



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

Performance Use Cases

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

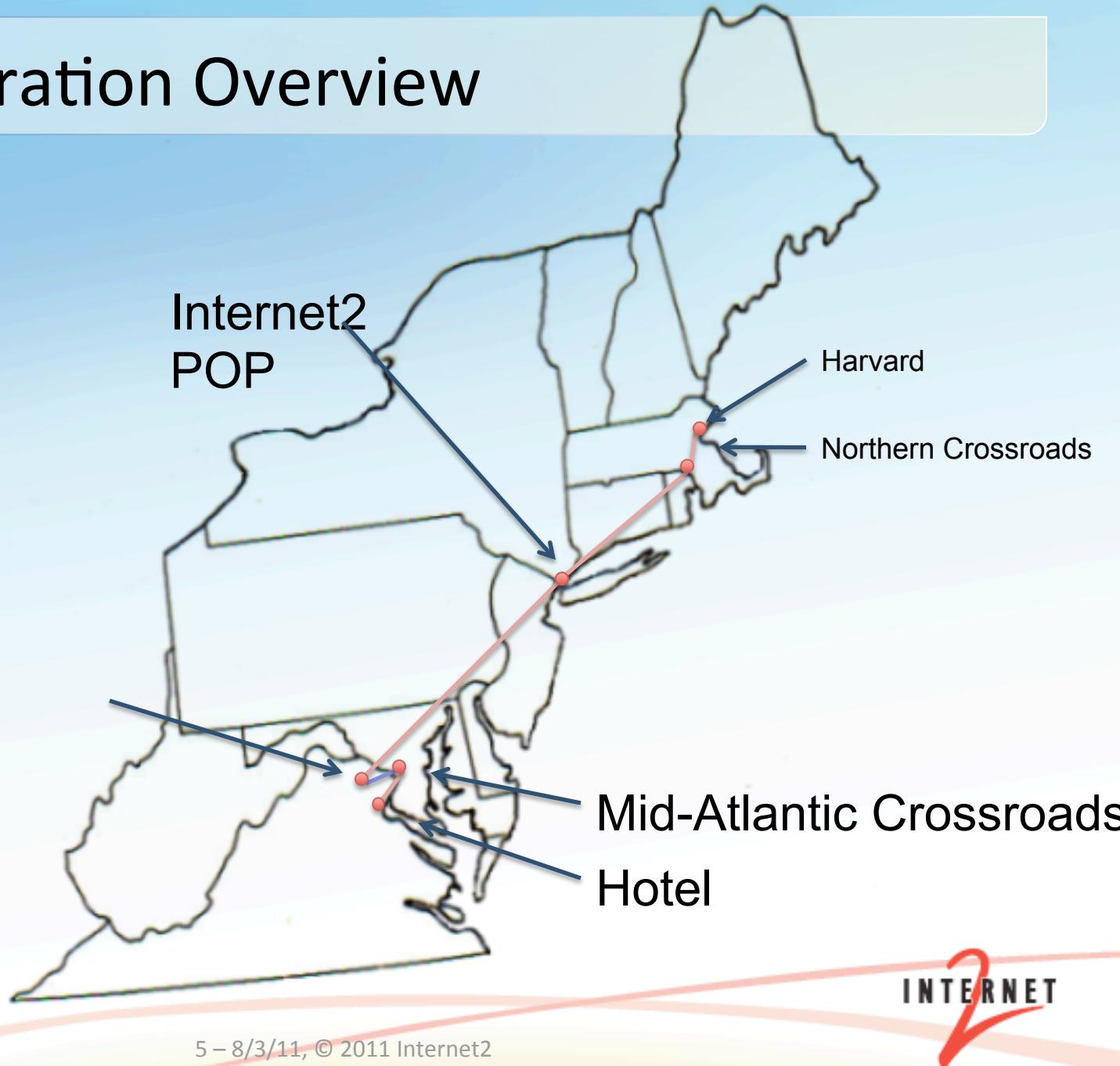
Use Cases

- The following use cases demonstrate use of perfSONAR tools to solve sometimes complex performance problems
 - Cisco Telepresence
 - Multi-domain path where performance guarantees dictate use of a specific application
 - Internet2 Backbone Incident
 - Learning the value of trusting the measurement tools

Cisco TelePresence Demo

- 2 Locations
 - Harvard University (Boston, MA)
 - Spring Member Meeting (Arlington, VA)
- Must meet or exceed performance expectations
 - < 10 ms Jitter (Packet Arrival Variation)
 - < 160 ms End-to-End Delay
 - < 0.05% Packet Loss
- Network Path spanned:
 - ~450 Miles
 - 4 Distinct Domains
 - Internet2
 - Mid Atlantic Crossroads (MAX)
 - Northern Crossroads (NOX)
 - Harvard University

Demonstration Overview

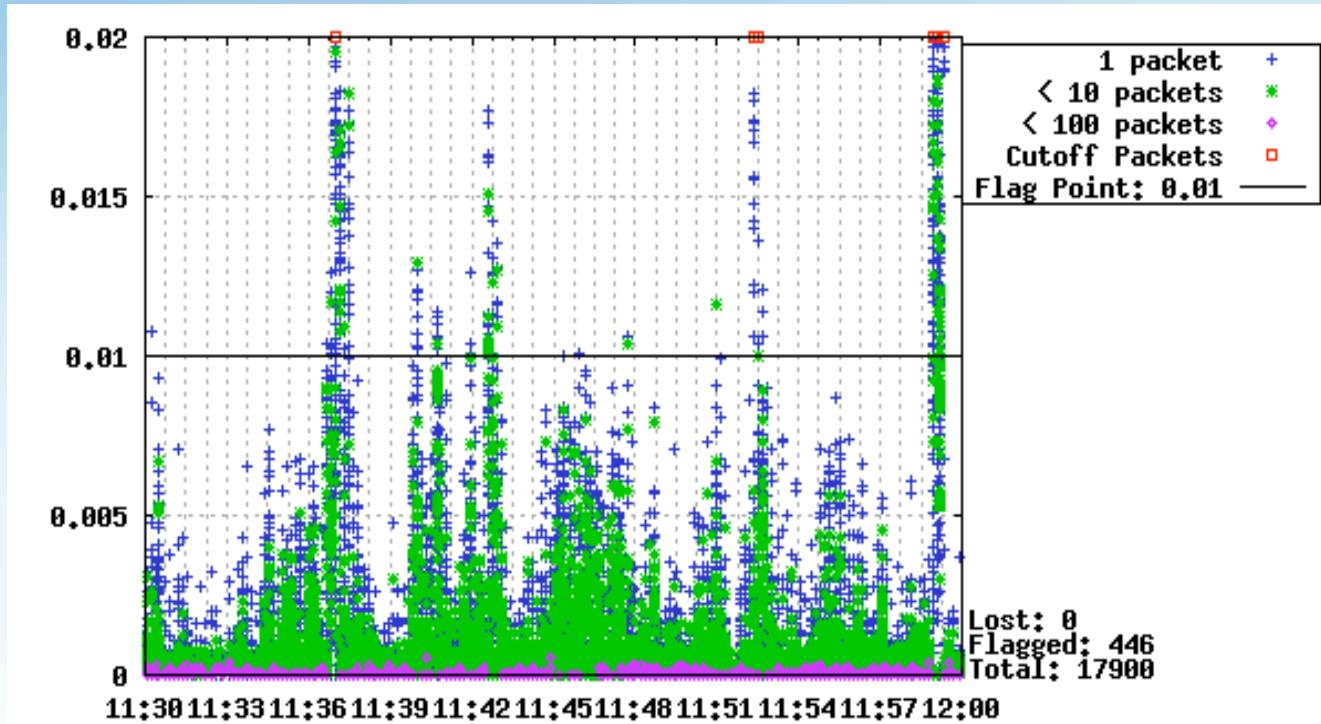


Cisco TelePresence Demo

- Performance Monitoring
 - Tools installed within each domain
 - [pS Performance Toolkit](#) – Bootable CD with performance tools installed and configured
 - Interested in several ‘metrics’
 - One Way Delay – [OWAMP](#)
 - Network Utilization – [SNMP](#)
- Several Problems Found (And Corrected)
 - Over-utilized Link
 - Traffic Spikes from Cross Traffic

Over-utilized Link

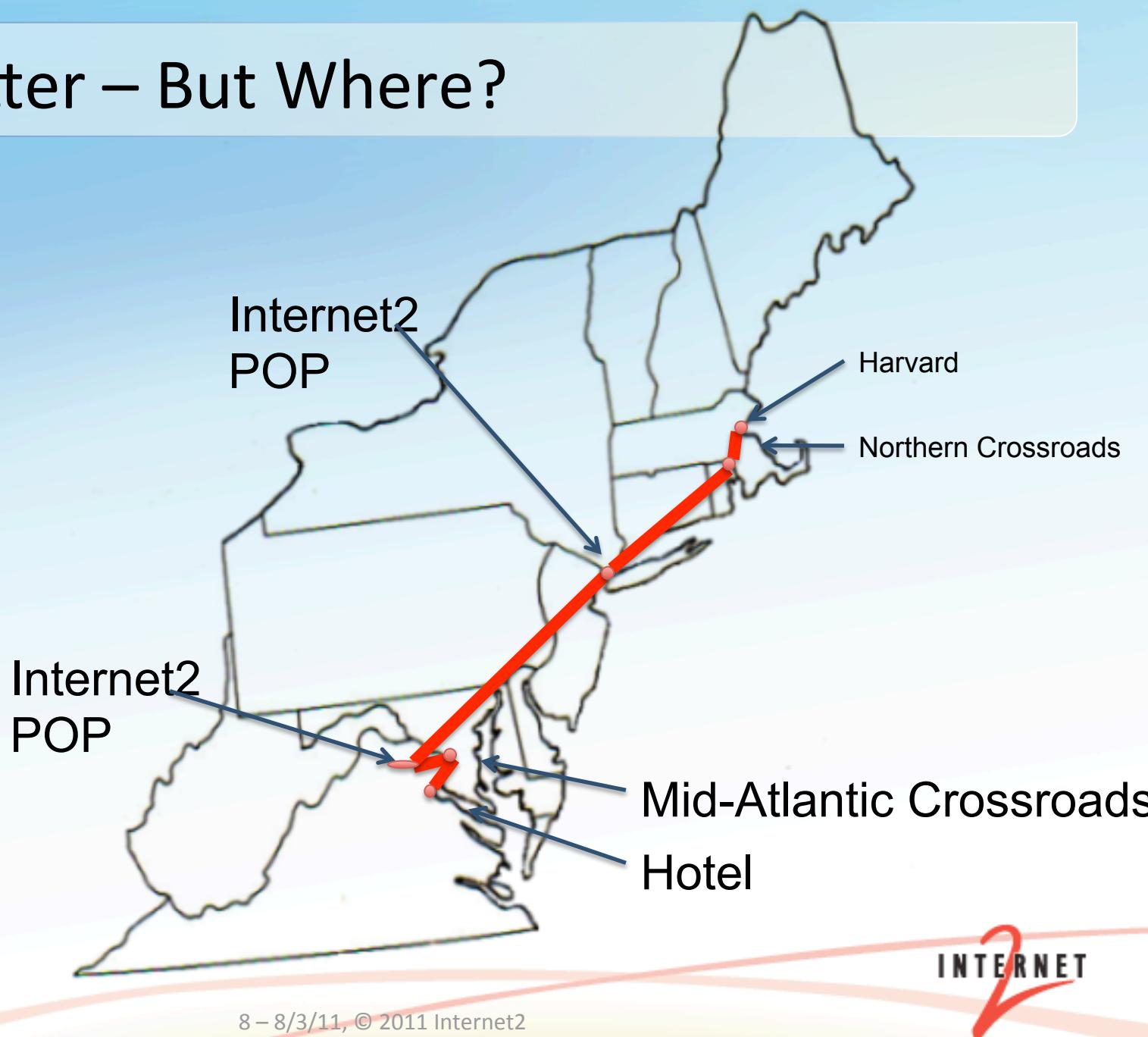
- Tools indicated high amounts of end-to-end Jitter:



- Goal: Isolate which segment (or segments) to examine further.



High Jitter – But Where?

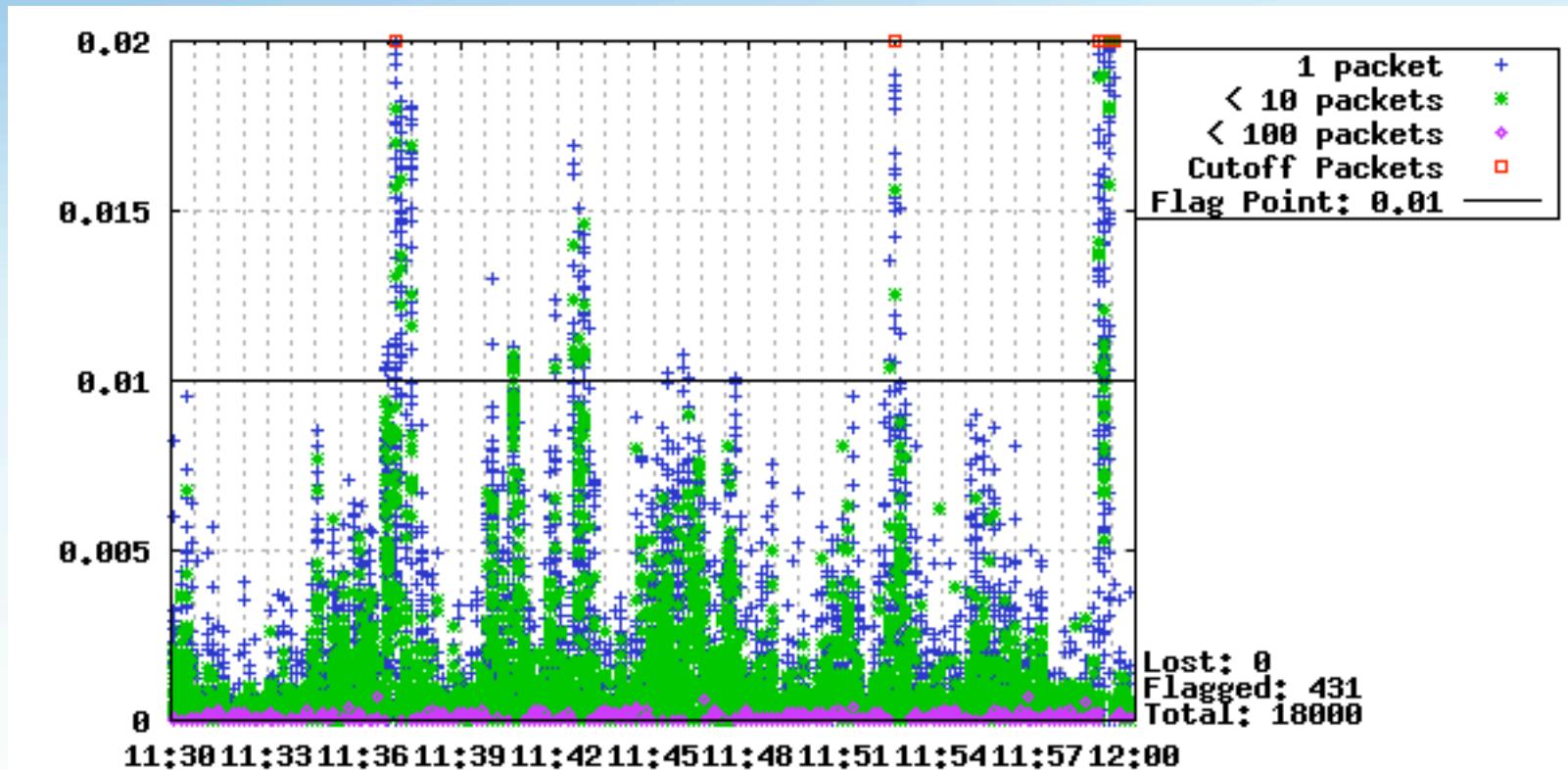


Over-utilized Link

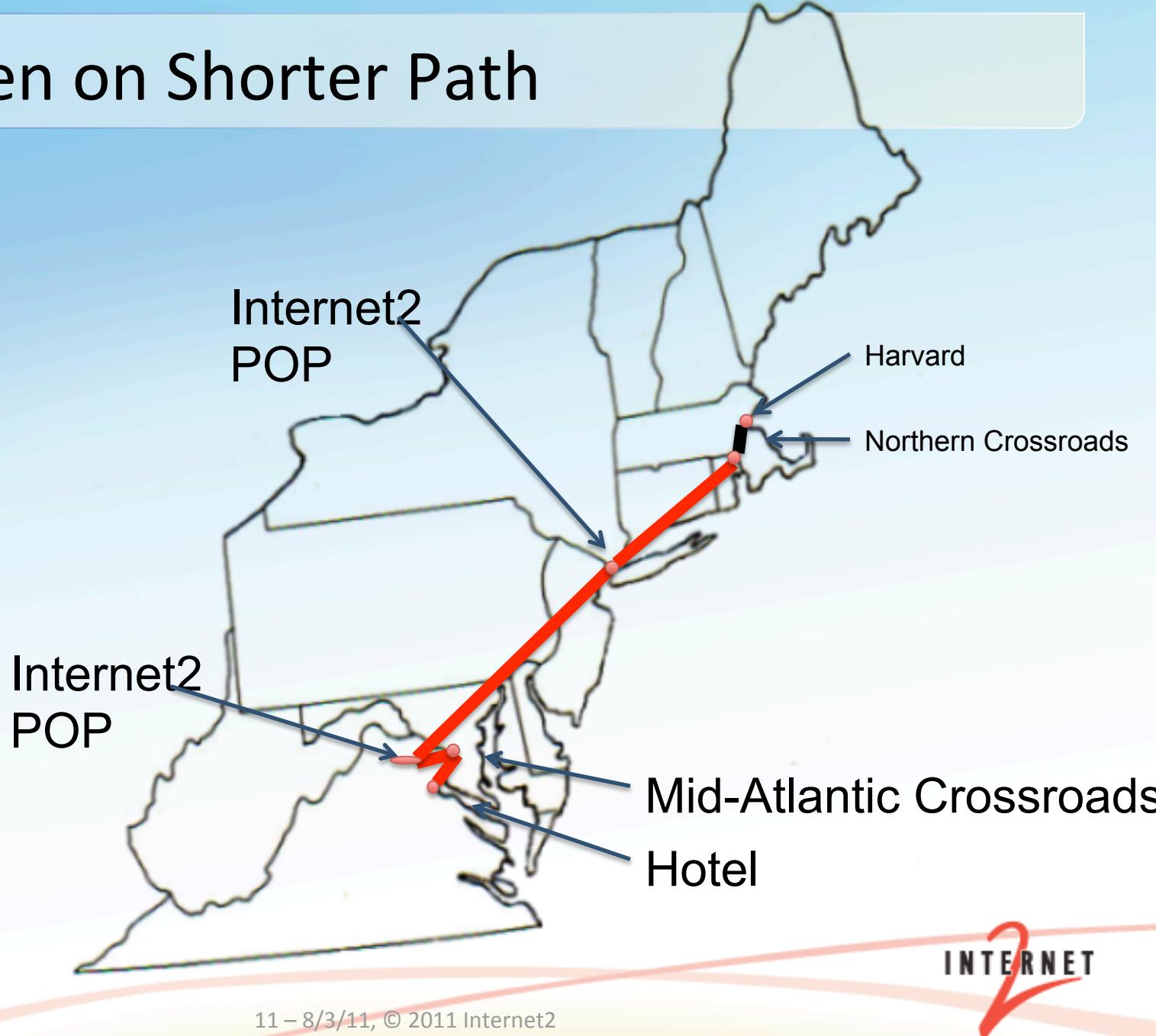
- Process:
 - Tools are installed and available in each domain
 - ‘Decompose’ the entire end-to-end path, and examine the performance between testing points:
 - Meeting Hotel to NOX
 - Meeting Hotel to Internet2 (New York)
 - Meeting Hotel to Internet2 (Washington)
 - Meeting Hotel to MAX

Over-utilized Link

- Meeting Hotel to NOX

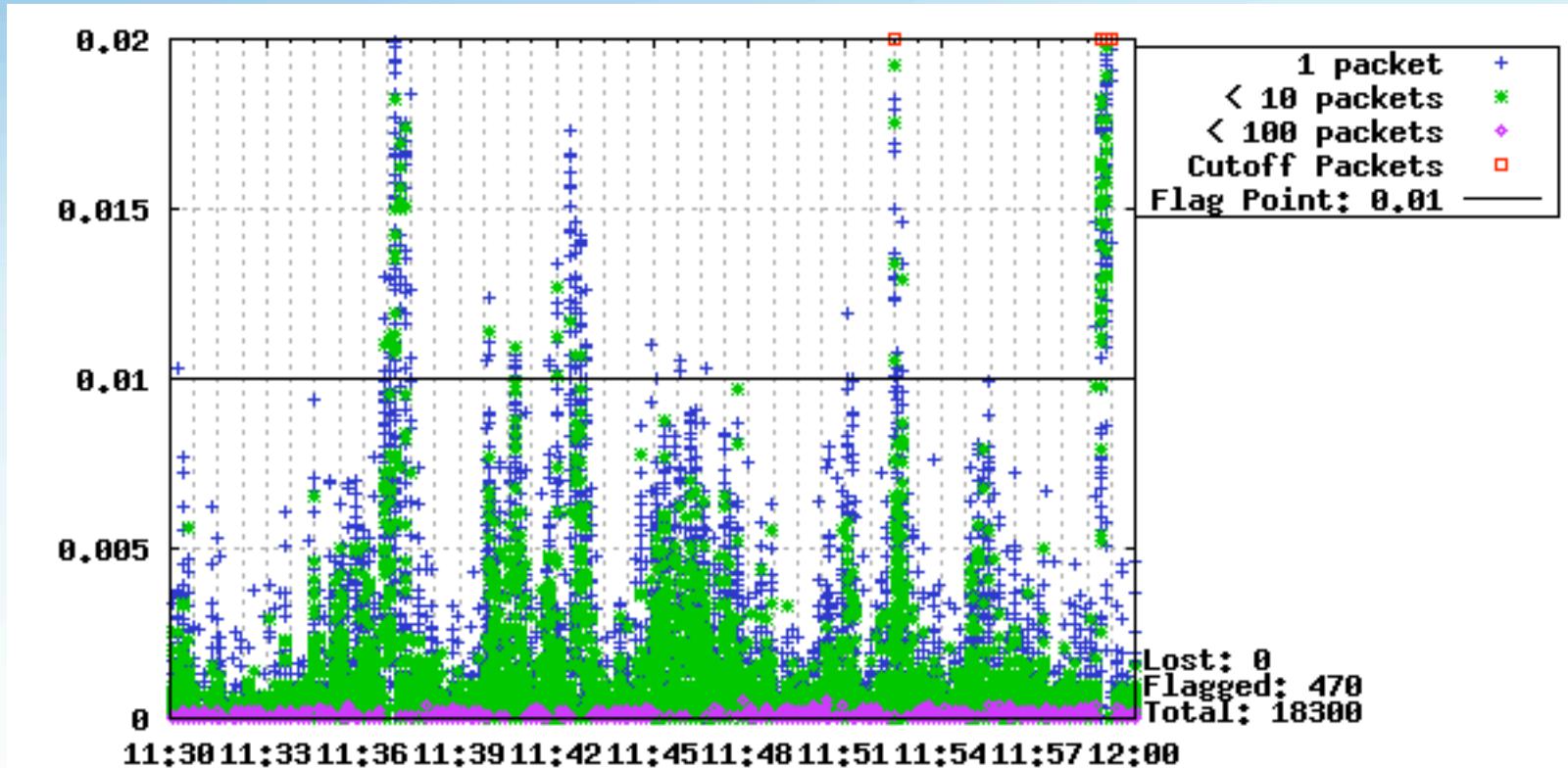


Still Seen on Shorter Path

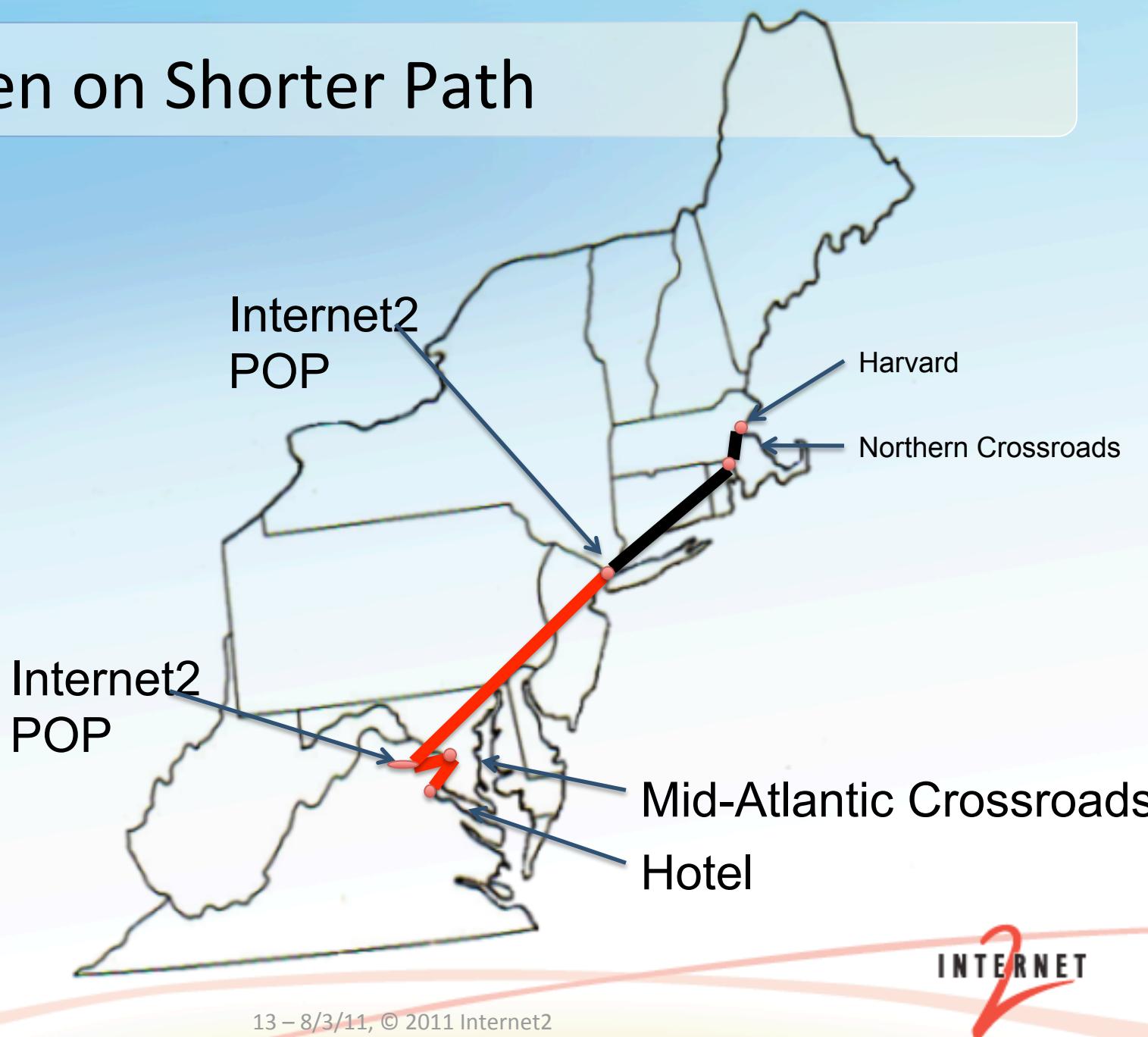


Over-utilized Link

- Meeting Hotel to Internet2 (New York)

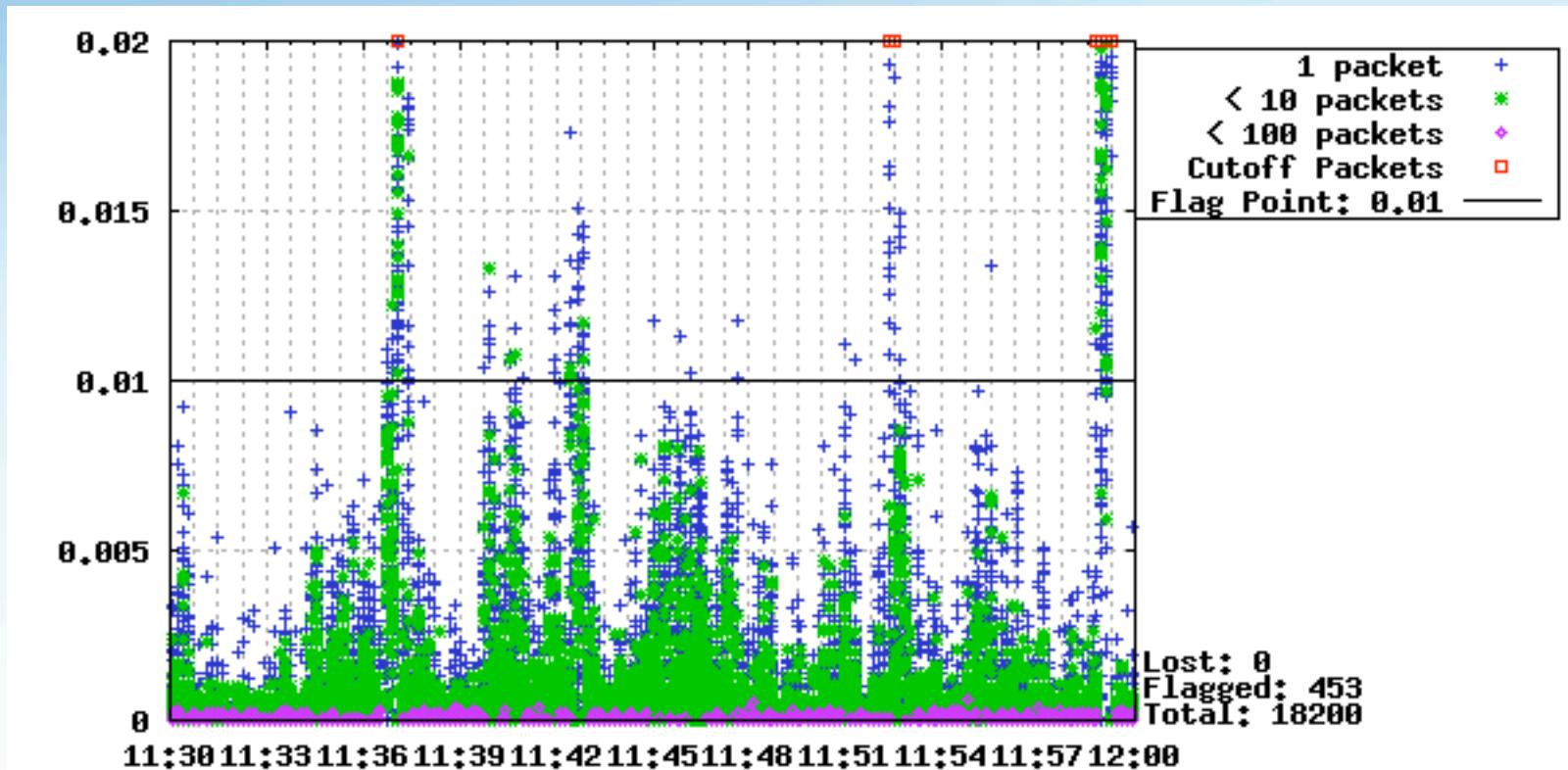


Still Seen on Shorter Path

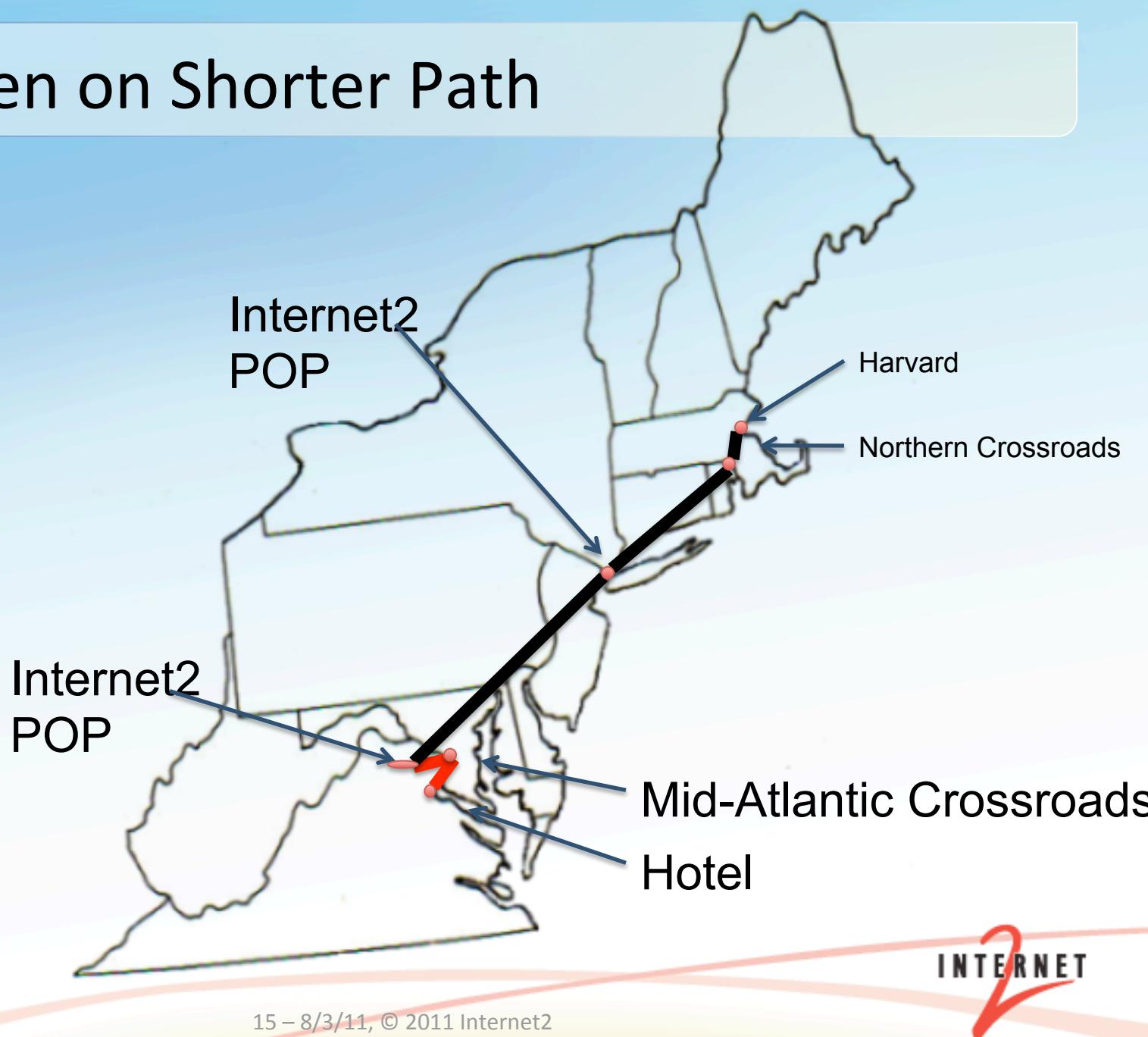


Over-utilized Link

- Meeting Hotel to Internet2 (Washington)

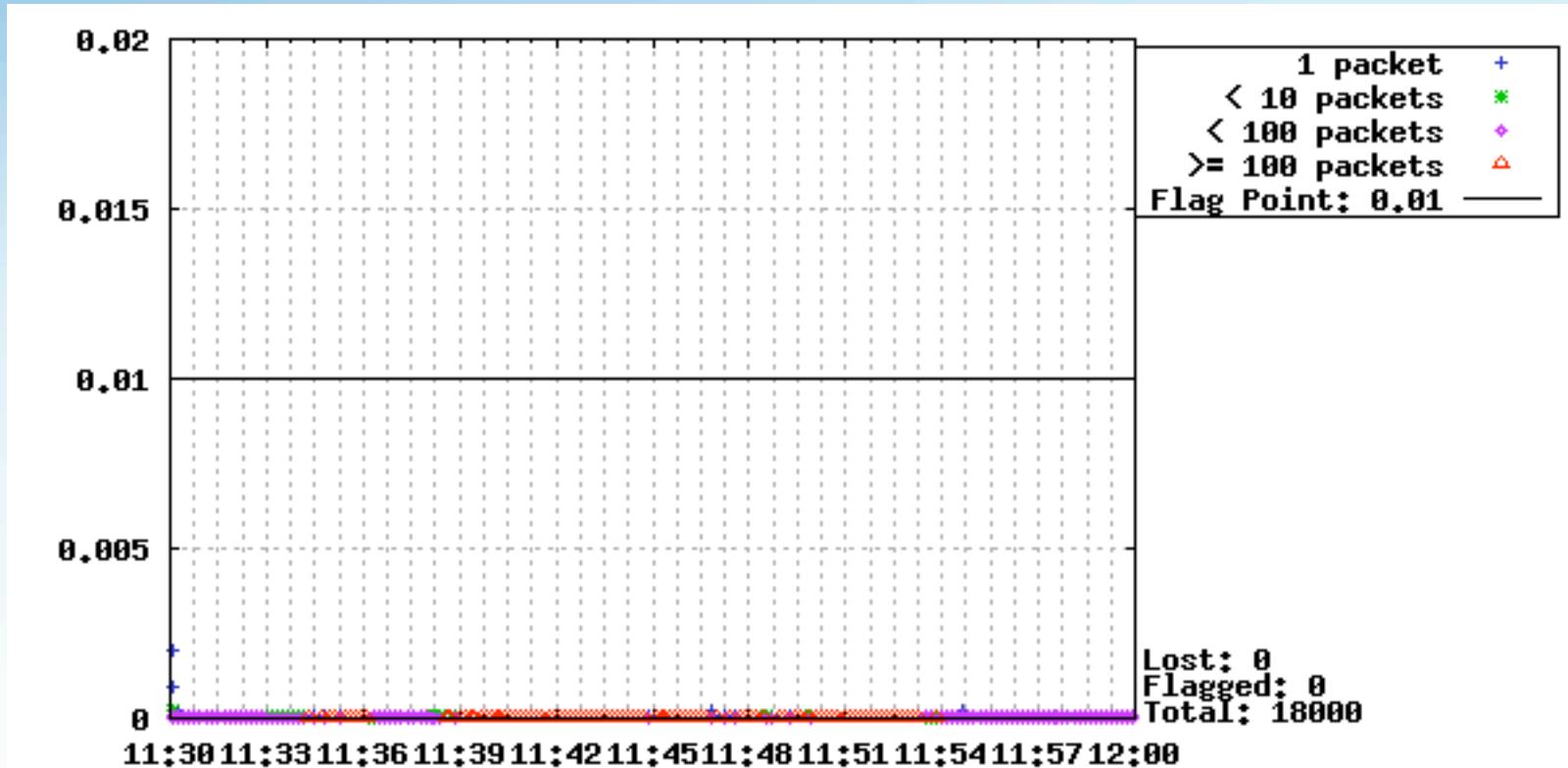


Still Seen on Shorter Path



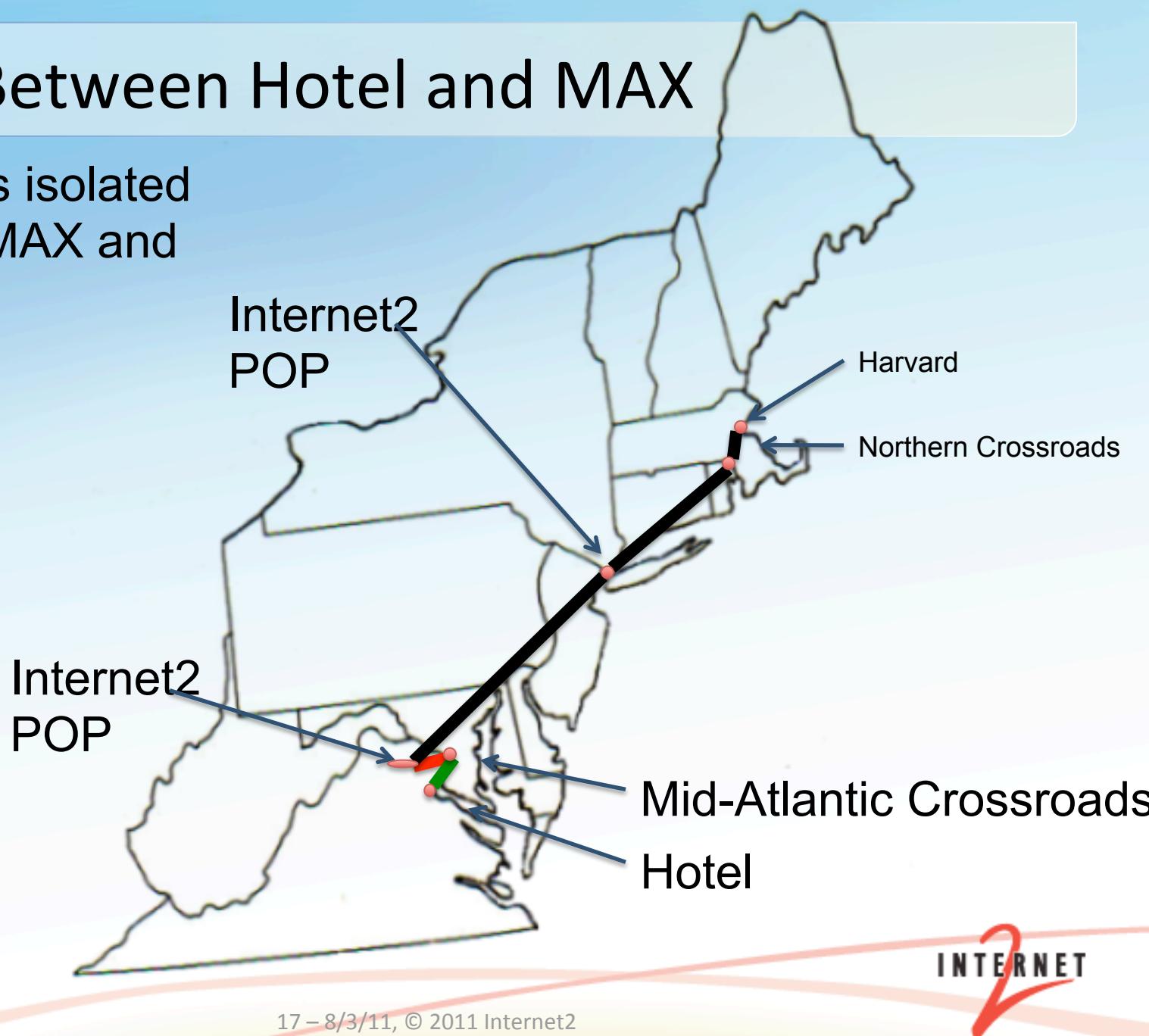
Over-utilized Link

- Meeting Hotel to MAX



Clean Between Hotel and MAX

Problem is isolated
between MAX and
Harvard



Over-utilized Link

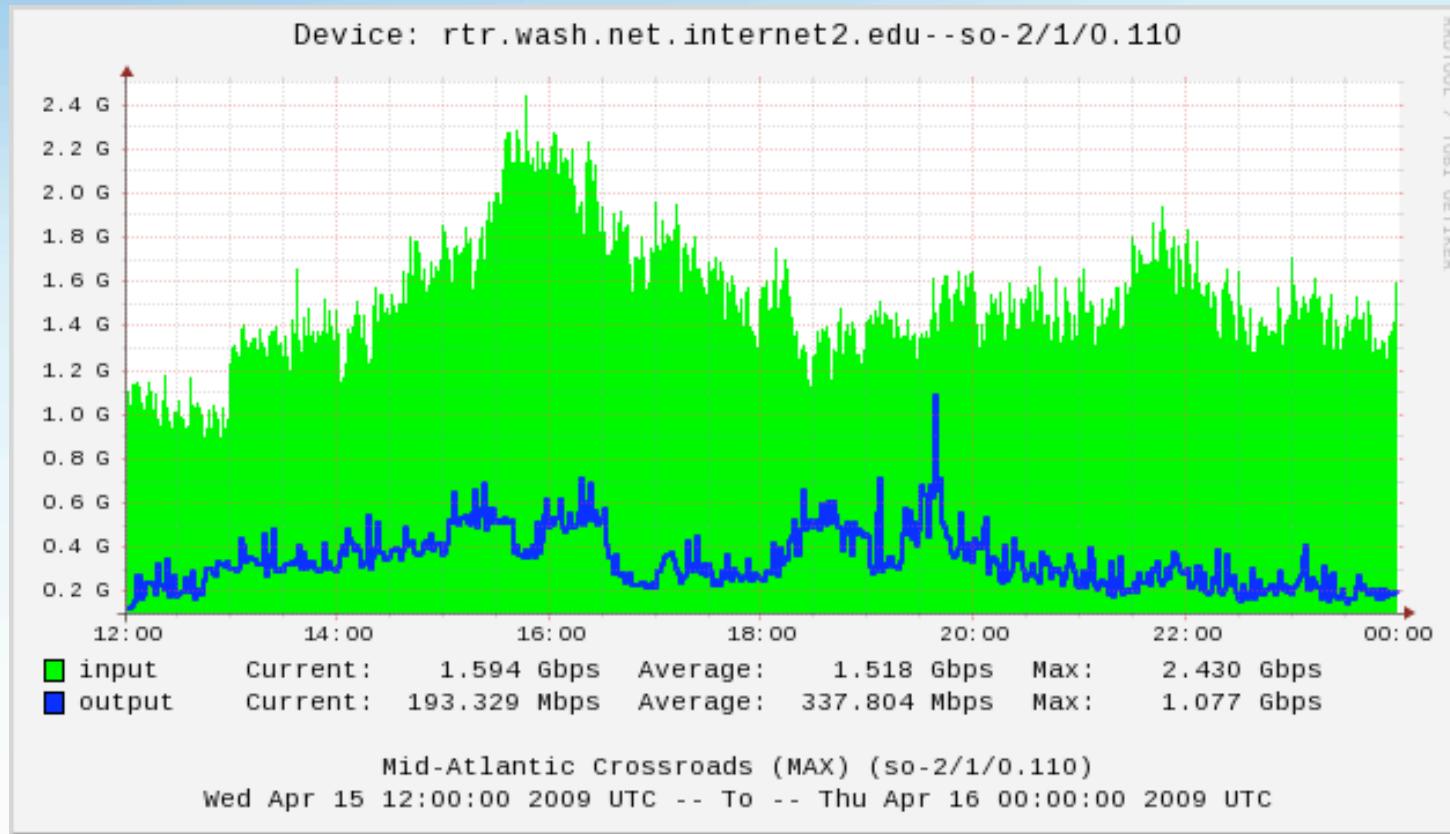
- Results of 1st Round of Debugging
 - OWAMP Confirms that the path is ‘clean’ between the Hotel and MAX.
 - The path is ‘noisy’ between MAX and Harvard (could be anywhere – we only know where it isn’t)
- Action Plan
 - Use other resource available, Utilization, to see if there is a ‘pinch point’ on one of the links.
 - Isolate our search to areas between MAX and Harvard
 - Start at MAX

Over-utilized Link

- Starting in the MAX domain, we know of 4 links:
 - Hotel to College Park MD
 - MAX Core in College Park MD
 - College Park MD to McLean VA
 - Internet2 Uplink in McLean VA
- Get information on each link:
 - 1G from Hotel to College Park MD
 - 10G MAX Core and transit to McLean VA
 - 2.5G Uplink to Internet2 in McLean VA

Over-utilized Link

- Utilization on Internet2 Uplink from MAX:



Over-utilized Link

- 2nd Round Debugging Results:
 - ‘Pinch Point’ found: traffic was coming very close to 2.5G limit
 - Not constant – but noticeable during network busy hours
 - ‘Pinch Point’ corrected (e.g. 2.5G uplink replaced with 10G uplink)
 - All other segments of the path appeared clean
 - Further end-to-end testing after upgrade revealed no additional problems.

Over-utilized Link

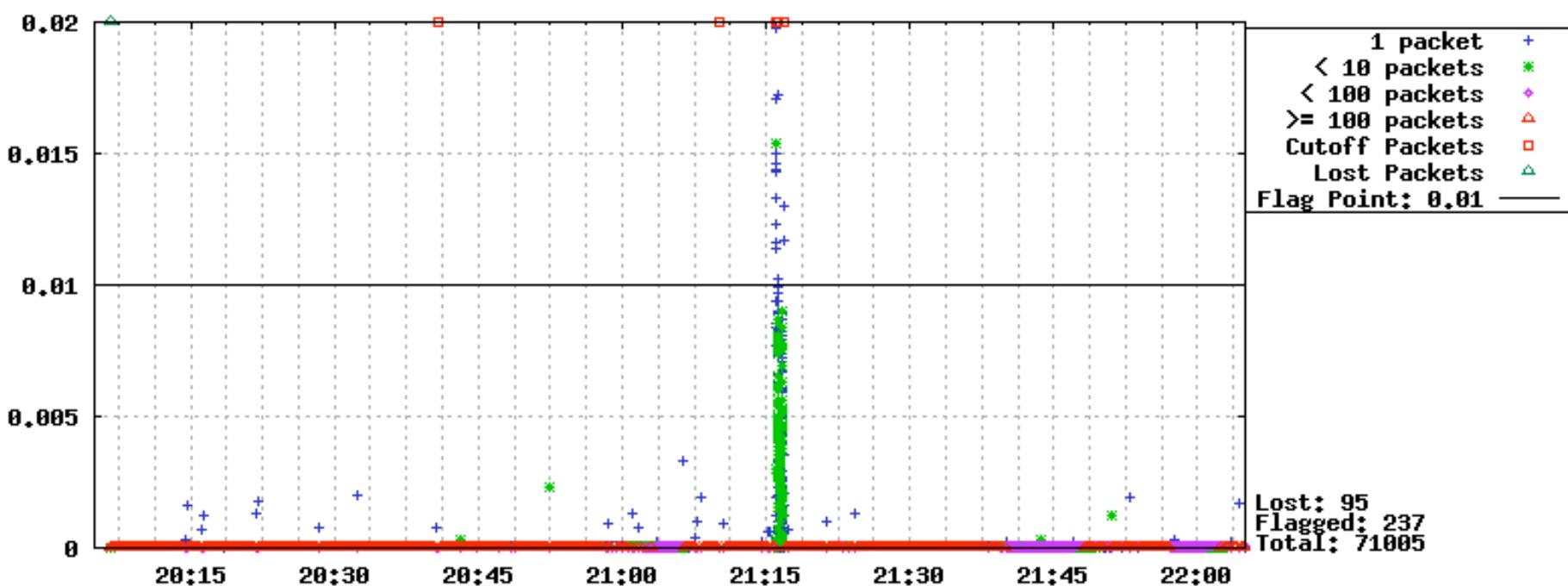
- Epilogue
 - Problem was only identified via access to performance tools
 - Necessary to have tools at each segment to truly isolate the problem
- Results
 - Increase MAX Headroom to 10G



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Cross Traffic

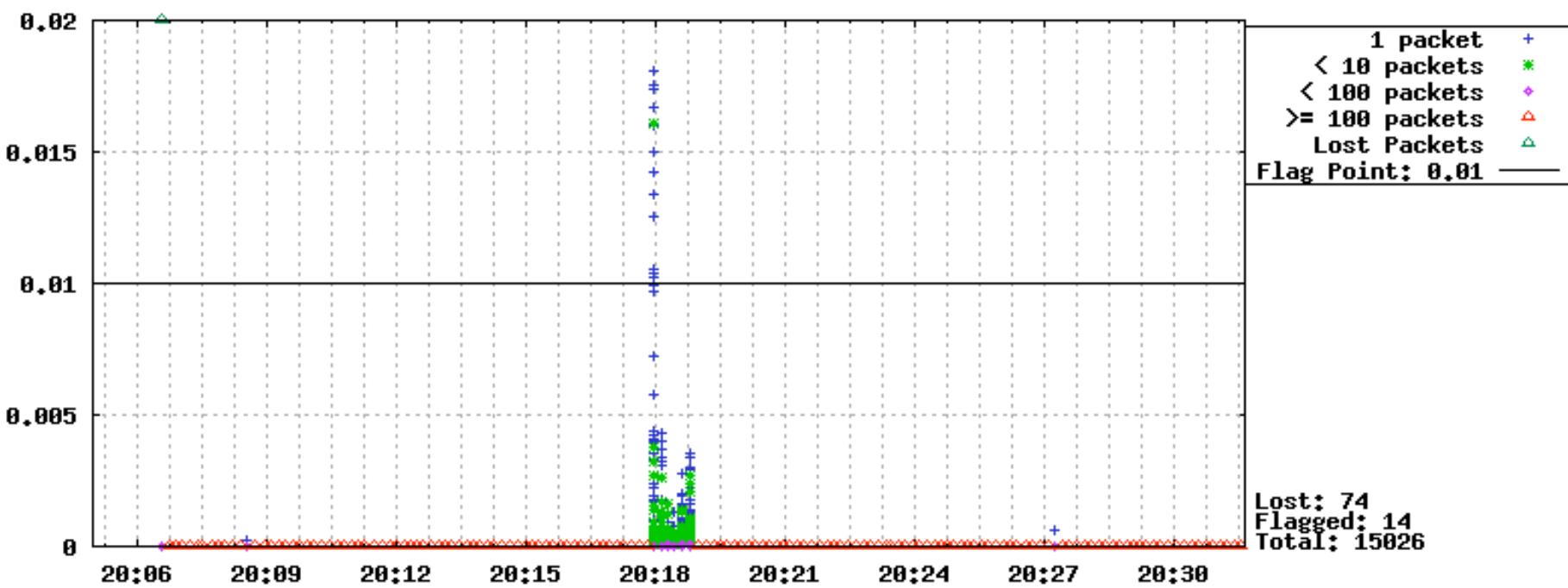
- A second issue was sporadic, spikes of Jitter on certain segments:



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Cross Traffic

- Isolated to 2 places on Internet2 Backbone (Washington and New York):

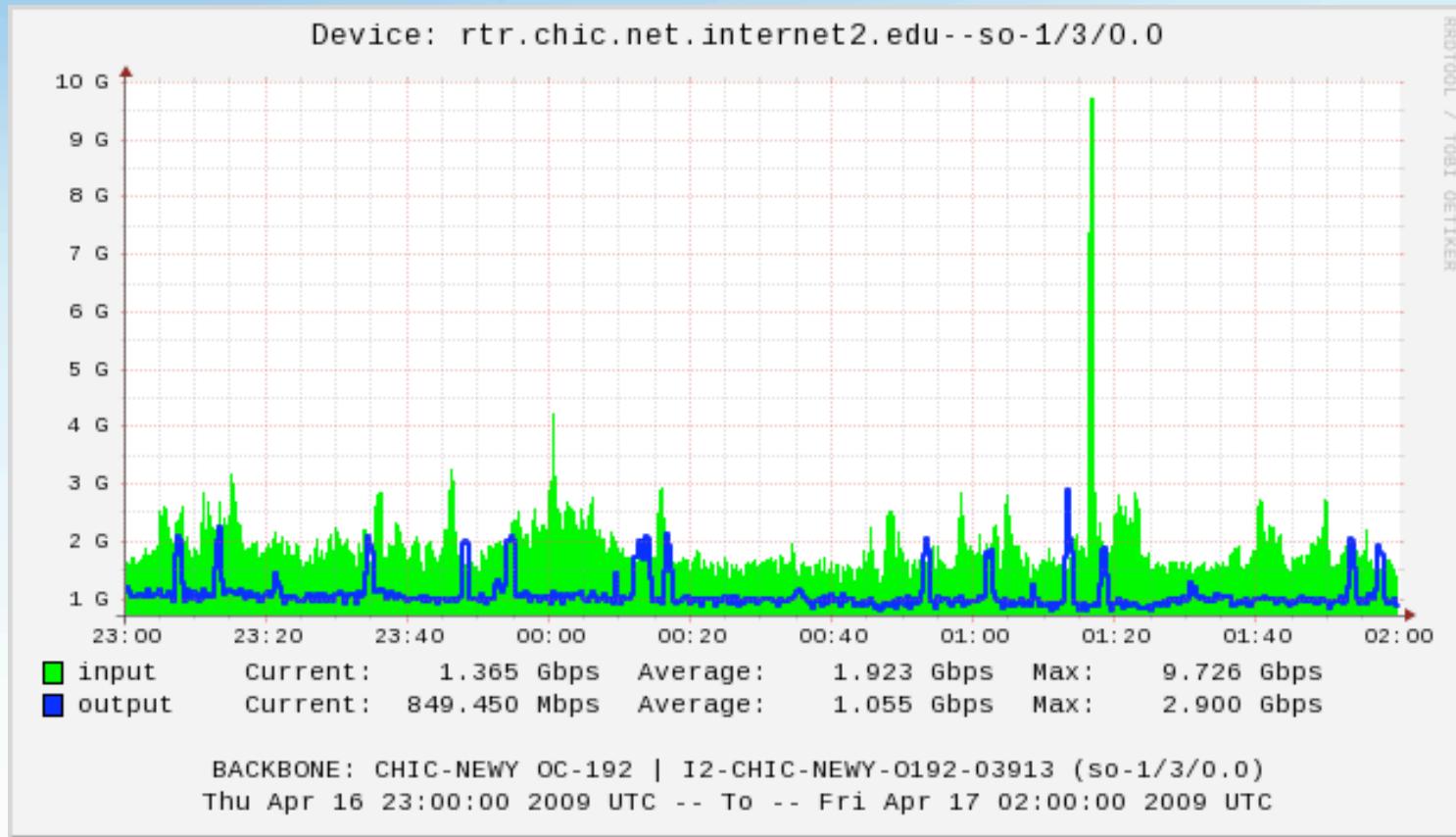


Cross Traffic

- Observations
 - Events were not directly related
 - Were sporadic, but seemingly periodic (every 12 hours)
 - Theories
 - Experiments on the Internet2 Network
 - Large Research Flows
 - Equipment Related (e.g. CPU/Memory use on testing machines)
- Action plan was to use Utilization data (again)

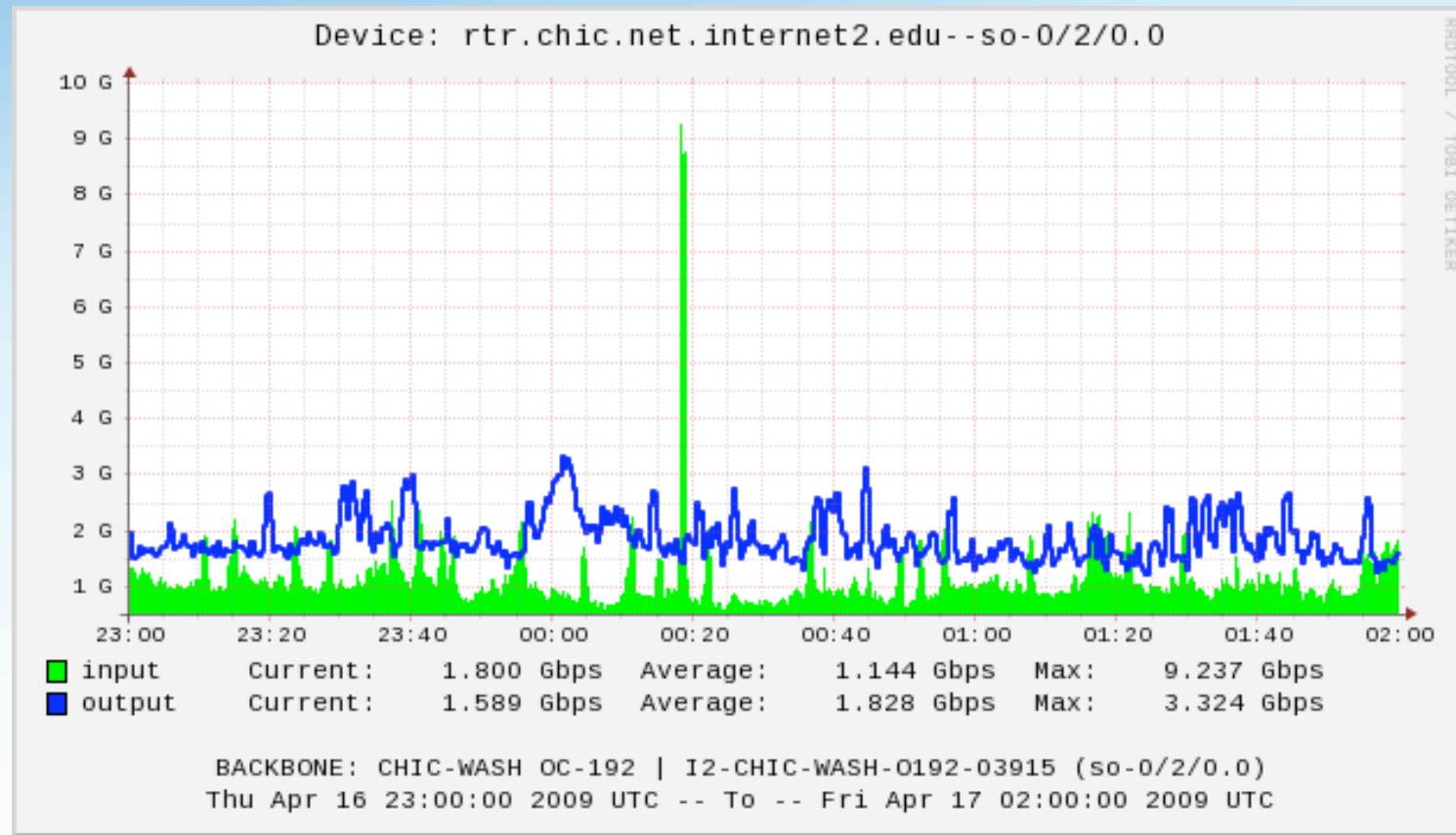
Cross Traffic

- Observed between New York and Chicago:



Cross Traffic

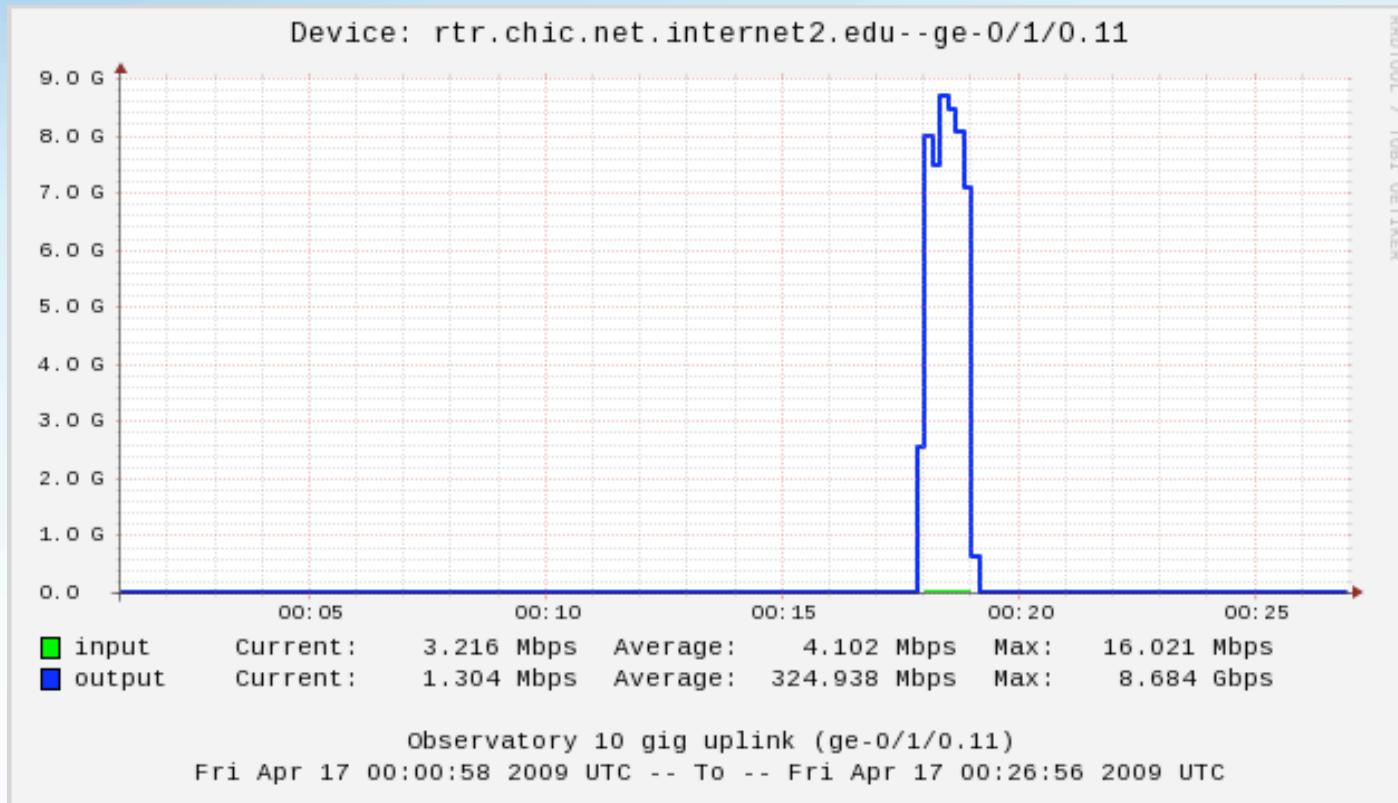
- Observed between Washington and Chicago



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Cross Traffic

- Digging deeper, it was another host on the same network:



Cross Traffic

- Debugging Results:
 - A host on the same network (a 10G bandwidth test host) was sending traffic
 - This traffic was not isolated properly (shared a VLAN)
- Solution:
 - Disable testing (temporary)
 - Traffic engineer the hosts to prevent in the future
- Epilogue
 - Different types of measurement strategies will help debug complex problems

Internet2 Backbone Incident

Original Report – The Network is Broken!

- Feb 10th 2011 – Original report from Vanderbilt University (US CMS Heavy ION Tier2 Facility, Nashville TN) noting problems to Port d'Informació Científica (PIC – Barcelona Spain)
 - Concern #1 – Report was to me directly, does not scale
- Observation from users:
 - *We are having trouble (slow transfers) with transfers from the CMS T1 sites in Spain (PIC). Here are traceroutes ... who can I talk to about this? Are we at least going along reasonable routes?*
- Quick mental triage on my part:
 - **Users are sharp, they have done this sort of thing before**
 - **They know the value of monitoring, and know when they are in over their head**
 - **Traceroutes are good, some real measurements would be better**
 - **Will require allocation of resources to address, coordinated by me now ☺**

Resource Allocation & Instrumentation

- “I wish someone would develop a framework to make this easier”
 - Yes, perfSONAR works well – **when it is deployed**.
 - We still don’t have universal deployment, so the backchannel network of emails to “people you know” is still required
- Coordination in domains, need to talk to people in each and allocate testers (if they don’t exist yet)
 - PIC*
 - CESCA
 - RedIRIS
 - GÉANT
 - Internet2*
 - SOX
 - Vanderbilt*

* Started with these for simplicity

Resource Allocation & Instrumentation

- End Systems @ PIC and Vanderbilt
 - [pS Performance Toolkit](#) on a spare server
 - Racked next to the data movement tools
 - Benefits:
 - The similar OS and performance settings on each end “*levels the playing field*”
 - All tools are now available, if we want to run an NDT we can, if we need regular BWCTL, we have it.
 - Cost to me and remote hands = < 1hr of installation/configuration
- Internet2
 - Regular BWCTL, OWAMP testing in place.
 - Interface Utilization and Errors available for all links
 - Web100 enabled services for NDT and NPAD
 - Cost to me = free

Long Path Testing

- Sanity Checking
 - Way to verify that the problem is not with the application (e.g. in this case it was a CMS product – [PhEDEx](#))
 - Establish some baselines with all tools
 - Try different times of day to rule out congestive issues
- Initial Results:
 - NDT confirms poor performance (100s of Kbps) in the PIC to Vanderbilt direction. Other way is not bad (500Mbps).
 - BWCTL is similar, even when using parallel streams
 - Traceroutes show a route asymmetry (although in practice this alone is not enough to cause this large of a problem...):
 - PIC->CESCA->RedIRIS->GEANT->Internet2->SOX->Vanderbilt
 - Vanderbilt->SOX->NLR->GEANT->RedIRIS->CESCA->PIC
- Time of day had no serious effect, this appears to be a real problem.



Parallel Effort

- PhEDEx has its own notion of the performance it gets, and the Vanderbilt and PIC operators know more about this than I ever will
 - Continued to ‘tweak’ application settings to see if they could do better than my tools
 - Still didn’t get very far
- Sidebar – PhEDEx is pretty intelligent
 - Will alter its behavior due to historical results
 - Takes advantage of fast paths
 - Does this over time, not instant



Structured Debugging Methodology

- Divide and Conquer
 - Bisect the path and test the segments individually
 - Rule out paths that are doing well, subdivide those that aren't again and again
- Use of one tool a time
 - Collect as much as you can with each tool
 - Move to the next to gather different metrics
- Patience
 - Its not hard, but it is time consuming
- If only we had a way to teach this to people...
 - Wait ... we do!
 - <http://www.internet2.edu/workshops/npw/>

Real Debugging – Timeline and Results

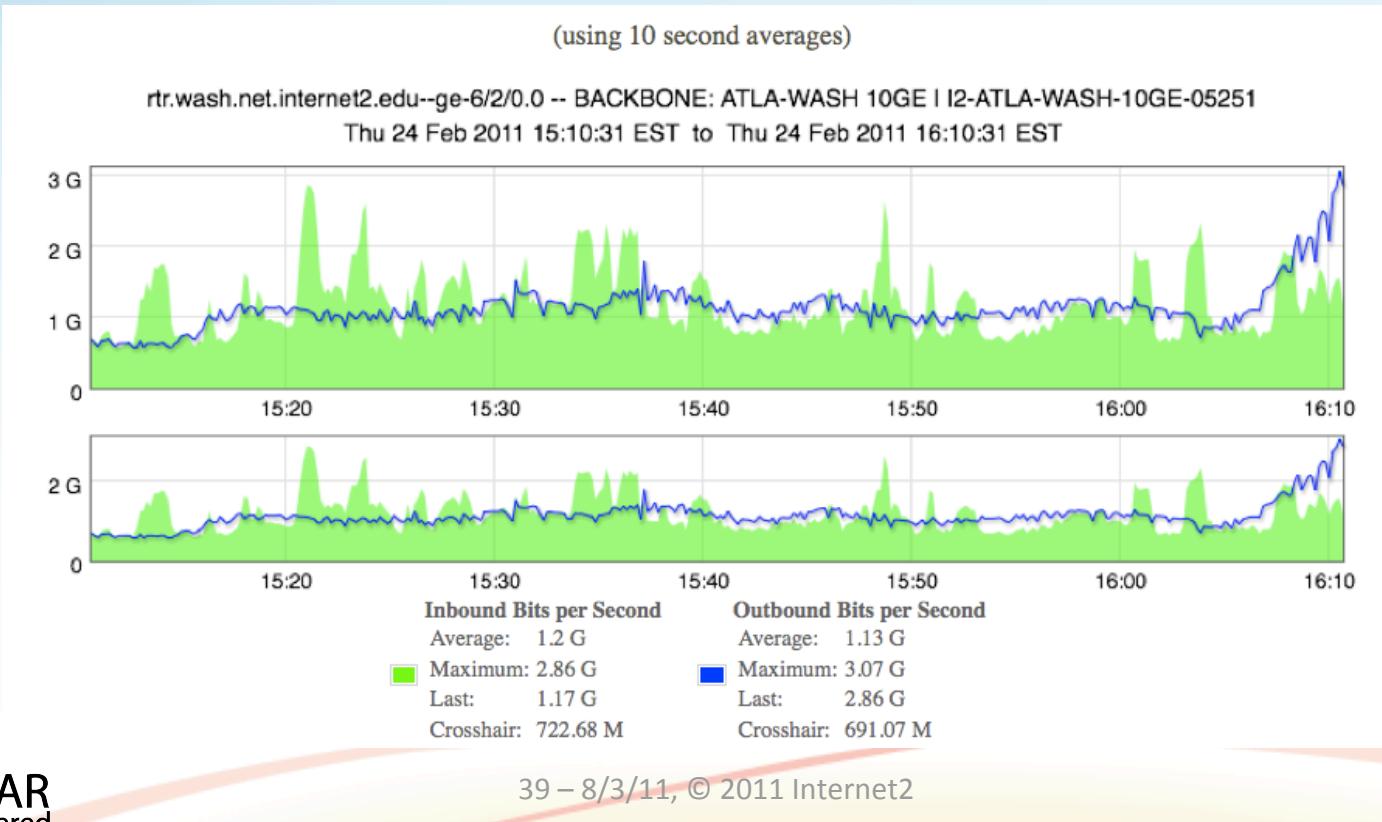
- Initial Report: Feb 10th 2011
- CMS Testing: Feb 11th – 21st 2011
- Long Path Testing: Feb 21st – 23rd 2011
- Structured Debugging: Feb 23rd – 24th 2011
- Methodology
 - GÉANT Circuit from Frankfurt terminates at Internet2 Washington DC. Use test points here.
 - Vanderbilt connects through SOX, which connects to Internet2 in Atlanta GA. Use test points here too.
 - 2 10G backbone links separate Atlanta and Washington.

Real Debugging – Results (Traceroutes)

- Between PIC and Vanderbilt were asymmetric
 - PIC->CESCA->RedIRIS->GEANT->Internet2->SOX->Vanderbilt
 - Vanderbilt->SOX->NLR->GEANT->RedIRIS->CESCA->PIC
- Focus on the US connectivity:
 - Between Vanderbilt and 2 Internet2 hosts, no asymmetry was observed
 - Path:
 - Vanderbilt->SOX->Internet2 (ATLA)->Internet2 (WASH)

Real Debugging – Results (Utilization)

- In the Internet2 case, utilization and errors are available.
- There are two backbone links between ATLA and WASH
 - 10G CPS Link – ruled this out of the process
 - 10G R&E Link



Real Debugging – Results (NDT)

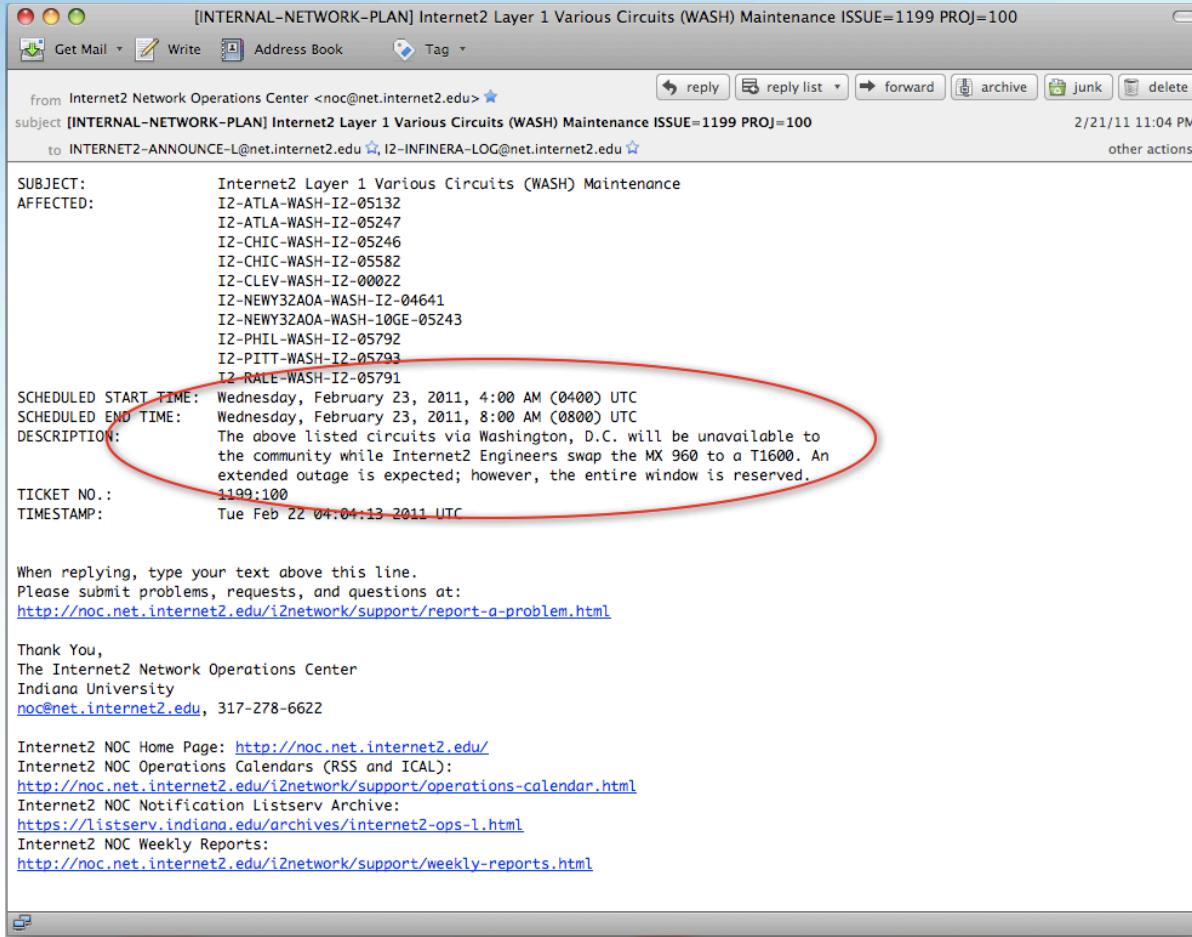
- NDT is not run “*regularly*”, so our use will strictly be diagnostic.
- Vanderbilt (client) -> PIC (server)
 - running 10s outbound test (client to server) 522.24 Mb/s
 - running 10s inbound test (server to client) 169.89 kb/s
- Vanderbilt (client) -> WASH (server)
 - running 10s outbound test (client to server) 922.47 Mb/s
 - running 10s inbound test (server to client) 1.35 Mb/s
- Vanderbilt (client) -> ATLA (server)
 - running 10s outbound test (client to server) 935.98 Mb/s
 - running 10s inbound test (server to client) 933.82 Mb/s

Real Debugging – Results (NDT, cont.)

- We now have a minor result
 - Performance on a shorter path to from Vanderbilt to ATLA seems expected.
 - Can we use this to our advantage?
- Internet2 Atlanta (client) -> Internet2 Washington (server)
 - running 10s outbound test (client to server) 978.44 Mb/s
 - running 10s inbound test (server to client) 251.95 kb/s
- Very promising result ... but we aren't done!
 - Can't declare victory with just this
 - Use other tools as much as we can
 - See if we can confirm that this segment is a problem
- Reality Check
 - Concern #2 – This could potentially be a backbone link ... how could something that is monitored 24/7/365 be in that poor of a state ...

Real Debugging – Side Bar

- Related information is a good thing. There is a trouble ticket system that alerts to changes in the network:



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Real Debugging – Results (BWCTL)

- Regular monitoring is your friend ... **WHEN YOU USE IT PROPERLY** ☺
 - Internet2 has lots of fancy GUIs that expose the BWCTL data, these should be viewed every now and then
 - We even have plugins for NAGIOS developed by perfSONAR-PS to alarm when performance dips below expectations
 - We did neither of these properly ☺

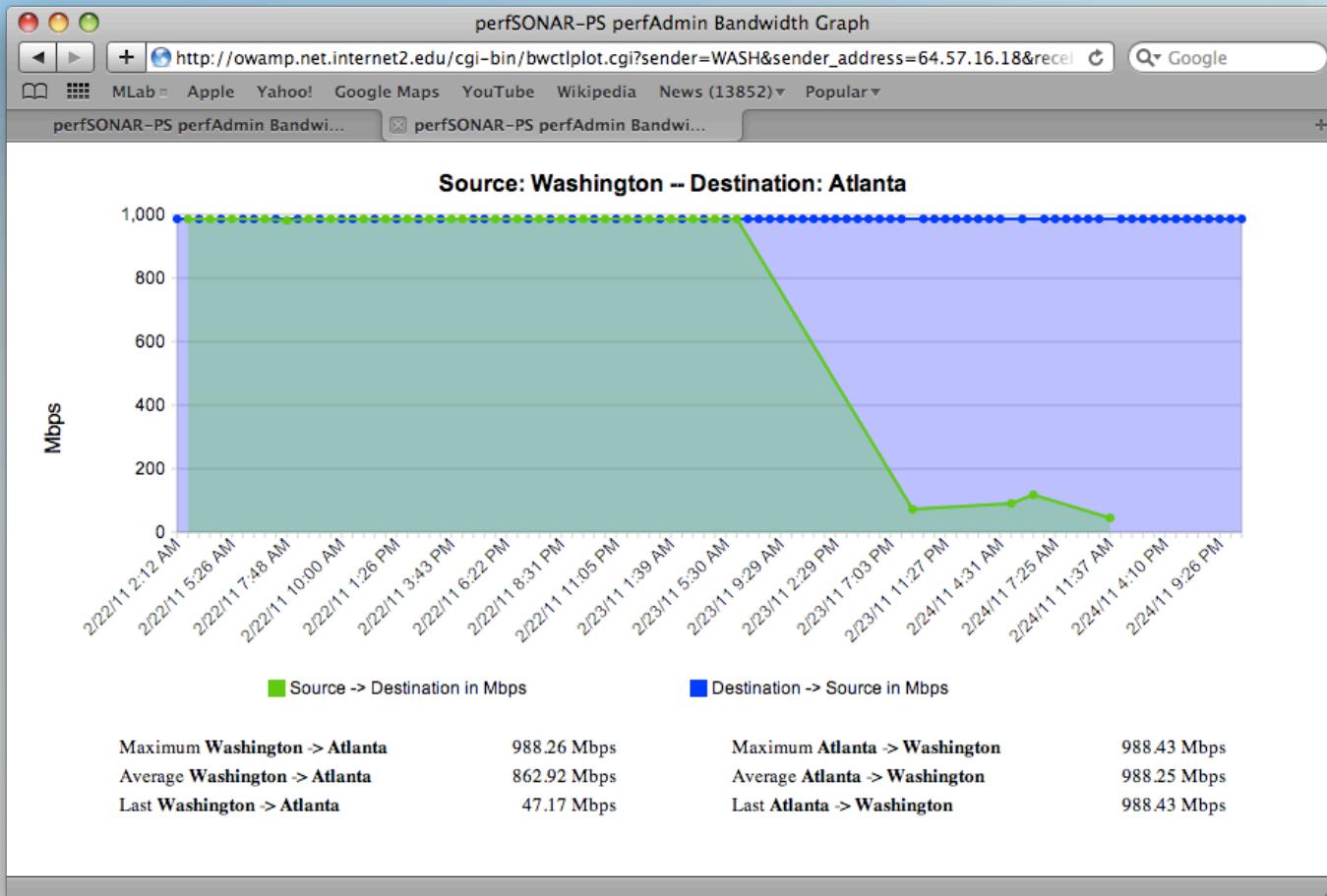
BWCTL - Internet2 Network IPv4 TCP Throughput

bwctl/iperf	Senders										
	Atlanta	Chicago	Houston	KansasCity	LosAngeles	NewYorkCity	SaltLakeCity	Seattle	Washington		
	Atlanta		942.06 Mbps / 2011-02-24 20:29:23UTC	941.72 Mbps / 2011-02-24 19:00:00UTC	940.73 Mbps / 2011-02-24 20:43:25UTC	739.75 Mbps / 2011-02-24 20:06:08UTC	132.37 Mbps / 2011-02-24 16:32:41UTC	751.79 Mbps / 2011-02-24 20:00:55UTC	584.60 Mbps / 2011-02-24 20:21:30UTC	44.99 Mbps / 2011-02-24 11:37:04UTC	



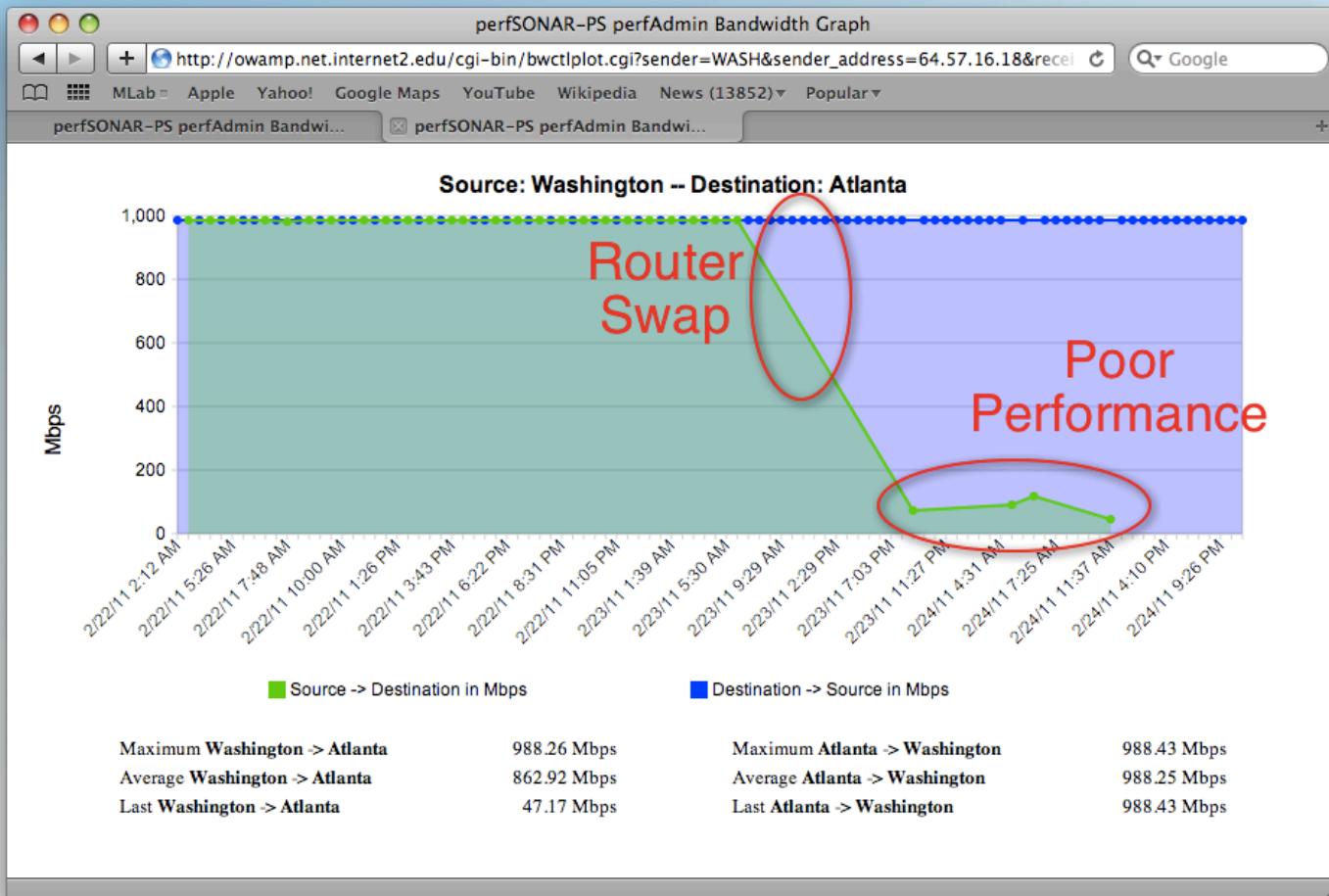
Real Debugging – Results (BWCTL)

- Digging Deeper on WASH:



Real Debugging – Results (BWCTL)

- Remember that trouble ticket ...



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Real Debugging – Results (BWCTL)

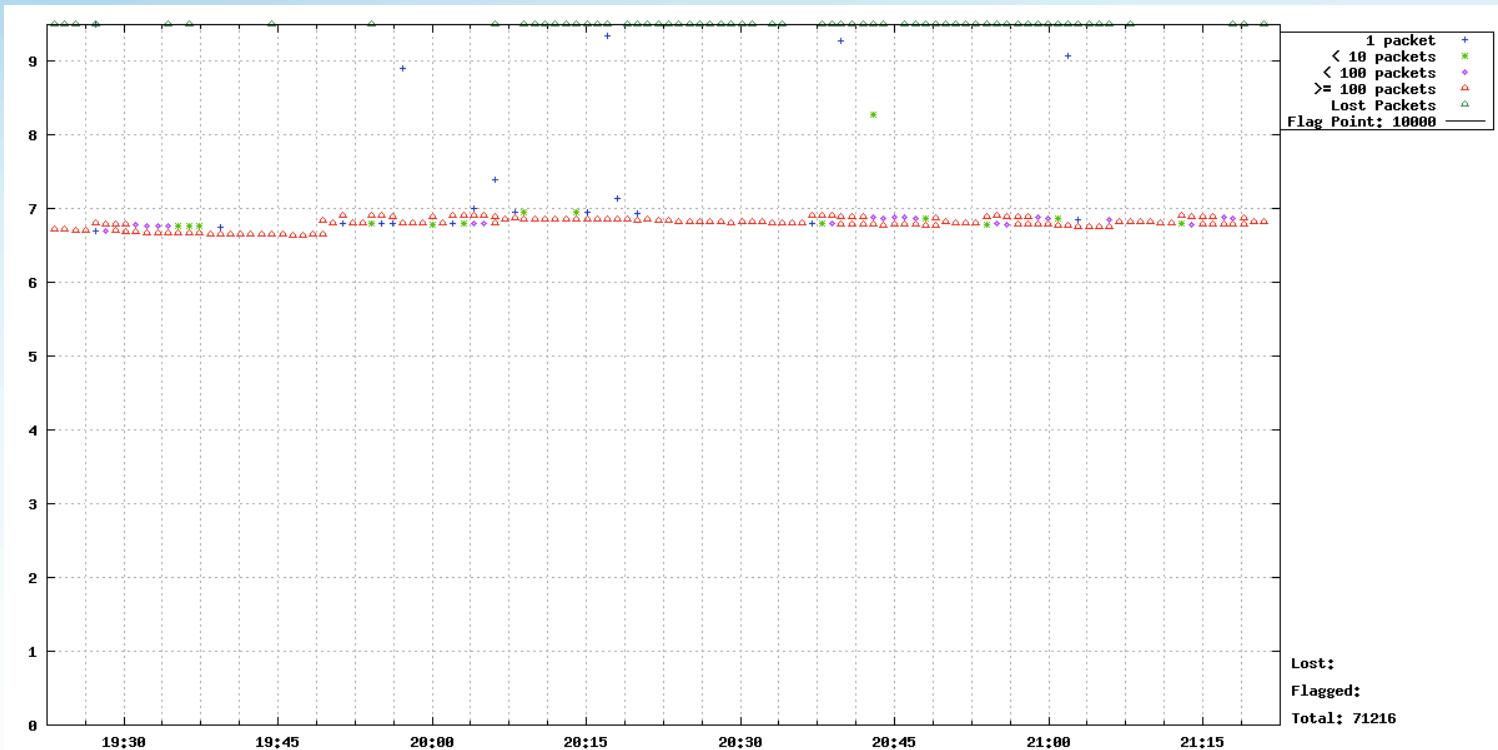
- Concern #3 – This poor performance was detected by the tools, but went undetected by the humans in operations. Need to change the culture of operations - learn to listen to (and trust!) the tools

Real Debugging – Results Review

- Now we have several results
 - NDT diagnostics show poor results
 - PIC->Vanderbilt
 - WASH->Vanderbilt
 - WASH->ATLA
 - NDT diagnostics show good results
 - ATLA->Vanderbilt
 - BWCTL regular monitoring shows poor results
 - ATLA to WASH
 - ATLA to NEWY (which goes over the WASH path), we can ignore further debugging for here for now
 - BWCTL regular monitoring shows good results
 - Everywhere else
- Don't call it a day yet! One more tool to look at.

Real Debugging – Results (OWAMP)

- Much like BWCTL, we keep this going all the time. Also like BWCTL, we don't have alarms to tell us things are bad
😊



Real Debugging – Results (OWAMP)

- Interpreting the graph shows a pretty constant stream of loss (WASH -> ATLA). Note this is a “soft failure”, not loss of connectivity



Problem Location and Reporting

- At this stage we have our evidence from all of the tools.
- Time to escalate – this is why we have 24/7/365 NOCs after all
- Problem reported Feb 24th 2011 @ 4pm EST
 - Evidence from tests above provided, lots of detail!
- First response from operations:

```
> Jason,  
>  
> I'm not seeing any degradation over that backbone link. Could you  
> provide me with a trace? Perhaps there is loss occurring elsewhere along  
> the path?  
>  
> Thanks,  
>  
> Greg
```

Denial?

- This first response should make anyone upset, especially after providing evidence from four (4!) tools
 - Concern #4 – Listening to the tools is one problem, **TRUSTING** them is another that needs to be overcome in the operations space
- To be fair ... operations may have a different set of tools they are working with:
 - Monitoring of the Interface counters is something most are taught to watch – we revealed on Slide 11 that there was no evidence of errors. Utilization looked “ok”
 - Can’t speak for the regular monitoring – these have been in place on the Internet2 observatory for around 6 years. Alarming is not in place at a minimum.

Ok, Not Complete Denial ...

- Bringing in more eyes sometimes gets results, especially when they have looked at the evidence and can agree something doesn't smell right...

Entered on 02/24/2011 at 22:32:07 UTC (GMT+0000) by Tom Knoeller:

We are seeing errors increasing on the ATLA side. But light levels look good on both sides. Probably need to do some emergency work to throw some loops in the circuit to see where the problem is. My guess is going to be the XENPAK PIC on the WASH router as that is what changed 2 days ago, but testing will confirm that.

Traffic on the link is light, so I think we can turn off ISIS to divert the traffic without too much pain.

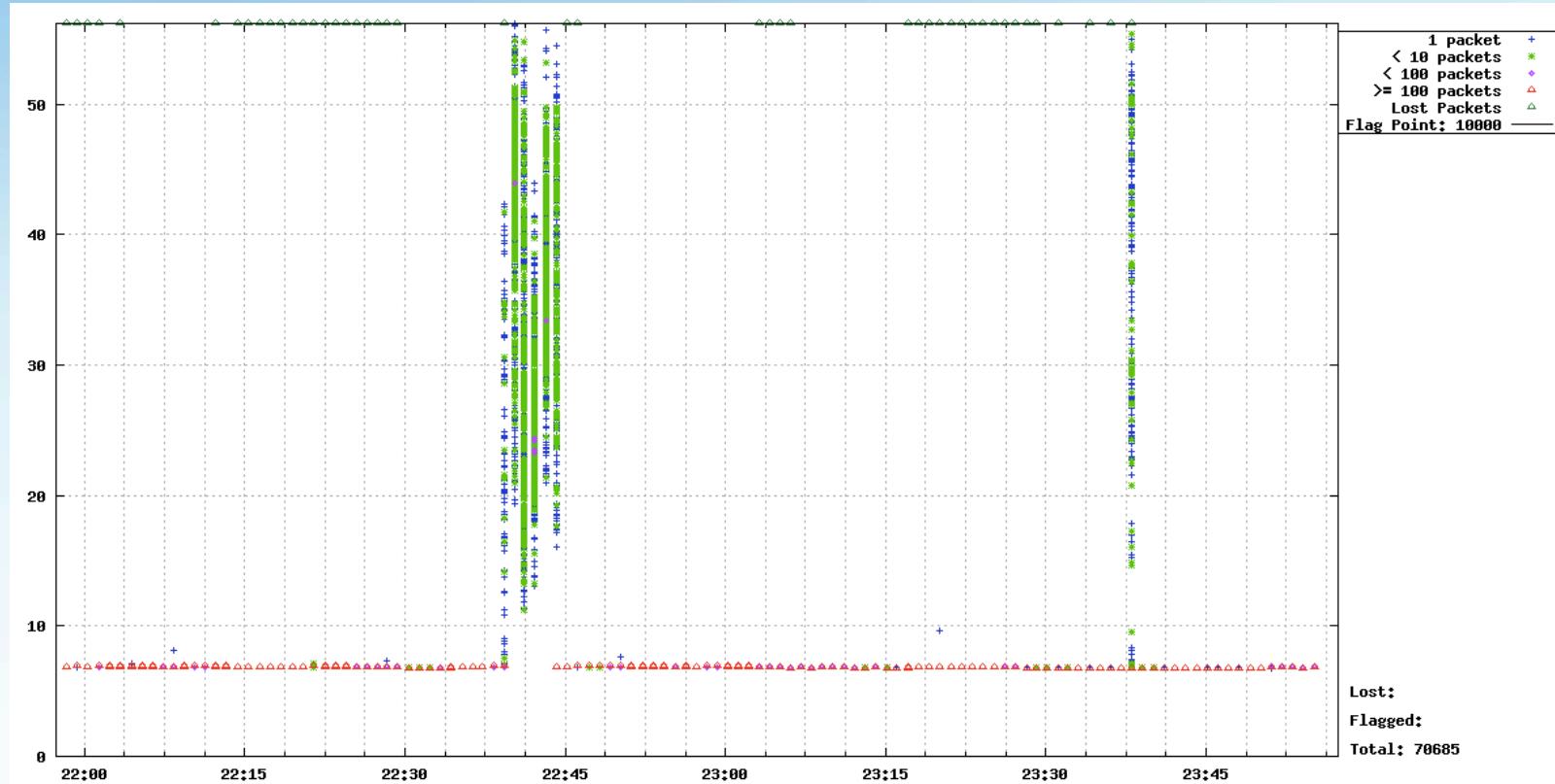
Service Desk: Lets get this into the hands of the oncall to work tonight.

Thanks,
-Tom



Testing Hypothesis

- When operations tweaks things, the tools know:



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Testing Hypothesis

- Explanation from the trouble ticket:

Entered on 02/24/2011 at 23:35:07 UTC (GMT+0000) by Tom Knoeller:

- > Traffic on the link is light, so I think we can turn off
- > ISIS to divert the traffic without too much pain.

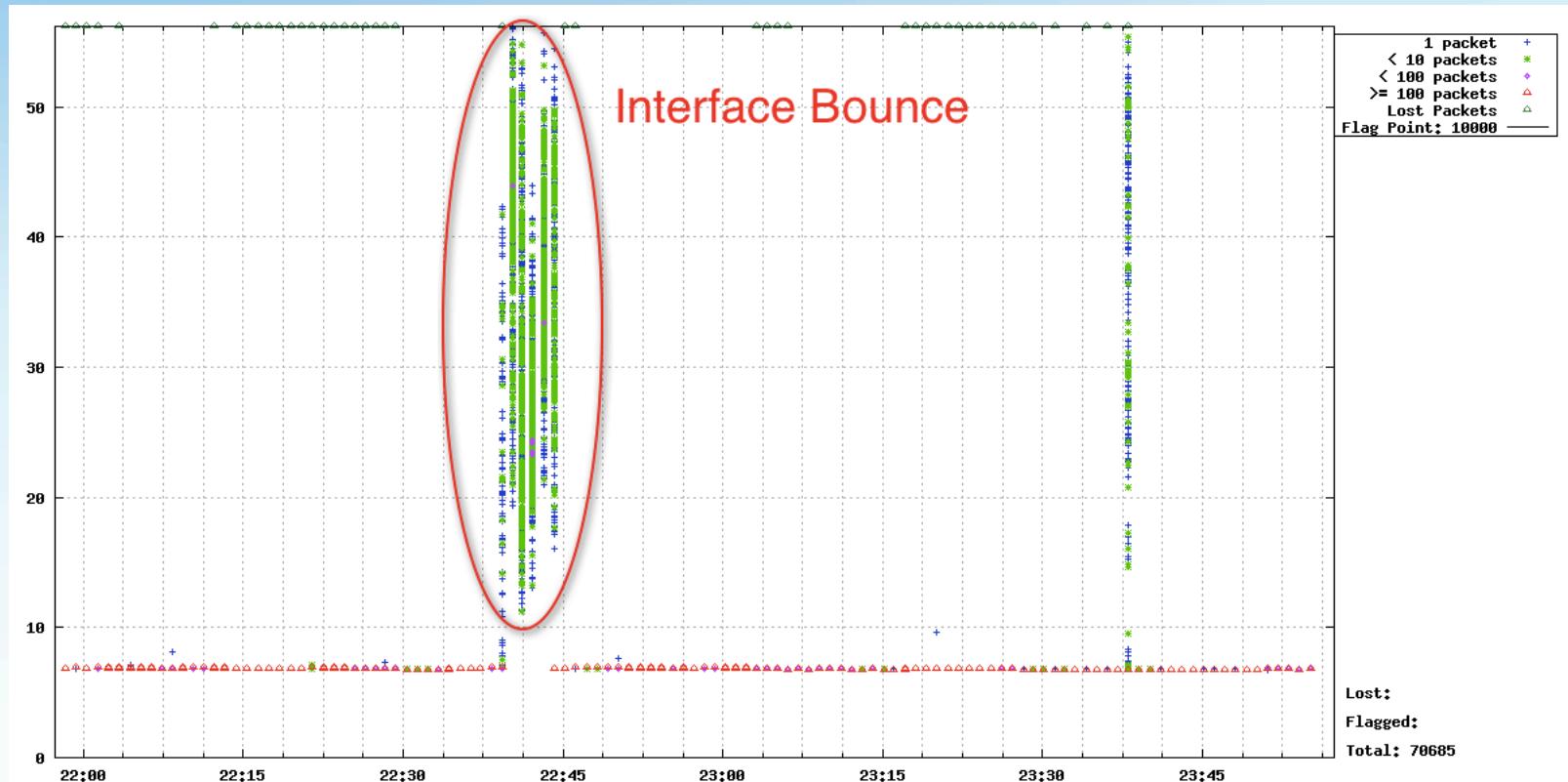
And for those playing the home game, we tried to turn off the link, but I did not think about the offered load being higher with no packet loss, so it overloaded the other backbone link. At this point, the interface is turned on and running in a degraded state until a emergency FSR can be done to move to a new PIC.

-Tom



Testing Hypothesis

- Interpretation:



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Testing Hypothesis

- Next step:

Entered on 02/24/2011 at 23:47:08 UTC (GMT+0000) by Hans Addleman:

Tom suspected and I agreed that this might be the XENPAK optic failing in the T1600. I had a tech run a new fiber over to a new port (1/1/3) and the errors are still being observed on the ATLA side.

Next course is going to be terminal looping the circuit and doing some testing to see if this is a layer 1 issue perhaps.

Hans Addleman
IU Global NOC Engineer
addlema@grnoc.iu.edu

- Maintenance was scheduled for Feb 24th 2011 @ 6:30PM EDT
 - If you are keeping track, this is only 2.5 hours since the ticket was opened



Solution In Place ... Will It Hold?

- Not longer after swapping to a different interface:

Entered on 02/25/2011 at 00:02:08 UTC (GMT+0000) by Hans Addleman:

Okay.. it just took a minute for the counters to settle down.

The swap of interfaces fixed the problem! Traffic on that link jumped up by almost 3gig and the link looks healthy again.

So we have a bad xenpak in WASH that we can worry about in the morning. Tom is going to work with Ross to start sending out spares to the sites.

Thanks to Tom for all the initial leg work on this.. Made my part of it this evening very easy.

Hans Addleman

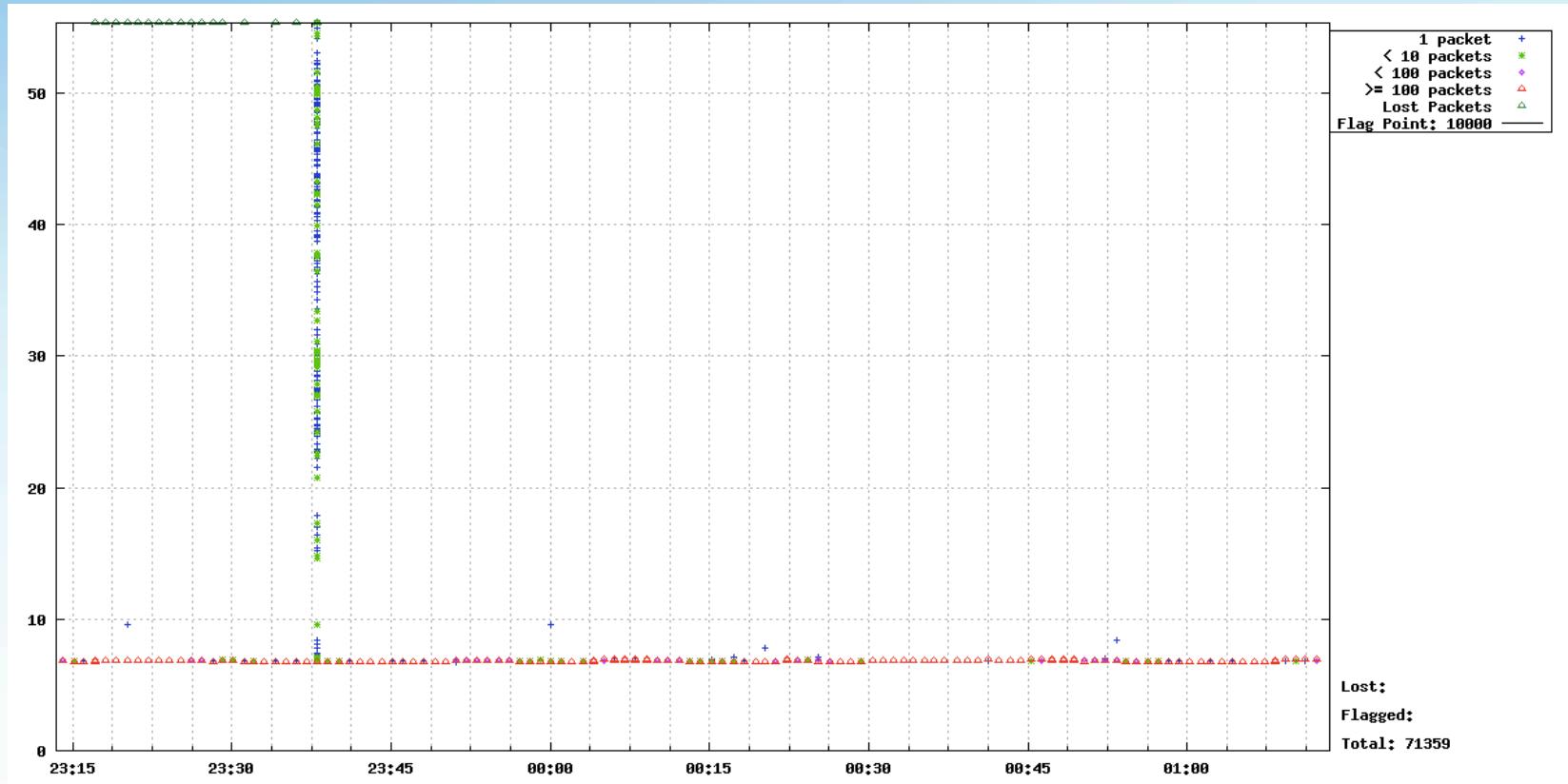
IU Global NOC Engineer

addlema@grnoc.iu.edu

- And what do the tools say ...

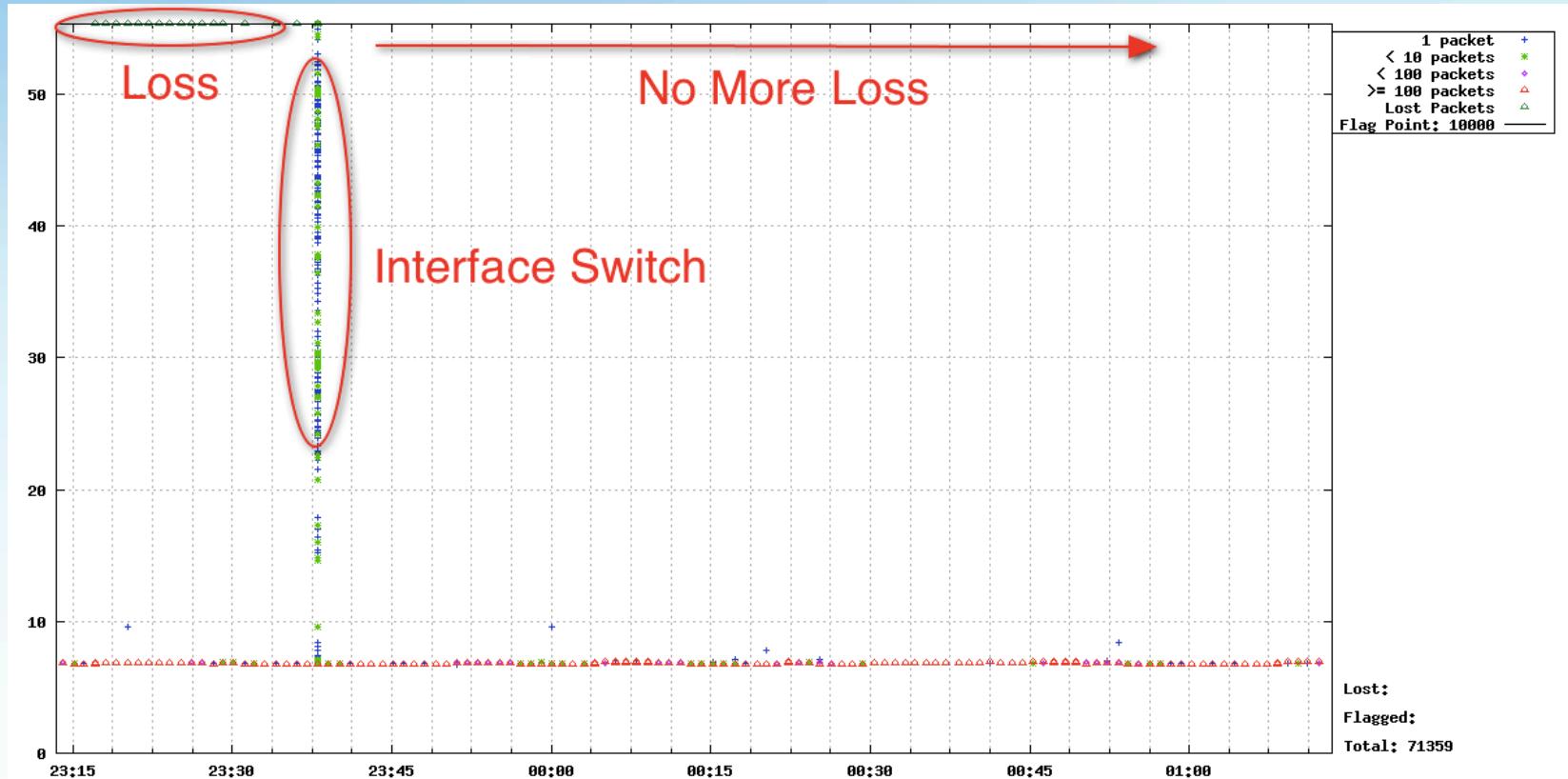
Solution In Place ... Will It Hold?

- OWAMP is sensitive, so lets go back to it:



Solution In Place ... Will It Hold?

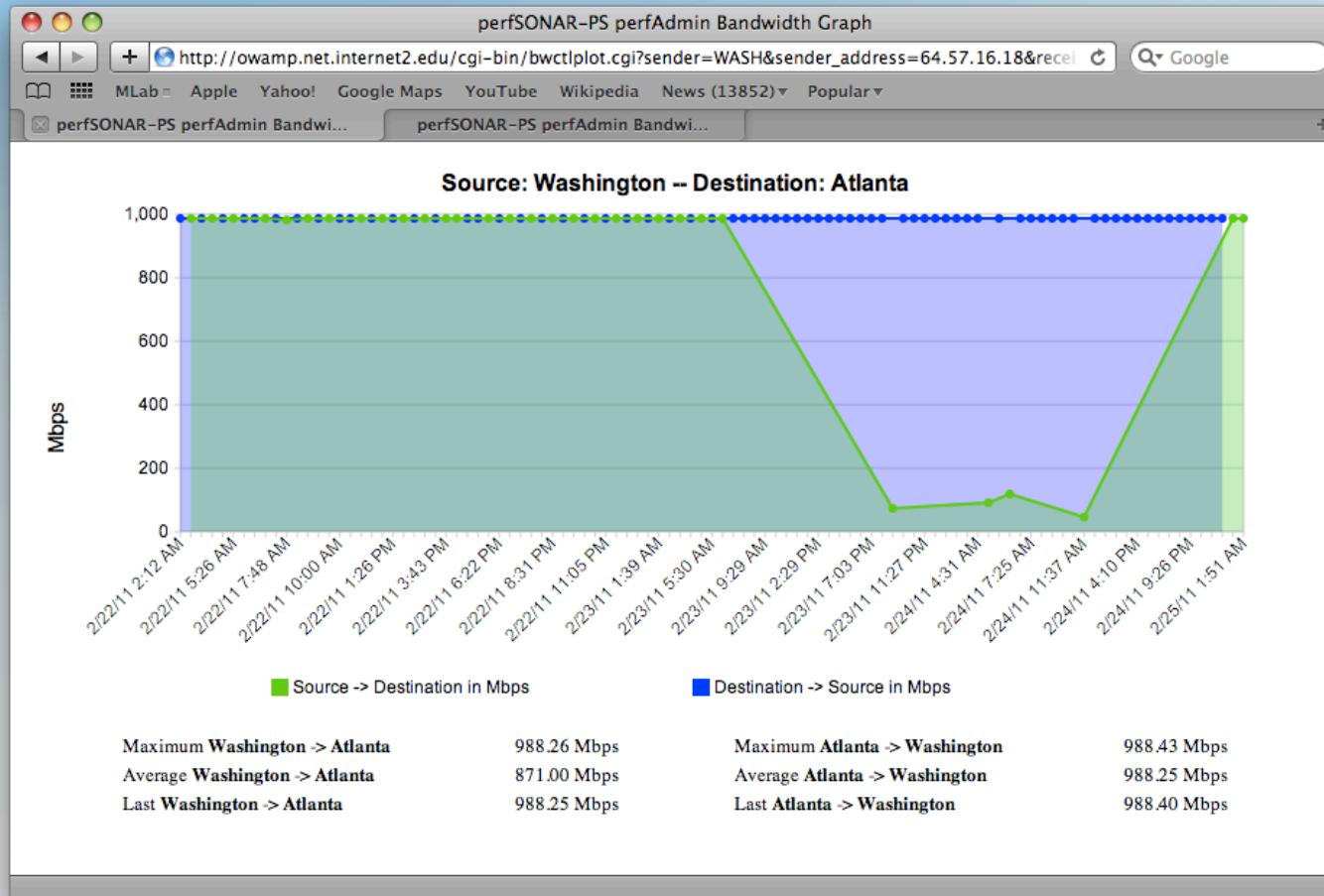
- Interpreting:



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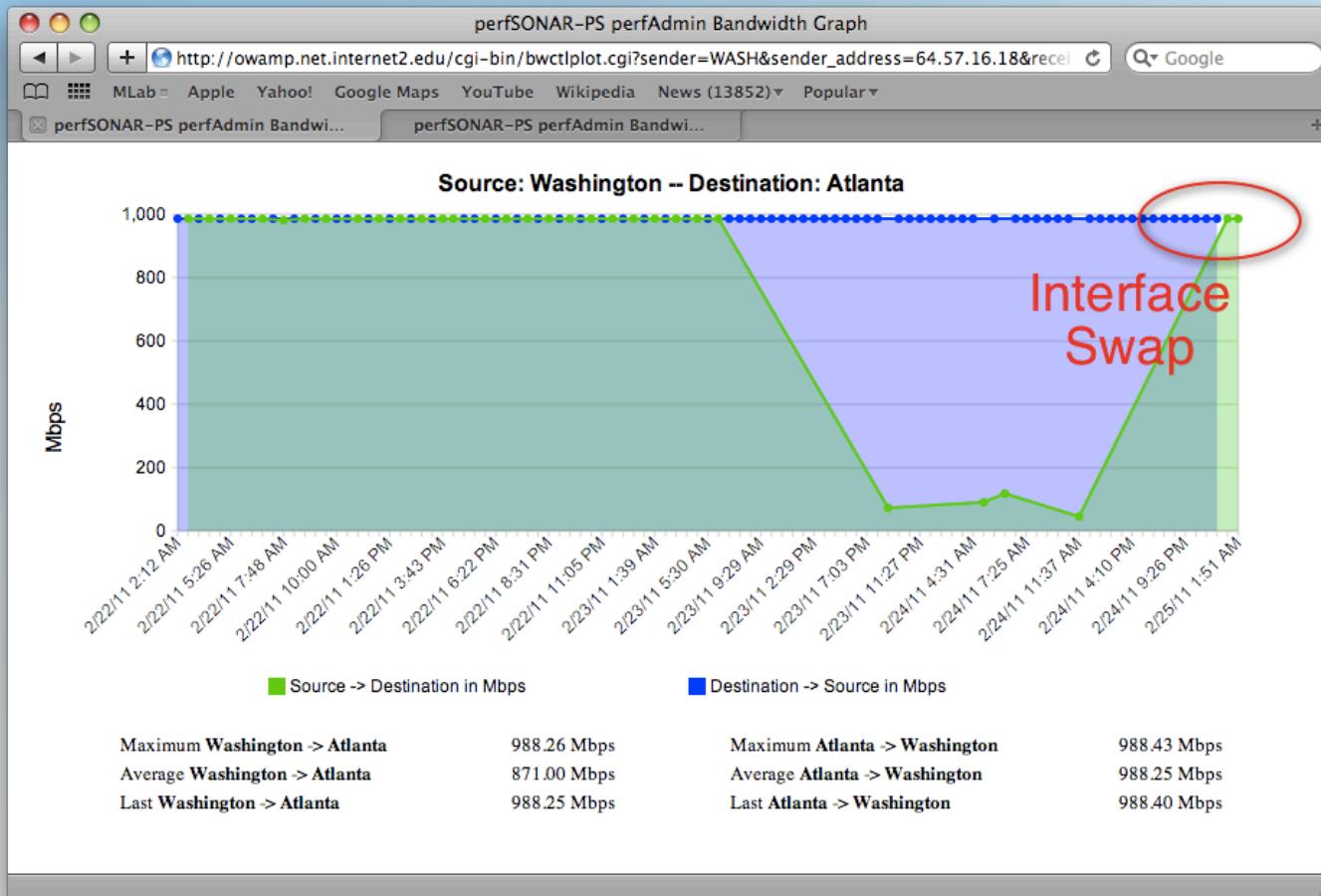
Solution In Place ... Will It Hold?

- What about BWCTL?



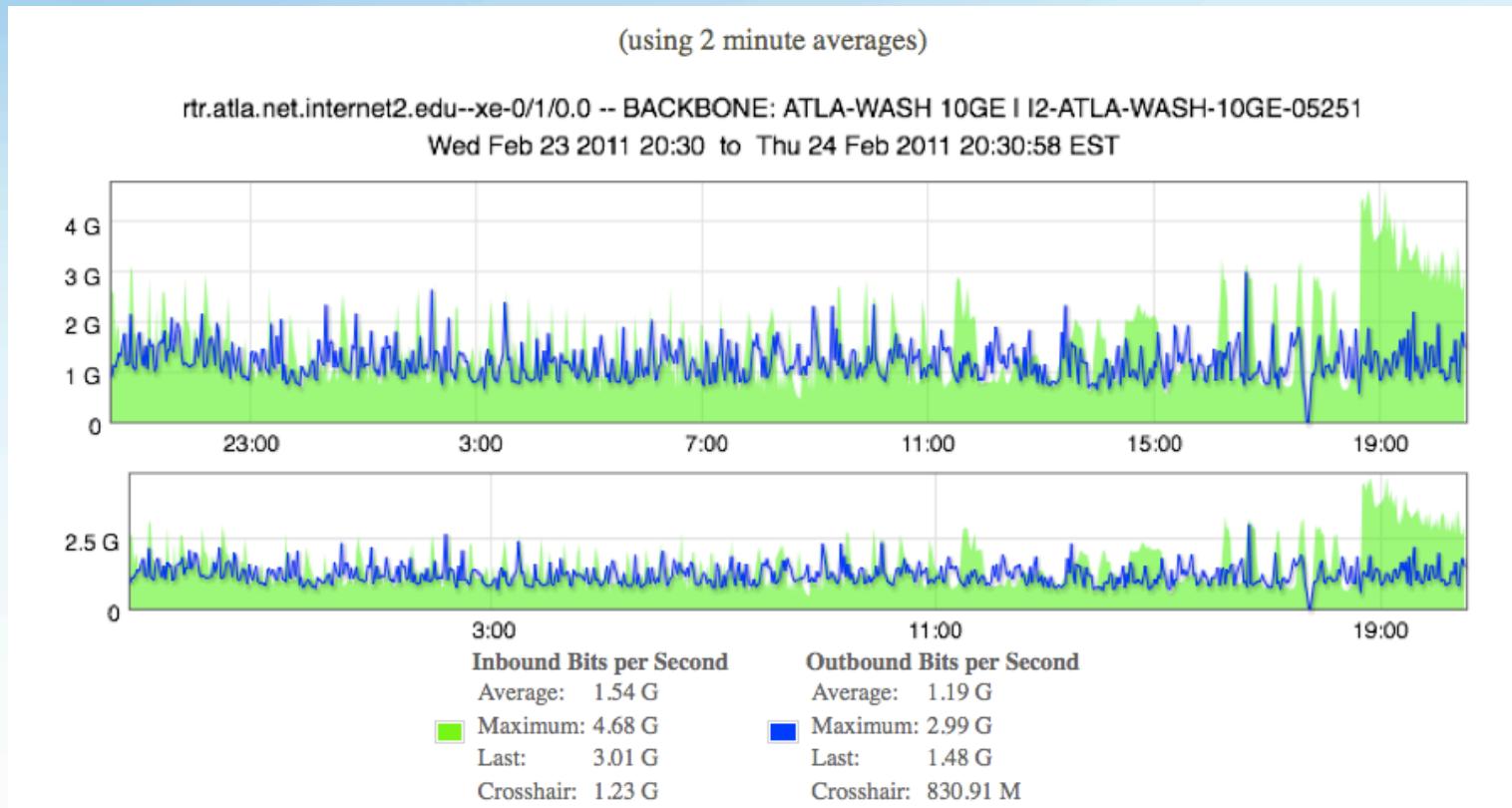
Solution In Place ... Will It Hold?

- Interpreting:



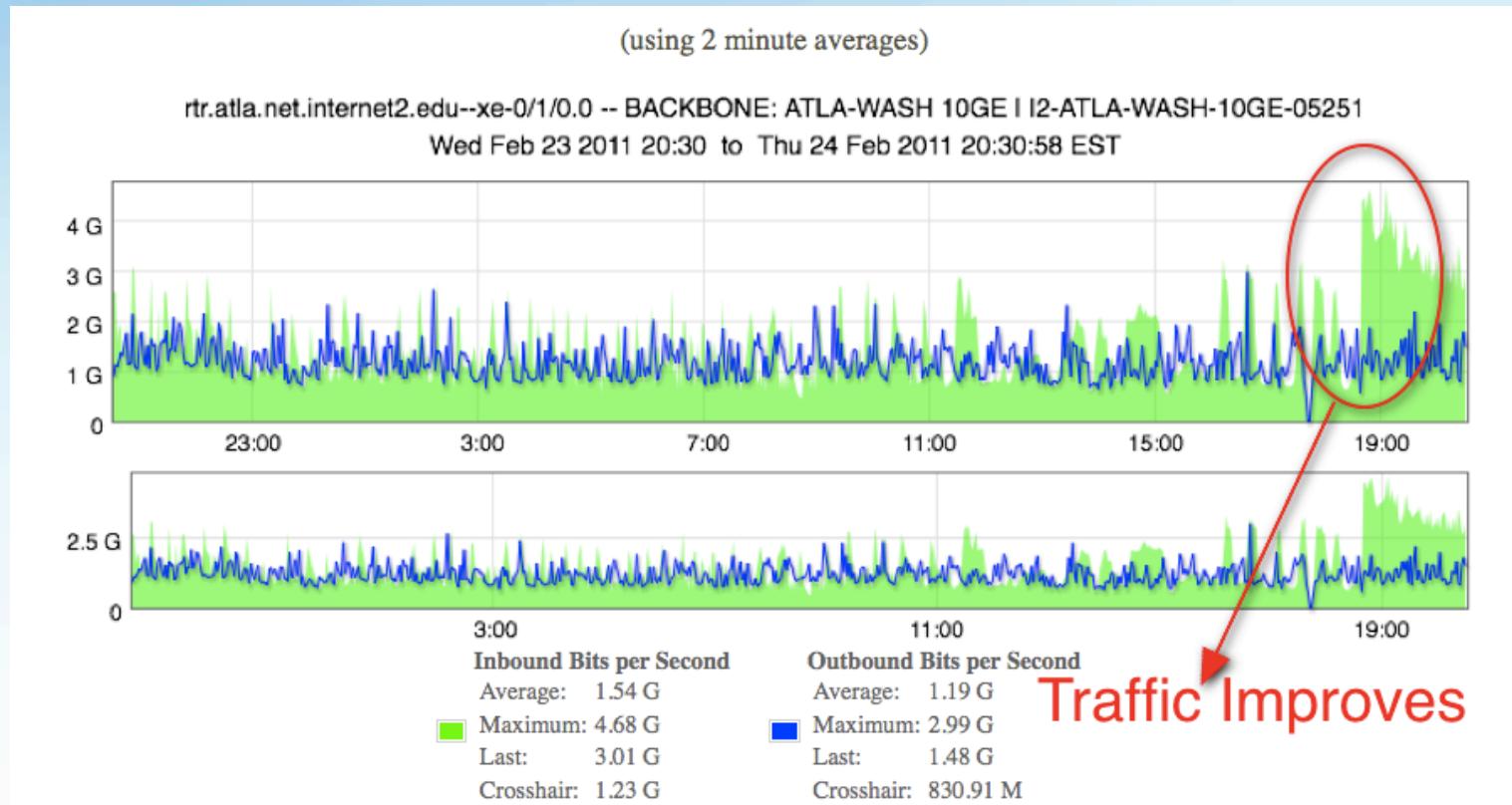
Solution In Place ... Will It Hold?

- Lastly, how about network utilization. In theory this should have limited all traffic...



Solution In Place ... Will It Hold?

- And it did ...



Re-testing, Notification of Customer

- NDT is good for a one off, lets verify the paths again
- Vanderbilt (client) -> WASH (server)
 - running 10s outbound test (client to server) 923.47 Mb/s
 - running 10s inbound test (server to client) 914.02 Mb/s
- Vanderbilt (client) -> PIC (server)
 - running 10s outbound test (client to server) 524.05 Mb/s
 - running 10s inbound test (server to client) 550.64 Mb/s
- Not “perfect”, but closer
 - Client was asked to verify CMS applications
 - Debugging shouldn’t stop, there are more parts of the path to explore.

Conclusion

- Performance tools are more than capable of helping to diagnose and fix network problems
- Success depends on several factors
 - Full deployment
 - Sound methodology
 - Patience!
- The use cases spotlight common themes
- These won't be the last performance problems we solve



Performance Use Cases

August 9th 2011, OSG Site Admin Workshop

Jason Zurawski – Internet2 Research Liaison

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

Use Cases - REDDnet

REDDnet Use Case

- **REDDnet** (Research and Education Data Depot network) is an NSF-funded infrastructure project designed to provide a large distributed storage facility for data intensive collaboration among the nation's researchers and educators in a wide variety of application areas.
- Its mission is to provide "working storage" to help manage the logistics of moving and staging large amounts of data in the wide area network, e.g. among collaborating researchers who are either trying to move data from one collaborator (person or institution) to another or who want share large data sets for limited periods of time (ranging from a few hours to a few months) while they work on it.

REDDnet Use Case

- Fall 2008
 - REDDnet and Partners University of Delaware, University of Tennessee Knoxville, and Vanderbilt University enter the SC08 Bandwidth Challenge
 - Utilize resources on the Internet2 backbone to move large science data sets from REDDnet storage to remote compute facilities
 - Use Phoebus to speed up data movement
 - Use perfSONAR for monitoring
 - Patterns emerged during the ramp up to the BWC:
 - Performance in/out of REDDnet locations was severely limited
 - No form of performance monitoring available
 - No access to diagnostic tools

REDDnet Use Case

- Early/Mid 2009:
 - Work with Internet2 engineers to formulate a diagnostic and monitoring plan
 - Tune all REDDnet hosts for WAN performance
 - Install tools on all REDDnet depots (BWCTL/OWAMP/NDT client)
 - Configure a central host to act as a database of monitoring information
 - Perform regular BWCTL/OWAMP tests between one machine at each of the 10 Locations
 - Collect SNMP statistics where available
 - Host a Network Performance Workshop to educate NOC staff
 - Interpret the results of the regular monitoring
 - Identify the ‘slow’ spots based on observed BWCTL results
 - Identify infrastructure faults (e.g. loss, excessive delay) based on OWAMP results
 - Work with Remote hands to identify and correct problems

REDDnet Use Case – Found Problems

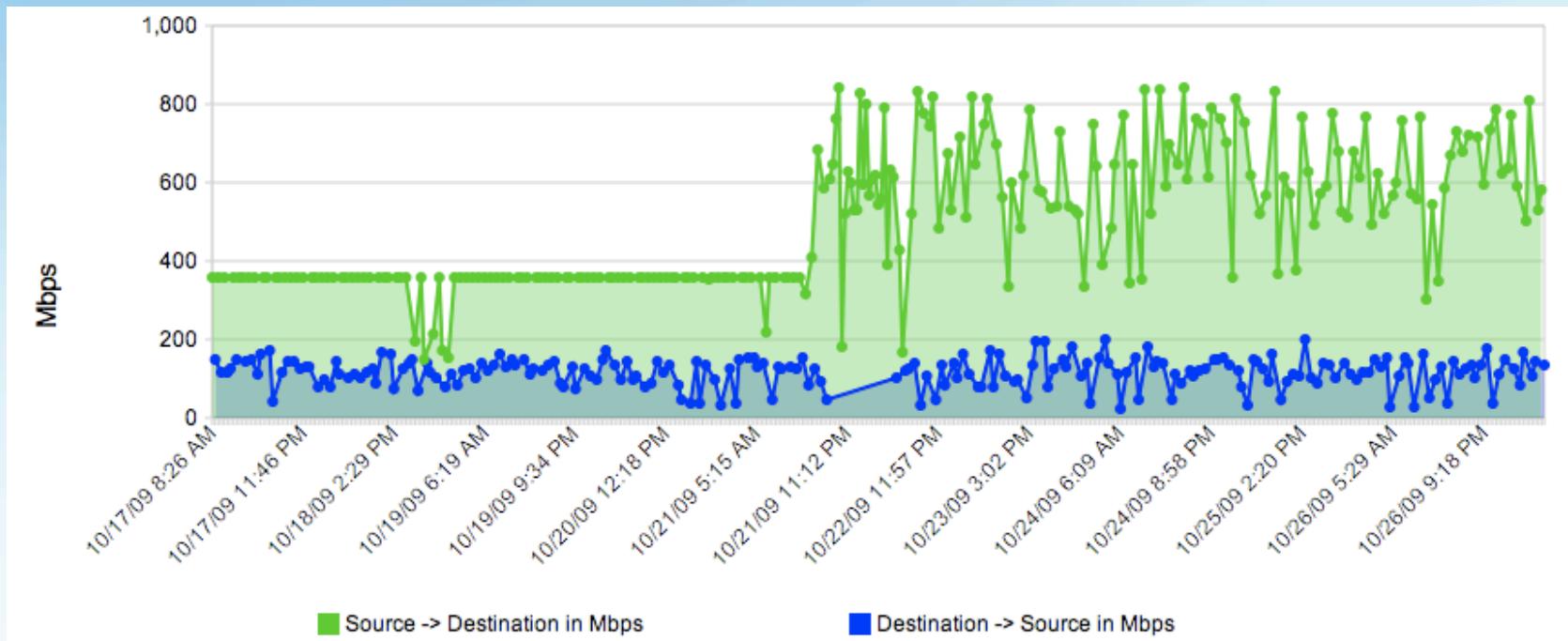
- Poorly Tuned Hosts
- Asymmetric Routing
- Switch/Router with Dirty Optics
- Mis-configured Switch
- Hardware Capability
- Malfunctioning Switch

REDDnet Use Case – Hosts

- LAN flows are much different than WAN flows. The TCP settings of a Linux kernel are normally tuned more for LAN performance.
 - Smaller buffers can't drive a long flow at a high rate of speed
 - **Tradeoff:** how much Kernel memory space to reserve for TCP vs other needs
 - Interface queue is small to prevent long lines from growing
- Auto-tuning is helping, but not to the level science users need
- Instructions: <http://fasterdata.es.net/tuning.html>
 - Changes to several parameters can yield 4 – 10X improvement
 - Takes minutes to implement/test

REDDnet Use Case – Hosts

- Host Configuration – spot when the settings were tweaked...



- N.B. Example Taken from REDDnet (UMich to TACC, using BWCTL measurement)

REDDnet Use Case – Routing

- *A tale of two paths*, Vanderbilt and University of Michigan are the start and destination, but how to travel between the two?
 - VU → SOX → Internet2 → Ultralight → UM
 - VU → SOX → NLR → Ultralight → UM
- Asymmetric Routing:
 - The send and receive paths may not be the same
 - Normally based on policy on one end or the other (prefer a certain route, *Hot Potato* vs *Cold Potato*)
- Performance Implications:
 - Different return vs send path changes the traffic profile
 - Queuing on one network may not be present on the other (e.g. is it worse to queue data packets or acknowledgement packets)
 - Path loss on one could not happen on the other; latency would differ greatly.

REDDnet Use Case – Dirty Optics

- Dirty Optics should throw off some form of error if monitored via SNMP (e.g. **CRC** errors)
- Would only be present for one direction of a transfer:
 - Assume the ‘in’ direction is dirty.
 - If we are sending data, what happens?
 - Data packets are flowing out of the router, acknowledgements are flowing in.
 - Dropping ACKs is not so bad for TCP (cumulative ACKs), performance issue may not be noticed.
 - If we are receiving data, what happens?
 - Data packets are flowing into the router, acknowledgements are flowing out.
 - Dropping data is very bad – all have to be recent. For a WAN flow this can cut performance by a lot.
 - E.g. our ‘*downloaders*’ are experiencing problems. Would we fix the problem?
 - What if the direction was reversed...

REDDnet Use Case – Switch Configuration

- Observed at UMich/Ultralight
 - Couldn't exceed 1 Gbps across a 10GE end to end path that included 5 administrative domains
 - Used perfSONAR tools to localize problem
 - Identified problem device
 - An unrelated domain had leaked a full routing table to the router for a short time causing FIB corruption. The routing problem was fixed, but router started process switching some flows after that.
 - Fixed it
 - Rebooting device fixed the symptoms of the problem
 - Better BGP filters on that peer will prevent reoccurrence (of 1 cause of this particular class of soft faults)

REDDnet Use Case – Hardware

- Older switch used to interconnect several REDDnet servers
 - Single 10G Fiber uplink
 - Multiple 1G Copper ports
- Experienced problems when multiple servers tried to exceed 1G offsite
- LAN testing revealed no problems
- Mitigating Factors
 - Small loss rates on the uplink
 - Switching fabric tried to be *fair* and limit everyone
 - Lack of SNMP meant this was only found after logging on and viewing switch manually
- Moral: You get what you pay for. A *free* switch that is more than 5 years old is not worth the price.

REDDnet Use Case – Switch Fault

- Transfers into and out of Vanderbilt.
- Low levels of periodic loss (bursty loss, every couple of seconds).
- Isolate the problem:
 - End to end – Vanderbilt to Univ of Florida. Loss is seen and it impacts bandwidth.
 - Bi-sect – Vanderbilt to SOX. Loss still seen
 - Bi-sect again – Vanderbilt (ACCRE) to the edge of the campus. Loss is still seen.
 - Bi-sect again – Host to ACCRE edge. Loss is isolated to first hop switch
- Cause:
 - Switch has 2 PCUs. One was plugged in completely, the other was slightly ajar.
 - The switching between PCUs had an internal effect on performance, dropping small amounts of packets very frequently.