TCP Performance and Diagnostics:
Optimizing for High Performance Networks

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The Scientific Workflow and HPNs

- Collaboration requires optimized reliable networks
  - The scientific work flow often depends on the transfer of massive data sets
    - E.g. 1000 Genomes Public Data set is 232TB
  - Data sets will continue to grow in size
  - Transferring those data sets to and from compute nodes is critical
  - Failures in the network can delay the workflow by days if not longer

The Bandwidth Delay Product

- Bandwidth delay product
  - BW * RTT = BDP
  - ‘carrying’ capacity of the path between endpoints
    - Think of it like the water in a hose between the faucet and the nozzle.
  - Example: 10Gb path with 250ms RTT
    - 1280MB/s * .250 s = 320 MB in transit between endpoints.
  - In order to maximize utilization you need to keep the path full.

ACKs and Receive Buffers

- TCP is a reliable and congestion avoidant protocol because of ACKs
  - Reliable:
    - Used to inform the sender that the data arrived and ready to receive new data.
    - Duplicate acks indicates missing data
  - Congestion avoidant: Receive buffer & window
    - Max receive window size determined by receive buffer
      - Modulated by the window scaling option
    - Tells the sender exactly how much data it can send at one time.
    - The window size increases each RTT until the window is full or congestion is encountered.

How BDP, Buffers, and ACKs relate

- The goal is to have as much data in flight as possible.
  - The physical maximum is the BDP.
  - The sender moderates the amount of data being sent based on the ACKs received.
  - The maximum allowed in transit before having to ACK is the minimum of the window and buffer
- Ergo: The receive buffer should always be as close to the BDP as possible.
  - This also applies to the sender's send window

Automatic Receive Buffer Tuning

- No need to tune buffers by hand (sort of)
  - This used to be a requirement
    - Automatic receive buffer tuning developed at PSC and now part of every major operating system
  - The default values are *undersized* for large TCP flows on HPN though
    - Usually around 4MB
      - BWmax = RcvBuf / RTT
        - » 4MB on a 250ms path = 128Mb/s
    - For large TCP flows the maximum receive buffer *must* be increased. A lot.
      - Don't forget the send buffer either!

Back to ACKs

- ACKs are used to indicate loss
  - So how much loss can a given path tolerate?
    - *Rate <= (MSS/RTT)*(1 / sqrt{p})*
  - To maintain a single 10Gb/s TCP flow
    - 9K packets: loss rate of less than 1:10^9
    - 1500B packets: loss rate of less that 1:10^10
  - Excessive loss can drop a connection back into slow start
    - Recovery can take a *very* long time in high RTT environments

How to avoid loss

- You can't. Loss is unavoidable.
  - You can learn to live with it though
  - More advanced congestion control algorithms make a difference
    - Stop using Reno (especially if you have older installations)
    - Default for Linux is now CUBIC
      - Other algorithms may be more effective (HTCP, Fast TCP, etc) so be sure to test them on your network.
  - If using Linux update your kernel
    - Proportional Rate Reduction ensures the window size is set as close as possible to SSThresh after loss. In a lossy network PRR provides a 10% improvement in average latency and recovery timeout reduced by 5%. That's a win.

Other Options

- Don’t use a single high bandwidth stream
  - Multiple parallel streams provide insurance against loss without extreme tuning
    - A 1Gb/s connection is roughly 100 times less sensitive to loss.
    - In the event of loss recovery is significantly faster
- Use alternative protocols
  - UDP-based Data Transfer Protocol
    - A reliable UDP protocol designed for use in high performance environments.
    - Optional in GridFTP

The Impact of IPv6 on Performance

- IPv6 is part of the HPN environment
- Fortunately, it should have little impact on network performance:
  - Assuming that your average packet size is more than 256 bytes.
    - IPv6 increases the header size to 60 bytes. In a 9k packet this is 0.66% of the datagram as opposed to 4% in IPv4.
    - As packet sizes decrease it has more impact but not until the 256 byte threshold.
  - And that the path is IPv6 end to end
  - And, of course, application performance is dependent on the underlying code.
    - Mostly a DNS issue though
  - NB: It doesn't fix any of the problems with TCP

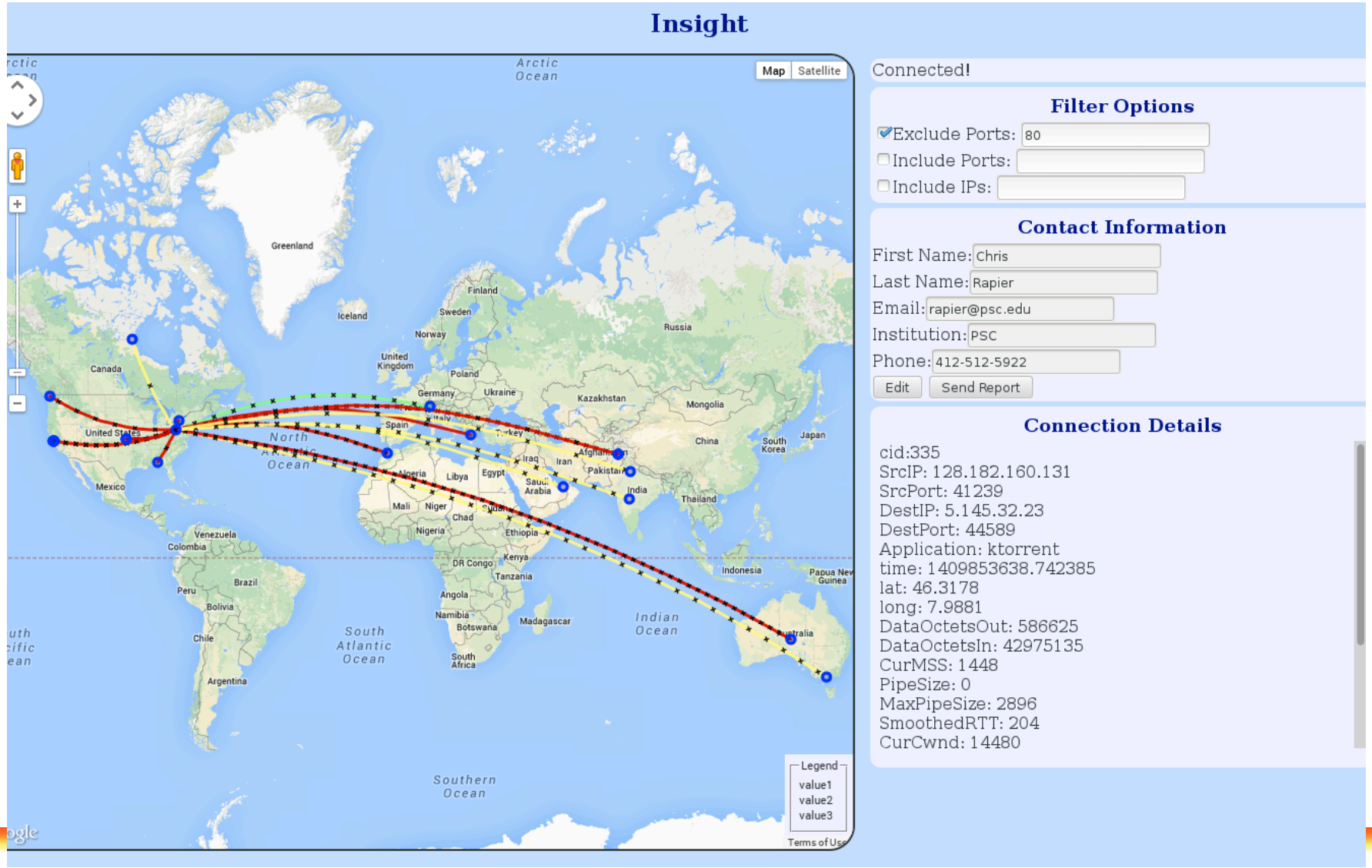
Infrastructure Considerations

- Firewalls, Deep Packet Inspection, and other middleboxes can destroy performance
  - Use a Science DMZ if at all possible
- You have to know what is happening
  - Not just in your network but along the path as a whole
  - Internal: SNMP, NetFlow, logs, Web10G
  - External: perfSonar is a key tool
    - limited to synthetic benchmarks within the infrastructure

Metrics on the Stack

- Web10G!
  - Joint project between PSC and Google
  - Brings 127 different TCP metrics out of the kernel and to the user (RFC 4898)
  - Metrics are provided on a per connection basis
    - Detailed look at how the application interacts with the network in real time
    - Applications can be easily instrumented or 3rd party monitor can report on all network applications
  - Passive monitoring of real world applications
  - Foundation for new tools

Web10G: Insight Project



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The limits of metrics

- Metrics are only the beginning, not the goal
  - Data doesn't mean anything if you can't make sense of it
    - The more metrics you have the more difficult it can be to recognize the important ones.
  - Heuristic approaches to the identification of poorly performing flows is a hard problem
    - If you don't know the initial characteristics of the path you cannot absolutely determine if you are on a bad 1Gb/s connect or a great DSL line.
    - It's much easier for a path where the initial conditions are known
      - Eg. VLANs created via SDN for single use
- With the right heuristics what could we do?
  - And do we want to do it?

Networking and Researchers

- The users depend on us to inform them of best practices
  - Provide them with the tools they need
    - HPN-SSH
    - Science DMZs
    - GridFTP
    - Responsive NOCs and NOC tools to reduce turnaround
  - Educate users about how to file a trouble ticket
    - Turn around on collecting initial information can take days – anything you can do to reduce this delay helps
  - Educate your staff on how to work with users

HPN-SSH and GridFTP

- GridFTP
  - An FTP like file transfer tool built with HPC needs in mind
    - Supports 3rd party transfers.
    - Well Supported
    - Flexible
    - Striped transfers using multiple TCP connections
    - Can be hard to install, configure, and maintain
- HPN-SSH
  - Set of patches to OpenSSH that dramatically improves performance
    - Lightweight and familiar to most users
    - As much as two orders of magnitude faster than OpenSSH
    - Multithreaded AES-CTR cipher
    - Optional switch to NULL cipher post auth to decrease CPU load

Tying it all together

- Pay attention to the basics
  - High latency is a major determinant of TCP behaviour
  - Loss is unavoidable but can be minimized
  - BDP must inform TCP options
- Know your path
  - Metrics and measurements are critical to providing rapid response to problems
- Work with your users
  - Provide the best possible tools
  - Educate them and your front line support staff

Questions?

- Web10g:
  - www.web10g.org
- HPN-SSH:
  - www.psc.edu/networking/projects/hpn-ssh
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