Module: Distributed and Cloud Computing

Lecture 1.02 Technologies for Network-based Systems Computing

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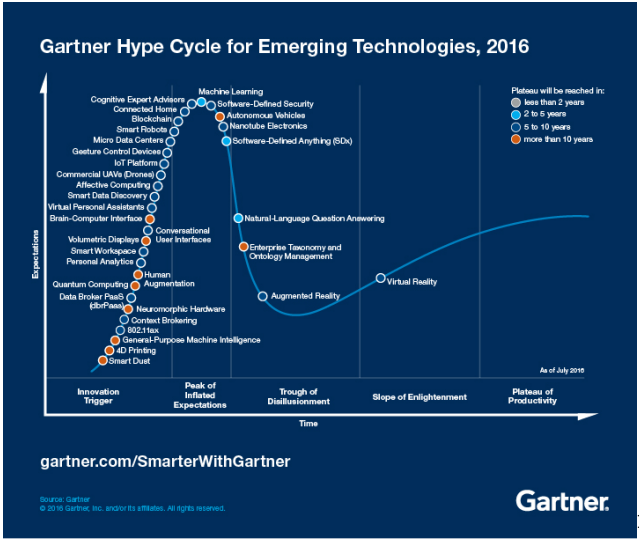
Computer Networks and Systems Management

The Gartner Hype Cycle of New Technologies



[1]

[1] http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Scalable Computing Trends and New Paradigms

- Several predictable trends in technology are known to drive computing applications.
  - Jim Gray's paper, "Rules of Thumb in Data Engineering,"[2]
  - Moore's law indicates that processor speed doubles every 18 months.
  - Gilder's law indicates that network bandwidth has doubled each year in the past.

[2] http://research.microsoft.com/pubs/68636/ms_tr_99_100_rules_of_thumb_in_data_engineering.pdf

Degrees of Parallelism

- 50 years ago
  - bit-level parallelism (BLP) converts bit-serial processing to word-level processing gradually.
- 30 years ago to present
  - 4-bit microprocessors to 8-,16-, 32-, and 64-bit CPU
    - instruction-level parallelism (ILP), processor executes multiple instructions simultaneously
    - For the past 30 years, we have practiced ILP through pipelining, superscalar computing, VLIW (very long instruction word) architectures, and multithreading
  - Data-level parallelism (DLP) was made popular through SIMD (single instruction, multiple data) and vector machines
  - multicore processors and chip multiprocessors (CMPs) give us task-level parallelism (TLP)
- Moving parallel processing to distributed processing, we see an increase in computing granularity to job-level parallelism (JLP).

The Internet of Things and Cyber-Physical Systems

The Internet of Things

- The concept of the IoT was introduced in 1999 at MIT
- The IoT refers to the networked interconnection of everyday objects, tools, devices, or computers.
- One can view the IoT as a wireless network of sensors that interconnect all things in our daily life.
- IoT researchers have estimated that every human being will be surrounded by 1,000 to 5,000 objects.

Cyber-Physical Systems

- A cyber-physical system (CPS) is the result of interaction between computational processes and the physical world.
- A CPS integrates "cyber" (heterogeneous, asynchronous) with "physical" (concurrent and information-dense) objects.
- A CPS merges the "3C" technologies of computation, communication, and control into an intelligent closed feedback system between the physical world and the information world
- The IoT emphasizes various networking connections among physical objects, while the CPS emphasizes exploration of virtual reality (VR) applications in the physical world.

Multicore CPUs and Multithreading Technologies

Advances in CPU Processors

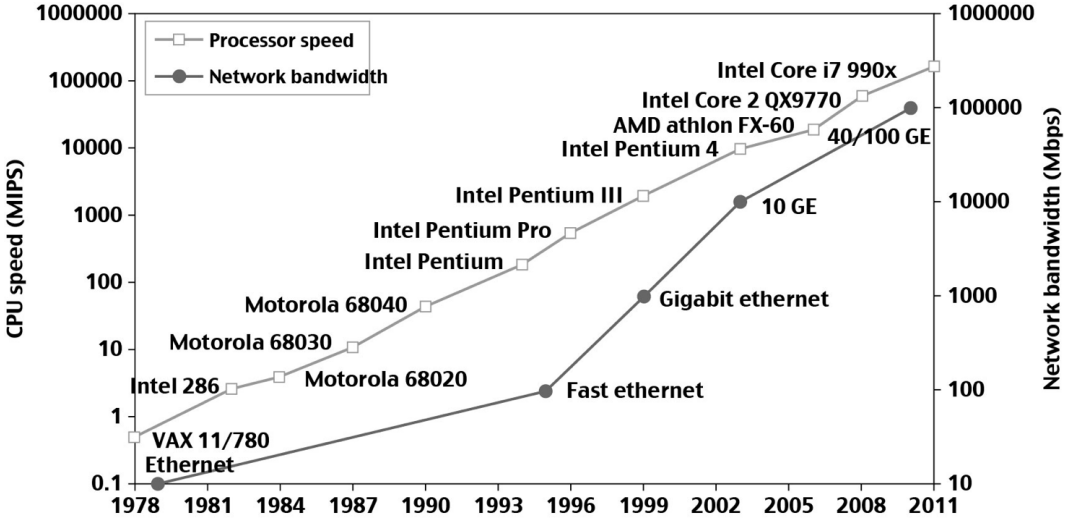


Figure 1: 33 years of improvement in processor and network technology

Modern Multi-core CPU Chip

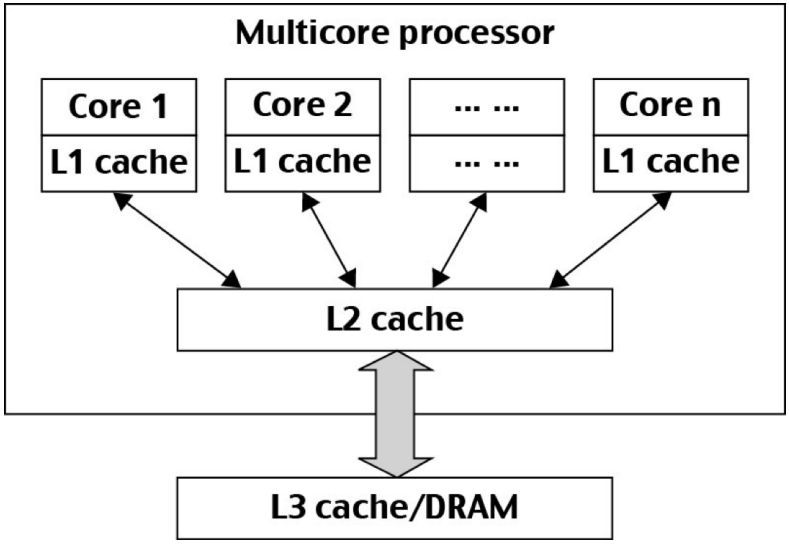


Figure 2: Modern Multi-core CPU Chip

Multicore CPU and Many-Core GPU Architectures

- Multicore CPUs may increase from the tens of cores to hundreds or more in the future.
- but CPU has reached its limit in terms of exploiting massive DLP due to the memory wall problem[3]
  - This has triggered the development of many-core GPUs with thousands or more thin cores
  - Many RISC processors have been replaced with multicore x-86 processors and many-core GPUs in the Top 500 systems.
  - The GPU also has been applied in large clusters to build supercomputers in MPPs

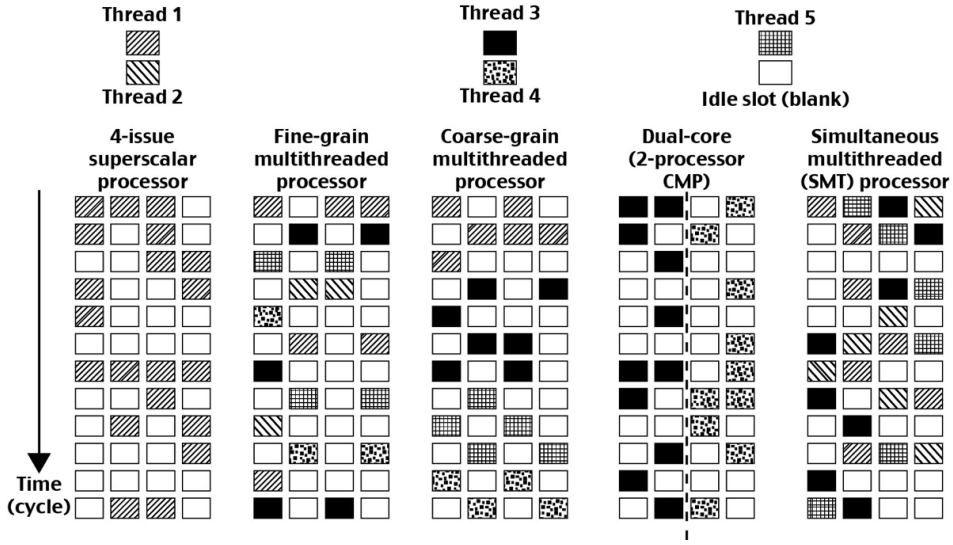
[3] http://www.di.unisa.it/~vitsca/SC-2011/DesignPrinciplesMulticoreProcessors/Wulf1995.pdf

Multithreading Technology

- Four-issue superscalar (e.g. Sun Ultrasparc I)
  - Implements instruction level parallelism (ILP) within a single processor.
  - Executes more than one instruction during a clock cycle by sending multiple instructions to redundant functional units.
- Fine-grain multithreaded processor
  - Switch threads after each cycle
  - Interleave instruction execution
  - If one thread stalls, others are executed
- Coarse-grain multithreaded processor
  - Executes a single thread until it reaches certain situations
- Simultaneous multithread processor (SMT)
  - Instructions from more than one thread can execute in any given pipeline stage at a time.

CPU and GPU based Architectures

5 Micro-architectures of CPUs



* Each row represents the issue slots for a single execution cycle: * A filled box indicates that the processor found an instruction to execute in that issue slot on that cycle * An empty

GPU Computing to Exascale and Beyond

- A GPU is a graphics coprocessor or accelerator mounted on a computer's graphics card or video card. A GPU offloads the CPU from tedious graphics tasks in video editing applications
- Unlike CPUs, GPUs have a throughput architecture that exploits massive parallelism by executing many concurrent threads slowly, instead of executing a single long thread in a conventional microprocessor very quickly
- General-purpose computing on GPUs, known as GPGPUs, have appeared in the HPC field and power exacale[4]
- NVIDIA's CUDA model was for HPC using GPGPUs

[4]Exascale computing refers to computing systems capable of at least one exaFLOPS, or a billion billion calculations per second. Such capacity represents a thousandfold increase over the first petascale computer that came into operation in 2008.

Architecture of A Many-Core Multiprocessor GPU interacting with a CPU Processor

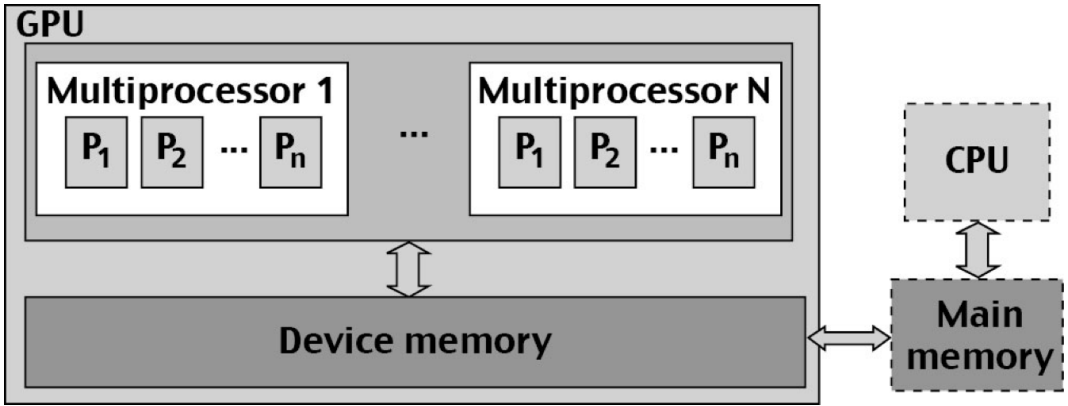


Figure 3: Architecture of A Many-Core Multiprocessor GPU interacting with a CPU Processor

NVIDIA Fermi GPU

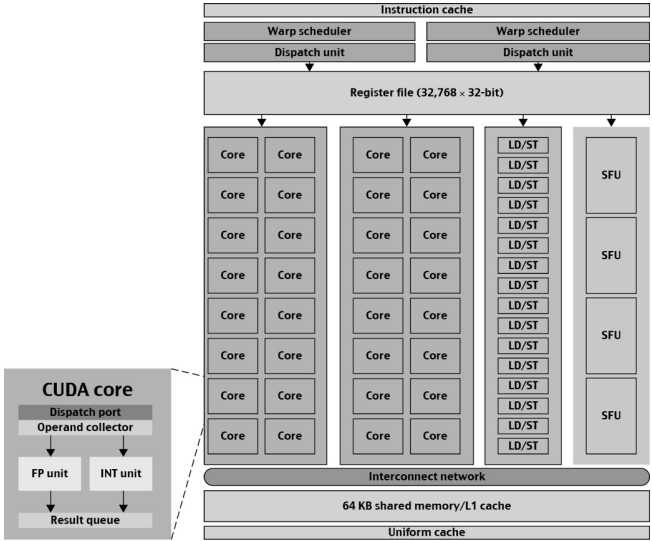


Figure 4: NVIDIA Fermi GPU

Power Efficiency of the GPU

Bill Dally of Stanford University considers power and massive parallelism as the major benefits of GPUs over CPUs for the future

GPU Performance

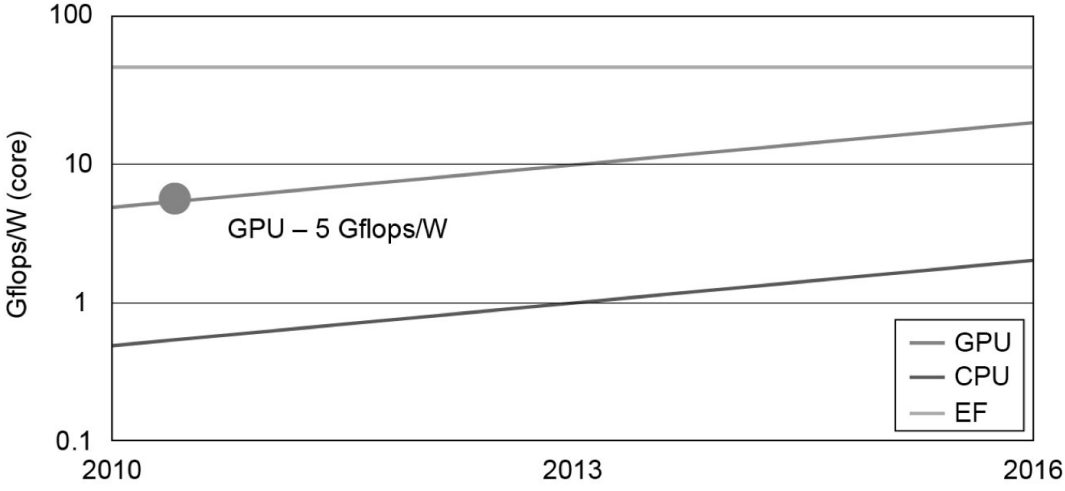


Figure 5: GPU Performance

Memory, Storage, and Wide-Area Networking

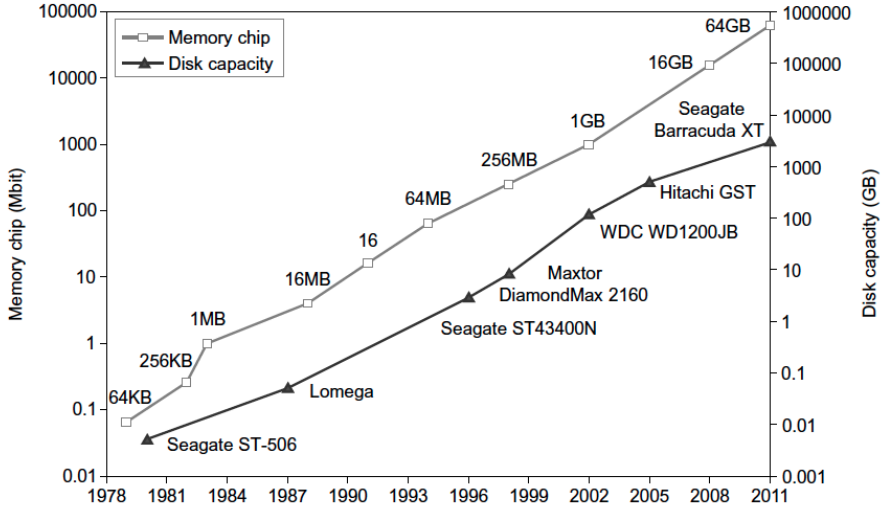


Figure 6: disk and memory capacity

System-Area Interconnects

Network Interconnections

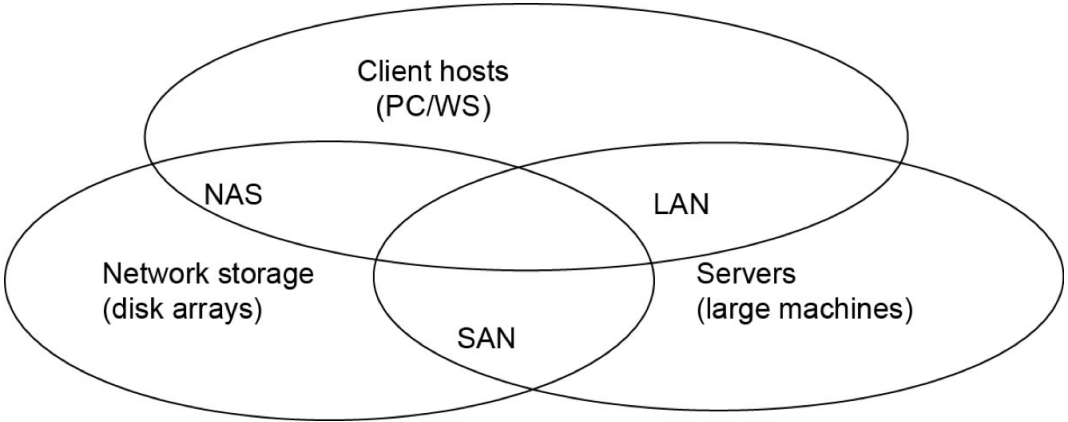


Figure 7: Network Interconnections

Network Interconnections

- SAN (storage area network) - connects servers with disk arrays
- LAN (local area network) - connects clients, hosts, and servers
- NAS (network attached storage) - connects clients with large storage systems

Wide Area Networking

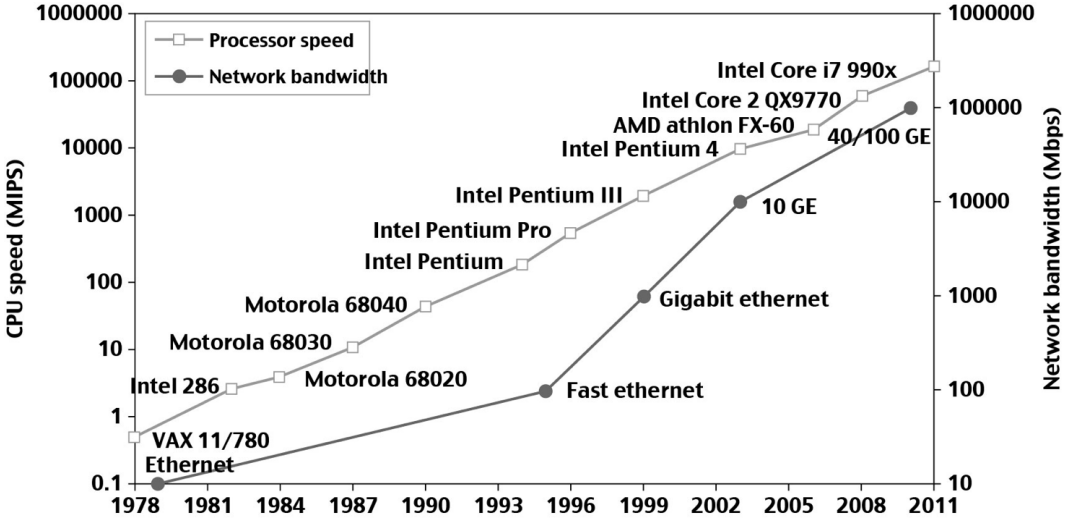


Figure 8: 33 years of improvement in processor and network technology

Wide Area Networking

- The lower curve here plots the rapid growth of Ethernet bandwidth from 10 Mbps in 1979 to 1 Gbps in 1999, and 40 $\sim$ 100 GE in 2011.
- We have recently seen a 255Tbps link created in 2014[5]

[5] http://bit.ly/cnsm4dcc-255tbps

Virtualisation

Virtual Machines and Virtualization Middleware

- A conventional computer has a single OS image. This offers a rigid architecture that tightly couples application software to a specific hardware platform.
- Some software running well on one machine may not be executable on another platform with a different instruction set under a fixed OS.
- Virtual machines (VMs) offer novel solutions to underutilized resources, application inflexibility, software manageability, and security concerns in existing physical machines.

VM Architectures

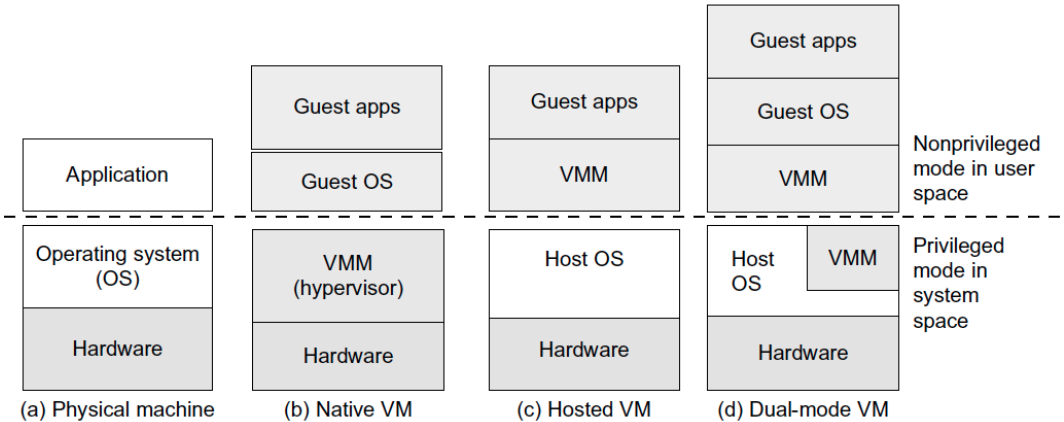
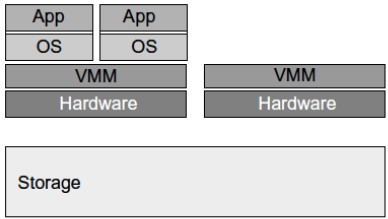
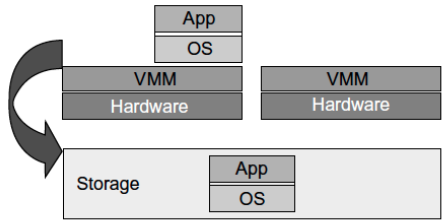


Figure 9: VM Architectures

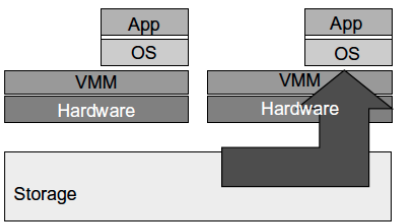
VM Operations



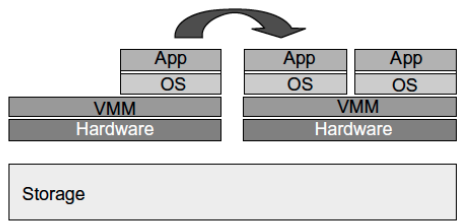
(a) Multiplexing



(b) Suspension (storage)



(c) Provision (resume)



(d) Life migration

Figure 10: VM Management

Next Lesson

- Cloud Centres
  - What are they ?
  - Are they all the same ?
  - Whats different about them ?

Thank You

Questions?

References I