PetaCache: Data Access Unleashed

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Outline

- Motivation – Is there a Problem?
- Economics of Solutions
- Practical Steps – Hardware/Software
- Some Performance Measurements

Motivation

Storage In Research:
Financial and Technical Observations

- Storage costs often dominate in research
  - CPU per $ has fallen faster than disk space per $ for most of the last 25 years
- Accessing data on disks is increasingly difficult
  - Transfer rates and access times (per $) are improving more slowly than CPU capacity, storage capacity or network capacity.
- The following slides are based on equipment and services that I* have bought for data-intensive science

* The WAN services from 1998 onwards were bought by Harvey Newman of Caltech

Price/Performance Evolution: My Experience

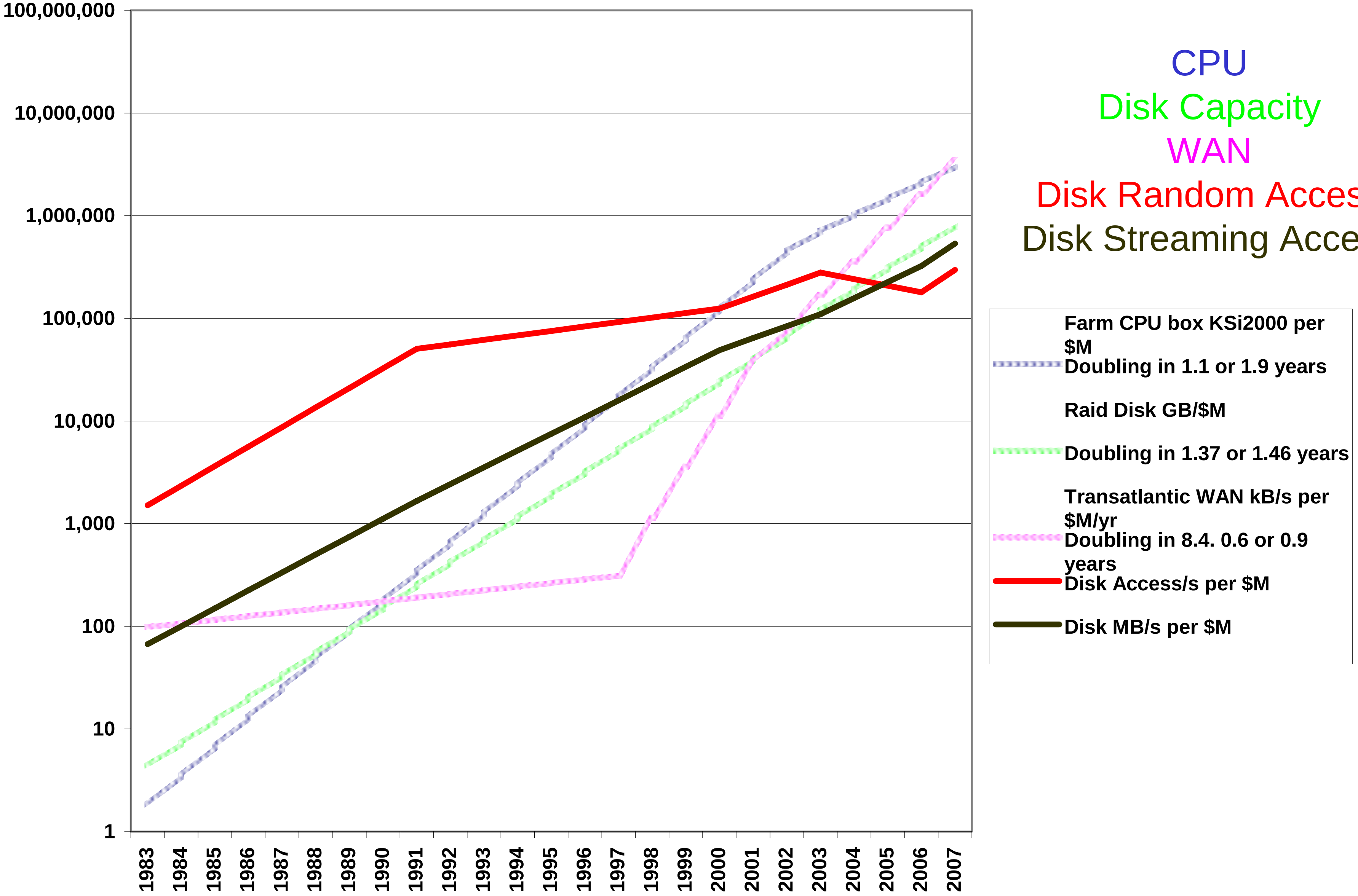
CPU

Disk Capacity

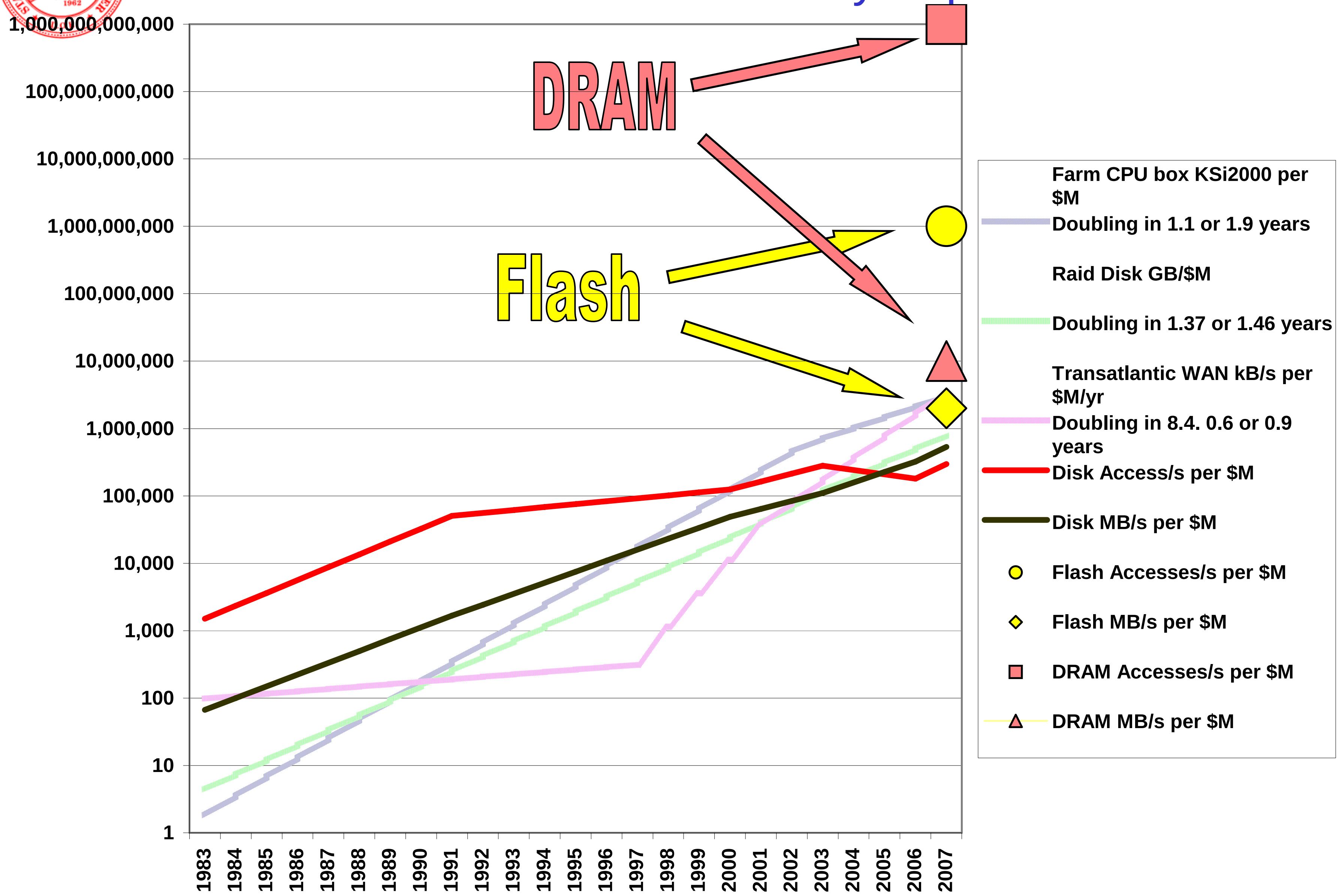
WAN

Disk Random Access

Disk Streaming Access



Price/Performance Evolution: My Experience



Another View

- In 1997 $M bought me:

  ~ 200-core CPU farm
(~few x 10^8 ops/sec/core)

  or

  ~ 1000-disk storage system
(~2 x 10^3 ops/sec/disk)

- Today $1M buys me (you):

  ~ 2500-core CPU farm
(~few x 10^9 ops/sec/core)

  or

  ~ 2500-disk storage system
(~2 x 10^3 ops/sec/disk)

- In 5 – 10 years ?

Impact on Science

- Sparse or random access must be derandomized
- Define, in advance, the interesting subsets of the data
- Filter (skim, stream) the data to instantiate interest-rich subsets

Economics of Solutions

Economics of LHC Computing

- Difficult to get $10M additional funding to improve analysis productivity
- Easy to re-purpose $10M of computing funds if it would improve analysis productivity

Cost-Effectiveness

- DRAM Memory:
  - $100/gigabyte
  - SLAC spends ~12% of its hardware budget on DRAM
- Disks (including servers)
  - $1/gigabyte
  - SLAC spends about 40% of its hardware budget on disk
- Flash-based storage (SLAC design)
  - $10/gigabyte
  - If SLAC had been spending 20% of its hardware budget on Flash we would have over 100TB today.

Practical Steps

The PetaCache Project

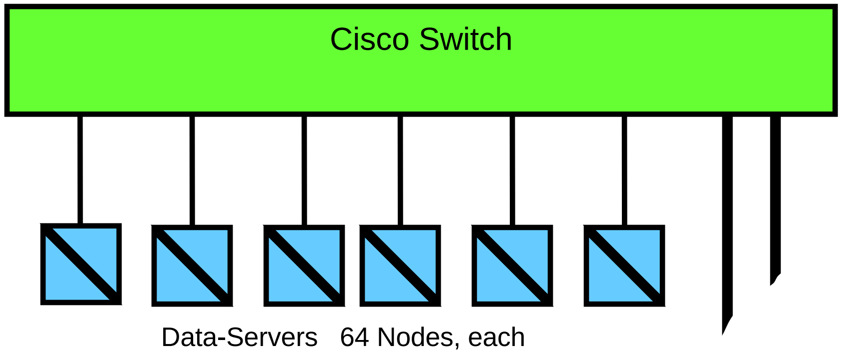
PetaCache Goals

1. Demonstrate a revolutionary but cost effective new architecture for science data analysis
2. Build and operate a machine that will be well matched to the challenges of SLAC/Stanford science

The PetaCache Story So Far

- We (BaBar, HEP) had data-access problems
- We thought and investigated
  - Underlying technical issues
  - Broader data-access problems in science
- We devised a hardware solution
  - We built a DRAM-based prototype
  - We validated the efficiency and scalability of our low-level data-access software, xrootd
  - We set up a collaboration with SLAC’s electronics wizards (Mike Huffer and Gunther Haller) to develop a more cost-effective Flash-based prototype
- We saw early on that new strategies and software for data access would also be needed

DRAM-Based Prototype Machine (Operational early 2005)



Data-Servers   64 Nodes, each
Sun V20z, 2 Opteron CPU, 16 GB memory
1TB total Memory
Solaris or Linux (mix and match)

PetaCache
MICS + HEP-
BaBar Funding

DRAM-Based Prototype

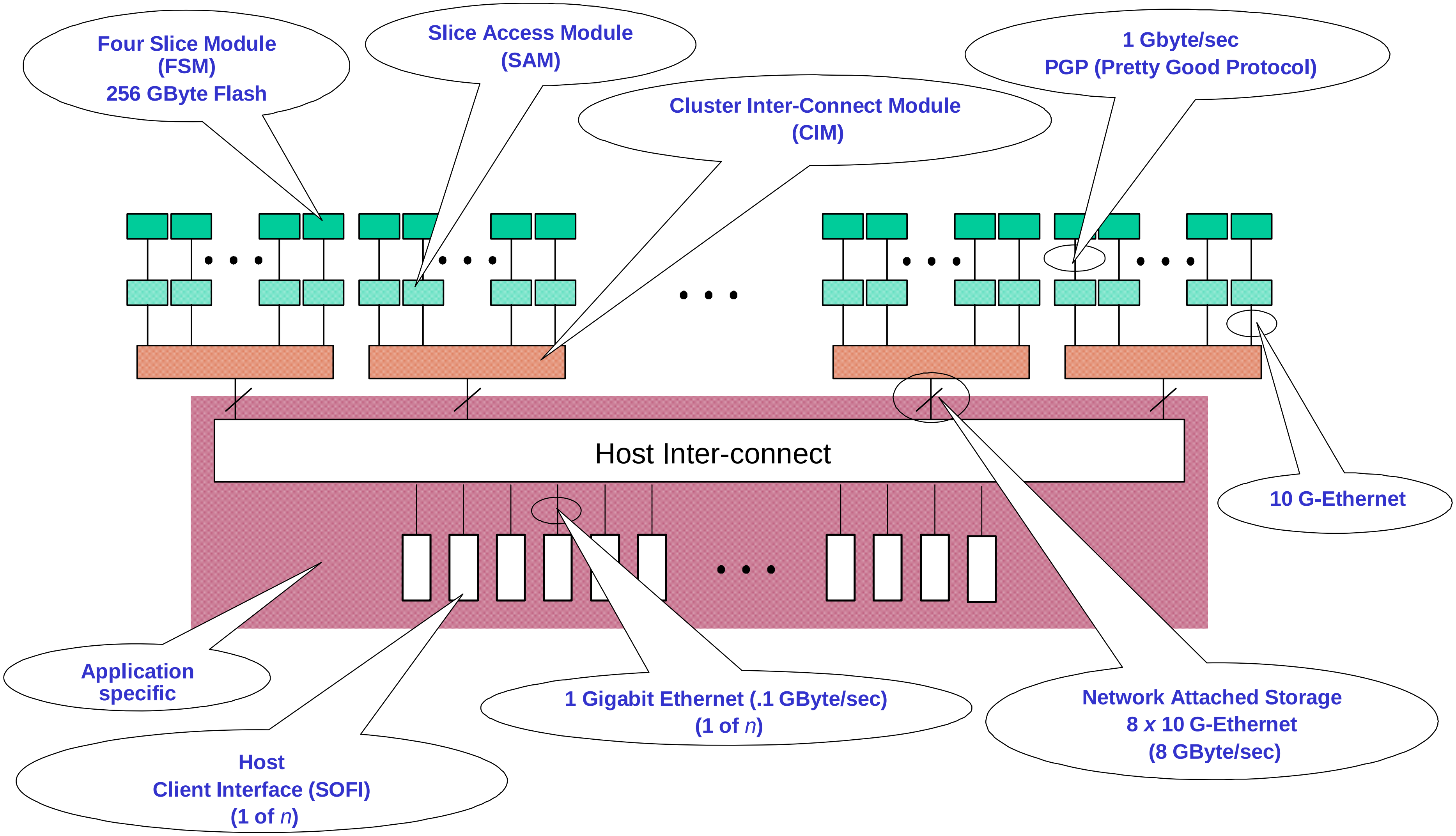
FLASH-Based Prototype Operational Real Soon Now

- 5 TB of Flash memory
- Fine-grained, high bandwidth access

SLAC Department of Particle & Particle Astrophysics

Office of Science/ U.S. D.O.E.

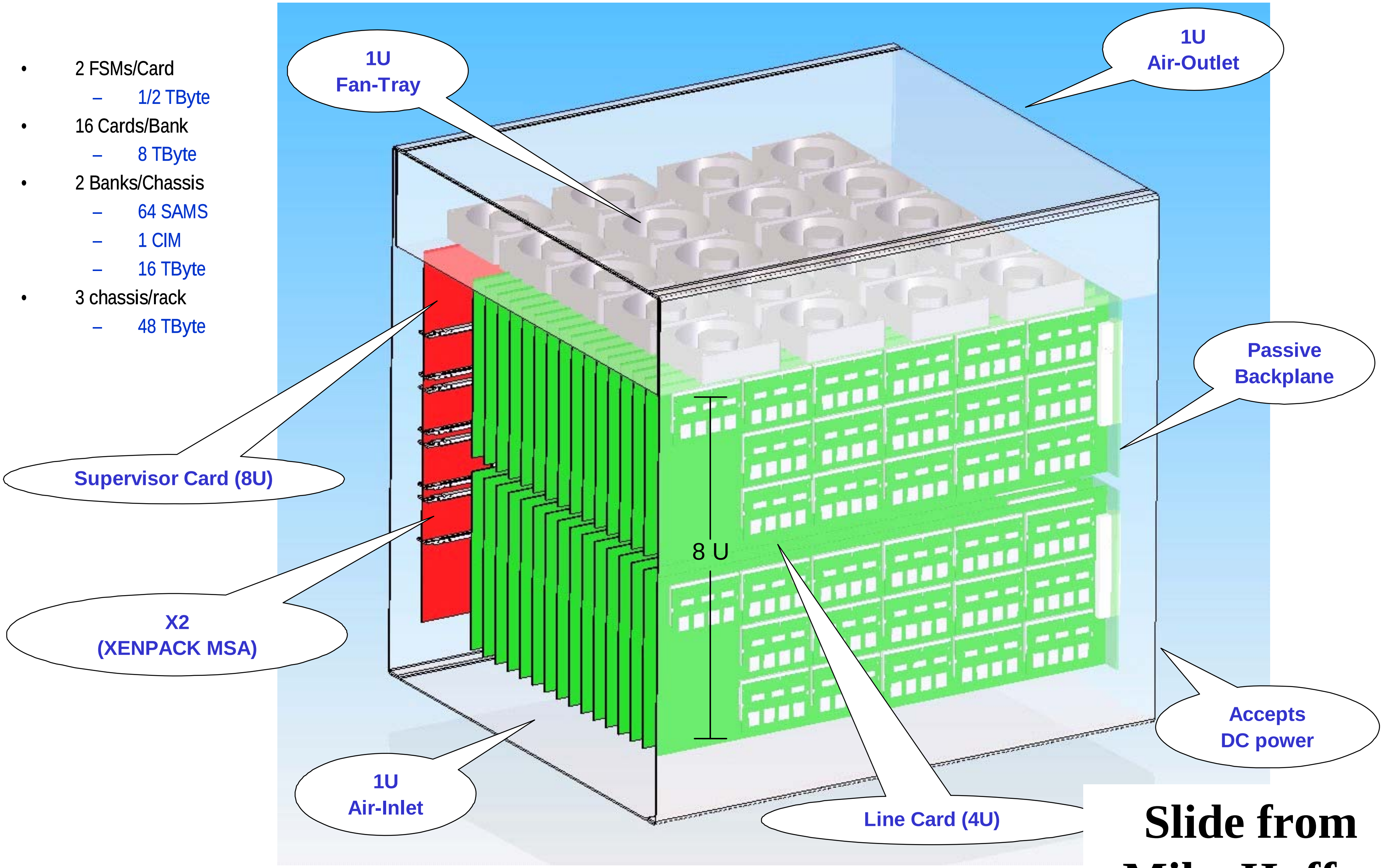
Building Blocks



Slide from
Mike Huffer

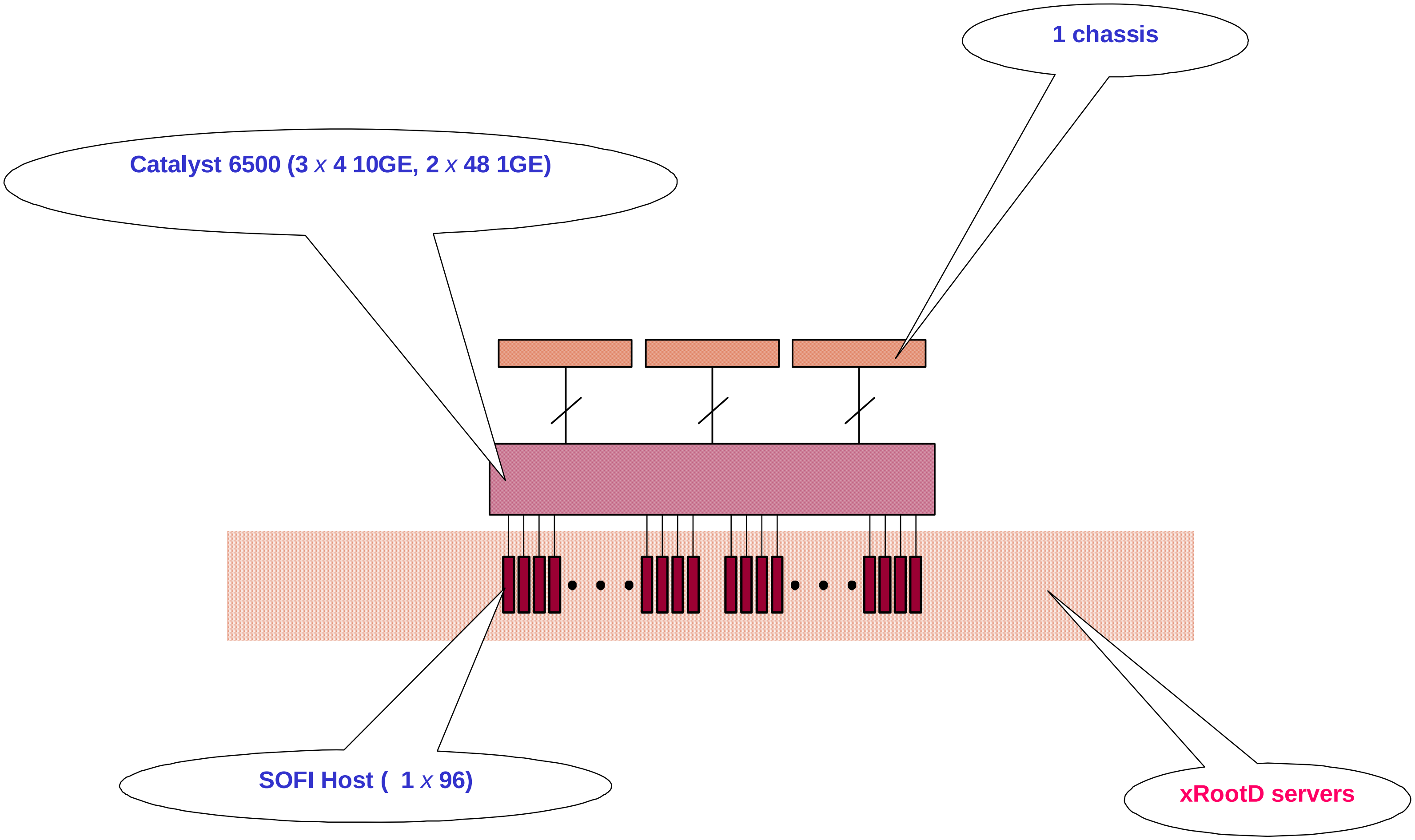
The "Chassis"

- 2 FSMs/Card
  - 1/2 TByte
- 16 Cards/Bank
  - 8 TByte
- 2 Banks/Chassis
  - 64 SAMS
  - 1 CIM
  - 16 TByte
- 3 chassis/rack
  - 48 TByte



Slide from Mike Huffer

48 TByte facility



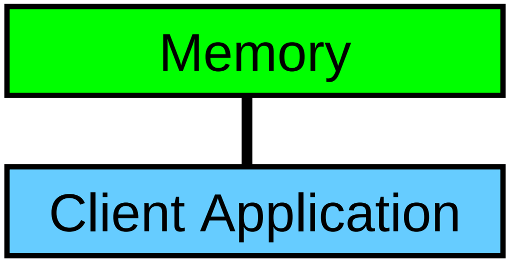
**Slide from
Mike Huffer**

Commercial Product

- Violin Technologies
  - 100s of GB of DRAM per box (available now)
  - TB of Flash per box (available real soon now)
  - PCIe hardware interface
  - Simple block-level device interface
  - DRAM prototype tested at SLAC

Some Performance Measurements

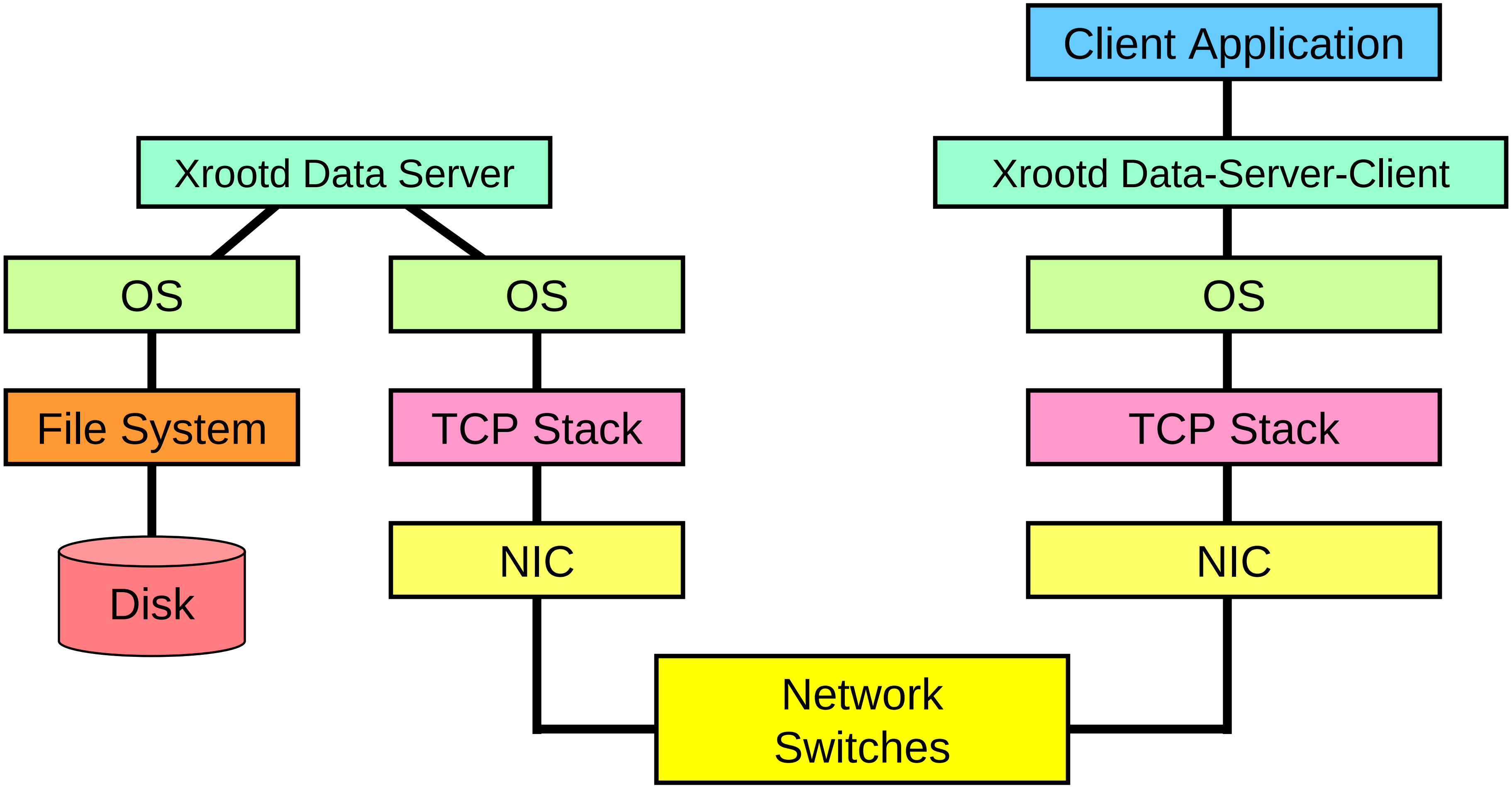
Latency (1)
Ideal



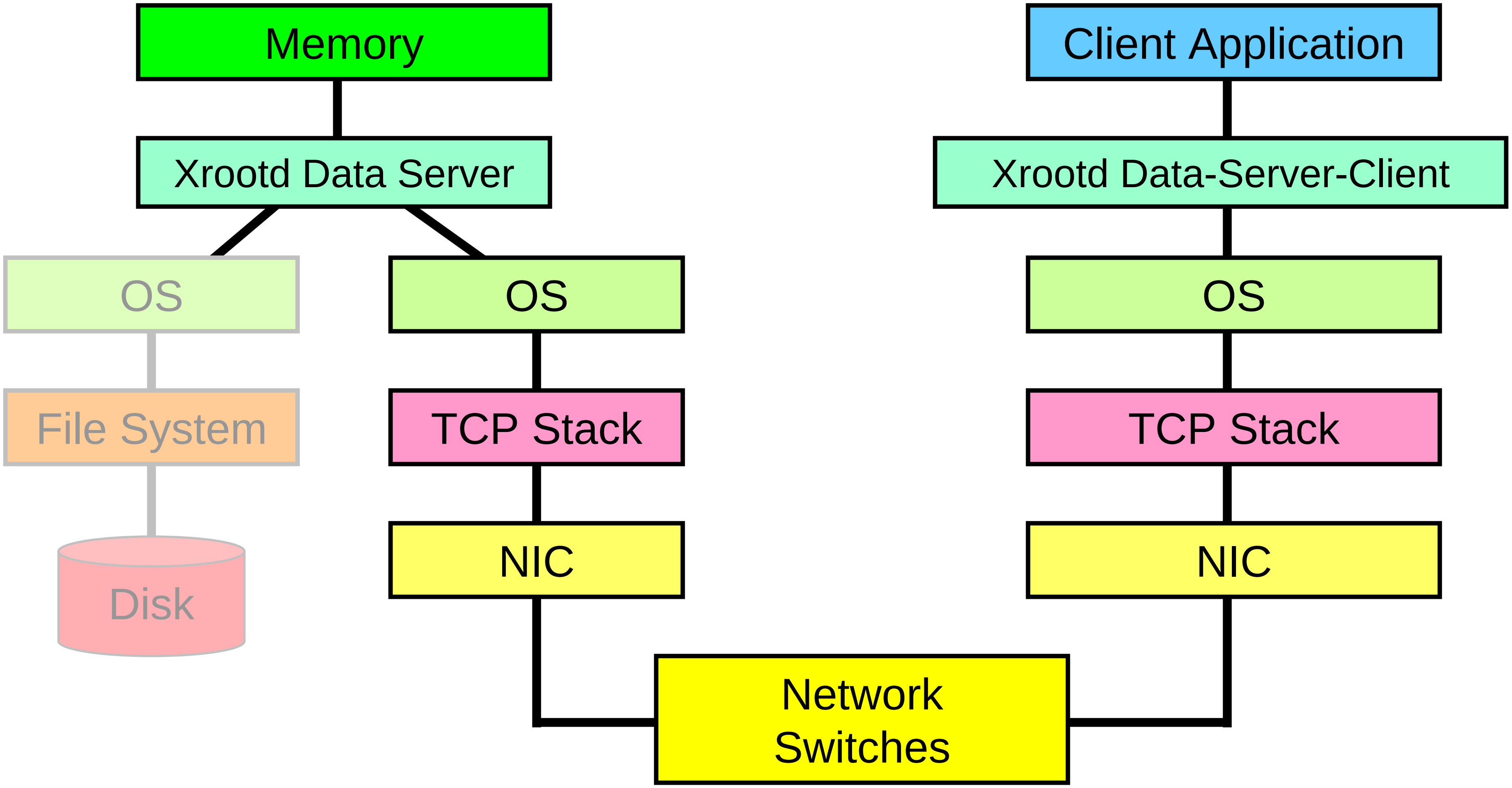
Memory

Client Application

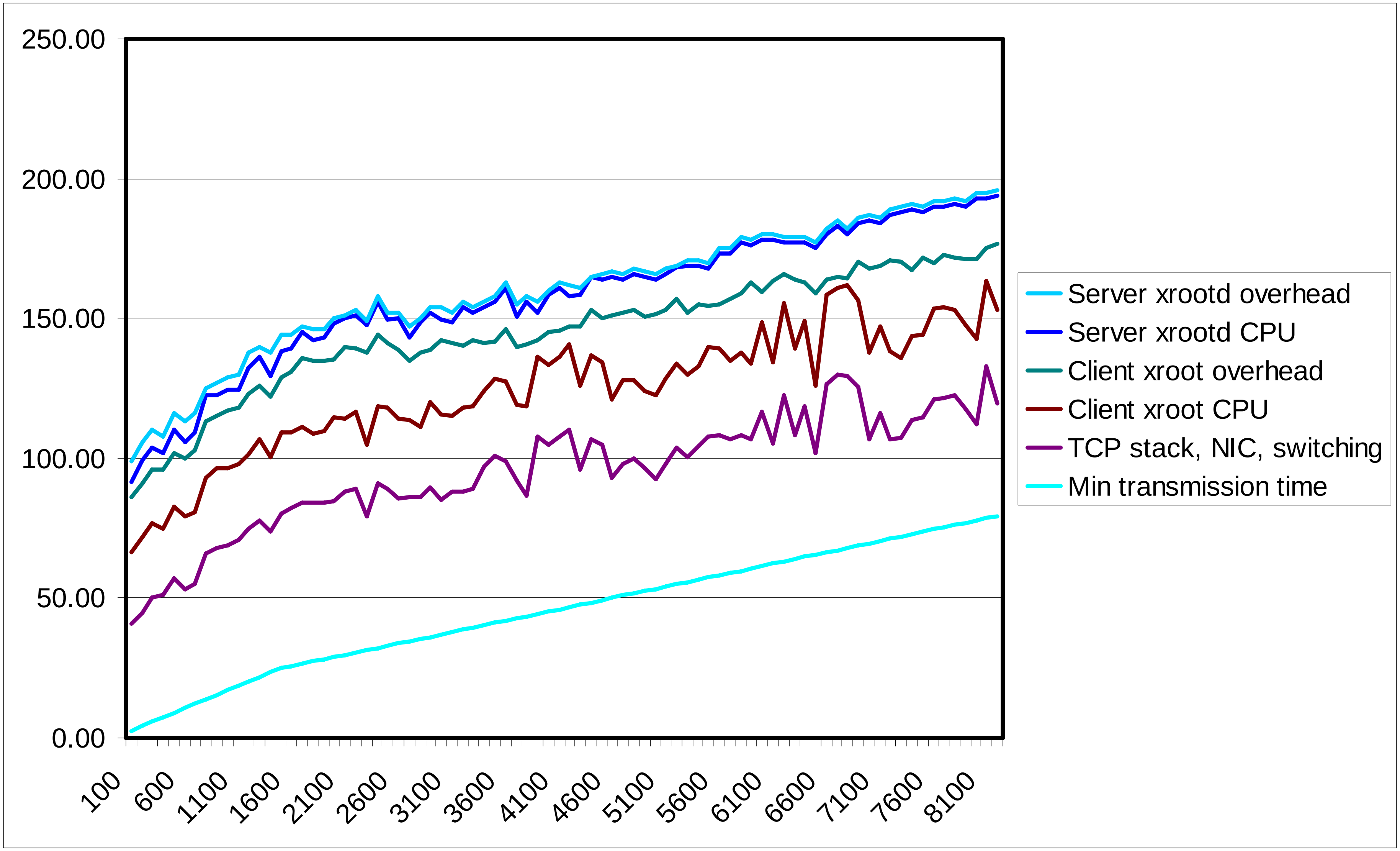
Latency (2)
Current reality



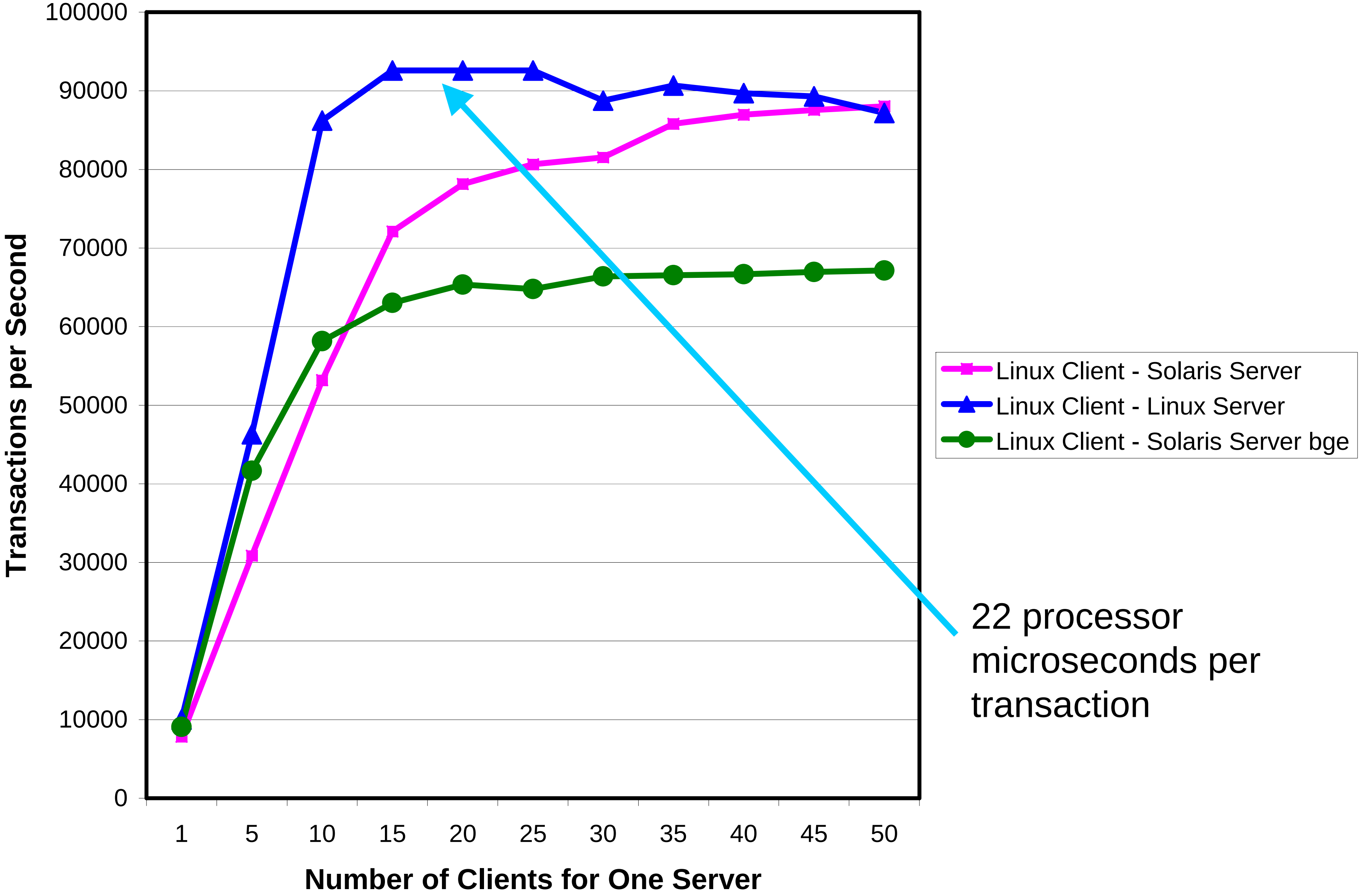
Latency (3)
Immediately Practical Goal



DRAM-Based Prototype
Latency (microseconds) versus data retrieved (bytes)



DRAM-Based Prototype Throughput Measurements

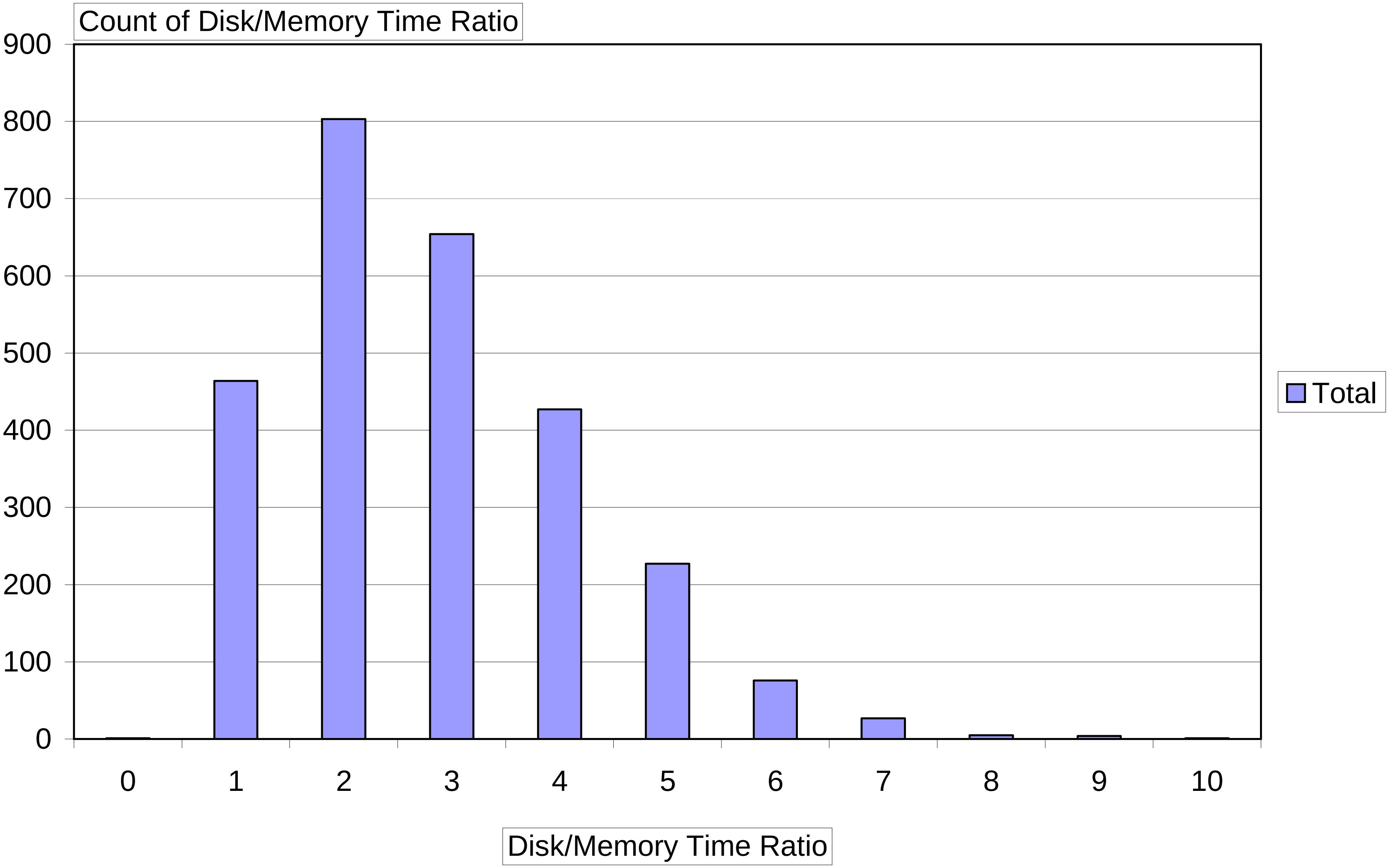


22 processor microseconds per transaction

Throughput Tests

- ATLAS AOD Analysis
  - 1 GB file size (a disk can hold 500 – 1000 of these)
  - 59 xrootd client machines (up to 118 cores) performing top analysis getting data from 1 server.
  - The individual analysis jobs perform sequential access.
  - Compare time to completion when server uses its disk, compared with time taken when server uses its memory.

DRAM-based Protoype ATLAS AOD Analysis



Comments and Outlook

- Significant, but not revolutionary, benefits for high-load sequential data analysis – as expected.
- Revolutionary benefits expected for pointer-based data analysis – but not yet tested.
- The need to access storage in serial mode has become part of the culture of data-intensive science – why design a pointer-based analysis when its performance is certain to be abysmal?
- TAG database driven analysis?