



August 10th 2010, OSG Site Admin Workshop - Network Performance

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Performance Measurement Tools

Agenda

- Tutorial Agenda:
 - Network Performance Primer - Why Should We Care? **(15 Mins)**
 - **Getting the Tools (10 Mins)**
 - Use of the BWCTL Server and Client **(30 Mins)**
 - Use of the OWAMP Server and Client **(30 Mins)**
 - Use of the NDT Server and Client **(30 Mins)**
 - **BREAK (15 mins)**
 - Diagnostics vs Regular Monitoring **(30 Mins)**
 - Network Performance Exercises **(1 hr 30 Mins)**

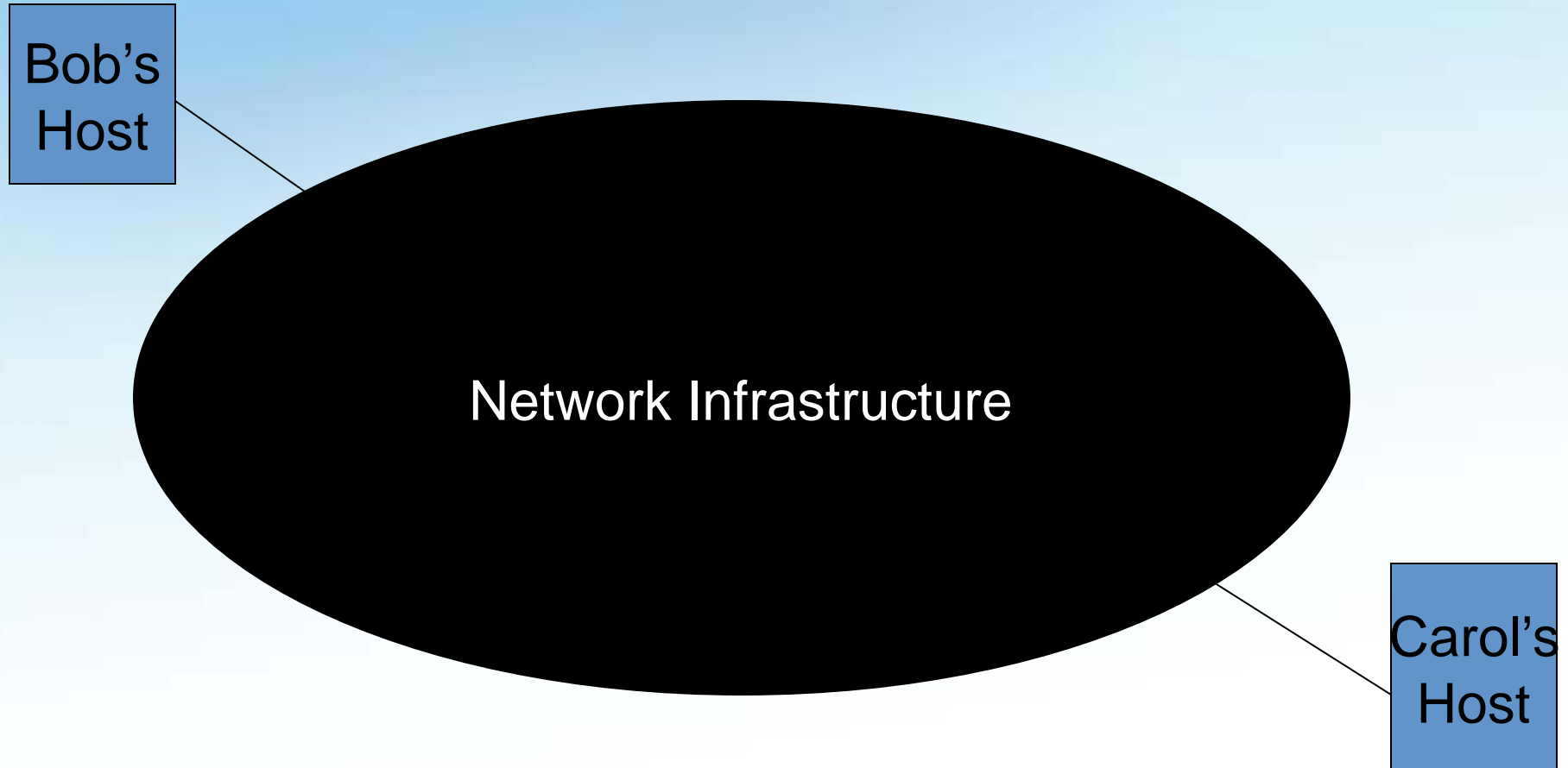
Basic Premise

- Use of the network should meet user expectations.
 - See Examples from earlier
 - When things don't look right, time to explore 'why'
- If they don't you should complain!
 - Learn how to do so effectively
 - Produce results
 - Isolate problem
 - 'The network is slow' is not how to complain effectively

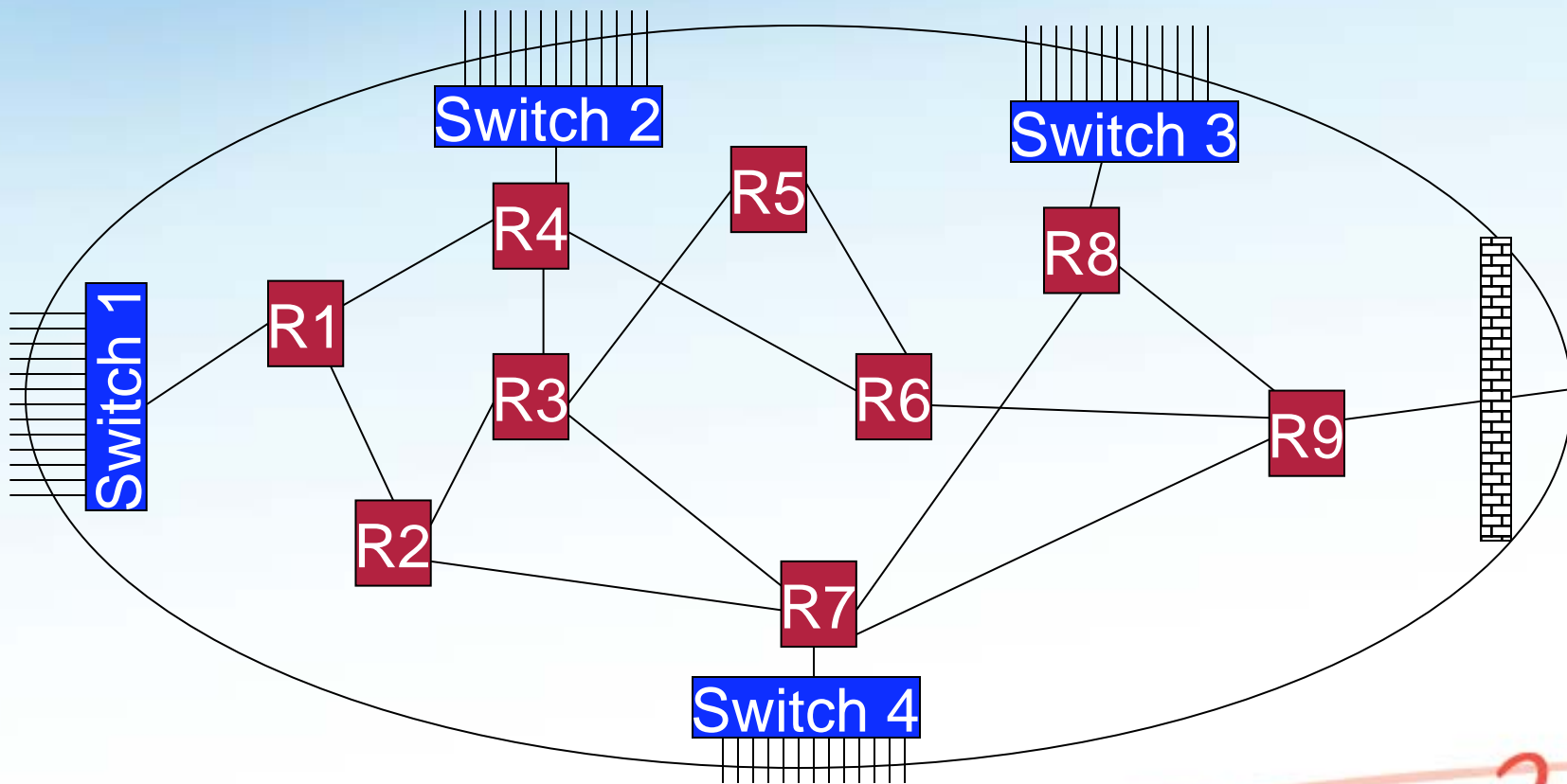
Underlying Assumption

- When problems exist, it's the networks fault!
 - Easy to blame a resource, but where else could a problem be when transferring large data sets?
 - Host (Disk, CPU, Kernel, NIC Drivers)
 - Network Interface Cards
 - Routers/Switches, Routing and Configuration
 - Physical Infrastructure
 - Protocols
- The network is viewed as a single resource in many cases
 - Reality – complex series of components
 - Multiple vendors/technologies
 - Multiple configuration options
 - Crossing administrative domains

Network View (Layman's Terms)



Network View (Actual)



Addressing a Performance Discrepancy

- What are the first steps to address problems related to network performance?
 - Try a Tool
- What tools are out there
 - Numerous
 - Different metrics (measurements) available
 - How to interpret the results?

Tools, Tools, Tools

- Ping
- Traceroute
- Iperf
- Tcpdump
- Tcptrace
- BWCTL
- NDT
- OWAMP
- AMP
- Advisor
- Thrulay
- Web100
- MonaLisa
- pathchar
- NPAD
- Pathdiag
- Surveyor
- Ethereal
- CoralReef
- MRTG
- Skitter
- Cflowd
- Cricket
- Net100
- Pathload
- Pathchrip
- MRTG
- Cacti
- Smokeping
- PingER
- FDT
- perfSONAR
- Nagios
- Ganglia
- Thurlay
- Etc. etc. etc.

Highlighting some Interesting Tools

- Focus on 3 Types of tools (for now)
 - Basic Diagnostics
 - Ping, Traceroute
 - Advanced User Tools
 - NDT
 - Network Admin Focused
 - OWAMP, BWCTL
- What about the others?
 - Try them out, learn how they work.
 - Most tools are designed to solve a specific problem and they may add value to your organization
- Integration of multiple solutions
 - Measurement frameworks integrate use of tools (operation, collecting results) along with analysis and presentation
 - perfSONAR

Software Availability

- BWCTL, OWAMP, NDT client applications are available in VDT
- Source Packages (Client and Server)
 - <http://software.internet2.edu/sources/>
 - Typical 'configure/make/make install'
- RPM Installation (CentOS 5.x Supported):
 - Install our RPM package to enable the Internet2 Repository
 - See instructions here: <http://software.internet2.edu/>
 - Support for YUM and APT-RPM
- pS Performance Toolkit ISO
 - All tools, pre-installed and configured
 - More info: <http://psps.perfsonar.net/toolkit/>
- Others Notes:
 - Other RPM based distros (Fedora/RHEL) may work with packaged RPMs ... YMMV
 - To install on Debian, consider source. Alien conversions of RPMs may be problematic

Basic Diagnostic Tools

- Ping
 - Round Trip (e.g. source to destination, and back)
 - Confirms that remote host is 'up'
 - Some network operators block these packets
 - Play w/ command options to see if that will change anything
- Traceroute
 - Identifies the routers along the path
 - Same blocking problem as above
 - Routers treat TR packets with lower priority
 - See presentation from prior JTs:
 - <http://www.internet2.edu/presentations/jt2009jul/20090722-litvanyi.pdf>

Ping Output

```
zurawski@latrobe:~ — ssh — ttys001 — 85x25
[zurawski@latrobe ~]$ ping -c 4 packrat.internet2.edu
PING packrat.internet2.edu (207.75.164.10) 56(84) bytes of data:
64 bytes from packrat.internet2.edu (207.75.164.10): icmp_seq=1 ttl=57 time=16.2 ms
64 bytes from packrat.internet2.edu (207.75.164.10): icmp_seq=2 ttl=57 time=16.4 ms
64 bytes from packrat.internet2.edu (207.75.164.10): icmp_seq=3 ttl=57 time=16.5 ms
64 bytes from packrat.internet2.edu (207.75.164.10): icmp_seq=4 ttl=57 time=16.4 ms

--- packrat.internet2.edu ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3000ms
rtt min/avg/max/mdev = 16.225/16.423/16.594/0.204 ms
[zurawski@latrobe ~]$
```

Ping Output

- Intro message
 - Identifies remote host name and IP address
 - States size of packets being sent
 - Setting larger sizes may reveal hidden problems
- Output lines
 - Who responded, and the RTT, maybe other details
- Summary lines
 - Number of packets sent/received/lost
 - RTT statistics min/average/max

N.B. 1 msec RTT = ~50 miles of between hosts

Traceroute Output

```
zurawski@latrobe:~ — ssh — ttys001 — 88x24

[zurawski@latrobe ~]$ traceroute packrat.internet2.edu
traceroute to packrat.internet2.edu (207.75.164.10), 30 hops max, 40 byte packets
 1  192.52.179.1 (192.52.179.1)  0.445 ms  0.427 ms  0.388 ms
 2  clpk-ucaid-gige.maxgigapop.net (206.196.177.29)  1.772 ms  1.737 ms  1.737 ms
 3  xe-7-2-0-0.lvl3-t640.maxgigapop.net (206.196.178.90)  2.954 ms  2.969 ms  2.936 ms
 4  i2-lvl3.maxgigapop.net (206.196.178.46)  2.841 ms  2.812 ms  2.918 ms
 5  xe-0-1-0x1004.wsu5.mich.net (192.122.183.9)  14.723 ms  14.567 ms  14.623 ms
 6  tenge0-0-0-0x22.aa2.mich.net (198.108.23.49)  16.617 ms tenge0-0-0-0x76.aa2.mich.net
    (198.108.23.10)  16.617 ms tenge0-0-0-0x22.aa2.mich.net (198.108.23.49)  16.724 ms
 7  mam-77.merit.edu (192.122.200.77)  16.492 ms  16.497 ms  16.603 ms
 8  packrat.internet2.edu (207.75.164.10)  16.324 ms  16.292 ms  16.282 ms
[zurawski@latrobe ~]$ _
```

Traceroute Output

- Intro messages
 - Name and address of remote host
 - Maximum number of link before giving up
- Status messages
 - One line per router in path
 - '*' indicates router didn't respond
 - Routers usually rate limit replies
 - No name indicates DNS entry is missing
 - Hops required to reach remote host or max number from above

Advanced User Tool - NDT

- NDT = Network Diagnostics Tool
- Measure performance to users desktop
- Identify real problems for real users
 - Network infrastructure could be the problem
 - Host tuning issues could be the problem
- Make tool simple to use and understand
 - Presentation in a method almost all users can access: web browser
- Make tool useful for users and network administrators
 - Variables for many aspects of host, protocol, and network performance

NDT User Interface

- Web-based JAVA applet allows testing from any browser
 - One Click testing
 - Option to dig deep into available results
 - Send report of results to network administrators
- Command-line client allows testing from remote login shell
 - Same options available
 - Client software can be build independent of server software

NDT Results

The screenshot shows a web browser window with the address bar displaying `http://207.75.164.80:7123/`. The page content includes a "Getting Started" section with a "Latest Headlines" link. The main text describes the NDT applet's purpose and lists the tests it performs:

- The slowest link in the end-to-end path (Dial-up modem to 10 Gbps Ethernet/OC-192)
- The Ethernet duplex setting (full or half);
- If congestion is limiting end-to-end throughput.

It also identifies two serious error conditions:

- Duplex Mismatch
- Excessive packet loss due to faulty cables.

A test takes about 20 seconds. Click on "start" to begin.

The test results are displayed in a text box:

```
TCP/Web100 Network Diagnostic Tool v5.3.4e
click START to begin
Checking for Middleboxes ..... Done
running 10s outbound test (client to server) ..... 360.76Kb/s
running 10s inbound test (server to client) ..... 20.53Mb/s
Warning! Client time-out while reading data, possible duplex mismatch exists
The slowest link in the end-to-end path is a 100 Mbps Full duplex Fast Ethernet subnet
Alarm: Duplex Mismatch condition detected Switch=Full and Host=half

click START to re-test
```

Below the text box are four buttons: "START", "Statistics", "More Details...", and "Report Problem". The status bar at the bottom of the browser window shows "Tcpbw100 done".

Finding Results of Interest

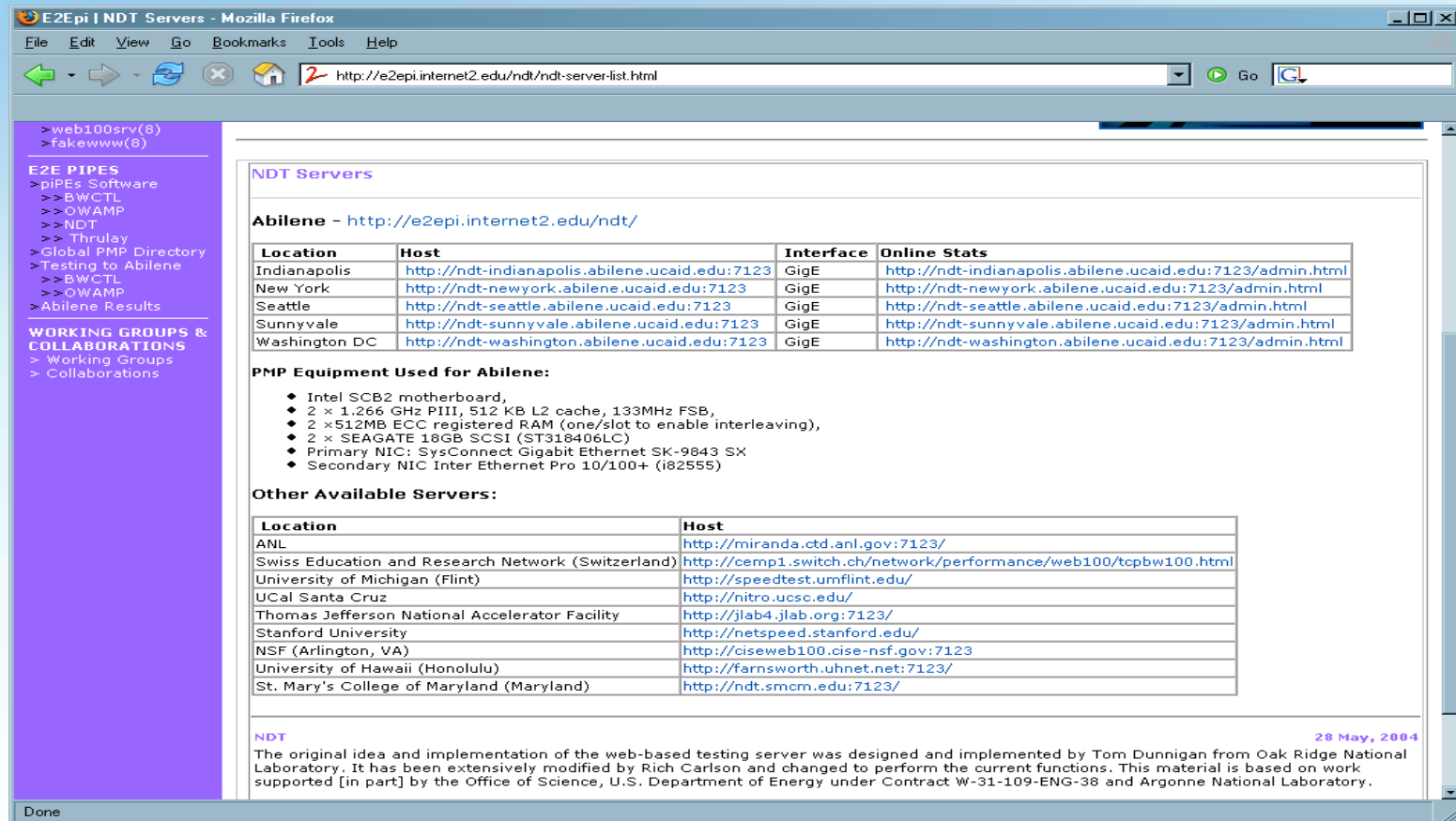
- Duplex Mismatch
 - This is a serious error and nothing will work right. Reported on *main* page, on *Statistics* page, and **mismatch:** on *More Details* page
- Packet Arrival Order
 - Inferred value based on TCP operation. Reported on *Statistics* page, (with loss statistics) and **order:** value on *More Details* page
- Packet Loss Rates
 - Calculated value based on TCP operation. Reported on *Statistics* page, (with out-of-order statistics) and **loss:** value on *More Details* page
- Path Bottleneck Capacity
 - Measured value based on TCP operation. Reported on *main* page

Installation

- Software Dependencies
 - Web100 Patched Kernel
 - Traditionally not a 'simple' operation to maintain
 - Questions on security when patching a kernel – also may not cleanly apply to a 'vendor' kernel
 - NDT Client/Server Package
- Software available as:
 - Source
 - RPM for Kernel and NDT (Available August 2010)
 - pS Performance Toolkit
 - Web100 patched kernel, all measurement tools on a Live Linux CD

Finding a Server – The Old Way

- Static List of servers – doesn't scale



The screenshot shows a Mozilla Firefox browser window with the address bar displaying <http://e2epi.internet2.edu/ndt/ndt-server-list.html>. The page content is titled "NDT Servers" and includes a sidebar with navigation links. The main content area lists servers for Abilene, including their locations, hosts, interfaces, and online stats. It also details the PMP Equipment Used for Abilene and lists other available servers.

NDT Servers

Abilene - <http://e2epi.internet2.edu/ndt/>

Location	Host	Interface	Online Stats
Indianapolis	http://ndt-indianapolis.abilene.ucaid.edu:7123	GigE	http://ndt-indianapolis.abilene.ucaid.edu:7123/admin.html
New York	http://ndt-newyork.abilene.ucaid.edu:7123	GigE	http://ndt-newyork.abilene.ucaid.edu:7123/admin.html
Seattle	http://ndt-seattle.abilene.ucaid.edu:7123	GigE	http://ndt-seattle.abilene.ucaid.edu:7123/admin.html
Sunnyvale	http://ndt-sunnyvale.abilene.ucaid.edu:7123	GigE	http://ndt-sunnyvale.abilene.ucaid.edu:7123/admin.html
Washington DC	http://ndt-washington.abilene.ucaid.edu:7123	GigE	http://ndt-washington.abilene.ucaid.edu:7123/admin.html

PMP Equipment Used for Abilene:

- Intel SCB2 motherboard,
- 2 x 1.266 GHz PIII, 512 KB L2 cache, 133MHz FSB,
- 2 x 512MB ECC registered RAM (one/slot to enable interleaving),
- 2 x SEAGATE 18GB SCSI (ST318406LC)
- Primary NIC: SysConnect Gigabit Ethernet SK-9843 SX
- Secondary NIC: Inter Ethernet Pro 10/100+ (i82555)

Other Available Servers:

Location	Host
ANL	http://miranda.ctd.anl.gov:7123/
Swiss Education and Research Network (Switzerland)	http://cemp1.switch.ch/network/performance/web100/tcpbw100.html
University of Michigan (Flint)	http://speedtest.umflint.edu/
UCal Santa Cruz	http://nitro.ucsc.edu/
Thomas Jefferson National Accelerator Facility	http://jlab4.jlab.org:7123/
Stanford University	http://netspeed.stanford.edu/
NSF (Arlington, VA)	http://ciseweb100.cise-nsf.gov:7123
University of Hawaii (Honolulu)	http://farnsworth.uhnet.net:7123/
St. Mary's College of Maryland (Maryland)	http://ndt.smc.edu:7123/

NDT

28 May, 2004

The original idea and implementation of the web-based testing server was designed and implemented by Tom Dunnigan from Oak Ridge National Laboratory. It has been extensively modified by Rich Carlson and changed to perform the current functions. This material is based on work supported [in part] by the Office of Science, U.S. Department of Energy under Contract W-31-109-ENG-38 and Argonne National Laboratory.

Finding a Server – The New Way

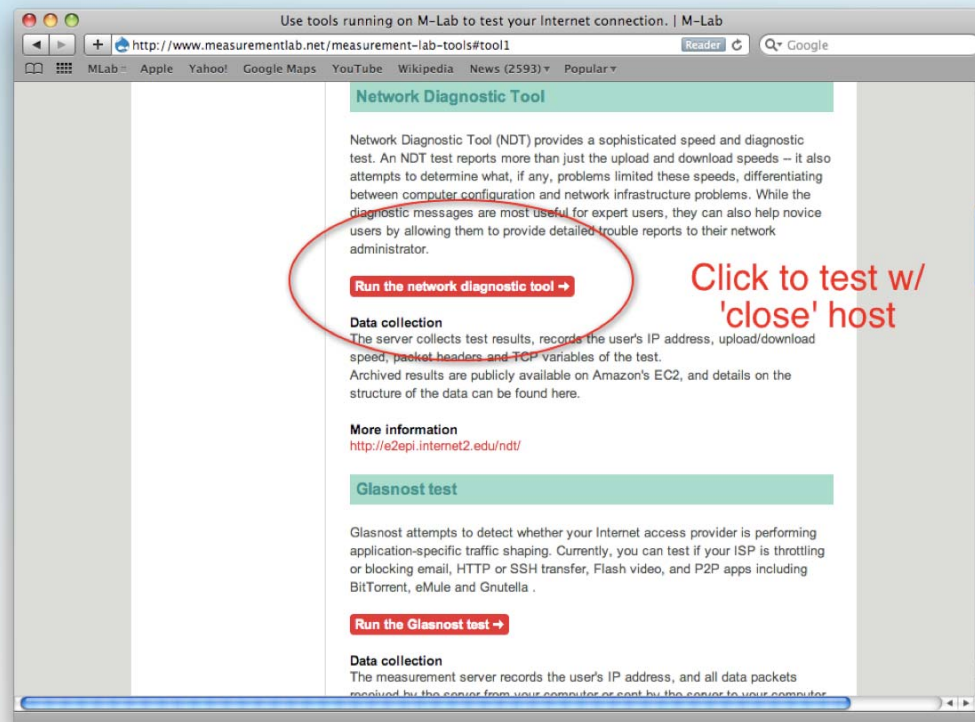
- perfSONAR Infrastructure – automatically search for instances

The screenshot shows a web browser window titled "perfAdmin - Directory of Services". The address bar displays "http://ndb1.internet2.edu/perfAdmin/directory.cgi". The page content includes a "Table of Contents" with links to "Measurement Tools" (OWAMP Daemon, TRACEROUTE Daemon, PING Daemon, PHOEBUS Daemon, NPAD Daemon, NDT Daemon, REDDNET Daemon, BWCTL Daemon) and "perfSONAR Services" (PSB_BWCTL Service, SNMP Service, PINGER Service, PSB_OWAMP Service). Below this is a table titled "OWAMP Daemons" with columns for Service Name, Service Type, Address, and Description.

OWAMP Daemons			
Service Name	Service Type	Address	Description
ESnet-kans OWAMP Server	owamp	tcp://kans-owamp.es.net:861	OWAMP Server at ESnet-kans in KANAS, Kansas City, MO, USA
ESnet-hous OWAMP Server	owamp	tcp://hous-owamp.es.net:861	OWAMP Server at ESnet-hous in HOUS, Houston, TX, USA

Finding a Server – MLab

- Measurement Lab
 - Joint Project between several partners
 - More Info Here: <http://www.measurementlab.net/>
- Locate a 'close' NDT server using DONAR (<http://donardns.org/>)



Network Administration Tools

- BWCTL – Bandwidth Control
 - Allows single person operation over wide area testing environment
 - Runs NLNR ‘iperf’ program
 - Support for Thrulay, nuttcp
- OWAMP – One way Delay Measurement
 - Advanced ‘ping’ command
 - One way vs round trip
 - Allows single person operation over wide area testing environment

BWCTL Sample Results

```
nmsx.internet2 - SecureCRT
File Edit View Options Transfer Script Tools Window Help

[rcarlson@nmsx-aami rcarlson]$ bwctl -L90 -i2 -t20 -w8388608 -A AE AESKEY rcarlson .aeskey
-s nms1-sttl.abilene.ucaid.edu -c nms1-ipls.abilene.ucaid.edu
bwctl: 107 seconds until test results available
RECEIVER START
3349536592.521172: /ami/bin/iperf -B 198.32.8.174 -P 1 -s -f b -m -p 5002 -w 8388608 -t 20
-i 2
-----
Server listening on TCP port 5002
Binding to local address 198.32.8.174
TCP window size: 16777216 Byte (WARNING: requested 8388608 Byte)
-----
[ 14] local 198.32.8.174 port 5002 connected with 198.32.8.190 port 5002
[ 14] 0.0- 2.0 sec 203240632 Bytes 812962528 bits/sec
[ 14] 2.0- 4.0 sec 247453364 Bytes 989813456 bits/sec
[ 14] 4.0- 6.0 sec 247453276 Bytes 989813104 bits/sec
[ 14] 6.0- 8.0 sec 247392040 Bytes 989568160 bits/sec
[ 14] 8.0-10.0 sec 247454640 Bytes 989818560 bits/sec
[ 14] 10.0-12.0 sec 247451404 Bytes 989805616 bits/sec
[ 14] 12.0-14.0 sec 247447240 Bytes 989788960 bits/sec
[ 14] 14.0-16.0 sec 247459968 Bytes 989839872 bits/sec
[ 14] 16.0-18.0 sec 247445468 Bytes 989781872 bits/sec
[ 14] 18.0-20.0 sec 247453536 Bytes 989814144 bits/sec
[ 14] 0.0-20.0 sec 2435407872 Bytes 972137651 bits/sec
[ 14] MSS size 8948 bytes (MTU 8988 bytes, unknown interface)
RECEIVER END
[rcarlson@nmsx-aami rcarlson]$
```

BWCTL Highlights

- You must pre-install BWCTL software package
 - Server/Client required for ends of a test
- Internet2 default permission: TCP test from any member
 - UDP available on request
- Sites can restrict access to 'known' remote users
 - Rich set of permissions and limitations

BWCTL Commands

```
bwctl -L90 -i2 -t20 -c bwctl.losa.net.internet2.edu
```

```
bwctl -L90 -i2 -t20 -s bwctl.newy.net.internet2.edu
```

- Bwctl = name of program
- L90 = wait up to 90 seconds for a test
- i2 = report intermediate results every 2 seconds
- t20 – run test for 20 seconds
- s name = remote end will send data to you
- c name = you will send data to the remote host

BWCTL 3rd Party Testing

```
bwctl -L90 -i2 -t20
```

```
-c bwctl.salt.net.internet2.edu
```

```
-s bwctl.atla.net.internet2.edu
```

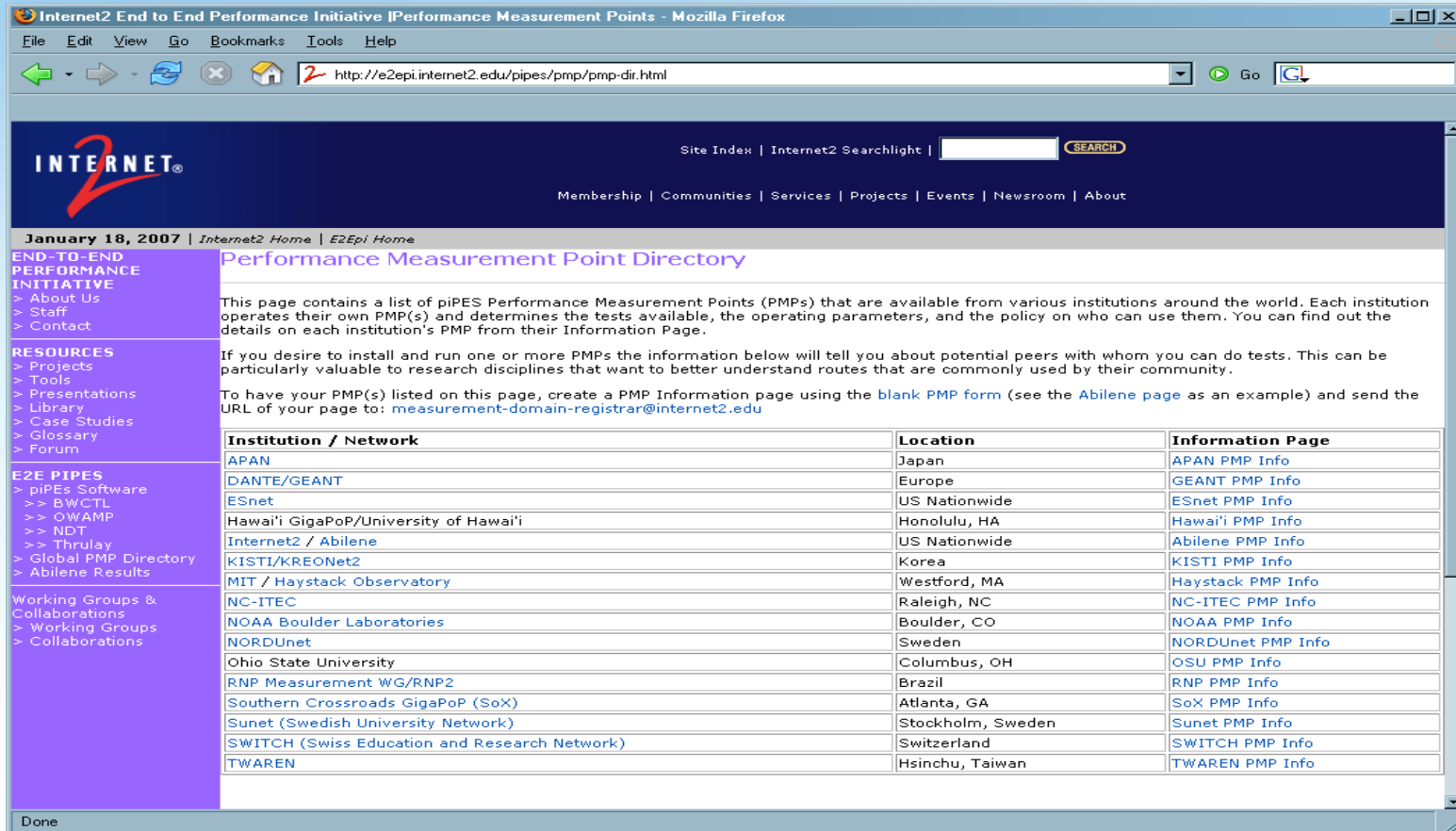
- User can run a test between 2 remote hosts

Installation

- Software available as:
 - Source
 - RPM – Installable through YUM/APT-RPM
 - pS Performance Toolkit
 - Web100 patched kernel, all measurement tools on a Live Linux CD

Finding a Server – The Old Way

- Static List of servers – doesn't scale



The screenshot shows a Mozilla Firefox browser window displaying the Internet2 End-to-End Performance Initiative website. The address bar shows the URL <http://e2epi.internet2.edu/pipes/pmp/pmp-dir.html>. The page title is "Performance Measurement Point Directory". The left sidebar contains a navigation menu with links such as "About Us", "Staff", "Contact", "Resources", "E2E PIPES", and "Working Groups & Collaborations". The main content area includes a search bar, a date "January 18, 2007", and a table listing various institutions and their PMPs.

Performance Measurement Point Directory

This page contains a list of piPES Performance Measurement Points (PMPs) that are available from various institutions around the world. Each institution operates their own PMP(s) and determines the tests available, the operating parameters, and the policy on who can use them. You can find out the details on each institution's PMP from their Information Page.

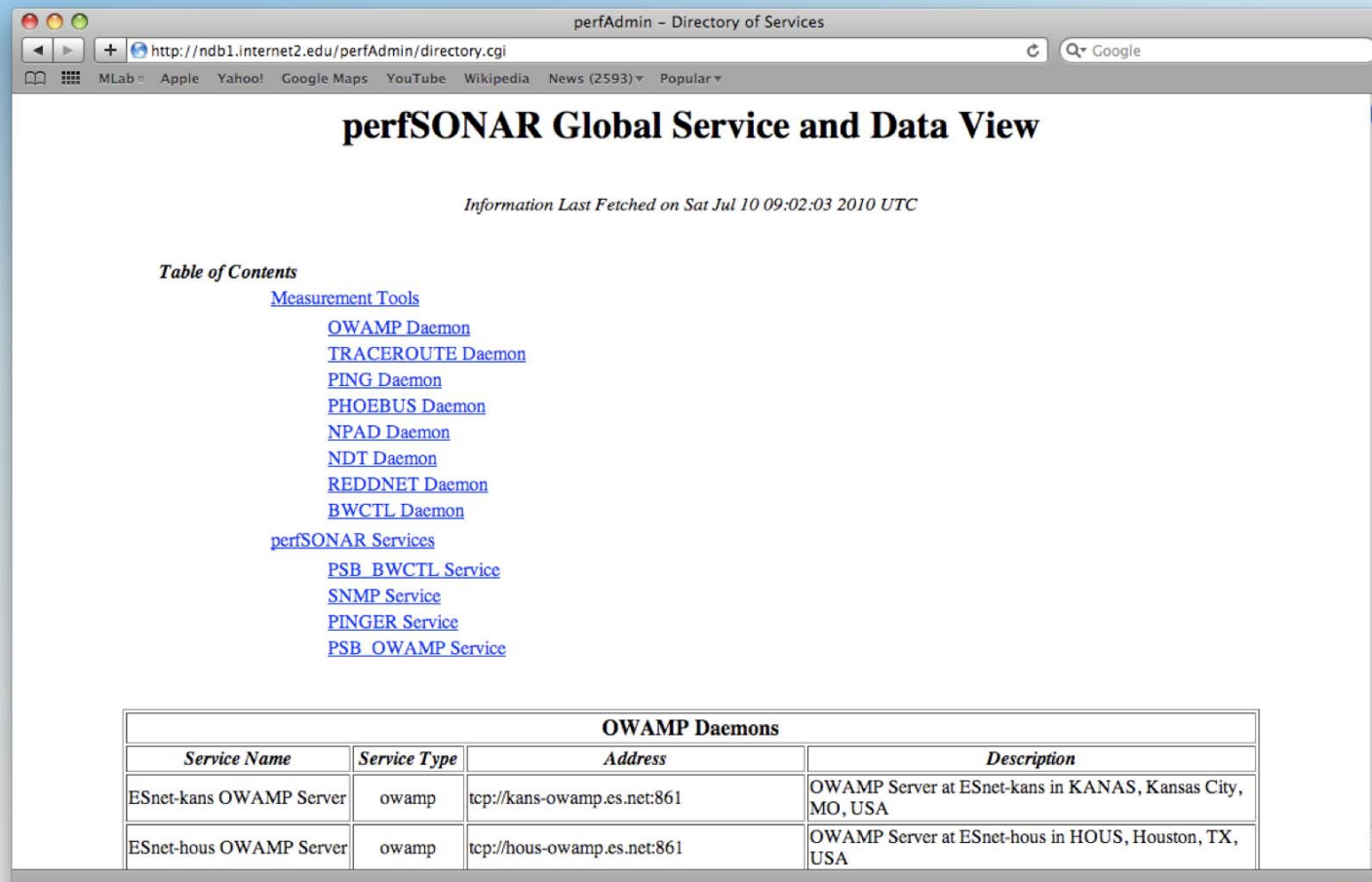
If you desire to install and run one or more PMPs the information below will tell you about potential peers with whom you can do tests. This can be particularly valuable to research disciplines that want to better understand routes that are commonly used by their community.

To have your PMP(s) listed on this page, create a PMP Information page using the [blank PMP form](#) (see the [Abilene page](#) as an example) and send the URL of your page to: measurement-domain-registrar@internet2.edu

Institution / Network	Location	Information Page
APAN	Japan	APAN PMP Info
DANTE/GEANT	Europe	GEANT PMP Info
ESnet	US Nationwide	ESnet PMP Info
Hawai'i GigaPoP/University of Hawai'i	Honolulu, HA	Hawai'i PMP Info
Internet2 / Abilene	US Nationwide	Abilene PMP Info
KISTI/KREONet2	Korea	KISTI PMP Info
MIT / Haystack Observatory	Westford, MA	Haystack PMP Info
NC-ITEC	Raleigh, NC	NC-ITEC PMP Info
NOAA Boulder Laboratories	Boulder, CO	NOAA PMP Info
NORDUnet	Sweden	NORDUnet PMP Info
Ohio State University	Columbus, OH	OSU PMP Info
RNP Measurement WG/RNP2	Brazil	RNP PMP Info
Southern Crossroads GigaPoP (SoX)	Atlanta, GA	SoX PMP Info
SUNET (Swedish University Network)	Stockholm, Sweden	SUNET PMP Info
SWITCH (Swiss Education and Research Network)	Switzerland	SWITCH PMP Info
TWAREN	Hsinchu, Taiwan	TWAREN PMP Info

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OWAMP Daemons			
Service Name	Service Type	Address	Description
ESnet-kans OWAMP Server	owamp	tcp://kans-owamp.es.net:861	OWAMP Server at ESnet-kans in KANAS, Kansas City, MO, USA
ESnet-hous OWAMP Server	owamp	tcp://hous-owamp.es.net:861	OWAMP Server at ESnet-hous in HOUS, Houston, TX, USA

OWPing Results

```
nmsy.internet2 - SecureCRT
File Edit View Options Transfer Script Tools Window Help

rcarlson@nmsy-aami$ ./owping -F /tmp/from.owamp -T /tmp/to.owamp nms4-ipls.abilene.ucaid.edu
Approximately 12.8 seconds until results available

--- owping statistics from [207.75.164.84]:61960 to [nms4-ipls.abilene.ucaid.edu]:57501 ---
SID: c6200ae4c7a5e3dc5ffc50773bbbed85a
100 sent, 0 lost (0.0%), 0 duplicates
one-way delay min/median/max = 5.04/5.1/5.2 ms, (err=5.2 ms)
one-way jitter = 0.1 ms (P95-P50)
Hops = 5 (consistently)
no reordering

--- owping statistics from [nms4-ipls.abilene.ucaid.edu]:63467 to [207.75.164.84]:61887 ---
SID: cf4ba454c7a5e3dc67124c14947f2e5d
100 sent, 0 lost (0.0%), 0 duplicates
one-way delay min/median/max = 5.14/5.2/5.35 ms, (err=5.35 ms)
one-way jitter = 0.1 ms (P95-P50)
Hops = 5 (consistently)
no reordering

rcarlson@nmsy-aami$ ./owstats -a99 /tmp/to.owamp

--- owping statistics from [nmsy-aami-abilene.internet2.edu]:61960 to [nms4-ipls.abilene.ucaid.edu]:57501 ---
SID: c6200ae4c7a5e3dc5ffc50773bbbed85a
100 sent, 0 lost (0.0%), 0 duplicates
one-way delay min/median/max = 5.04/5.1/5.2 ms, (err=5.2 ms)
one-way jitter = 0.1 ms (P95-P50)
Percentiles:
    99.0: 5.2 ms
Hops = 5 (consistently)
```


OWAMP Results

- You must pre-install OWAMP software package
- User program is called 'owping'
- Internet2 default permissions: basic test from any member
 - Other options (e.g. longer test, more data sent) available on request
- Sites can restrict access to 'known' remote users
 - Similar rich set of permissions to BWCTL

Using OWPing

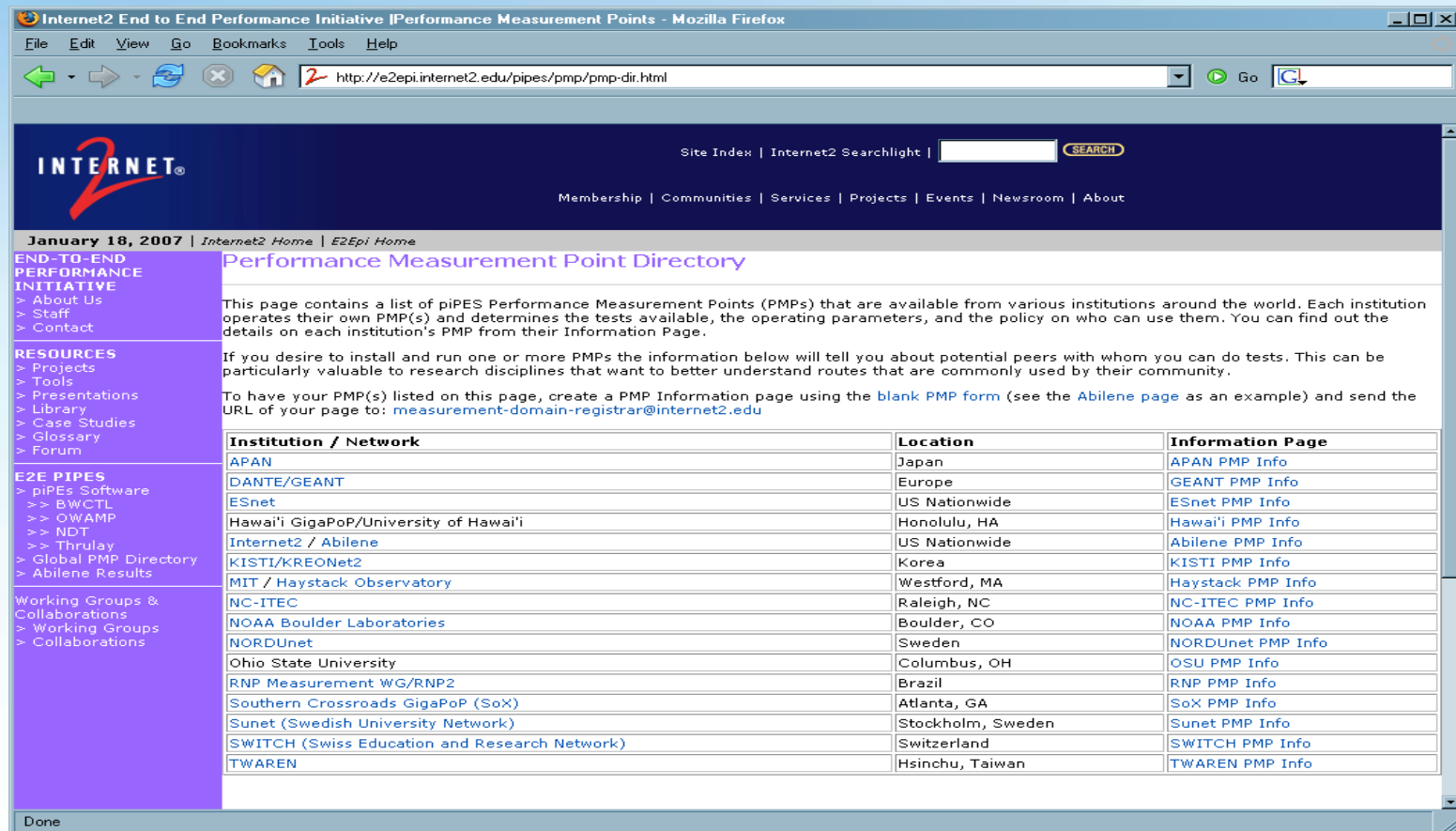
- `owping owamp.salt.net.internet2.edu`
 - `owping` = program name
 - `owamp...` = name of server
- Output results
 - Separate statistics for both directions
 - Number of packets sent and lost
 - One-way delay statistics min/median/max
 - Number of IP hops in path
 - Number of packets that arrives out-of-order

Installation

- Software available as:
 - Source
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DANTE/GEANT	Europe	GEANT PMP Info
ESnet	US Nationwide	ESnet PMP Info
Hawai'i GigaPoP/University of Hawai'i	Honolulu, HA	Hawai'i PMP Info
Internet2 / Abilene	US Nationwide	Abilene PMP Info
KISTI/KREONet2	Korea	KISTI PMP Info
MIT / Haystack Observatory	Westford, MA	Haystack PMP Info
NC-ITEC	Raleigh, NC	NC-ITEC PMP Info
NOAA Boulder Laboratories	Boulder, CO	NOAA PMP Info
NORDUnet	Sweden	NORDUnet PMP Info
Ohio State University	Columbus, OH	OSU PMP Info
RNP Measurement WG/RNP2	Brazil	RNP PMP Info
Southern Crossroads GigaPoP (SoX)	Atlanta, GA	SoX PMP Info
SUNET (Swedish University Network)	Stockholm, Sweden	Sunet PMP Info
SWITCH (Swiss Education and Research Network)	Switzerland	SWITCH PMP Info
TWAREN	Hsinchu, Taiwan	TWAREN PMP Info

Finding a Server – The New Way

- perfSONAR Infrastructure – automatically search for instances

The screenshot shows a web browser window titled "perfAdmin - Directory of Services". The address bar shows the URL "http://ndb1.internet2.edu/perfAdmin/directory.cgi". The page content includes a "Table of Contents" with links to "Measurement Tools" (OWAMP Daemon, TRACEROUTE Daemon, PING Daemon, PHOEBUS Daemon, NPAD Daemon, NDT Daemon, REDDNET Daemon, BWCTL Daemon) and "perfSONAR Services" (PSB_BWCTL Service, SNMP Service, PINGER Service, PSB_OWAMP Service). Below this is a table titled "OWAMP Daemons" with columns for Service Name, Service Type, Address, and Description.

OWAMP Daemons			
Service Name	Service Type	Address	Description
ESnet-kans OWAMP Server	owamp	tcp://kans-owamp.es.net:861	OWAMP Server at ESnet-kans in KANAS, Kansas City, MO, USA
ESnet-hous OWAMP Server	owamp	tcp://hous-owamp.es.net:861	OWAMP Server at ESnet-hous in HOUS, Houston, TX, USA

Conclusions

- Primary tools still useful
 - Know the tool
- Advanced tools are being developed all the time
- Installation using simple methods (e.g. VDT, RPM based package managers)



Performance Measurement Tools

August 10th 2010, OSG Site Admin Workshop – Network Performance
Jason Zurawski – Internet2

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