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What we talk about when we talk about scheduling

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How many schedulers do we need?

Analytics workload running on a shared cluster

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1. Long-term allocation of a set of machines using Slurm. Run Yarn within those.

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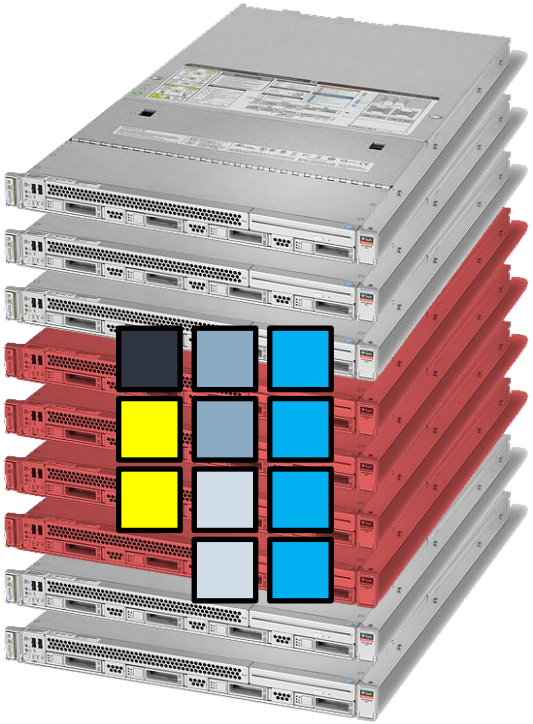
2. Start job running within Yarn – let's assume it just needs to run on two machines.



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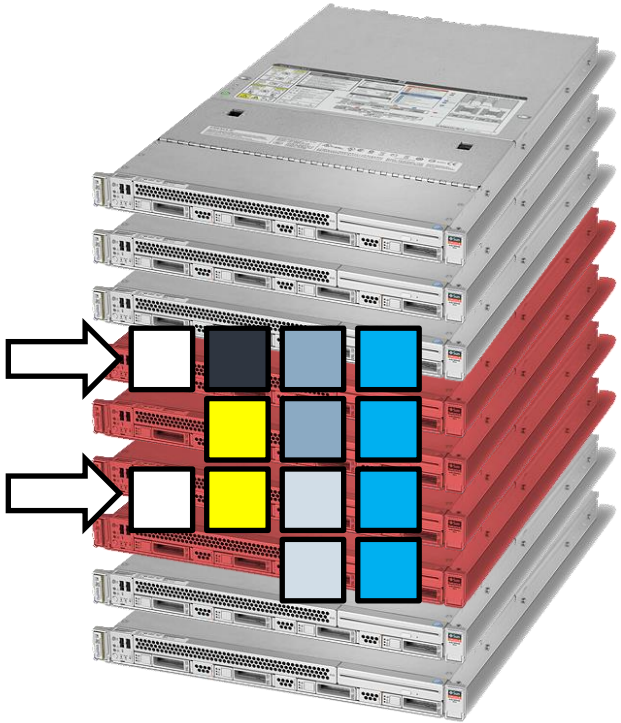

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3. Load data into memory. Contention with other jobs accessing HDFS.

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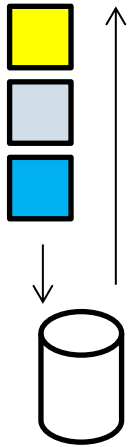
- Which replica to access?
- Which order should that replica service requests?



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4. Within a query, how to distribute tasks between the machines involved.

- If using work-stealing, who to steal from? How important is it to preserve locality?

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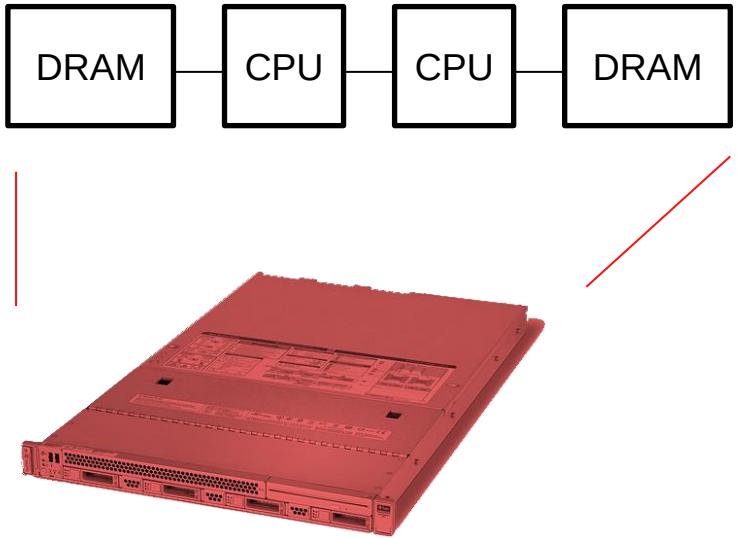
5. How to lay out data in memory – spread across memory banks for b/w, or keep close to a given CPU for latency?



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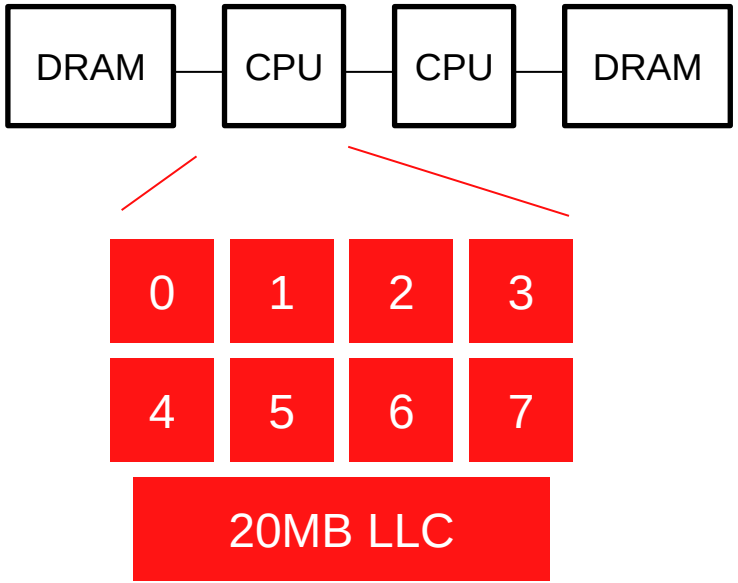
6. Where to place the computation?



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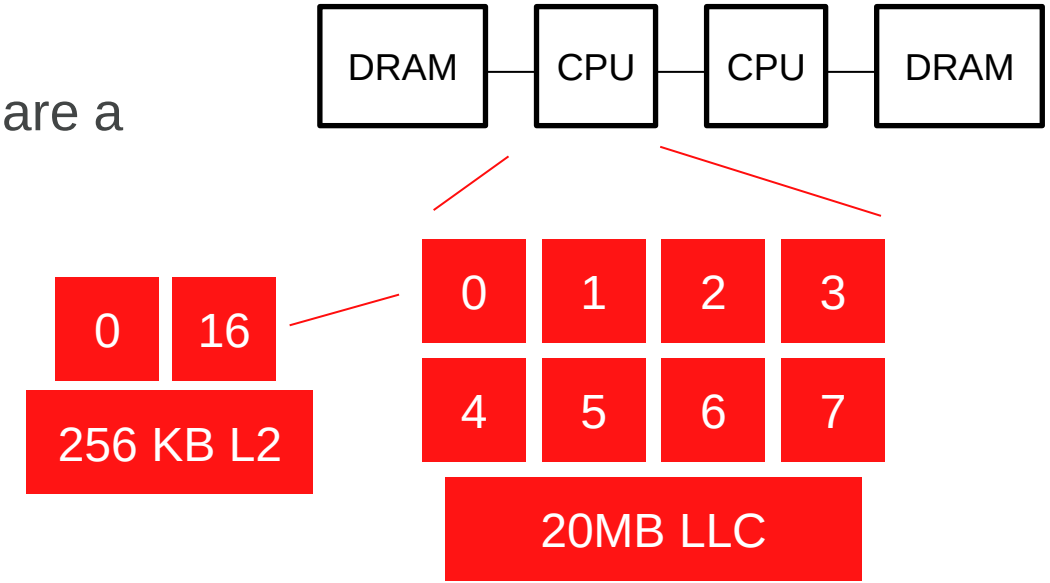
7. What to place on hyperthreads that share a core?



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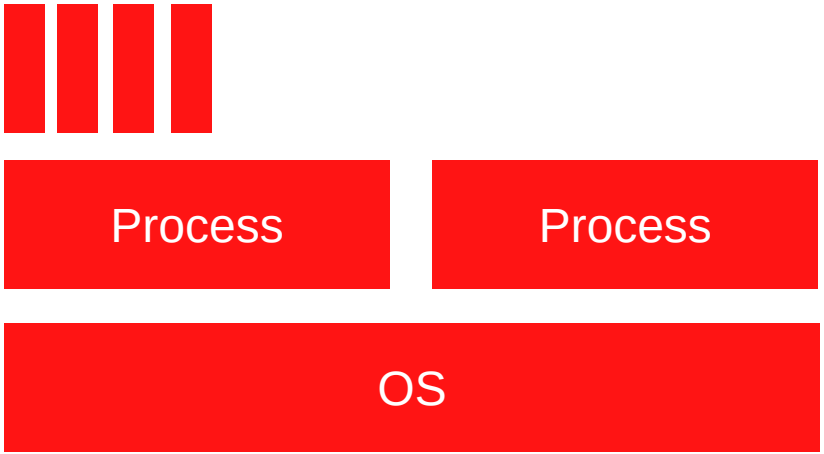
8. OS thread scheduler



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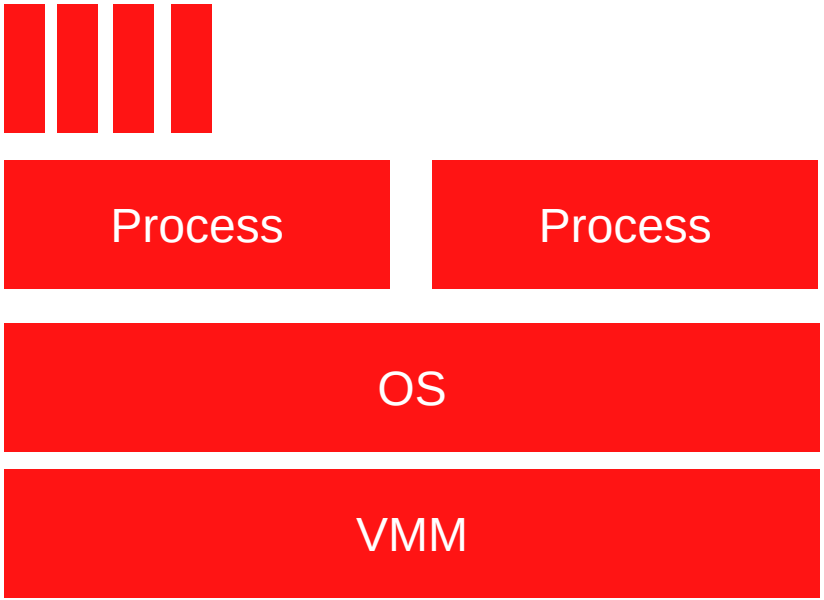
9. VMM thread scheduler



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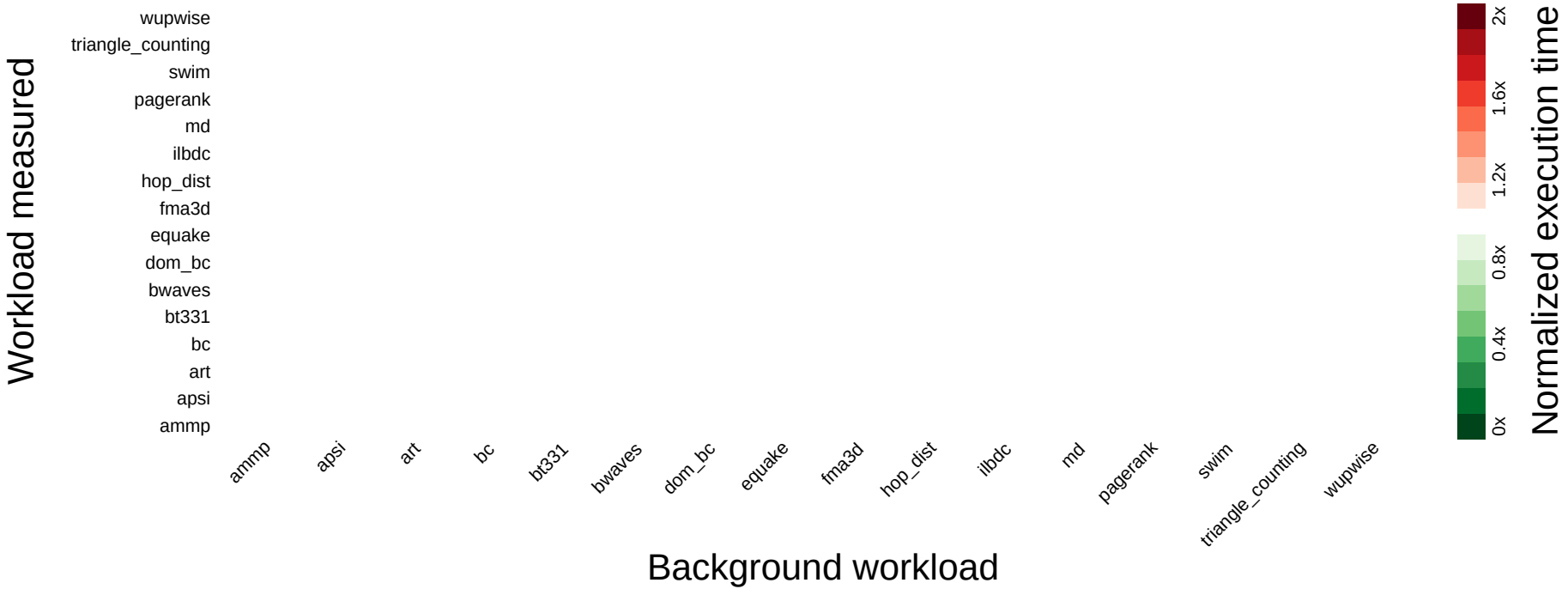
- And of course there are many more things going on as well
  - When to run GC or JIT, (lack of) co-ordination across distributed jobs
  - Background jobs, monitoring, profiling, etc.
  - Contention in the interconnect, on-chip or between machines
  - Live migration of VMs
  - Power management, thermal throttling
  - …

How bad is the problem?

2-socket Xeon E5-2660, Linux 2.6.32, GCC 4.8.0



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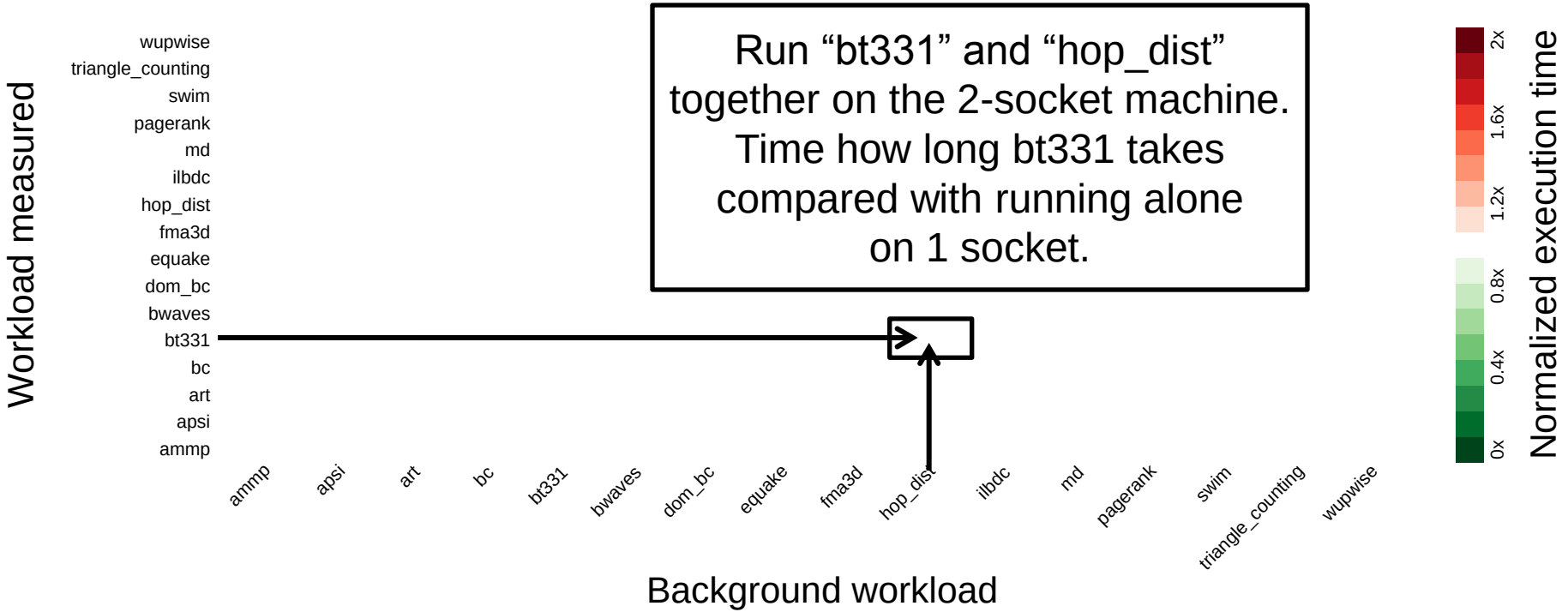

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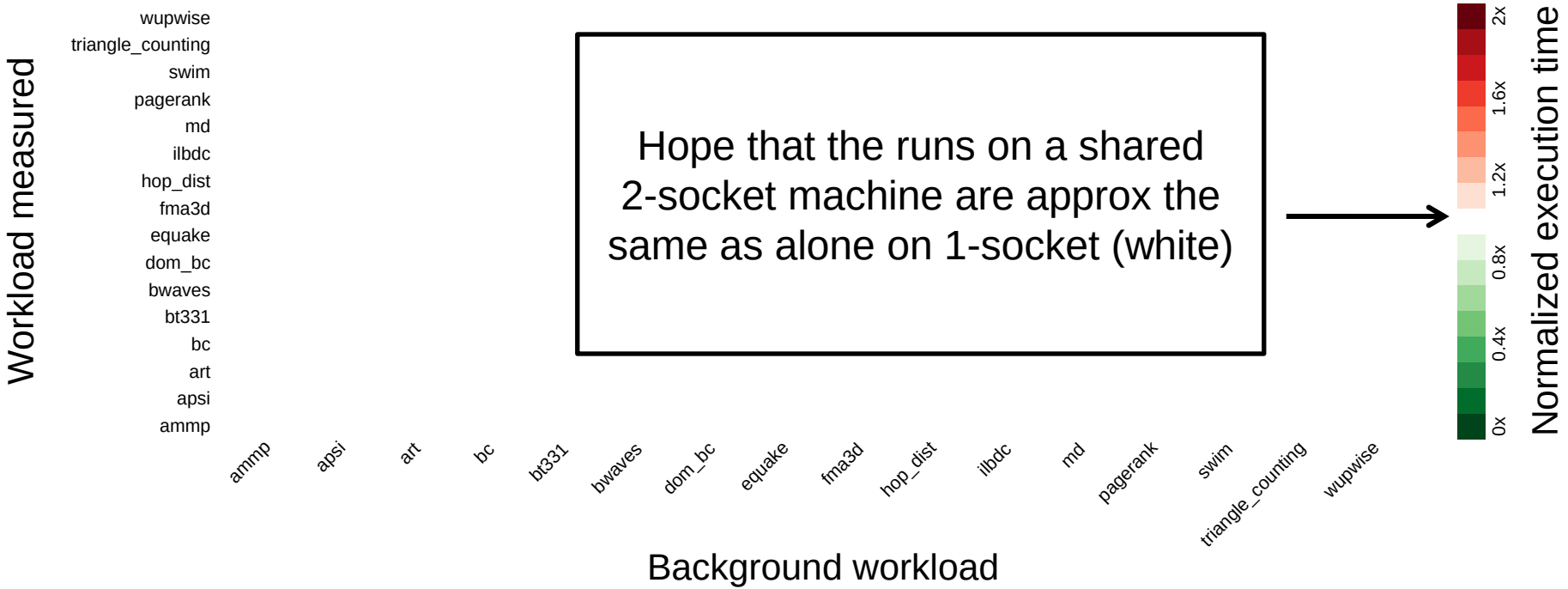
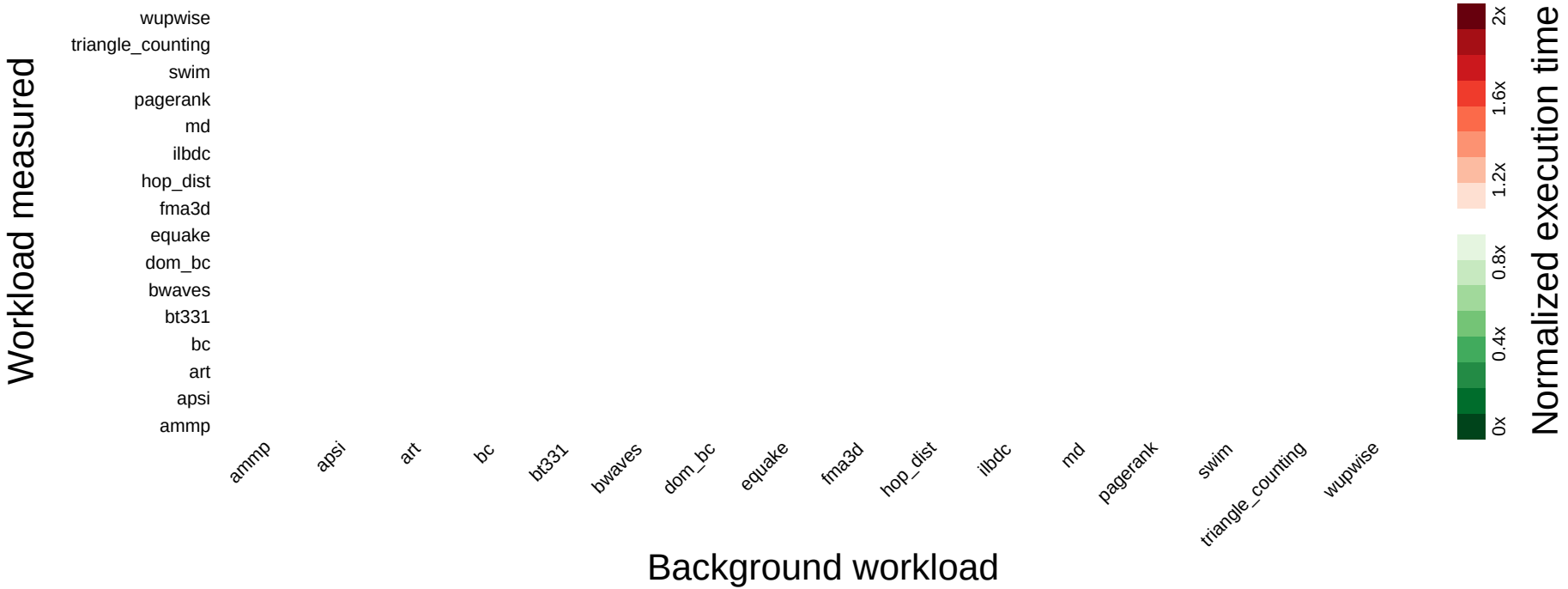


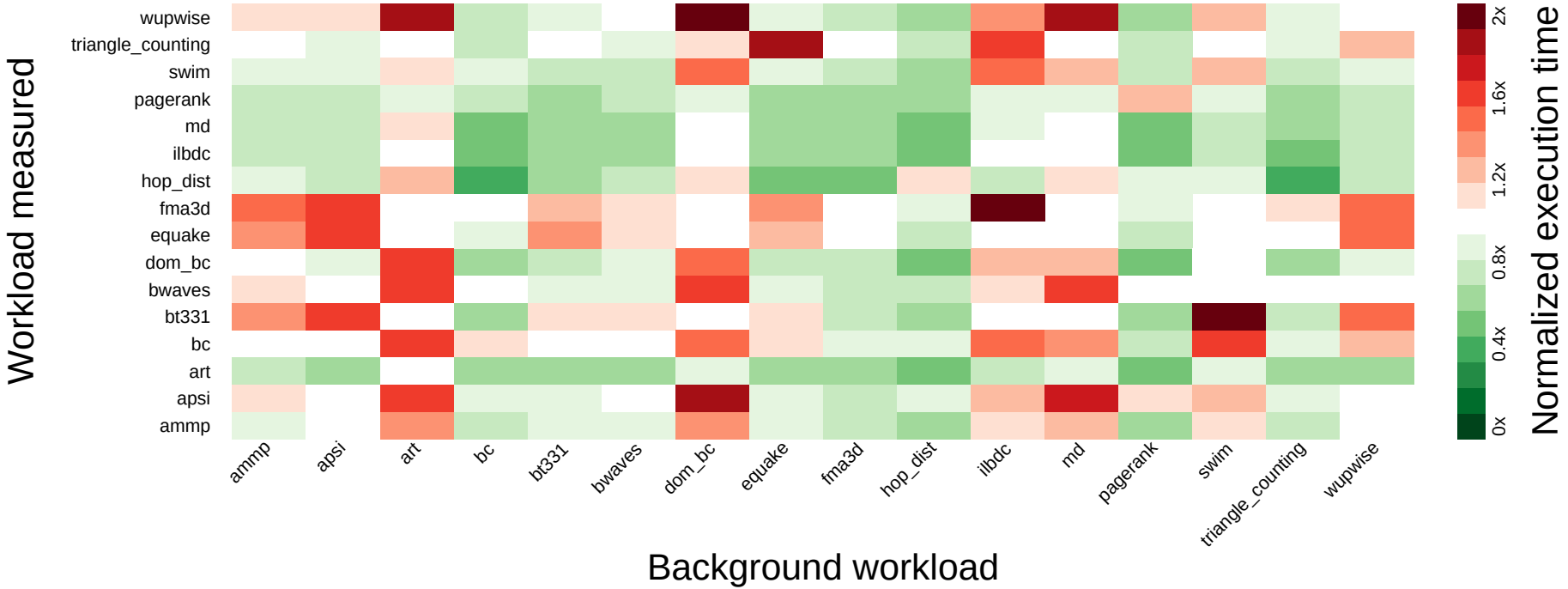
Instead of this…

2-socket Xeon E5-2660, Linux 2.6.32, GCC 4.8.0



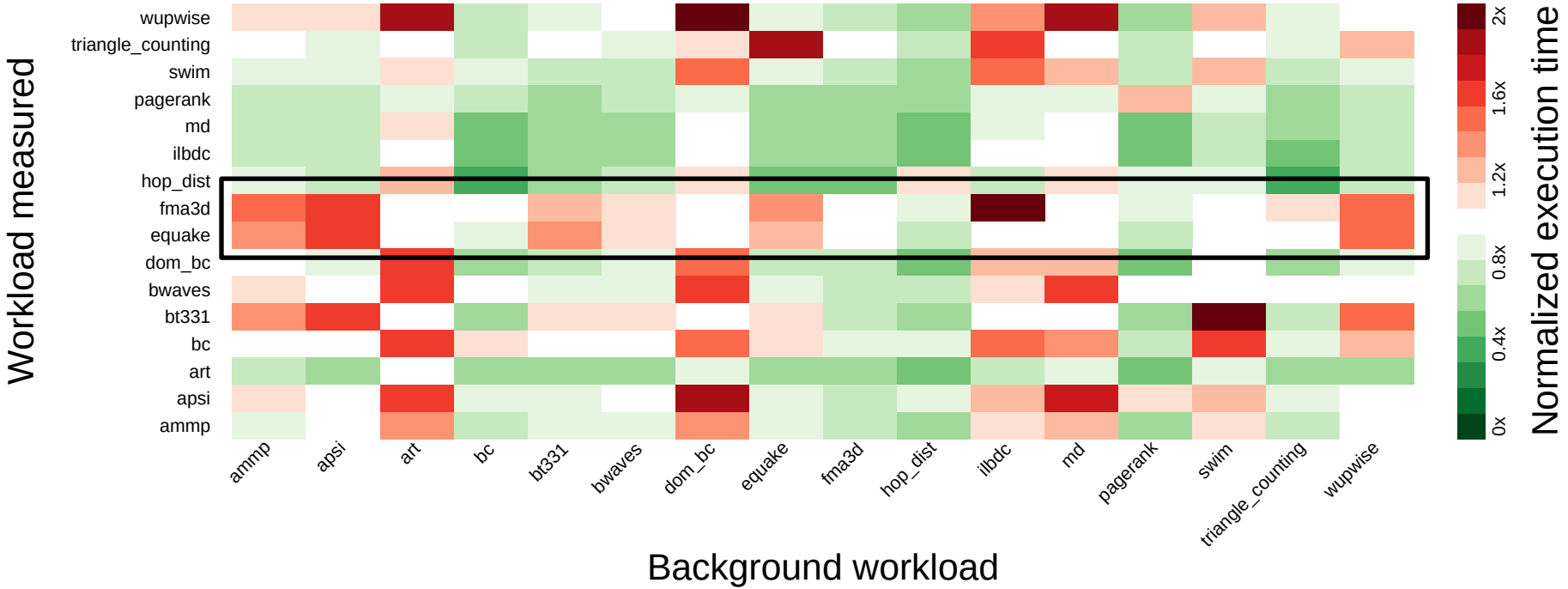
…it looks like this.

2-socket Xeon E5-2660, Linux 2.6.32, GCC 4.8.0



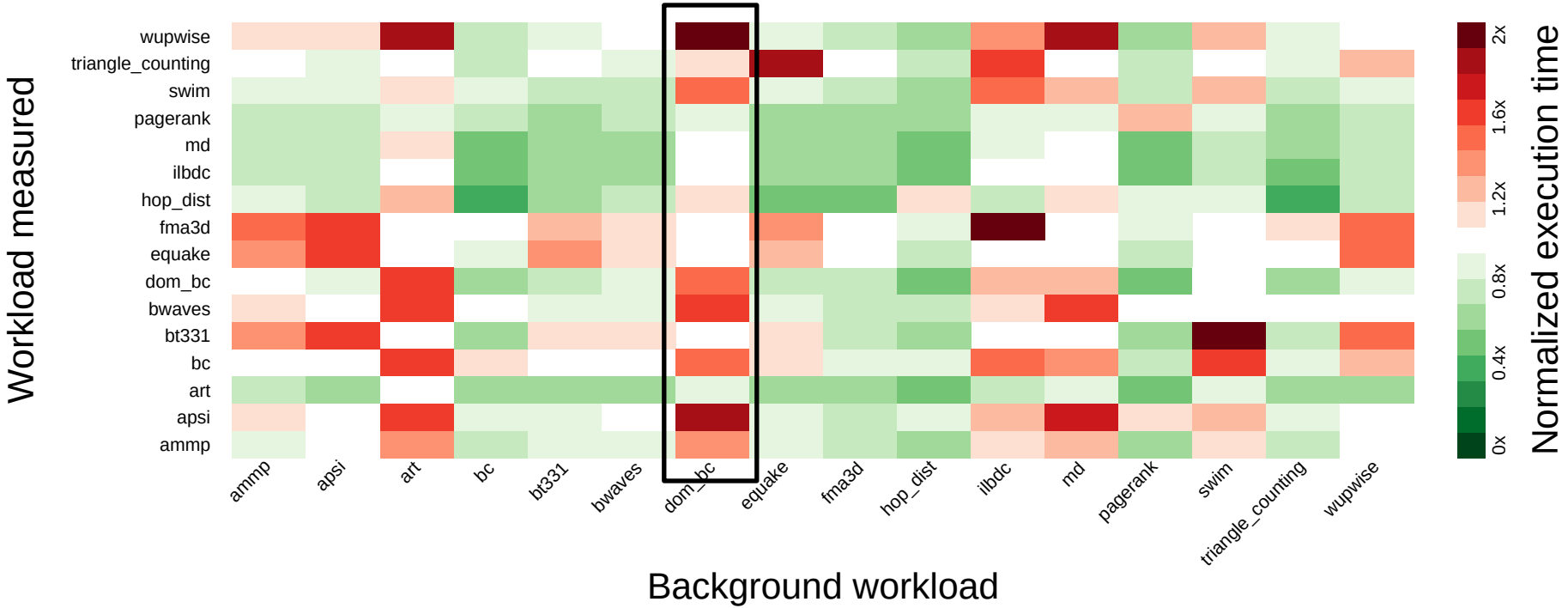
We see some patterns…

Red rows: sensitive applications



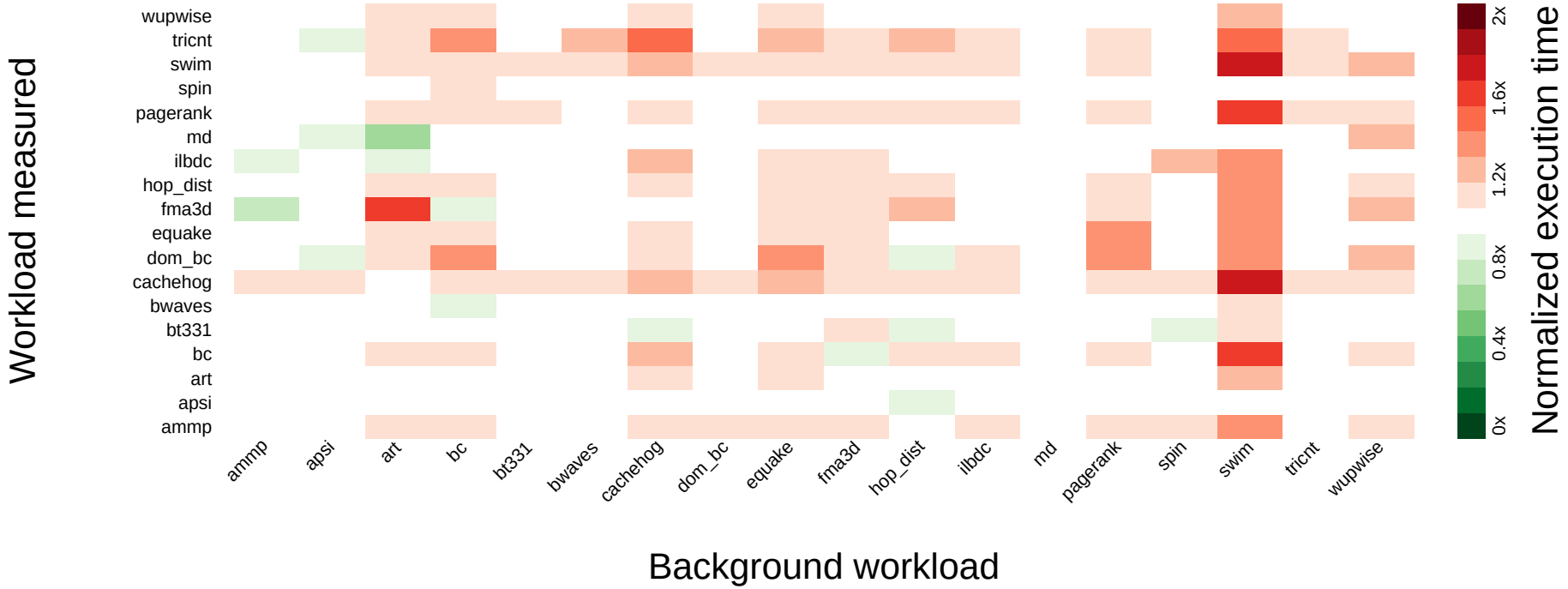
We see some patterns…

Red columns: aggressive applications



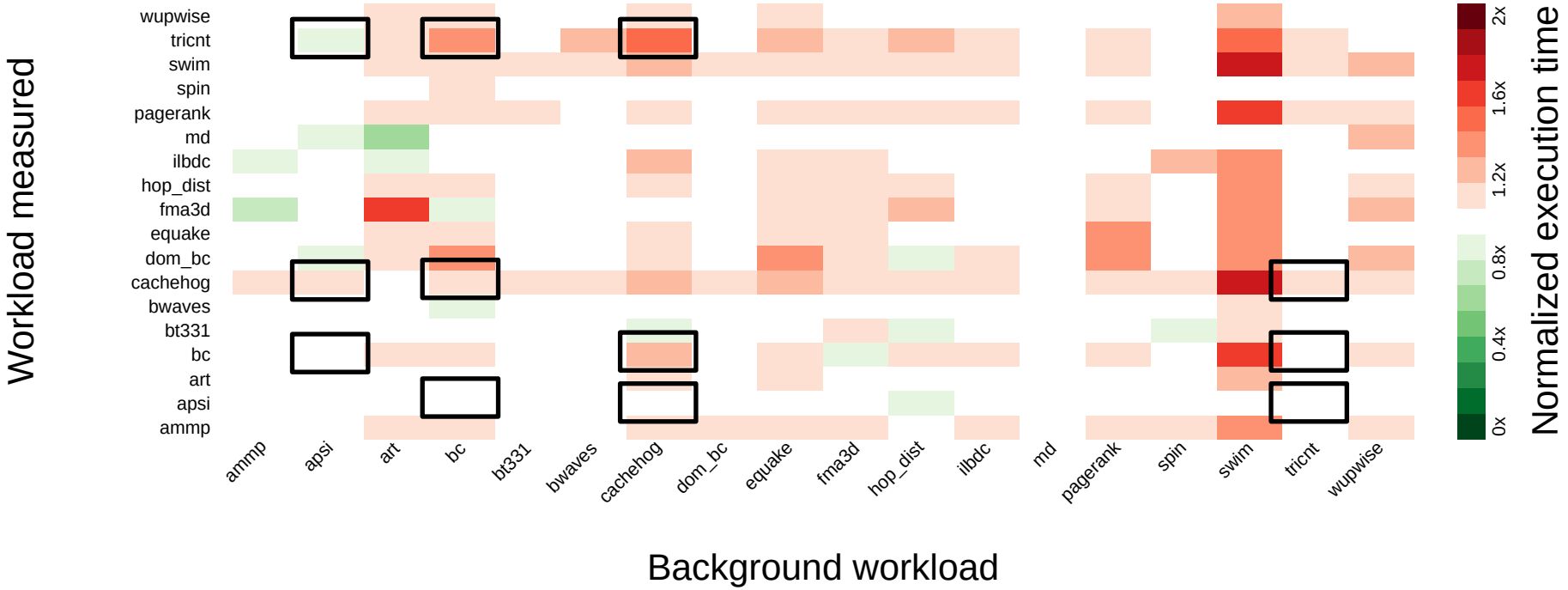
Sharing a socket

4-core jobs, sharing a socket vs separate sockets



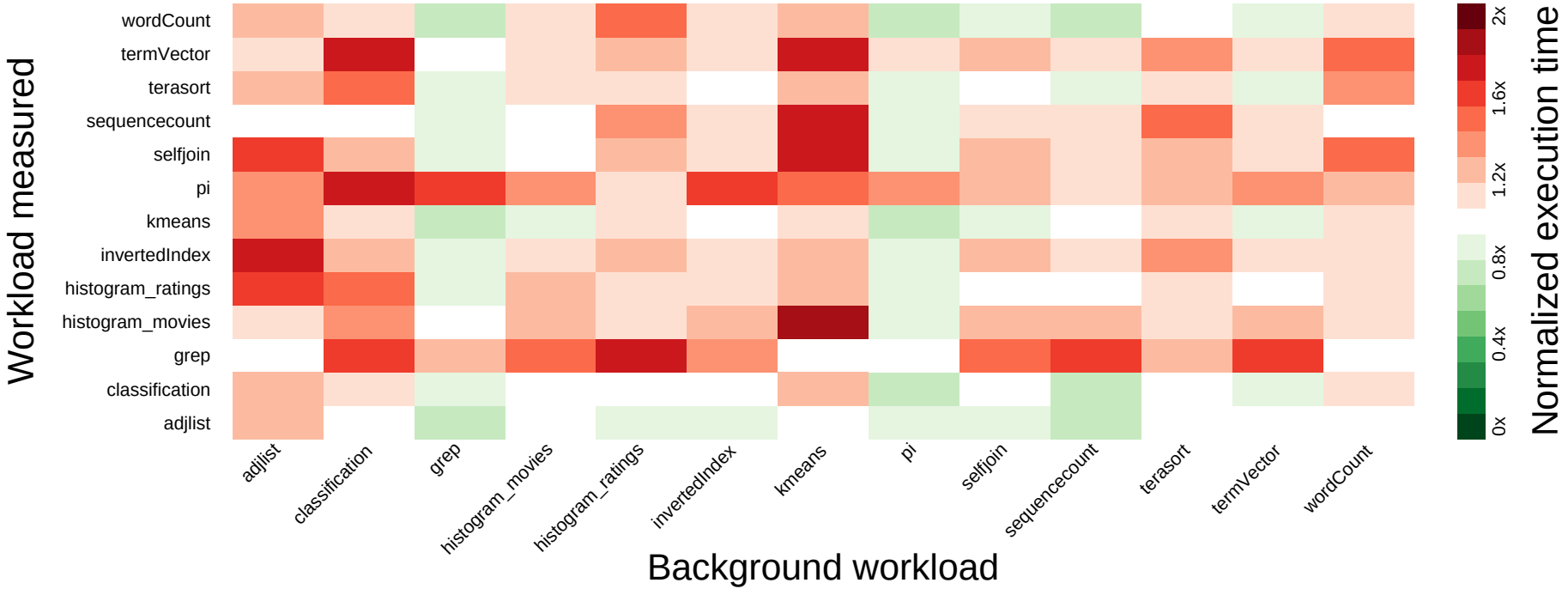
Sharing a socket

Given a set of jobs, which combinations are best?



Sharing a cluster

2 jobs on a shared cluster vs 1 job on half



Bad interactions at every level

(we've looked at so far)

- >2x difference between best and worst cases
- Often different results on different metrics
  - System-metrics (e.g., STP)
  - Per-job metrics (e.g., ANTT)

What can we do?

Over-provisioning

- No scheduling if there's no sharing
- Perhaps applicable to some resources
- But…
  - How to handle large bursty workloads?
  - The same problems remain within software (e.g., multiple parallel queries within an RDBMS)
  - Still need to use resources effectively when running on different machines, or within different allocations

What can we do?

Reduce performance fragility

- Trade some best-case performance for reduced sensitivity to dynamic scheduling decisions
- Lock-free algorithms
  - Don’t stall complete process if one thread is pre-empted or slow
- Over-partitioning
  - N processors, but divide work 4N ways and use work-stealing
- Cache-oblivious algorithms
  - Design algorithms to exploit a cache without knowing its size

What can we do?

Exploit knowledge of system structure

- Know the physical structure of the machine
- Know which core(s) and memory / interconnect is being used
- Tailor algorithms to exploit these resources
  - Pick from library of alternatives
  - Parameterize by resources
  - Use machine-learning to match algorithms and storage to systems?
- Make resource allocation/deallocation explicit to the application
  - Adapt when resources change

What can we do?

Vertically structures systems

- Eliminate or minimize sharing
  - "Layed Multiplexing Considered Harmful" – Tennenhouse '89
  - Nemesis research OS – Roscoe et al
- Provide abstraction via libraries, not servers
  - Push protection to h/w devices – now emerging via e.g. SR-IOV
- How would these ideas look in a rack-scale system?
  - E.g., considering communication between parts of a distributed job

What we talk about when we talk about scheduling

- Systems work from the early ’90s focused on resource management
  - With care, commodity hardware could handle audio and video
  - …but with time, over-provisioning removed the need for care
- Today, rack-scale systems can handle diverse workloads with substantial resource requirements
  - The problem now is sharing resources between jobs
  - Over-provisioning cannot be relied upon this time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