Avoiding Achilles' Heel in Exascale Computing with Distributed File Systems

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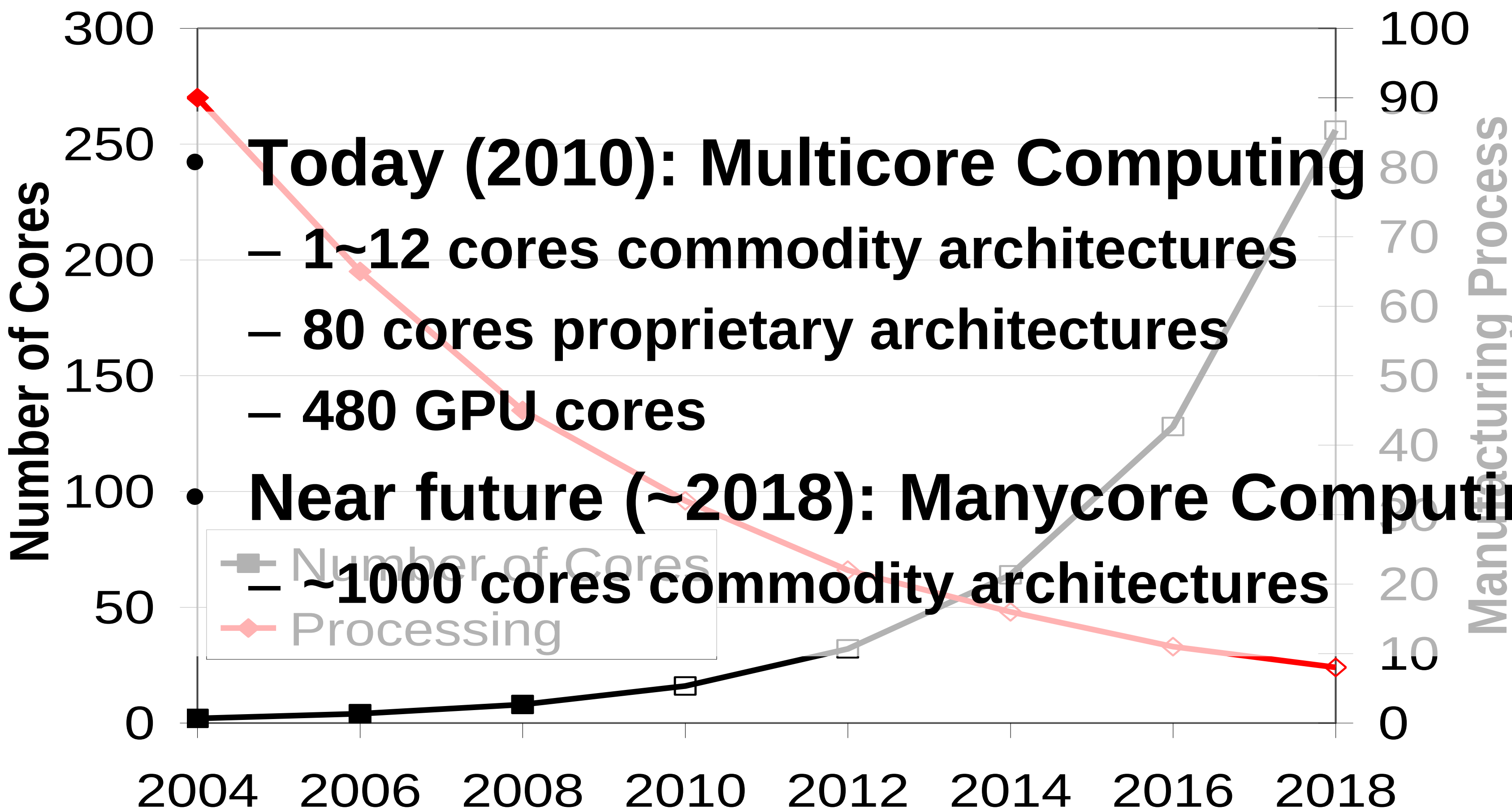
DLS Seminar
January 14th, 2011

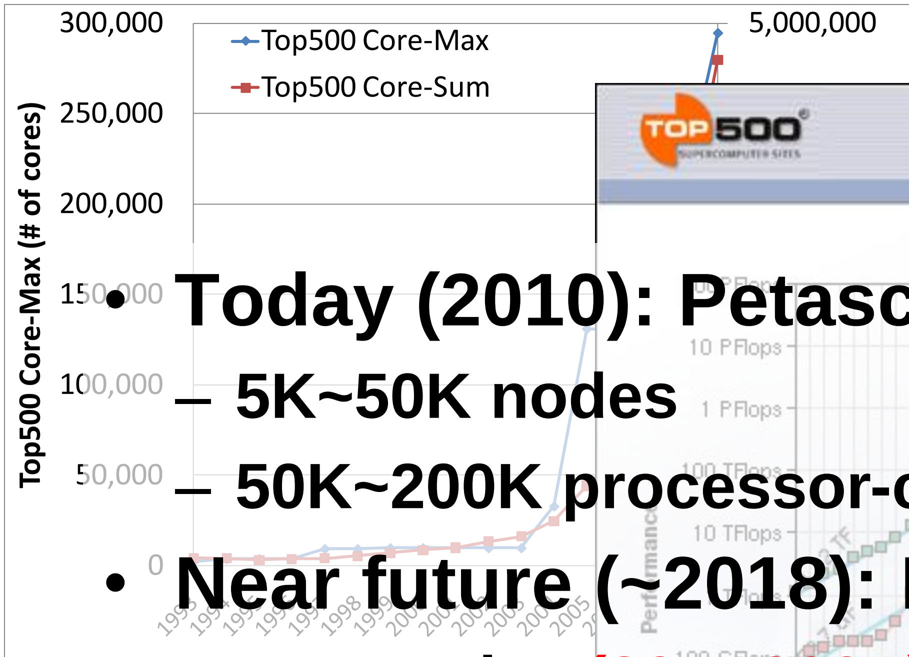
Manycore Computing

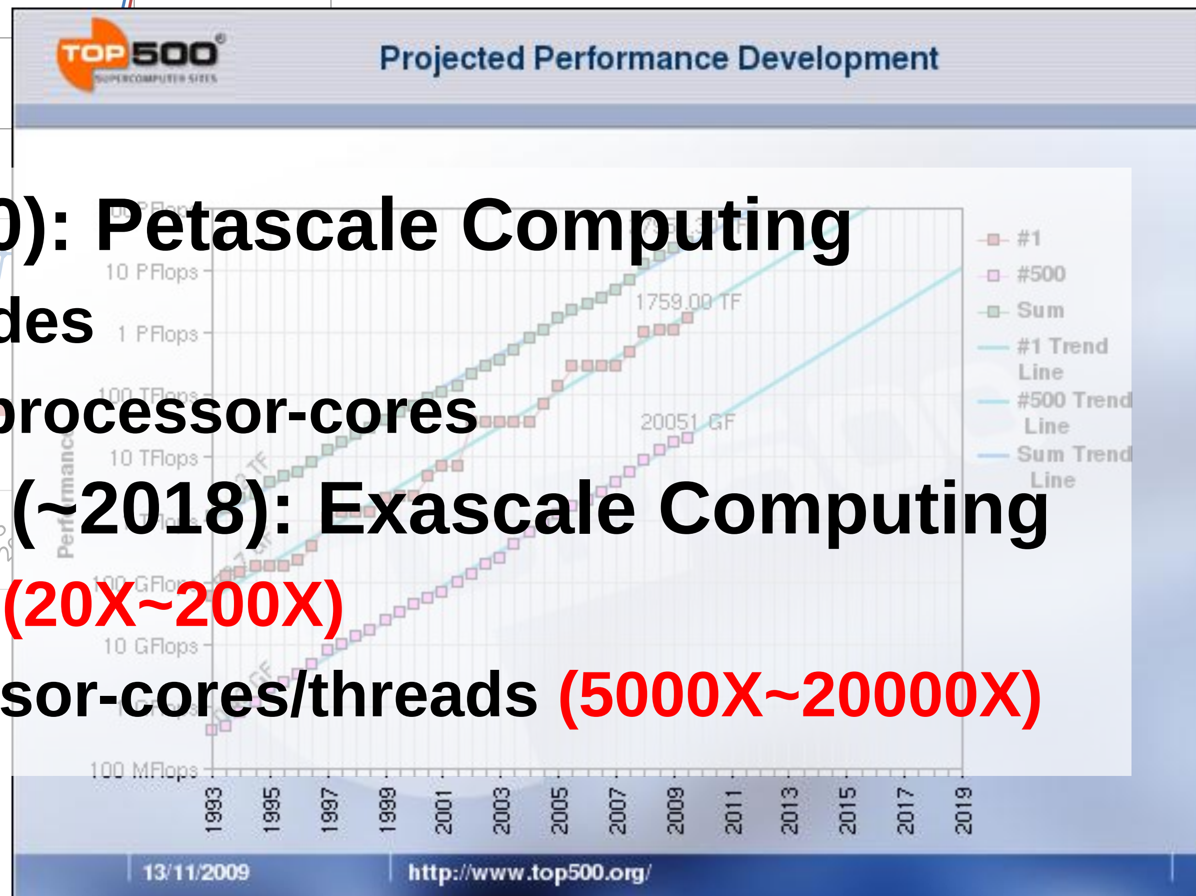


- **Today (2010): Multicore Computing**
  - **1~12 cores commodity architectures**
  - **80 cores proprietary architectures**
  - **480 GPU cores**
- **Near future (~2018): Manycore Computing**
  - **~1000 cores commodity architectures**

Pat Helland, Microsoft, The Irresistible Forces Meet the Movable Objects, November 9th, 2007

Exascale Computing





- **Today (2010): Petascale Computing**
  - **5K~50K nodes**
  - **50K~200K processor-cores**
- **Near future (~2018): Exascale Computing**
  - **~1M nodes (20X~200X)**
  - **~1B processor-cores/threads (5000X~20000X)**

Top500 Projected Development, http://www.top500.org/lists/2009/11/performance_development

Cloud Computing

- Relatively new paradigm… 3 years old
- Amazon in 2009
  - 40K servers split over 6 zones
    - 320K-cores, 320K disks
    - $100M costs + $12M/year in energy costs
    - Revenues about $250M/year
- Amazon in 2018
  - Will likely look similar to exascale computing
    - 100K~1M nodes, ~1B-cores, ~1M disks
    - $100M~$200M costs + $10M~$20M/year in energy
    - Revenues 100X~1000X of what they are today

Common Challenges

- Power efficiency
  - Will limit the number of cores on a chip (Manycore)
  - Will limit the number of nodes in cluster (Exascale and Cloud)
  - Will dictate a significant part of the cost of ownership
- Programming models/languages
  - Automatic parallelization
  - Threads, MPI, workflow systems, etc
  - Functional, imperative
  - Languages vs. Middlewares

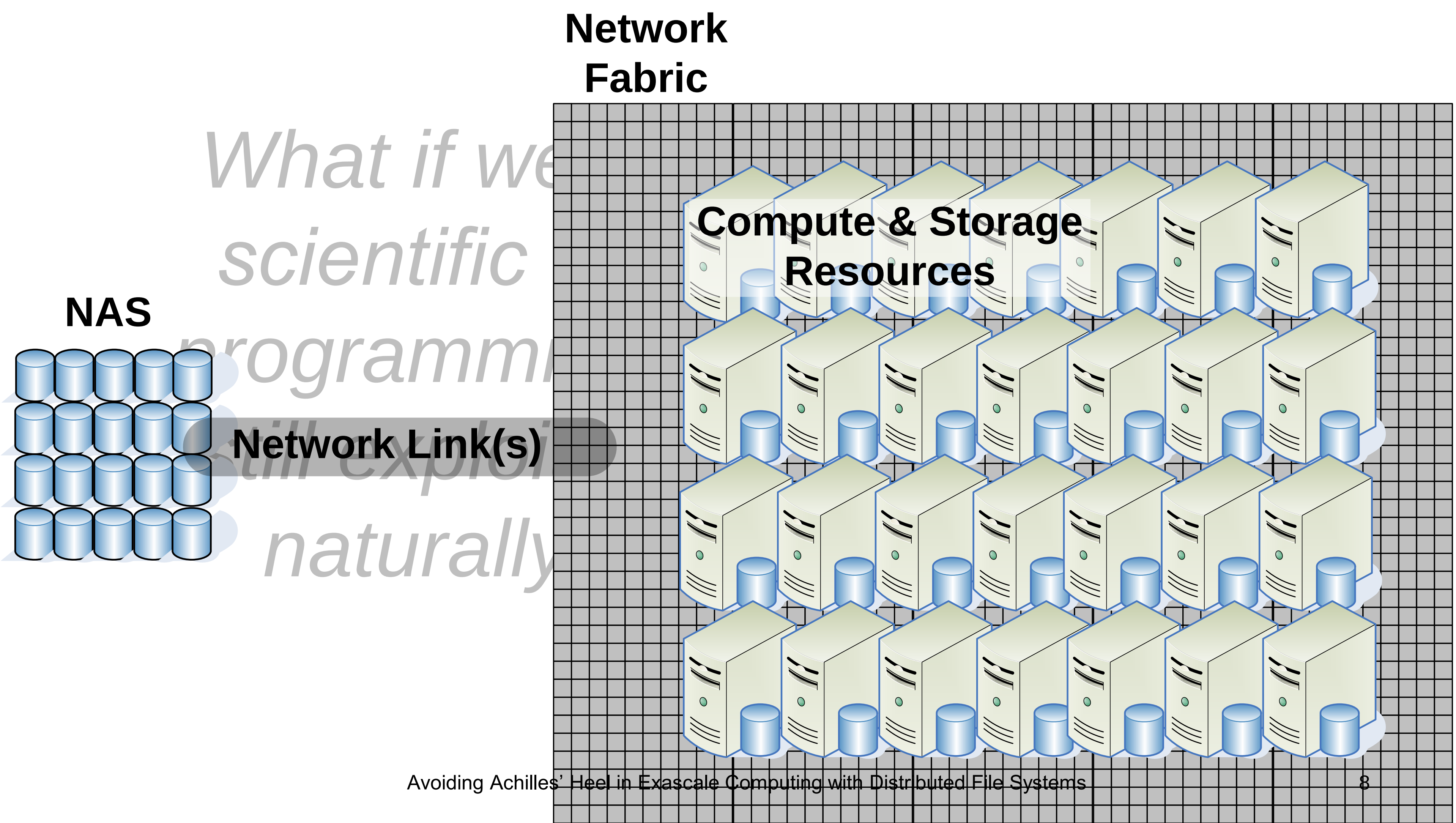
Common Challenges

- Bottlenecks in scarce resources
  - Storage (Exascale and Clouds)
  - Memory (Manycore)
- Reliability
  - How to keep systems operational in face of failures
  - Checkpointing (Exascale)
  - Node-level replication enabled by virtualization (Exascale and Clouds)
  - Hardware redundancy and hardware error correction (Manycore)

Research Directions

- ***Decentralization is critical***
  - Computational resource management (e.g. LRMs)
  - Storage systems (e.g. parallel file systems)
- ***Data locality must be maximized, while preserving I/O interfaces***
  - POSIX I/O on shared/parallel file systems ignore locality
  - Data-aware scheduling coupled with distributed file systems that expose locality is the key to scalability over the next decade

Storage System Architecture



Plan of Work

- ***Building on my own research (e.g. data-diffusion), parallel file systems (PVFS), and distributed file systems (e.g. GFS)***
- Build a distributed file system for HEC
  - It should complement parallel file systems, not replace them
- Critical issues:
  - Must mimic parallel file systems interfaces and features in order to get wide adoption
  - Must handle some workloads currently run on parallel file systems significantly better

Plan of Work (cont)

- Access Interfaces and Semantics
  - POSIX-like compliance for generality (e.g. via FUSE)
  - Relaxed semantics to increase scalability
    - Eventual consistency on data modifications
    - Write-once read-many data access patterns
- Distributed metadata management
  - Employ structured distributed hash tables like data-structures
  - Must have O(1) put/get costs
  - Can leverage network-aware topology overlays
- Distribute data across many nodes
  - Must maintain and expose data locality in access patterns

Access Patterns

- **1-many read** (all processes read the same file and are not modified)
- **many-many read/write** (each process read/write to a unique file)
- **write-once read-many** (files are not modified after it is written)
- **append-only** (files can only be modified by appending at the end of files)
- **metadata** (metadata is created, modified, and/or destroyed at a high rate).

Usage Scenarios

- **machine boot-up** (e.g. reading OS image on all nodes)
- **application loading** (e.g. reading scripts, binaries, and libraries on all nodes/processes)
- **common user data loading** (e.g. reading a common read-only database on all nodes/processes)
- **checkpointing** (e.g. writing unique files per node/process)
- **log writing** (writing unique files per node/process)
- **many-task computing** (each process reads some files, unique or shared, and each process writes unique files)

Collaborations

- Mike Wilde
  – Swift: allow Swift to scale better where parrallel file systems pose a scalability bottleneck
- Matei Ripeanu (who is also working with Mike Wilde)
  – Integrate research results into MosaStore (e.g. distributed meta-data)
- Rob Ross
  – Guidance and comparison with PVFS
- Others: Ian Foster, Kamil Iskra, Pete Beckman

More Information

- More information:
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