

EE533 Lab4 Team 6

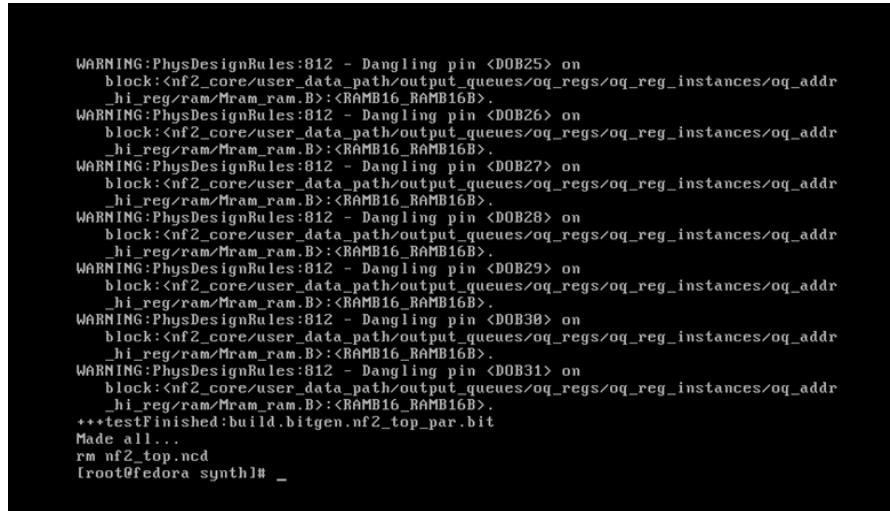
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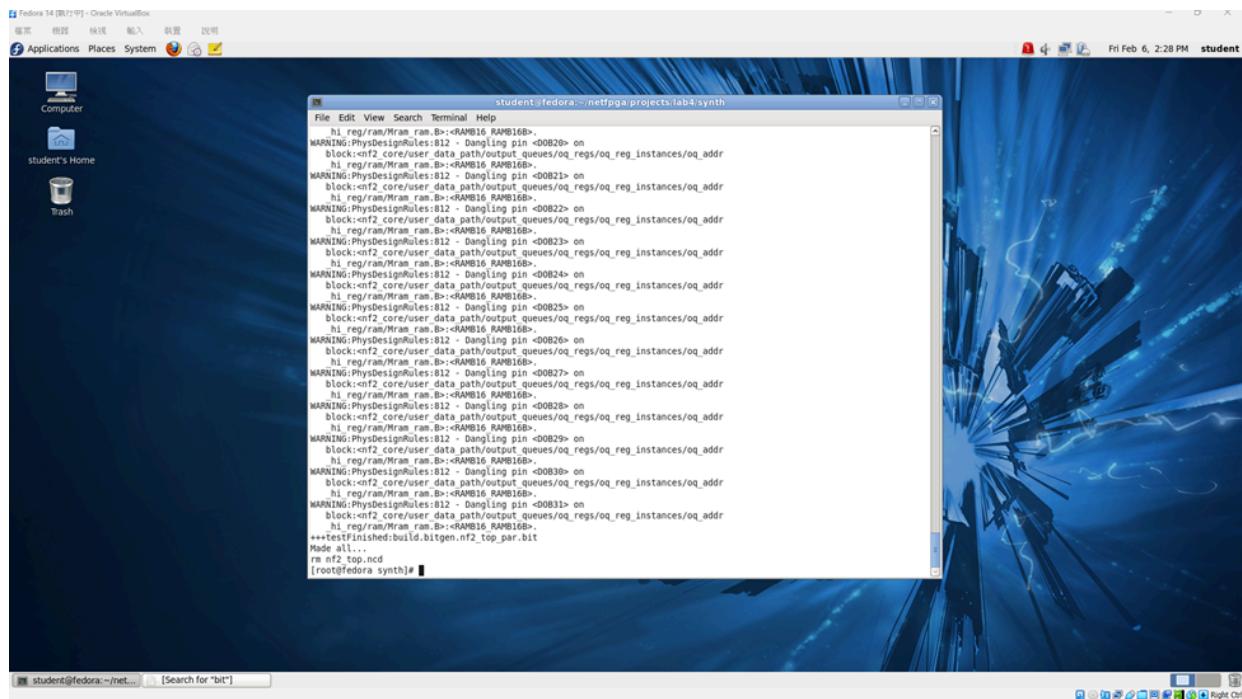
Github:https://github.com/rita0128/EE533_LAB4

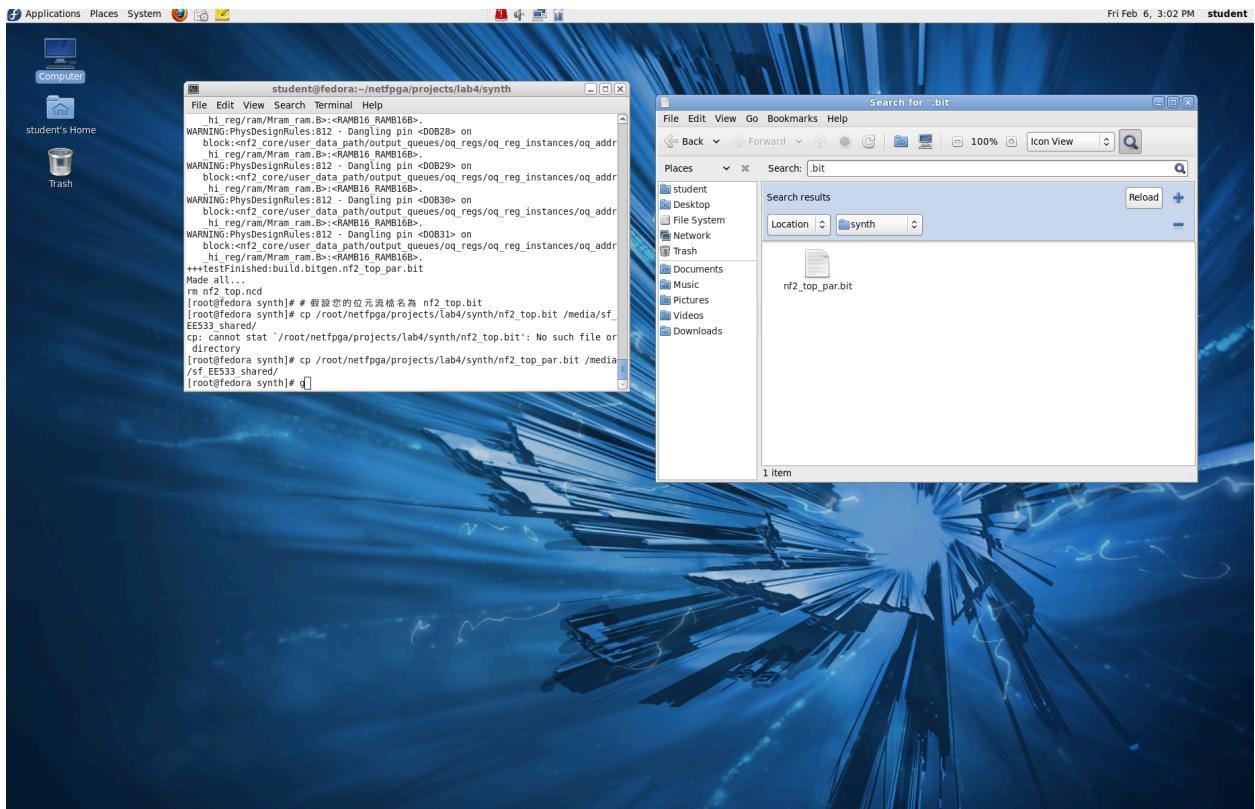
1. Set up NetFPGA Tool Virtual Machine



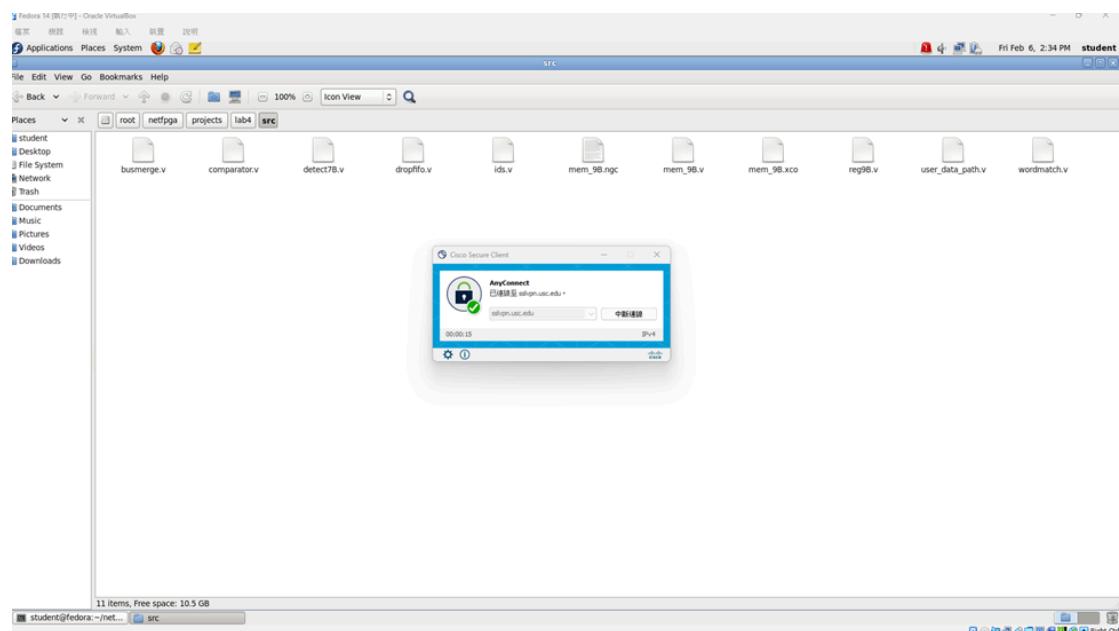
```
WARNING:PhysDesignRules:812 - Dangling pin <DOB25> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB26> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB27> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB28> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB29> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB30> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
WARNING:PhysDesignRules:812 - Dangling pin <DOB31> on
    block:<nf2_core/user_data_path/output_queues/oq_regs/oq_reg_instances/oq_addr
    _hi_reg/ram/Mram_ram.B>:<RAMB16_RAMB16B>.
++testFinished:build.bitgen.nf2_top.par.bit
Made all...
rm nf2_top.ncd
[root@fedora synth]# _
```

2. Compile and generate a design bitfile for NetFPGA



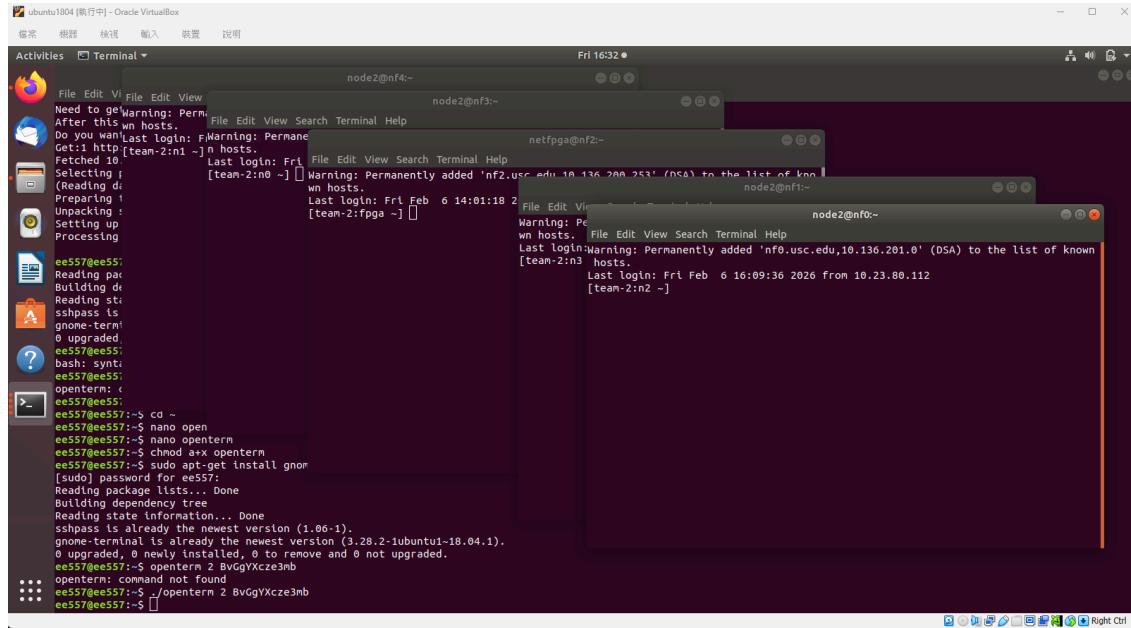


3. Set up VPN to USC

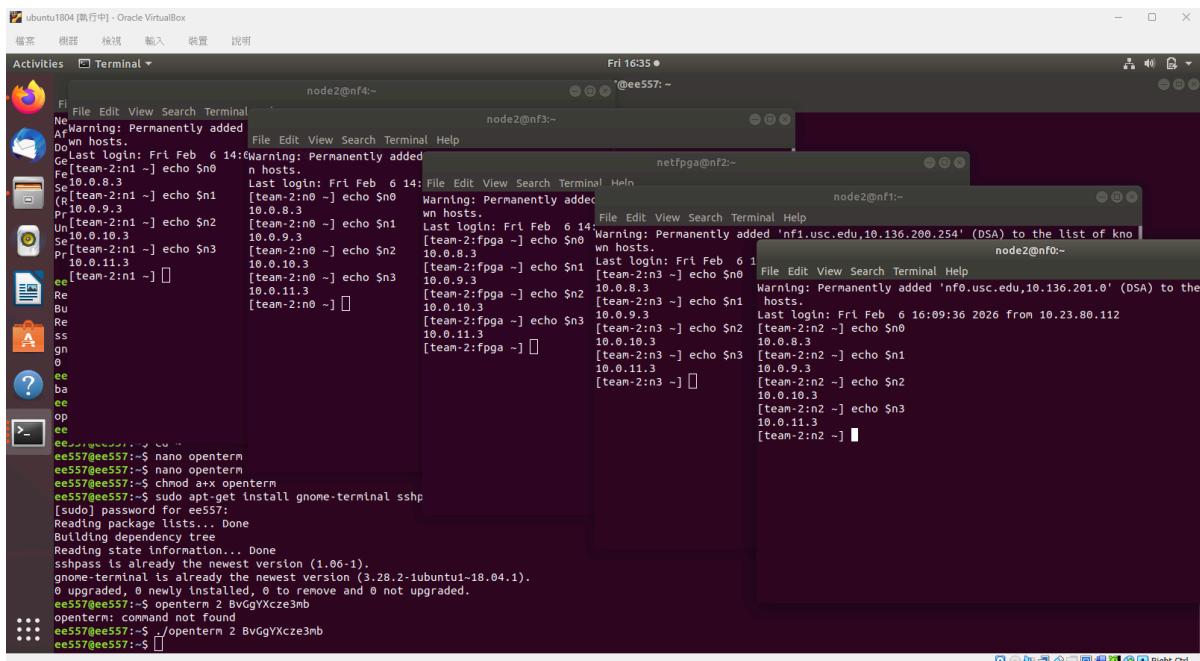


4. NetFPGA Environment

- a. execute openterm with our team number and the corresponding password



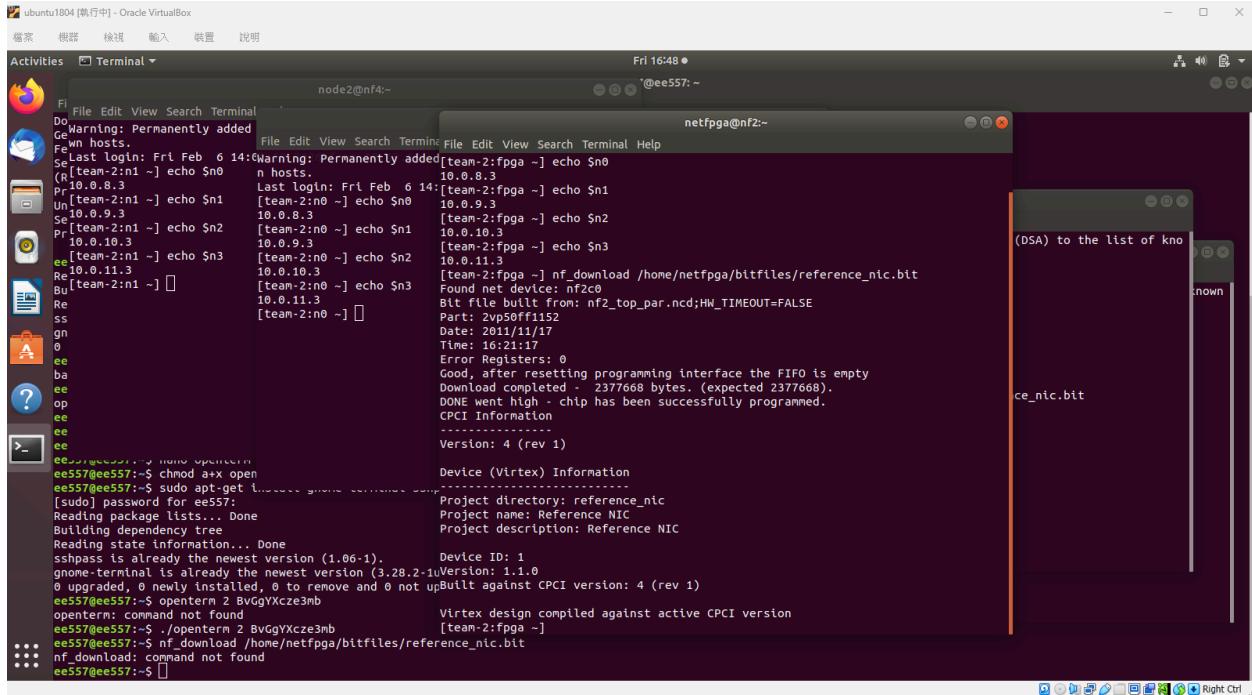
b. Type “echo ” command to see the IP addresses for the nodes 0 through 3



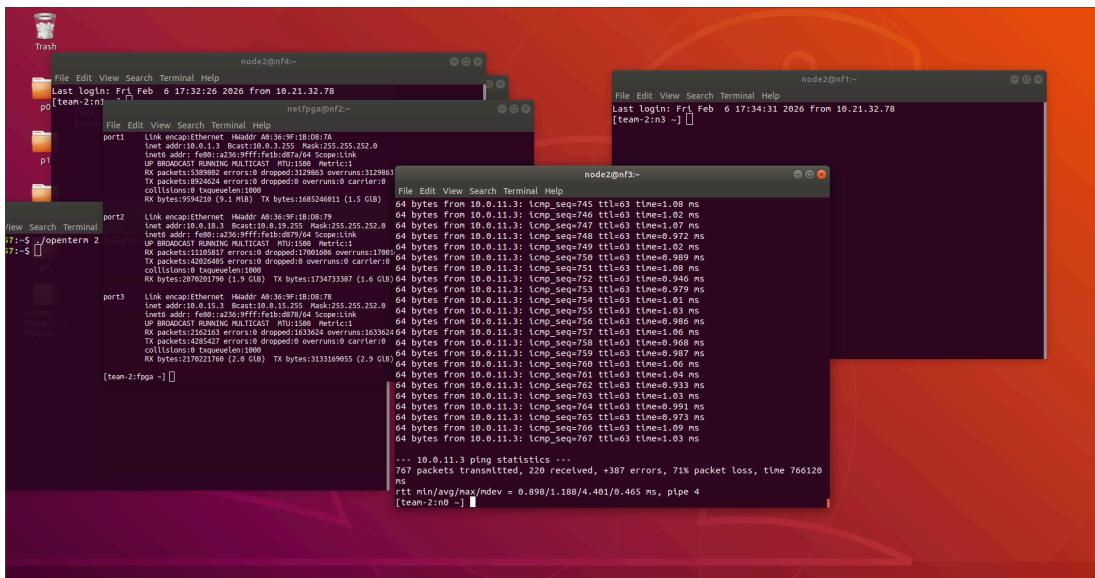
5. NetFPGA-based Linux Kernel IP Router

a. On FPGA node, run the command: > nf_download

/home/netfpga/bitfiles/reference_nic.bit



b. From n0, we ping n3 by typing “ping \$n3”



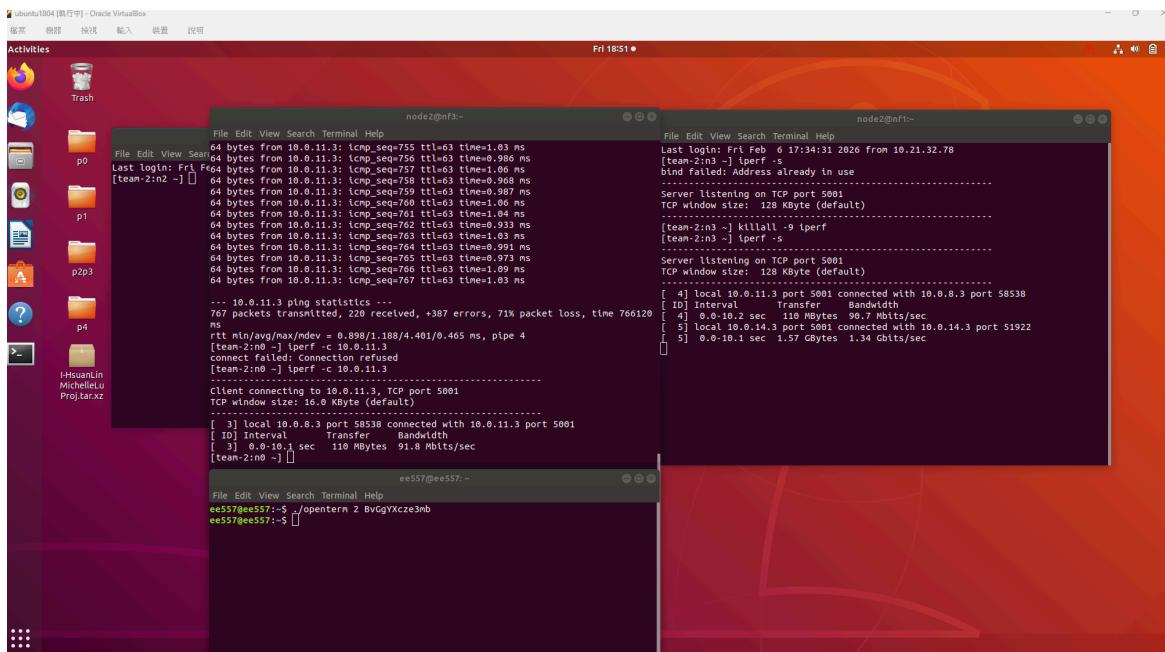
Here we found that it takes a few minutes to send the package successfully, the initial attempts would be lost.

6. NetFPGA Hardware IP Router

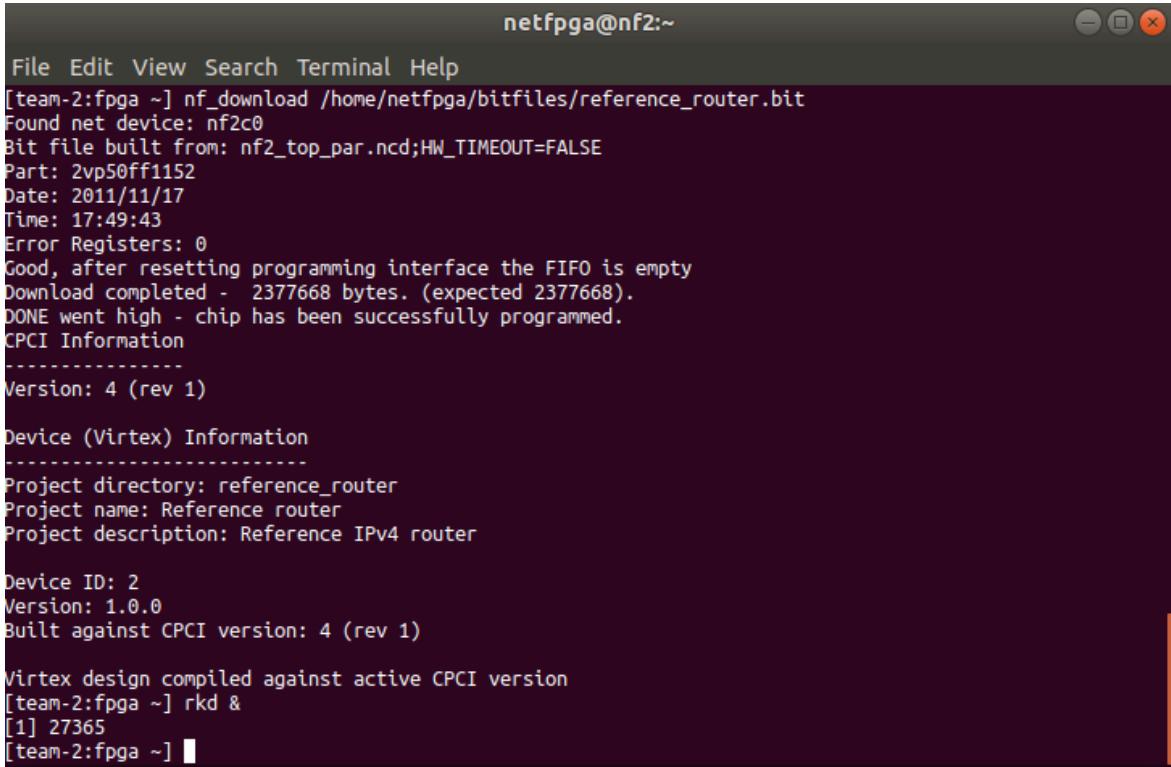
a. Load the reference router into the NetFPGA

Q: What does the reference router do? How should this help?

A: This reference router is a fully functional router on IPv4, it addresses the packets like the hardware circuit. (means CPU doesn't involve the packet processing, avoid the bottleneck problem of the CPU)



b. Run the following command on the FPGA node. > rkd &



```
netfpga@nf2:~
```

```
File Edit View Search Terminal Help
[team-2:fpga ~] nf_download /home/netfpga/bitfiles/reference_router.bit
Found net device: nf2c0
Bit file built from: nf2_top_par.ncd;HW_TIMEOUT=FALSE
Part: 2vp50ff1152
Date: 2011/11/17
Time: 17:49:43
Error Registers: 0
Good, after resetting programming interface the FIFO is empty
Download completed - 2377668 bytes. (expected 2377668).
DONE went high - chip has been successfully programmed.
CPCI Information
-----
Version: 4 (rev 1)

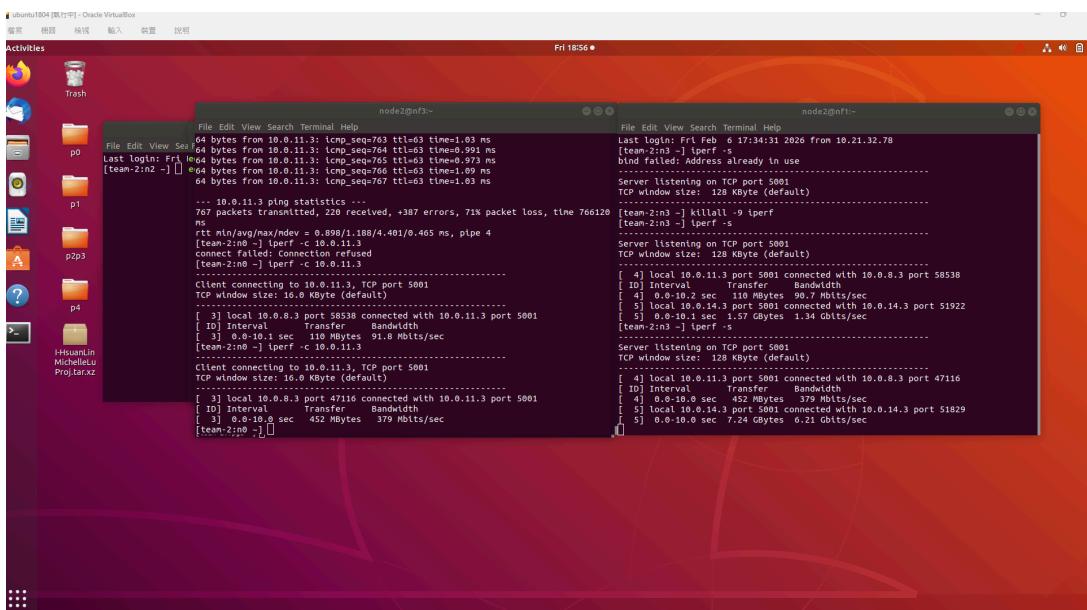
Device (Virtex) Information
-----
Project directory: reference_router
Project name: Reference router
Project description: Reference IPv4 router

Device ID: 2
Version: 1.0.0
Built against CPCI version: 4 (rev 1)

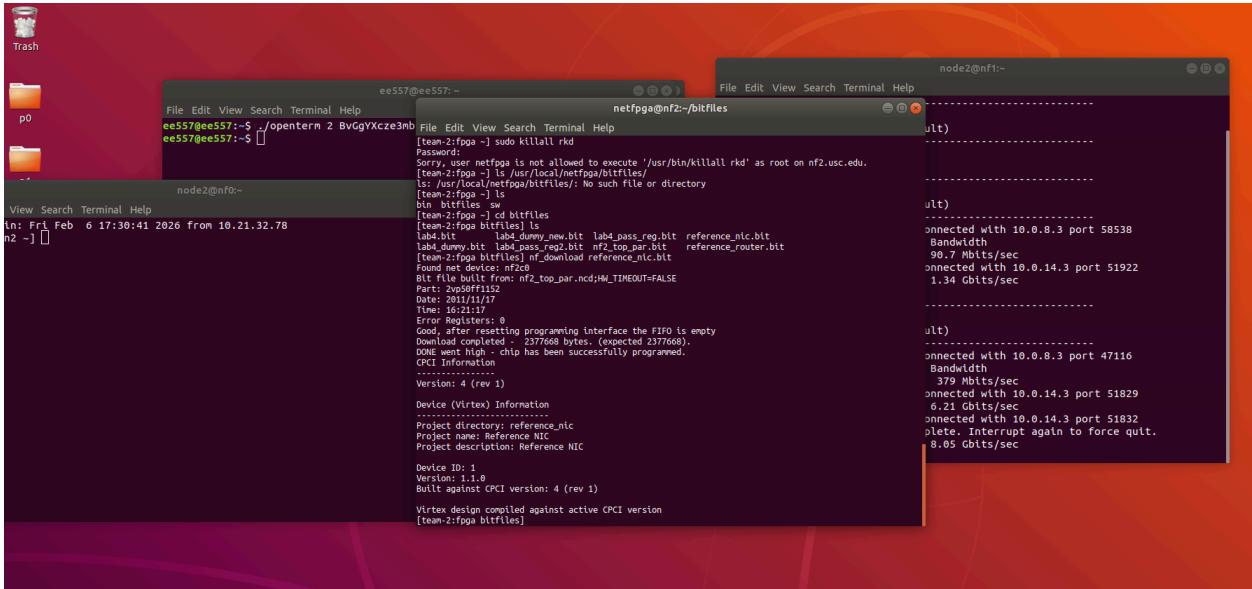
Virtex design compiled against active CPCI version
[team-2:fpga ~] rkd &
[1] 27365
[team-2:fpga ~] 
```

c. re-run iperf test (bandwidth become bigger)

Because of using the Hardware Routing. The packet forwarding logic is handled entirely by the FPGA hardware.

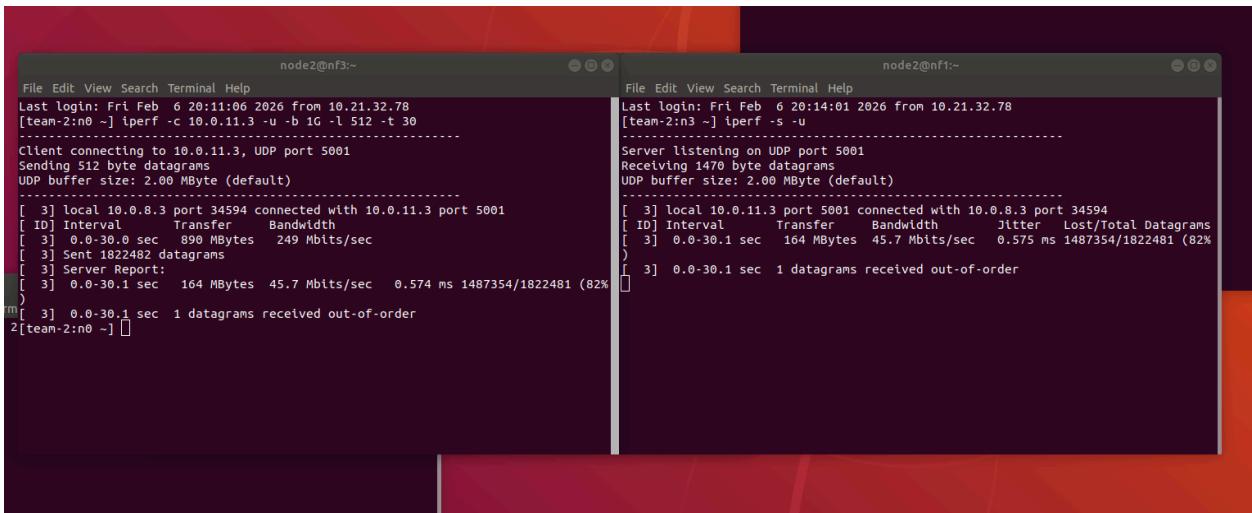


d. Entering > sudo killall rkd , > nf download /usr/local/netfpga/bitfiles/reference_nic.bit



e. Launch an iperf server in UDP mode on each node(512k bytes and 30 seconds)

N0 TO N3



N3 TO N0

The screenshot shows two terminal windows side-by-side. Both are titled 'node2@nf3:~'. The left window displays the client's perspective, showing a connection to '10.0.11.3' via UDP port 5001. The right window displays the server's perspective, showing a connection from '10.0.11.3' via UDP port 5001. Both windows show performance metrics over a 30-second interval, including bandwidth, jitter, and lost datagrams.

```
File Edit View Search Terminal Help
Client connecting to 10.0.11.3, UDP port 5001
Sending 512 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.8.3 port 34594 connected with 10.0.11.3 port 5001
[ ID] Interval Transfer Bandwidth
[ 3] 0.0-30.0 sec 899 MBytes 249 Mbits/sec
[ 3] Sent 1822482 datagrams
[ 3] Server Report:
[ 3] 0.0-30.1 sec 164 MBytes 45.7 Mbits/sec 0.574 ms 1487354/1822481 (82%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n0 -] iperf -s -u

File Edit View Search Terminal Help
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.11.3 port 5001 connected with 10.0.8.3 port 34594
[ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[ 3] 0.0-30.0 sec 895 MBytes 248 Mbits/sec 0.575 ms 1487354/1822481 (82%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n3 -] iperf -c 10.0.8.3 -u -b 1G -l 512 -t 30

Client connecting to 10.0.8.3, UDP port 5001
Sending 512 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.11.3 port 32957 connected with 10.0.8.3 port 5001
[ ID] Interval Transfer Bandwidth
[ 3] 0.0-30.0 sec 885 MBytes 248 Mbits/sec
[ 3] Sent 1813217 datagrams
[ 3] Server Report:
[ 3] 0.0-30.0 sec 261 MBytes 73.0 Mbits/sec 0.049 ms 1279341/1813216 (71%)
[ 3] 0.0-30.0 sec 1 datagrams received out-of-order
[team-2:n3 -]
```

N1TO N2

The screenshot shows two terminal windows side-by-side. Both are titled 'node2@nf4:~'. The left window displays the client's perspective, connecting to '10.0.10.3' via UDP port 5001. The right window displays the server's perspective, connecting from '10.0.10.3' via UDP port 5001. Both windows show performance metrics over a 30-second interval, including bandwidth, jitter, and lost datagrams.

```
File Edit View Search Terminal Help
Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.9.3 port 5001 connected with 10.0.10.3 port 39567
[ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[ 3] 0.0-30.1 sec 199 MBytes 55.6 Mbits/sec 0.504 ms 1407881/1815499 (78%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n1 -] iperf -c 10.0.10.3 -u -b 1G -l 512 -t 30

Client connecting to 10.0.10.3, UDP port 5001
Sending 512 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.9.3 port 41717 connected with 10.0.10.3 port 5001
[ ID] Interval Transfer Bandwidth
[ 3] 0.0-30.0 sec 886 MBytes 248 Mbits/sec
[ 3] Sent 1814804 datagrams
[ 3] Server Report:
[ 3] 0.0-30.0 sec 258 MBytes 72.3 Mbits/sec 0.589 ms 1285559/1814803 (71%)
[ 3] 0.0-30.0 sec 1 datagrams received out-of-order
[team-2:n1 -]

File Edit View Search Terminal Help
Client connecting to 10.0.9.3, UDP port 5001
Sending 512 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.10.3 port 5001 connected with 10.0.9.3 port 41717
[ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[ 3] 0.0-30.0 sec 886 MBytes 248 Mbits/sec 0.504 ms 1407881/1815499 (78%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n2 -] iperf -s -u

Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.10.3 port 5001 connected with 10.0.9.3 port 41717
[ ID] Interval Transfer Bandwidth
[ 3] 0.0-30.0 sec 886 MBytes 248 Mbits/sec
[ 3] Sent 1815500 datagrams
[ 3] Server Report:
[ 3] 0.0-30.0 sec 199 MBytes 55.6 Mbits/sec 0.504 ms 1407881/1815499 (78%)
[ 3] 0.0-30.0 sec 1 datagrams received out-of-order
[team-2:n2 -]
```

N2 TO N1

The screenshot shows two terminal windows side-by-side. Both are titled 'node2@nf4:~'. The left window displays the client's perspective, connecting to '10.0.9.3' via UDP port 5001. The right window displays the server's perspective, connecting from '10.0.9.3' via UDP port 5001. Both windows show performance metrics over a 30-second interval, including bandwidth, jitter, and lost datagrams.

```
File Edit View Search Terminal Help
Last login: Fri Feb 6 20:11:56 2026 from 10.21.32.78
[team-2:n1 -] iperf -s -u

Server listening on UDP port 5001
Receiving 1470 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.9.3 port 5001 connected with 10.0.10.3 port 39567
[ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[ 3] 0.0-30.1 sec 199 MBytes 55.6 Mbits/sec 0.504 ms 1407881/1815499 (78%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n1 -]

File Edit View Search Terminal Help
Last login: Fri Feb 6 20:10:11 2026 from 10.21.32.78
[team-2:n2 -] iperf -c 10.0.9.3 -u -b 1G -l 512 -t 30

Client connecting to 10.0.9.3, UDP port 5001
Sending 512 byte datagrams
UDP buffer size: 2.00 MByte (default)
[ 3] local 10.0.10.3 port 39567 connected with 10.0.9.3 port 5001
[ ID] Interval Transfer Bandwidth
[ 3] 0.0-30.0 sec 886 MBytes 248 Mbits/sec
[ 3] Sent 1815500 datagrams
[ 3] Server Report:
[ 3] 0.0-30.1 sec 199 MBytes 55.6 Mbits/sec 0.504 ms 1407881/1815499 (78%)
[ 3] 0.0-30.1 sec 1 datagrams received out-of-order
[team-2:n2 -]
```

N0-N4 SEND AT THE SAME TIME(through NetFPGA)

```
[team2:nf1 -] node2@nf1:~  
File Edit View Search Terminal Help  
[team2:nf1 -] Server listening on UDP port 5001  
Receiving 1470 byte datagrams  
UDP buffer size: 2.00 MByte (default)  
iperf -c 10.0.10.3 -u -b 1G -l 512 -t 30  
Client connecting to 10.0.10.3, UDP port 5001  
Sending 512 byte datagrams  
UDP buffer size: 2.00 MByte (default)  
[team2:nf1 -] [team2:nf1 -]  
[ 3 ] Local 10.0.9.3 port 38242 connected with 10.0.10.3 port 5001  
[ ID ] Interval Transfer Bandwidth  
[ 3 ] 0.0-30.1 sec 885 MBytes 247 Mbytes/sec  
[ 3 ] Sent 1809918 datagrams  
[ 3 ] Server Report:  
[ 3 ] 0.0-30.1 sec 257 MBytes 71.7 Mbytes/sec 9.537 ms 1285304/1812608 (71%)  
[ 3 ] 0.0-30.1 sec 1 datagrams received out-of-order  
[ 3 ] 0.0-30.1 sec 1 datagrams received out-of-order  
[ 3 ] Local 10.0.9.3 port 38242 connected with 10.0.10.3 port 5001  
[ ID ] Interval Transfer Bandwidth Jitter Lost/Total Datagrams  
[ 3 ] 0.0-30.2 sec 886 MBytes 248 Mbytes/sec 71.7 Mbytes/sec 9.537 ms 1285304/1812608 (71%)  
[ 3 ] 0.0-30.2 sec 1 datagrams received out-of-order  
[ 3 ] 0.0-30.2 sec 1 datagrams received out-of-order  
[team2:nf1 -] [team2:nf1 -]  
[team2:nf2 -] node2@nf2:~  
File Edit View Search Terminal Help  
[team2:nf2 -] Server listening on UDP port 5001  
Receiving 1470 byte datagrams  
UDP buffer size: 2.00 MByte (default)  
[team2:nf2 -] [team2:nf2 -]  
[ 3 ] Local 10.0.9.3 port 38242 connected with 10.0.9.3 port 38242  
[ ID ] Interval Transfer Bandwidth Jitter Lost/Total Datagrams  
[ 3 ] 0.0-30.1 sec 257 MBytes 71.7 Mbytes/sec 9.537 ms 1285304/1812608 (71%)  
[ 3 ] 0.0-30.1 sec 1 datagrams received out-of-order  
iperf -c 10.0.9.3 -u -b 1G -l 512 -t 30  
Client connecting to 10.0.9.3, UDP port 5001  
Sending 512 byte datagrams  
UDP buffer size: 2.00 MByte (default)  
[team2:nf2 -] [team2:nf2 -]  
[team2:nf3 -] node2@nf3:~  
File Edit View Search Terminal Help  
[team2:nf3 -] Server listening on UDP port 5001  
Receiving 1470 byte datagrams  
UDP buffer size: 2.00 MByte (default)  
[team2:nf3 -] [team2:nf3 -]  
[ 3 ] Local 10.0.9.3 port 38242 connected with 10.0.9.3 port 38242  
[ ID ] Interval Transfer Bandwidth Jitter Lost/Total Datagrams  
[ 3 ] 0.0-30.0 sec 884 MBytes 247 Mbytes/sec  
[ 3 ] Sent 1809918 datagrams  
[ 3 ] Server Report:  
[ 3 ] 0.0-30.2 sec 144 MBytes 40.1 Mbytes/sec 5.869 ms 1514033/1809916 (84%)  
[team2:nf3 -] [team2:nf3 -]
```

The screenshot shows two terminal windows side-by-side. The left window is titled 'node2@nf3-' and the right window is titled 'node2@nf2-'. Both windows show the output of an iPerf test. The test details are as follows:

- Protocol:** UDP
- Port:** 5001
- Bandwidth:** 2.00 MByte (default)
- Server IP:** 10.0.11.3
- Client IP:** 10.0.11.3
- Test Duration:** 0.0-30.0 sec
- Throughput:** 874 MBytes / 244 Mbit/s
- Datagrams Sent:** 1788978
- Warning:** did not receive ack of last datagram after 10 tries.

The right terminal window shows a similar test, but with a higher bandwidth of 2.80 MByte (default) and a higher throughput of 898 MBytes / 249 Mbit/s. The warning message is also present.

Below the main terminal windows, there are several smaller windows showing network traffic analysis using Wireshark. One window is titled 'netfpga@nf2-' and another is titled 'node2@nf1-'. These windows display raw network traffic, including captured frames and their details.

Q: Why does using small packets stress the system?

A: Because of the overhead of processing a packet. Interrupts, PCI transactions, OS kernel routing lookups are per-packet, not per-byte

f. Load the reference router.bit file again and start the rkd daemon

```
node2@nf4:~$ iperf -c 10.0.10.3 -u -b 1G -l 512 -t 30
[team:2:n1 ~] [ 3] local 10.0.10.3 port 5001 connected with 10.0.10.3 port 5001
[team:2:n1 ~] [ 3] Server listening on UDP port 5001
[team:2:n1 ~] [ 3] Recieving 1470 byte datagrams
[team:2:n1 ~] [ 3] UDP buffer size: 2.00 MByte (default)
[team:2:n1 ~] [ 3] Client connecting to 10.0.10.3, UDP port 5001
[team:2:n1 ~] [ 3] Sending 512 byte datagrams
[team:2:n1 ~] [ 3] UDP buffer size: 2.00 MByte (default)
[team:2:n1 ~] [ 3] local 10.0.9.3 port 38242 connected with 10.0.10.3 port 5001
[team:2:n1 ~] [ 3] [ ID] Interval Transfer Bandwidth
[team:2:n1 ~] [ 3] [ 0..0..30.0 sec 885 MBbytes 247 Mbit/sec
[team:2:n1 ~] [ 3] Sent 1812660 datagrams
[team:2:n1 ~] [ 3] Server Report:
[team:2:n1 ~] [ 3] [ 0..0..30.1 sec 257 MBBytes 71.7 Mbit/sec 9.537 ms 1285304/1812600 (71%)
[team:2:n1 ~] [ 3] [ 0..0..30.1 sec 1 datagrams received out-of-order
[team:2:n1 ~] [ 3] local 10.0.9.3 port 5001 connected with 10.0.10.3 port 53863
[team:2:n1 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n1 ~] [ 3] [ 0..0..30.2 sec 144 MBbytes 48.1 Mbit/sec 5.870 ms 1514033/1809916 (84%)
[team:2:n1 ~] [ 3]
[team:2:n1 ~] [ 3]

[team:2:n1 ~] [ 3] local 10.0.11.3 port 36313 connected with 10.0.11.3 port 5001
[team:2:n1 ~] [ 3] local 10.0.11.3 port 5001 connected with 10.0.11.3 port 38785
[team:2:n1 ~] [ 3] [ ID] Interval Transfer Bandwidth
[team:2:n1 ~] [ 3] [ 0..0..30.0 sec 868 MBBytes 243 Mbit/sec
[team:2:n1 ~] [ 3] Sent 1777110 datagrams
[team:2:n1 ~] [ 3] Server Report:
[team:2:n1 ~] [ 3] [ 0..0..30.2 sec 133 MBBytes 37.0 Mbit/sec 0.732 ms 1508407/1777109 (85%)
[team:2:n1 ~] [ 3] [ 0..0..30.2 sec 1 datagrams received out-of-order
[team:2:n1 ~] [ 3] local 10.0.11.0 port 38705 connected with 10.0.11.3 port 5001
[team:2:n1 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n1 ~] [ 3] [ 0..0..30.1 sec 136 MBBytes 37.8 Mbit/sec 0.621 ms 1536391/1814105 (85%)
[team:2:n1 ~] [ 3] [ 0..0..30.1 sec 1 datagrams received out-of-order
[team:2:n1 ~] [ 3]

[team:2:n0 ~] [ 3]

node2@nf2:~$ iperf -c 10.0.9.3 -u -b 1G -l 512 -t 30
[team:2:n2 ~] [ 3] local 10.0.10.3 port 5001 connected with 10.0.9.3 port 38242
[team:2:n2 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n2 ~] [ 3] [ 0..0..30.1 sec 257 MBBytes 71.7 Mbit/sec 9.537 ms 1285304/1812600 (71%)
[team:2:n2 ~] [ 3] [ 0..0..30.1 sec 1 datagrams received out-of-order
[team:2:n2 ~] [ 3] Client connecting to 10.0.9.3, UDP port 5001
[team:2:n2 ~] [ 3] Sending 512 byte datagrams
[team:2:n2 ~] [ 3] UDP buffer size: 2.00 MByte (default)
[team:2:n2 ~] [ 3] local 10.0.10.3 port 53863 connected with 10.0.9.3 port 5001
[team:2:n2 ~] [ 3] [ ID] Interval Transfer Bandwidth
[team:2:n2 ~] [ 3] [ 0..0..30.0 sec 884 MBBytes 247 Mbit/sec
[team:2:n2 ~] [ 3] Sent 1809918 datagrams
[team:2:n2 ~] [ 3] Server Report:
[team:2:n2 ~] [ 3] [ 0..0..30.2 sec 144 MBBytes 40.1 Mbit/sec 5.869 ms 1514033/1809916 (84%)
[team:2:n2 ~] [ 3]
[team:2:n2 ~] [ 3]

[team:2:n2 ~] [ 3] local 10.0.11.3 port 36313 connected with 10.0.8.3 port 36313
[team:2:n2 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n2 ~] [ 3] [ 0..0..30.2 sec 133 MBBytes 37.6 Mbit/sec 0.732 ms 1508407/36313 (85%)
[team:2:n2 ~] [ 3] [ 0..0..30.2 sec 1 datagrams received out-of-order
[team:2:n2 ~] [ 3] Client connecting to 10.0.8.3, UDP port 5001
[team:2:n2 ~] [ 3] Sending 512 byte datagrams
[team:2:n2 ~] [ 3] UDP buffer size: 2.00 MByte (default)
[team:2:n2 ~] [ 3] local 10.0.11.3 port 38705 connected with 10.0.8.3 port 5001
[team:2:n2 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n2 ~] [ 3] [ 0..0..30.2 sec 133 MBBytes 37.6 Mbit/sec 0.732 ms 1508407/1777109 (85%)
[team:2:n2 ~] [ 3] [ 0..0..30.2 sec 1 datagrams received out-of-order
[team:2:n2 ~] [ 3] local 10.0.11.0 port 38705 connected with 10.0.8.3 port 5001
[team:2:n2 ~] [ 3] [ ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[team:2:n2 ~] [ 3] [ 0..0..30.1 sec 136 MBBytes 37.8 Mbit/sec 0.621 ms 1536391/1814105 (85%)
[team:2:n2 ~] [ 3] [ 0..0..30.1 sec 1 datagrams received out-of-order
[team:2:n2 ~] [ 3]

[team:2:n0 ~] [ 3]
```