Introduction to Networking and Systems Measurements

Measurement Pitfalls

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Everything that can go wrong will go wrong

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Common Measurement Pitfalls

- What are the hidden assumptions?
- What did you not notice (in the system, setup, ….)?
- What can your tool do?
- Vantage points
- Latency pitfalls
- BW pitfalls
- Reading the results
- …

Hidden Assumptions - Examples

- The path from A to B is the same (reverse) as the path from B to A
- There is no packet reordering
- Device throughput is the same for all packet sizes
- The effect of DNS lookup is negligible

Hidden Assumptions - Examples

- Test packets will experience the same effects as application's traffic
- The measurement tool has negligible overhead
- Previous work was correct

System and Setup
Did you notices that….

- There are other jobs running on the same core
- Kernel version has been updated overnight
- CPU frequency scaling is enabled
- The CPU that you are using is not connected directly to the NIC
- ICMP traffic is throttled by the OS
- The 2x40G NIC uses PCIe Gen 3 x8 (~60Gbps)
- There is a new Errata…

What can your tool do? - Examples

- SSD can write at 450MB/s
  - Don’t try to write data captured at 10Gbps
- The latency for reading CPU timestamp is ~tens of cycles
  - Don’t try to use it to measure cache access time
- DAG resolution is 4ns
  - Don’t try to measure the propagation delay through 1m fibre
- OSNT can only capture at low rate
  - Don’t try to measure latency of 10Gbps flows

Latency Pitfalls - Examples

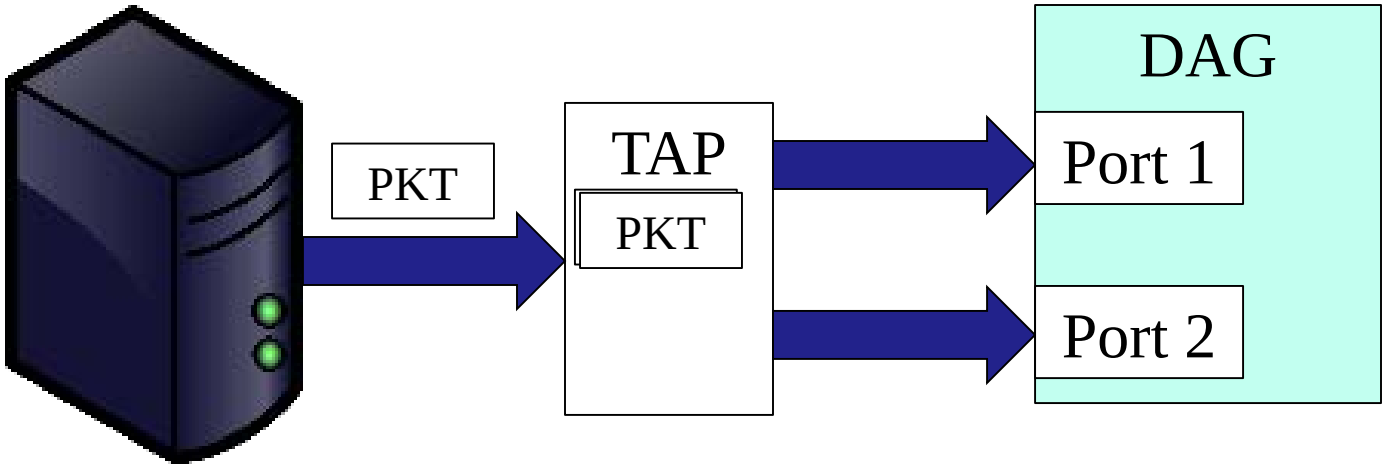
- What is the definition of “latency”?
  - Propagation delay? Inter packet gap? Round trip time? Flow completion time?
- How was the latency measured?
  - Start of packet to start of packet? Start of packet to end of packet?
  - Single packet? Packet-pair? Packet-train?
- Where was the timestamp taken?
  - …and how did it affect the measurement?
- Resolution, precision and accuracy…

Bandwidth Pitfalls - Examples

- What is the definition of “bandwidth”?
  - Link capacity? Average throughput? Peak throughput?
- Controllability
  - Packet size? Protocol? QoS?
- What was the status of the network?
- Net neutrality?
- Did you pass through the bottlenecks?
- Resolution, precision and accuracy…

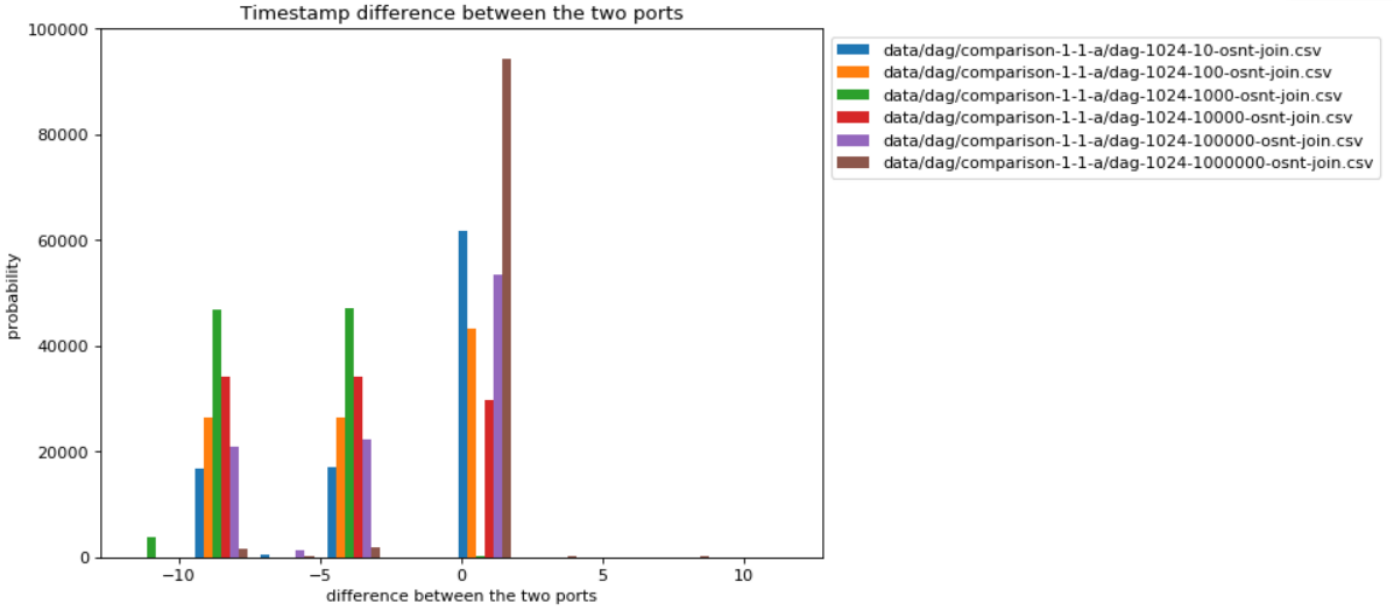
Example: Timestamp difference between ports

- Recall Lab 2, experiment 2.1 b
- Measuring the timestamp difference between 2 ports:



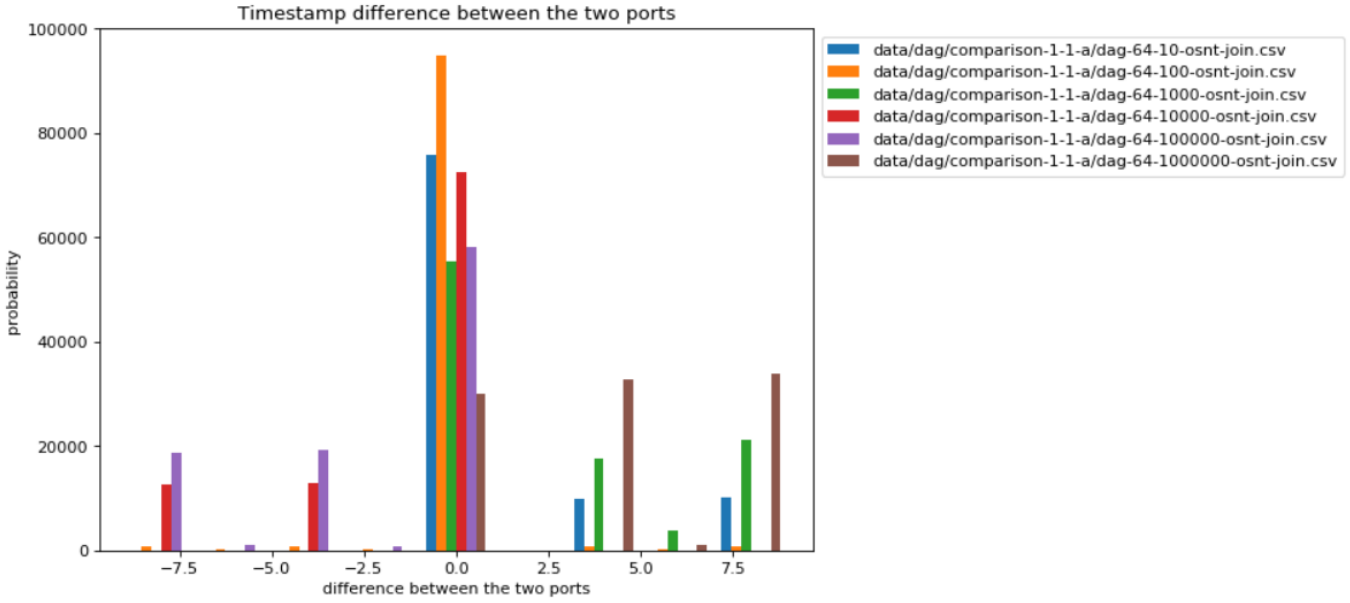
Example: Timestamp difference between ports

- 100,000 packets, **1024B**
- Different Inter Packet Gaps (IPG)



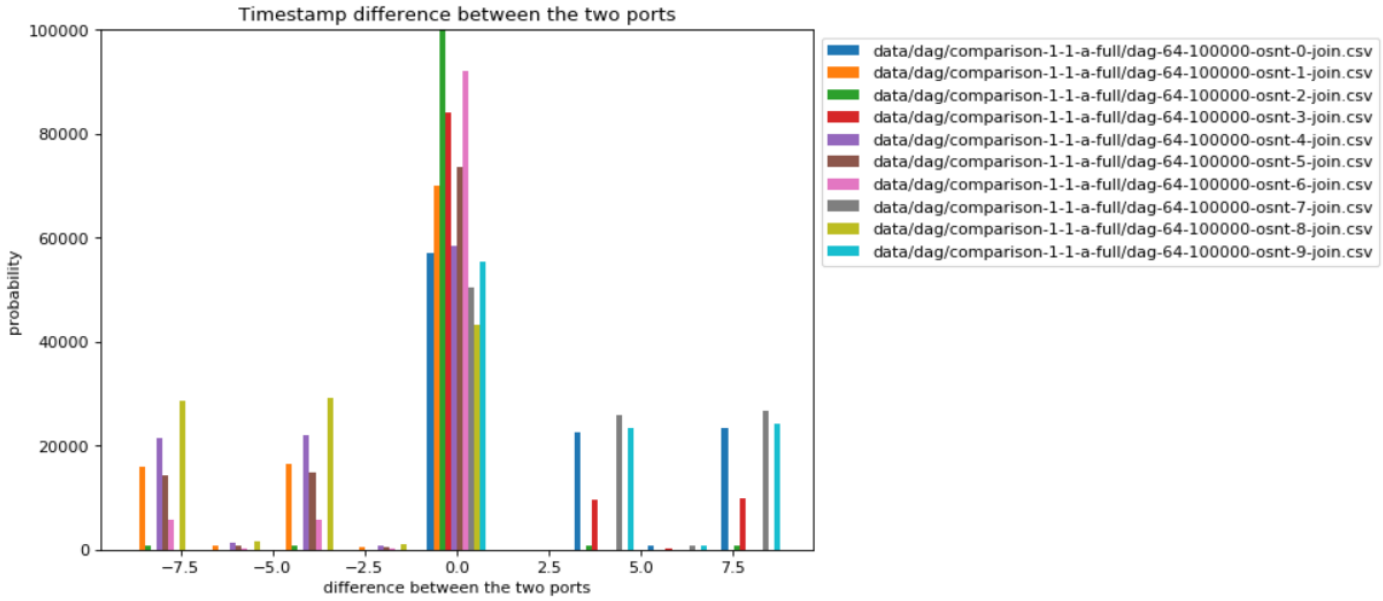
Example: Timestamp difference between ports

- 100,000 packets, **64B**
- Different Inter Packet Gaps (IPG)



Example: Timestamp difference between ports

- 100,000 packets, **64B**, running 10 times
- Same Inter Packet Gap (IPG)



Example: Switch Throughput

- The reported iperf result for a NetFPGA reference switch is 9.4Gbps
- User complaint: I see only 8.9Gbps and packet drop in the switch

```
Connecting to host 10.0.0.13, port 5201
[  4] local 10.0.0.12 port 54764 connected to 10.0.0.13 port 5201
[ ID] Interval           Transfer     Bandwidth       Retr  Cwnd
[  4]   0.00-1.00   sec  1.02 GBytes  8.76 Gbits/sec   74    313 KBytes
[  4]   1.00-2.00   sec  1.03 GBytes  8.86 Gbits/sec   34    198 KBytes
[  4]   2.00-3.00   sec  1.03 GBytes  8.87 Gbits/sec   34    281 KBytes
[  4]   3.00-4.00   sec  1.04 GBytes  8.92 Gbits/sec   34    238 KBytes
[  4]   4.00-5.00   sec  1.04 GBytes  8.93 Gbits/sec   32    208 KBytes
[  4]   5.00-6.00   sec  1.04 GBytes  8.92 Gbits/sec   29    187 KBytes
[  4]   6.00-7.00   sec  1.04 GBytes  8.95 Gbits/sec   27    365 KBytes
[  4]   7.00-8.00   sec  1.04 GBytes  8.94 Gbits/sec   28    233 KBytes
[  4]   8.00-9.00   sec  1.03 GBytes  8.88 Gbits/sec   30    420 KBytes
[  4]   9.00-10.00  sec  1.04 GBytes  8.96 Gbits/sec   33    423 KBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bandwidth       Retr
[  4]   0.00-10.00  sec  10.4 GBytes  8.90 Gbits/sec  355             sender
[  4]   0.00-10.00  sec  10.4 GBytes  8.90 Gbits/sec                  receiver
```

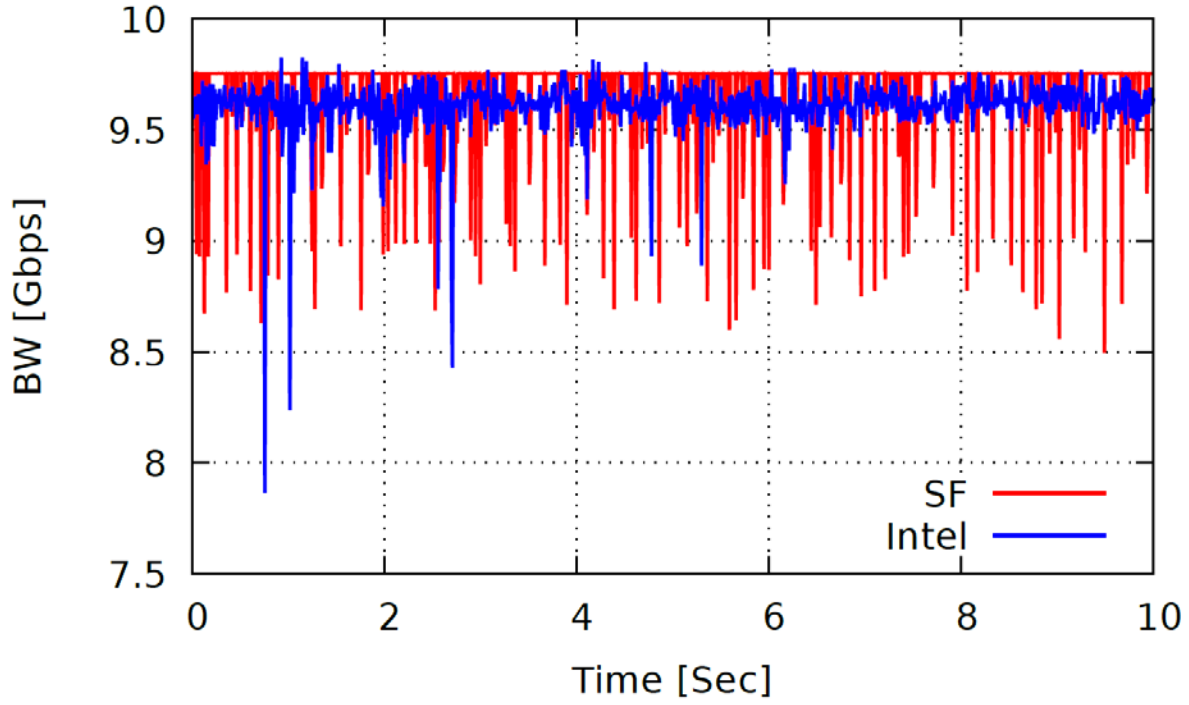
Example: Switch Throughput

- Debug: Have you tried changing rx-usec?
- User: no more packet drop in the switch!
- …but bandwidth is down to 7.5Gbps…

- New insight: NIC used on reference setup (Solarflare) is different than the NIC used by user (Intel)
- (skipping a few steps forward)

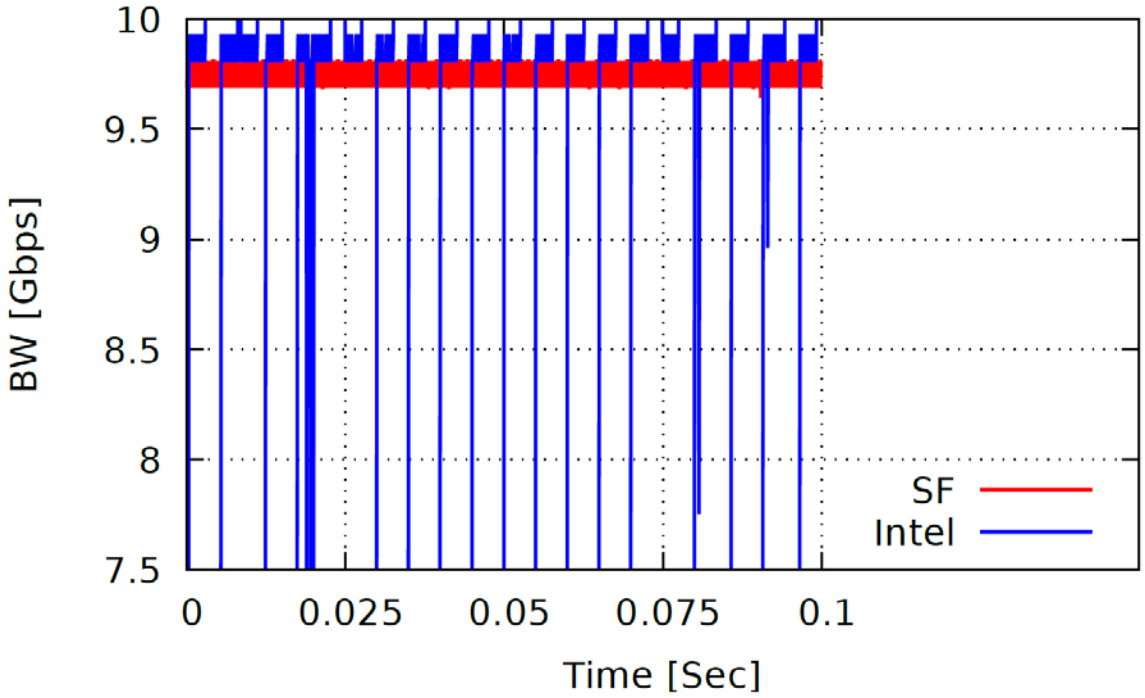
Example: Switch Throughput

- Switch throughput over time (10ms sampling resolution)



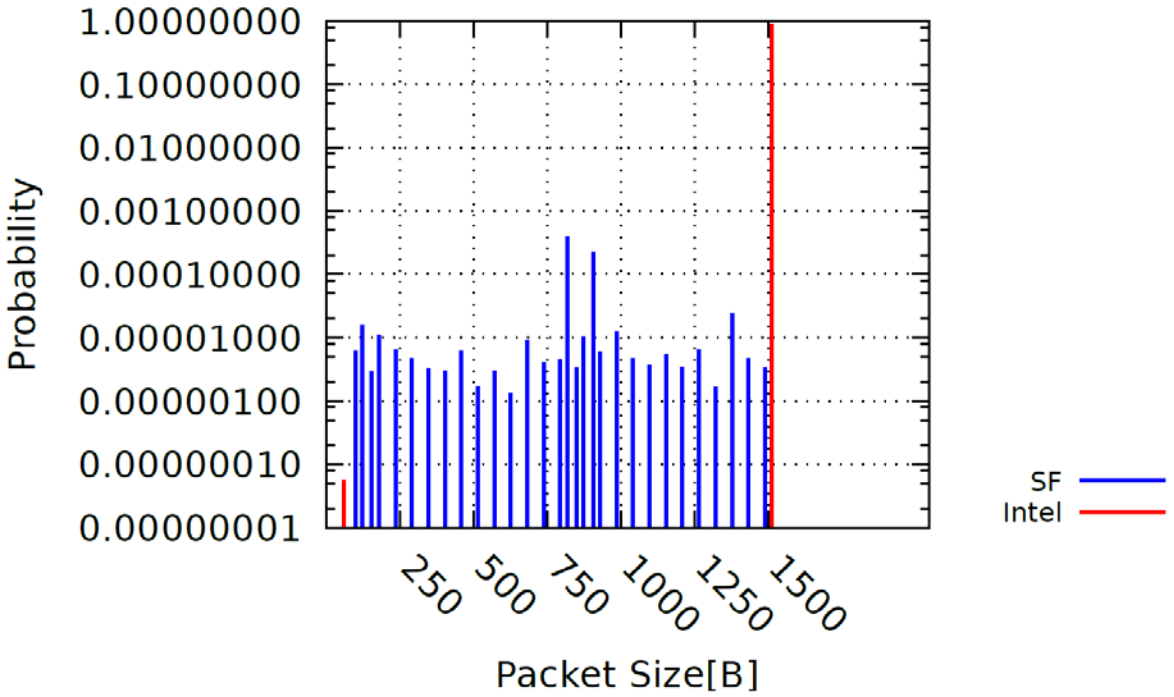
Example: Switch Throughput

- Switch throughput over time (100µs sampling resolution)



Example: Switch Throughput

- What else is different?



Example: TSC Access

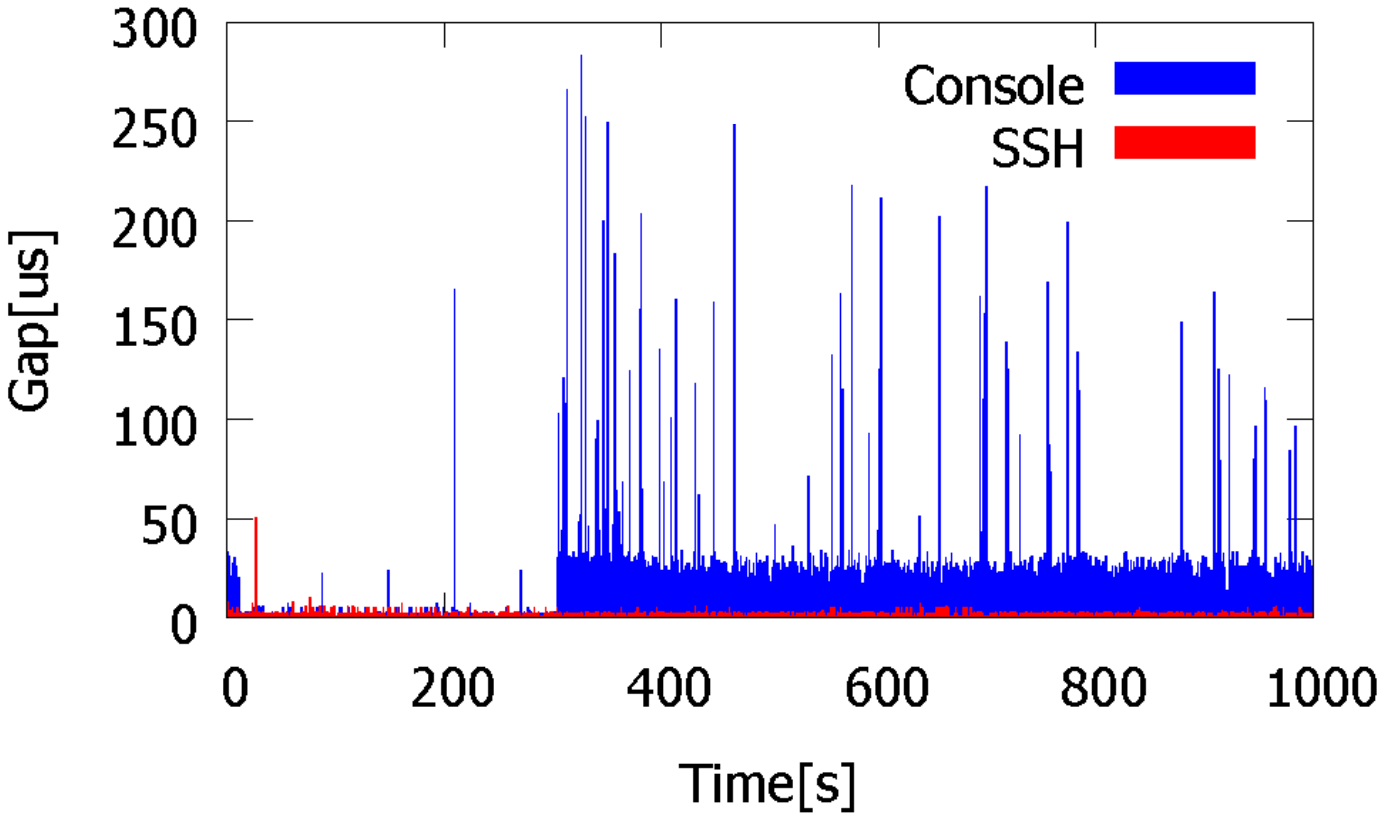
- Goals:
  - Evaluate the accuracy & precision of time-taking using CPU time stamp counter (TSC)
- Methodology:
  - Read TSC twice
  - Measure the time-gap between the two consecutive reads
- Results:
  - Min/Median/99.9%: 9ns/10ns/11ns

Example: TSC Access

```
1    while (!done)
2    {
3        //Read TSC twice, one immedately after the other
4        do_rdtscp(tsc, cpu);
5        do_rdtscp(tsc2,cpu2);
6        //If the gap between the two reads is above a
             certain threshold, save it
7        if ((tsc2 - tsc > threshold) && (cpu == cpu2))
8           buffer[samples++] = tsc2-tsc;
9    }
```

Example: TSC Access

What happens over time?



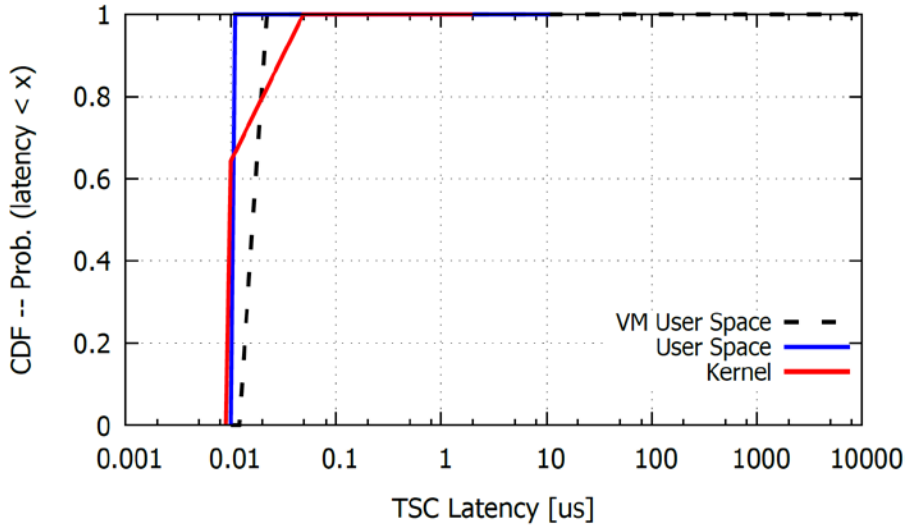
Example: TSC Access

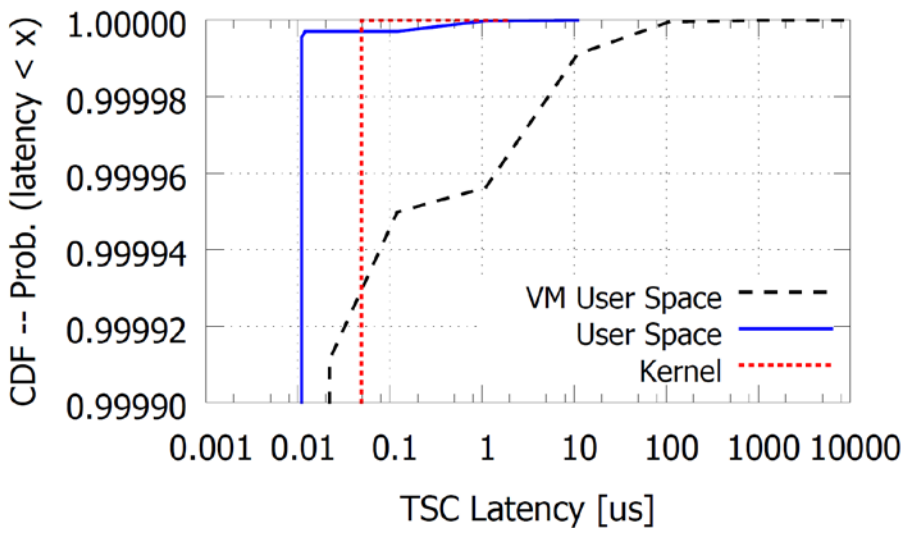
- Source data:

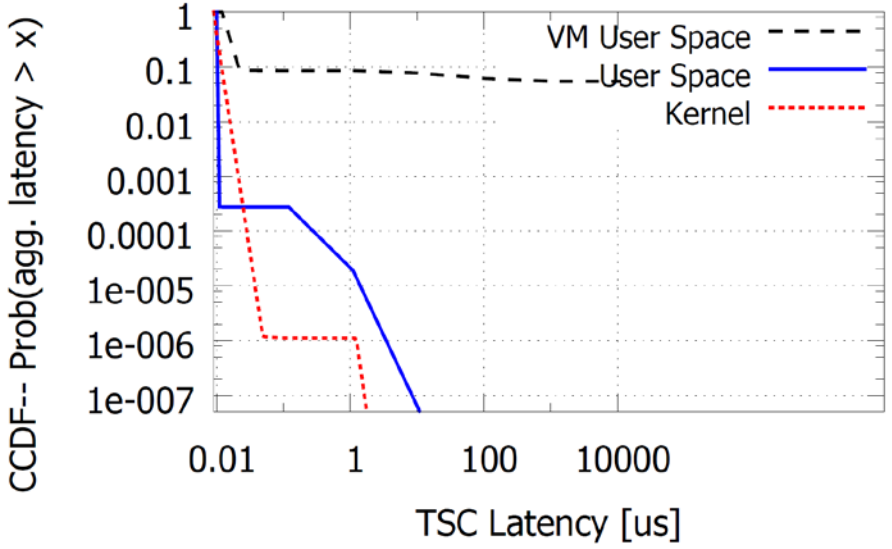
X ≤	User space Events
10	91428291492
11	404700
12	268521
22	268291
120	267465
1097	10768
10869	1

X ≤	Kernel Events
9	11117819727
10	3973891503
49	287
53	201
98	90
1155	86
1184	85
1241	77
1982	1

Example: TSC Access







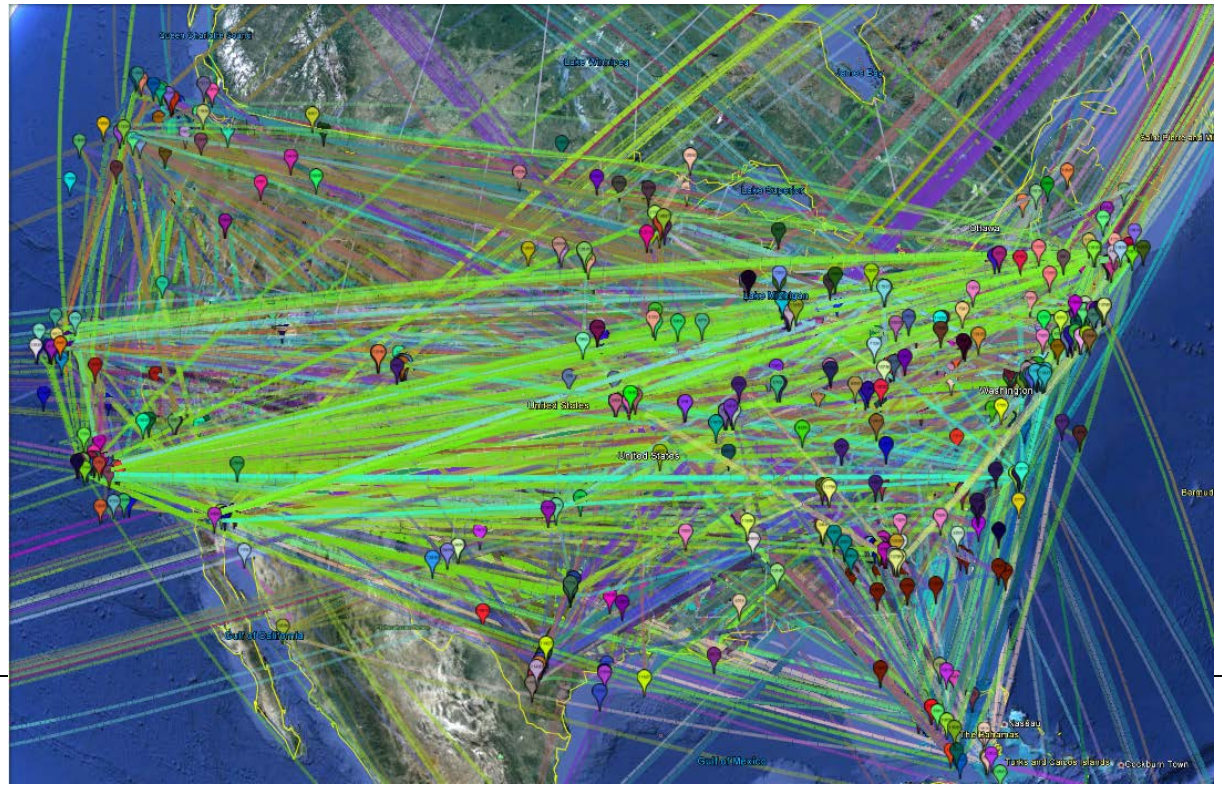
Example: Topology Measurements

- Goal:
  - Build a map of network connectivity that assigns IP addresses to locations
- Method:
  - Simple option: name resolution
    - 4.69.166.1 ⇒ ae-119-3505.edge4.London1.Level3.net
    - But many times information is missing, not indicative or is inaccurate
  - Better option: use geolocation services
    - Most services claim to be over 99% accurate

Example: Topology Measurements

Building a map of the network:

- Measurements for connectivity
- Geolocation databases for location

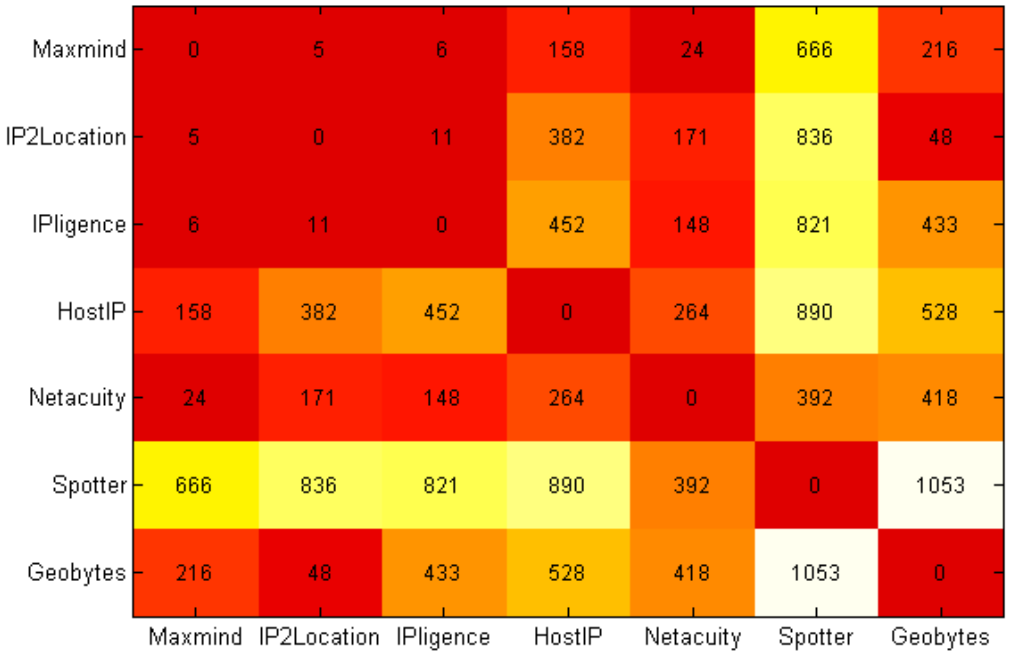


Example: Topology Measurements What is your ground truth?

- Gelolocation databases are over 99% accurate!

Verizon/MCI/UUNET (ASN 703)

10-nodes PoP



Heatmap – Median distance between databases (2011)

Validation

- Measurements need to be validated
- Don’t make assertions!
- Use ground truth (where available)
- Compare different tools and methodologies
- Do the results make sense?
  - RTT can’t be faster than traveling at the speed of light…
- Have I mentioned validation?

Final Report - Recommendations

- Include all figures within the report
  - Use proper scale, adapt the template if need be
- Make sure that your environment does not affect the results
- Do not make assertions
  - Support your claims through experimentations
- Discuss your results in depth:
  - Compare and contrast results gained through different vantage points, using different tools, on different platforms etc
  - Provide side-by-side comparisons
  - Use the questions in the handouts as guiding examples
- Use the right terminology (accuracy, precision, resolution)
- Correct typos and grammar mistakes
- Make sure not to run out of budget
- Follow the instructions in the handout

Course Summary

- This course covered measurements tools and measurement techniques
- But also “why out most basic assumptions are wrong”, “graphs lie”, “what you don’t know about your system”, …
- Remember:
  - Constant vigilance
  - Look at the data, best-practice, think.
- Applies to all types of measurements