Automated Performance Testing For Virtualization with MMTests

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Testing / Benchmarking / CI Tools & Suites

- OpenQA
- Jenkins
- Kernel CI
- Autotest / Avocado-framework / Avocado-vt
- Phoronix Test Suite
- Fuego
- Linux Test Project
- Xen-Project's OSSTests
- …
- …

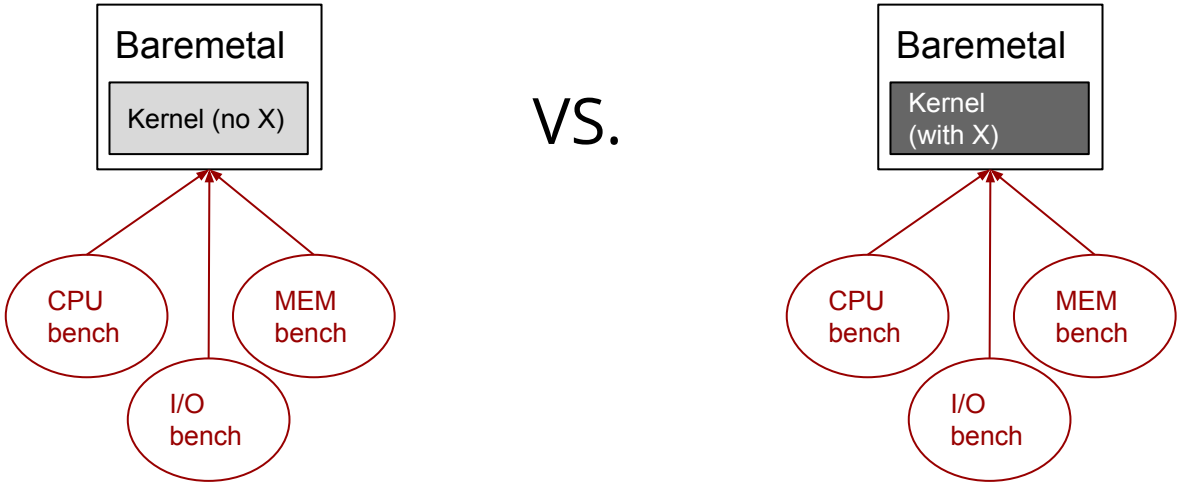
SRSLY THINKING I'll TALK ABOUT & SUGGEST USING ANOTHER ONE ?

REALLY ?


HELL YEAH
I AM!

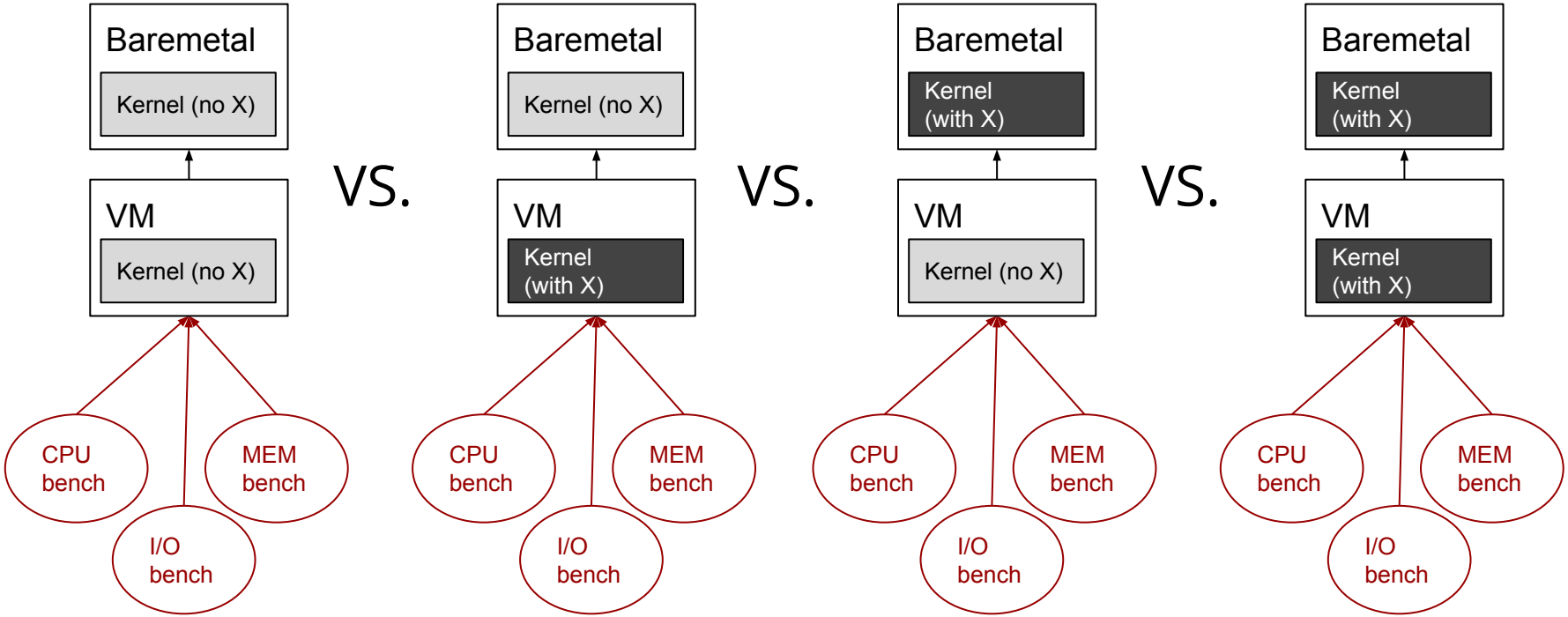
Benchmarking on Baremetal

What's the performance impact of kernel code change "X" ?



Benchmarking in Virtualization

What's the performance impact of kernel code change "X" ?



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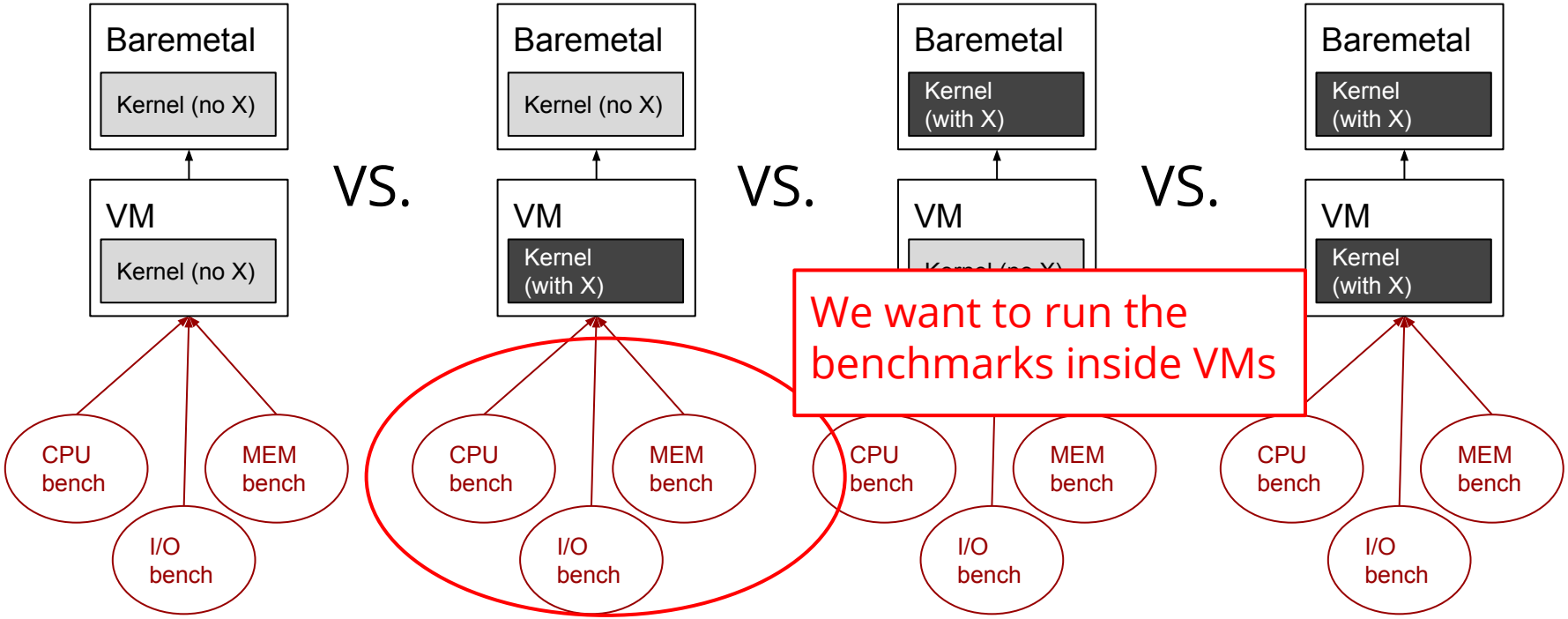

Benchmarking in Virtualization

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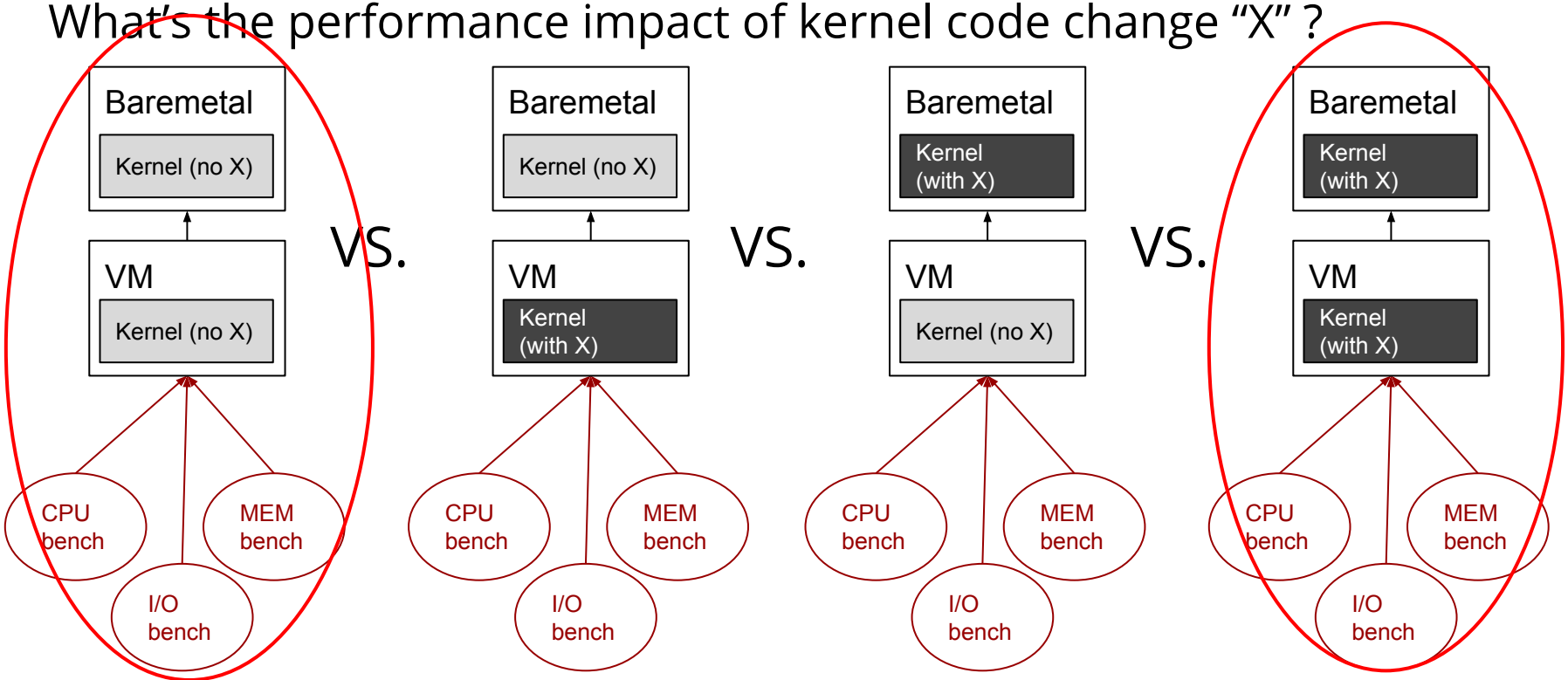
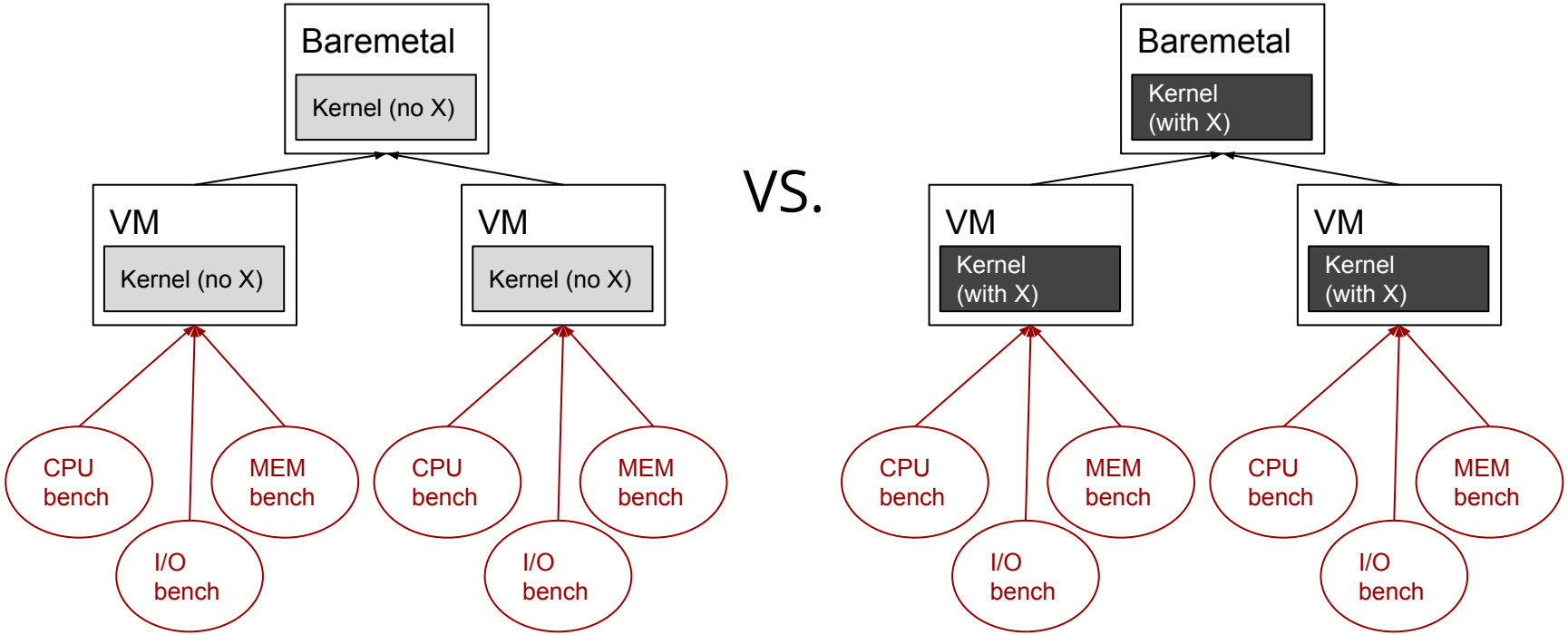


Benchmarking in Virtualization (II)

What's the performance impact of kernel code change "X" ?

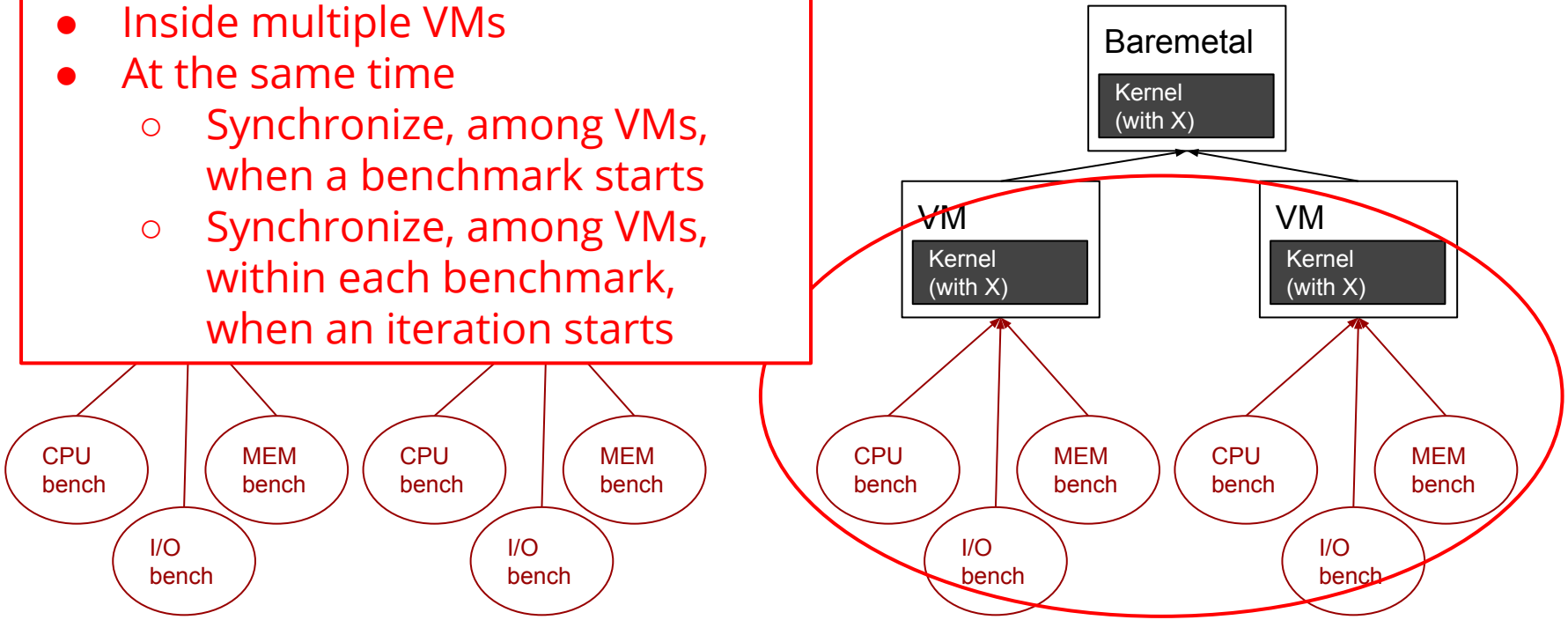


Benchmarking in Virtualization (II)

We need to be able to run the benchmarks:

- Inside multiple VMs
- At the same time
  - Synchronize, among VMs, when a benchmark starts
  - Synchronize, among VMs, within each benchmark, when an iteration starts

ernel code change “X” ?



Some History of MMtests

“MMTests is a configurable test suite that runs a number of common workloads of interest to MM developers.”

E.g., MMTests 0.05, in Sept. 2012 (on LKML)

Evolved a lot. Not MM-only any longer

Now on https://github.com/gormanm/mmtests

- Emails to: Mel Gorman <mgorman@suse.com>
- Or me, ~~or GH issues~~

MMTests

- Bash & Perl
- Fetch, buildd, configure & run a (set of) benchmark(s)
  - Configuration: through bash exported variables (put in config files)
  - Run the bench through wrappers (“shellpacks”)
  - Tests are run multiple times (configurable) for statistical significance
- Collects and store results
- Let you compare results
  - We have statistics: A-mean, H-mean, Geo-mean, significance, etc.
  - Can plot
- Monitors
  - While the benchmark is running:
    - Sampling `top`, `mpstat`, `vmstat`, `iostat`, …
    - Collecting data from: `perf`, `ftrace`, …

MMTests: Available Benchmarks

Among the others, already preconfigured:

- pgbench, sysbench-oltp (mariadb and postgres), pgioperf, ...
- bonnie, fio, filebench, iozone, tbench, dbench4, ...
- redis, memcached, john-the-ripper, ebizzy, nas-pb, ...
- hackbench, schbench, cyclictest, ...
- netperf, iperf, sockperf, ...
- Custom ones:
  - Linux kernel load balancer, program startup time, ...
- Workload like:
  - Git workload, kernel dev. Workload, ...
- Check in configs/ directory
  - More combination autogenerated (bin/generate-* scripts)

A Benchmark Config File

```
# MM Test Parameters
export MMTESTS="stream"

. $SHELLPACK_INCLUDE/include-sizes.sh
get_numa_details

# Test disk to setup (optional)
#export TESTDISK_PARTITION=/dev/sda6
#export TESTDISK_FILESYSTEM=xfs
#export TESTDISK_MKFS_PARAM="-f -d agcount=8"

# List of monitors
export RUN_MONITOR=yes
export MONITORS_ALWAYS=
export MONITORS_GZIP="proc-vmstat top"
export MONITORS_WITH_LATENCY="vmstat"
export MONITOR_UPDATE_FREQUENCY=10
```

```
# stream
export STREAM_SIZE=$((1048576*3*2048))
export STREAM_THREADS=$((NUMNODES*2))
export STREAM_METHOD=omp
export STREAM_ITERATIONS=5
export OMP_PROC_BIND=SPREAD
export MMTESTS_BUILD_CFLAGS="-m64 -lm -Ofast
   -march=znver1 -mcmodel=medium -DOFFSET=512"
```

MMTests

```
# ./run-mmtests.sh --config configs/config-netperf BASELINE
<change kernel / configuration / etc >
# ./run-mmtests.sh --config configs/config-netperf PTI-OFF

$ ./compare-kernels.sh
```

… Or

```
$ ./bin/compare-mmtests.pl --directory work/log --benchmark netperf-tcp \
 --names BASELINE,PTI-OFF
                                BASELINE                PTI-OFF
    Hmean     64         1205.33 (   0.00%)     2451.01 ( 103.35%)
    Hmean     128        2275.90 (   0.00%)     4406.26 (  93.61%)
    … … …
    Hmean     8192      36768.43 (   0.00%)    43695.93 (  18.84%)
    Hmean     16384     42795.57 (   0.00%)    48929.16 (  14.33%)
```

MMTests: Recap Comparisons

```
$ ./bin/compare-mmtests.pl --directory work/log --benchmark netperf-tcp \
 --names BASELINE,PTI-OFF --print-ratio

                BASELINE PTI-OFF
   Gmean Higher    1.00    0.28
```

- Useful as an overview
  - E.g., multiple runs of `netperf`, different packet sizes
  - … But how are things looking overall (taking account all the sized) ?
- Ratios between baseline and compares + geometric mean of ratios
- Geometric mean, because it's ratio friendly (nice explanation here)
- (First column, always 1.00… it's the baseline)

MMTests: Monitors

```
$ ./bin.compare-mmtests.pl -d work/log -b stream -n SINGLE,OMP \
    --print-monitor duration
```

	SINGLE	OMP
Duration User	45.04	50.75
Duration System	6.15	20.36
Duration Elapsed	51.16	20.26

Monitors:

- Top, iotop, vmstat, mpstat, iostat, df, ...
- Perf-event-stat, perf-time-stat, pert-top, ...
- monitors/

MMTests: Monitors

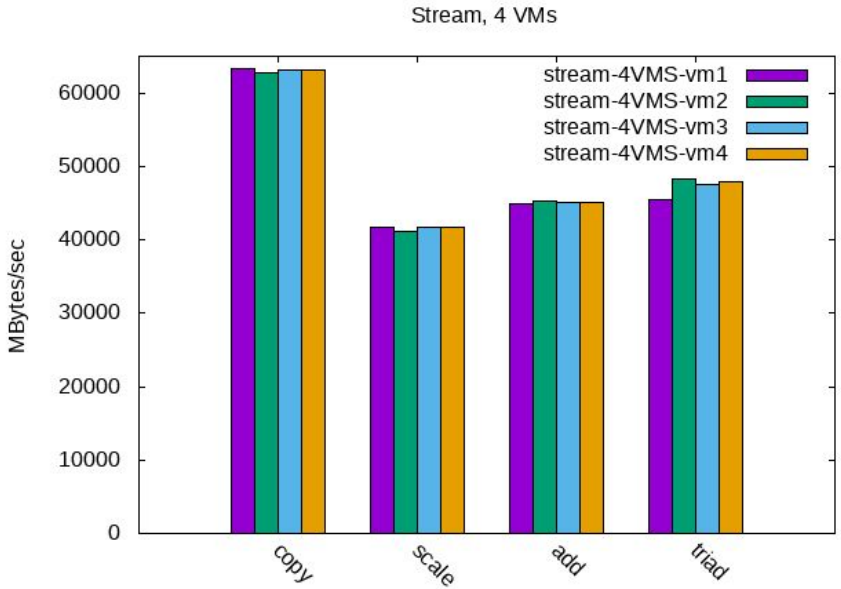
```
$ egrep "MONITORS|EVENTS" configs/config-workload-stockfish
export MONITORS_GZIP="proc-vmstat mpstat perf-time-stat"
export MONITOR_PERF_EVENTS=cpu-migrations,context-switches

$ ./bin/compare-mmtests.pl -d work/log/ -b stockfish -n BASELINE,LOADED \
    --print-monitor perf-time-stat
```

		BASELINE	LOADED
Hmean	cpu-migrations	3.33	2.01
Hmean	context-switches	29.12	30.73
Max	cpu-migrations	999.00	999.00
Max	context-switches	195.61	72.69

MMTests: Plots

```
graph-mmtests.sh -d . -b stream -n stream-4VMS-vm1,stream-4VMS-vm2, \
    stream-4VMS-vm3,stream-4VMS-vm4 --format png --yrange 0:65000 \
    --title "Stream, 4 VMs"
```



Beware of

- (Kinf of) requires `root`
  - May need to change system properties (e.g., cpufreq governor)
  - Tries to undo all it has done…
  - … IAC, better used on “cattle” test machines than on “pet” workstations

- It downloads the benchmarks from Internet
  - Slow ? Can be trusted ?
  - Easy enough to configure a mirror (how it’s used internally)

MMTests & Virtualization

Doesn't have to be KVM, can be anything that Libvirt can manage

```
# ./run-kvm.sh -k -L --vm VM1 --config configs/config-netperf-unbound BASELINE
# ./run-kvm.sh -k -L --vm VM1 --config configs/config-netperf-unbound PTI-ON

$ ./bin/compare-mmtests.pl --directory work/log --benchmark netperf-tcp \
 --names BASELINE-VM1,PTI-ON-VM1
```

- Start the VM with `virsh start`
  - The VM needs to exist already on the host
  - The host and guest must be able to talk via network
  - The host must be able to SSH in the VM without password (keys)
- Copy the whole MMTests directory in the VM
- Run the benchmark in the VM with `run-mmtests.sh`
- Store the host logs and info
- Fetch the logs and the results from the VM back in the host

MMTests & Virtualization

The config file must have the following variables:

```
export MMTESTS_HOST_IP=192.168.122.1
export AUTO_PACKAGE_INSTALL=yes
```

MMTests & Multiple VMs

```
# ./run-kvm.sh -k -L --vm VM1,VM2 --config configs/config-netperf BASELINE
# ./run-kvm.sh -k -L --vm VM1,VM2 --config configs/config-netperf PTI-ON

$ ./bin/compare-mmtests.pl --directory work/log --benchmark netperf-tcp \
 --names BASELINE-VM1,BASELINE-VM2,PTI-ON-VM1,PTI-ON-VM1
```

- Start all the VMs
- Copy MMTests dir in all of them (with *pscp*)
- Invoke `run-mmtests.sh` in all of them (with *pssh*)
- Benchmarks iterations run in sync in all VMs
- Store the host logs and info
- Fetch logs and results from the VMs and store them

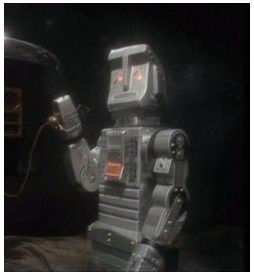
MMTests & Synchronized Iterations

How to make sure tests / iterations execution is synchronized?

- VMs and host communicate:
  - Over network, for now (future: virtio-vsock / Xen's pvcalls ?)
  - With `nc` (future: gRPC ?)
- Tokens:
  - Host (in `run-kvm.sh`):
    - In state n (e.g., "test_do", or "iteration_begin", or "iteration_end")
    - Wait for all the VMs to send state n token (== they have all reached that point)
    - Signal all the VMs (at same time, with *GNU parallel*) and go to state n+1
  - VMs (in `run-mmtests.sh`):
    - When reaching stage n, send the relevant token to host (e.g., "test_do, or "iteration_begin", or "iteration_end")
    - Wait for the host signal. When signal received, continue

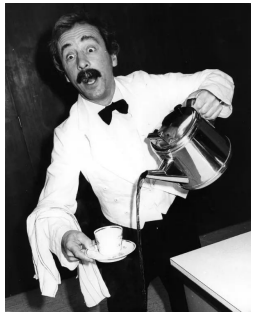
MMTests & Synchronized Iterations

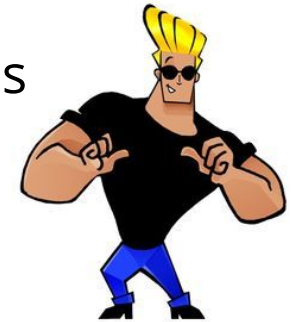
MMTests as (part of) a CI loop



Already! Marvin: SUSE's Performance Team CI

- *Marvin* : reserves machines, manages deployments (with autoyast), copies MMTests across, executes tests and copies results back
- *Bob The Builder* : monitors kernel trees, trigger (re)builds
- *Johnny Bravo* : generating reports
- *Manual* : developer tool (manual queueing)
- *Sentinel* : "guards" against regressions
- *Impera* : bisection





SUSE Labs Conference 2018 - Marvin: Automated assistant for development and CI

MMTests as (part of) a CI loop

Planned: SUSE's Virtualization Team

- Jenkins: builds packages (QEMU, libvirt, ...) for all our distros
- Install packages on a "slave"
- Start (predefined) VMs and do functional testing

TODO:

- Deploy MMTests on the slave and do performance testing
- Store results
- Check for performance regressions

TODO / Doing

- VM management: define or tweak XML files
- Remote management: trigger the test from outside the host
- Improved usability: more feedback while benchmarks are running in guests
- VMs-host communications: add more means
- Monitors on the host: not only in guests
- Non VM usecases: run benchmarks in (Kata :-P) containers
- More parallelism: VM starting / stopping (already in the works)
- Packaging: make sure all dependencies available on major distros
- ...

Documentation

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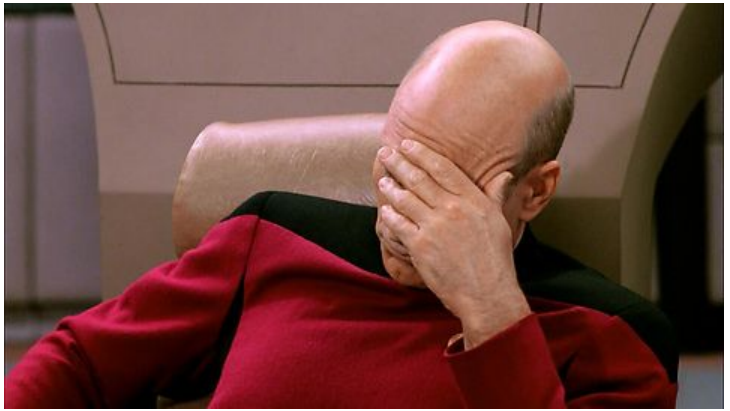

Documentation

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But we plan to improve on that!

Conclusions

Give it a try to MMTests... Especially for Virt. benchmarking! :-)

Tell us what you think, what issues you found, etc

Myself and… Questions?

- Ph.D on Real-Time Scheduling, `SCHED_DEADLINE`
- 2011, Sr. Software Engineer @ Citrix
  The Xen-Project, hypervisor internals,
  Credit2 scheduler, Xen scheduler maintainer
- 2018, Virtualization Software Engineer @ SUSE
  Still Xen, but also KVM, QEMU, Libvirt;
  Scheduling, VM's virtual topology,
  performance evaluation & tuning
- Spoke at XenSummit, Linux Plumbers, FOSDEM,
  LinuxLab, OSPM, KVM Forum, …

Backup

Virtualization Benchmarking “War” Stories

Physical CPUs have topology:

- Sockets, cores, threads, L{1,2,3} Caches, ...

Virtual machine *can* have **virtual** topology:

- Sockets, cores, threads: important when doing vCPU pinning
- Caches:
  - does it really matter that the VM “thinks” its CPU has caches?
  - (if yes) does the layout of such virtual caches matters?

Virtual Topology: Caches

Cache layout: does it affect guest scheduling (& performance)?

- ~~No~~ Yes!!
-

```
ttwu_queue(p, cpu)                                          kernel/sched/core.c:1875
if (cpus_share_cache(spm_processor_id(), cpu)) {            kernel/sched/core.c:1869
  rq_lock(cpu_rq(cpu))
  ttwu_do_activate(cpu_rq(cpu), p)                          kernel/sched/core.c:1730
    ttwu_do_wakeup(cpu_rq(cpu), p)
      check_preempt_curr(cpu_rq(cpu), p)                    kernel/sched/core.c:884
        /* If cpu_rq(cpu)->curr higher prio *              kernel/sched/fair.c:L7661
         * no IPI to cpu                    */
  rq_unlock()
} else {                                                    kernel/sched/core.c:1883
  ttwu_queue_remote()                                       kernel/sched/core.c:1831
  llist_add(cpu_rq(cpu)->wake_list)                         kernel/sched/core.c:1837
  smp_send_reschedule(cpu)                                  kernel/sched/core.c:1839
  /* IPI to cpu */
}
```

Virtual Topology: Caches

Cache layout: does i

- ~~No~~ Yes!!
- ttwu_queue(p, cpu)

```
if (cpus_share_cache(smp_processor_id(), cpu)) {
  rq_lock(
  ttwu_do_
    ttwu_d
      check_preempt_curr(cpu_rq(cpu), p)
        /* If cpu_rq(cpu)->curr is higher prio *
         * no IPI to cpu                       */
  rq_unlock()
} else {
  ttwu_queue_remote()
  llist_add(cpu_
  smp_send_resch
  /* IPI to cpu
}
```

kernel/sched/core.c:1875
kernel/sched/core.c:1869
kernel/sched/core.c:1730
kernel/sched/core.c:884
kernel/sched/fair.c:L7661
kernel/sched/core.c:1883
kernel/sched/core.c:1831
ore.c:1837
ore.c:1839

VM cache layout (before QEMU commit git:9308401):

- No L3 cache at all

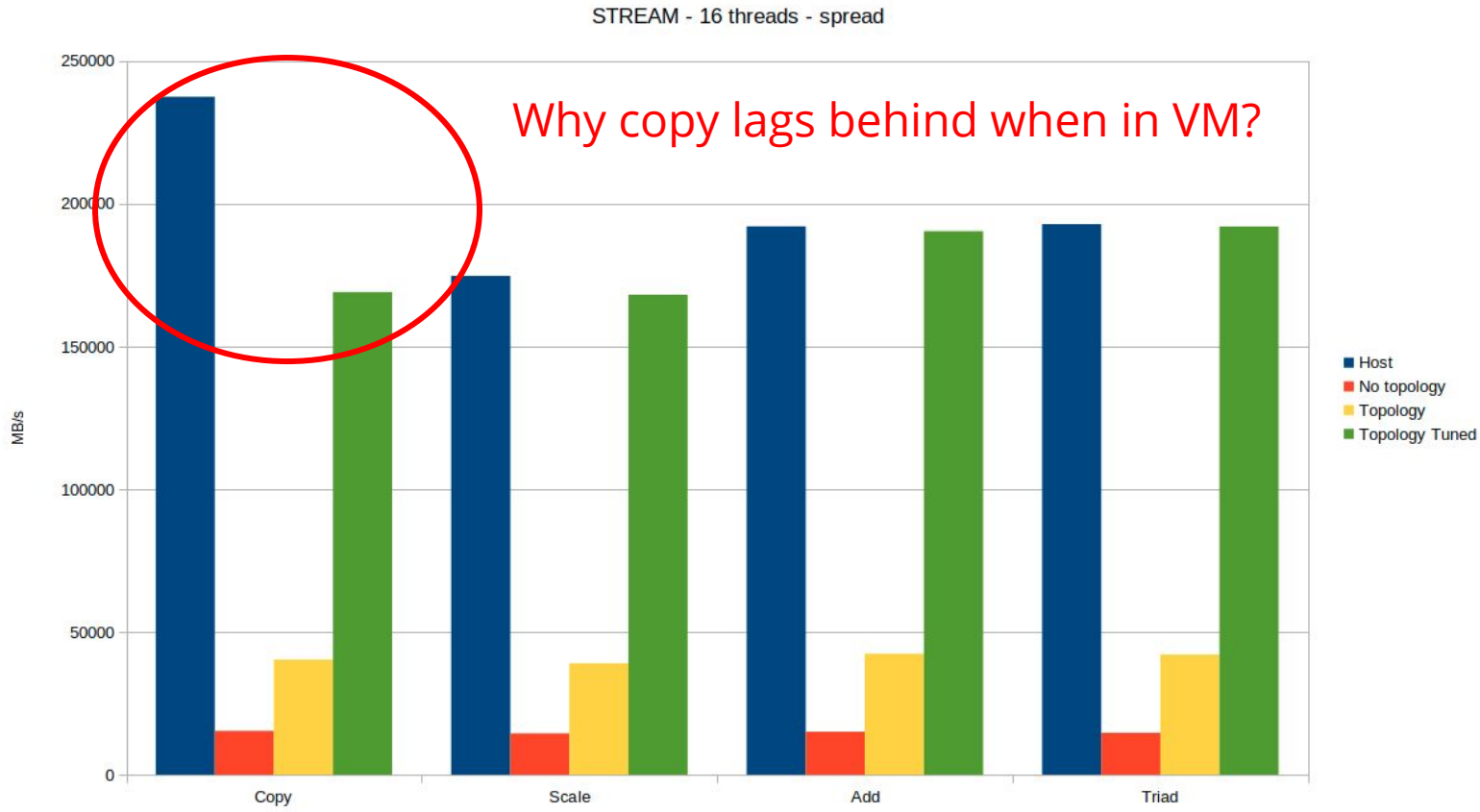
`cpus_share_cache()`, always `false`

Always send IPI... TO ANOTHER _virtual_ CPU!
Difference shows!

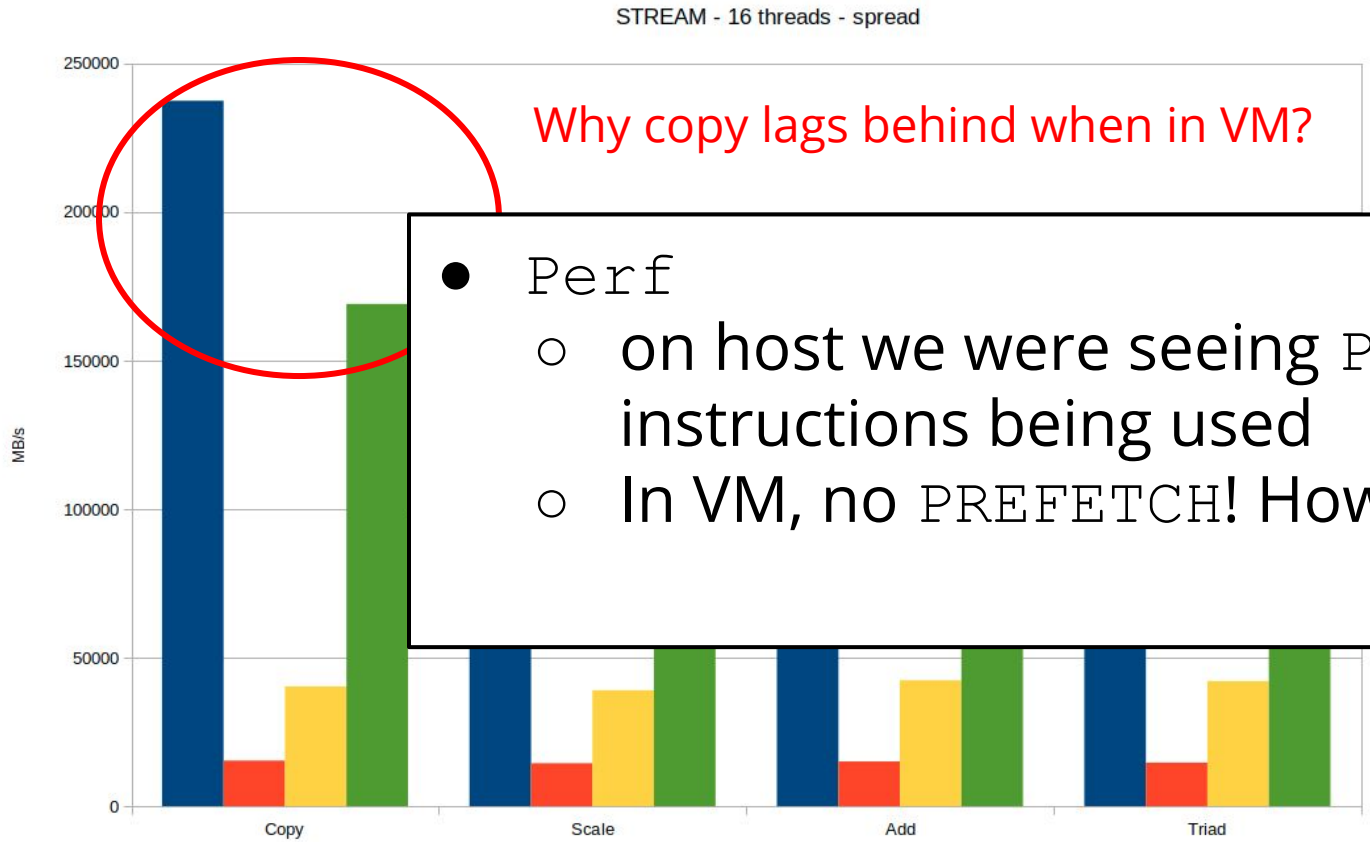
Virtual Topology: Cache Layout

- STREAM benchmark
- VM (KVM) with pinning and virtual topology tuned to match host performance

Virtual Topology: Cache Layout



Virtual Topology: Cache Layout



Why copy lags behind when in VM?

- `Perf`
  - on host we were seeing `PREFETCH` instructions being used
  - In VM, no `PREFETCH`! How so ?!?!

Virtual Topology: Cache Layout

- *<<Let's just expose to the VM whether vCPUs share an L3, no big deal how big such L3 the VM sees>>*
- Not quite:
  - Glibc heuristics for deciding whether or not memcpy uses non-temporal stores and `PREFETCH` instrs.
  - `thrs` = (L3 cache size / nr. threads sharing it) + L2 cache size
  - Don't `PREFETCH` if amount of data mem-copied is smaller than `thrs`

We need to expose the correct cache size to the VM