Measure Twice, Code Once

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AsiaBSDCon 2015

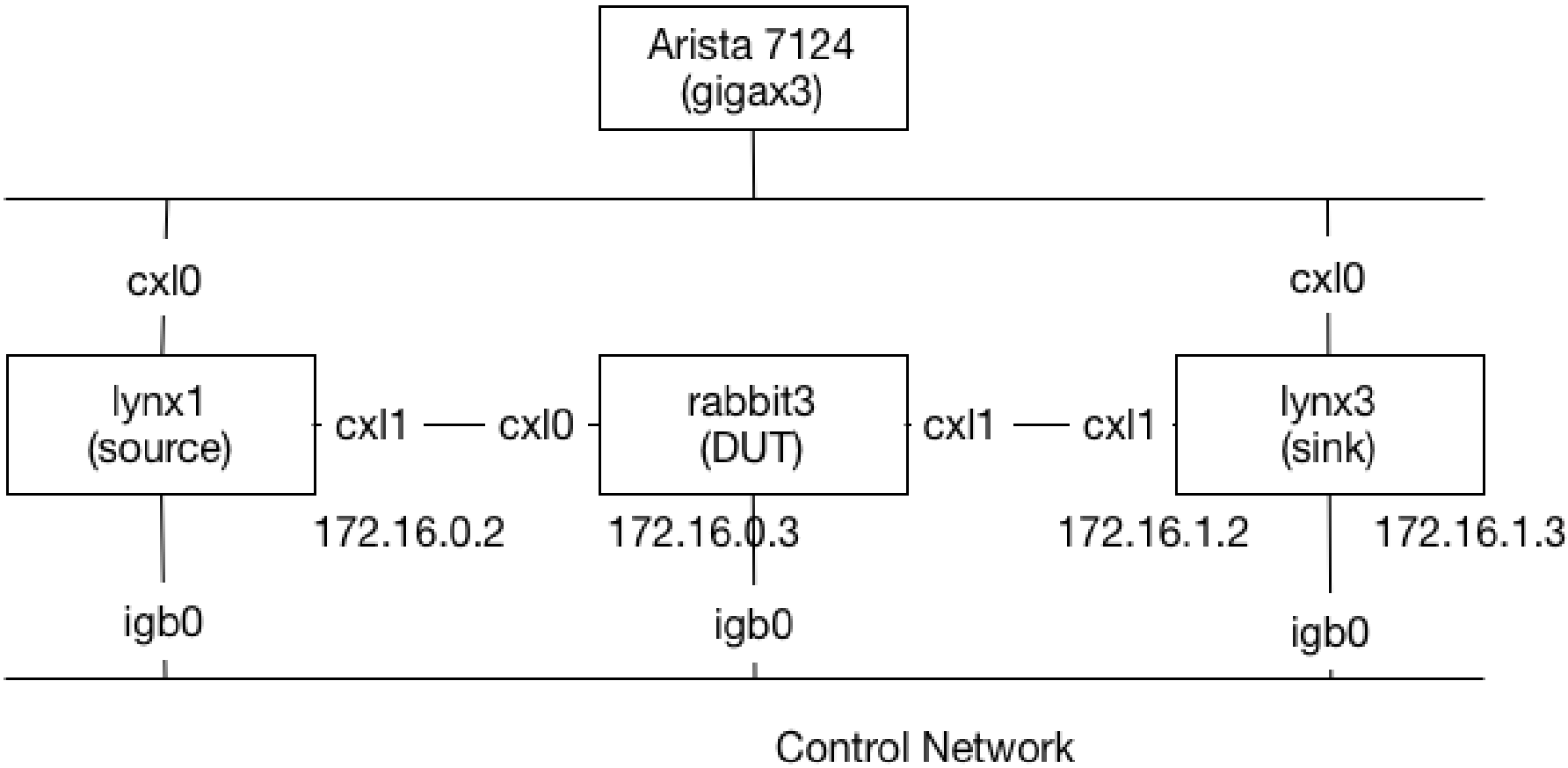
Benchmarks are Hard

- What do we measure?
- How do we measure it?
- How do we verify our measurements?
- Can our measurement be repeated?
- Can our meaurement be replicated?
- Is our measurement relevant?
- How do we generate a workload?
- Does our measurement technology disturb the measurement?
  - Heisentesting

Network Benchmarks are Harder

- Aysnchrony
- Best effort delivery
- Lack of open source test tools
- Control of distributed systems

Lab Setup


Arista 7124
(gigax3)
cxl0
cxl0
lynx1
(source)
cxl1
cxl0
rabbit3
(DUT)
cxl1
cxl1
lynx3
(sink)
172.16.0.2
172.16.0.3
172.16.1.2
172.16.1.3
igb0
igb0
igb0
Control Network

Hardware Used

lynx1/lynx3	dual socket, 10 core, 2.8GHz E5-2680 Xeon processors
rabbit3	single socket, four core, 3GHz E5-2637 Xeon processor
NIC	Chelsio T520, dual port, 10G NIC
Switch	Arista 7124 10G switch

Modern Hardware

- 10Gbps is 14.8 million 64 byte packets per second
- 67.5ns per packet or 200cycles at 3GHz
- Cache miss is 32ns
- Multi-core
- Multi-queue
- Lining it all up

Test Automation: Conductor

- Set of Python libraries
- *Conductor* and 1, or more, *Players*
- Four Phases

Startup	Set up system, load drivers, set routes, etc.
Run	Execute the test
Collect	Retrieve log files and output
Reset	Return system to original state

Conductor Config

```
# Master config file to run an iperf test WITHOUT PF enabled.
[Test]
trials: 1

[Clients]
# Sender
client1: source.cfg
# DUT
client2: dut.cfg
# Receiver
client3: sink.cfg
```

Player Config

```
[Master]
player: 192.168.5.81
conductor: 192.168.5.1
cmdport: 6970
resultsport: 6971

[Startup]
step1:ifconfig ix0 172.16.0.2/24
step2:ifconfig ix1 172.16.1.2/24
step3:ping -c 3 172.16.0.1
step4:ping -c 3 172.16.1.3

[Run]
step1:echo "running"
step2:pmcstat -O /mnt/memdisk/pktgen-instruction-retired.pmc -S instruction-retired -l 25

[Collect]
step1:echo "collecting"
step2:mkdir /tmp/results
step3:cp -f /mnt/memdisk/pktgen-instruction-retired.pmc /tmp/results/
step4:pmcstat -R /tmp/results/pktgen-instruction-retired.pmc -G \
          /tmp/results/pktgen-instruction-retired.graph
step5:pmcstat -R /tmp/results/pktgen-instruction-retired.pmc -D /tm/results -g
step6:pmcannotate /tmp/results/pktgen-instruction-retired.pmc \
            /boot/kernel/kernel > /tmp/results/pktgen-instruction-retired.ann

[Reset]
step1:echo "system reset: goodbye"
```

Host to Host Baseline Measurement

iperf TCP based test

netperf Packet based test using `netmap(4)`

Baseline TCP Measurement

```
0.00-1.00   sec 1.09 GBytes 9.41 Gbits/sec
1.00-2.00   sec 1.10 GBytes 9.41 Gbits/sec
2.00-3.00   sec 1.10 GBytes 9.41 Gbits/sec
3.00-4.00   sec 1.10 GBytes 9.41 Gbits/sec
4.00-5.00   sec 1.10 GBytes 9.41 Gbits/sec
5.00-6.00   sec 1.10 GBytes 9.42 Gbits/sec
6.00-7.00   sec 1.10 GBytes 9.41 Gbits/sec
7.00-8.00   sec 1.10 GBytes 9.41 Gbits/sec
8.00-9.00   sec 1.10 GBytes 9.41 Gbits/sec
9.00-10.00 sec 1.10 GBytes 9.41 Gbits/sec
```

Baseline pkt-gen Measurement

- Source

```
827.257743 main_thread [1512] 14697768 pps
828.259812 main_thread [1512] 14668997 pps
829.261742 main_thread [1512] 14695277 pps
830.263743 main_thread [1512] 14685547 pps
```

- Sink

```
866.466039 main_thread [1512] 11943109 pps
867.468024 main_thread [1512] 11946111 pps
868.469126 main_thread [1512] 11942020 pps
869.471027 main_thread [1512] 11939957 pps
```

Baseline Discussion

- TCP uses full sized packets
- pkt-gen uses minimum sized (64 byte) packets
- The DUT cannot quite keep up

Forwarding Measurements

Size	TX	RX	Stddev	% Line Rate
64	14,685,502	1,069,691	165	7
128	8,215,485	1,051,849	177	14
256	4,464,323	952,227	154	21
512	2,332,123	949,432	165	41
1024	1,192,770	948,172	100	80
1500	820,229	820,215	1.44	100

Fast Forwarding Measurements

Size	TX	RX	Stddev	% Line Rate
64	14,685,502	1,093,090	634	7
128	8,215,485	1,079,852	549	14
256	4,464,323	1,273,975	141	28
512	2,332,123	1,267,776	136	54
1024	1,192,770	1,192,755	11595	100
1500	820,229	820,215	2.08	100

Why?

- Fewer function calls?
- Better code?
- How do we find out?

DTrace Analysis

- Look at packet path call graphs
- Measure time from `ether_input` to `ether_output`

Call graph Comparison

```
1  ether_input()
2  netisr_dispatch_src()
3  ether_nh_input()
4  ether_demux()
5  netisr_dispatch_src()
6  ip_input()
7  ip_forward()
8  ip_output()
9  ether_output()
```

```
1  ether_input()
2  netisr_dispatch_src()
3  ether_nh_input()
4  ether_demux()
5  ip_fastforward()
6  ether_output()
```

Time Analysis

- Normal Path

```
value  ------------- Distribution ------------- count
512 |                                           0
1024 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@  1414505
2048 |@                                          35478
4096 |                                           481
8192 |                                           0
```

- Fast Path

```
 value  ------------- Distribution ------------- count
512 |                                           0
1024 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@  1721837
2048 |@                                          41287
4096 |                                           490
8192 |                                           0
```

DTrace Script

```
::ether_input:entry
{
        self->before = timestamp;
}
::ether_output:return
/self->before > 0/
{
        @count = quantize(timestamp - self->before);
}
tick-30sec
{
        normalize(@count, 10);
        printa(@count);
        printf("\n");
        clear(@count);
}
```

Firewall Comparison

- pfSense 2.2 (FreeBSD 10.1)
- OpenBSD 5.6
- FreeBSD HEAD (GENERIC-NODEBUG)
- Linux iptables

- Firewall Rules are given in the Paper

Single Core w/o Filtering

OS Version	PPS	StdDev
pfSense 2.2	494,224	1944
OpenBSD,5.6	360,147	1162
FreeBSD 11-CURRENT	249,464	498
CentOS 7	198,239	172

Single Core with Filtering

OS Version	PPS	StdDev
pfSense 2.2	228,558	1440
OpenBSD 5.6	187,523	78
CentOS 7	139,797	95
FreeBSD 11-CURRENT	131,795	229

Multicore w/o Filtering

OS Version	Multi-Core	Single Core	Speedup
CentOS 7	945,807	198,239	4.7x
pfSense 2.2	920,415	494,224	1.8x
FreeBSD 11-CURRENT	684,721	249,464	2.4x
OpenBSD 5.6	361,253	360,147	N/A

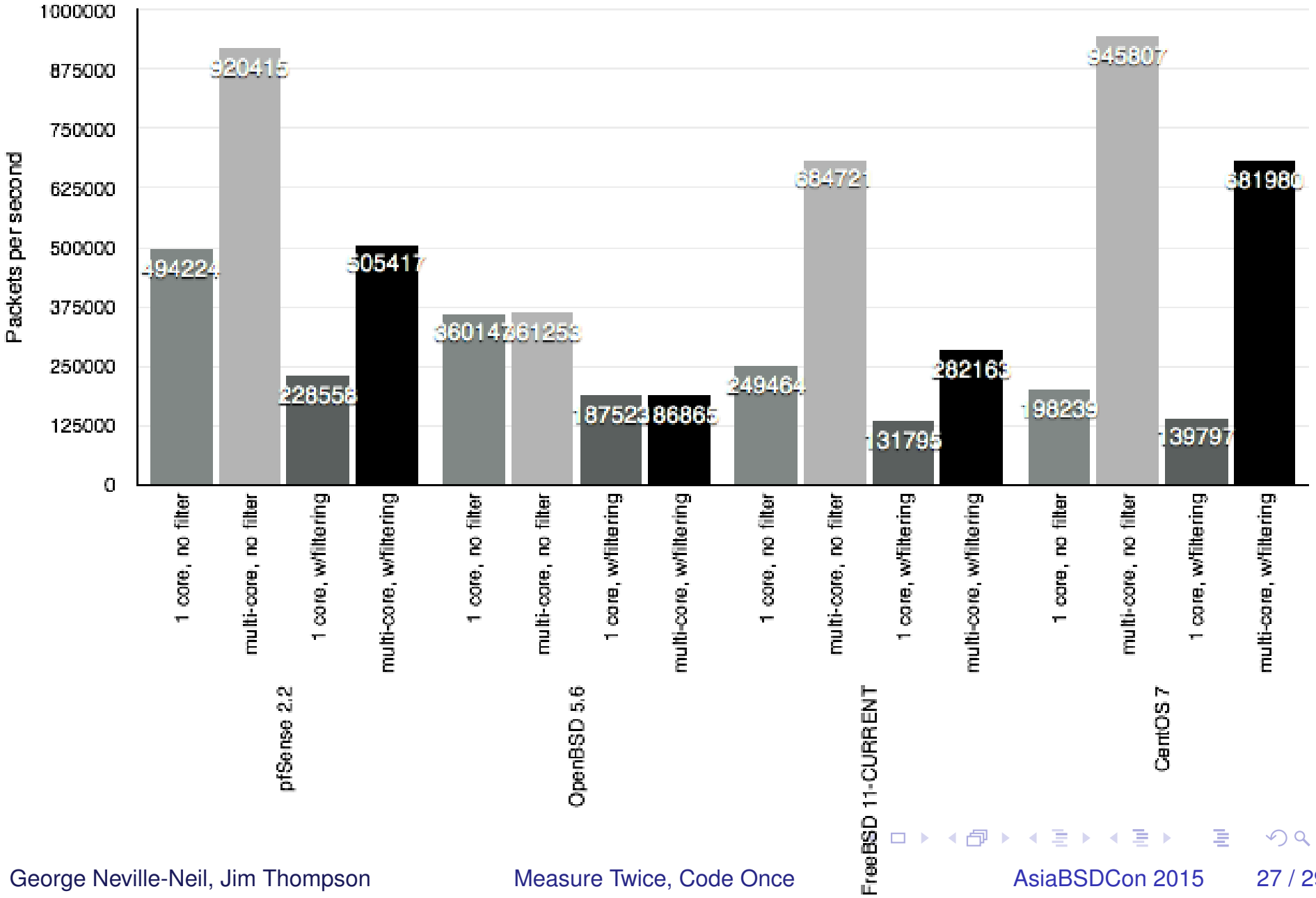
Multicore with Filtering

OS Version	Multi-Core	Single Core	Speedup
CentOS 7	681,980	139,797	4.8x
pfSense 2.2	505,417	228,558	2.2x
FreeBSD 11-CURRENT	282,163	131,795	2.1x
OpenBSD 5.6	186,865	187,523	N/A

Discussion

- Answers and more questions
- Mutli-core Matters
- Fast Multi-core matters even more
- Why is iptables the fastest?
- Why does FreeBSD lag pfSense, which is based on FreeBSD?

The Full Picture



An Ongoing Longitudinal Study

- First of many measurements
- Will be conducted at least yearly
  - More if funding appears
- Expand tests to native send and receive
- Expand list of NICs

Where to get it all

Netperf `http://github.com/gvnn3/netperf`

- Includes scripts and results

Conductor `http://github.com/gvnn3/conductor`

- The test framework

pfSense `http://www.pfsense.org`

FreeBSD `http://www.freebsd.org`

Raj Jain *The Art of Computer Systems Performance Analysis: Techniques for Experimental Design, Measurement, Simulation, and Modeling*