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Callisto: Rethinking the stack for parallel & distributed runtime systems

Tim Harris, Architect, Oracle Labs, Cambridge, UK

Meeting in the middle

Research often targets shared-memory multi-processor machines, and “warehouse-scale” distributed systems

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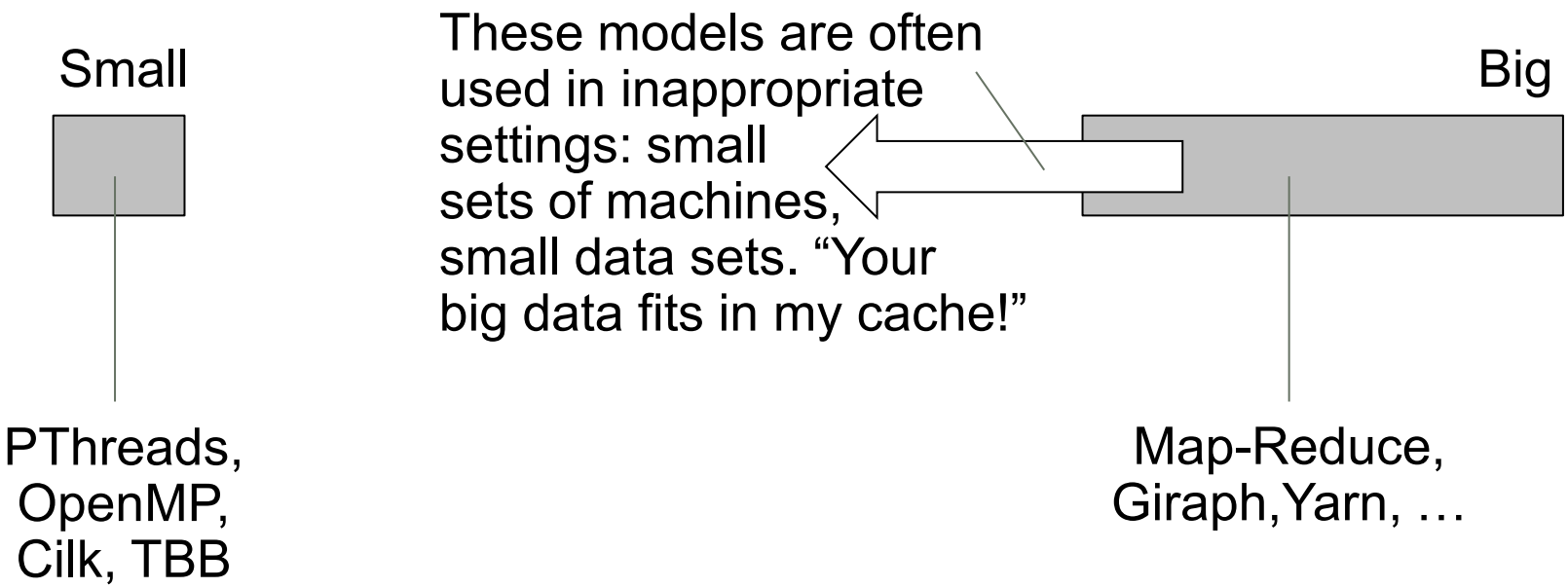
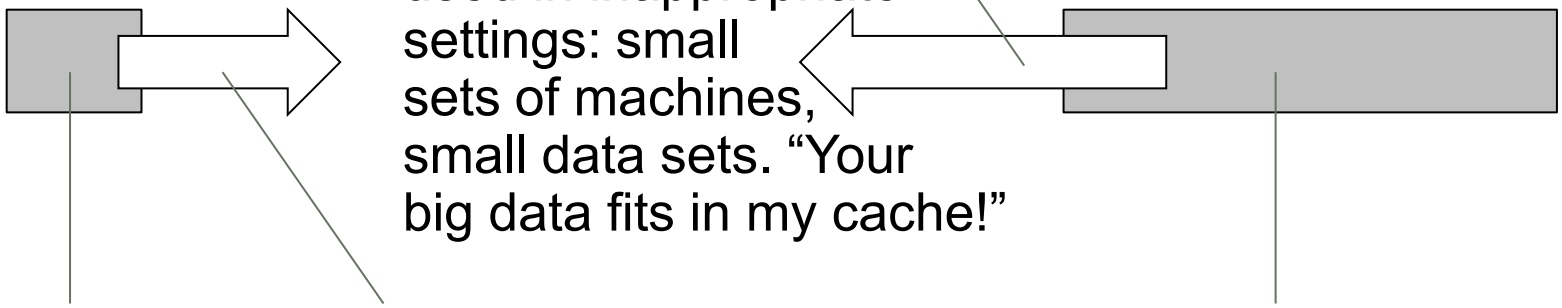
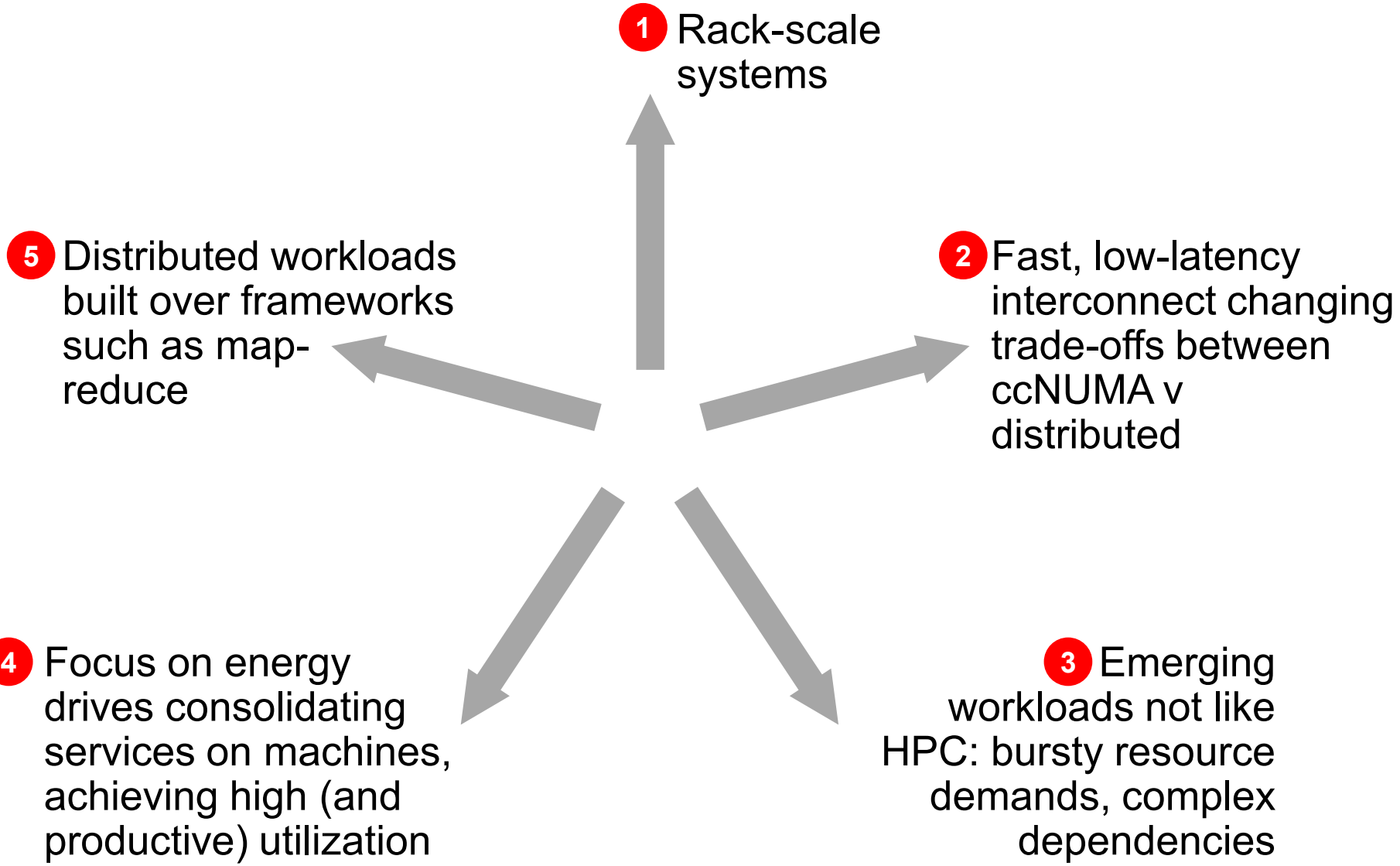


Meeting in the middle

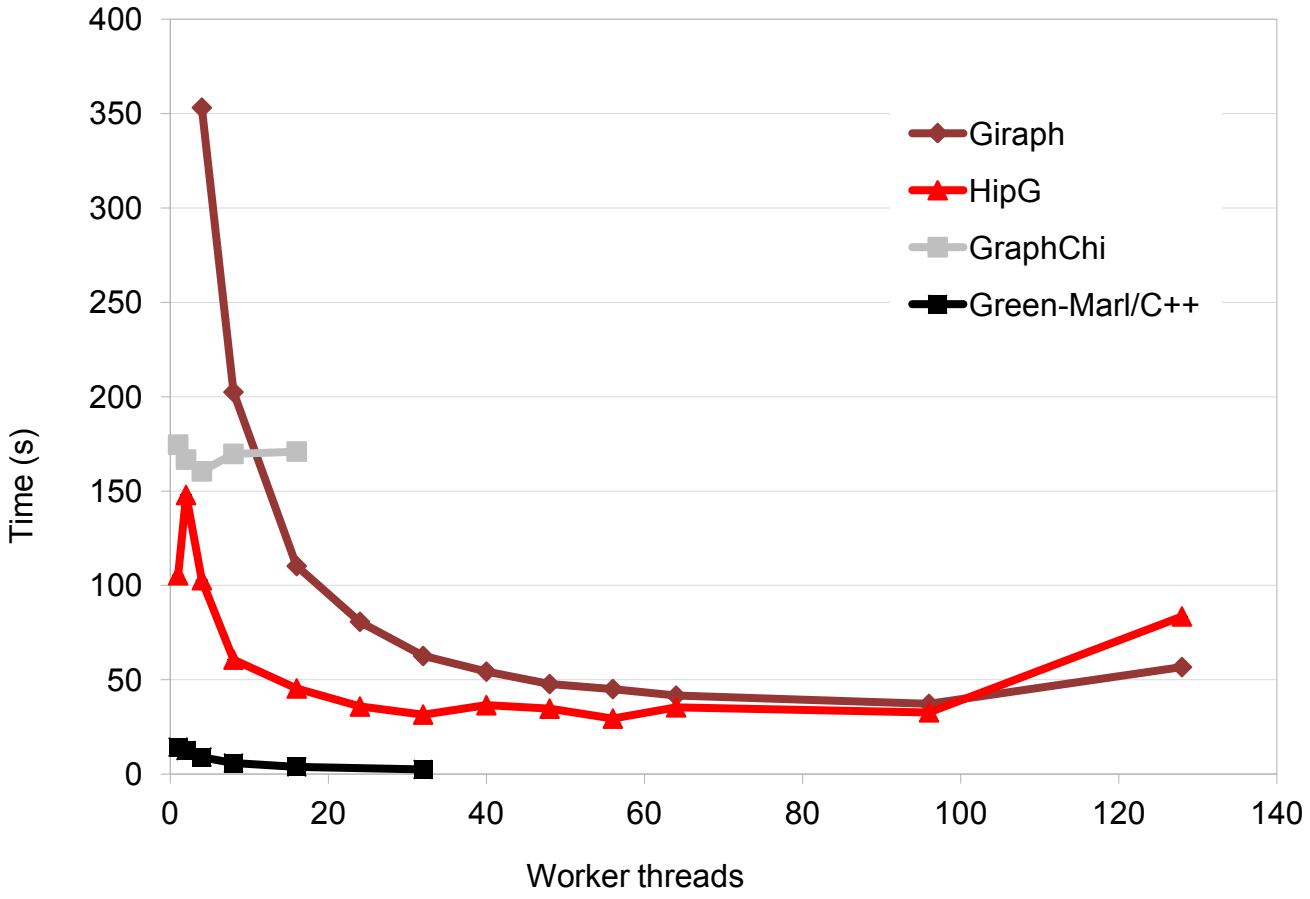
Research often targets shared-memory multi-processor machines, and “warehouse-scale” distributed systems



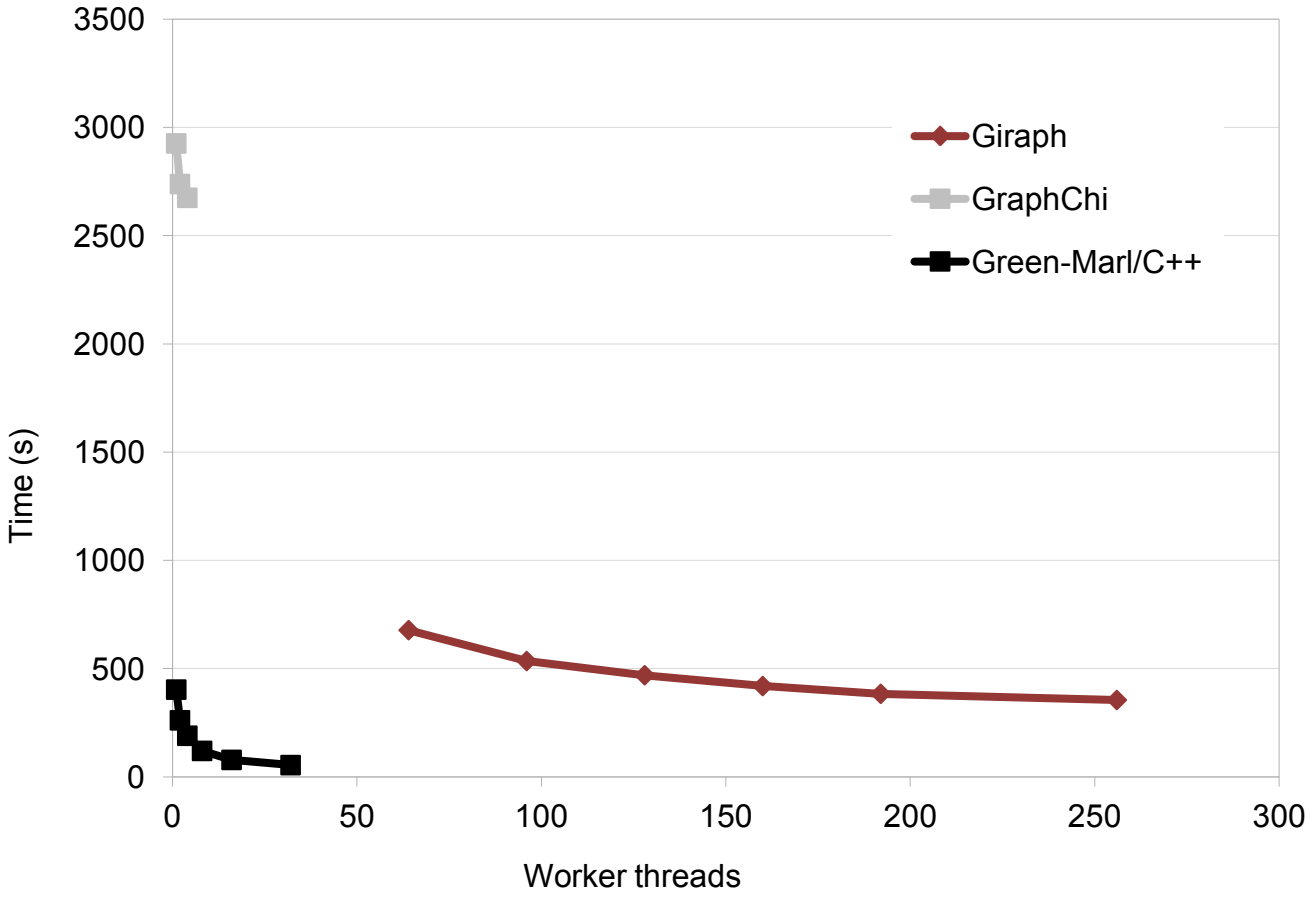
Current trends



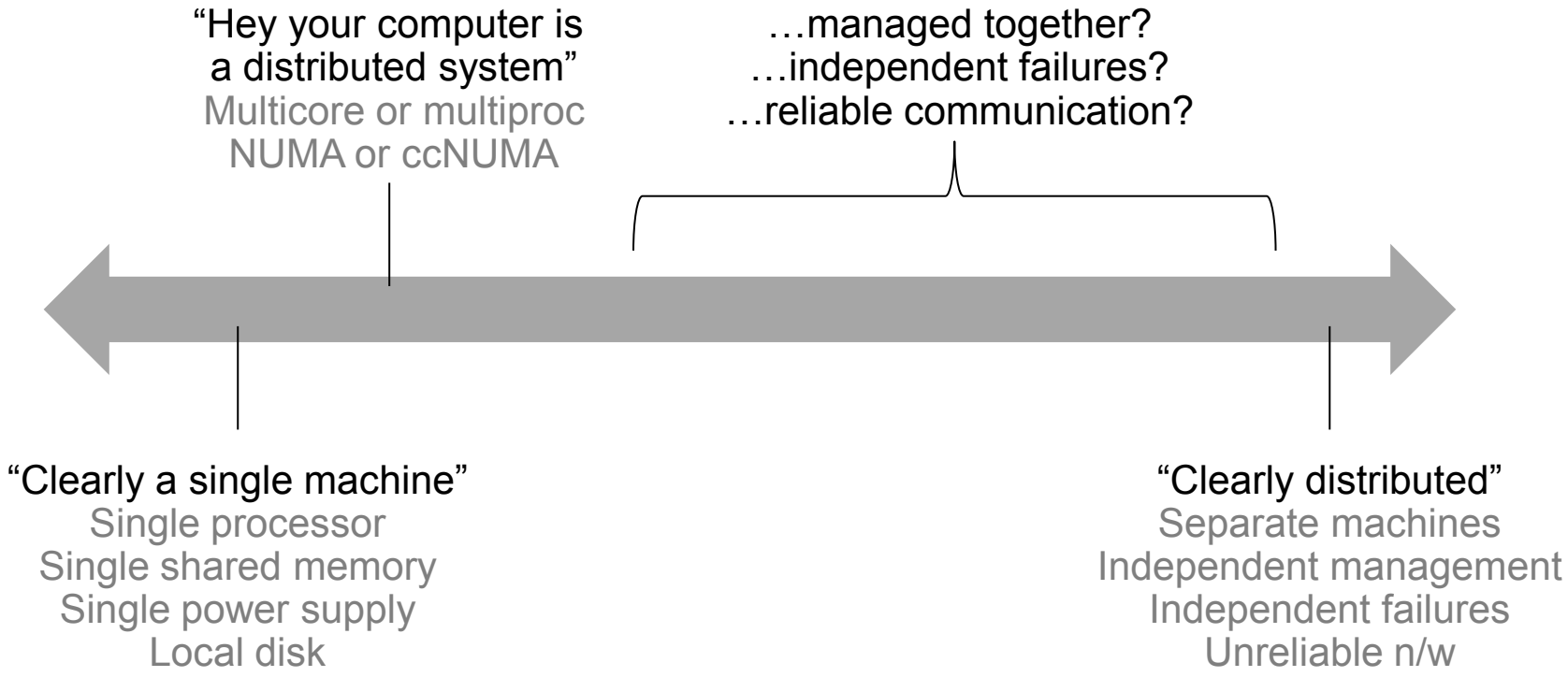
1. PageRank (social-net 4.8M vertices, 69M edges)



1. PageRank (social-net 41.6M vertices, 1.46B edges)



1. What I mean by a cluster



Motivation

1. The line between “single machine” and “distributed system” is getting blurred: shared components, often shared storage, while single machines exhibit partial failures.

2: Shared v distributed memory trade-off

```
do {
   cl.send.ping(&cl, val);
   cl.recv.pong(&cl, &val);
} while (val < ITERATIONS);
```

	Ping-pong latency (cycles)
Using UMP channel directly (threads sharing L3 on AMD 4*4-core)	931
Using event-based stubs	1134
Synchronous model (client only)	1266
Synchronous model (client and server)	1405

2: Shared v distributed memory trade-off

```
for (int iter = 0; iter < ITERATIONS; iter ++) {
  if (rank == 0) {
    MPI_Send(&msg, 1, MPI_INT, next, 0, MPI_COMM_WORLD);
    MPI_Recv(&msg, 1, MPI_INT, prev, MPI_ANY_TAG, MPI_COMM_WORLD, &Stat);
  } else {
    MPI_Recv(&msg, 1, MPI_INT, prev, MPI_ANY_TAG, MPI_COMM_WORLD, &Stat);
    MPI_Send(&msg, 1, MPI_INT, next, 0, MPI_COMM_WORLD);
} }
```

	Ping-pong latency (cycles)
MPI ping-pong (Mellanox ConnectX MT26428 QDR)	560

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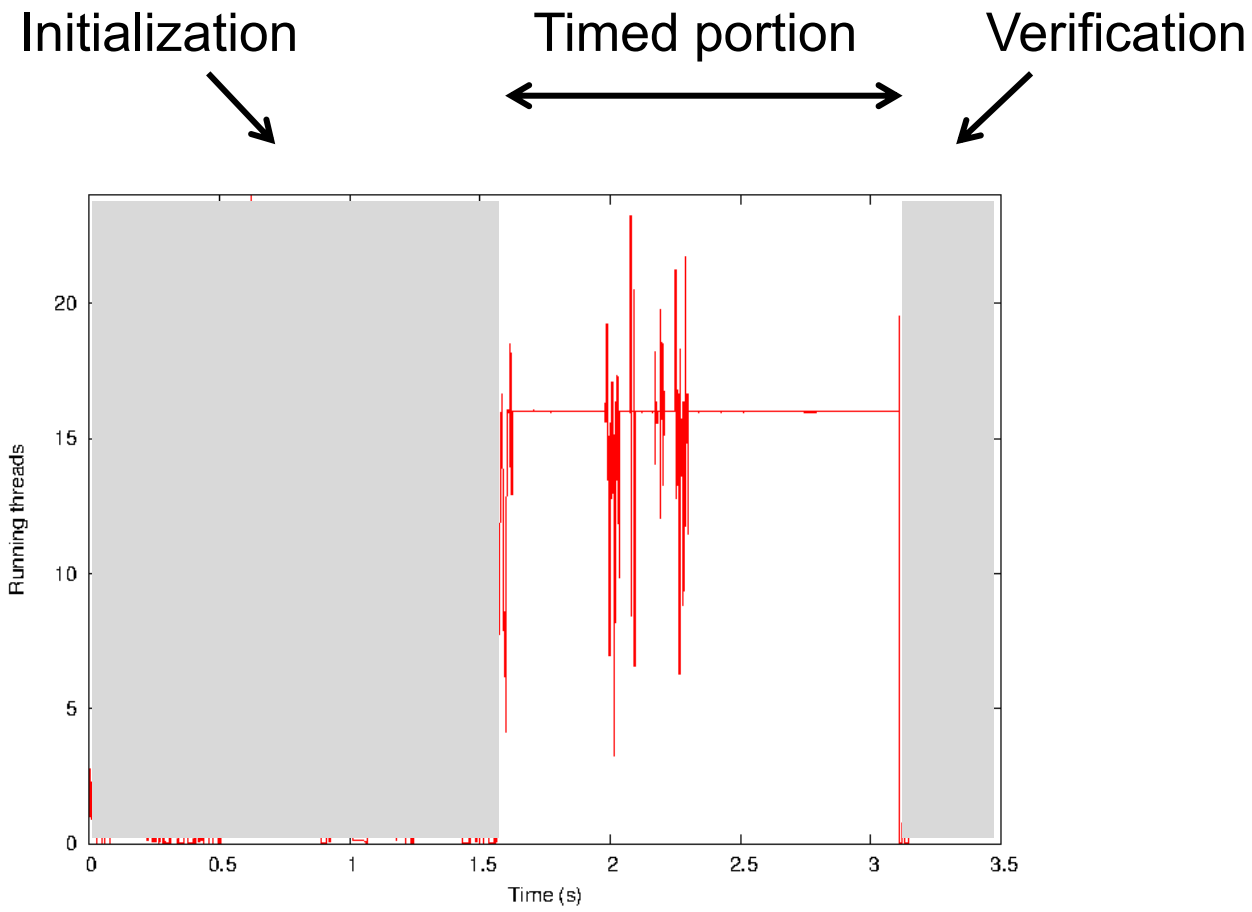
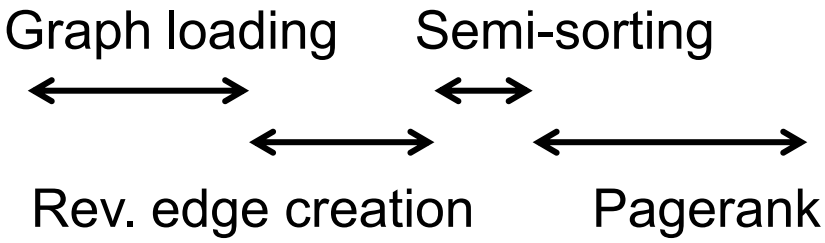
3: Workload demands

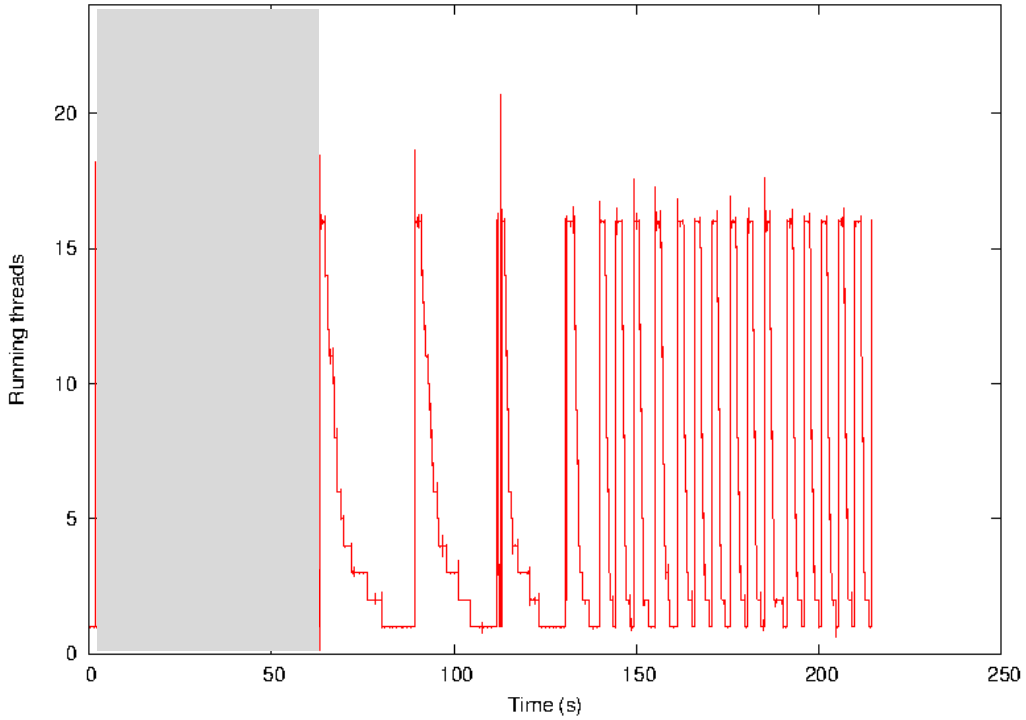
- Scheduler events on x86_64 Linux 2.6.32
  - 2* 8-core Xeon
  - Each core 2-way HT
- Distributed workloads: look at one node on a cluster
- Plot shows number of running threads, mean over 1ms or 10ms depending on run length
- Shaded area hides initialization etc.

3: Workload demands: NAS IS MPI (Integer Sort)



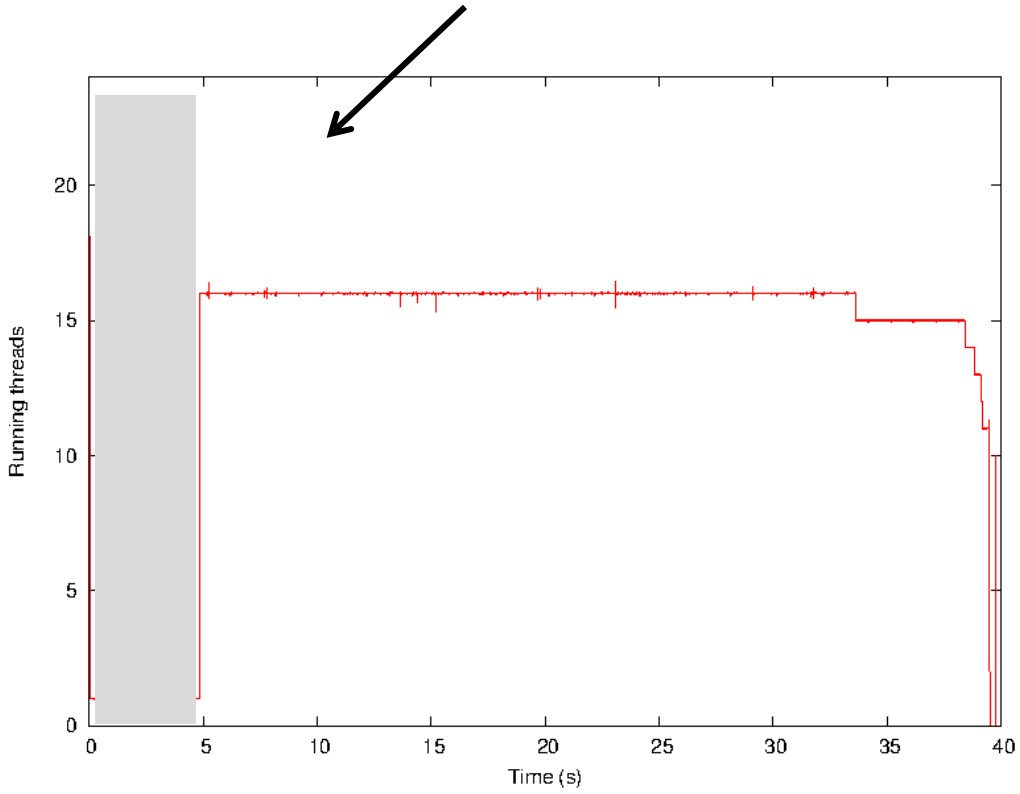
3: Workload demands: Green-Marl (Pagerank)





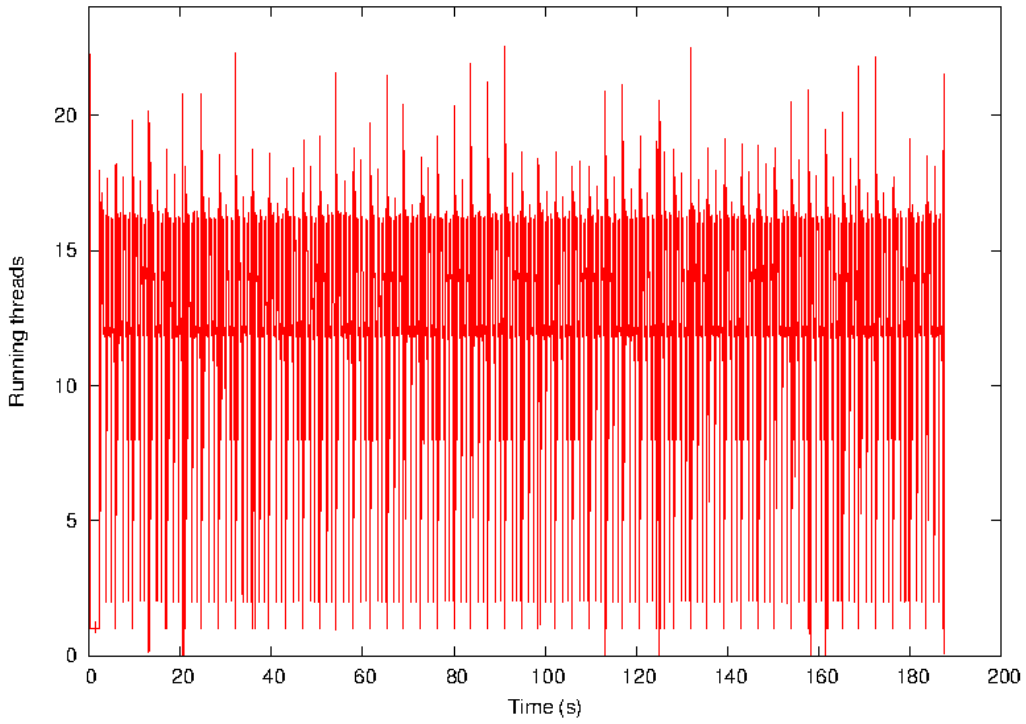
3: Workload demands: OMP (ART – neural network)

Mainly a single Open MP parallel region, dynamically scheduled



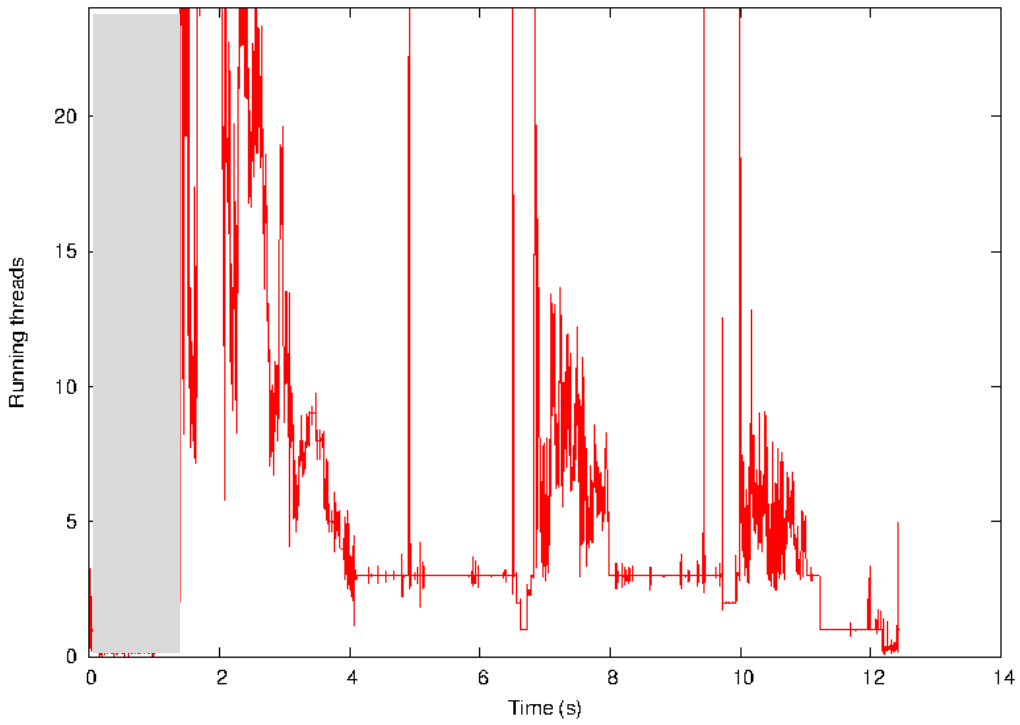
3: Workload demands: OMP (APSI – weather model)

Many parallel regions, linked by short sequential sections. Mean 13.5 running threads



3: Workload demands: DaCapo (PMD – source analysis)

Each of three iterations



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1. The line between “single machine” and “distributed system” is getting blurred: shared components, often shared storage, while single machines exhibit partial failures.
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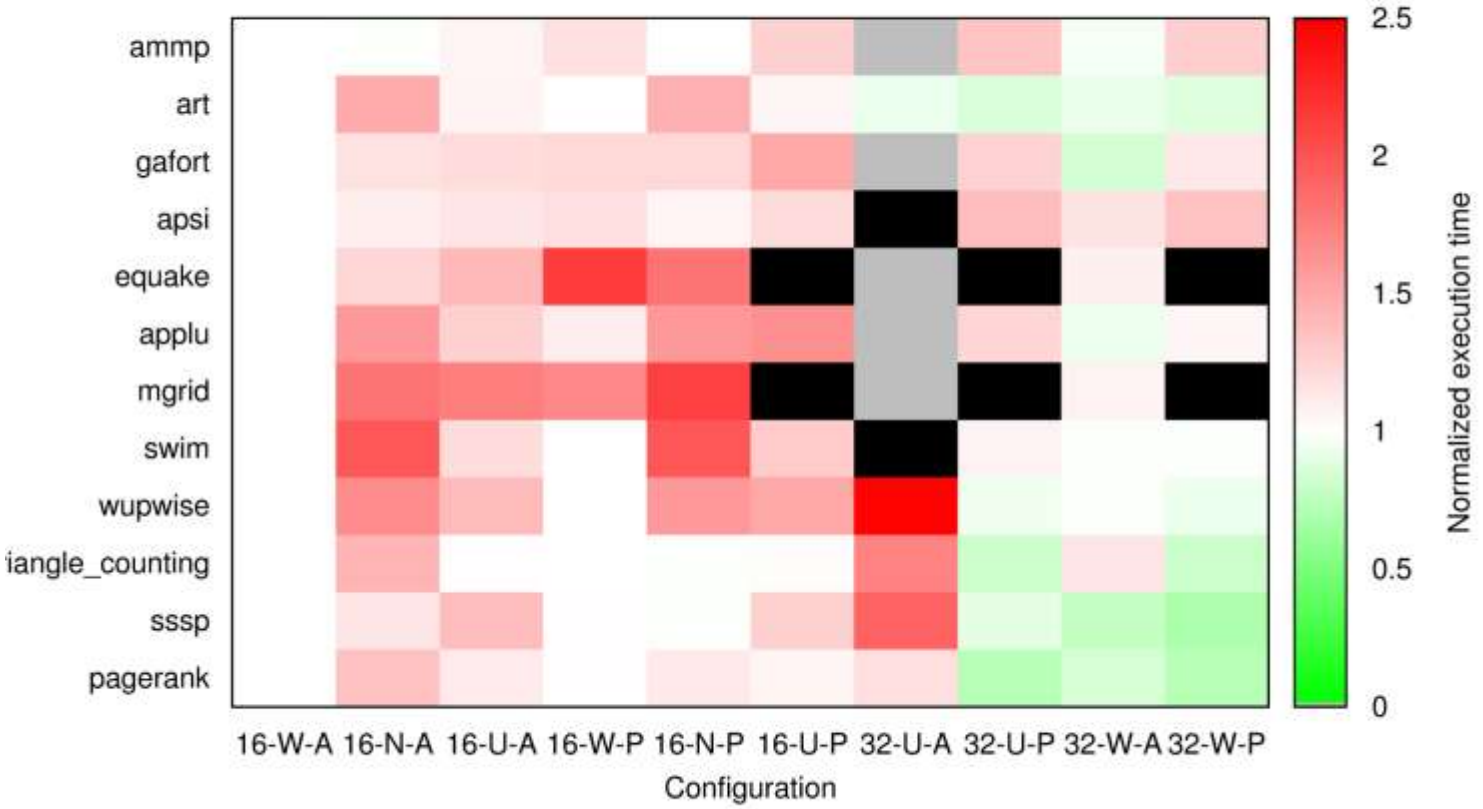
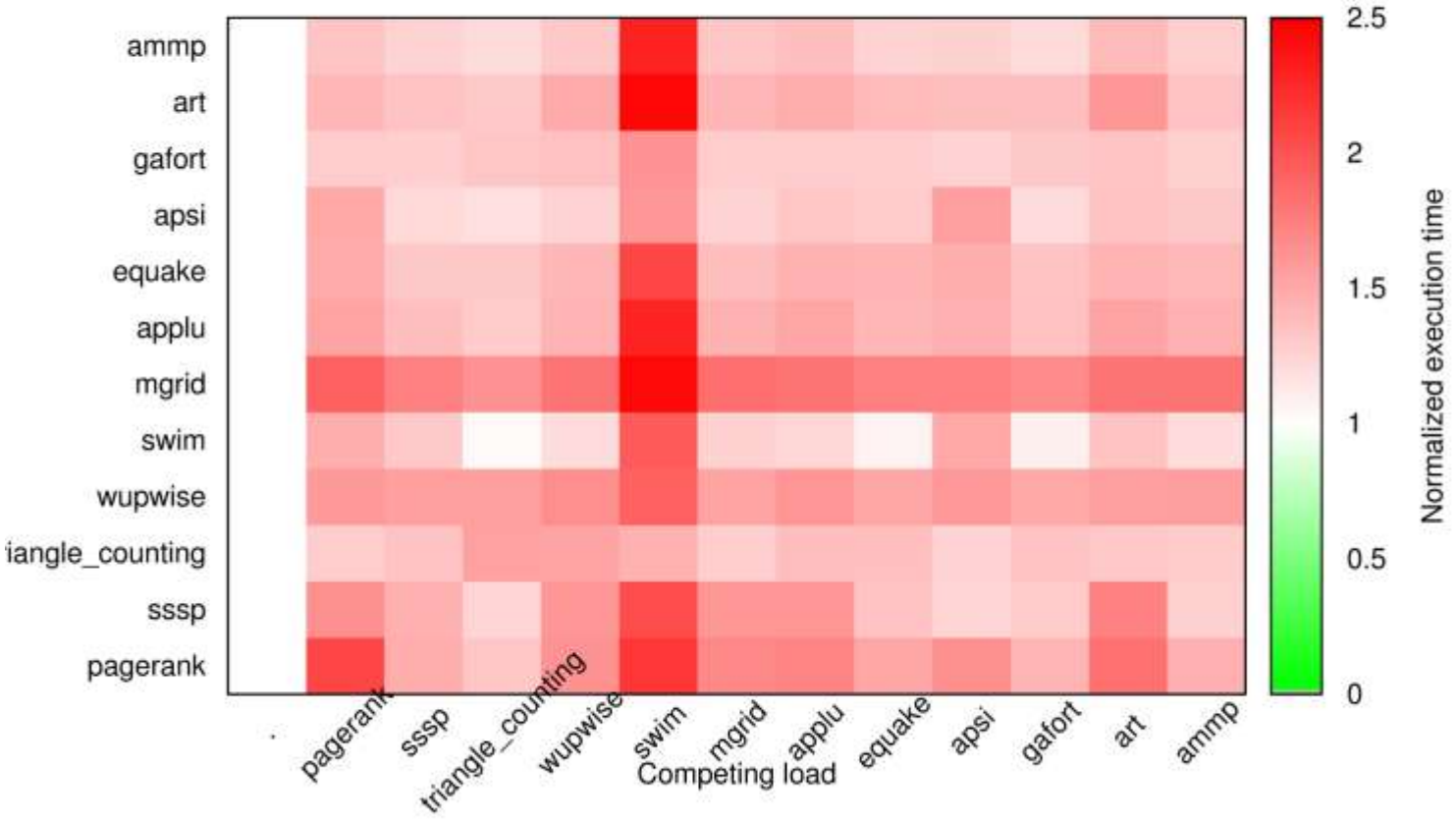
4: Consolidating workloads

- Look at a range of parallel workloads
  - Currently single-machine Green-Marl (soon distributed)
  - Currently SpecOMP 2001 on larger input sets (soon OMP 2012 and CPU)
- Run together on Bunch machines
  - 2-socket * 8-core * 2-way-HT
  - How well does the current OS and runtime system work under different configuration settings?
- Scheduler configurations:
  - 16-W-A
  - W (bound, wide), N (bound, narrow), U (unbound)
  - A (active waiting, spin), P (passive waiting, block)

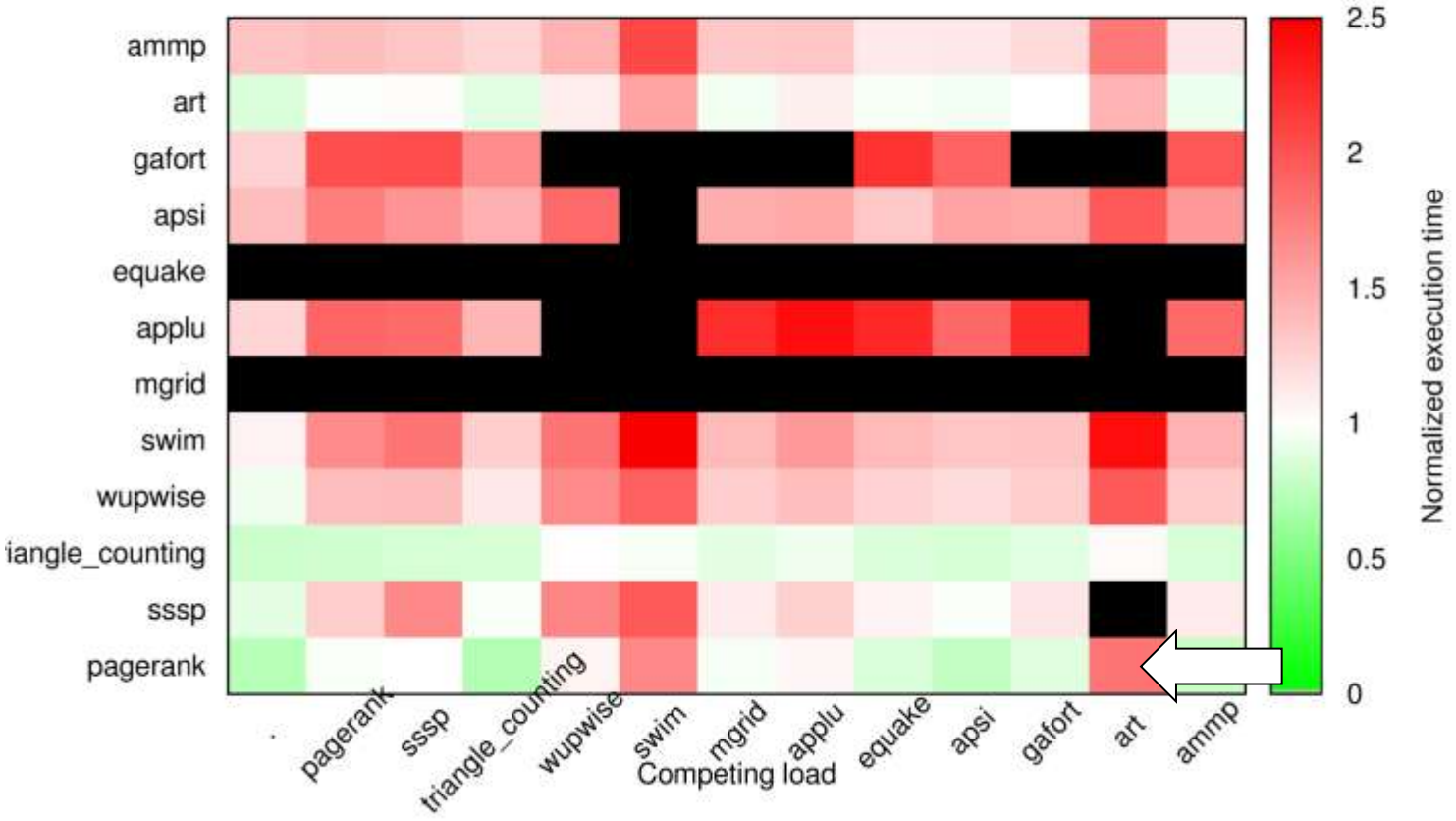
4: Consolidating workloads, running alone



4: Consolidating workloads, one hyperthread each



4: Consolidating workloads, 32-U-P



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5. Distributed runtime systems

Cluster-OS work in the 80s-90s

- Exploit PCs and emerging LAN technology
- Explore new OS structure, services, and programming models
  - Often in the same project
- Software (re-)developed using new mechanisms e.g.,
  - IPC
  - Distributed object models
  - DSM
- Abstraction of diverse and evolving h/w

Today

- Common frameworks enable distribution
  - E.g., Hadoop
- In other domains, a shift to DSLs for which we can build distributed implementations
  - E.g., Green-Marl
- OS itself is off the data path in high-perf software
  - Direct access to virtual n/w hardware
  - Access to storage over the n/w
  - Ref early ideas from Nemesis & ExoKernel

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5. An opportunity: so long as we support the required dependencies we do not need to develop new programming models.

Summary

- Clusters have traditionally supported HPC…
  - Workloads assigned to fixed machines / partitions of machines
  - Size often set when starting a job (e.g., MPI)
  - Early use of map-reduce style frameworks can look similar to HPC: long-running “embarrassingly parallel” tasks with occasional communication between them (or no “reduce” at all)
- …and long-running distributed / replicated workloads
  - Replication for HA, with monitoring and control of replicas
  - Changes in size over long timescales via management interfaces to add/remove nodes
- These workloads are handled well, but
  - Emerging workloads are not handled well
  - …and they make poor use of modern clusters

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