UCSDCSE
Computer Science and Engineering

DieCast: Testing Distributed Systems with an Accurate Scale Model

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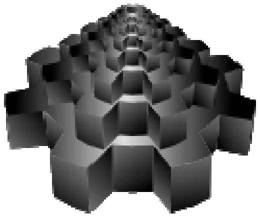


High performance filesystem

Diverse deployment environments

Limited testing infrastructure

Use smaller infrastructure to test a much larger system

Goals

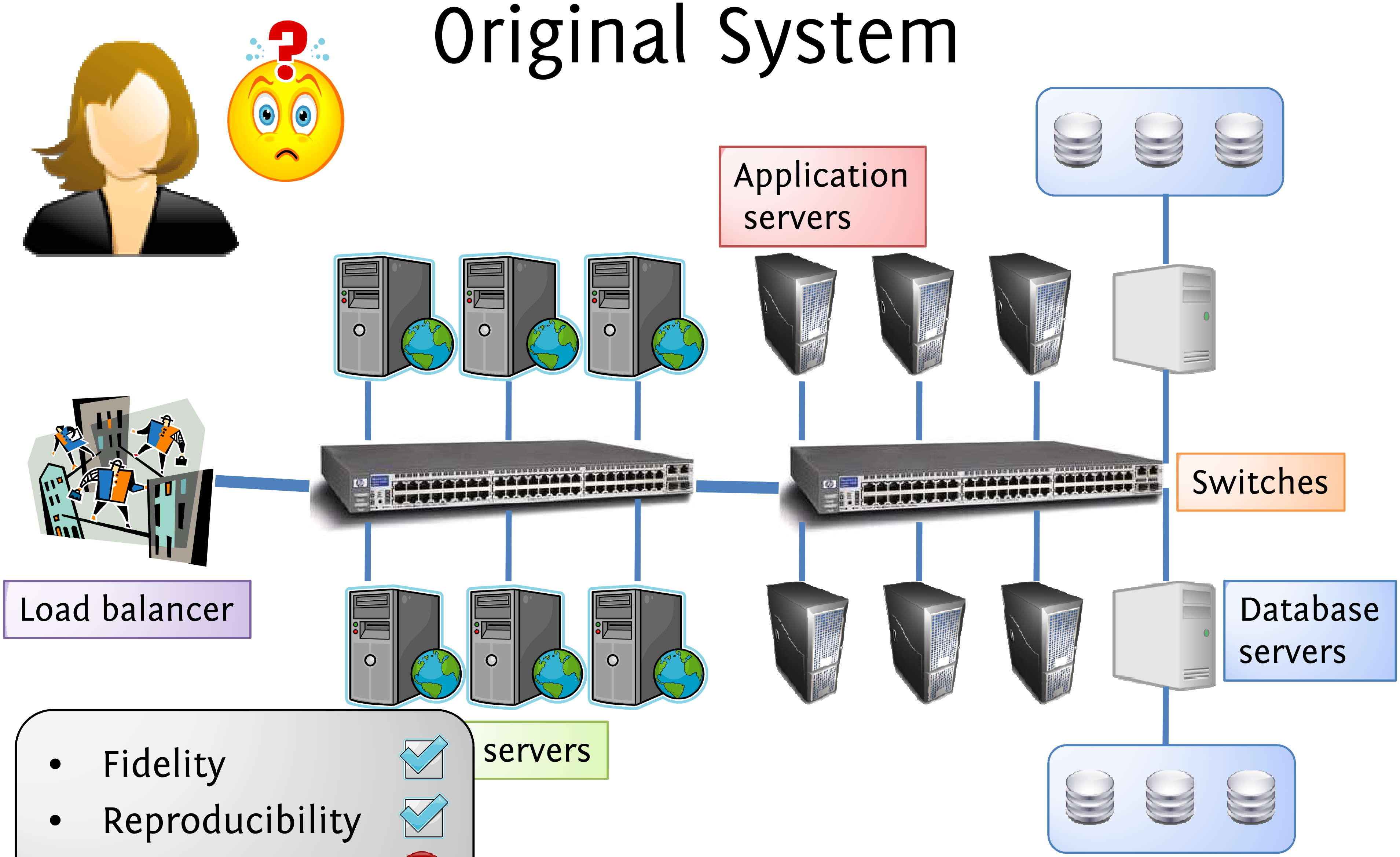
- Fidelity
  - How closely can we replicate the target system?
- Reproducibility
  - Can we do controlled experiments?
- Efficiency
  - Use fewer resources

DieCast can scale up a test infrastructure by an order of magnitude

DieCast Overview

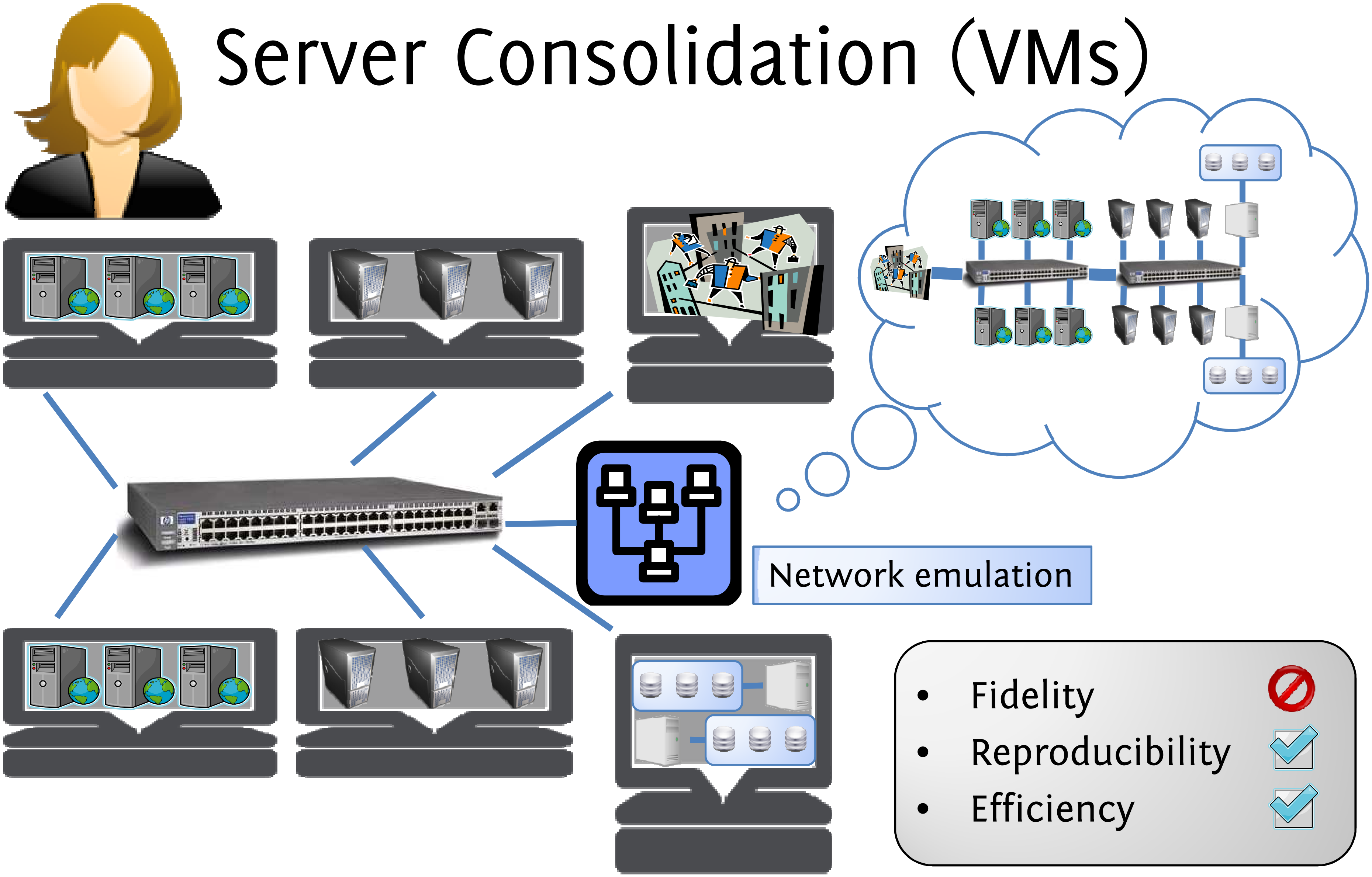
- ✓ Replicate target system using fewer machines
- ✓ Resource equivalence: *perceived* CPU capacity, disk and network characteristics
- ✓ Preserve application performance
- ✗ Not scaled
  - ✗ Physical memory: mitigating solutions
  - ✗ Secondary storage: cheap

Original System



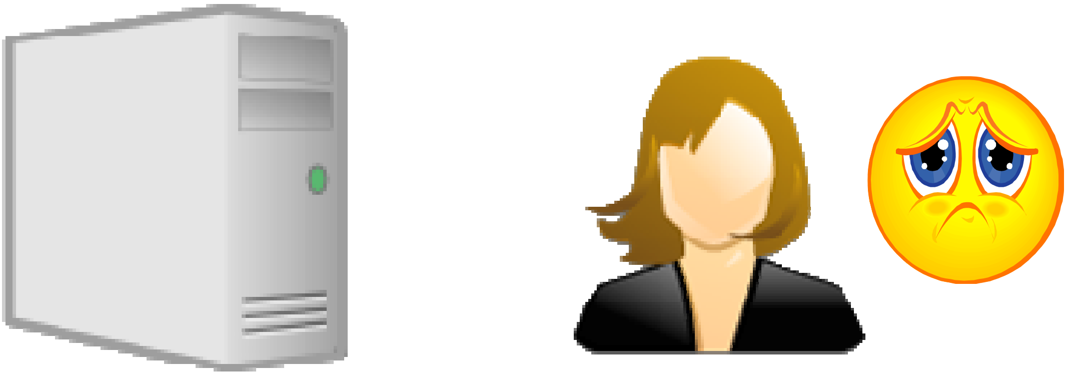
- Fidelity ✓
- Reproducibility ✓
- Efficiency ⊘

Server Consolidation (VMs)



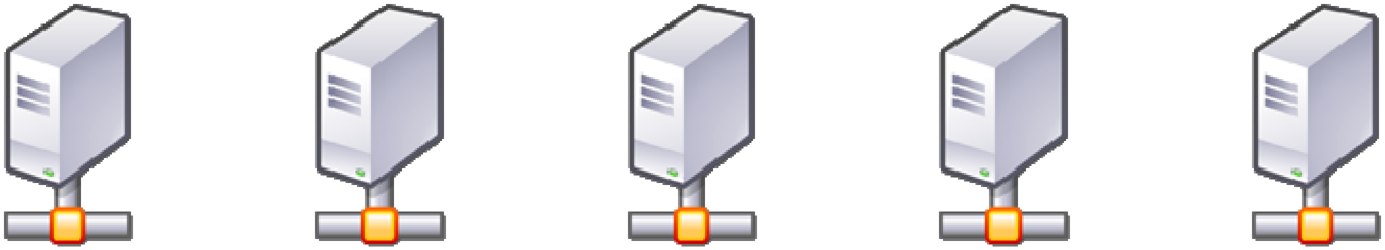
- Fidelity 🚫
- Reproducibility ✓
- Efficiency ✓

Multiplexing Leads to Resource Partitioning



3 GHz CPU, 1 Gbps N/W, 15 Mbps disk I/O, 2 GB RAM

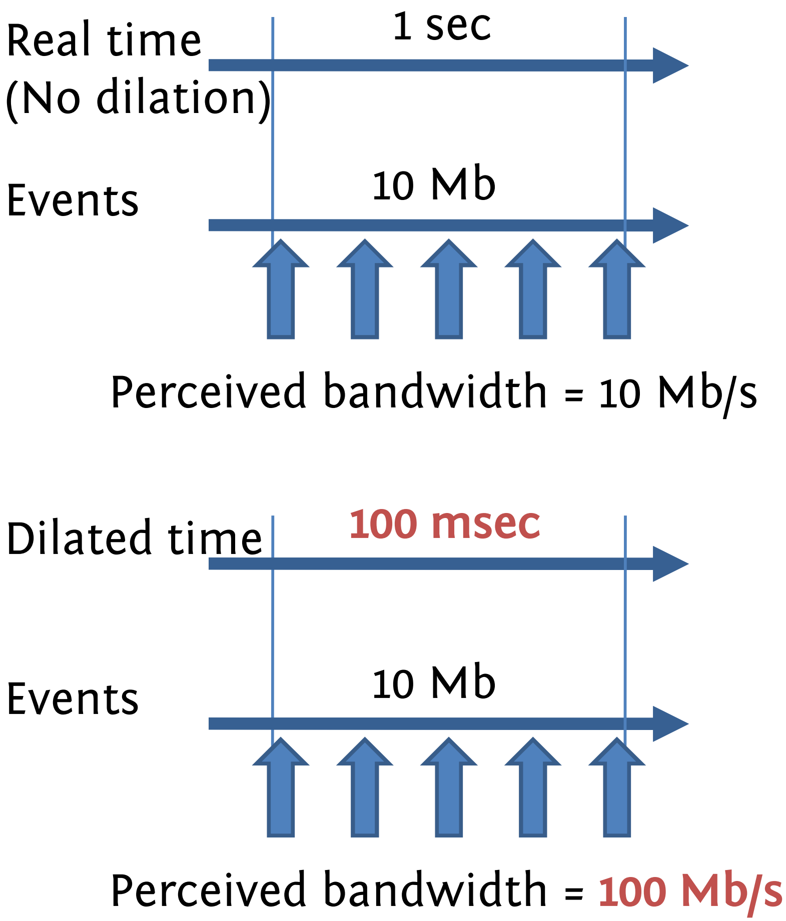
Split equally among 5 VMs



~ 600 MHz CPU, 200 Mbps N/W, 3 Mbps disk I/O, 400 MB RAM **each**

Time Dilation [NSDI 2006]

Key idea: time is also a resource!



Real time (No dilation)

1 sec

Events

10 Mb

Perceived bandwidth = 10 Mb/s

Dilated time

100 msec

Events

10 Mb

Perceived bandwidth = **100 Mb/s**

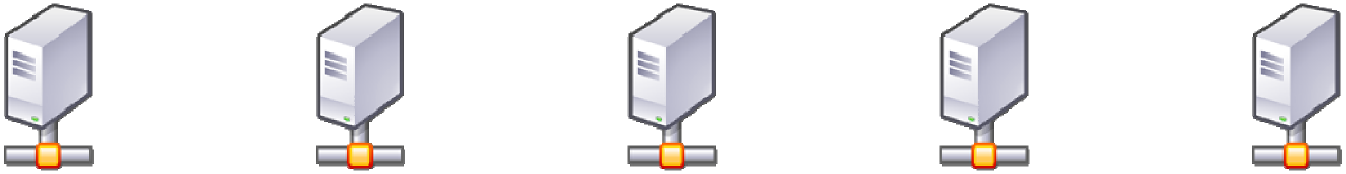
- Slow down passage of time within the OS
- CPU, network, disk – all *appear* faster
- Experiments take longer

Time Dilation Factor (TDF) = Real time/Virtual time

In this example,
TDF = 1sec/100ms = 10

Multiplexing Under Time Dilation

3 GHz CPU, 1 Gbps N/W, 15 Mbps disk I/O, 2 GB RAM

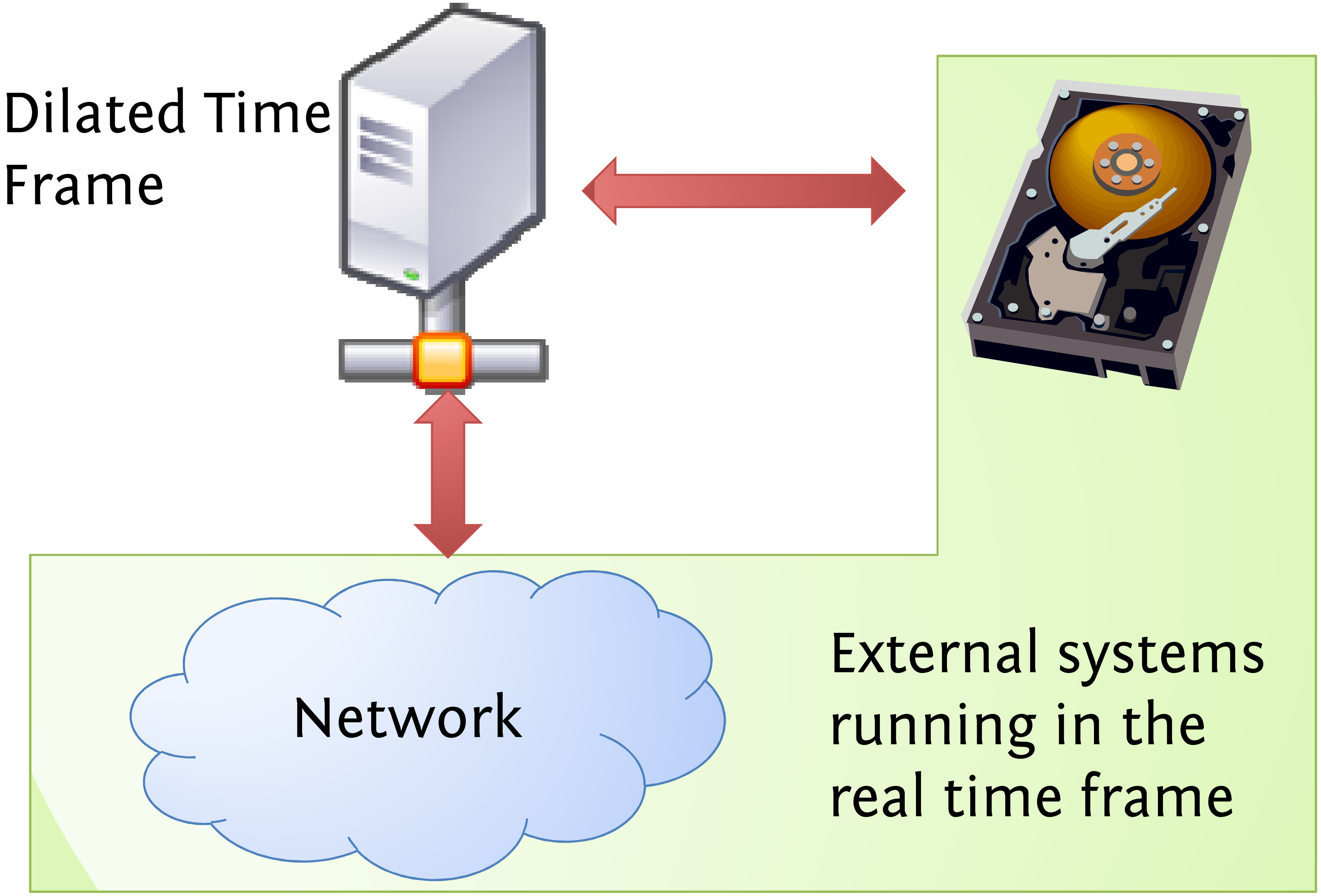


~ 600 MHz CPU, 200 Mbps N/W, 3 Mbps disk I/O, 400-MB RAM, **each**

TDF 5

~ 3 GHz CPU, 1 Gbps N/W, 15 Mbps disk I/O?, 400 MB RAM each

Time Dilation: External Interactions



Dilated Time Frame

Network

External systems running in the real time frame

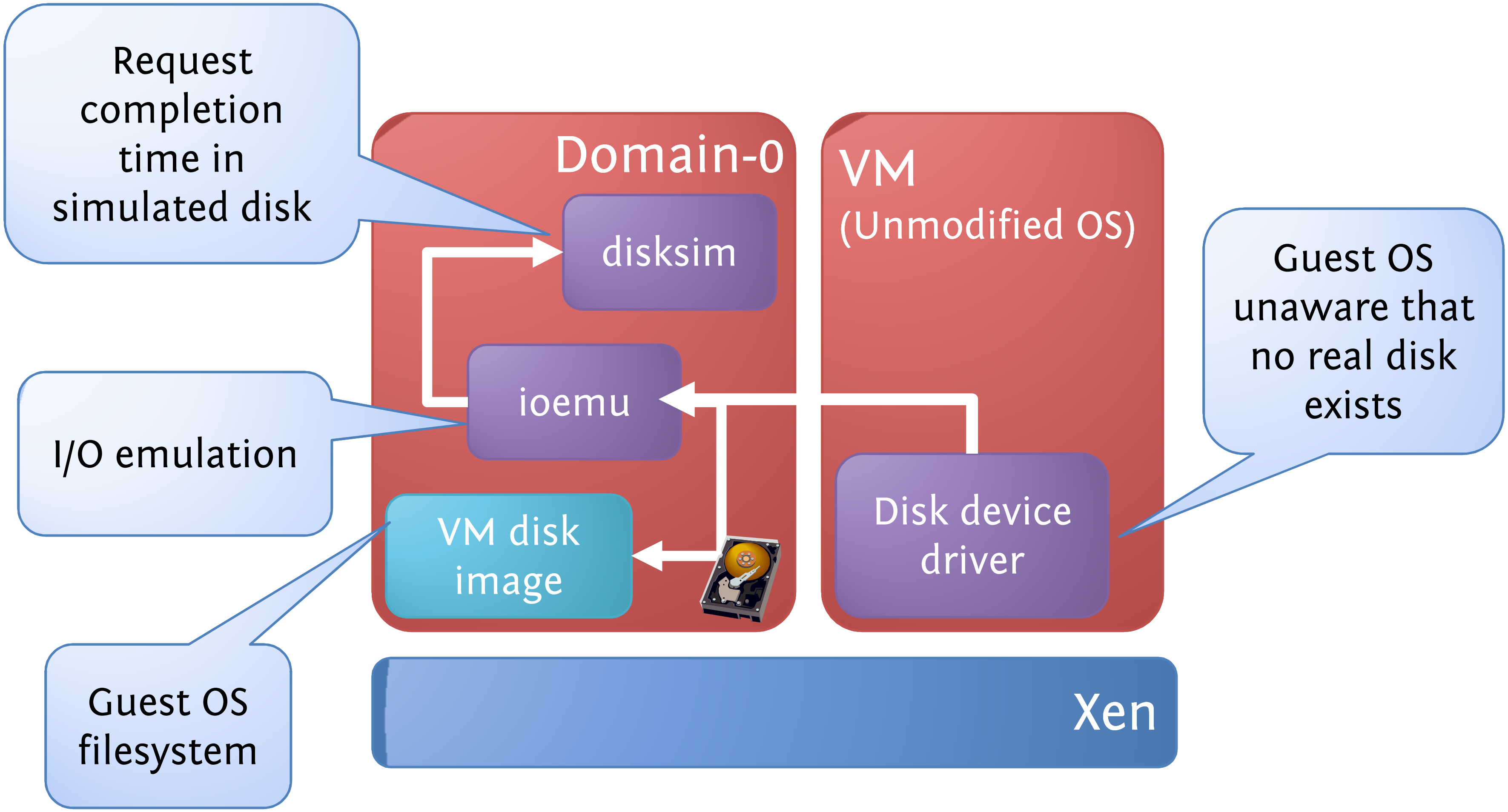
Disk I/O Scaling

- **Invariant**: perceived disk characteristics are preserved
  - Seek time
  - Read/write throughput
- Issues
  - Low level functionality in firmware
  - Different I/O models
  - Per request scaling is difficult

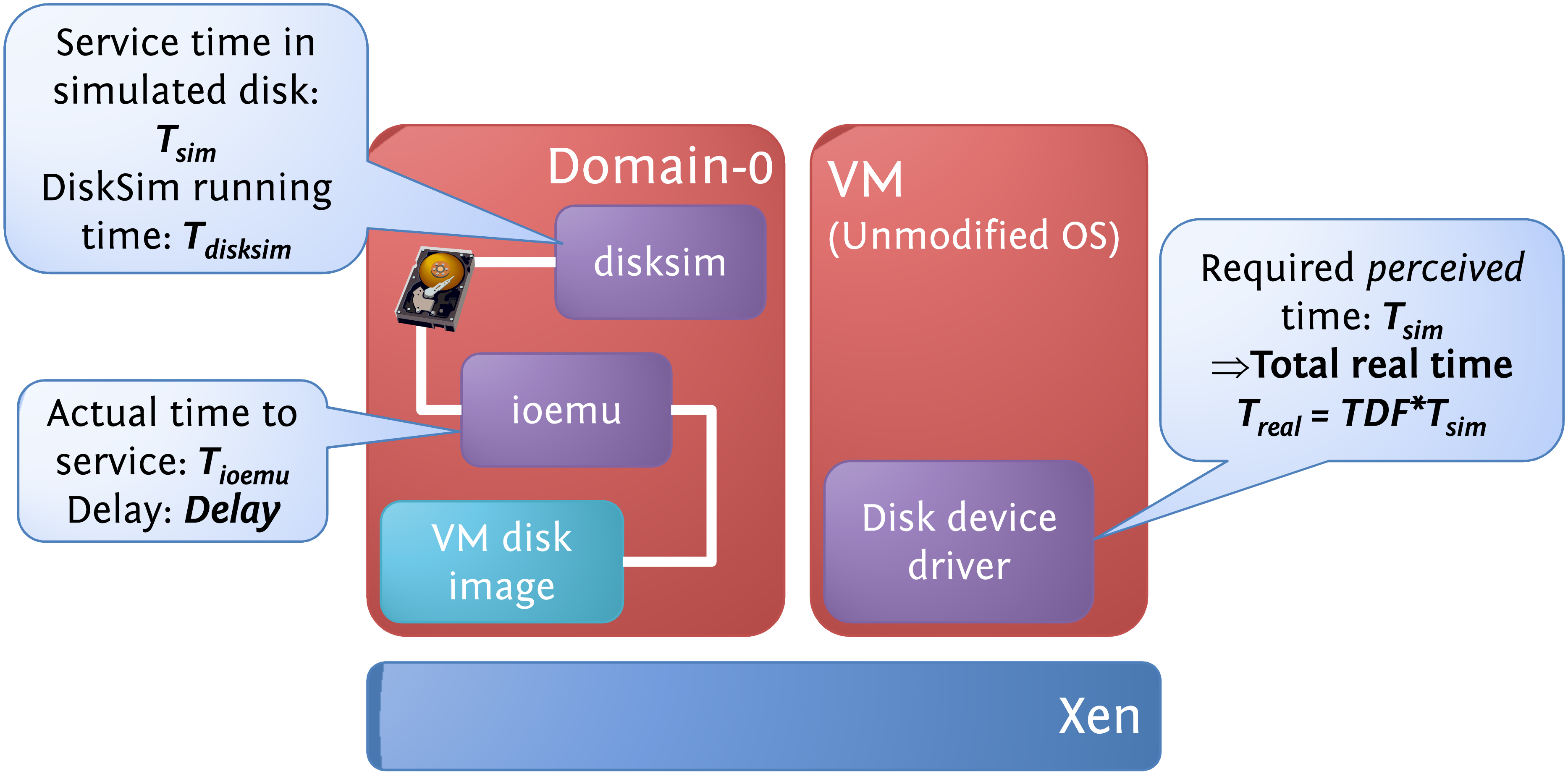
Implementation Details

- Supported platforms
  - Xen 2.0.7, 3.0.4, 3.1
  - Can be ported to non-virtualized systems
- Support for unmodified guest OSes
- Disk I/O scaling for different I/O models
  - Fully virtualized: **integration with DiskSim**
  - Paravirtualized: scaling in device driver

Disk I/O Scaling: Fully Virtualized VMs



Disk I/O Scaling: Fully Virtualized VMs



Service time in simulated disk: T_{sim}
DiskSim running time: $T_{disksim}$

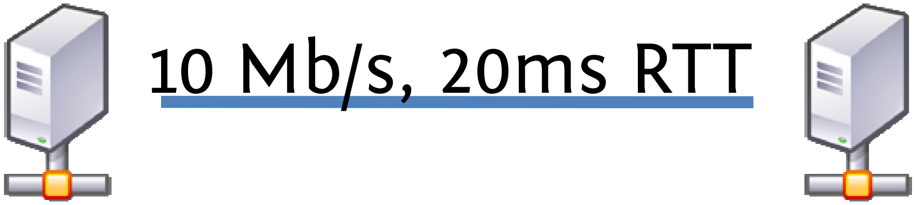
Actual time to service: T_{ioemu}
Delay: ***Delay***

Required *perceived* time: T_{sim}
⇒**Total real time $T_{real} = TDF^{*}T_{sim}$**

$$T_{real} = T_{ioemu} + \mathit{Delay} + T_{disksim}$$
$$\Rightarrow \mathit{Delay} = (TDF^{*}T_{sim}) - T_{disksim} - T_{ioemu}$$

Network I/O Scaling

Invariant: *Perceived* network characteristics (bandwidths and latencies) must be preserved



10 Mb/s, 20ms RTT

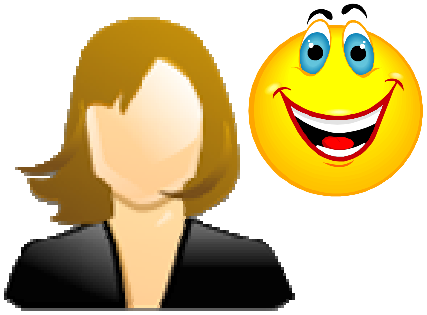
	Real Configuration	Perceived Configuration
Original system (TDF 1)	10 Mb/s, 20 ms	10 Mb/s, 20 ms
Time Dilation (TDF 5)	10 Mb/s, 20 ms	**50 Mb/s, 4 ms**
DieCast (TDF 5)	2 Mb/s, 100 ms	**10 Mb/s, 20 ms**

Network emulation: ModelNet, Dummynet

Recap

- Multiplex VMs for efficiency
- Time dilation to scale resources
- Disk I/O scaling
- Network I/O scaling

- Fidelity ✓
- Reproducibility ✓
- Efficiency ✓

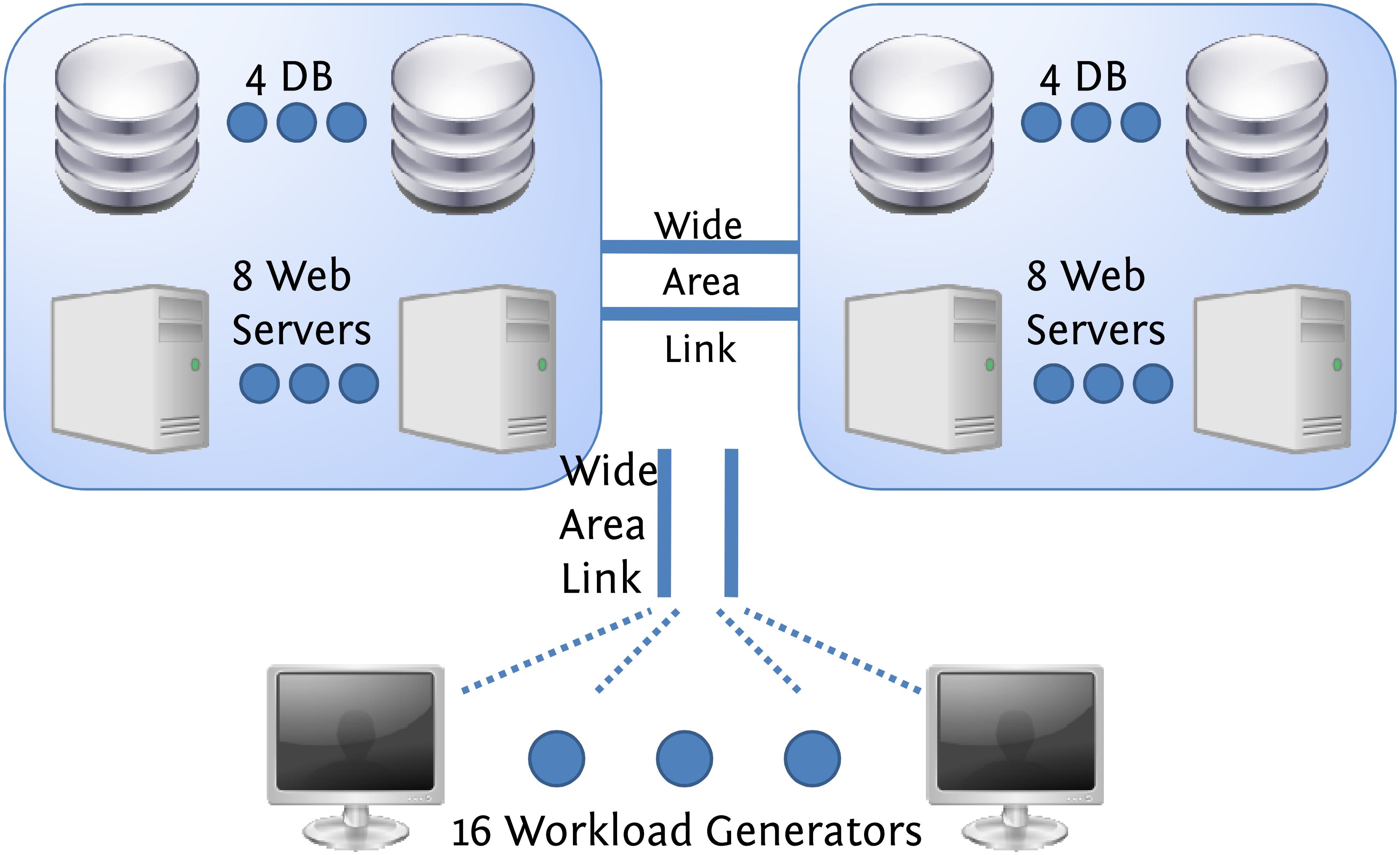


At this point, the scaled system *almost* looks like original system!

Validation

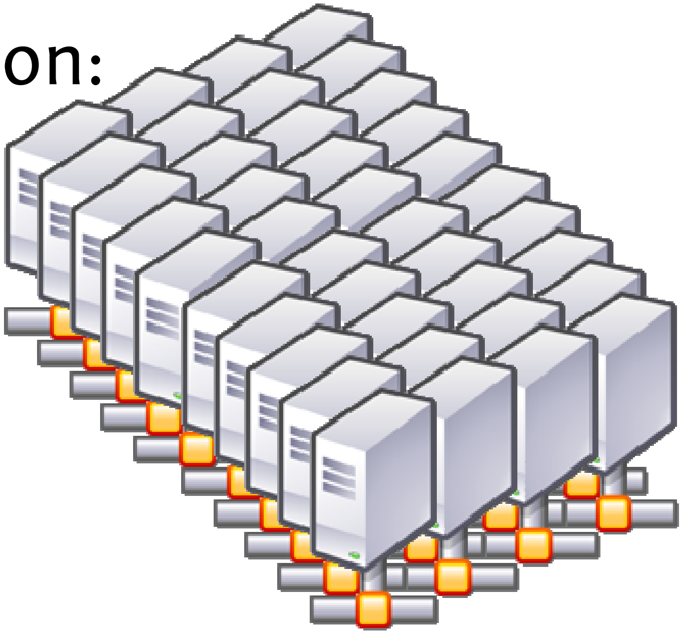
- How well does DieCast scaled performance match the original system?
  - Application specific metrics
- Can a smaller system be configured to match the resources of a larger system?
  - Resource utilization profiles
- Applications: **RUBiS**, BitTorrent, Isaac
- RUBiS
  - eBay like e-Commerce service
  - Ships with workload generator

RUBiS: Topology

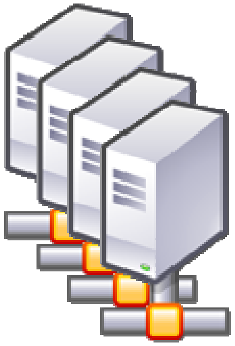


Experimental Setup

Baseline configuration: 40 physical machines

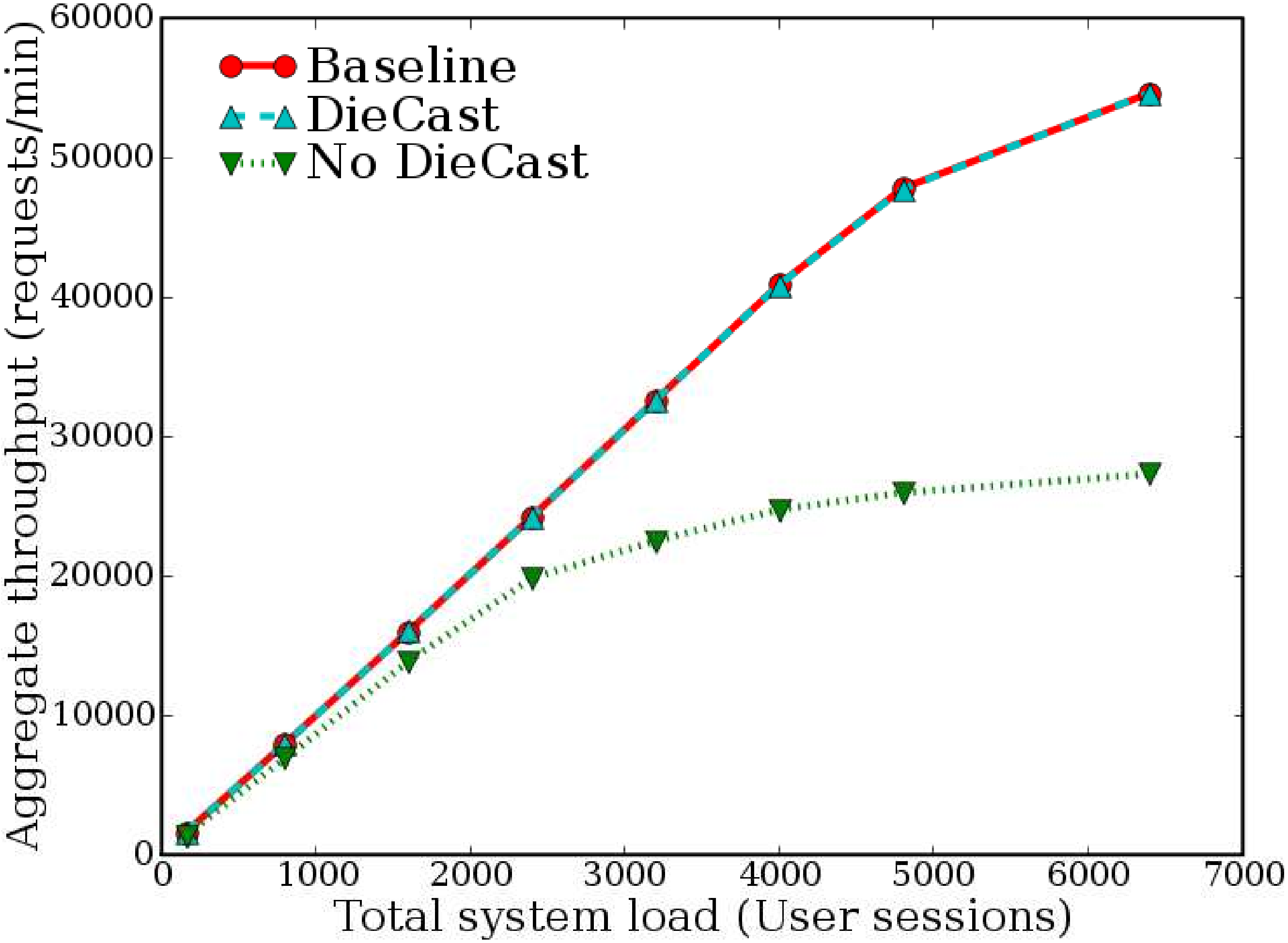


DieCast scaled Configuration: 4 physical machines, 10 VMs each

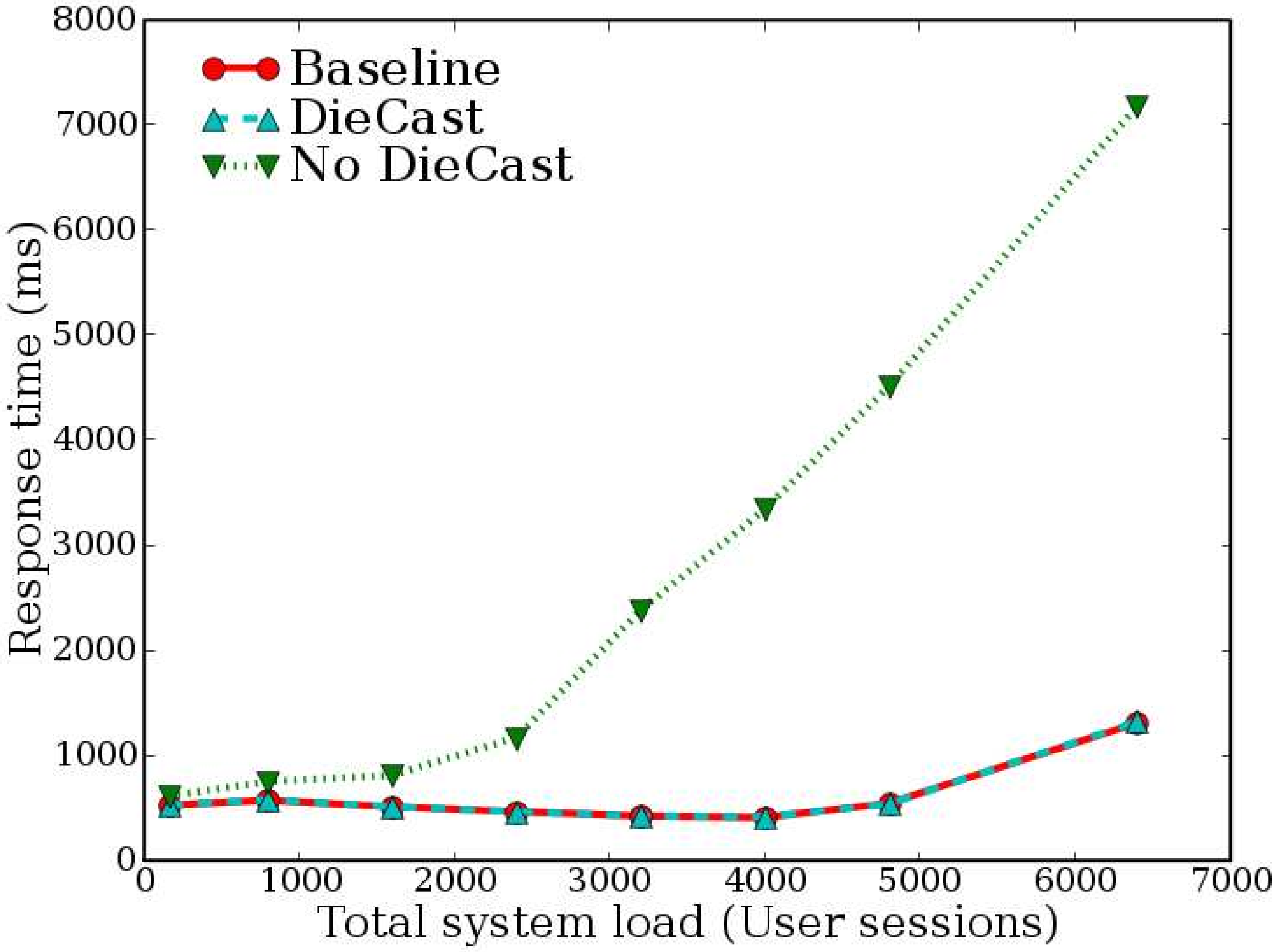


- Xen 3.1, fully virtualized VMs
- Debian Etch, Linux 2.6.17, 256 MB RAM
- DiskSim emulating Seagate ST3217
- Network emulation using ModelNet

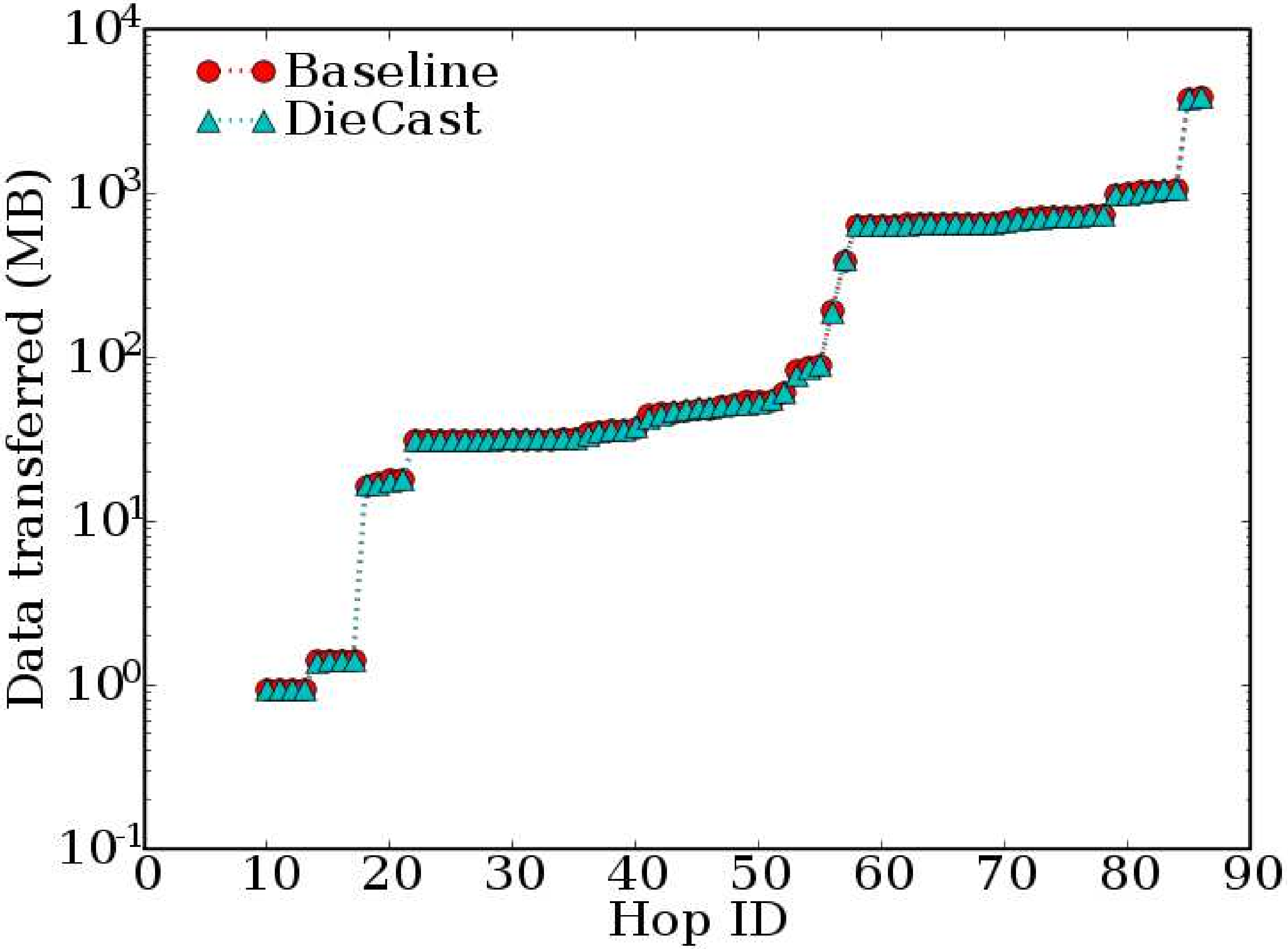
RUBiS: Throughput



RUBiS: Response Time



RUBiS: Resource Usage



Validation Recap

- Evaluated
  - RUBiS
  - BitTorrent
  - Isaac
- Demonstrated
  - Match application specific metrics
  - Preserve resource utilization profile

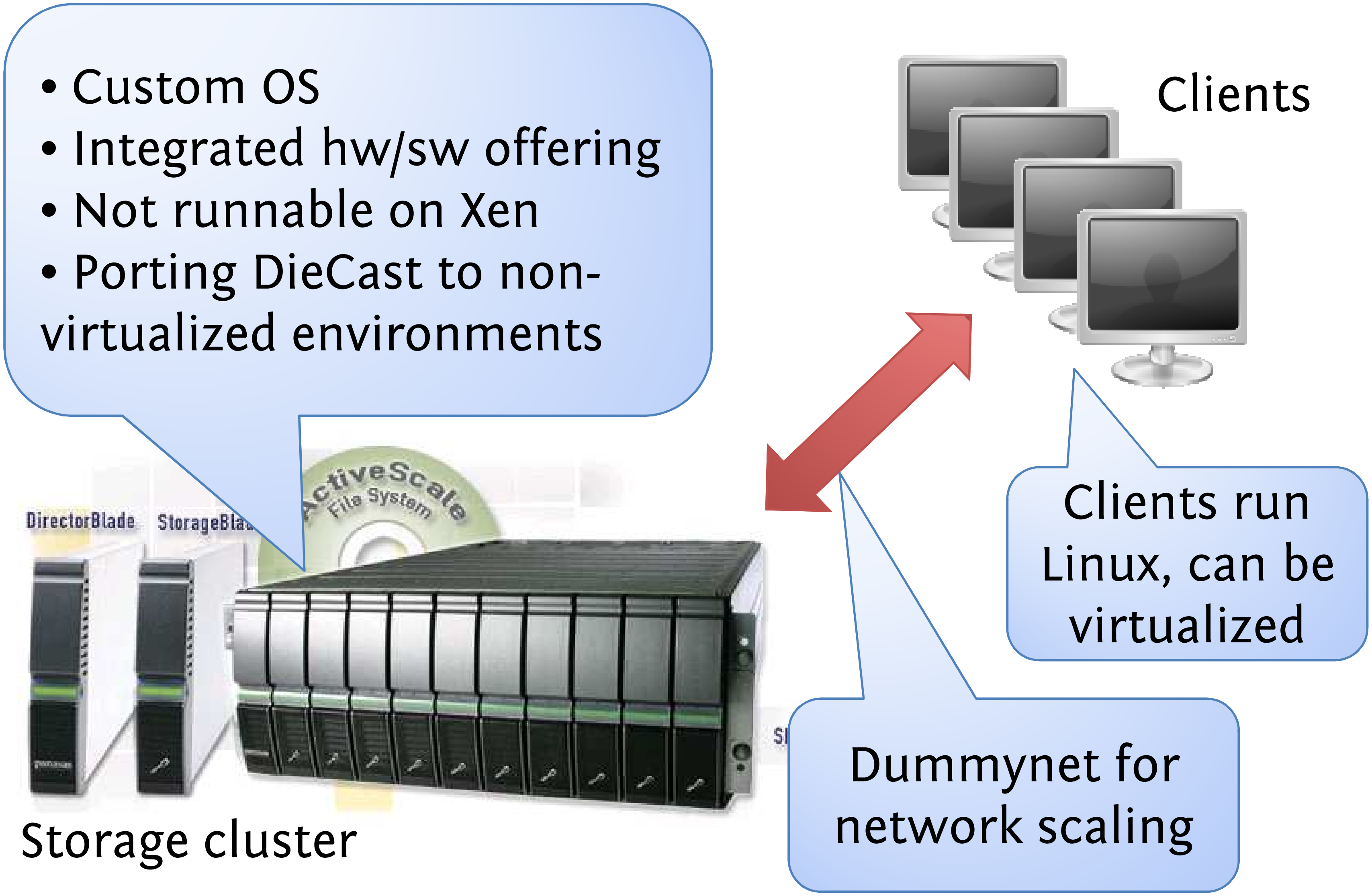
Many more details in the paper

Case study: Panasas

- Panasas builds scalable storage systems for high performance computing
  - http://www.panasas.com
- Caters to variety of clients
- Difficult or even impossible to replicate deployment environment of all clients
- Limited resources for testing

DieCast in Panasas

- Custom OS
- Integrated hw/sw offering
- Not runnable on Xen
- Porting DieCast to non-virtualized environments



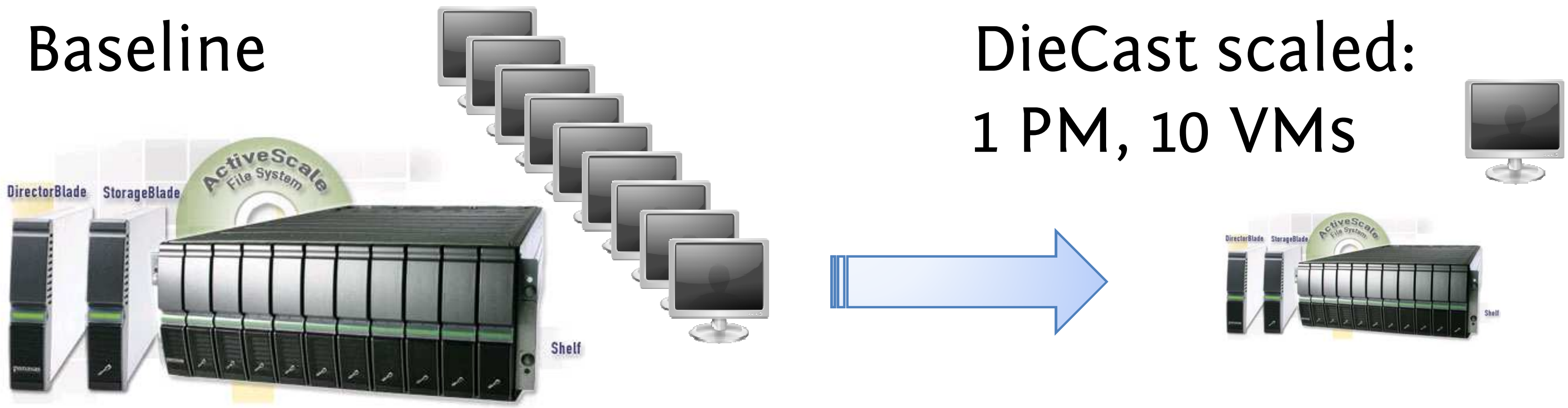
Clients

Clients run Linux, can be virtualized

Dummynet for network scaling

Storage cluster

Panasas: Evaluation Summary



Baseline

DieCast scaled:
1 PM, 10 VMs

- Validation
  - Two benchmarks from standard test suite: IOZone, MPI-IO; varying block sizes
  - Match performance metrics

Scaling: Used 100 machines to scale to **1000 clients**

Limitations

- Memory scaling
- Long running workloads
- Specialized hardware appliances
- Fine grained timing

Summary

- DieCast: scalable testing
  - Fidelity, Reproducibility, Efficiency
- Contributions
  - Support for unmodified operating systems
  - Implement disk I/O scaling (DiskSim integration)
  - CPU scheduler enhancements for time dilation
  - Comprehensive evaluation, including a commercial storage system

Thanks!

Questions?

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