Network Support for Resource Disaggregation in Next-Generation Datacenters

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Future datacenters will look fundamentally different.

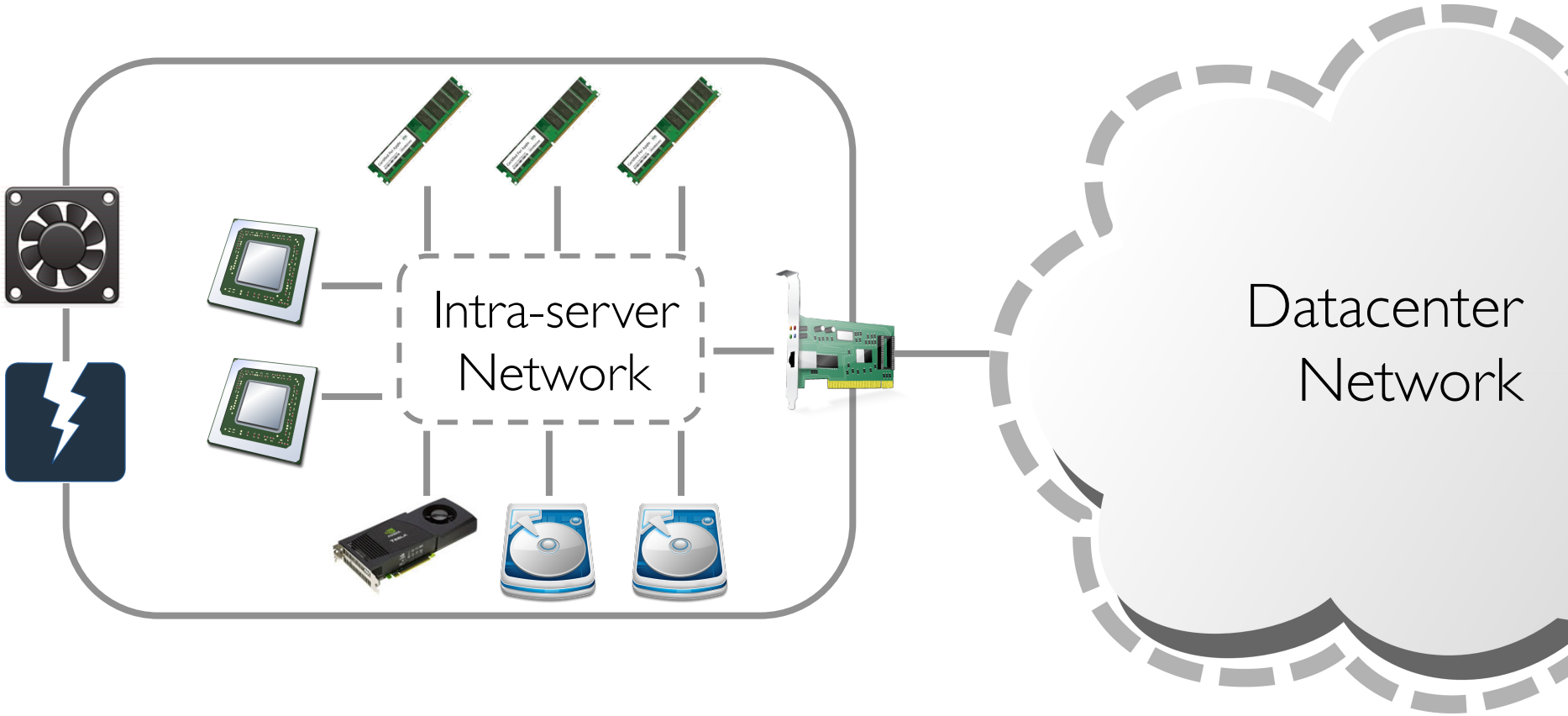
There will be no “servers”.

Like it or not.

Outline:

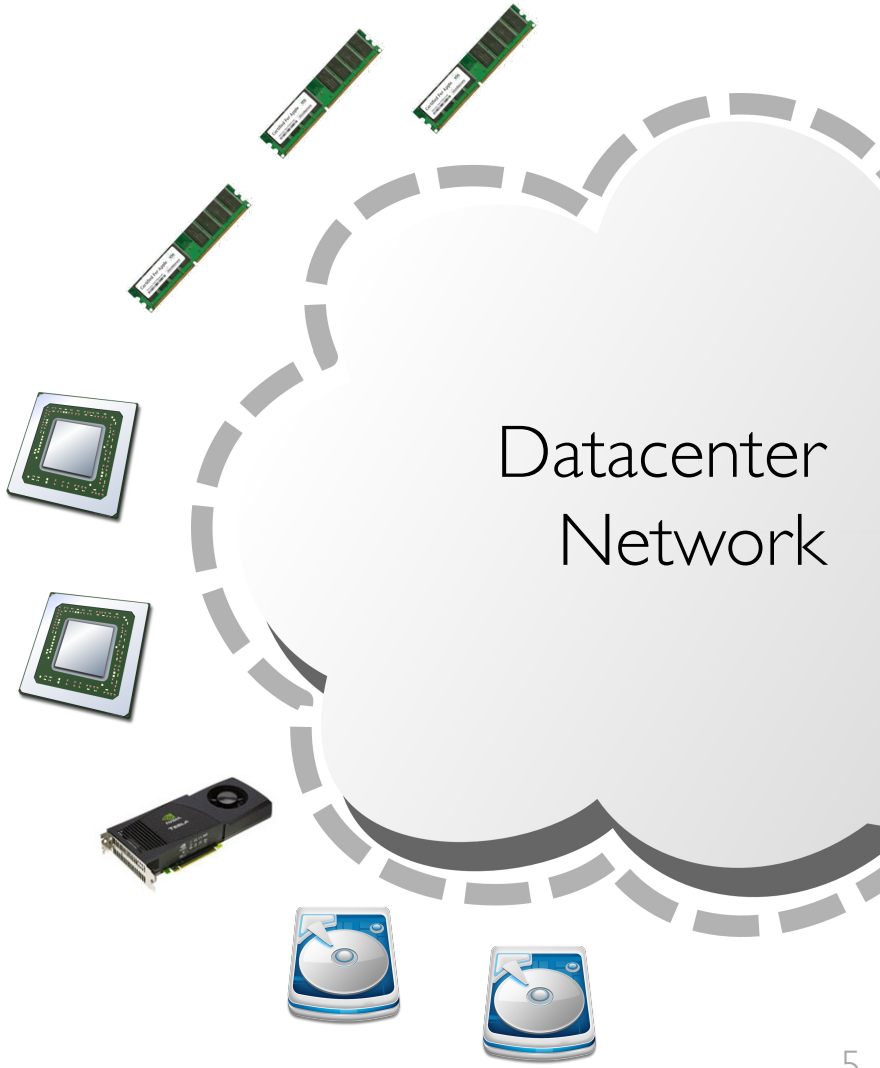
1. What will happen?
2. Why will it happen?
3. How will it happen?

Today: Server-Centric Architecture



Tomorrow: Resource-Centric Architecture

All resources are individually addressable

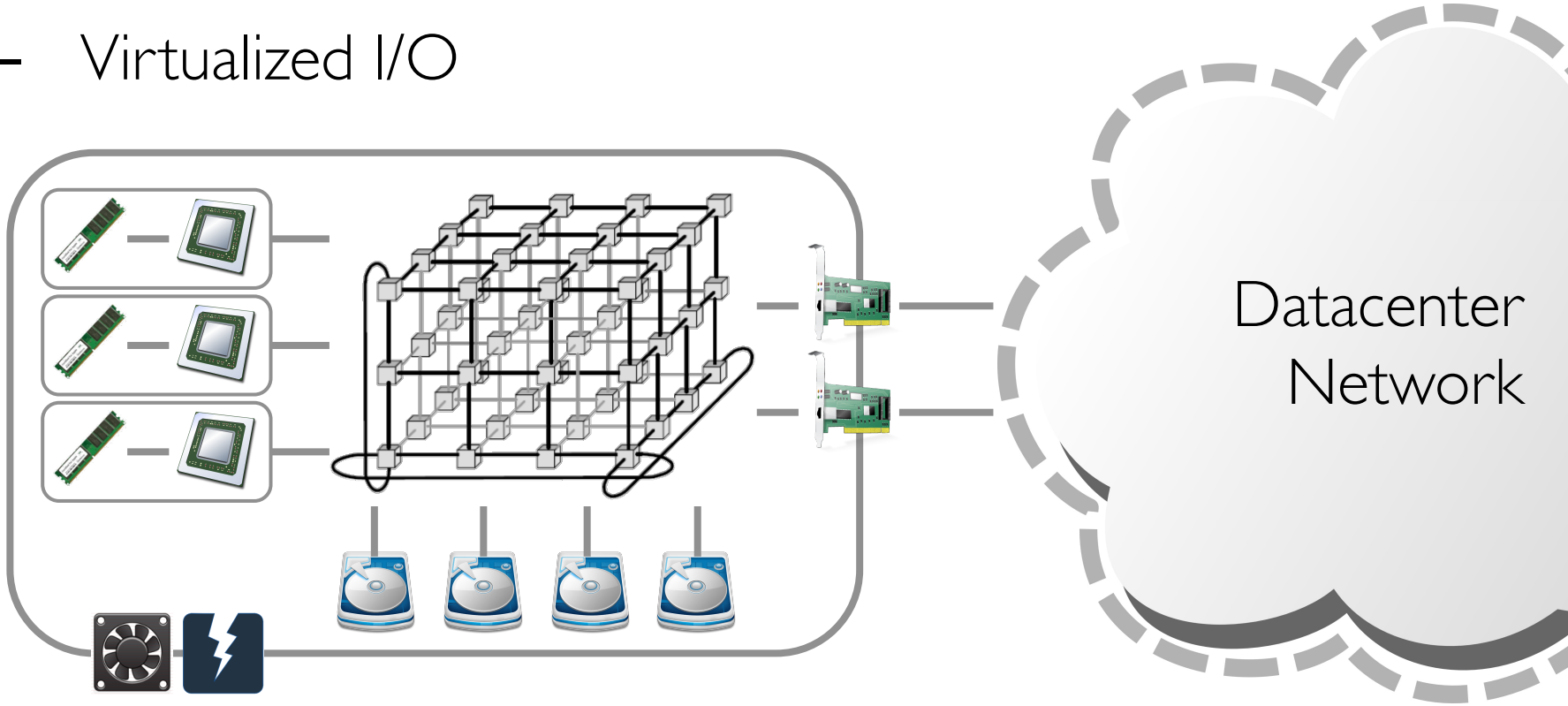


The Trends: Disaggregation

1. HP MoonShot
   - Shared cooling/casing/power/mgmt for server blades

The Trends: Disaggregation

1. HP MoonShot
2. AMD SeaMicro
   - Virtualized I/O



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The Trends: Disaggregation

1. HP MoonShot
2. AMD SeaMicro
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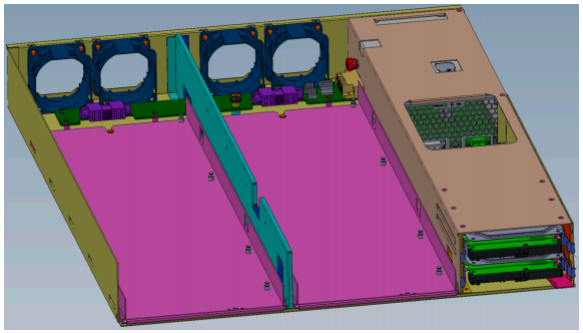
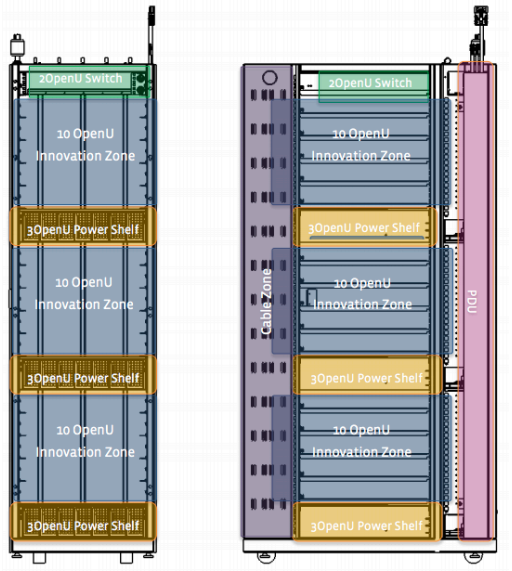
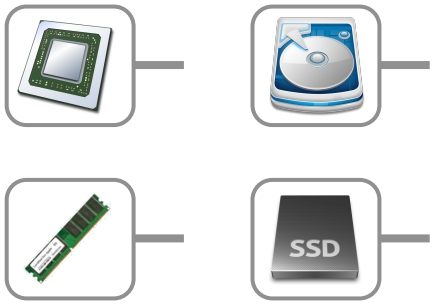
4. Open Compute Project

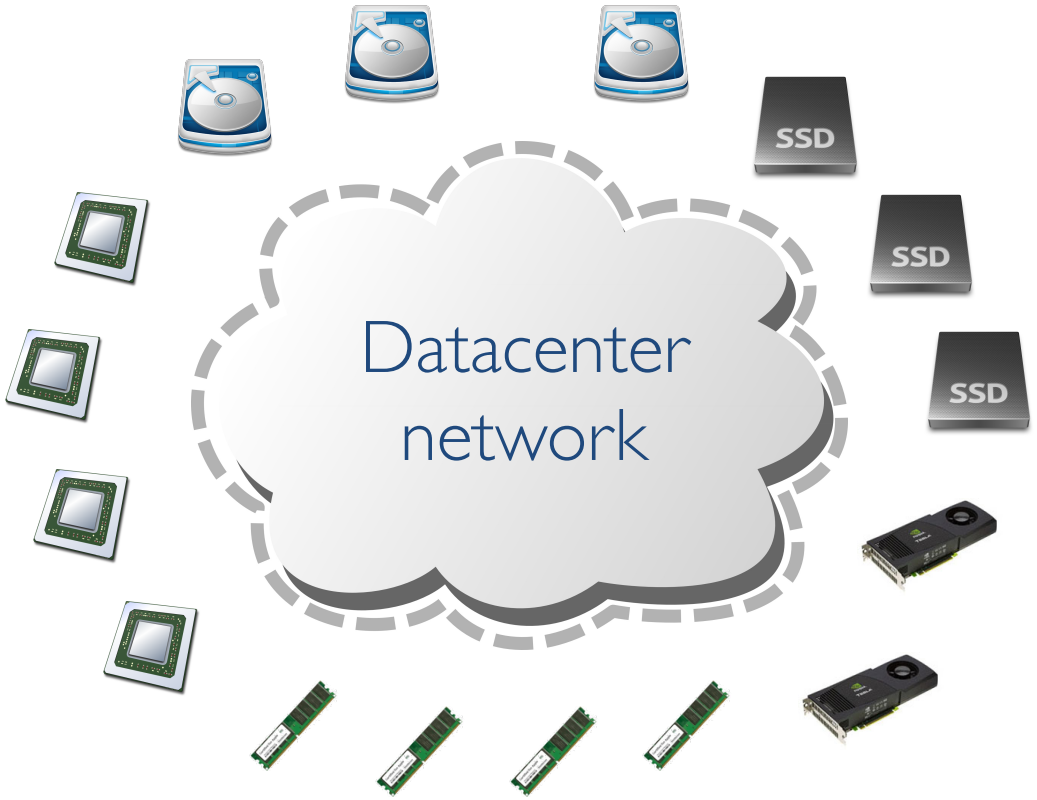




Disaggregated Datacenter



Resource as a standalone blade



Why will it happen?

: Extreme resource modularity

Benefits of Resource Modularity

1. Easier to build & evolve
   - Resources have different cycles/trends/constraints.
     - Tight integration in a server is a huge pain
     - E.g., "Memory capacity per core drops 30% for every 2 years" [Lim et al., ISCA '09]
   - Disaggregation enables independent evolution
   - The biggest driving force from vendor's viewpoint

Benefits of Resource Modularity

1. Easier to build & evolve
2. Fine-grained resource provisioning
   - Current practice: replace/buy an entire server, rack, or even datacenter.
   - e.g., "I want just more processors, not servers!"
     - Go buy some CPU blades at Best Buy® and plug them in.
   - e.g., "I want to try the new NVRAM technology!"
     - Again, go for it.

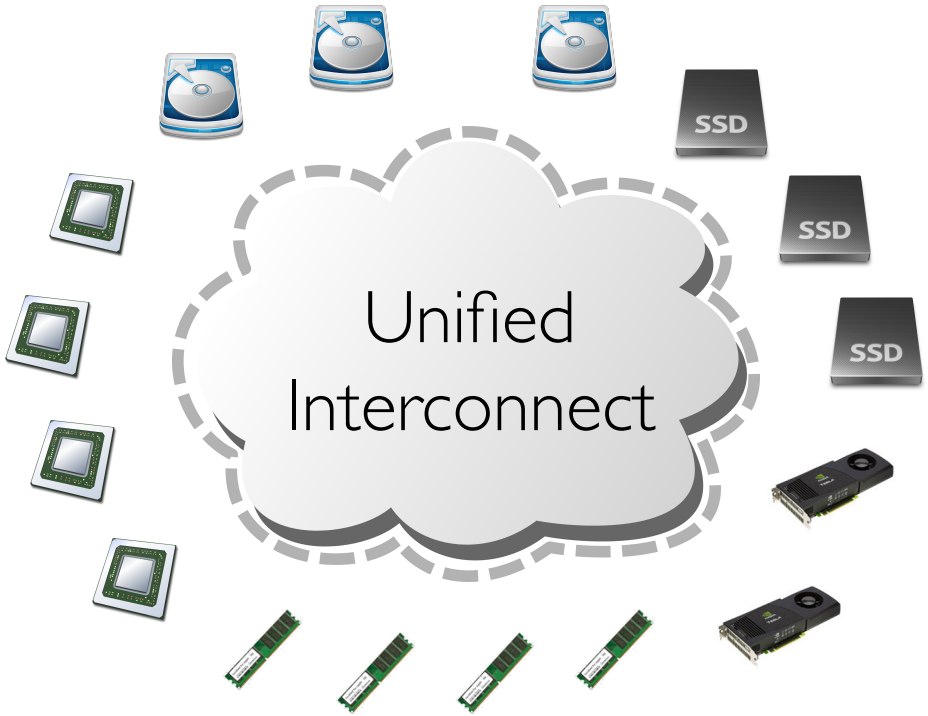
Benefits of Resource Modularity

1. Easier to build & evolve
2. Fine-grained resource provisioning
3. Operational efficiency
   - Datacenter as a single giant computer
   - Higher utilization with statistical multiplexing
   - (I will get back to this)

How will it happen?

: Incrementally and radically.

THIS IS NOT A CRAZY IDEA



- Do we need to change everything? NO.
  - HW change is minimal.
  - SW change is minimal, too.

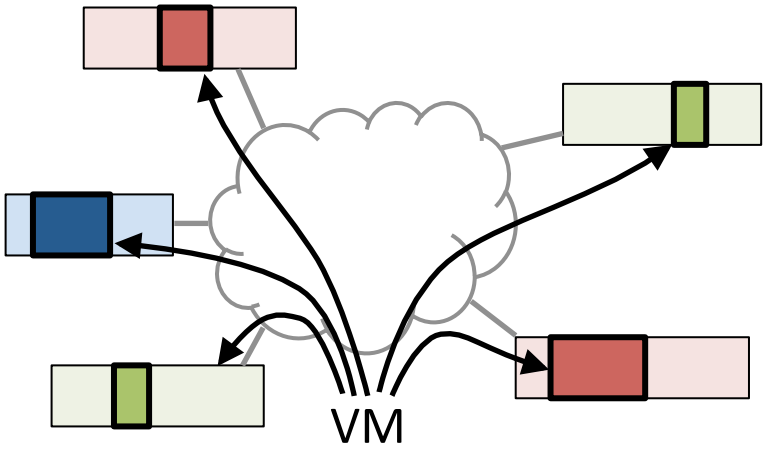
HW Requires Minimal Modification

Resource as a standalone blade

- The internals don't need to change.
- All we need is embedded network controller.
  - They already have: QPI, HT, PCIe, SATA, …
  - Can be very cheap
    - E.g., a whole graphics card w/ 128Gbps for only $50

How About SW?

- Existing SW infrastructure heavily relies on the concept of "server"
  - We don't want to rewrite it from scratch.
  - How to utilize the "giant computer"?



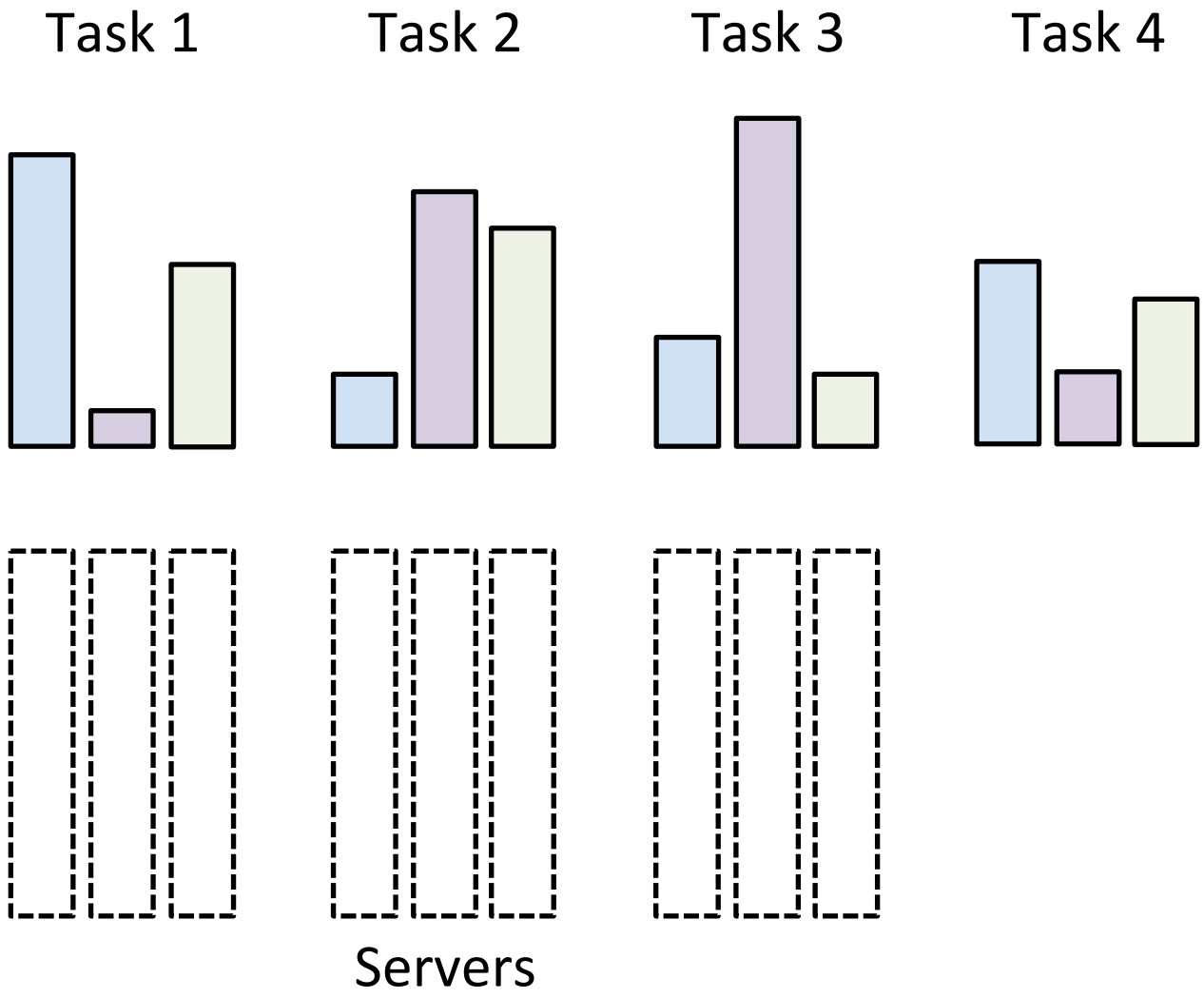
Disaggregated VM

No modification for App/OS

Minor changes in VMM.

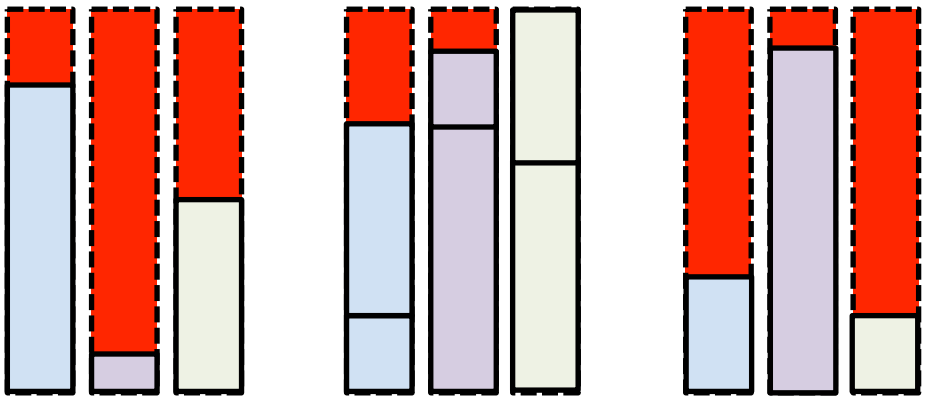
Much higher utilization!

Elastic VMs Achieve High Utilization!



Elastic VMs Achieve High Utilization!

40% of resources are wasted

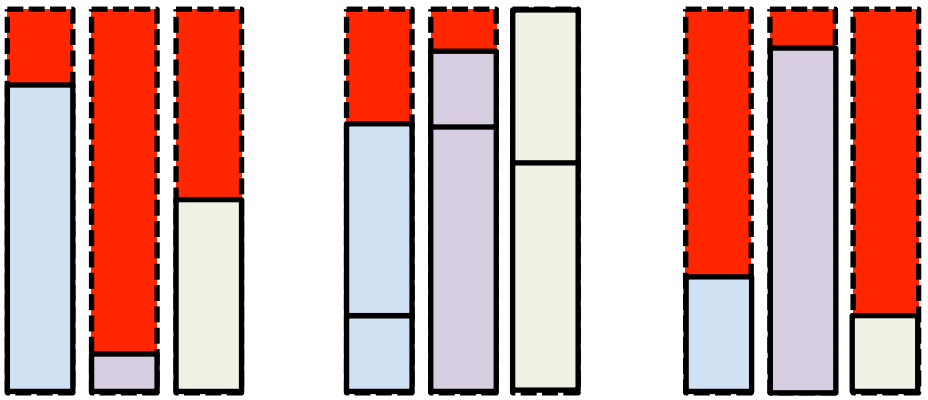


Servers

Elastic VMs Achieve High Utilization!

1. No "server boundary"
2. Statistical multiplexing at a larger scale
3. Higher utilization!

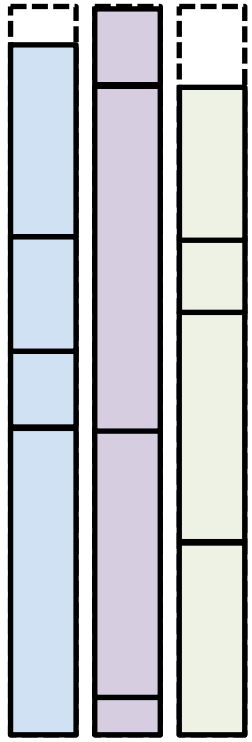
40% of resources are wasted



Servers

vs.

Disaggregated datacenter



(tasks vary greatly)

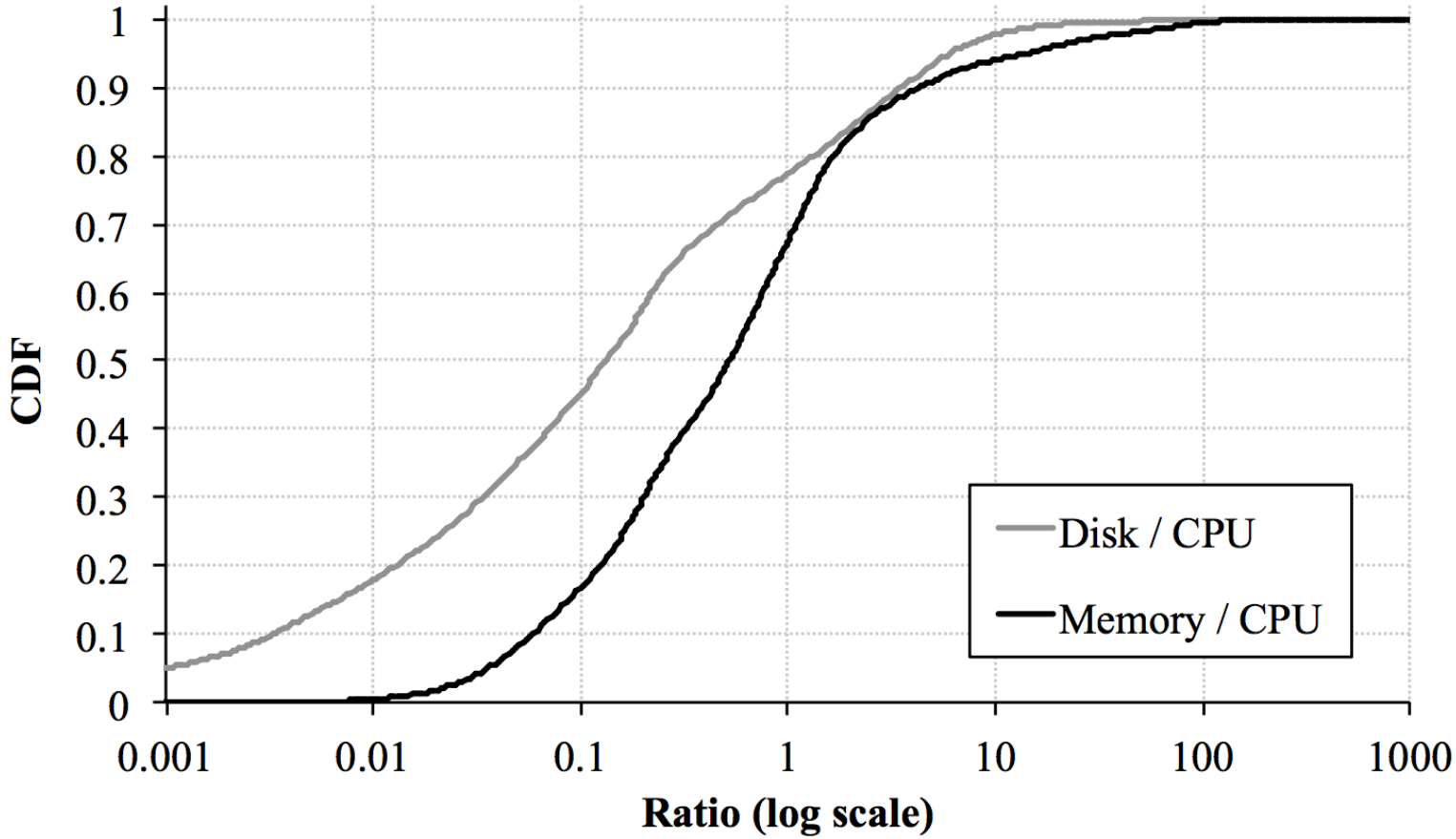


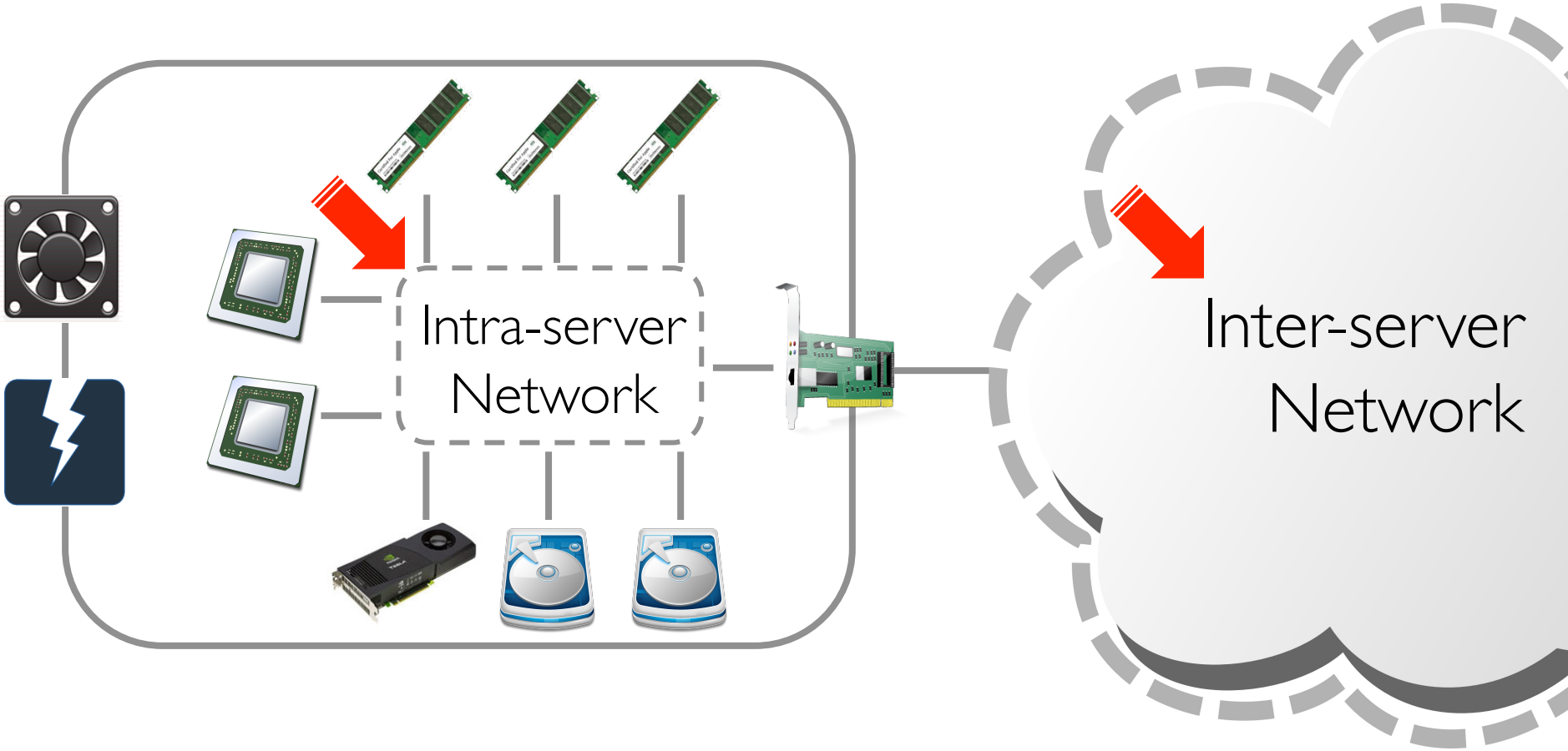
Figure 1: Distribution of disk/memory capacity demand to CPU usage ratio for tasks in Google's datacenter.

THIS IS NOT A CRAZY IDEA, part 2

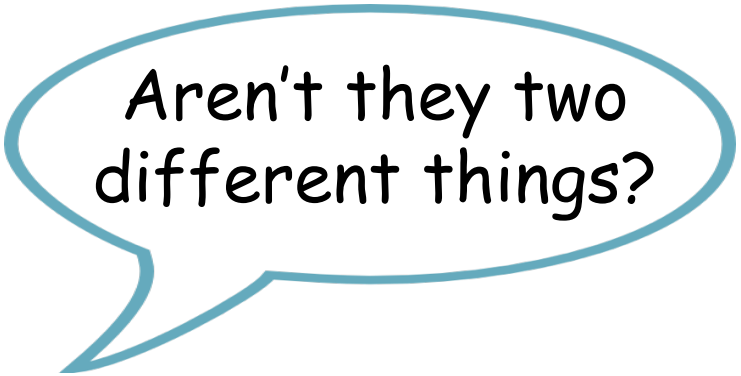
- We don't need to change everything.
  - HW change is minimal.
  - SW change is minimal, too.

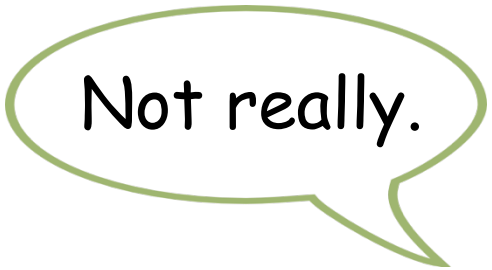
- A unified network is plausible
  - The intra-/inter-server networks can be unified.
  - Bandwidth/latency requirements are within reach.

Two Different(?) Types of Network



Intra- vs. Inter-Server Networking



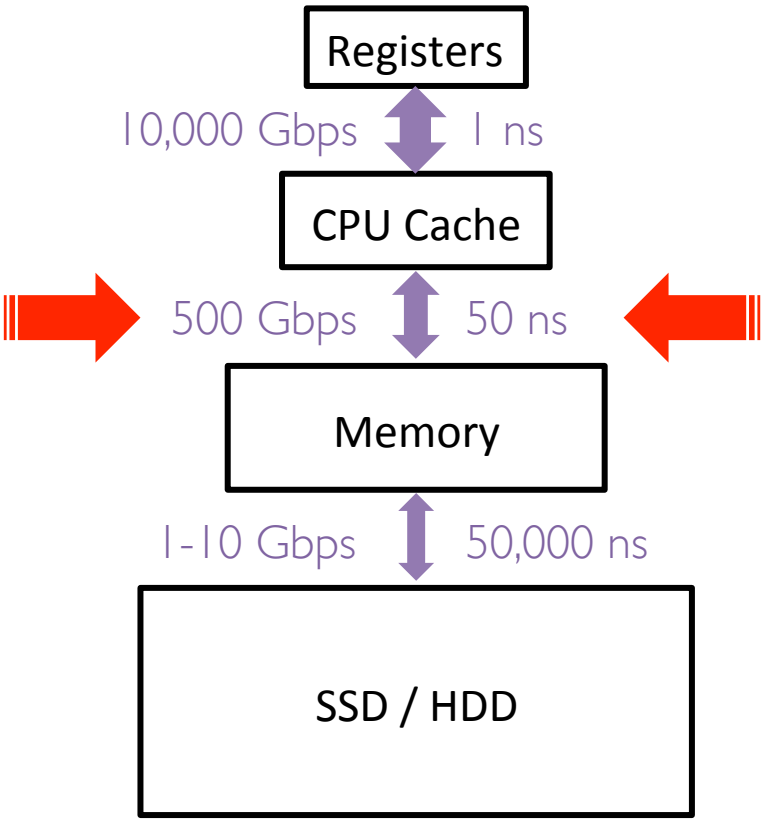


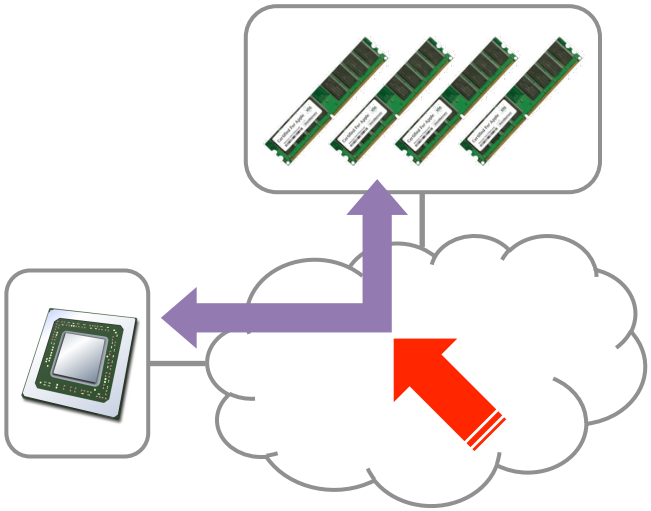
E.g., PCIe and 10GbE

- Serial
- Point-to-point
- Full duplex
- Packet-switched
- Variable packet size
- Supports both message and read/write semantics

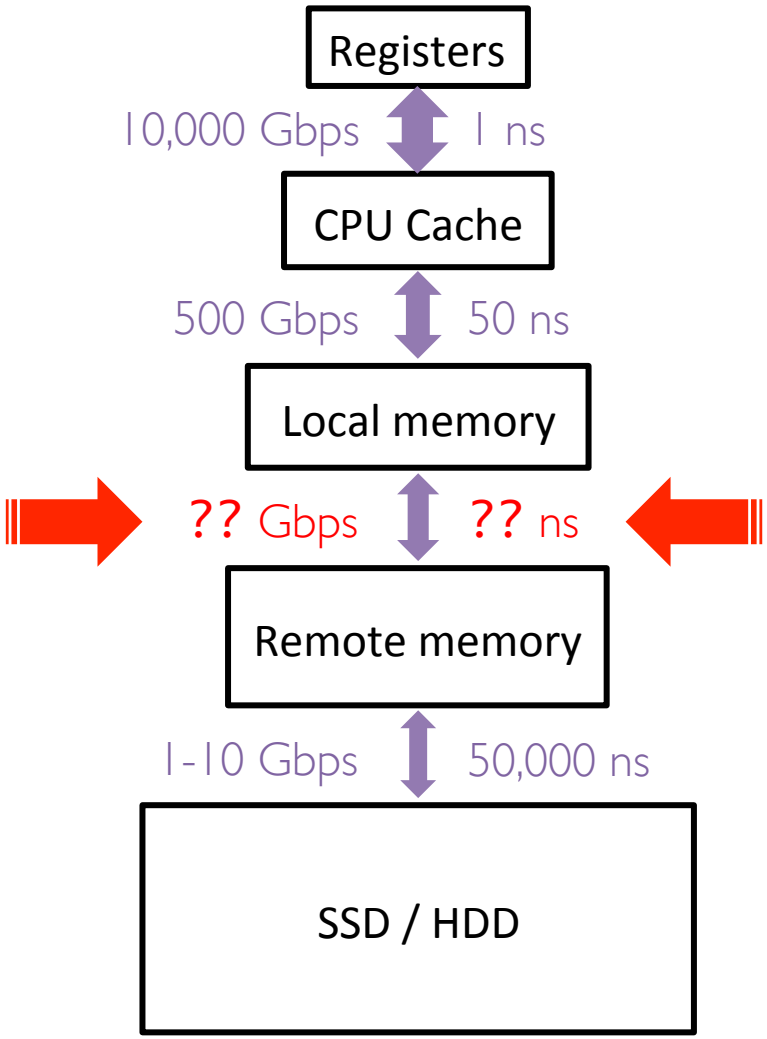
No fundamental™ difference!

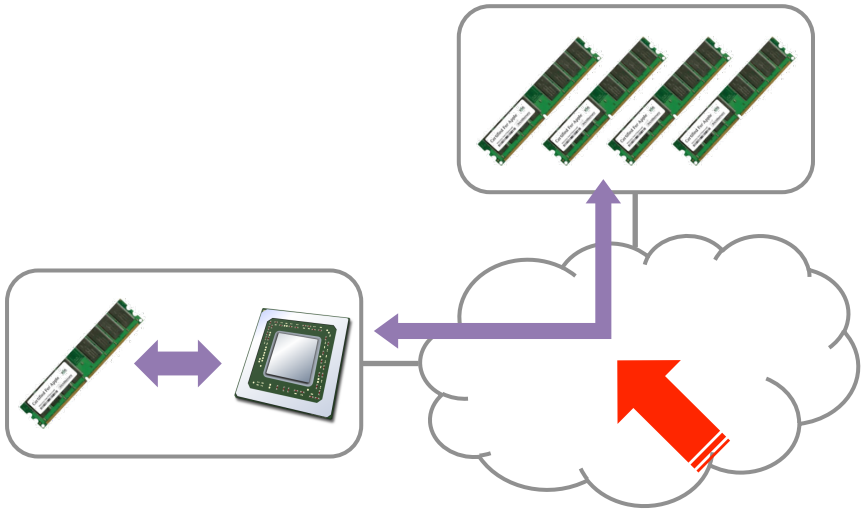
Making Memory Traffic Manageable





Making Memory Traffic Manageable

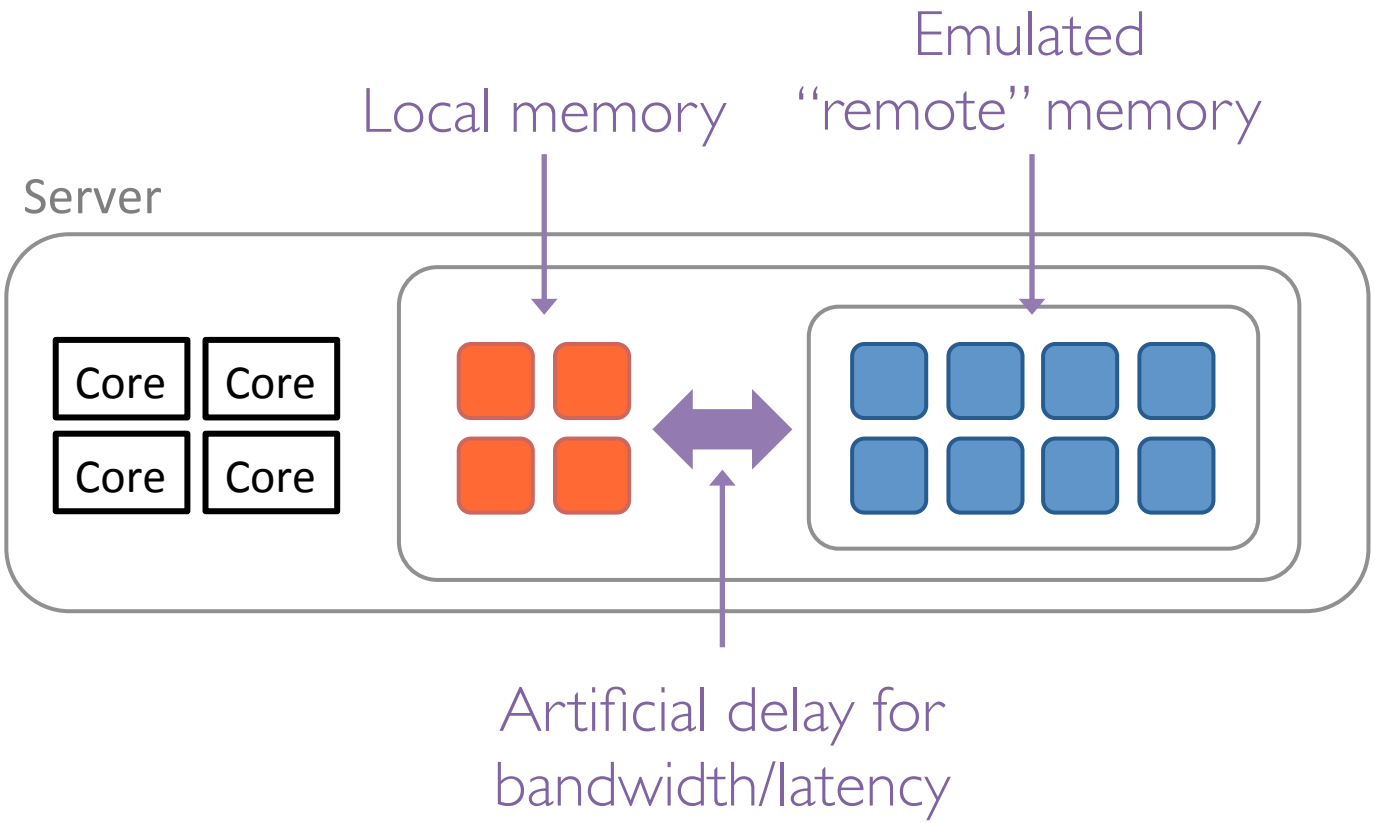




A small amount of local memory as a "cache"

Desirable Network Speed?

- A quick-and-dirty experiment



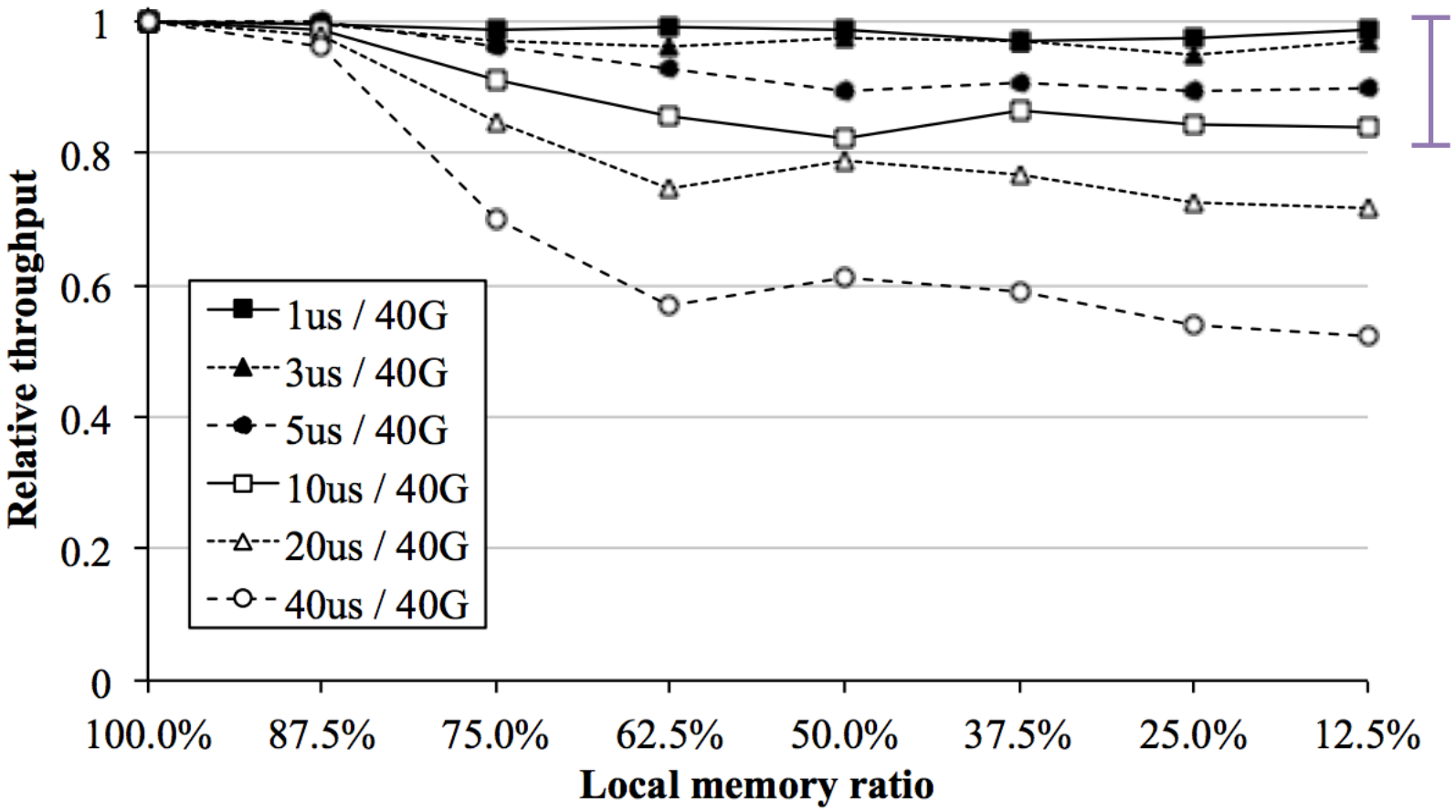
Desirable Network Speed?

- 4 CPU cores, 8GB working set size
- GraphLab, memcached, Pig

- Findings (read the paper)
  1. 10-40 Gbps is enough.
     1. Feasible even today!
     2. Average link utilization: < 1-5Gbps
  2. Latency matters.

WANTED: Low Latency

memcached with varying latency



< 10µs latency, < 20% overhead

Research Questions

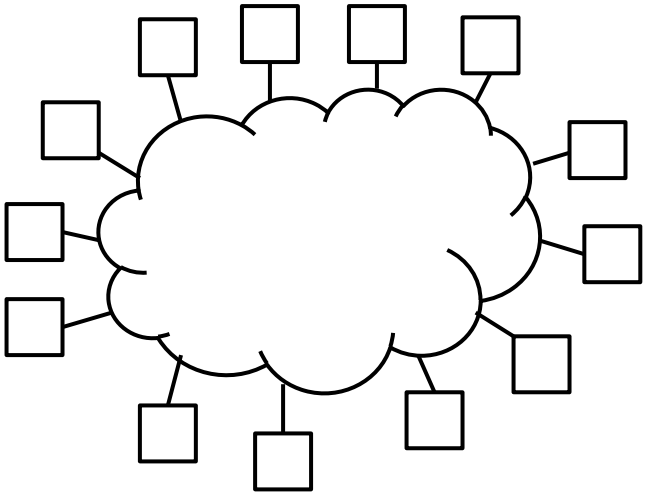
Questions

- Answered:
  - How fast should it be? >10-40Gbps, <1-10μs.

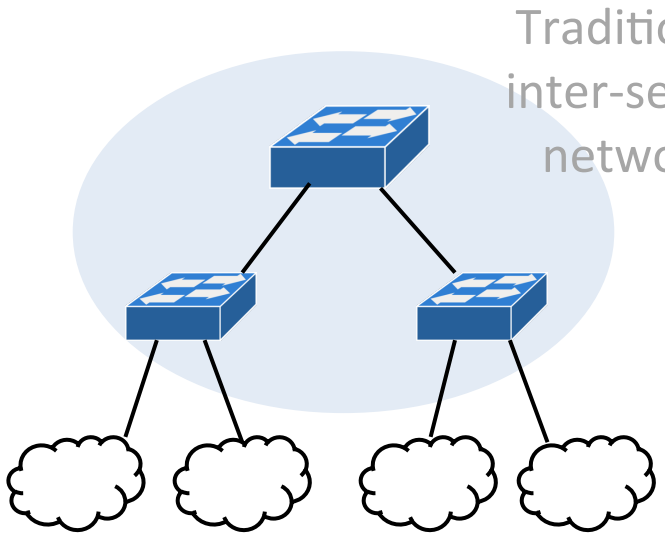
- Unanswered:
  - Scalability?
  - Reliable transfer?
  - QoS?
  - Packet? Circuit?
  - …

1. "Right" Scale of Disaggregation

- Disaggregation scale: where is the sweet spot?



datacenter-scale
(flat)



chassis/rack/pod-scale
(two-tier)

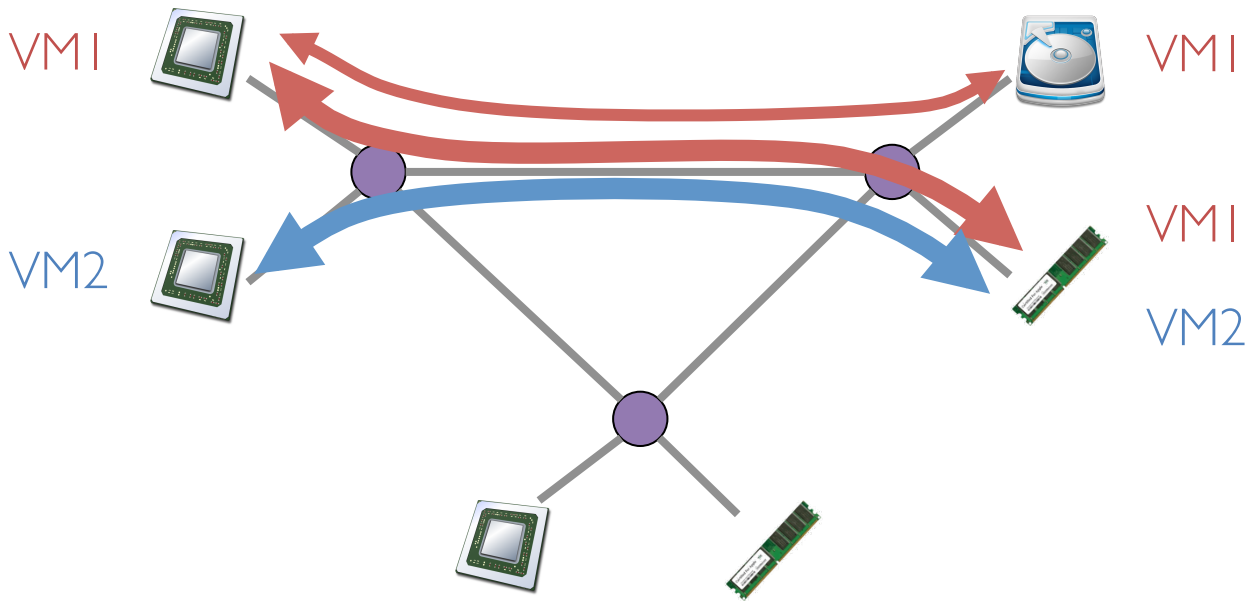
2. Realizing Low Latency

- It's time for low latency [Rumble et al., HotOS '11]
  - "5-10µs latency is possible in the short term"
  - "1µs round-trip times cannot be achieved off-processor"

- Congestion avoidance/control should be "close to the metal".
  - A lot of research efforts are ongoing.
  - Will they be still valid in disaggregated datacenters?

3. Unified Scheduler

- We will need a unified scheduler:
  - Job scheduler + network controller



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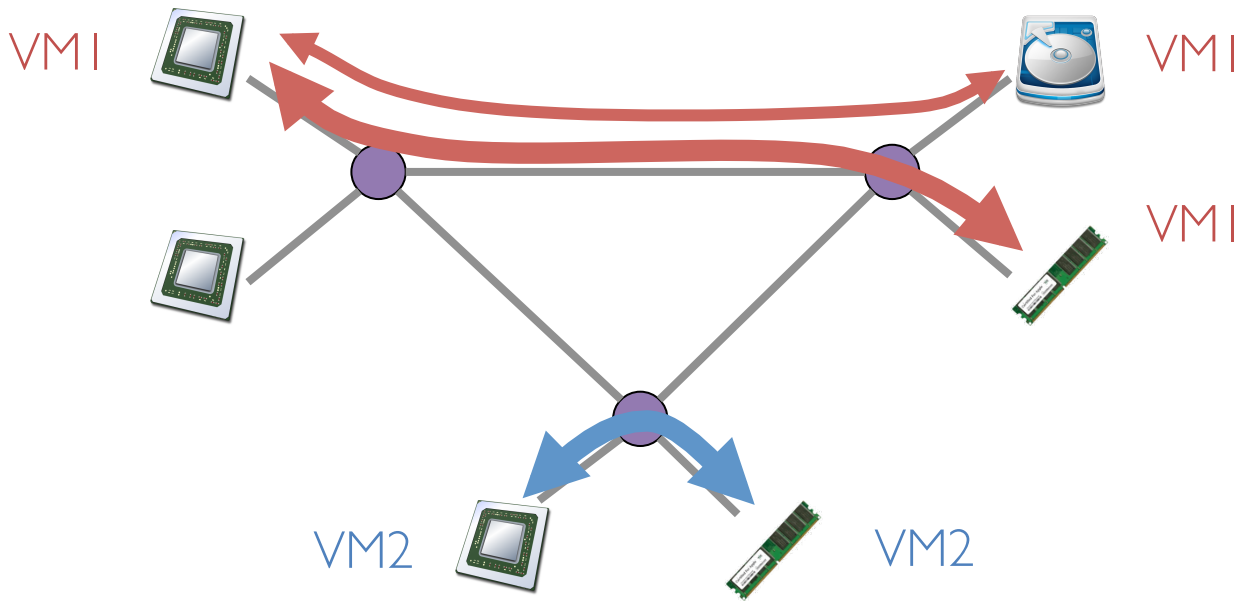

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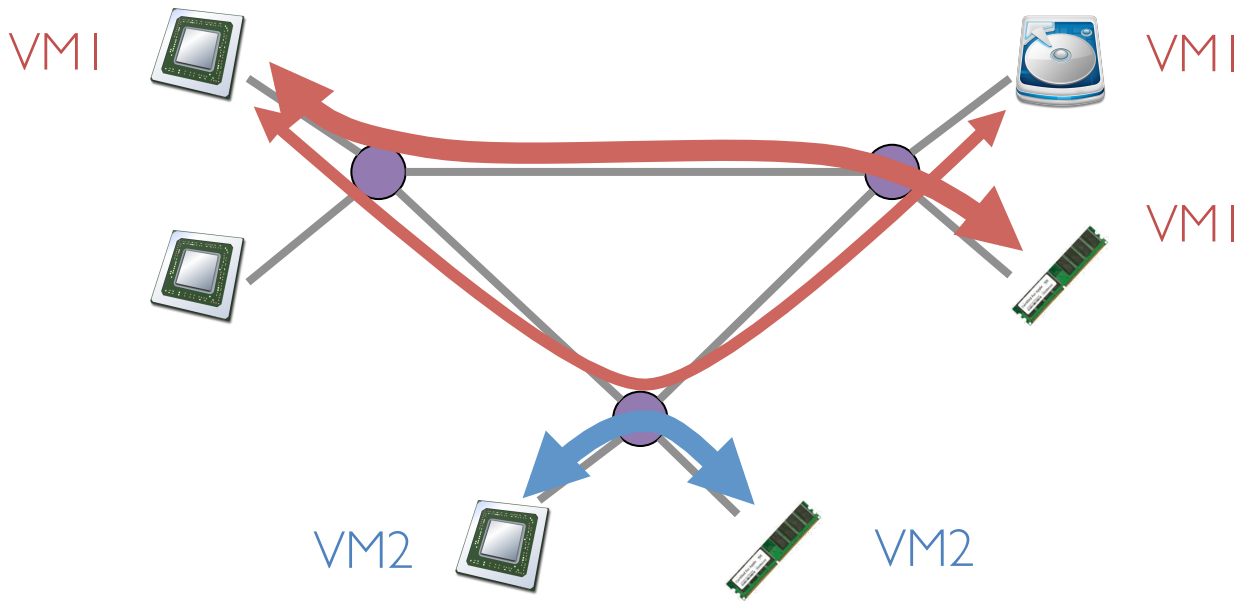

Closing Remarks

- Disaggregated datacenter will be "the next big thing"
  - Already happening. We need to catch up!

- We are working on a small-scale prototype.
  - Disaggregated resource blades on existing SW/HW
    - 40 CPUs
    - 6 remote memory blades
    - 8 GPU/NIC/storage blades
  - PCIe as the "unified interconnect"