System Administration and IP Services

Performance Definitions and Measurement

Metrics

Network performance metrics

- Channel capacity, nominal & effective
- Channel utilization
- Delay and *jitter*
- Packet loss and errors

Nominal Channel Capacity

The maximum number of bits that can be transmitted on a unit of time (eg: bits per second)

Depends on:

- Bandwidth of the physical medium
  - Cable
  - Electromagnetic waves
- Processing capacity for each transmission element
- Efficiency of algorithms in use to access medium
- Channel encoding and compression

Effective Channel Capacity

Always a fraction of the nominal channel capacity

Dependent on:

- Additional overhead of protocols in each layer
- Device limitations on both ends
  - Flow control algorithm efficiency, etc.
    - For example: TCP

Channel Utilization

What fraction of the nominal channel capacity is actually in use

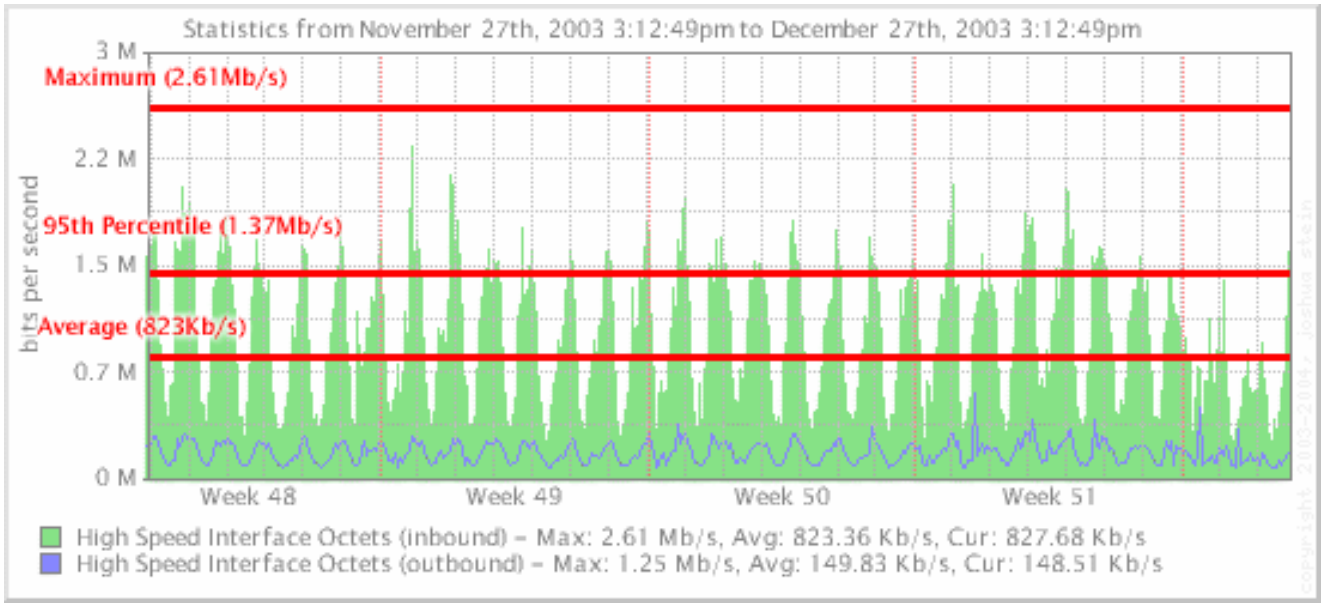
Important!

- Future planning
  - What utilization growth rate am I seeing?
  - For when should I plan on buying additional capacity?
  - Where should I invest for my updates?
- Problem resolution
  - Where are my bottlenecks, etc.

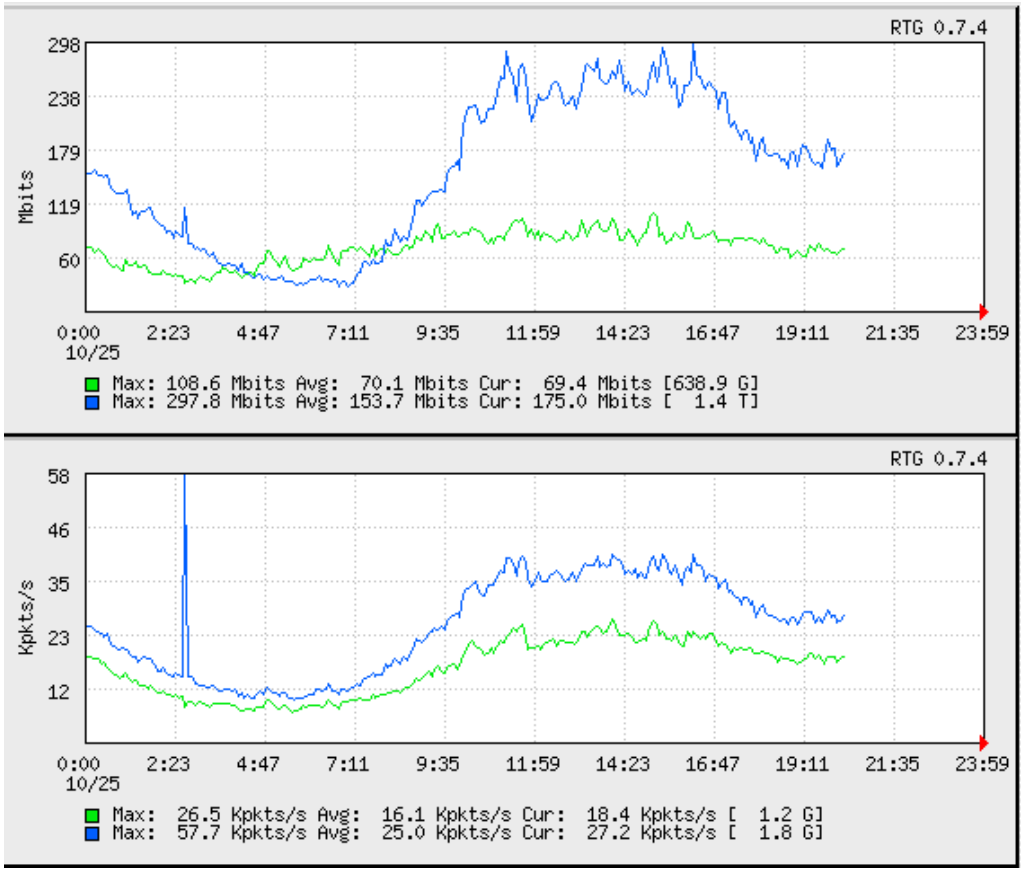
95th Percentile

- The smallest value that is larger than 95% of the values in a given sample
- This means that 95% of the time the channel utilization is equal to or *less* than this value
  - Or rather, the peaks are discarded from consideration
- Why is this important in networks?
  - Gives you an idea of the standard, sustained channel utilization.
  - ISPs use this measure to bill customers with "larger" connections.

95th Percentile



Bits per second vs Packets p.s.



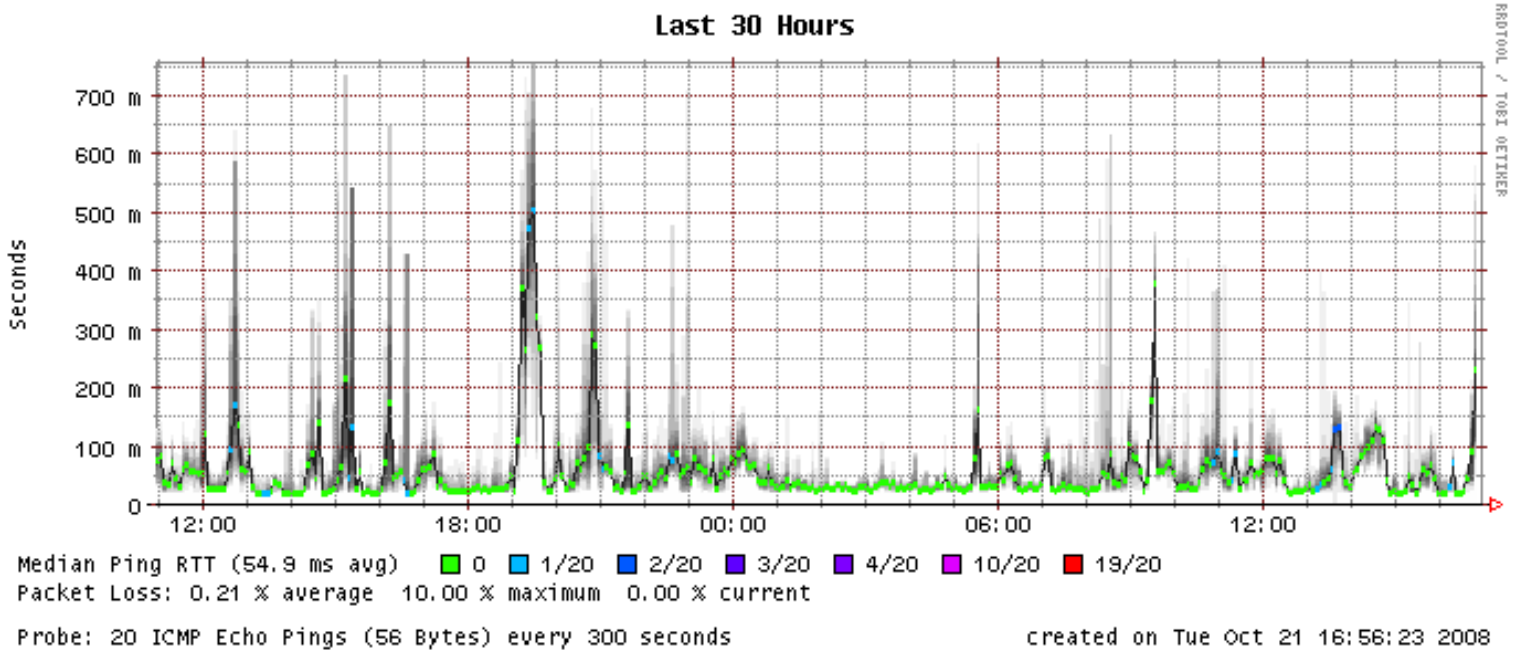
End-to-end Delay

The time required to transmit a packet along its entire path

- *Created by an application, handed over to the OS, passed to a network card (NIC), encoded, transmitted over a physical medium (copper, fibre, air), received by an intermediate device (switch, router), analyzed, retransmitted over another medium, etc.*

- The most common measurement uses *ping* for total round-trip-time (RTT).

Historical Measurement of Delay



Types of Delay

Causes of end-to-end delay:

- Processing delays
- Buffer delays
- Transmission delays
- Propagation delays

Processing Delay

Required time to analyze a packet header and decide where to send the packet (e.g. a routing decision)

Inside a router this depends on the number of entries in the routing table, the implementation of data structures, hardware in use, etc.

This can include error verification, such as IPv4, IPv6 header checksum calculations.

Queuing Delay

- The time a packet is enqueued until it is transmitted
- The number of packets waiting in the queue will depend on traffic intensity and of the type of traffic (bursty or sustained)
- Router queue algorithms try to adapt delays to specific preferences, or impose equal delay on all traffic.

Transmission Delay

The time required to push all the bits in a packet on the transmission medium in use

For N=Number of bits, S=Size of packet, d=delay

d = S/N

For example, to transmit 1024 bits using Fast Ethernet (100Mbps):

d = 1024/1x10e8 = 10.24 micro seconds

Propagation Delay

- Once a bit is 'pushed' on to the transmission medium, the time required for the bit to propagate to the end of its physical trajectory
- The velocity of propagation of the circuit depends mainly on the actual distance of the physical circuit
- In the majority of cases this is close to the speed of light.

  For d = distance, s = propagation velocity

  PD = d/s

Transmission vs. Propagation

Can be confusing at first

Consider this example:

Two 100 Mbps circuits

- 1 km of optic fiber
- Via satellite with a distance of 30 km between the base and the satellite

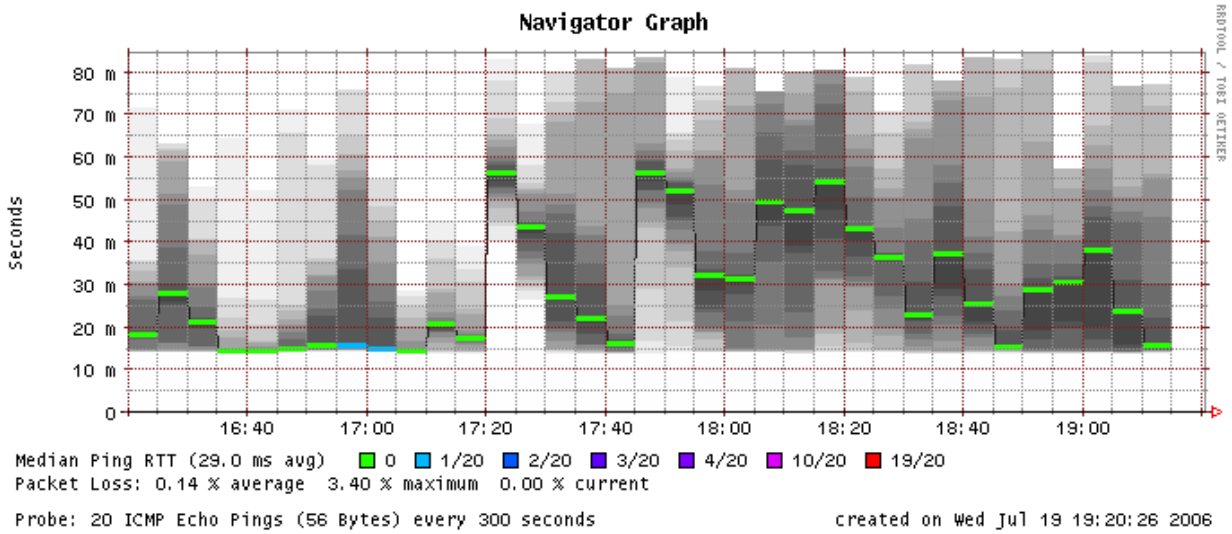
For two packets of the same size which will have the larger transmission delay? Propagation delay?

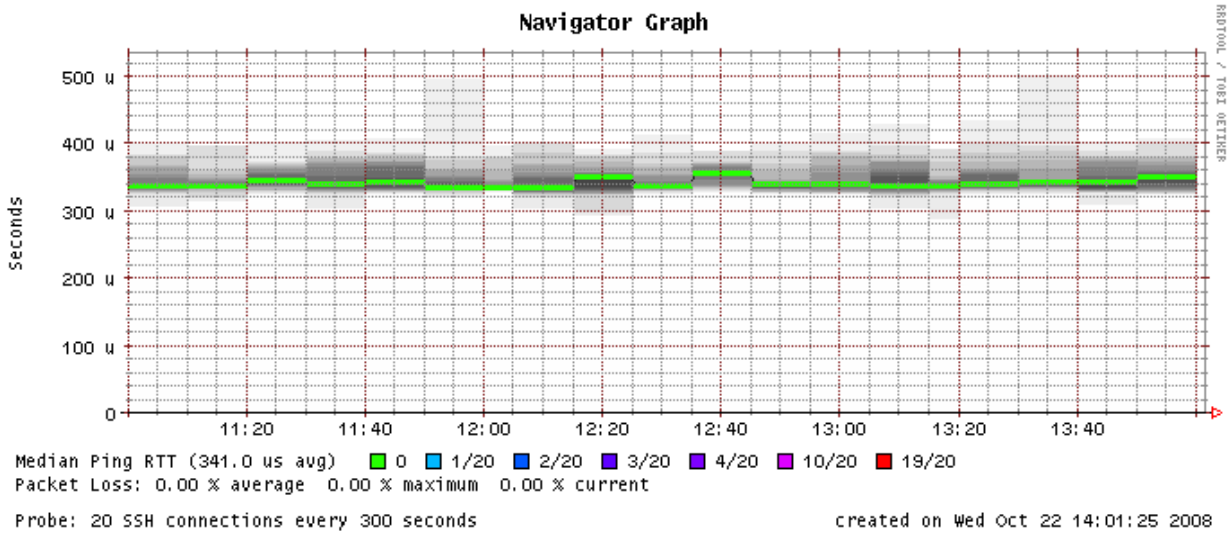
Packet Loss

Occurs due to the fact that buffers are not infinite in size

- When a packet arrives to a buffer that is full the packet is discarded.
- Packet loss, if it must be corrected, is resolved at higher levels in the network stack (transport or application layers)
- Loss correction using retransmission of packets can cause yet more congestion if some type of (flow) control is not used (to inform the source that it's pointless to keep sending more packets at the present time)

Jitter


Navigator Graph
Seconds
80 m
70 m
60 m
50 m
40 m
30 m
20 m
10 m
0
16:40
17:00
17:20
17:40
18:00
18:20
18:40
19:00
Median Ping RTT (29.0 ms avg)
0
1/20
2/20
3/20
4/20
10/20
19/20
Packet Loss: 0.14 % average 3.40 % maximum 0.00 % current
Probe: 20 ICMP Echo Pings (56 Bytes) every 300 seconds
created on Wed Jul 19 19:20:26 2006


Navigator Graph
Seconds
500 u
400 u
300 u
200 u
100 u
0
11:20
11:40
12:00
12:20
12:40
13:00
13:20
13:40
Median Ping RTT (341.0 us avg)
0
1/20
2/20
3/20
4/20
10/20
19/20
Packet Loss: 0.00 % average 0.00 % maximum 0.00 % current
Probe: 20 SSH connections every 300 seconds
created on Wed Oct 22 14:01:25 2008

Questions

?

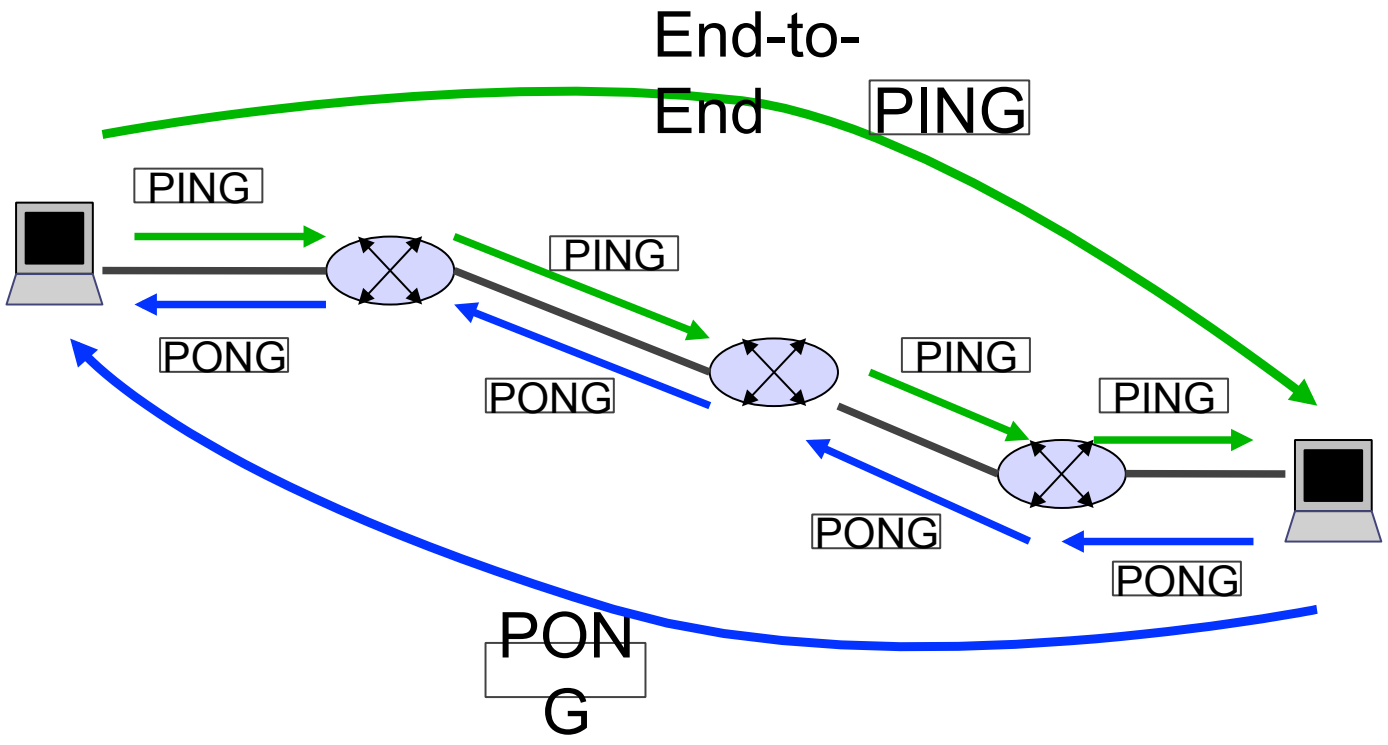
IP End-to-End principle

- IP is an end-to-end protocol
- The network doesn't keep track of connections
- The host takes a decision on where to send *each packet*
- The network equipment takes a decision on where to forward packets *every time*

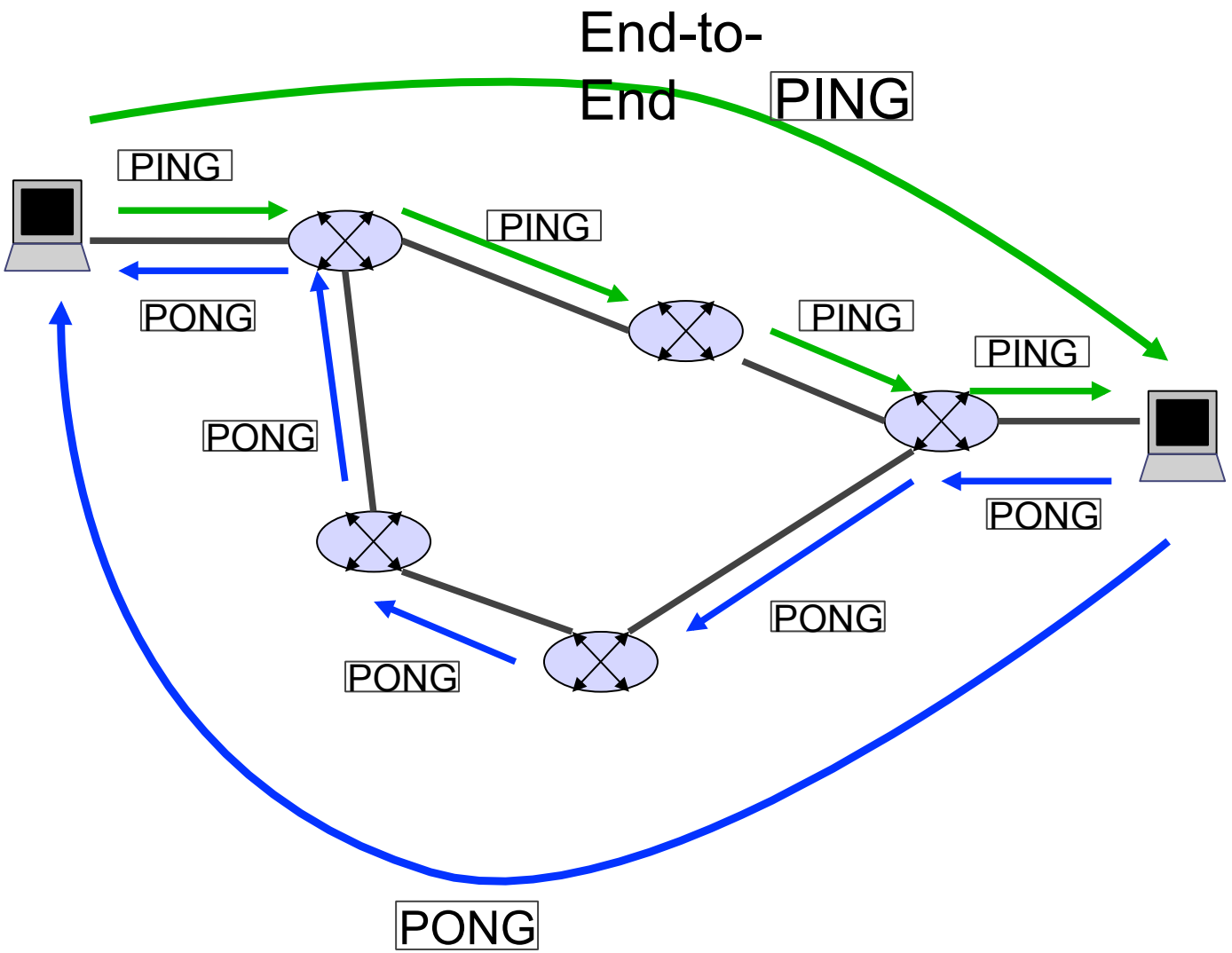
The path is not necessarily symmetric

Cost constraints, reconfiguration of the network, network failures can make the IP packets travel different routes going out and coming back.

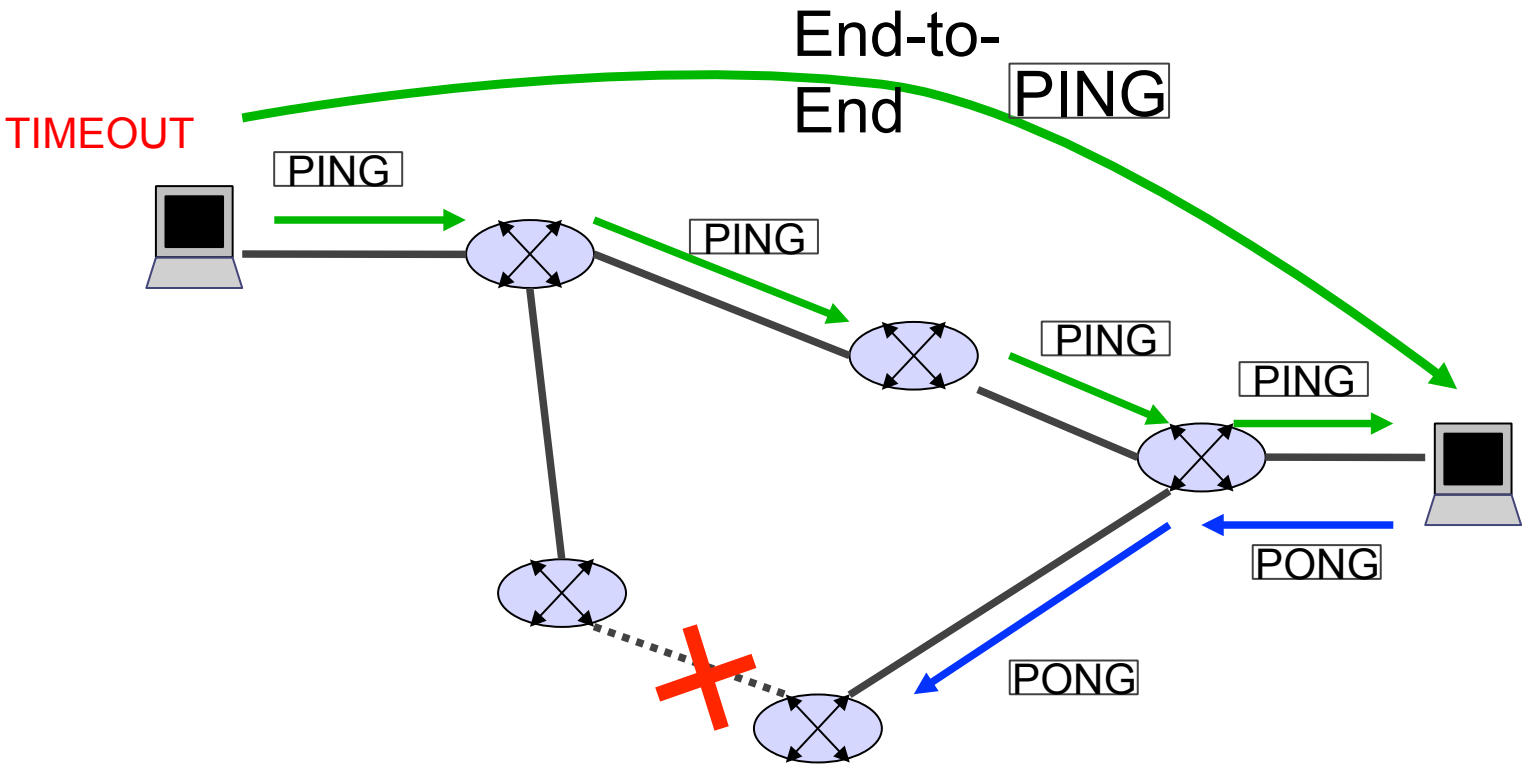
IP path



IP path


End-to-End
PING
PING
PING
PING
PING
PING
PONG
PONG
PONG
PONG
PONG
PONG

IP path



Network configuration

- Done in the file: **/etc/network/interfaces**
- Either static or dynamic (DHCP)

Static

```
# The primary network interface
# nsrc.org
auto eth0
iface eth0 inet static
        address 128.223.157.19
        netmask 255.255.255.128
        network 128.223.157.0
        broadcast 128.223.157.127
        gateway 128.223.157.1
# IPv6 address. This resolves to nsrc.org
iface eth0 inet6 static
        address 2001:0468:0d01:0103:0000:0000:80df:9d13
        netmask 64
        network 2001:468:D01:103::/64
        gateway 2001:468:D01:103::1
```

Network configuration

Dynamic

```
# The primary network interface
# nsrc.org
auto eth0
iface eth0 inet dhcp
```

- Addressing is received from a DHCP server.
- Classroom DHCP server is on noc.
- Can still be “static” if DHCP server knows MAC address

top

- Basic performance tool for Unix/Linux environments
- Periodically show a list of system performance statistics:
  - CPU use
  - RAM and SWAP memory usage
  - Load average (cpu utilization)
  - Information by process

top cont.

- **Information by process (most relevant columns shown):**
  - PID: Process ID
  - USER: user running (owner) of the process
  - %CPU: Percentage of CPU utilization by the process since the last sample
  - %MEM: Percentage of physical memory (RAM) used by the process
  - TIME: Total CPU time used by the process since it was started

top

```
top - 19:45:25 up  4:05,  1 user,  load average: 1.18, 0.94, 0.88
Tasks: 122 total,   2 running, 116 sleeping,   0 stopped,   4 zombie
Cpu(s): 27.7%us, 13.3%sy,  0.2%ni, 58.7%id,  0.0%wa,  0.0%hi,  0.2%si,  0.0%st
Mem:   2052028k total,   612020k used,  1440008k free,    86784k buffers
Swap:  2588668k total,        0k used,  2588668k free,   172348k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
22005 www-data  20   0 39796  13m 5512 S   68  0.7   0:15.72 php
 1033 mysql     20   0  315m  44m 6416 S   15  2.2   4:23.46 mysqld
21964 root      20   0  2836 1132  876 R    1  0.1   0:00.83 top
 1012 dhcpd     20   0  5088 3128 1264 S    0  0.2   0:04.64 dhcpd
 1282 nobody    20   0  5028 3000 2680 S    0  0.1   0:24.16 softflowd
20984 root      20   0 11820 3728 2932 S    0  0.2   0:00.21 sshd
22011 www-data  20   0 40404  13m 5716 S    0  0.7   0:00.58 php
    1 root      20   0  3640 2044 1348 S    0  0.1   0:03.08 init
    2 root      20   0     0    0    0 S    0  0.0   0:00.00 kthreadd
    3 root      20   0     0    0    0 S    0  0.0   0:00.90 ksoftirqd/0
    4 root      20   0     0    0    0 S    0  0.0   0:05.41 kworker/0:0
    6 root      RT   0     0    0    0 S    0  0.0   0:00.00 migration/0
```

Load Average

Average number of active processes in the last 1, 5 and 15 minutes

- A simple yet useful measurement
- Depending on the machine the acceptable range considered to be normal can vary:
  - Multi-processor machines can handle more active processes per unit of time (than single processor machines)

netstat

Show us information about:

- Network connections
- Routing tables
- Interface (NIC) statistics
- Multicast group members

netstat

Some useful options

-n: Show addresses, ports and userids in numeric form

-r: Routing table

-s: Statistics by protocol

-i: Status of interfaces

-l: Listening sockets

--tcp, **--udp**: Specify the protocol

-A: Address family [inet | inet6 | unix | etc.]

-p: Show the name of each process for each port

-c: Show output/results continuously

netstat

Examples (follow along):

```
# netstat -anr
Kernel IP routing table
Destination     Gateway         Genmask         Flags   MSS Window  irtt Iface
192.168.5.128   0.0.0.0         255.255.255.128 U         0 0          0 eth0
0.0.0.0         192.168.5.129   0.0.0.0         UG        0 0          0 eth0
```

```
# netstat -o -t
Active Internet connections (w/o servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       Timer
tcp        0      0 192.168.5.135:ssh       192.168.3.124:34155     ESTABLISHED
keepalive (6754.95/0/0)
```

```
# netstat -atv
Active Internet connections (servers and established)
Proto Recv-Q Send-Q Local Address           Foreign Address         State
tcp        0      0 *:ssh                   *:*                     LISTEN
tcp        0      0 192.168.5.135:ssh       192.168.3.124:34155     ESTABLISHED
tcp6       0      0 [::]:ssh                [::]:*                  LISTEN
```

netstat cont.

Examples:

```
# netstat -tcp -listening --program
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 *:5001                  *:*                     LISTEN      13598/iperf
tcp        0      0 localhost:mysql         *:*                     LISTEN      5586/mysqld
tcp        0      0 *:www                   *:*                     LISTEN      7246/apache2
tcp        0      0 t60-2.local:domain      *:*                     LISTEN      5378/named
tcp        0      0 t60-2.local:domain      *:*                     LISTEN      5378/named
tcp        0      0 t60-2.local:domain      *:*                     LISTEN      5378/named
tcp        0      0 localhost:domain        *:*                     LISTEN      5378/named
tcp        0      0 localhost:ipp           *:*                     LISTEN      5522/cupsd
tcp        0      0 localhost:smtp          *:*                     LISTEN      6772/exim4
tcp        0      0 localhost:953           *:*                     LISTEN      5378/named
tcp        0      0 *:https                 *:*                     LISTEN      7246/apache2
tcp6       0      0 [::]:ftp                [::]:*                  LISTEN      7185/proftpd
tcp6       0      0 [::]:domain             [::]:*                  LISTEN      5378/named
tcp6       0      0 [::]:ssh                [::]:*                  LISTEN      5427/sshd
tcp6       0      0 [::]:3000               [::]:*                  LISTEN      17644/ntop
tcp6       0      0 ip6-localhost:953       [::]:*                  LISTEN      5378/named
tcp6       0      0 [::]:3005               [::]:*                  LISTEN      17644/ntop
```

lsof (LiSt of Open Files)

`lsof` is particularly useful because in Unix everything is a file: unix sockets, ip sockets, directories, etc.

Allows you to associate open files by:

-p: PID (Process ID)

-i : A network address (protocol:port)

-u: A user

lsof

Example:

- First, using *netstat -ln –tcp* determine that port 6010 is open and waiting for a connection (LISTEN)

```
# netstat -ln --tcp
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address               Foreign Address             State

tcp        0      0 127.0.0.1:6010              0.0.0.0:*                   LISTEN
tcp        0      0 127.0.0.1:6011              0.0.0.0:*                   LISTEN
```

lsof

Determine what process has the port (6010) open and what other resources are being used:

```
# lsof -i tcp:6010
COMMAND   PID   USER   FD   TYPE DEVICE SIZE NODE NAME
sshd      10301 root    6u  IPv4  53603       TCP localhost.localdomain:x11-ssh-offset (LISTEN)
sshd      10301 root    7u  IPv6  53604       TCP [::1]:x11-ssh-offset (LISTEN)
```

```
# lsof -p 10301
COMMAND   PID USER   FD   TYPE     DEVICE    SIZE    NODE NAME
sshd    10301 root  cwd    DIR        8,2    4096       2 /
sshd    10301 root  rtd    DIR        8,2    4096       2 /
sshd    10301 root  txt    REG        8,2  379720 1422643 /usr/sbin/sshd
sshd    10301 root  mem    REG        8,2   32724 1437533 /usr/lib/libwrap.so.0.7.6
sshd    10301 root  mem    REG        8,2   15088 3080329 /lib/libutil-2.4.so
sshd    10301 root  mem    REG        8,2   75632 1414093 /usr/lib/libz.so.1.2.3
sshd    10301 root  mem    REG        8,2   96040 3080209 /lib/libnsl-2.4.so
sshd    10301 root  mem    REG        8,2  100208 1414578 /usr/lib/libgssapi_krb5.so.2.2
sshd    10301 root  mem    REG        8,2   11684 1414405 /usr/lib/libkrb5support.so.0.0
sshd    10301 root  mem    REG        8,2   10368 3080358 /lib/libsetrans.so.0
sshd    10301 root  mem    REG        8,2    7972 3080231 /lib/libcom_err.so.2.1
sshd    10301 root  mem    REG        8,2   30140 1420233 /usr/lib/libcrack.so.2.8.0
sshd    10301 root  mem    REG        8,2   11168 3080399 /lib/security/pam_succeed_if.so
...
```

lsof cont.

What network services am I running?

```
# lsof -i
COMMAND     PID        USER   FD   TYPE  DEVICE SIZE NODE NAME
firefox    4429      hervey   50u  IPv4 1875852       TCP 192.168.179.139:56890-
>128.223.60.21:www (ESTABLISHED
named      5378        bind   20u  IPv6   13264       TCP *:domain (LISTEN)
named      5378        bind   21u  IPv4   13267       TCP localhost:domain (LISTEN)
sshd       5427        root    3u  IPv6   13302       TCP *:ssh (LISTEN)
cupsd      5522        root    3u  IPv4 1983466       TCP localhost:ipp (LISTEN)
mysqld     5586       mysql   10u  IPv4   13548       TCP localhost:mysql (LISTEN)
snmpd      6477        snmp    8u  IPv4   14633       UDP localhost:snmp
exim4      6772 Debian-exim    3u  IPv4   14675       TCP localhost:smtp (LISTEN)
ntpd       6859         ntp   16u  IPv4   14743       UDP *:ntp
ntpd       6859         ntp   17u  IPv6   14744       UDP *:ntp
ntpd       6859         ntp   18u  IPv6   14746       UDP [fe80::250:56ff:fec0:8]:ntp
ntpd       6859         ntp   19u  IPv6   14747       UDP ip6-localhost:ntp
proftpd    7185     proftpd    1u  IPv6   15718       TCP *:ftp (LISTEN)
apache2    7246    www-data    3u  IPv4   15915       TCP *:www (LISTEN)
apache2    7246    www-data    4u  IPv4   15917       TCP *:https (LISTEN)
...
iperf     13598        root    3u  IPv4 1996053       TCP *:5001 (LISTEN)
apache2   27088    www-data    3u  IPv4   15915       TCP *:www (LISTEN)
apache2   27088    www-data    4u  IPv4   15917       TCP *:https (LISTEN)
```

tcpdump

- Show received packet headers by a given interface. Optionally filter using boolean expressions.
- Allows you to write information to a file for later analysis.
- Requires administrator (root) privileges to use since you must configure network interfaces (NICs) to be in “promiscuous” mode.

tcpdump

Some useful options:

- **-i** : Specify the interface (ex: -i eth0)
- **-l** : Make stdout line buffered (view as you capture)
- **-v**, **-vv**, **-vvv**: Display more information
- **-n** : Don't convert addresses to names (avoid DNS)
- **-nn** : Don't translate port numbers
- **-w** : Write raw packets to a file
- **-r** : Read packets from a file created by '-w'

tcpdump

Boolean expressions:

- Using the 'AND', 'OR', 'NOT' operators
- Expressions consist of one, or more, primtives, which consist of a qualifier and an ID (name or number):

Expression ::= [NOT] <primitive> [AND | OR | NOT <primitive> ...]
<primitive> ::= <qualifier> <name|number>
<qualifier> ::= <type> | <address> | <protocol>
<type> ::= host | net | port | port range
<address> ::= src | dst
<protocol> ::= ether | fddi | tr | wlan | ip | ip6 | arp | rarp | decnet | tcp | udp

tcpdump

Examples:

- Show all HTTP traffic that originates from 10.10.0.250

```
# tcpdump -lnXvvv port 80 and src host 10.10.0.250
```

- Show all traffic originating from 10.10.0.250 *except* SSH

```
# tcpdump -lnXvvv src host 10.10.0.250 and not port 22
```

Bibliography

- *Monitoring Virtual Memory with vmstat*
  http://www.linuxjournal.com/article/8178
- *How to use TCPDump*
  http://www.erg.abdn.ac.uk/users/alastair/tcpdump.html
- *linux command tcpdump example*
  http://smartproteam.com/linux-tutorials/linux-command-tcpdump/
- *simple usage of tcpdump*
  http://linux.byexamples.com/archives/283/simple-usage-of-tcpdump/
- *TCPDUMP Command man page with examples*
  http://www.cyberciti.biz/howto/question/man/tcpdump-man-page-with-examples.php
- *TCPDump Tutorial*
  http://inst.eecs.berkeley.edu/~ee122/fa06/projects/tcpdump-6up.pdf