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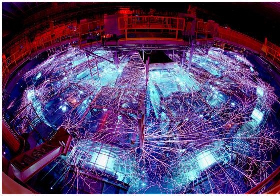

Lessons Learned from 10k Experiments to Compare Virtual and Physical Testbeds

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Goals

Discover where and how virtual and physical testbeds differ

- “Virtualization artifacts”

Goals

Discover where and how virtual and physical testbeds differ

- "Virtualization artifacts"

Methodology:

- Run representative workloads on physical and virtual testbeds
- Collect, compare, and contrast metrics
  - Application-, OS-, and network-level

Lessons Learned

Methodology and experimental results presented in previous work:

Jonathan Crussell, Thomas M. Kroeger, Aaron Brown, and Cynthia Phillips. Virtually the same: Comparing physical and virtual testbeds. In 2019 International Conference on Computing, Networking and Communications (ICNC), pages 847–853, Feb 2019.

This work focuses on lessons learned in four areas:

- Tool Validation and Development
- Instrumentation
- Data Collection and Aggregation
- Data Analysis

Methodology & Results

ApacheBench fetching fixed pages from an HTTP server

- Over 10,000 experiments across three clusters
- Over 500TB of data (without full packet captures)
- Varied payload size, network drivers, network bandwidth
- Large variations in network driver *offloading* behavior
- Near-identical sequences of system calls

Leverage *minimega* toolset (see `http://minimega.org` for details)

Tool Validation and Development

Lesson: Using a testbed toolset for experimentation requires substantial effort and consideration to put tools together in a workable and validated fashion.

Tool Validation and Development

```
bash$ bash run.bash
USAGE: run.bash DIR ITER DURATION CONCURRENT VMTYPE
    DRIVER NCPUS OFFLOAD RATE NWORKERS URL NREQUESTS
    INSTRUMENT
bash$ bash sweep.bash /scratch/output params.bash >
    sweep-params.bash
bash$ head -n 1 sweep-params.bash
bash /root/run.bash /scratch/output/ 1 360 1 kvm e1000 1
     on 1000 1 http://10.0.0.1/ 100000 true
bash$ sort -R sweep-params.bash | parallel -j1 --eta -S
    $(python igor.py --heads jc[0-9])
```

Tool Validation and Development

Running thousands of repetitions:

- Handle all edge cases (rare bug in *minimega*'s capture API)
- Clean up all state (failed to unmount container filesystem)

```
bash$ mount | grep megamount | head -n 5
megamount_5562 on /tmp/minimega/5562/fs type overlay
megamount_5566 on /tmp/minimega/5566/fs type overlay
megamount_5611 on /tmp/minimega/5611/fs type overlay
megamount_5752 on /tmp/minimega/5752/fs type overlay
megamount_5774 on /tmp/minimega/5774/fs type overlay
bash$ mount | grep megamount | wc -l
96
```

Tool Validation and Development

Toolset improvements:

- Add snaplen option to capture API
- Add standalone C2 server

```
# On VMs
minimega -e cc exec mkdir /que
minimega -e cc background protonuke -serve -http
minimega -e cc recv /miniccc.log

# On physical nodes
rond -e exec mkdir /que
rond -e bg protonuke -serve -http
rond -e recv /miniccc.log
```

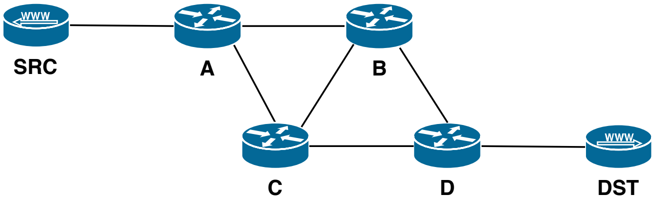
Instrumentation

Lesson: Instrumentation is invaluable but it is often manually added, expensive, and experiment-specific. Integrating more forms of instrumentation into the toolset could help researchers to more rapidly develop experiments.

Instrumentation

Two forms of instrumentation:

- Verify functionality of environment
- Understand and evaluate experiments



Integrating the former into the toolset could simplify experiments

Instrumentation

- Mismatch between capture locations
- Dropped events for containers

```
bash$ tcpdump -i eth0 -w foo.pcap
tcpdump: listening on eth0, link-type EN10MB (Ethernet),
     capture size 262144 bytes
9001 packets captured
9000 packet received by filter
1 packets dropped by kernel
bash$ sysdig -w foo.scap
<no indication of dropped events>
```

Instrumentation

Many ways to instrument experiment at many levels, mostly by hand

- Application-level: RPS, Jitter, ...
- OS-level: System calls, utilization, perf stats, ...
- Network-level: Flow statistics, bandwidth, ...

Use to understand anomalies

- e1000 stalls
- Performance increase

Data Collection and Aggregation

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Lesson: Testbeds can provide a wealth of data to researchers but should do more to streamline the process of collecting and aggregating it into a usable form.

Data Collection and Aggregation

How to extract instrumentation data from VMs?

- C2 has limits on file size
- VMs write to qcow2, host extracts
- Future: mount guest filesystem?

How to aggregate data?

- Dump per-iteration data into SQLite database
- Combine SQLite databases after all iterations complete

Data Analysis

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How to reduce storage?

```
total packets:              5        total packets:              5
ack pkts sent:              4        ack pkts sent:              5
pure acks sent:             2        pure acks sent:             2
sack pkts sent:             0        sack pkts sent:             0
dsack pkts sent:            0        dsack pkts sent:            0
max sack blks/ack:          0        max sack blks/ack:          0
unique bytes sent:         72        unique bytes sent:        486
actual data pkts:           1        actual data pkts:           1
actual data bytes:         72        actual data bytes:        486
rexmt data pkts:            0        rexmt data pkts:            0
rexmt data bytes:           0        rexmt data bytes:           0
zwnd probe pkts:            0        zwnd probe pkts:            0
zwnd probe bytes:           0        zwnd probe bytes:           0
outoforder pkts:            0        outoforder pkts:            0
pushed data pkts:           1        pushed data pkts:           1
SYN/FIN pkts sent:        1/1        SYN/FIN pkts sent:        1/1
req 1323 ws/ts:           Y/Y        req 1323 ws/ts:           Y/Y
adv wind scale:             7        adv wind scale:             7
========================== <15 lines omitted> ==========================
missed data:                0 bytes  missed data:                0 bytes
truncated data:             0 bytes  truncated data:           352 bytes
truncated packets:          0 pkts   truncated packets:          1 pkts
data xmit time:         0.000 secs   data xmit time:         0.000 secs
idletime max:             1.0 ms     idletime max:             0.7 ms
throughput:             38482 Bps    throughput:            259754 Bps
```

Data Analysis

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How to reduce storage?

- *tcptrace* produces 78 statistics per flow
- Compute summary statistics over all flows for iteration
- Compare mean of means across iterations and parameters

Data Analysis

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Lesson: Testbeds allow for many repetitions but care should be used when analyzing the data, especially in conflating statistical significance with practical importance.

Data Analysis

Hypothesis testing

- Everything seems significant with many iterations
- But practically important? (*e.g.* 0.1% decrease in latency)

Multiple comparisons

- Comparing many metrics can result in significance by chance

What's next?

Experiments with contention

- Run N client/server pairs on the same hardware
- Generates Nx the data
- Surprising performance **improvement** when N is small (<12)

Questions/Comments?

Lessons:

- Using a testbed toolset for experimentation requires substantial effort and consideration to put tools together in a workable and validated fashion.
- Instrumentation is invaluable but it is often manually added, expensive, and experiment-specific. Integrating more forms of instrumentation into the toolset could help researchers to more rapidly develop experiments.
- Testbeds can provide a wealth of data to researchers but should do more to streamline the process of collecting and aggregating it into a usable form.
- Testbeds allow for many repetitions but care should be used when analyzing the data, especially in conflating statistical significance with practical importance.

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