August 9th 2011, OSG Site Admin Workshop

Jason Zurawski – Internet2 Research Liaison

BWCTL

Agenda

- Tutorial Agenda:
  - Network Performance Primer - Why Should We Care? (**30 Mins**)
  - Introduction to Measurement Tools (**20 Mins**)
  - Use of NTP for network measurements (**15 Mins**)
  - Use of the BWCTL Server and Client (**25 Mins**)
  - Use of the OWAMP Server and Client (**25 Mins**)
  - Use of the NDT Server and Client (**25 Mins**)
  - perfSONAR Topics (**30 Mins**)
  - Diagnostics vs Regular Monitoring (**20 Mins**)
  - Use Cases (**30 Mins**)
  - Exercises

BWCTL – What is it?

- BWCTL is:
  - A command line client application
  - A scheduling and policy daemon
  - Wraps the throughput testing tools **Iperf** and **Nuttcp**.

- These tests are able to measure:
  - Maximum TCP bandwidth (with various tuning options available)
  - The delay, jitter, and datagram loss of a network when doing a UDP test

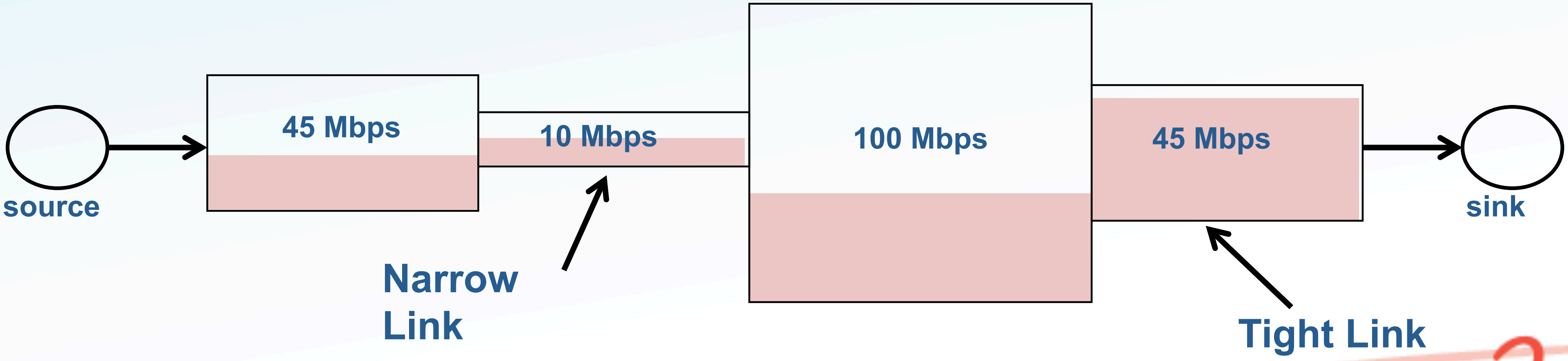
Problem Statement

- Users want to verify available bandwidth/throughput:
  - Between their site and a remote resource
  - Between two remote resources
  - Validate/Verify an SLA

- Methodology:
  - Verify available bandwidth from each endpoint to points in the middle
  - Determine problem area(s)
  - Re-run tests over time – requires access to tool instead of doing a 'one off' test

Throughput? Bandwidth?

- The term "throughput" is vague
  - Capacity: link speed
    - Narrow Link: link with the lowest capacity along a path
    - Capacity of the end-to-end path = capacity of the narrow link
  - Utilized bandwidth: current traffic load
  - Available bandwidth: capacity – utilized bandwidth
    - Tight Link: link with the least available bandwidth in a path
  - Achievable bandwidth: includes protocol and host issues



(Shaded portion shows background traffic)

Typical Solution

- Run “iperf” or similar tool on two endpoints and hosts on intermediate paths
  - Roadblocks:
    - Need software on all test systems
    - Need permissions on all systems involved (usually full shell accounts*)
    - Need to coordinate testing with others *
    - Need to run software on both sides with specified test parameters *
- Desirable features for an alternate method
  - ‘Daemon’ to run in the background
  - Protocol to exchange results/errors
  - Works with firewalls
  - Protect resources

- (* BWCTL was designed to help with these)

Implementation

- Applications
  - Daemon (bwctld)
  - Client (bwctl)

- Open Source License & Development
  - Modified BSD (http://www.internet2.edu/membership/ip.html)
  - Mailing lists for developer communication – come join us!

- Protocol Abstraction Library
  - Will support development of new clients
  - Add custom 'hooks' into the policy (e.g. add authentication via OpenID or similar)

Server Functionality (bwctld)

- bwctld on each test host
  - Accepts requests for "iperf" tests including time slot and parameters for test
  - Responds with a tentative reservation or a denied message
  - Reservations by a client must be confirmed with a "start session" message
  - Acts as the "Resource Broker"
  - Runs the test
  - Both "sides" of test get results

Client Functionality (bwctl)

- bwctl client application makes requests to both endpoints of a test
  - Communication can be “open”, “authenticated”, or “encrypted” (encrypted reserved for future use)
  - Requests include a request for a ***time slot*** as well as a full parameterization of the test
  - “Third party” requests – run a test on two distributed hosts
  - If no server is available on the localhost, client handles test endpoint
  - *Mostly* the same command line options as testers (e.g. iperf, nuttcp – read the help or man pages to be sure…)

TCP Measurements

- Measures TCP Achievable Bandwidth
  - Measurement includes the end system
  - Sometimes called "memory-to-memory" tests
  - Set expectations for well coded application
- Limits of what we can measure
  - TCP ***hides*** details
  - In hiding the details it can obscure what is causing errors
- Many things can limit TCP throughput
  - Loss
  - Congestion
  - Buffer Starvation
  - Out of order delivery

TCP – Quick Overview

- Data Packet
  - Contains some header overhead, and the broken up chunk of user data
- ACK Packet
  - Acknowledge the receipt of a data packet, “cumulative” in nature
- SACK Packet
  - Selective acknowledgement for a specific missing segment
- MSS
  - Maximum segment size (largest size of packets on a given network segment)
- Congestion Control
  - Process of self regulating flow speed due to loss in the network (e.g. making it fair)
- Slow Start
  - Avoid sending more data than the network is capable of consuming. Goal is to reach a loss (establishes window size by relying on acks)

TCP – Quick Overview

- Congestion Avoidance
  - Additive-increase/Multiplicative-decrease [AIMD] scheme to find a fair speed for a TCP flow by adjusting the sending window. Starts low (2 x MSS) and increase
- Fast Retransmit
  - Retransmit a single segment after receiving duplicate ACKs for the prior numbered segment
- Fast Recovery
  - Re-send packets in a window after a timeout
- Bandwidth Delay Product
  - The amount of "in flight" data allowed for a TCP connection
  - BDP = bandwidth * round trip time
  - Example: 1Gb/s cross country, ~100ms
    - 1,000,000,000 b/s * .1 s = 100,000,000 bits
    - 100,000,000 / 8 = 12,500,000 bytes
    - 12,500,000 bytes / (1024*1024) ~ 12MB

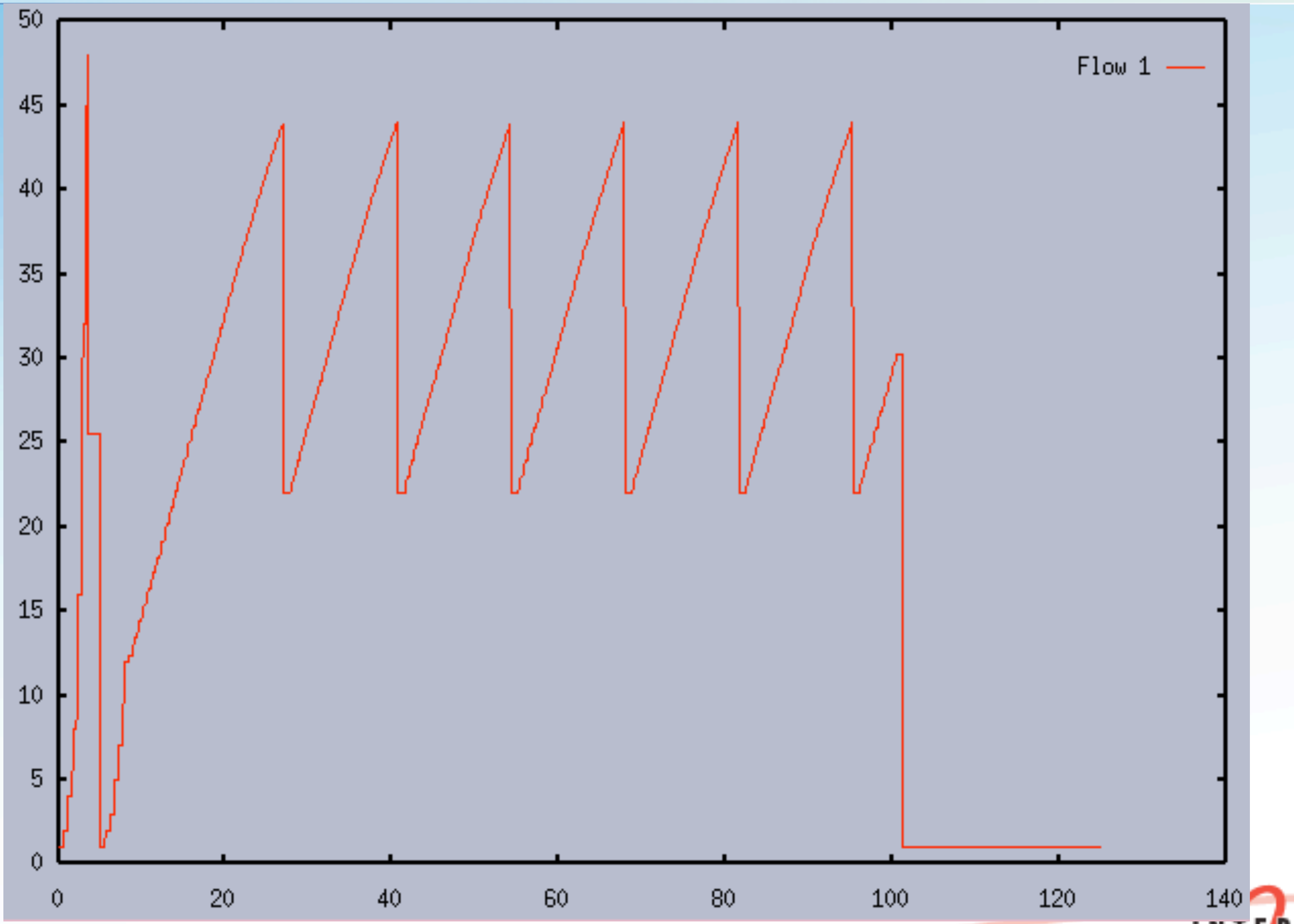
TCP – Quick Overview

- Congestion Control Algorithms (selectable in the Linux Kernel)
  - RENO (Slow Start, Cong. Avoidance, Fast Retransmit, Fast Recovery)
  - Cubic (Optimized for LFN [Long Fat Networks] with large latency, Cubic growth pattern)
  - HTCP (still additive-increase/multiplicative-decrease [AIMD], more agressive as loss decreases on high BDP paths)

TCP – Quick Overview

- General Operational Pattern
  - Sender buffers up data to send into segments (respect the MSS) and numbers each
  - The 'window' is established and packets are sent in order from the window
  - The flow of data and ACK packets will dictate the overall speed of TCP for the length of the transfer

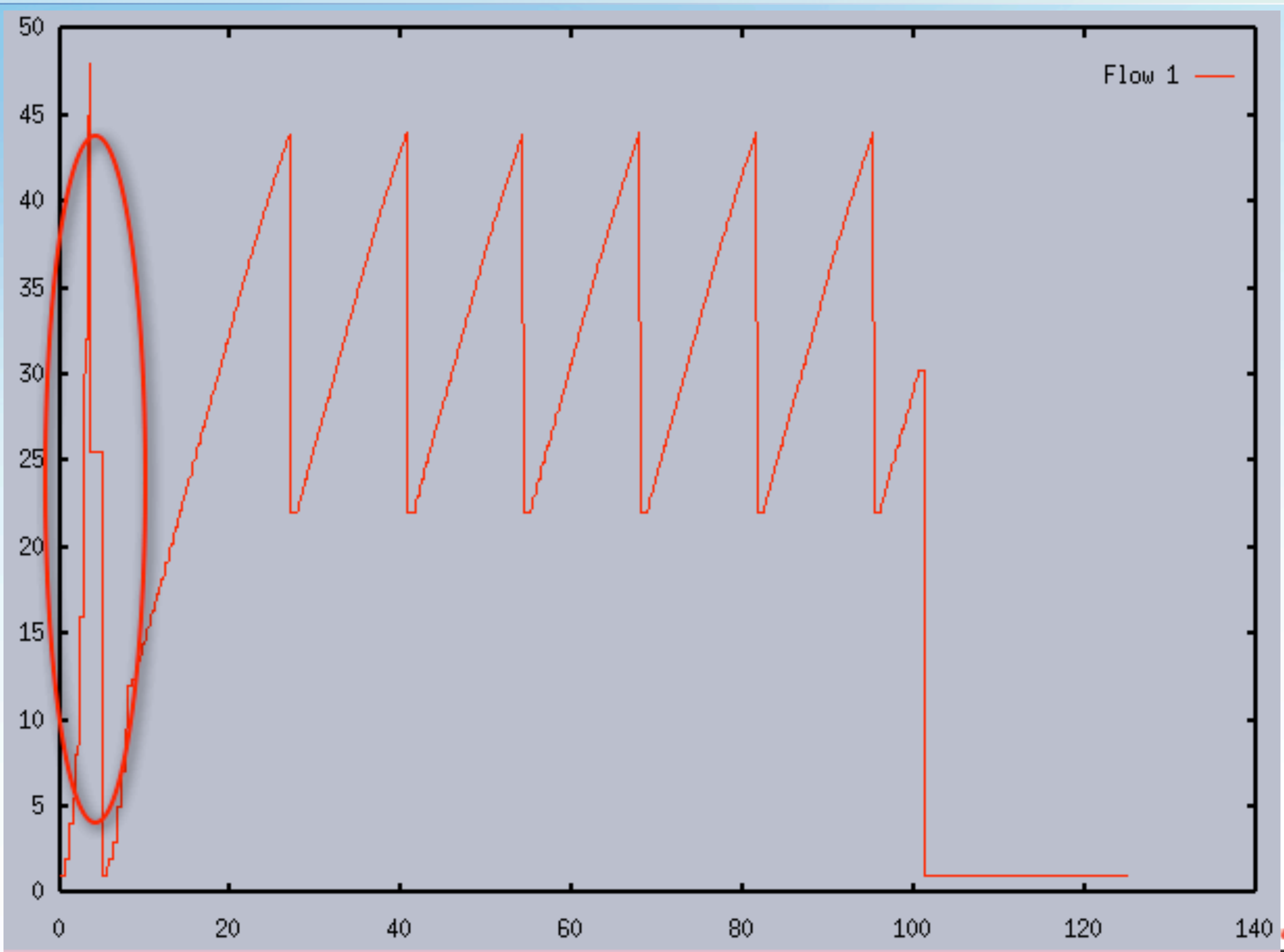
TCP – Quick Overview (Typical Sawtooth)



TCP – Quick Overview

- General Operational Pattern – cont
  - TCP starts slow, until it can establish the available resources on the network.
  - The idea is to grow the window until a loss is observed
  - This is the signal to the algorithm that it must limit the window for the time being, it can slowly build it back up

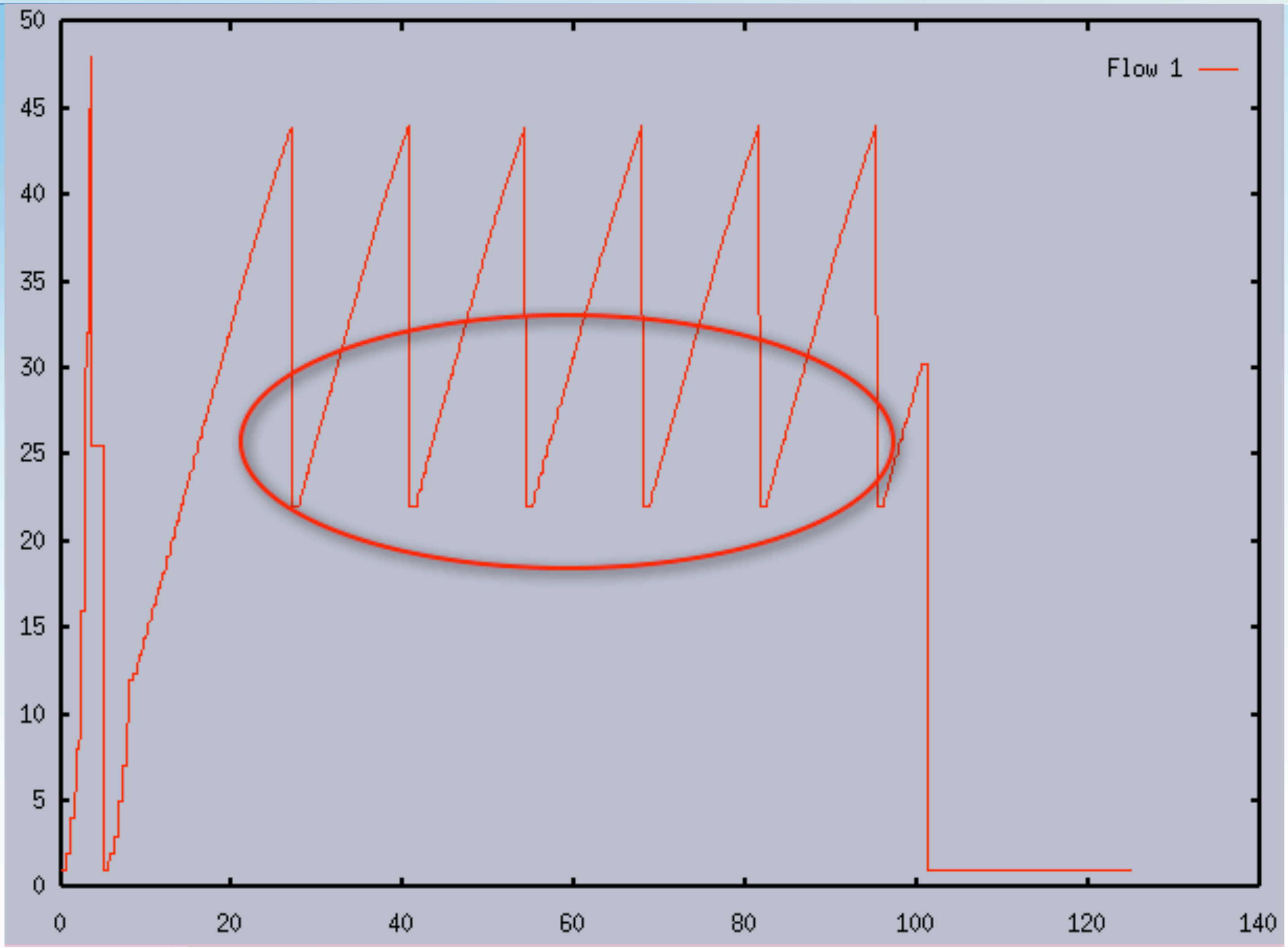
TCP – Quick Overview (Slow Start)



TCP – Quick Overview

- General Operational Pattern – cont
  - Receiver will acknowledge packets as they arrive
    - ACK Each (old style)
    - Cumulative ACK ("I have seen everything up to this segment"
    - Selective ACK (sent to combat a complete retransmit of the window)
  - TCP relies on loss to a certain extent – it will adjust it's behavior after each loss
    - Congestive (e.g. reaching network limitation, or due to traffic)
    - Non-congestive (due to actual problems in the network)
  - Congestion avoidance stage follows slow start, window will remain a certain size and data rates will increase/decrease based on loss in the network
  - Congestion Control algorithms modify the behavior over time
    - Control how large the window may grow
    - Control how fast to recover from any loss

TCP – Quick Overview (Cong. Avoidance)



TCP Performance: Window Size

- Use TCP auto tuning if possible
  - Linux 2.6, Mac OS X 10.5, FreeBSD 7.x, and Windows Vista
  - Allow the OS to decide how large the window needs to be based on current resources and performance
- The –w option can be used to request a particular buffer size.
  - Use this if your OS doesn’t have TCP auto tuning
  - This sets both send and receive buffer size.
  - The OS may need to be tweaked to allow buffers of sufficient size.
  - See http://fasterdata.es.net/fasterdata/host-tuning/ for more details
- Parallel transfers may help as well, the –P option can be used for this
- To get full TCP performance the TCP window needs to be large enough to accommodate the Bandwidth Delay Product

TCP Parallel Streams

- Parallel streams can help in some situations
- TCP attempts to be "fair" and conservative
  - Sensitive to loss, but more streams hedge bet
  - Circumventing fairness mechanism
    - 1 bwctl stream vs. n background: bwctl gets 1/(n+1)
    - X bwctl streams vs. n background: bwctl gets x/(n+x)
    - Example: 2 background, 1 bwctl stream: 1/3 = 33%
    - Example: 2 background, 8 bwctl streams: 8/10 = 80%
- How?
  - The –P option sets the number of streams/threads to use
  - There is a point of diminishing returns

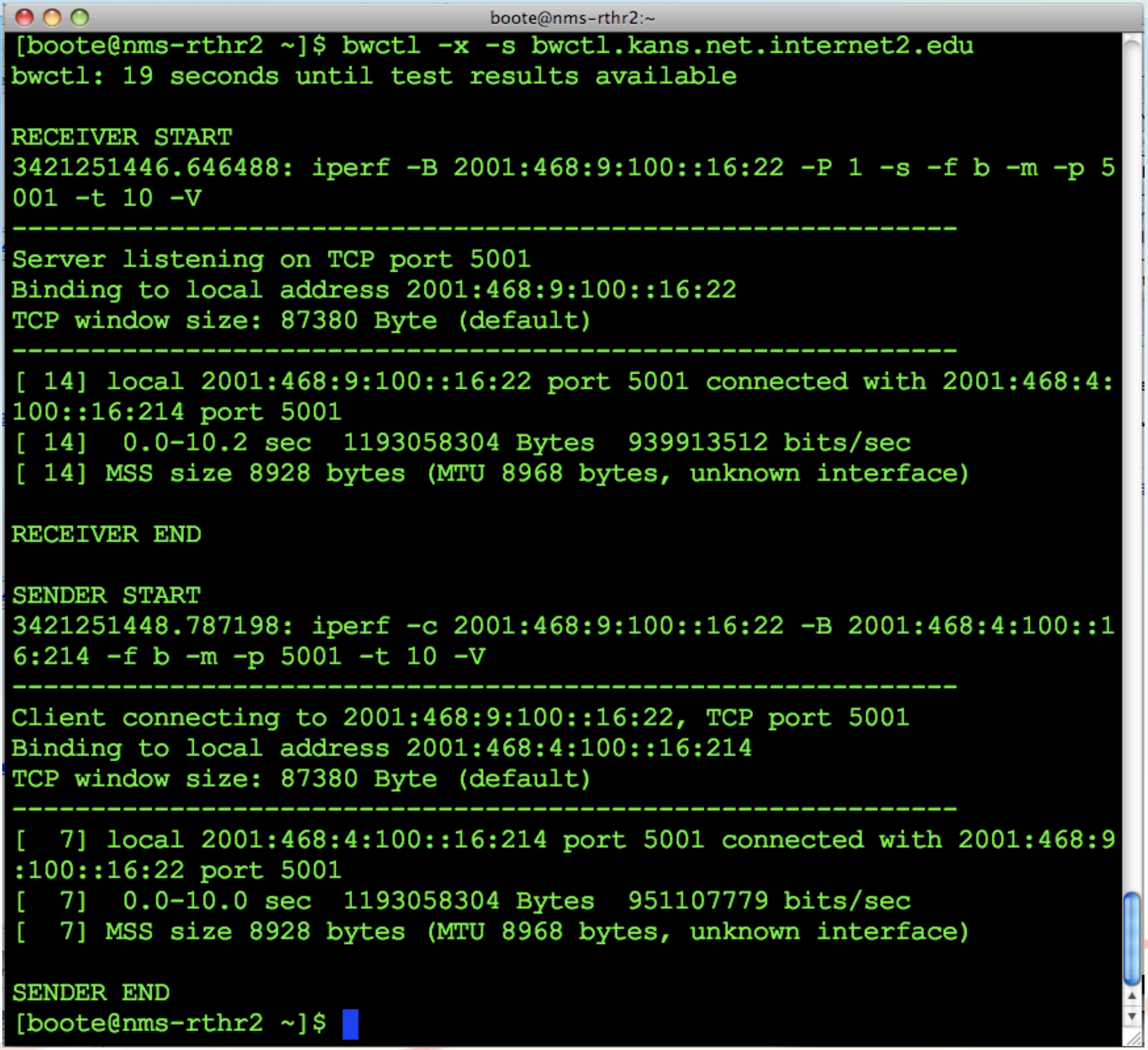
TCP Performance: Read/Write Buffer Size

- TCP breaks the stream into pieces transparently
- Longer writes often improve performance
  - Let TCP “do it’s thing”
  - Fewer system calls
- How?
  - -l <size> (lower case ell)
  - Example –l 128K
- UDP doesn’t break up writes, don’t exceed Path MTU

UDP Measurements

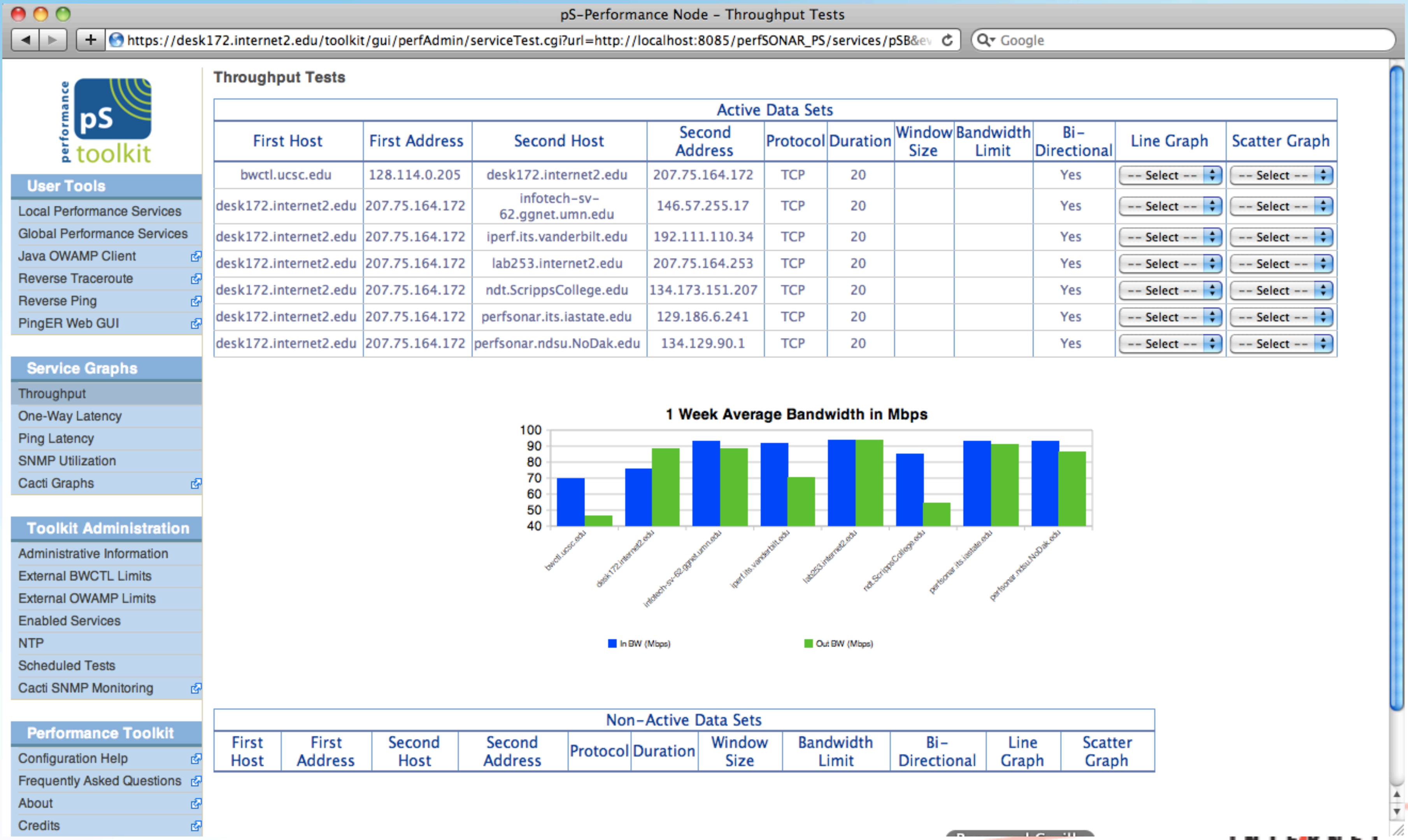
- UDP provides greater transparency
- We can directly measure some things TCP hides
  - Loss
  - Jitter
  - Out of order delivery
- Use -b to specify target bandwidth
  - Default is 1M
  - Two sets of multipliers
    - k, m, g multipliers are 1000, 1000^2,1000^3
    - K, M, G multipliers are 1024, 1024^2,1024^3
  - Eg, -b 1m is 1,000,000 bits per second

Example



```
[boote@nms-rthr2 ~]$ bwctl -x -s bwctl.kans.net.internet2.edu
bwctl: 19 seconds until test results available

RECEIVER START
3421251446.646488: iperf -B 2001:468:9:100::16:22 -P 1 -s -f b -m -p 5
001 -t 10 -V
------------------------------------------------------------
Server listening on TCP port 5001
Binding to local address 2001:468:9:100::16:22
TCP window size: 87380 Byte (default)
------------------------------------------------------------
[ 14] local 2001:468:9:100::16:22 port 5001 connected with 2001:468:4:
100::16:214 port 5001
[ 14]  0.0-10.2 sec  1193058304 Bytes  939913512 bits/sec
[ 14] MSS size 8928 bytes (MTU 8968 bytes, unknown interface)

RECEIVER END

SENDER START
3421251448.787198: iperf -c 2001:468:9:100::16:22 -B 2001:468:4:100::1
6:214 -f b -m -p 5001 -t 10 -V
------------------------------------------------------------
Client connecting to 2001:468:9:100::16:22, TCP port 5001
Binding to local address 2001:468:4:100::16:214
TCP window size: 87380 Byte (default)
------------------------------------------------------------
[  7] local 2001:468:4:100::16:214 port 5001 connected with 2001:468:9
:100::16:22 port 5001
[  7]  0.0-10.0 sec  1193058304 Bytes  951107779 bits/sec
[  7] MSS size 8928 bytes (MTU 8968 bytes, unknown interface)

SENDER END
[boote@nms-rthr2 ~]$
```

BWCTL GUIs



Throughput Tests

Active Data Sets

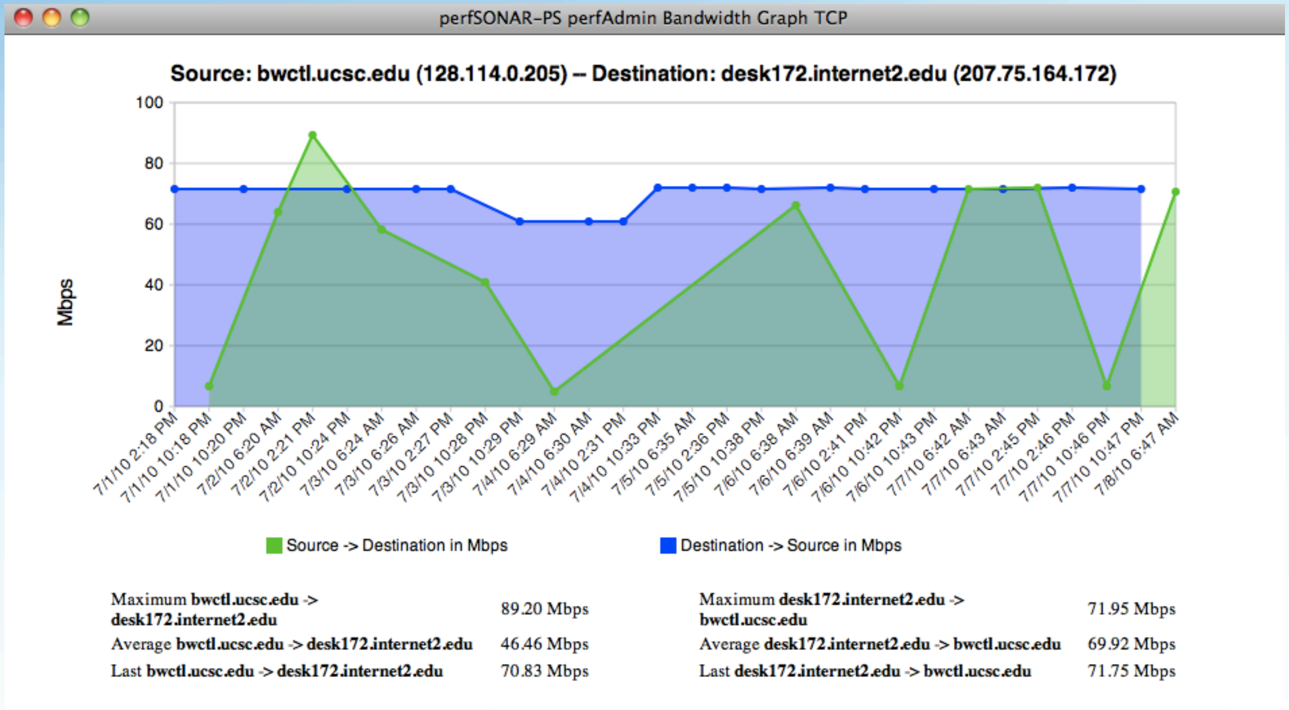
First Host	First Address	Second Host	Second Address	Protocol	Duration	Window Size	Bandwidth Limit	Bi-Directional	Line Graph	Scatter Graph
bwctl.ucsc.edu	128.114.0.205	desk172.internet2.edu	207.75.164.172	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	infotech-sv-62.ggnet.umn.edu	146.57.255.17	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	iperf.its.vanderbilt.edu	192.111.110.34	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	lab253.internet2.edu	207.75.164.253	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	ndt.ScrippsCollege.edu	134.173.151.207	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	perfsonar.its.iastate.edu	129.186.6.241	TCP	20			Yes	-- Select --	-- Select --
desk172.internet2.edu	207.75.164.172	perfsonar.ndsu.NoDak.edu	134.129.90.1	TCP	20			Yes	-- Select --	-- Select --

1 Week Average Bandwidth in Mbps

Non-Active Data Sets

First Host	First Address	Second Host	Second Address	Protocol	Duration	Window Size	Bandwidth Limit	Bi-Directional	Line Graph	Scatter Graph

BWCTL GUIs

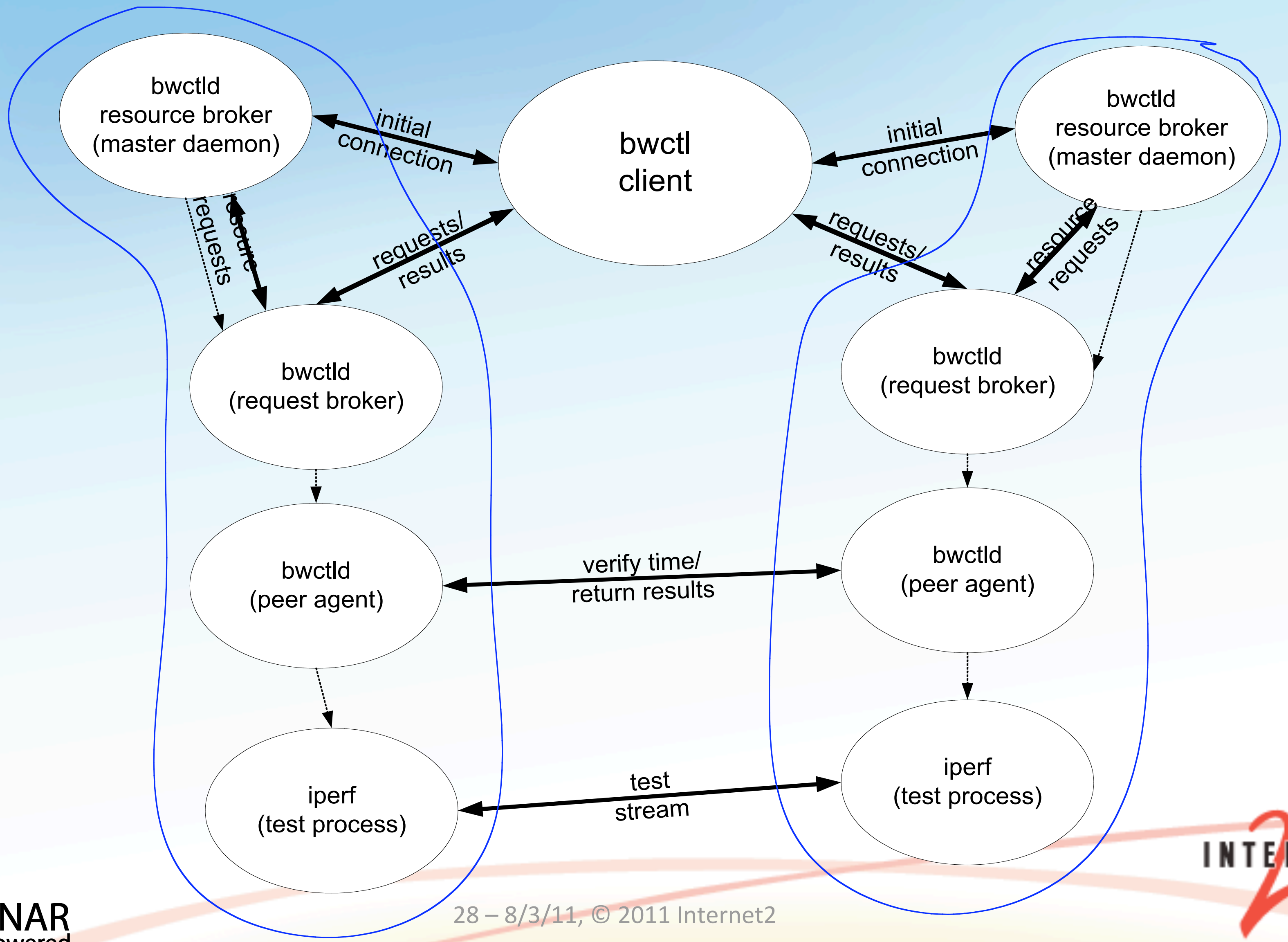


Maximum **bwctl.ucsc.edu -> desk172.internet2.edu**	89.20 Mbps	Maximum **desk172.internet2.edu -> bwctl.ucsc.edu**	71.95 Mbps
Average **bwctl.ucsc.edu -> desk172.internet2.edu**	46.46 Mbps	Average **desk172.internet2.edu -> bwctl.ucsc.edu**	69.92 Mbps
Last **bwctl.ucsc.edu -> desk172.internet2.edu**	70.83 Mbps	Last **desk172.internet2.edu -> bwctl.ucsc.edu**	71.75 Mbps

Resource Allocation

- Each connection is “classified” (authentication)
- Each classification is hierarchical and has an associated set of hierarchical limits:
  - Connection policy (allow_open_mode)
  - Bandwidth (allow_tcp,allow_udp,bandwidth)
  - Scheduling (duration,event_horizon,pending)
    - A time slot is simply a time-dependent resource that needs to be allocated just like any other resource. It therefore follows the resource allocation model.

3rd Party Testing



General Requirements

- Iperf version 2.0.x
- NTP (ntpd) synchronized clock on the local system
  - Used for scheduling
  - More important that errors are accurate than the clock itself
- Firewalls:
  - Lots of ports for communication and testing – see the web for specifics
- End hosts must be tuned!
  - http://fasterdata.es.net/fasterdata/host-tuning
  - http://www.psc.edu/networking/perf_tune.html

Supported Systems

- Source Code
  - All modern Unix distributions (Free BSD/Linux)
  - OS X
- Packages
  - Support for CentOS 5.5 (x86)
  - Packages have been shown to operate on similar systems (CentOS, Fedora, RHEL, and x86_64 architecture)

Security Considerations

- DoS source
  - Imagine a large number of compromised BWCTLD servers being used to direct traffic
- DoS target
  - Someone might attempt to affect statistics web pages to see how much impact they can have
- Resource consumption
  - Time slots
  - Network bandwidth

Policy Approaches

- Restrictive for UDP
  - Allow between peers
  - Limit bandwidth, and time of tests
- More liberal for TCP tests
  - Open for all (or peers)
  - Limit length of tests
- Protect AES keys!
  - If being used

Availability

- Currently available
  - http://www.internet2.edu/performance/bwctl
  - http://software.internet2.edu
- Mail lists:
  - https://lists.internet2.edu/sympa/info/bwctl-users
    - bwctl-users@internet2.edu
  - https://lists.internet2.edu/sympa/info/bwctl-announce
    - bwctl-announce@internet2.edu

BWCTL

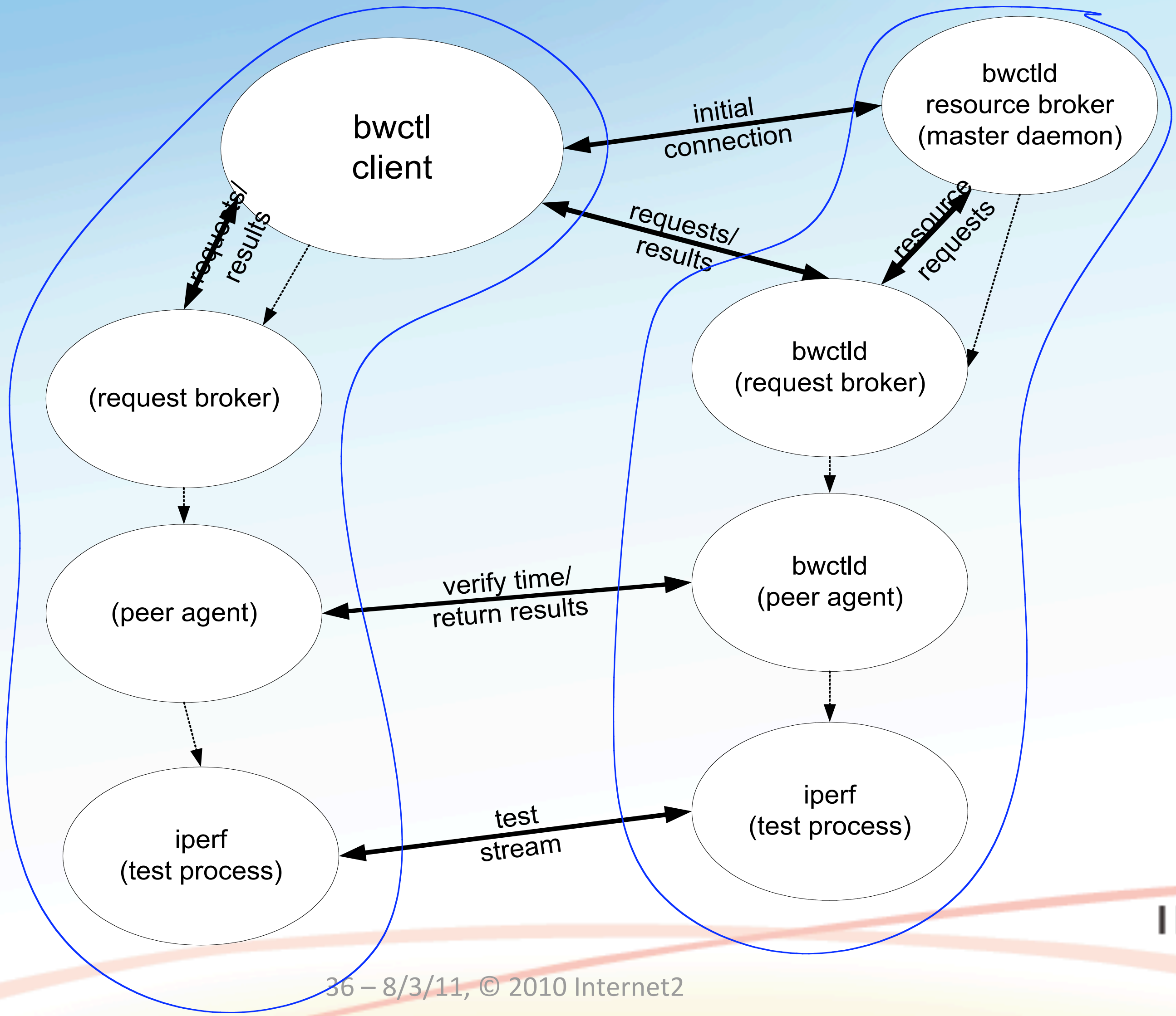
August 9th 2011, OSG Site Admin Workshop
Jason Zurawski – Internet2 Research Liaison

For more information, visit http://www.internet2.edu/workshops/npw

Tester Applications

- Iperf is primary “tester”
  - Well known – widely used
- Problems integrating exec’d tool
  - Server initialization (port number allocation)
  - error conditions
  - No indication of partial progress (How full was the send buffer when the session was killed?)
- thrulay/nuttcp are available also

Testing with no “Local” Server


bwctl
client
bwctld
resource broker
(master daemon)
initial
connection
requests/
results
requests/
results
resource
requests
(request broker)
bwctld
(request broker)
(peer agent)
verify time/
return results
bwctld
(peer agent)
iperf
(test process)
test
stream
iperf
(test process)