Troubleshooting Network Performance Issues with Active Monitoring

NANOG 64

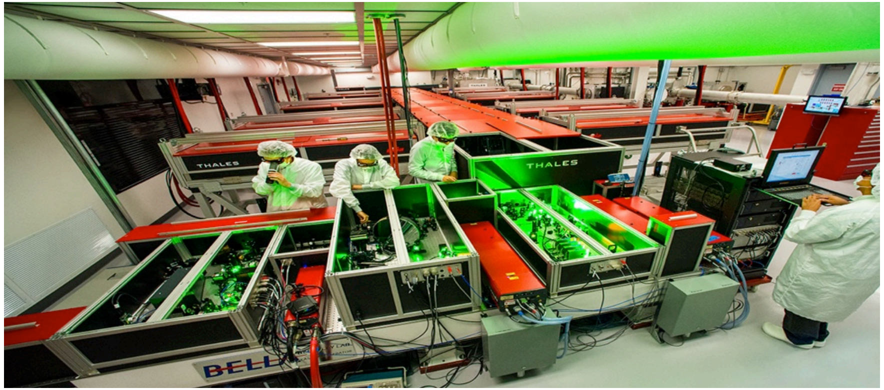
Brian Tierney, ESnet, bltierney@es.net

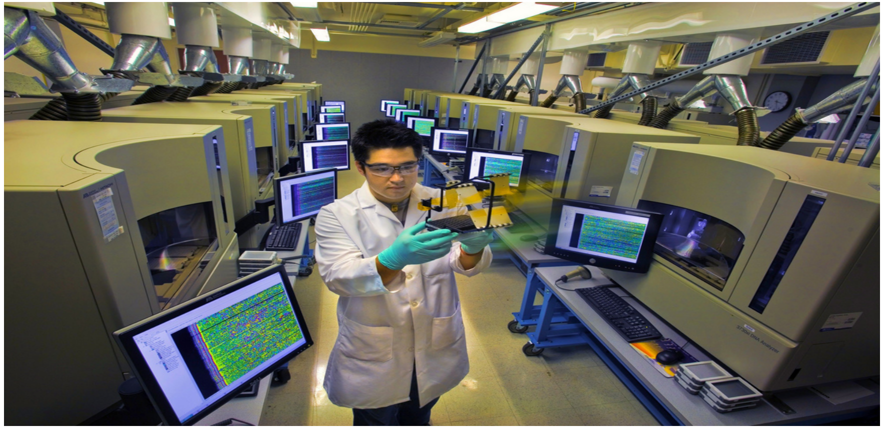
June 2, 2015

Who Am I?

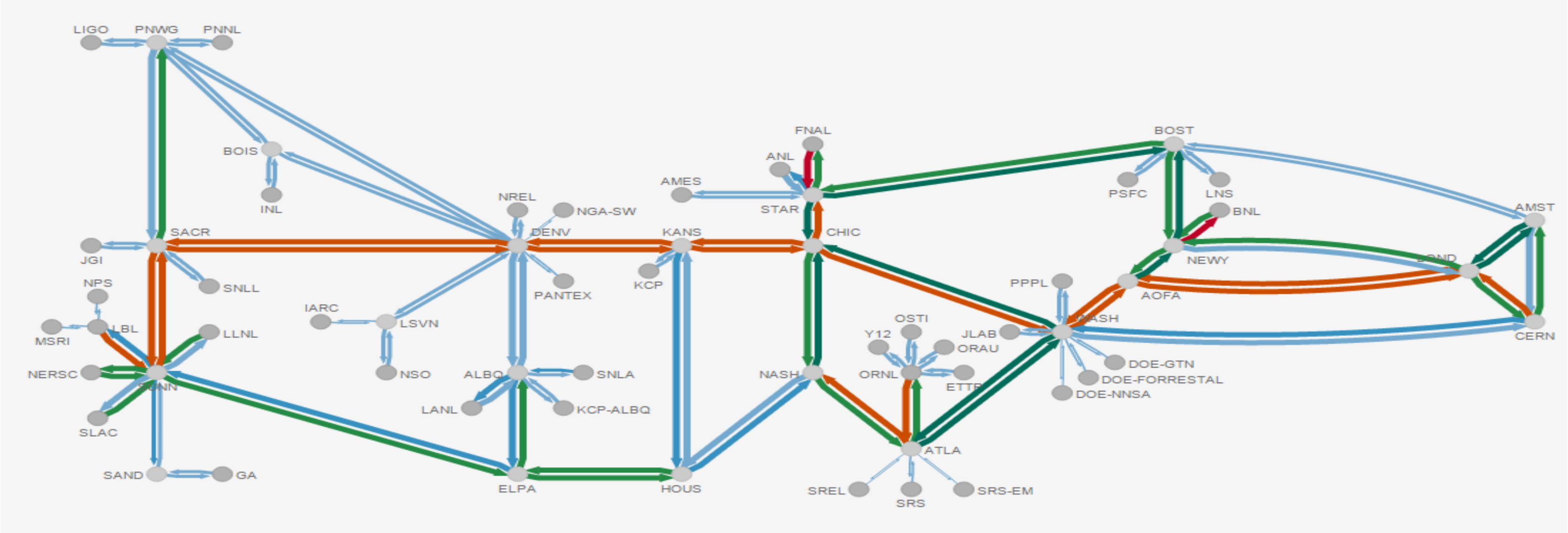
- My Background
  - Lawrence Berkeley National Lab
  - ESnet
  - Big Science Data

Lawrence Berkeley National Laboratory





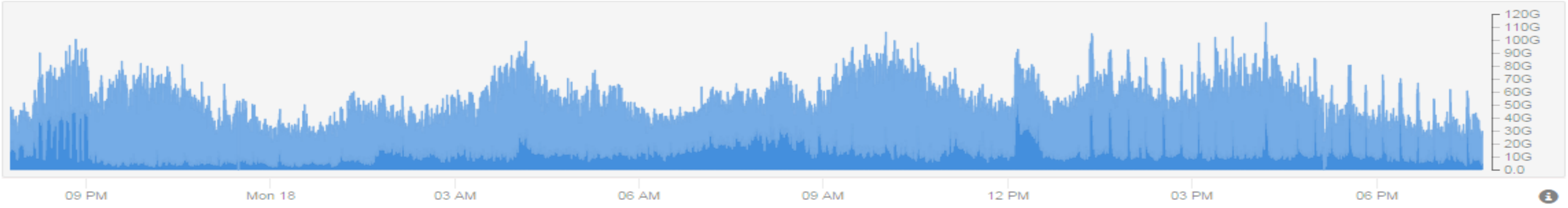
Energy Sciences Network



- Connects Department of Energy National Laboratories to universities and research institutions around the world
- Many sites with 100G connections to ESnet today - Berkeley, Livermore, Stanford, Fermi, Brookhaven, Oakridge, Argonne

ESnet / DOE National Lab Network Profile

- Small-ish numbers of very large flows over very long distances:
  - Between California, Illinois, New York, Tennessee, Switzerland
- High-speed “Access” links - 100G sites connected to 100G core
- Nx10G hosts, future Nx40G hosts, dedicated to Data Transfer
- GridFTP / Globus Online / Parallel FTP
- LHC detectors to data centers around the world (future 180Gbps)
- Electron microscopes to supercomputers (20k – 100k FPS per camera)



Introduction & Motivation

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perfSONAR Goals

- Originally developed to help troubleshoot large science data transfers
  - E.g.: LHC at CERN; Large genomic data sets, etc
- Useful for any network doing large file transfers. E.g.:
  - Into Amazon EC2
  - Large HD movies (Hollywood post production)
  - Many new “big data” applications

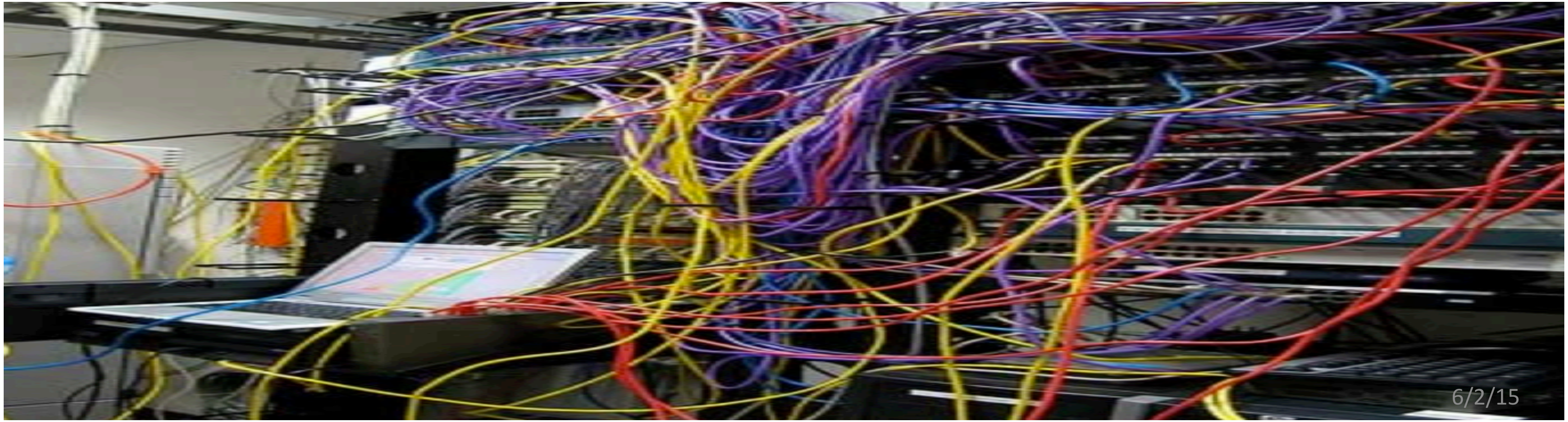
What is perfSONAR?

- perfSONAR is a tool to:
  - Set (hopefully raise) network performance expectations
  - Find network problems ("soft failures")
  - Help fix these problems
- All in multi-domain environments
- These problems are all harder when multiple networks are involved

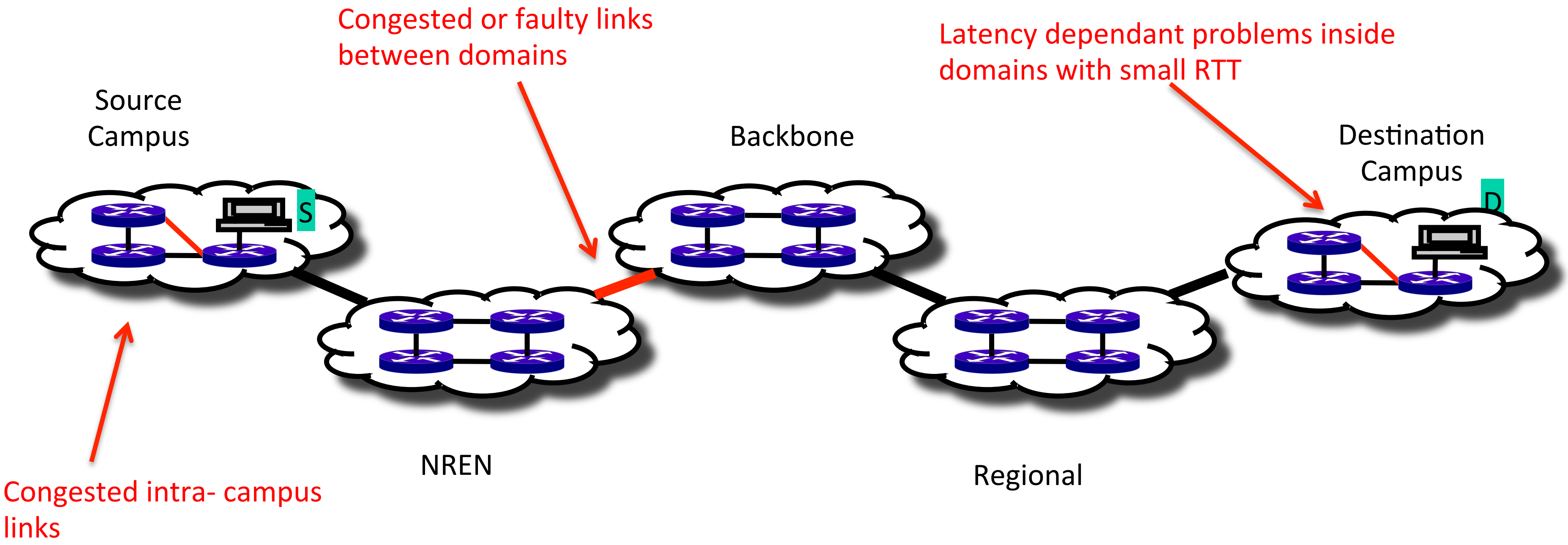
- perfSONAR is provides a standard way to publish active and passive monitoring data
  - This data is interesting to network researchers as well as network operators

Problem Statement

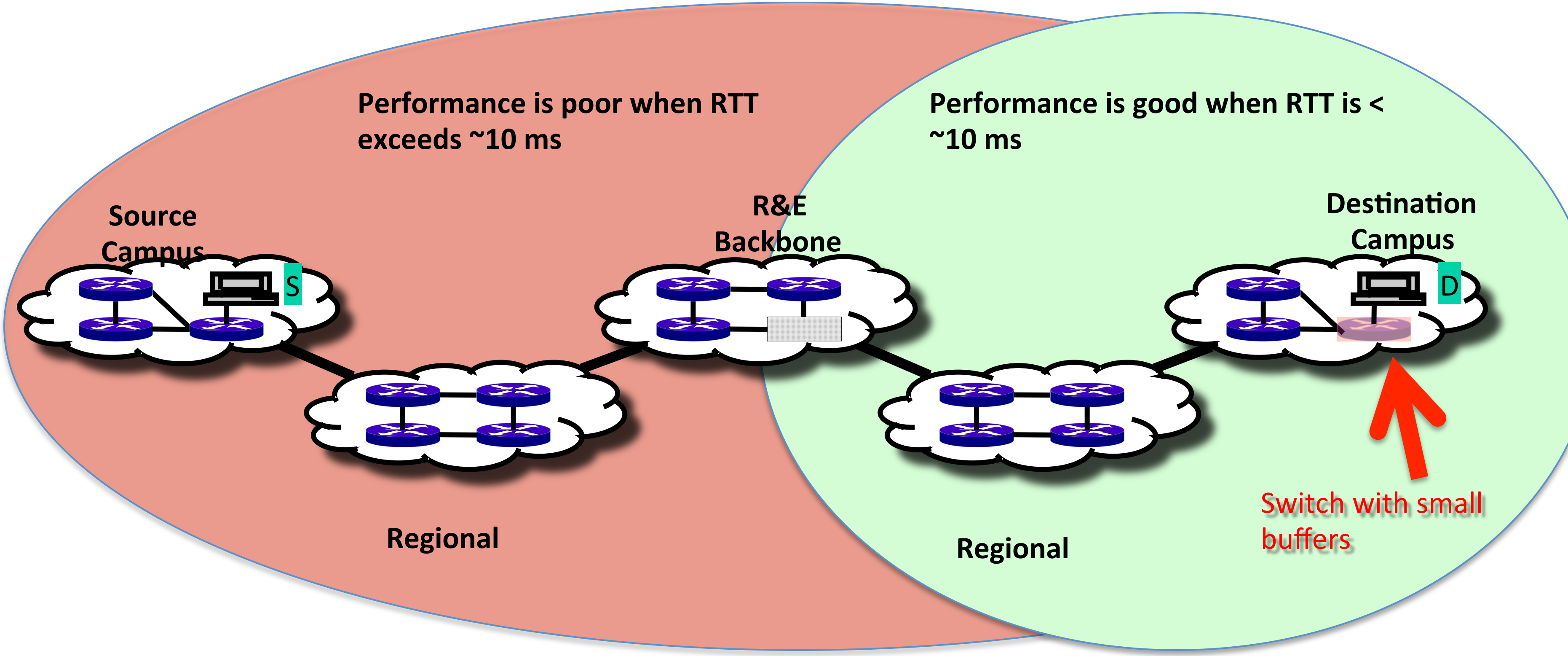
- In practice, performance issues are prevalent and distributed.
- When a network is underperforming or errors occur, it is difficult to identify the source, as problems can happen anywhere, in any domain.
- Local-area network testing is not sufficient, as errors can occur between networks.



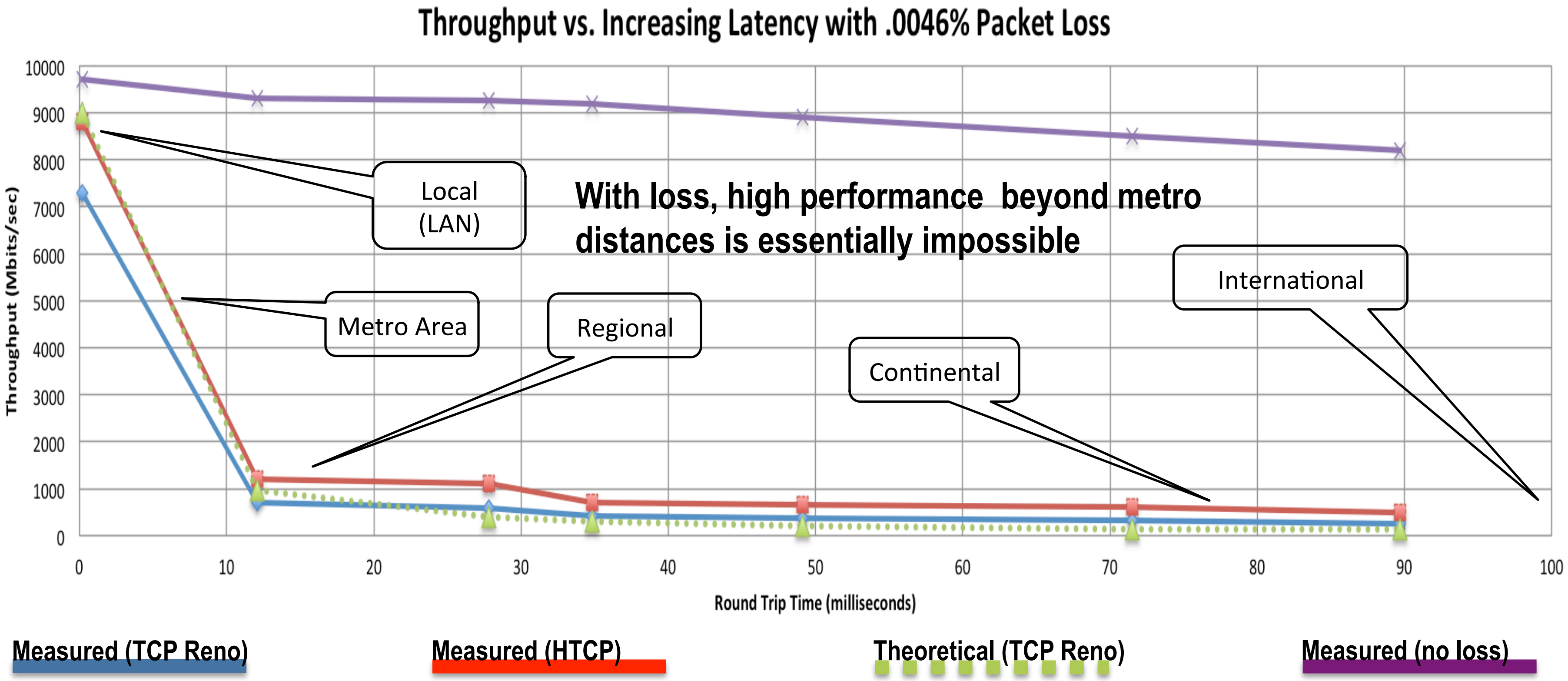
Where Are The Problems?



Local Testing Will Not Find Everything



A small amount of packet loss makes a huge difference in TCP performance



Soft Network Failures

- Soft failures are where basic connectivity functions, but high performance is not possible.
- TCP was intentionally designed to hide all transmission errors from the user:
  - "As long as the TCPs continue to function properly and the internet system does not become completely partitioned, no transmission errors will affect the users." (From IEN 129, RFC 716)
- Some soft failures only affect high bandwidth long RTT flows.
- Hard failures are easy to detect & fix
  - soft failures can lie hidden for years!
- One network problem can often mask others
- Hardware counters can lie!

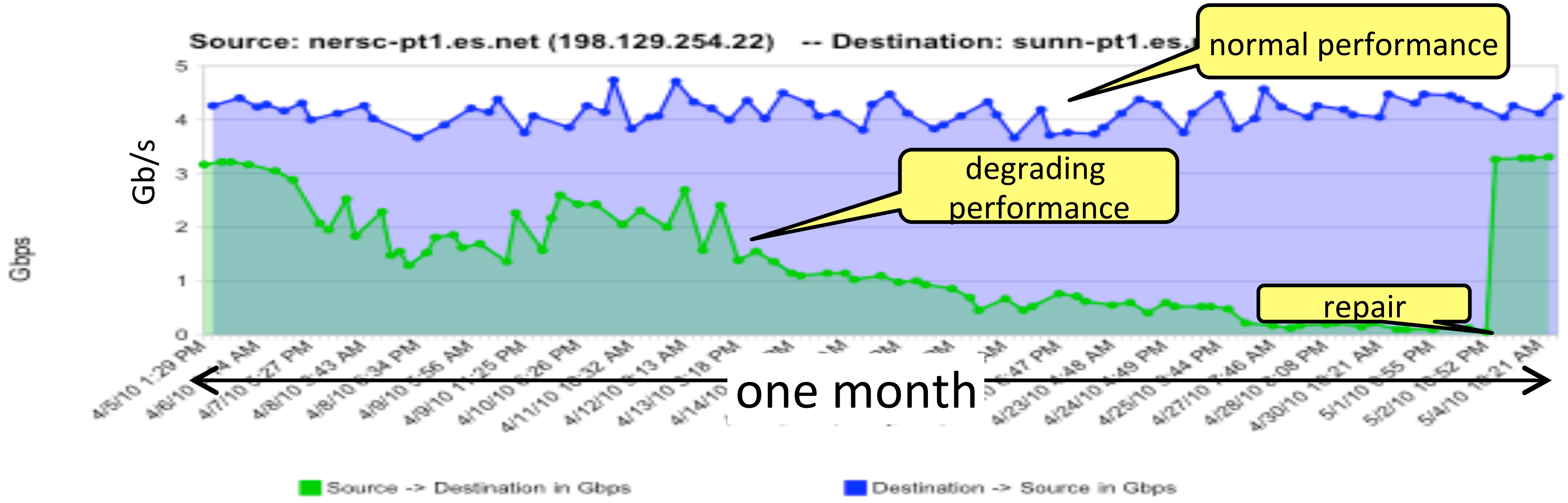
Hard vs. Soft Failures

- "Hard failures" are the kind of problems every organization understands
  - Fiber cut
  - Power failure takes down routers
  - Hardware ceases to function
- Classic monitoring systems are good at alerting hard failures
  - i.e., NOC sees something turn red on their screen
  - Engineers paged by monitoring systems
- "Soft failures" are different and often go undetected
  - Basic connectivity (ping, traceroute, web pages, email) works
  - Performance is just poor
- How much should we care about soft failures?

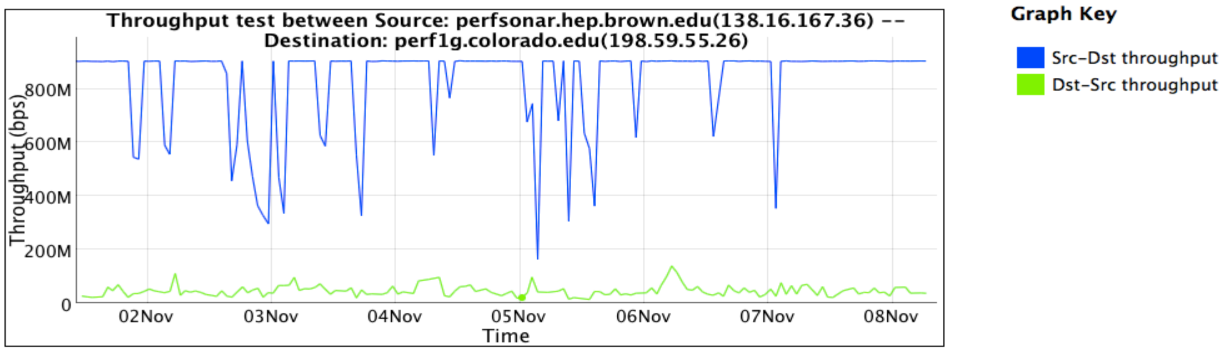
Causes of Packet Loss

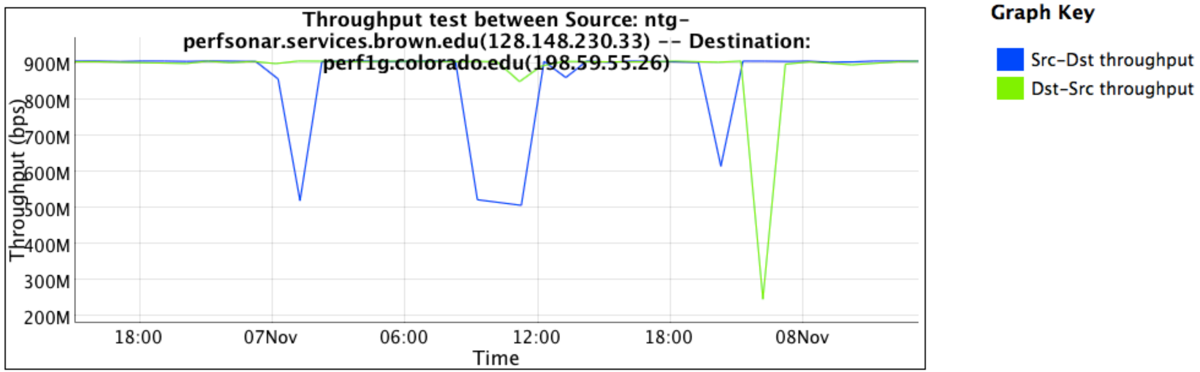
- Network Congestion
  - Easy to confirm via SNMP, easy to fix with $$
  - This is not a 'soft failure', but just a network capacity issue
  - Often people assume congestion is the issue when it fact it is not.
- Under-buffered switch dropping packets
  - Hard to confirm
- Under-powered firewall dropping packets
  - Hard to confirm
- Dirty fibers or connectors, failing optics/light levels
  - Sometimes easy to confirm by looking at error counters in the routers
- Overloaded or slow receive host dropping packets
  - Easy to confirm by looking at CPU load on the host

Sample Soft Failure: failing optics



Sample Soft Failure: Under-powered Firewall





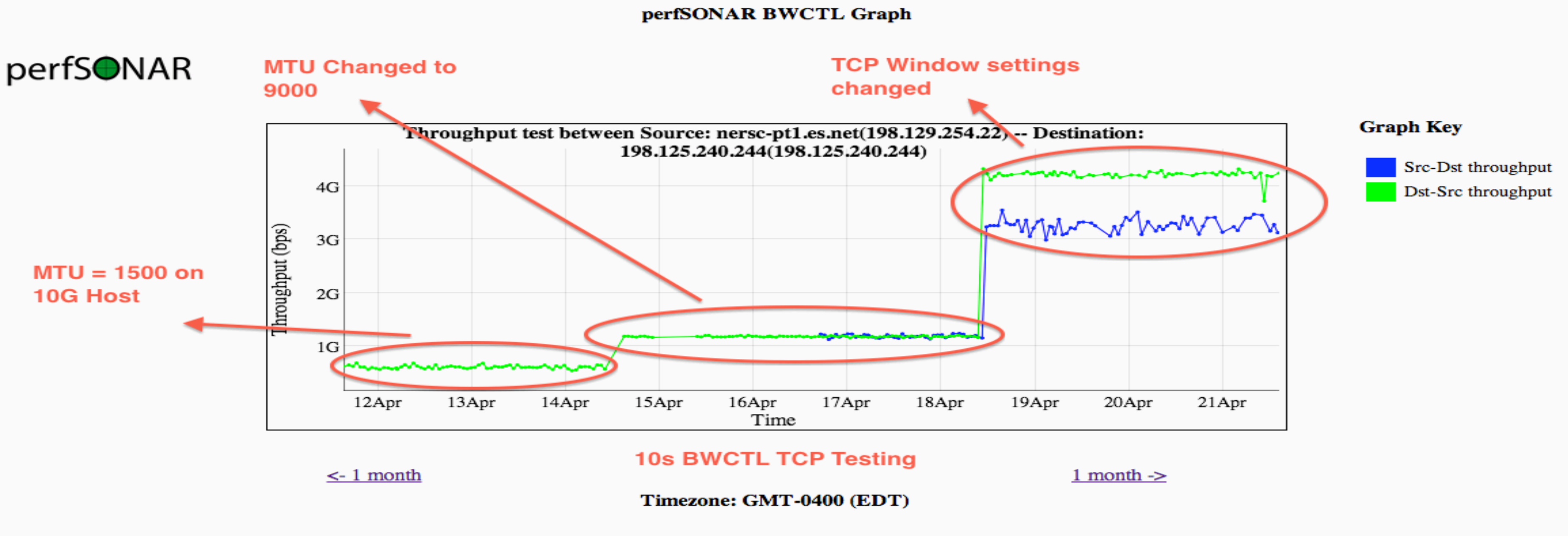
Inside the firewall

- One direction severely impacted by firewall
- Not useful for science data

Outside the firewall

- Good performance in both directions

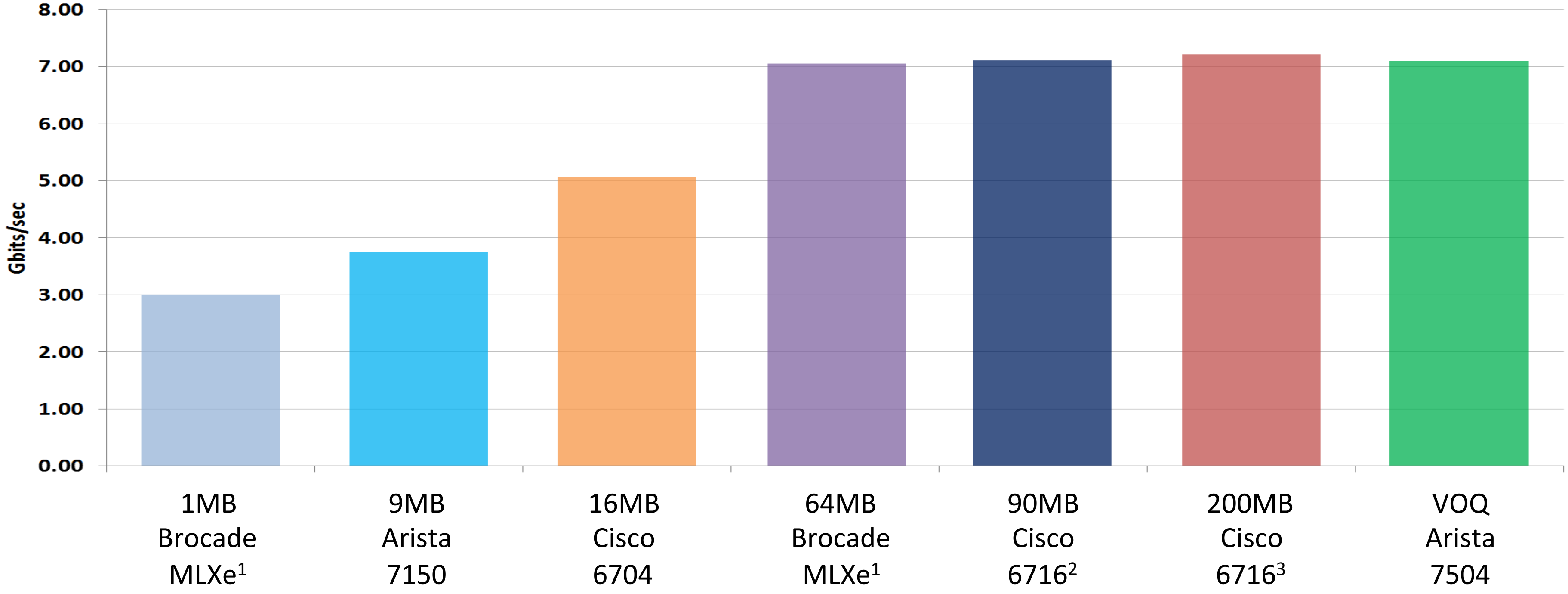
Sample Soft Failure: Host Tuning



Soft Failure: Under-buffered Switches

Average TCP results, various switches

- Buffers per 10G egress port, 2x parallel TCP streams,
- 50ms simulated RTT, 2Gbps UDP background traffic



What is perfSONAR?

- perfSONAR is a tool to:
  - Set network performance expectations
  - Find network problems ("soft failures")
  - Help fix these problems
  - All in multi-domain environments
- These problems are all harder when multiple networks are involved
- perfSONAR is provides a standard way to publish active and passive monitoring data
- perfSONAR = Measurement Middleware
  - ***You can't fix what you can't find***
  - ***You can't find what you can't see***
  - ***perfSONAR lets you see***

perfSONAR History

- perfSONAR can trace its origin to the Internet2 “End 2 End performance Initiative” from the year 2000.
- What has changed since 2000?
  - The Good News:
    - TCP is much less fragile; Cubic is the default CC alg, autotuning is and larger TCP buffers are everywhere
    - Reliable parallel transfers via tools like Globus Online
    - High-performance UDP-based commercial tools like Aspera
    - *more good news in latest Linux kernel, but it will take 3-4 years before this is widely deployed*
  - The Bad News:
    - The wizard gap is still large
    - Jumbo frame use is still small
    - Under-buffered and switches and routers are still common
    - Under-powered/misconfigured firewalls are common
    - Soft failures still go undetected for months
    - User performance expectations are still too low

The perfSONAR collaboration

- The perfSONAR collaboration is a Open Source project lead by ESnet, Internet2, Indiana University, and GEANT.
  - Each organization has committed 1.5 FTE effort to the project
  - Plus additional help from many others in the community (OSG, RNP, SLAC, and more)
- The perfSONAR Roadmap is influence by
  - requests on the project issue tracker
  - annual user surveys sent to everyone on the user list
  - regular meetings with VO using perfSONAR such as the WLCG and OSG
  - discussions at various perfSONAR related workshops
- Based on the above, every 6-12 months the perfSONAR governance group meets to prioritize features based on:
  - impact to the community
  - level of effort required to implement and support
  - availability of someone with the right skill set for the task

perfSONAR Toolkit

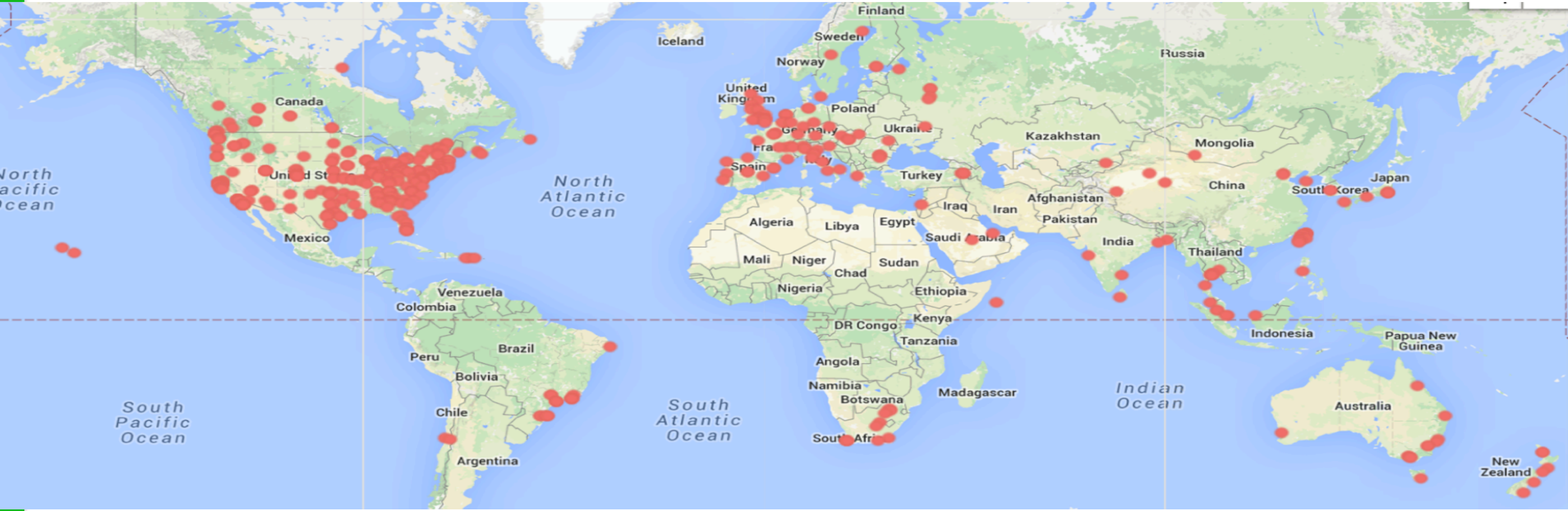
- The "perfSONAR Toolkit" is an *open source* implementation and packaging of the perfSONAR measurement infrastructure and protocols
  - http://www.perfsonar.net
- All components are available as RPMs, and bundled into a CentOS 6-based "netinstall" (Debian support in next release)
- perfSONAR tools are much more accurate if run on a dedicated perfSONAR host, not on the data server
- Easy to install and configure
  - Usually takes less than 30 minutes

perfSONAR Toolkit Components

- BWCTL for scheduling periodic throughout (iperf, iperf3), ping and traceroute tests
- OWAMP for measuring one-way latency and packet loss (RFC4856)
- "esmond" for storing measurements, summarizing results and making available via REST API
- Lookup service for discovering other testers
- On-demand test tools such as NDT (Network Diagnostic Test)
- Configuration GUIs to assist with managing all of the above
- Graphs to display measurement results

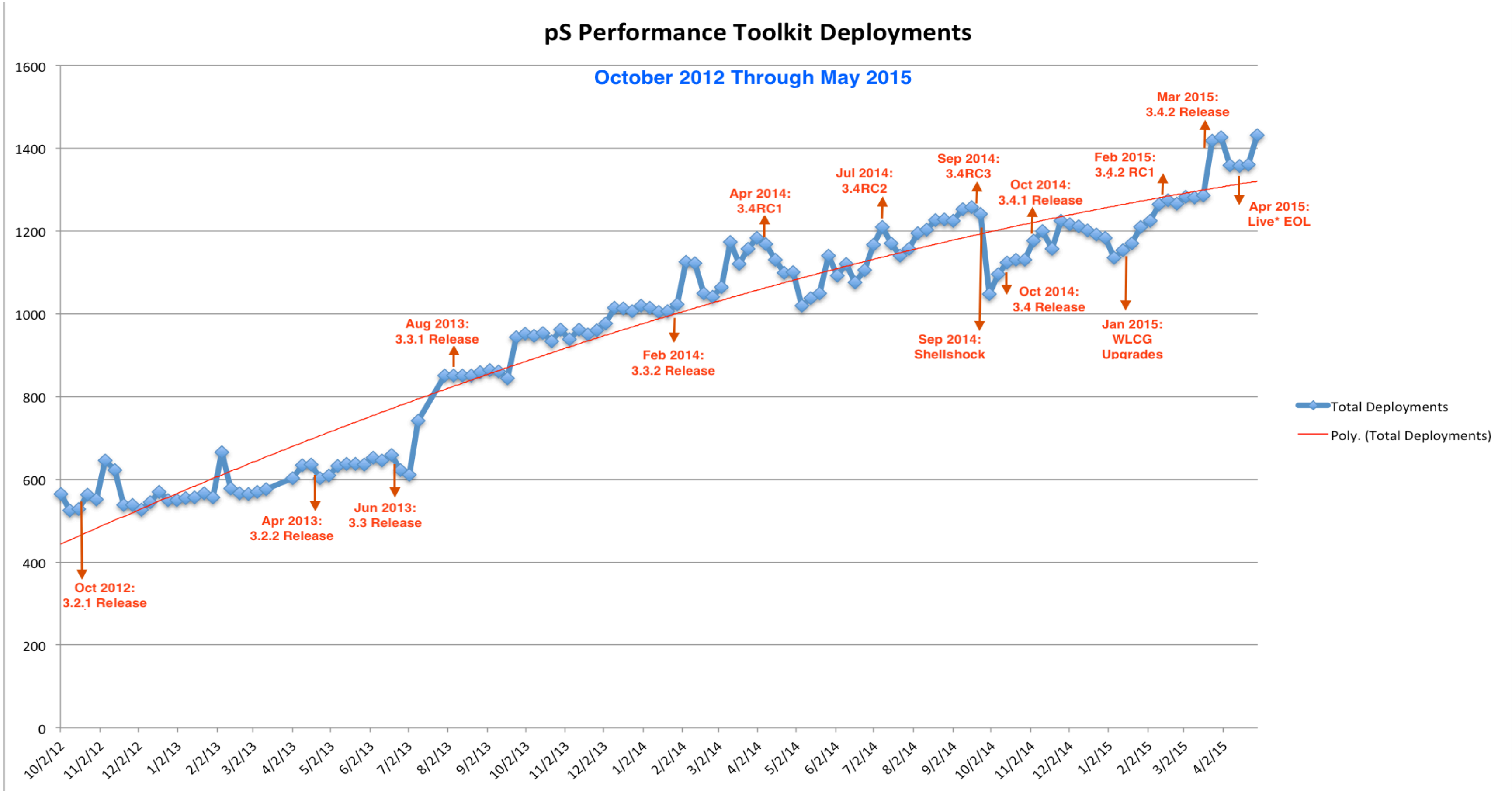
Who is running perfSONAR?

- Currently over 1400 deployments world-wide



http://stats.es.net/ServicesDirectory/

perfSONAR Deployment Growth



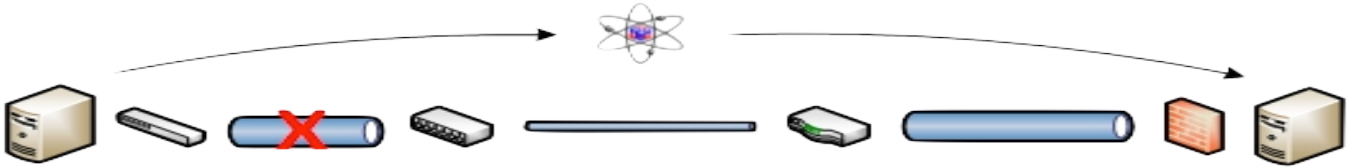
Active vs. Passive Monitoring

Passive monitoring systems have limitations

- Performance problems are often only visible at the ends
- Individual network components (e.g. routers) have no knowledge of end-to-end state
- perfSONAR tests the network in ways that passive monitoring systems do not

More perfSONAR hosts = better network visibility

- There are now enough perfSONAR hosts in the world to be quite useful

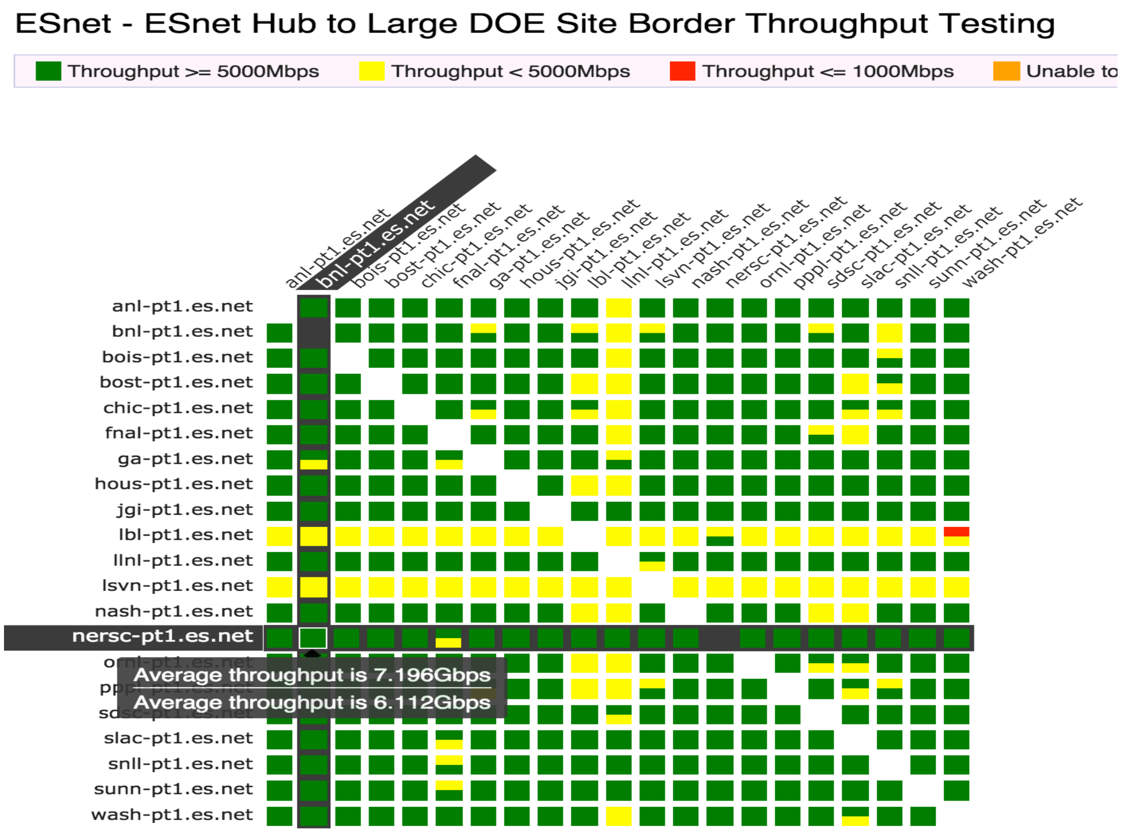


perfSONAR Dashboard: Raising Expectations and improving network visibility

Status at-a-glance
- Packet loss
- Throughput
- Correctness

Current live instances at:
- http://ps-dashboard.es.net/
- And many more

Drill-down capabilities:
- Test history between hosts
- Ability to correlate with other events
- Very valuable for fault localization and isolation



perfSONAR Hardware

- These days you can get a good 1U host capable of pushing 10Gbps TCP for around $500 (+10G NIC cost).
  - See perfSONAR user list
- And you can get a host capable of 1G for around $100!
  - Intel Celeron-based (ARM is not fast enough)
  - e.g.: http://www.newegg.com/Product/Product.aspx?Item=N82E16856501007
- VMs are not recommended
  - Tools work better if can guarantee NIC isolation

Active and Growing perfSONAR Community

- Active email lists and forums provide:
  - Instant access to advice and expertise from the community.
  - Ability to share metrics, experience and findings with others to help debug issues on a global scale.
- Joining the community automatically increases the reach and power of perfSONAR
  - The more endpoints means exponentially more ways to test and discover issues, compare metrics

perfSONAR Community

- The perfSONAR collaboration is working to build a strong user community to support the use and development of the software.
- perfSONAR Mailing Lists
  - Announcement Lists:
    - https://mail.internet2.edu/wws/subrequest/perfsonar-announce
  - Users List:
    - https://mail.internet2.edu/wws/subrequest/perfsonar-users

Use Cases & Success Stories

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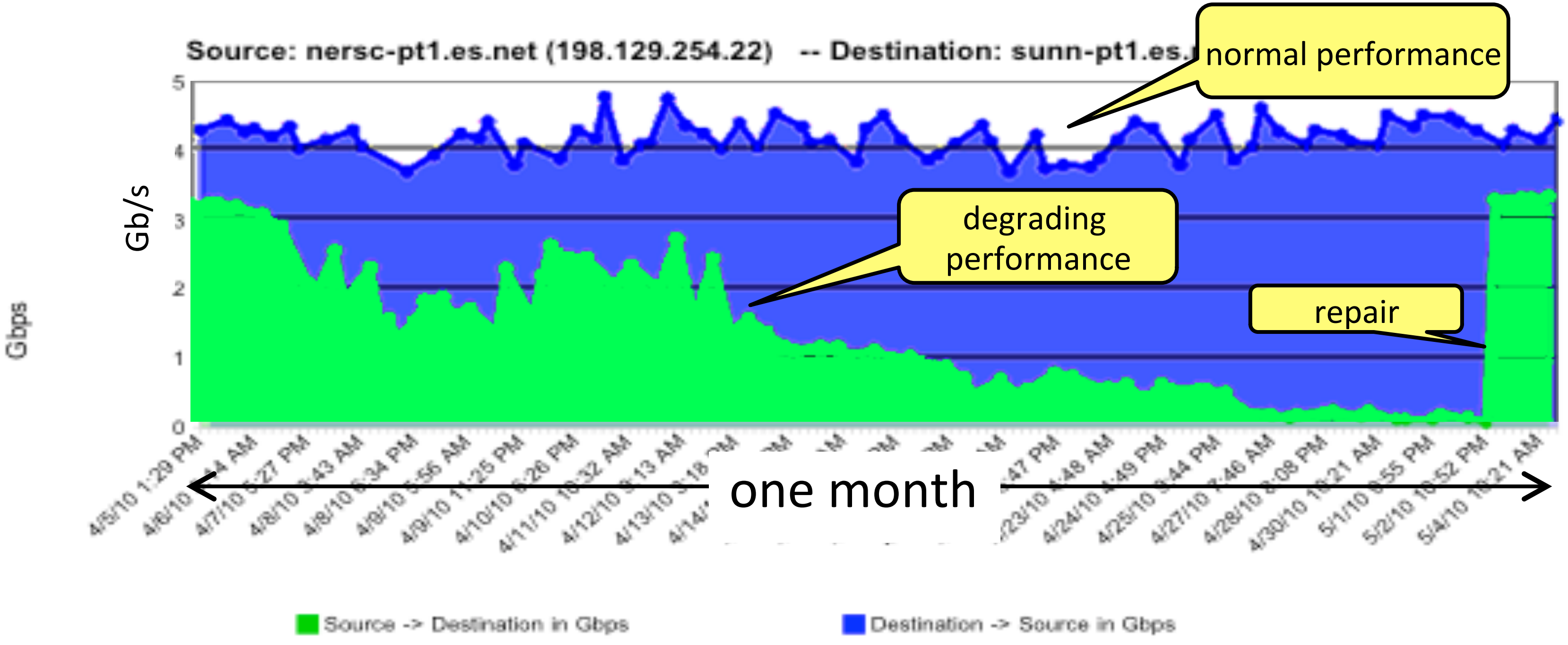
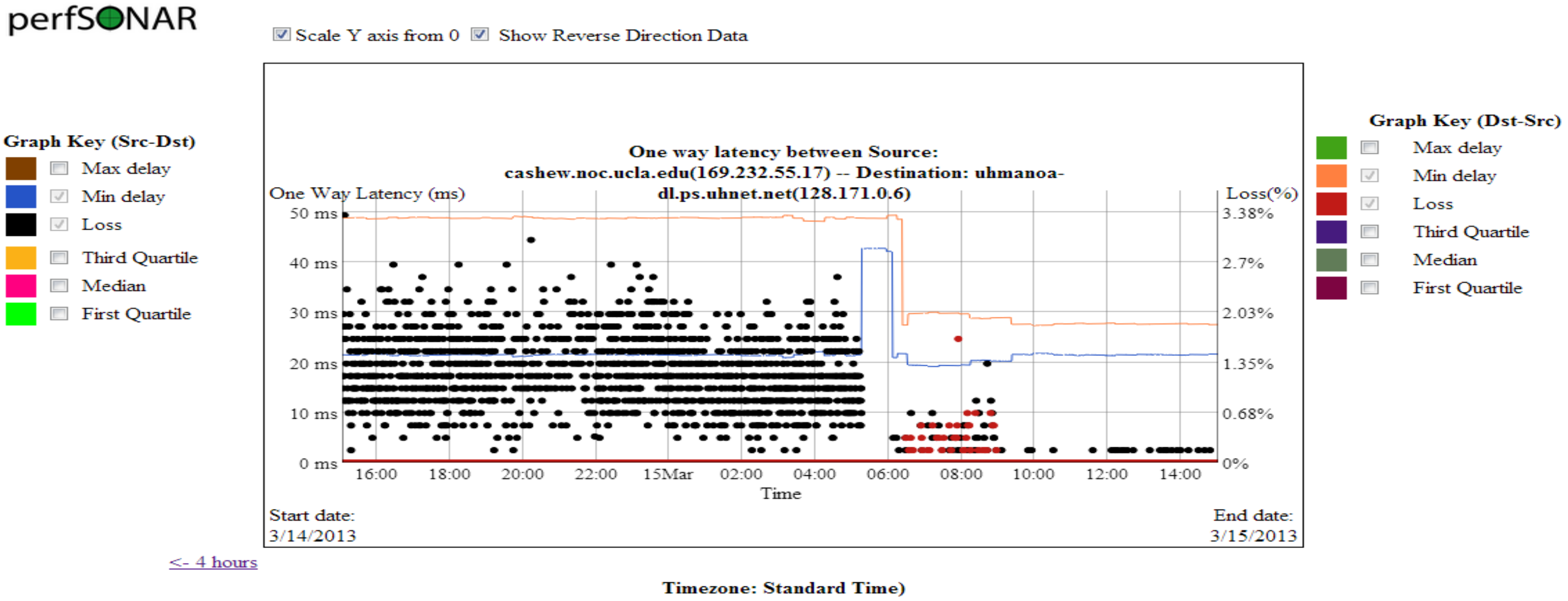
Success Stories - Failing Optic(s)

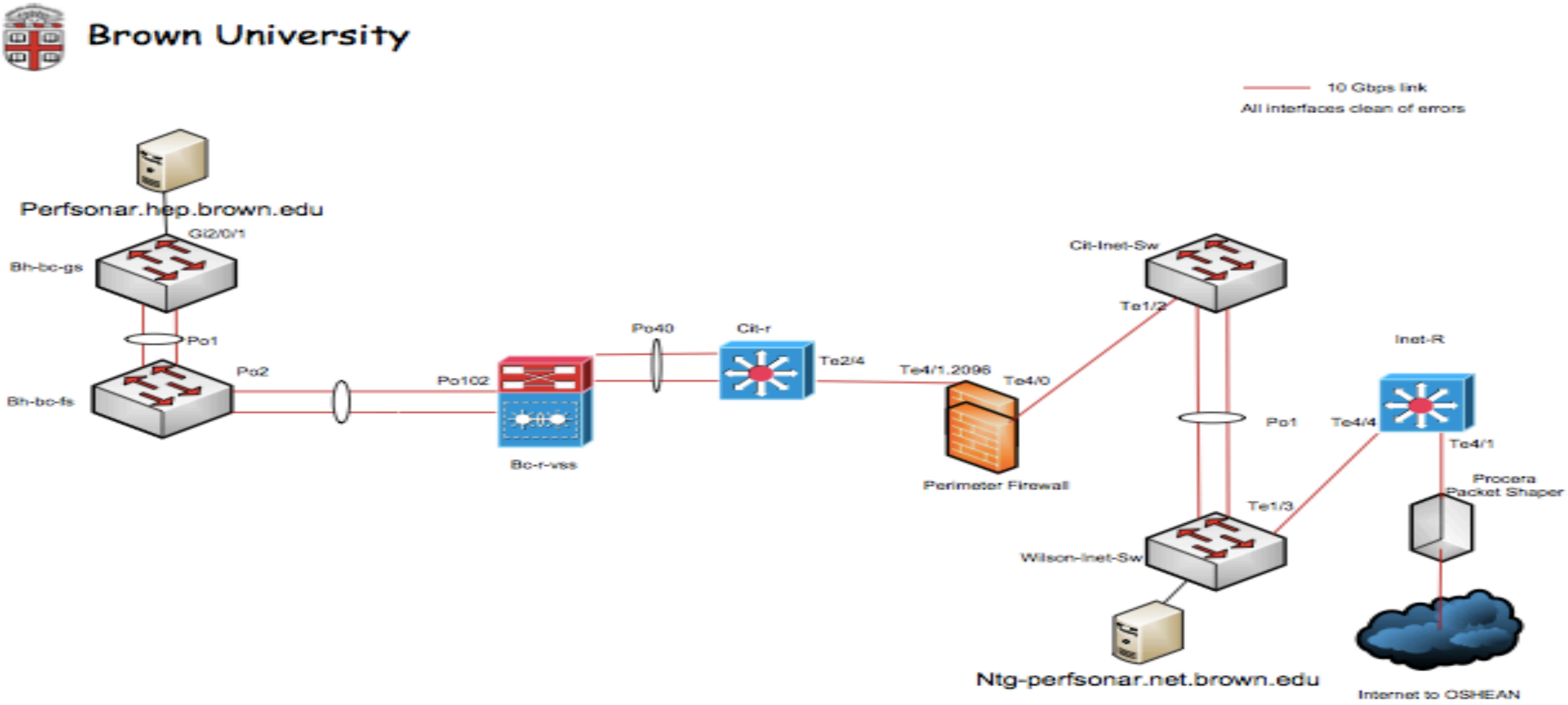


Success Stories - Failing Optic(s)

- Adding an Attenuator to a Noisy (discovered via OWAMP) Link

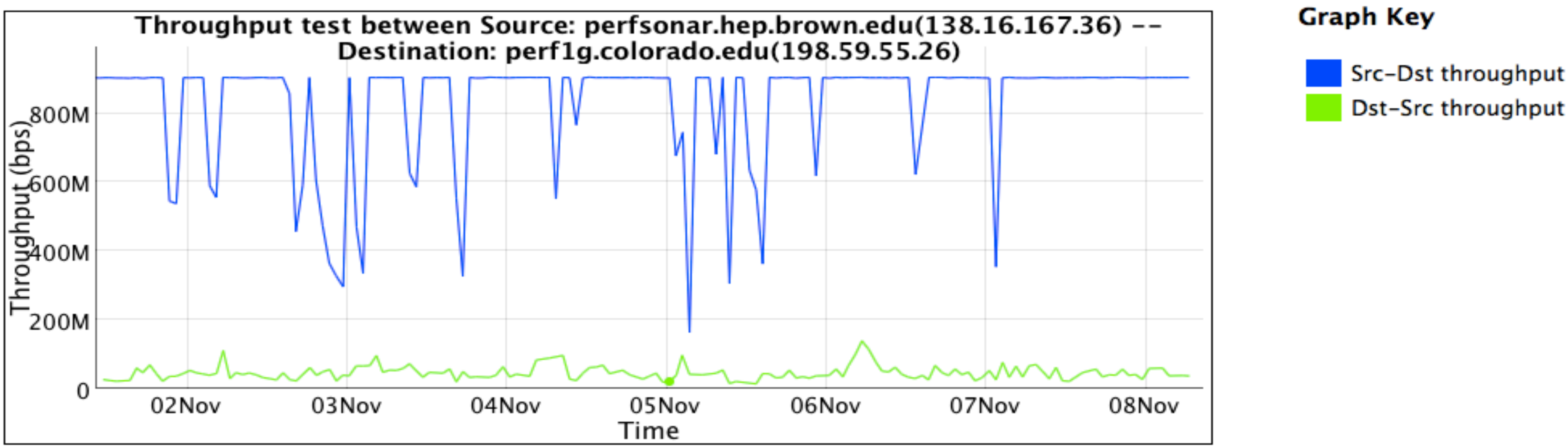


Success Stories – Firewall trouble



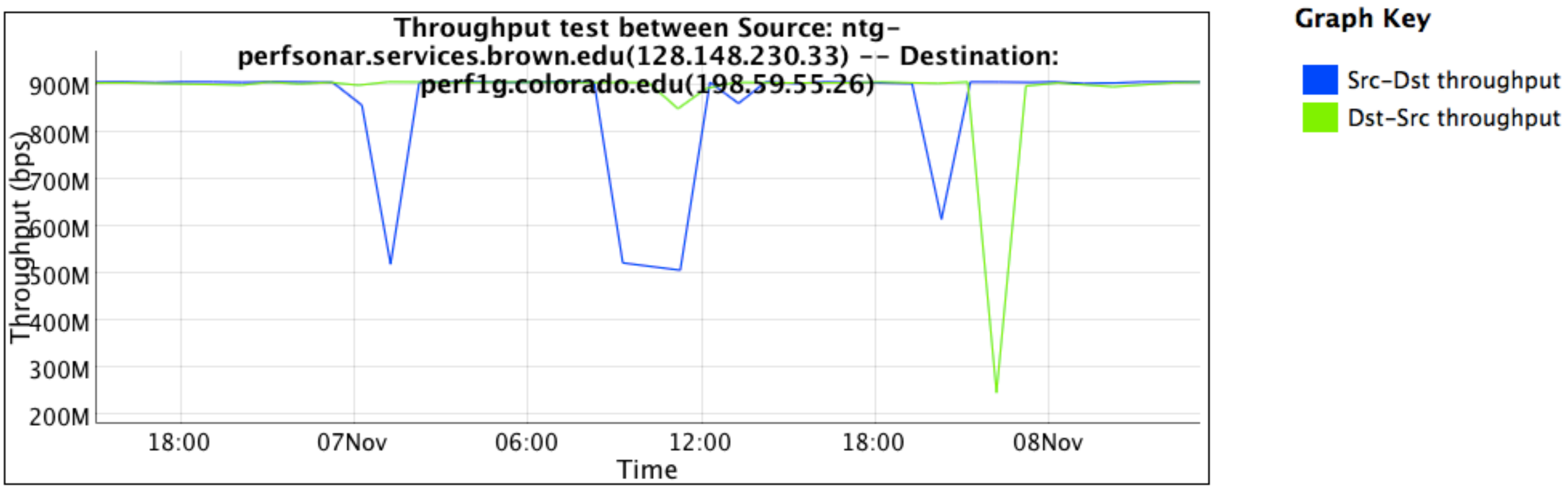
Success Stories – Firewall trouble

- Results to host behind the firewall:



Success Stories – Firewall trouble

- In front of the firewall:



Success Stories – Firewall trouble

- Want more proof – lets look at a measurement tool through the firewall.
  - Measurement tools emulate a well behaved application
- 'Outbound', not filtered:

```
nuttcp -T 10 -i 1 -p 10200 bwctl.newy.net.internet2.edu
   92.3750 MB /   1.00 sec =  774.3069 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.2879 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.3019 Mbps     0 retrans
  111.7500 MB /   1.00 sec =  938.1606 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.3198 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.2653 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.1931 Mbps     0 retrans
  111.9375 MB /   1.00 sec =  938.4808 Mbps     0 retrans
  111.6875 MB /   1.00 sec =  937.6941 Mbps     0 retrans
  111.8750 MB /   1.00 sec =  938.3610 Mbps     0 retrans

 1107.9867 MB /  10.13 sec =  917.2914 Mbps 13 %TX 11 %RX 0
retrans 8.38 msRTT
```

Success Stories – Firewall trouble

- 'Inbound', filtered:

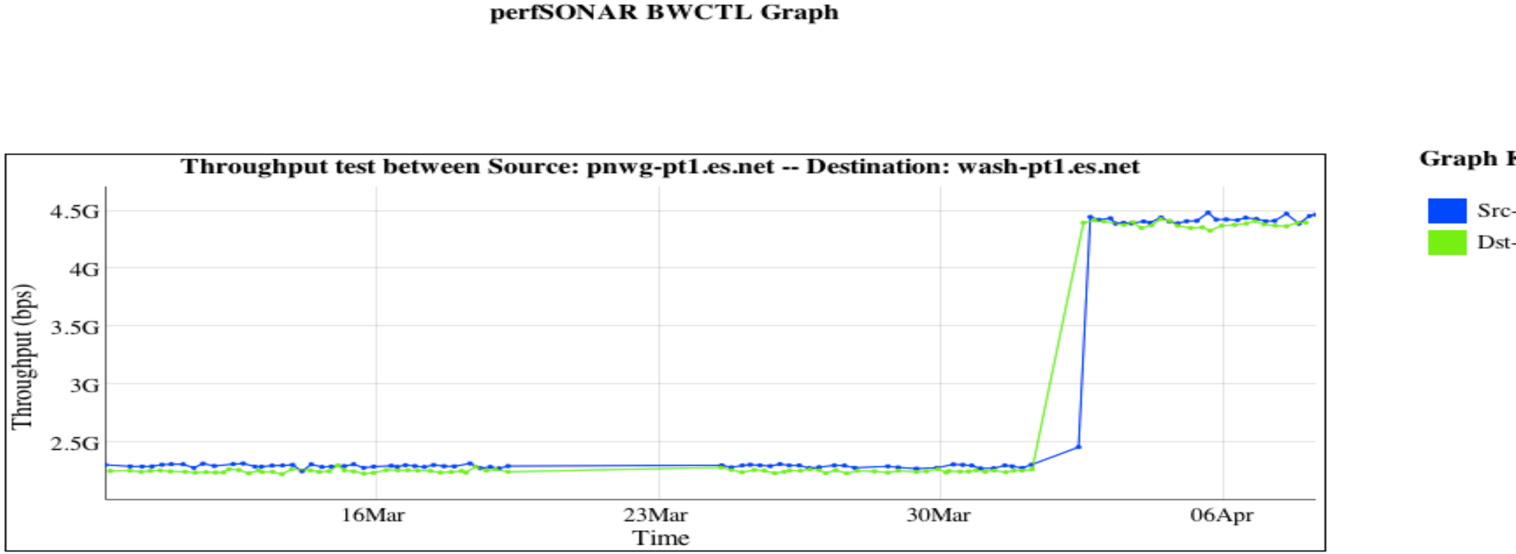
```
nuttcp -r -T 10 -i 1 -p 10200 bwctl.newy.net.internet2.edu
    4.5625 MB /   1.00 sec =   38.1995 Mbps    13 retrans
    4.8750 MB /   1.00 sec =   40.8956 Mbps     4 retrans
    4.8750 MB /   1.00 sec =   40.8954 Mbps     6 retrans
    6.4375 MB /   1.00 sec =   54.0024 Mbps     9 retrans
    5.7500 MB /   1.00 sec =   48.2310 Mbps     8 retrans
    5.8750 MB /   1.00 sec =   49.2880 Mbps     5 retrans
    6.3125 MB /   1.00 sec =   52.9006 Mbps     3 retrans
    5.3125 MB /   1.00 sec =   44.5653 Mbps     7 retrans
    4.3125 MB /   1.00 sec =   36.2108 Mbps     7 retrans
    5.1875 MB /   1.00 sec =   43.5186 Mbps     8 retrans

   53.7519 MB /  10.07 sec =   44.7577 Mbps 0 %TX 1 %RX 70 retrans 8.29
msRTT
```

Success Stories - Host Tuning

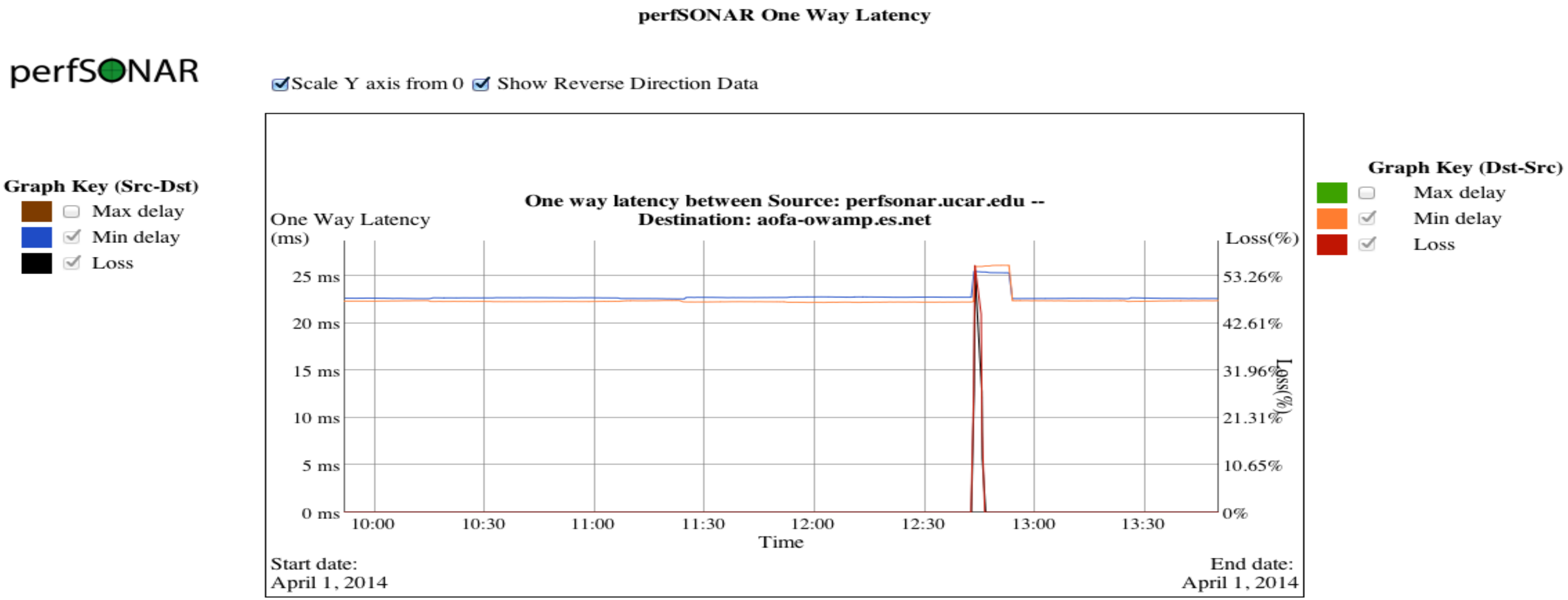
- long path (~70ms), single stream TCP, 10G cards, tuned hosts
- Why the nearly 2x uptick? Adjusted **`net.ipv4.tcp_rmem/wmem`** maximums (used in auto tuning) to 64M instead of 16M.

perfSONAR

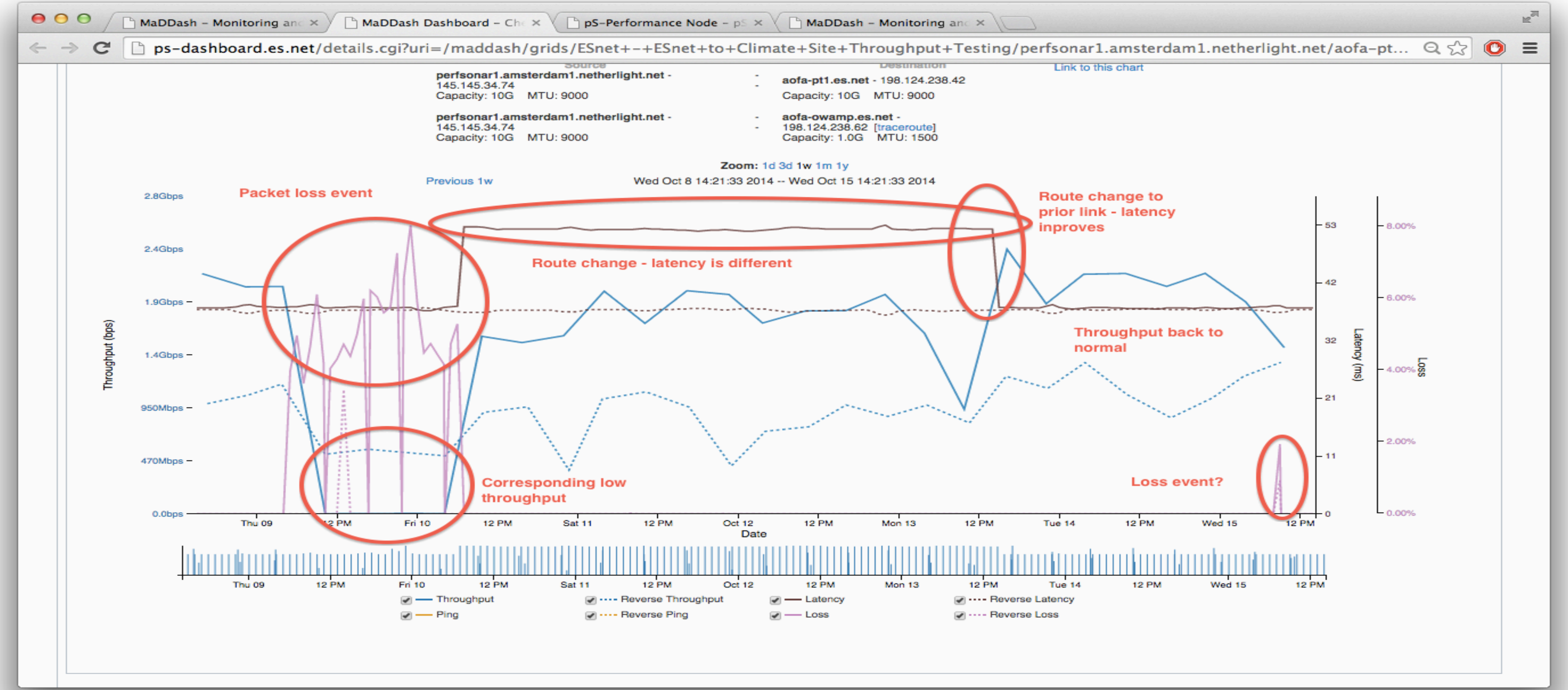


Success Stories - Fiber Cut

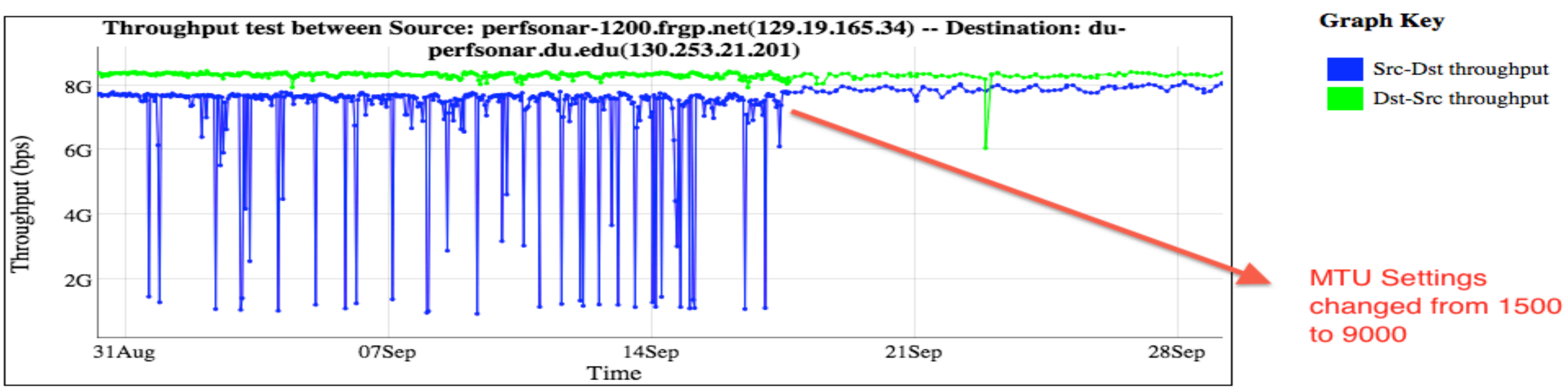
- perfSONAR can't fix fiber cuts, but you can see the loss event and the latency change due to traffic re-routing



Success Stories - Monitoring TA Links



Success Stories - MTU Changes



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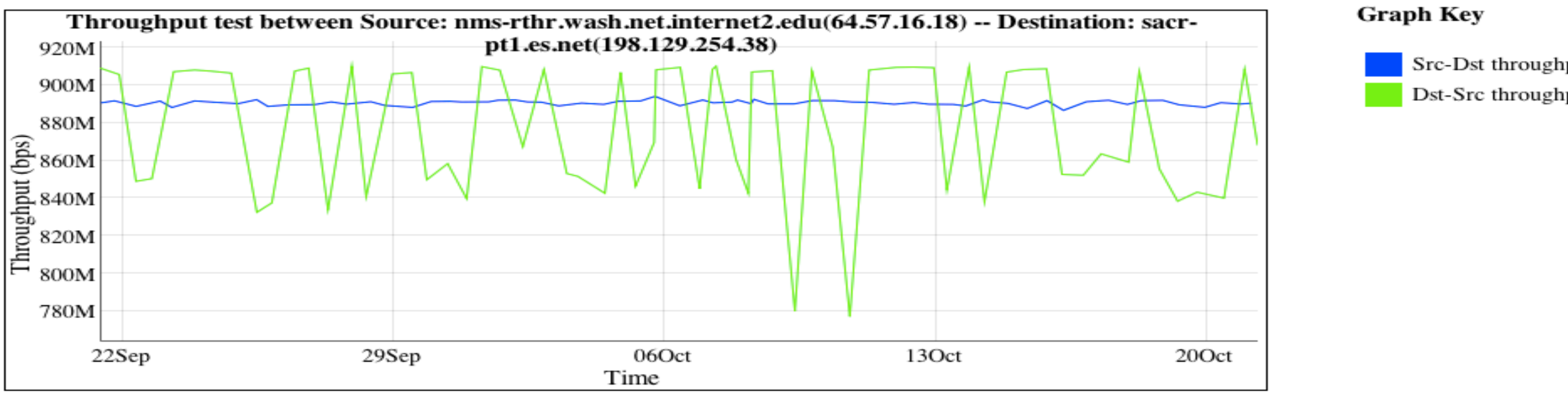
1 month ->

Timezone: GMT-0600 (MDT)

Success Stories - Host NIC Speed Mismatch



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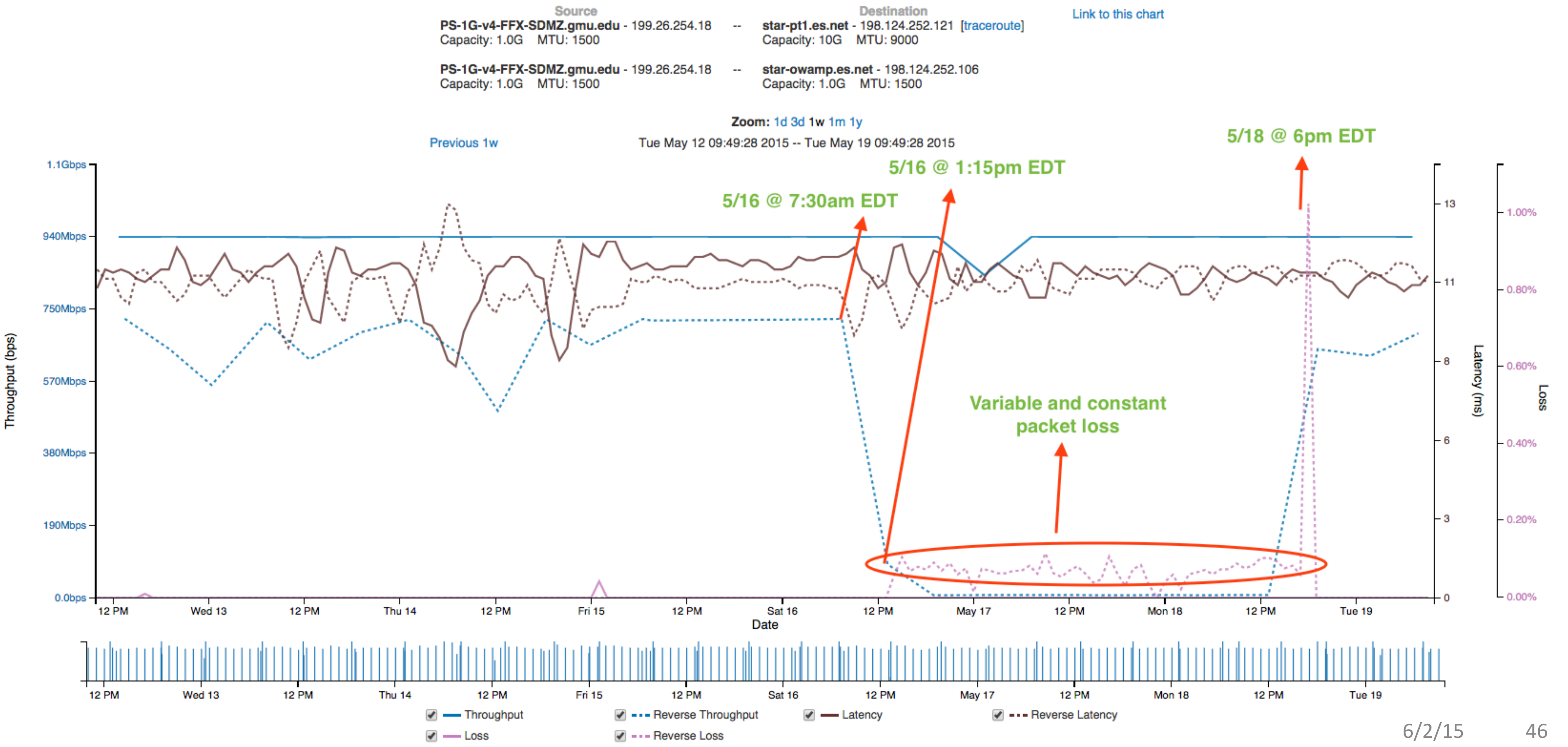
1 month ->

Timezone: GMT-0400 (EDT)

Sending from a 10G host to a 1G host leads to unstable performance

http://fasterdata.es.net/performance-testing/troubleshooting/interface-speed-mismatch/
http://fasterdata.es.net/performance-testing/evaluating-network-performance/impedence-mismatch/

Another Failing Line Card Example



Success Stories Summary

- ***Key Message(s)***:
- This type of active monitoring find problems in the network and on the end hosts.
- Ability to view long term trends in latency, loss, and throughput is very useful
  - Ability to show someone a plot, and say "what did you do on Day X? It broke something."
  - Ability to show impact of an upgrade (or lack thereof).

Deployment & Advanced Regular Testing Strategies

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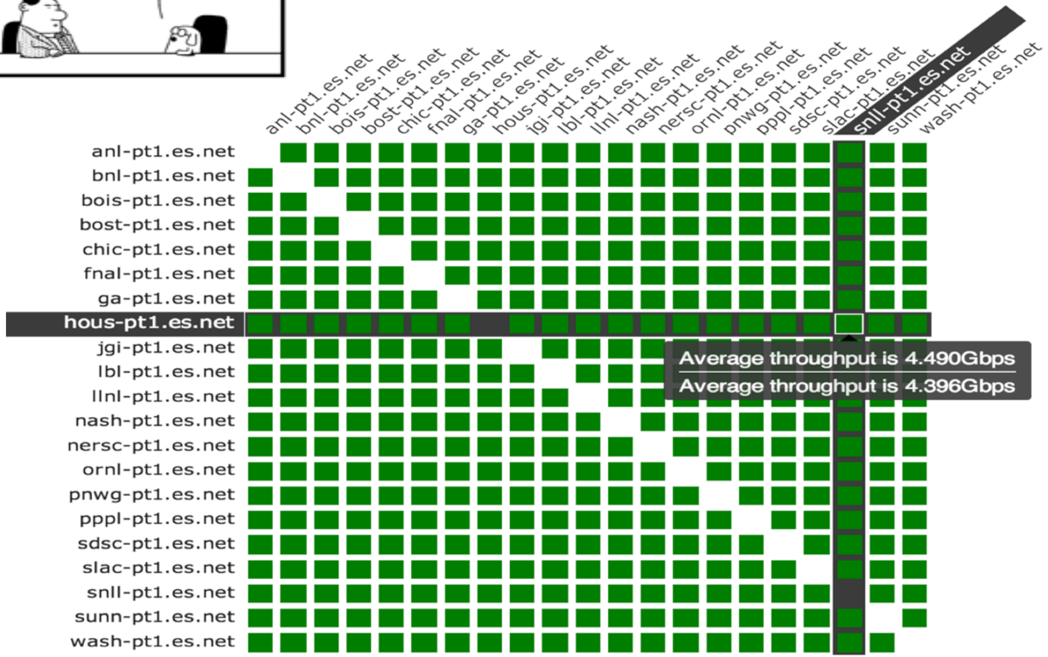
Importance of Regular Testing

- We can't wait for users to report problems and then fix them (soft failures can go unreported for years!)
- Things just break sometimes
  - Failing optics
  - Somebody messed around in a patch panel and kinked a fiber
  - Hardware goes bad
- Problems that get fixed have a way of coming back
  - System defaults come back after hardware/software upgrades
  - New employees may not know why the previous employee set things up a certain way and back out fixes
- Important to continually collect, archive, and alert on active throughput test results

A perfSONAR Dashboard



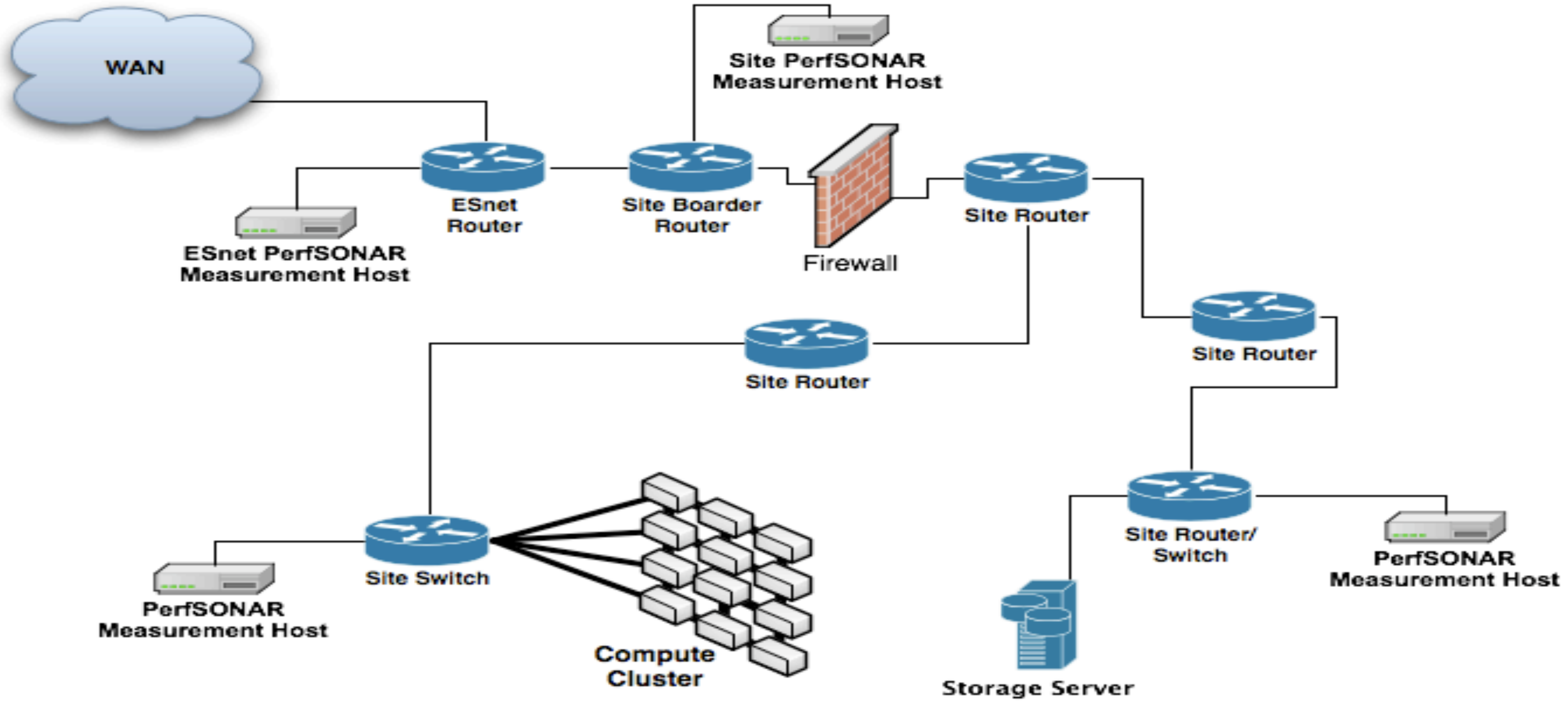
http://ps-dashboard.es.net

(google "perfSONAR Maddash" for other public dashboards)

perfSONAR Deployment Locations

- perfSONAR hosts are most useful if they are deployed near key resources such as data servers
- More perfSONAR hosts allow segments of the path to be tested separately
  - Reduced visibility for devices between perfSONAR hosts
  - Must rely on counters or other means where perfSONAR can't go

Example perfSONAR Host Placement



Regular perfSONAR Tests

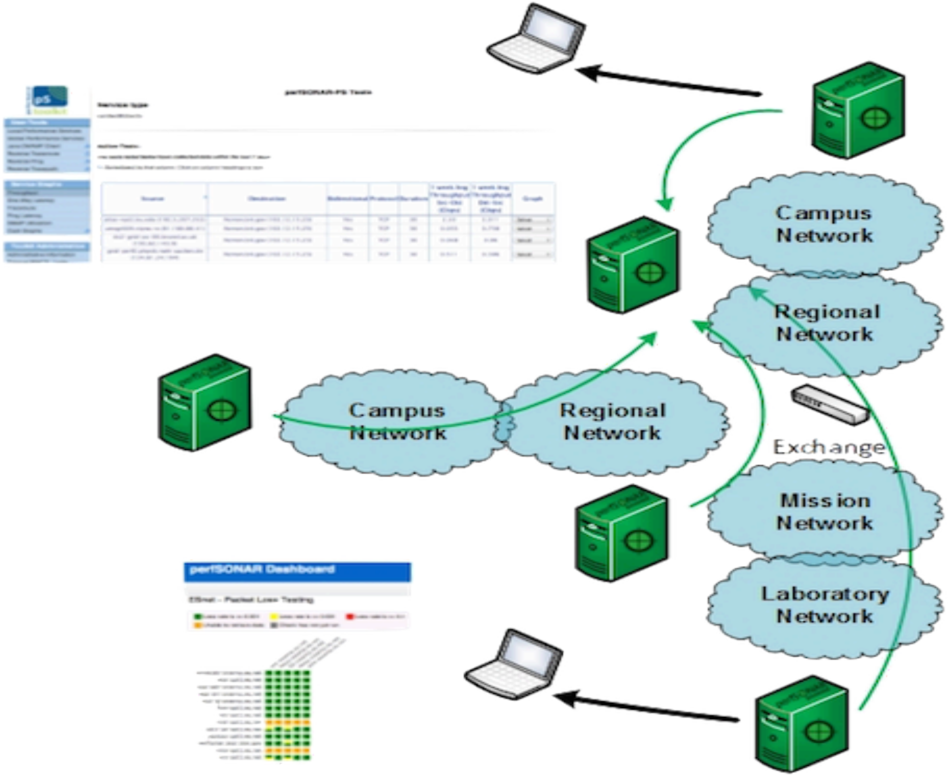
- We run regular tests to check for three things
  - TCP throughput
  - One way packet loss and delay
  - traceroute
- perfSONAR has mechanisms for managing regular testing between perfSONAR hosts
  - Statistics collection and archiving
  - Graphs
  - Dashboard display
  - Integration with NAGIOS
- Many public perfSONAR hosts around the world that you may be able to test against

Regular Testing

- Options:
  - Beacon: Let others test to you
    - No regular testing configuration is needed
  - Island: Pick some hosts to test to – you store the data locally.
    - No coordination with others is needed
  - Mesh: full coordination between you and others
    - Use a testing configuration that includes tests to everyone, and incorporate into a dashboard

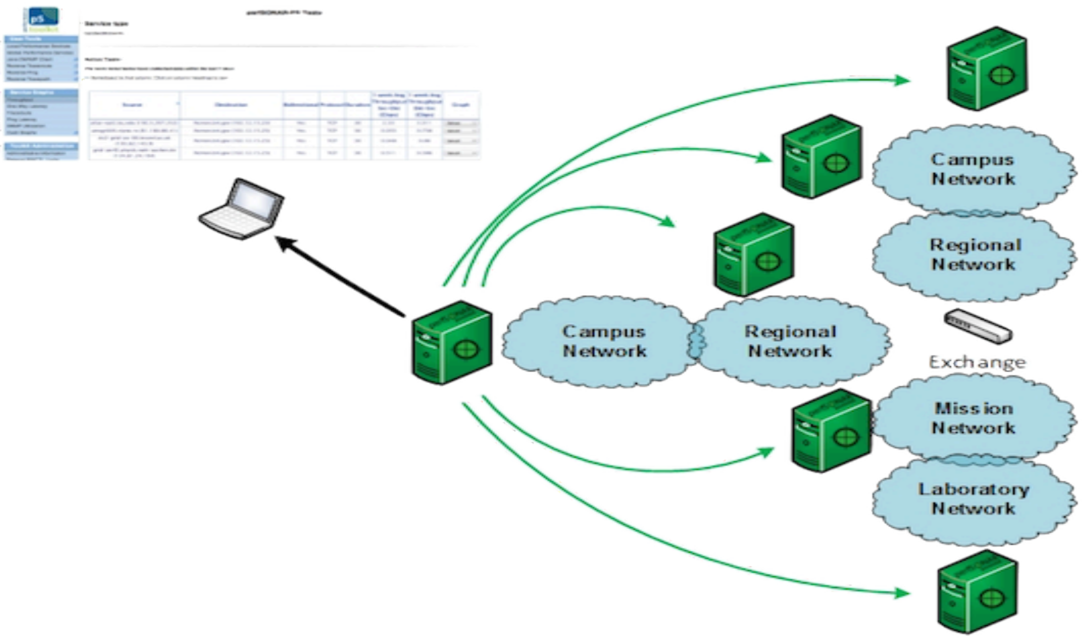
Regular Testing - Beacon

- The beacon setup is typically employed by a network provider (regional, backbone, exchange point)
  - A service to the users (allows people to test into the network)
  - Can be configured with Layer 2 connectivity if needed
  - If no regular tests are scheduled, minimum requirements for local storage.
  - Makes the most sense to enable all services (bandwidth and latency)



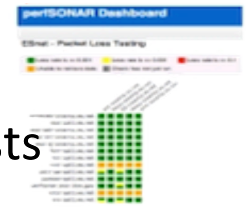
Regular Testing - Island

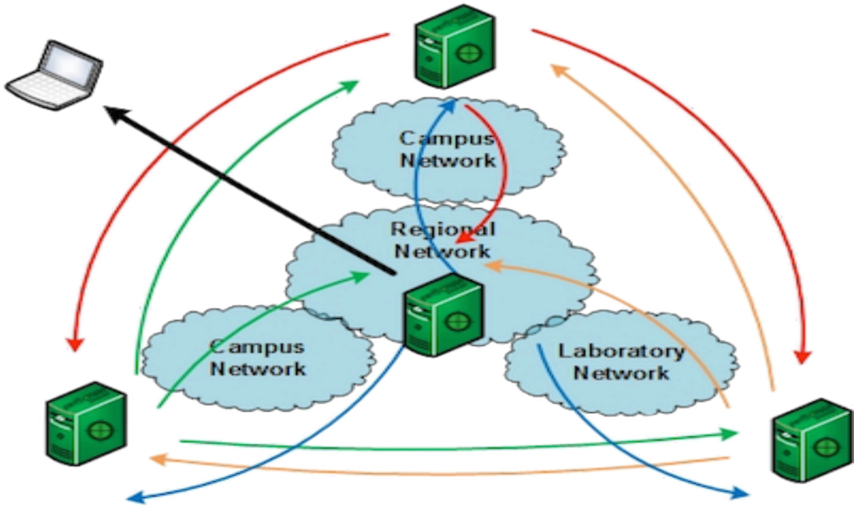
- The island setup allows a site to test against any number of the perfSONAR nodes around the world, and store the data locally.
  - No coordination required with other sites
  - Allows a view of near horizon testing (e.g. short latency – campus, regional) and far horizon (backbone network, remote collaborators).
  - OWAMP is particularly useful for determining packet loss in the previous cases.



Regular Testing - Mesh

- A full mesh requires more coordination:
  - A full mesh means all hosts involved are running the same test configuration
  - A partial mesh could mean only a small number of related hosts are running a testing configuration
- In either case – bandwidth and latency will be valuable test cases

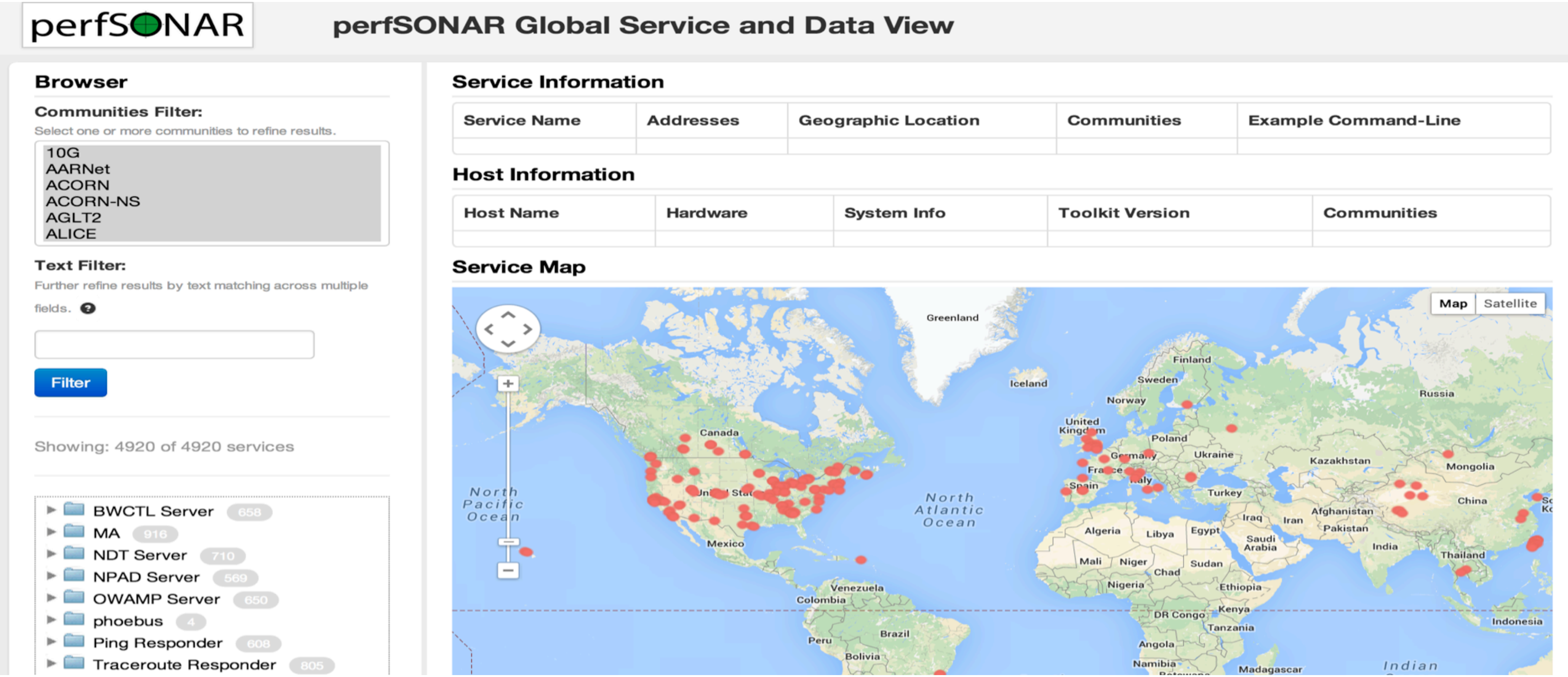




Develop a Test Plan

- What are you going to measure?
  - Achievable bandwidth
    - ***2-3 regional destinations***
    - 4-8 important collaborators
    - 4-6 times per day to each destination
    - 10-20 second tests within a region, maybe longer across oceans and continents
  - Loss/Availability/Latency
    - OWAMP: ~10-20 collaborators over diverse paths
  - Interface Utilization & Errors (via SNMP)
- What are you going to do with the results?
  - NAGIOS Alerts
  - Reports to user community?
  - Internal and/or external Dashboard

http://stats.es.net/ServicesDirectory/



Common Questions

- Q: Do most perfSONAR hosts accept tests from anyone?
  - A: Not most, but some do. ESnet allows owamp and iperf TCP tests from all R&E address space, but not the commercial internet.
- Q: Will perfSONAR test traffic step on my production traffic?
  - A: TCP is designed to be friendly; ESnet tags all our internal tests as 'scavenger' to ensure tests traffic is dropped first. But too much testing can impact production traffic. Need to be careful of this.
- Q: How can I control who can run tests to my host?
  - A: router ACLs, host ACLs, bwctld.limits
  - Future version of bwctl will include even more options to limit testing
    - only allow iperf between 12am and 6am
    - only allow 2 tests per day from all but the following subnets

Use of Measurement Tools

NANOG 64

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Tool Usage

- All of the previous examples were discovered, debugged, and corrected through the aide of the tools that are on the perfSONAR toolkit
  - perfSONAR specific tools
    - bwctl
    - owamp
  - Standard Unix tools
    - ping, traceroute, tracepath
  - Standard Unix add-on tools
    - Iperf, iperf3, nuttcp

Default perfSONAR Throughput Tool: iperf3

- iperf3 (http://software.es.net/iperf/) is a new implementation if iperf from scratch, with the goal of a smaller, simpler code base, and a library version of the functionality that can be used in other programs.
- Some new features in iperf3 include:
  - reports the number of TCP packets that were retransmitted and CWND
  - reports the average CPU utilization of the client and server (-V flag)
  - support for zero copy TCP (-Z flag)
  - JSON output format (-J flag)
  - "omit" flag: ignore the first N seconds in the results
- On RHEL-based hosts, just type 'yum install iperf3'
- More at: http://fasterdata.es.net/performance-testing/network-troubleshooting-tools/iperf-and-iperf3/

Sample iperf3 output on lossy network

- Performance is < 1Mbps due to heavy packet loss

```
[ ID] Interval            Transfer     Bandwidth       Retr  Cwnd
[ 15]   0.00-1.00   sec   139 MBytes  1.16 Gbits/sec  257   33.9 KBytes
[ 15]   1.00-2.00   sec   106 MBytes   891 Mbits/sec  138   26.9 KBytes
[ 15]   2.00-3.00   sec   105 MBytes   881 Mbits/sec  132   26.9 KBytes
[ 15]   3.00-4.00   sec  71.2 MBytes   598 Mbits/sec  161   15.6 KBytes
[ 15]   4.00-5.00   sec   110 MBytes   923 Mbits/sec  123   43.8 KBytes
[ 15]   5.00-6.00   sec   136 MBytes  1.14 Gbits/sec  122   58.0 KBytes
[ 15]   6.00-7.00   sec  88.8 MBytes   744 Mbits/sec  140   31.1 KBytes
[ 15]   7.00-8.00   sec   112 MBytes   944 Mbits/sec  143   45.2 KBytes
[ 15]   8.00-9.00   sec   119 MBytes   996 Mbits/sec  131   32.5 KBytes
[ 15]   9.00-10.00  sec   110 MBytes   923 Mbits/sec  182   46.7 KBytes
```

BWCTL

- BWCTL is the wrapper around all the perfSONAR tools
- Policy specification can do things like prevent tests to subnets, or allow longer tests to others. See the man pages for more details
- Some general notes:
  - Use '-c' to specify a 'catcher' (receiver)
  - Use '-s' to specify a 'sender'
  - Will default to IPv6 if available (use -4 to force IPv4 as needed, or specify things in terms of an address if your host names are dual homed)

bwctl features

- BWCTL lets you run any of the following between any 2 perfSONAR nodes:
  - iperf3, nuttcp, ping, owping, traceroute, and tracepath
- Sample Commands:
- `bwctl -c psmsu02.aglt2.org -s elpa-pt1.es.net -T iperf3`
- `bwping -s atla-pt1.es.net -c ga-pt1.es.net`
- `bwping -E -c www.google.com`
- `bwtraceroute -T tracepath -c lbl-pt1.es.net -l 8192 -s atla-pt1.es.net`
- `bwping -T owamp -s atla-pt1.es.net -c ga-pt1.es.net -N 1000 -i .01`

Host Issues: Throughput is dependent on TCP Buffers

- A prequel to using BWCTL throughput tests – The 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
  - Most OSs have a default TCP buffer size of 4MB per flow.
    - This is too small for long paths
    - More details at https://fasterdata.es.net/host-tuning/
- Host admins need to make sure there is enough TCP buffer space to keep the sender from waiting for acknowledgements from the receiver

Network Throughput

- Start with a definition:
  - ***network throughput*** is the rate of successful message delivery over a communication channel
  - Easier terms: how much data can I shovel into the network for some given amount of time
- What does this tell us?
  - Opposite of utilization (e.g. its how much we can get at a given point in time, minus what is utilized)
  - Utilization and throughput added together are capacity
- Tools that measure throughput are a simulation of a real work use case (e.g. how well might bulk data movement perform)
- Ways to game the system
  - Parallel streams
  - Manual window size adjustments
  - 'memory to memory' testing – no disk involved

Throughput Test Tools

- Varieties of throughput tools that BWCTL knows how to manage:
  - Iperf (v2)
    - Default for the command line (e.g. bwctl –c HOST will invoke this)
    - Some known behavioral problems (CPU hog, hard to get UDP testing to be correct)
  - Iperf3
    - Default for the perfSONAR regular testing framework, can invoke via command line switch (bwctl –T iperf3 –c HOST)
  - Nuttcp
    - Different code base, can invoke via command line switch (bwctl –T nuttcp –c HOST)
    - More control over how the tool behaves on the host (bind to CPU/core, etc.)
    - Similar feature set to iperf3

BWCTL Example (iperf)

```
> bwctl -T iperf -f m -t 10 -i 2 -c sunn-pt1.es.net
bwctl: 83 seconds until test results available
bwctl: exec_line: /usr/bin/iperf -B 198.129.254.58 -s -f m -m -p 5136 -t 10 -i 2.000000
bwctl: run_tool: tester: iperf
bwctl: run_tool: receiver: 198.129.254.58
bwctl: run_tool: sender: 198.124.238.34
bwctl: start_tool: 3598657357.738868
------------------------------------------------------------
Server listening on TCP port 5136
Binding to local address 198.129.254.58
TCP window size: 0.08 MByte (default)
------------------------------------------------------------
[ 16] local 198.129.254.58 port 5136 connected with 198.124.238.34 port 5136
[ ID] Interval       Transfer     Bandwidth
[ 16]  0.0- 2.0 sec  90.4 MBytes   379 Mbits/sec
[ 16]  2.0- 4.0 sec   689 MBytes  2891 Mbits/sec
[ 16]  4.0- 6.0 sec   684 MBytes  2867 Mbits/sec
[ 16]  6.0- 8.0 sec   691 MBytes  2897 Mbits/sec
[ 16]  8.0-10.0 sec   691 MBytes  2898 Mbits/sec
[ 16]  0.0-10.0 sec  2853 MBytes  2386 Mbits/sec
[ 16] MSS size 8948 bytes (MTU 8988 bytes, unknown interface)
```

This is what perfSONAR Graphs – the average of the complete test

BWCTL Example (iperf3)

```
> bwctl -T iperf3 -t 10 -i 2 -c sunn-pt1.es.net

bwctl: run_tool: tester: iperf3
bwctl: run_tool: receiver: 198.129.254.58
bwctl: run_tool: sender: 198.124.238.34
bwctl: start_tool: 3598657653.219168
Test initialized
Running client
Connecting to host 198.129.254.58, port 5001
[ 17] local 198.124.238.34 port 34277 connected to 198.129.254.58 port 5001
[ ID] Interval           Transfer     Bandwidth       Retransmits
[ 17]   0.00-2.00    sec   430 MBytes  1.80 Gbits/sec  2
[ 17]   2.00-4.00    sec   680 MBytes  2.85 Gbits/sec  0
[ 17]   4.00-6.00    sec   669 MBytes  2.80 Gbits/sec  0
[ 17]   6.00-8.00    sec   670 MBytes  2.81 Gbits/sec  0
[ 17]   8.00-10.00   sec   680 MBytes  2.85 Gbits/sec  0
[ ID] Interval           Transfer     Bandwidth       Retransmits
      Sent
[ 17]   0.00-10.00   sec  3.06 GBytes  2.62 Gbits/sec  2
      Received
[ 17]   0.00-10.00   sec  3.06 GBytes  2.63 Gbits/sec
iperf Done.
bwctl: stop_tool: 3598657664.995604
```

This is what perfSONAR Graphs – the average of the complete test

BWCTL Example (nuttcp)

```
> bwctl -T nuttcp -f m -t 10 -i 2 -c sunn-pt1.es.net
nuttcp-t: buflen=65536, nstream=1, port=5001 tcp -> 198.129.254.58
nuttcp-t: connect to 198.129.254.58 with mss=8948, RTT=62.418 ms
nuttcp-t: send window size = 98720, receive window size = 87380
nuttcp-t: available send window = 74040, available receive window = 65535
nuttcp-r: buflen=65536, nstream=1, port=5001 tcp
nuttcp-r: send window size = 98720, receive window size = 87380
nuttcp-r: available send window = 74040, available receive window = 65535
  131.0625 MB /   2.00 sec =  549.7033 Mbps     1 retrans
  725.6250 MB /   2.00 sec = 3043.4964 Mbps     0 retrans
  715.0000 MB /   2.00 sec = 2998.8284 Mbps     0 retrans
  714.3750 MB /   2.00 sec = 2996.4168 Mbps     0 retrans
  707.1250 MB /   2.00 sec = 2965.8349 Mbps     0 retrans
nuttcp-t: 2998.1379 MB in 10.00 real seconds = 307005.08 KB/sec = 2514.9856 Mbps
nuttcp-t: 2998.1379 MB in 2.32 CPU seconds = 1325802.48 KB/cpu sec
nuttcp-t: retrans = 1
nuttcp-t: 47971 I/O calls, msec/call = 0.21, calls/sec = 4797.03
nuttcp-t: 0.0user 2.3sys 0:10real 23% 0i+0d 768maxrss 0+2pf 156+28csw

nuttcp-r: 2998.1379 MB in 10.07 real seconds = 304959.96 KB/sec = 2498.2320 Mbps
nuttcp-r: 2998.1379 MB in 2.36 CPU seconds = 1301084.31 KB/cpu sec
nuttcp-r: 57808 I/O calls, msec/call = 0.18, calls/sec = 5742.21
nuttcp-r: 0.0user 2.3sys 0:10real 23% 0i+0d 770maxrss 0+4pf 9146+24csw
```

BWCTL Example (nuttcp, [1%] loss)

```
> bwctl -T nuttcp -f m -t 10 -i 2 -c sunn-pt1.es.net
bwctl: exec_line: /usr/bin/nuttcp -vv -p 5004 -i 2.000000 -T 10 -t 198.129.254.58
nuttcp-t: buflen=65536, nstream=1, port=5004 tcp -> 198.129.254.58
nuttcp-t: connect to 198.129.254.58 with mss=8948, RTT=62.440 ms
nuttcp-t: send window size = 98720, receive window size = 87380
nuttcp-t: available send window = 74040, available receive window = 65535
nuttcp-r: send window size = 98720, receive window size = 87380
nuttcp-r: available send window = 74040, available receive window = 65535
    6.3125 MB /   2.00 sec =   26.4759 Mbps    27 retrans
    3.5625 MB /   2.00 sec =   14.9423 Mbps     4 retrans
    3.8125 MB /   2.00 sec =   15.9906 Mbps     7 retrans
    4.8125 MB /   2.00 sec =   20.1853 Mbps    13 retrans
    6.0000 MB /   2.00 sec =   25.1659 Mbps     7 retrans
nuttcp-t: 25.5066 MB in 10.00 real seconds = 2611.85 KB/sec = 21.3963 Mbps
nuttcp-t: 25.5066 MB in 0.01 CPU seconds = 1741480.37 KB/cpu sec
nuttcp-t: retrans = 58
nuttcp-t: 409 I/O calls, msec/call = 25.04, calls/sec = 40.90
nuttcp-t: 0.0user 0.0sys 0:10real 0% 0i+0d 768maxrss 0+2pf 51+3csw

nuttcp-r: 25.5066 MB in 10.30 real seconds = 2537.03 KB/sec = 20.7833 Mbps
nuttcp-r: 25.5066 MB in 0.02 CPU seconds = 1044874.29 KB/cpu sec
nuttcp-r: 787 I/O calls, msec/call = 13.40, calls/sec = 76.44
nuttcp-r: 0.0user 0.0sys 0:10real 0% 0i+0d 770maxrss 0+4pf 382+0csw
```

Throughput Expectations

Q: What iperf through should you expect to see on a uncongested 10Gbps network?

A: 3 - 9.9 Gbps, depending on

- RTT
- TCP tuning
- CPU core speed, and ratio of sender speed to receiver speed

OWAMP

- OWAMP = One Way Active Measurement Protocol
  - E.g. 'one way ping'
- Some differences from traditional ping:
  - Measure each direction independently (recall that we often see things like congestion occur in one direction and not the other)
  - Uses small evenly spaced groupings of UDP (not ICMP) packets
  - Ability to ramp up the interval of the stream, size of the packets, number of packets
- OWAMP is most useful for detecting packet train abnormalities on an end to end basis
  - Loss
  - Duplication
  - Out of order packets
  - Latency on the forward vs. reverse path
  - Number of Layer 3 hops
- Does require some accurate time via NTP – the perfSONAR toolkit does take care of this for you.

What OWAMP Tells Us

- OWAMP is very useful in regular testing
  - Congestion or queuing often occurs in a single direction
  - Packet loss information (and how often/how much occurs over time) is more valuable than throughput
    - This gives you a ‘why’ to go with an observation.
  - If your router is going to drop a 50B UDP packet, it is most certainly going to drop a 1500B/9000B TCP packet
- Overlaying data
  - Compare your throughput results against your OWAMP – do you see patterns?
  - Alarm on each, if you are alarming (and we hope you are alarming …)

OWAMP (initial)

```
> owping sunn-owamp.es.net
Approximately 12.6 seconds until results available
--- owping statistics from [wash-owamp.es.net]:8885 to [sunn-owamp.es.net]:8827 ---
SID:  c681fe4ed67f1b3e5faeb249f078ec8a
first:     2014-01-13T18:11:11.420
last: 2014-01-13T18:11:20.587
100 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 31/31.1/31.7 ms, (err=0.00201 ms)
one-way jitter = 0 ms (P95-P50)
Hops = 7 (consistently)
no reordering

--- owping statistics from [sunn-owamp.es.net]:9027 to [wash-owamp.es.net]:8888 ---
SID:  c67cfc7ed67f1b3eaab69b94f393bc46
first:     2014-01-13T18:11:11.321
last: 2014-01-13T18:11:22.672
100 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 31.4/31.5/32.6 ms, (err=0.00201 ms)
one-way jitter = 0 ms (P95-P50)
Hops = 7 (consistently)
no reordering
```

This is what perfSONAR Graphs – the average of the complete test

OWAMP (w/ loss)

```
> owping sunn-owamp.es.net
Approximately 12.6 seconds until results available

--- owping statistics from [wash-owamp.es.net]:8852 to [sunn-owamp.es.net]:8837 ---
SID:  c681fe4ed67f1f0908224c341a2b83f3
first:      2014-01-13T18:27:22.032
last: 2014-01-13T18:27:32.904
100 sent, 12 lost (12.000%), 0 duplicates
one-way delay min/median/max = 31.1/31.1/31.3 ms, (err=0.00502 ms)
one-way jitter = nan ms (P95-P50)
Hops = 7 (consistently)
no reordering


--- owping statistics from [sunn-owamp.es.net]:9182 to [wash-owamp.es.net]:8893 ---
SID:  c67cfc7ed67f1f09531c87cf38381bb6
first:      2014-01-13T18:27:21.993
last: 2014-01-13T18:27:33.785
100 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 31.4/31.5/31.5 ms, (err=0.00502 ms)
one-way jitter = 0 ms (P95-P50)
Hops = 7 (consistently)
no reordering
```

This is what perfSONAR Graphs – the average of the complete test

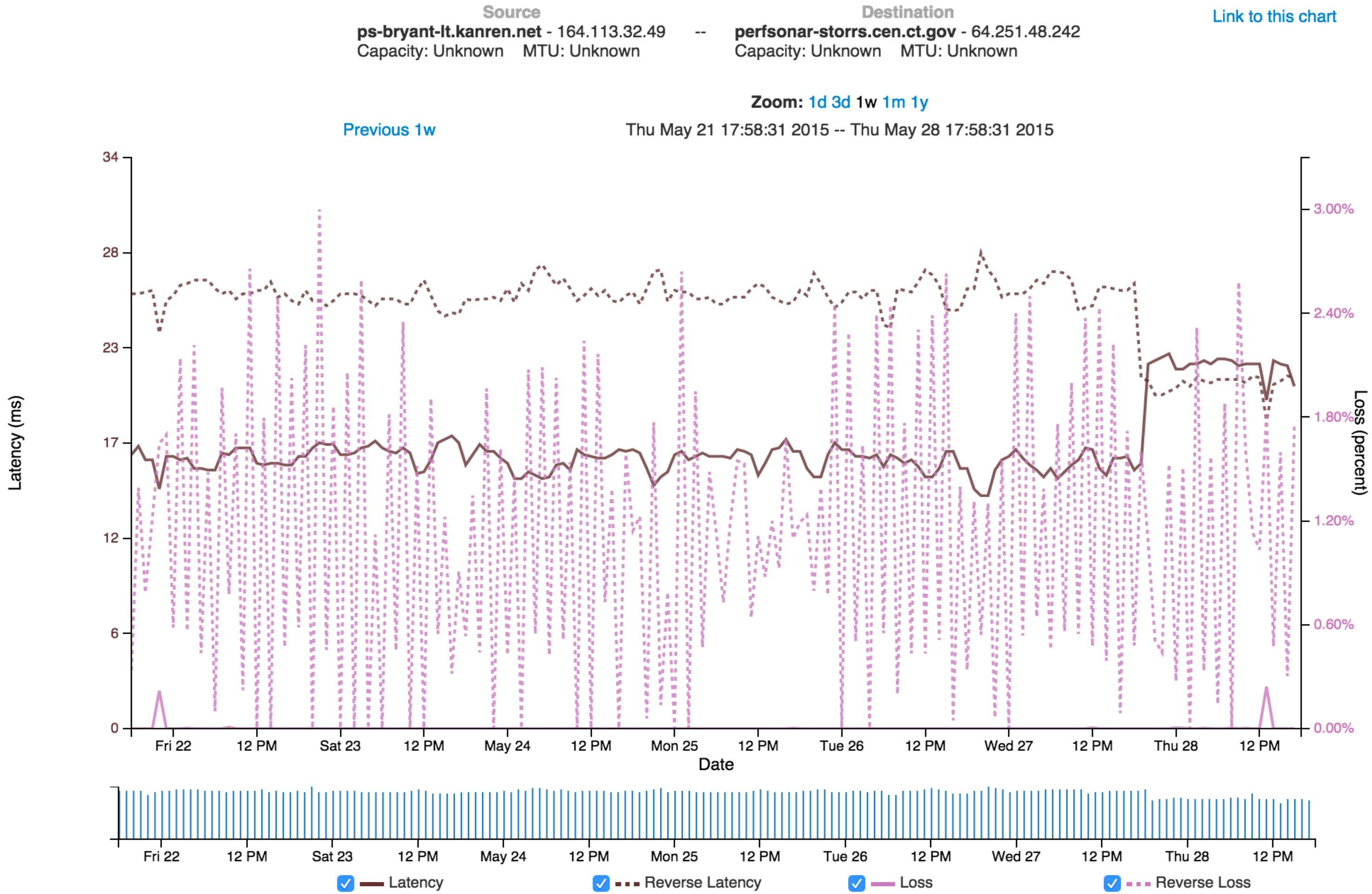
OWAMP (w/ re-ordering)

```
> owping sunn-owamp.es.net
Approximately 12.9 seconds until results available

--- owping statistics from [wash-owamp.es.net]:8814 to [sunn-owamp.es.net]:9062 ---
SID:   c681fe4ed67f21d94991ea335b7a1830
first: 2014-01-13T18:39:22.543
last:  2014-01-13T18:39:31.503
100 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 31.1/106/106 ms, (err=0.00201 ms)
one-way jitter = 0.1 ms (P95-P50)
Hops = 7 (consistently)
1-reordering = 19.000000%
2-reordering = 1.000000%
no 3-reordering

--- owping statistics from [sunn-owamp.es.net]:8770 to [wash-owamp.es.net]:8939 ---
SID:   c67cfc7ed67f21d994c1302dff644543
first: 2014-01-13T18:39:22.602
last:  2014-01-13T18:39:31.279
100 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 31.4/31.5/32 ms, (err=0.00201 ms)
one-way jitter = 0 ms (P95-P50)
Hops = 7 (consistently)
no reordering
```

Plotting owamp results



BWCTL (Traceroute)

```
> bwtraceroute -T traceroute -s sacr-pt1.es.net –c wash-pt1.es.net
bwtraceroute: Using tool: traceroute
traceroute to 198.124.238.34 (198.124.238.34), 30 hops max, 60 byte packets
 1  sacrcr5-sacrpt1.es.net (198.129.254.37)  0.490 ms  0.788 ms  1.114 ms
 2  denvcr5-ip-a-sacrcr5.es.net (134.55.50.202)  21.304 ms  21.594 ms  21.924 ms
 3  kanscr5-ip-a-denvcr5.es.net (134.55.49.58)  31.944 ms  32.608 ms  32.838 ms
 4  chiccr5-ip-a-kanscr5.es.net (134.55.43.81)  42.904 ms  43.236 ms  43.566 ms
 5  washcr5-ip-a-chiccr5.es.net (134.55.36.46)  60.046 ms  60.339 ms  60.670 ms
 6  wash-pt1.es.net (198.124.238.34)  59.679 ms  59.693 ms  59.708 ms

> bwtraceroute -T traceroute -c sacr-pt1.es.net –s wash-pt1.es.net
bwtraceroute: Using tool: traceroute
traceroute to 198.129.254.38 (198.129.254.38), 30 hops max, 60 byte packets
 1  wash-te-perf-if1.es.net (198.124.238.33)  0.474 ms  0.816 ms  1.145 ms
 2  chiccr5-ip-a-washcr5.es.net (134.55.36.45)  19.133 ms  19.463 ms  19.786 ms
 3  kanscr5-ip-a-chiccr5.es.net (134.55.43.82)  28.515 ms  28.799 ms  29.083 ms
 4  denvcr5-ip-a-kanscr5.es.net (134.55.49.57)  39.077 ms  39.348 ms  39.628 ms
 5  sacrcr5-ip-a-denvcr5.es.net (134.55.50.201)  60.013 ms  60.299 ms  60.983 ms
 6  sacr-pt1.es.net (198.129.254.38)  59.679 ms  59.678 ms  59.668 ms
```

BWCTL (Tracepath)

```
> bwtraceroute -T tracepath -s sacr-pt1.es.net –c wash-pt1.es.net
bwtraceroute: Using tool: tracepath
bwtraceroute: 36 seconds until test results available

SENDER START
 1?: [LOCALHOST]      pmtu 9000
 1:  sacrcr5-sacrpt1.es.net (198.129.254.37)                 0.489ms
 1:  sacrcr5-sacrpt1.es.net (198.129.254.37)                 0.463ms
 2:  denvcr5-ip-a-sacrcr5.es.net (134.55.50.202)            21.426ms
 3:  kanscr5-ip-a-denvcr5.es.net (134.55.49.58)             31.957ms
 4:  chiccr5-ip-a-kanscr5.es.net (134.55.43.81)             42.947ms
 5:  washcr5-ip-a-chiccr5.es.net (134.55.36.46)             60.092ms
 6:  wash-pt1.es.net (198.124.238.34)                       59.753ms reached
     Resume: pmtu 9000 hops 6 back 59

SENDER END
```

BWCTL (Tracepath with MTU mismatch)

> bwtraceroute -T tracepath -c nettest.lbl.gov -s anl-pt1.es.net
bwtraceroute: Using tool: tracepath

1?: [LOCALHOST] pmtu 9000
1: anlmr2-anlpt1.es.net (198.124.252.118) 0.249ms asymm 2
1: anlmr2-anlpt1.es.net (198.124.252.118) 0.197ms asymm 2
2: no reply
3: kanscr5-ip-a-chiccr5.es.net (134.55.43.82) 13.816ms
4: denvcr5-ip-a-kanscr5.es.net (134.55.49.57) 24.379ms
5: sacrcr5-ip-a-denvcr5.es.net (134.55.50.201) 45.298ms
6: sunncr5-ip-a-sacrcr5.es.net (134.55.40.6) 47.890ms
7: et-3-0-0-1411.er1-n1.lbl.gov (198.129.78.22) 50.093ms
8: t5-4.ir1-n1.lbl.gov (131.243.244.131) 50.772ms
9: t5-4.ir1-n1.lbl.gov (131.243.244.131) 52.669ms pmtu 1500
9: nettest.lbl.gov (131.243.24.11) 49.239ms reached
Resume: pmtu 1500 hops 9 back 56

BWCTL (Ping)

```
> bwping -c nettest.lbl.gov -s anl-pt1.es.net
bwping: Using tool: ping
PING 131.243.24.11 (131.243.24.11) from 198.124.252.117 : 56(84) bytes of data.
64 bytes from 131.243.24.11: icmp_seq=1 ttl=56 time=49.1 ms
64 bytes from 131.243.24.11: icmp_seq=2 ttl=56 time=49.1 ms
64 bytes from 131.243.24.11: icmp_seq=3 ttl=56 time=49.1 ms
64 bytes from 131.243.24.11: icmp_seq=4 ttl=56 time=49.1 ms
64 bytes from 131.243.24.11: icmp_seq=5 ttl=56 time=49.1 ms
```

To test to a host not running bwctl, use “-E”

```
> bwping -E -c www.google.com
bwping: Using tool: ping
PING 2607:f8b0:4010:800::1013(2607:f8b0:4010:800::1013) from 2001:400:2201:1190::3 : 56 data bytes
64 bytes from 2607:f8b0:4010:800::1013: icmp_seq=1 ttl=54 time=48.1 ms
64 bytes from 2607:f8b0:4010:800::1013: icmp_seq=2 ttl=54 time=48.2 ms
64 bytes from 2607:f8b0:4010:800::1013: icmp_seq=3 ttl=54 time=48.2 ms
64 bytes from 2607:f8b0:4010:800::1013: icmp_seq=4 ttl=54 time=48.2 ms
```

BWCTL (owamp)

```
> bwping -T owamp -4 -s sacr-pt1.es.net –c wash-pt1.es.net
bwping: Using tool: owamp
bwping: 42 seconds until test results available

--- owping statistics from [198.129.254.38]:5283 to [198.124.238.34]:5121 ---
SID: c67cee22d85fc3b2bbe23f83da5947b2
first:    2015-01-13T08:17:58.534
last:     2015-01-13T08:18:17.581
10 sent, 0 lost (0.000%), 0 duplicates
one-way delay min/median/max = 29.9/29.9/29.9 ms, (err=0.191 ms)
one-way jitter = 0.1 ms (P95-P50)
Hops = 5 (consistently)
no reordering
```

Testing Pitfalls

- Don't trust a single result
  - you should run any test a few times to confirm the results
  - Hop-by-hop path characteristics may be continuously changing
- A poor carpenter blames his tools
  - The tools are only as good as the people using them, do it methodically
  - Trust the results – remember that they are giving you a number based on the entire environment
- If the site isn't using perfSONAR – step 1 is to get them to do so
  - http://www.perfsonar.net
- Get some help from the community
  - perfsonar-user@internet2.edu

Resources

- perfSONAR website
  - http://www.perfsonar.net/
- perfSONAR Toolkit Manual
  - http://docs.perfsonar.net/
- perfSONAR mailing lists
  - http://www.perfsonar.net/about/getting-help/
- perfSONAR directory
  - http://stats.es.net/ServicesDirectory/
- FasterData Knowledgebase
  - http://fasterdata.es.net/

EXTRA SLIDES