytes=0, priority=500,udp,nw_dst=230.1.0.0/25 actions=mod_nw_dst:10.1.1.2,mod_tp_dst:50002,output:"s2-eth2"
cookie=0x0, duration=544.338s, table=0, n_packets=0, n_bytes=0, priority=500,udp,nw_dst=230.0.0.0/31 actions=mod_nw_dst:10.1.1.3,mod_tp_dst:50003,output:"s2-eth4"
cookie=0x0, duration=510.107s, table=0, n_packets=0, n_bytes=0, priority=100,udp,nw_dst=230.0.0.0/16 actions=mod_nw_dst:10.1.1.4,mod_tp_dst:50004,output:"s2-eth5"
cookie=0xa0000060a11945, duration=2844.225s, table=0, n_packets=103, n_bytes=10033, priority=1,ip,nw_dst=10.10.10.10 actions=output:"s2-eth1"
cookie=0xa000000b0d17da, duration=2844.319s, table=0, n_packets=49, n_bytes=2058, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa000003c954e4f, duration=2844.305s, table=0, n_packets=12, n_bytes=952, priority=1,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth1"
cookie=0xa000003e435370, duration=2844.292s, table=0, n_packets=28, n_bytes=3439, priority=1,dl_dst=00:00:00:00:00:02 actions=output:"s2-eth3"
cookie=0xa000003e435371, duration=2844.279s, table=0, n_packets=32, n_bytes=4536, priority=1,dl_dst=00:00:00:00:00:03 actions=output:"s2-eth2"
cookie=0xa000003e435372, duration=2844.265s, table=0, n_packets=50, n_bytes=7588, priority=1,dl_dst=00:00:00:00:00:04 actions=output:"s2-eth4"
cookie=0xa000003e435373, duration=2844.251s, table=0, n_packets=22, n_bytes=2572, priority=1,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth5"
cookie=0xafffffd26b9f66, duration=2844.239s, table=0, n_packets=14, n_bytes=588, priority=1,arp,arp_tpa=10.10.10.10,arp_op=2 actions=output:"s2-eth1"
cookie=0x0, duration=911.770s, table=0, n_packets=127, n_bytes=9513, priority=0 actions=CONTROLLER:65535
*** s3 --------------------------------------------------------------
cookie=0xa00000513a8c1f, duration=2844.198s, table=0, n_packets=8, n_bytes=336, priority=2,arp,arp_tpa=10.1.1.2,arp_op=2 actions=output:"s3-eth2"
cookie=0xa000000f19b5ee, duration=2844.170s, table=0, n_packets=24, n_bytes=4200, priority=2,ip,nw_dst=10.1.1.2 actions=output:"s3-eth2"
cookie=0xafffffc6b80995, duration=2844.212s, table=0, n_packets=49, n_bytes=2058, priority=1,arp,arp_op=1 actions=FLOOD
cookie=0xa000001a236c2f, duration=2844.185s, table=0, n_packets=8, n_bytes=336, priority=1,arp,arp_op=2 actions=output:"s3-eth1"
cookie=0xafffff9912e1cc, duration=2844.156s, table=0, n_packets=32, n_bytes=3312, priority=1,ip,nw_dst=10.0.0.0/8 actions=output:"s3-eth1"
cookie=0x0, duration=510.109s, table=0, n_packets=0, n_bytes=0, priority=0,ip,nw_dst=230.0.0.0/8 actions=output:"s3-eth2"
cookie=0x0, duration=911.773s, table=0, n_packets=62, n_bytes=4650, priority=0 actions=CONTROLLER:65535
```

Send GET request:

Run `java Subscriber g`
Before deleting the subscription for sub1

```
root@sdnfp04:~/ex4# java Subscriber g
Executing... curl -X GET http://10.10.10.10:8080/subscriptions/json
{"sub4":[{"udp_port":50004,"filter_enable":true,"type":0,"reference_value":50,"i
s_greater":true}],"sub2":[{"udp_port":50002,"filter_enable":true,"type":1,"refer
ence_value":100,"is_greater":false}],"sub3":[{"udp_port":50003,"filter_enable":t
rue,"type":0,"reference_value":1,"is_greater":false}],"sub1":[{"udp_port":50001,
"filter_enable":true,"type":1,"reference_value":150,"is_greater":true}]}
```

After deleting the subscription for sub1

```
root@sdnfp04:~/ex4# java Subscriber g
Executing... curl -X GET http://10.10.10.10:8080/subscriptions/json
{"sub4":[{"udp_port":50004,"filter_enable":true,"type":0,"reference_value":50,"i
s_greater":true}],"sub2":[{"udp_port":50002,"filter_enable":true,"type":1,"refer
ence_value":100,"is_greater":false}],"sub3":[{"udp_port":50003,"filter_enable":t
rue,"type":0,"reference_value":1,"is_greater":false}]}
```