CS550 "Advanced Operating Systems"

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Research Related Term Projects

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Storage systems, Parallel IO, IO & Machine Learning, Database Buffering

- **Luke Logan llogan@hawk.iit.edu**
  - Advanced OS

- **Xiaoyang Lu** xlu40@hawk.iit.edu
  - Heterogeneous Memory System

- **Any other** distributed system related topics

What Is Computer Science?

Computer science is laying the foundations and developments the real search paradigms and scientific methods for the exploration of the world of information and intellectual processes that are not directly governed by physical laws.

By Juris Hartimanis, Turing Award Lecture

Such people (computer scientists) are especially good at dealing with situations where different rules apply in different cases; they are individuals who can rapidly change levels of abstraction, simultaneously seeing things “in the large” and “in the small”.

By Donald Knuth, Turing Award Lecture

What Is an OS?

An OS is a program that manages various computer resources

- A program that acts as an interface between users and bare hardware
- Resources: CPU(s), memory, file systems, I/0, etc.

- OS: software or hardware?

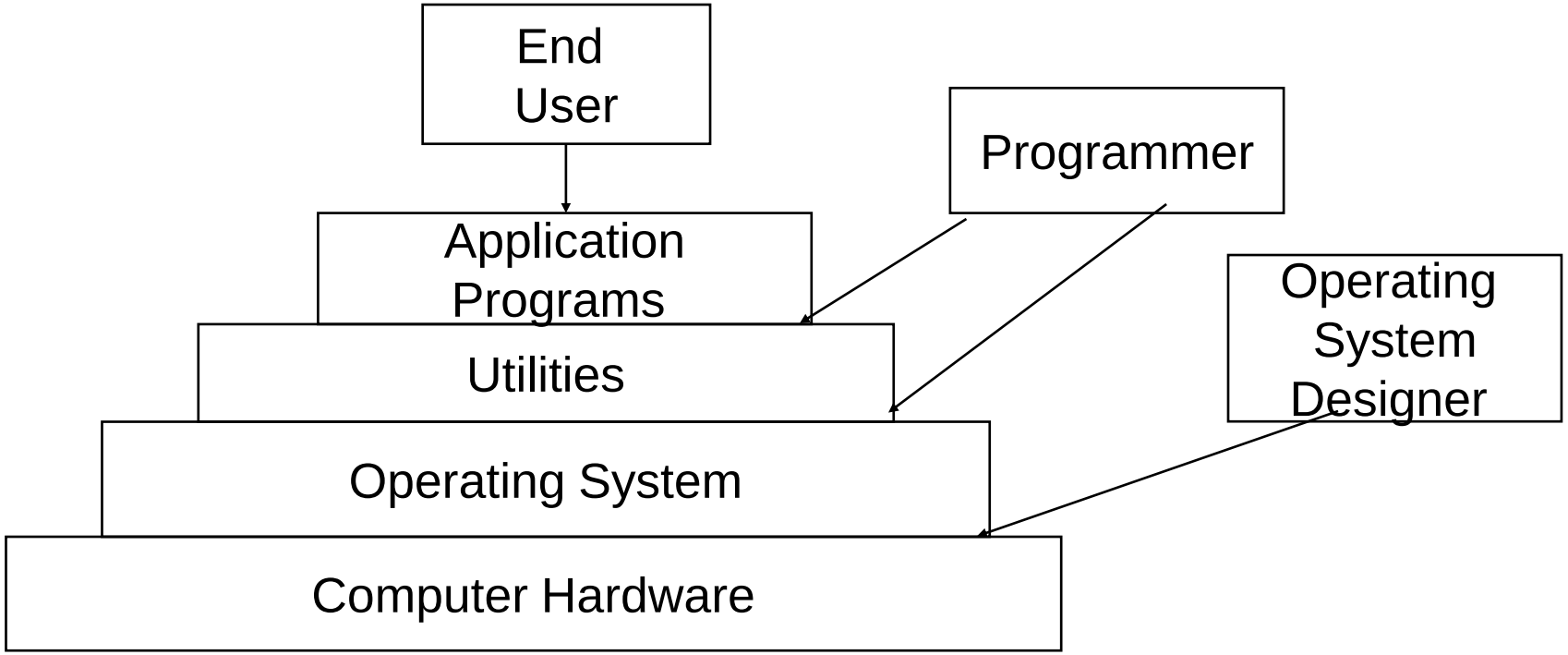


Figure 1 Layers and views of a computer system

Evolution of Operating Systems

Systems with single CPU

- Multitasking, multiprogramming

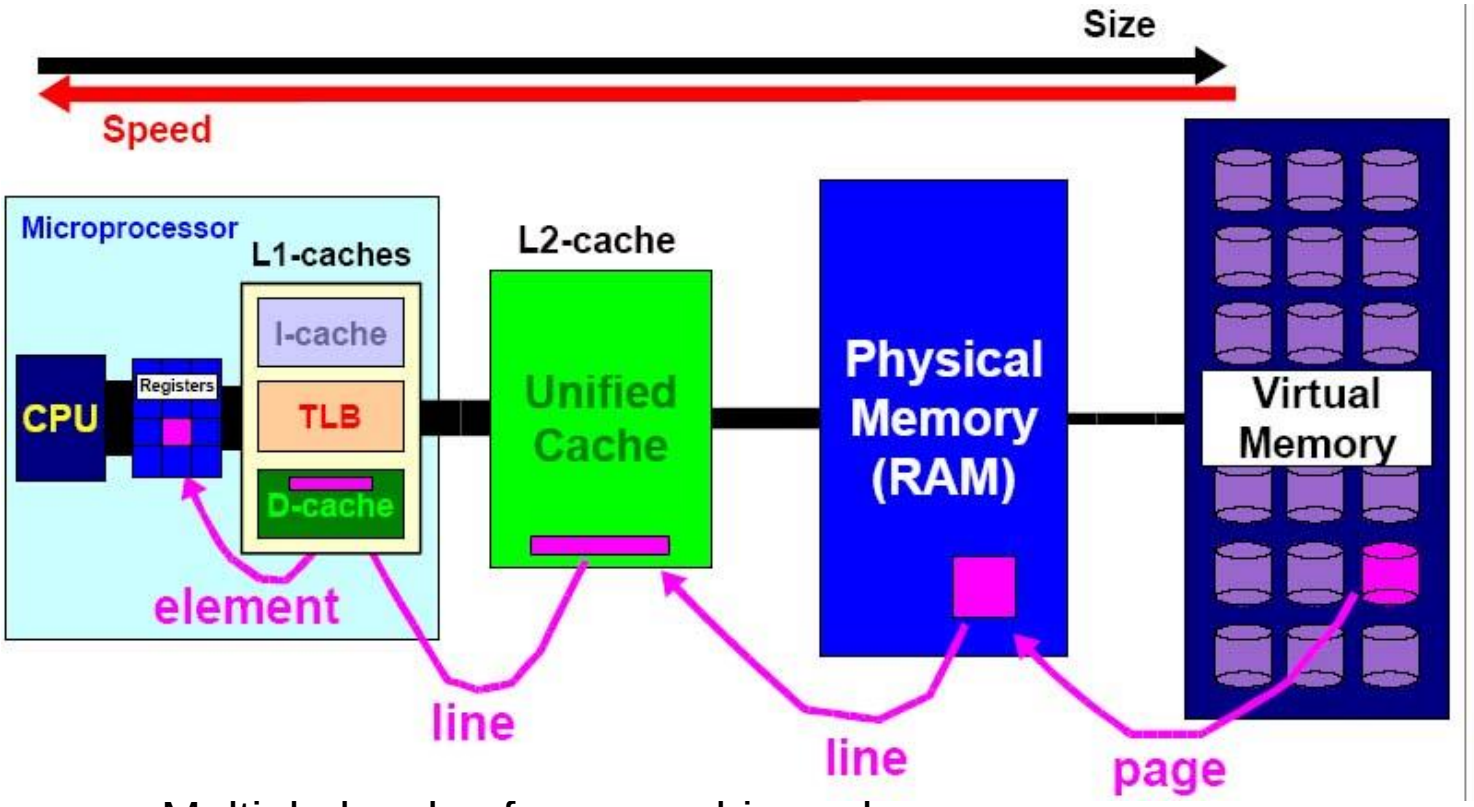
Systems with many CPUs

- Parallel processing and multiprocessors
- Networking and distributed systems

Technology Impacts

- CPU Technology
  - getting faster and less expensive, Moore's law
  - used to be time-sharing (overhead for context switching)
  - Now space-sharing: systems with multiple CPUs
  - Multi-core, many-core architecture
- Memory Technology (memory wall)
  - Unbalanced technology advance

Memory Hierarchy

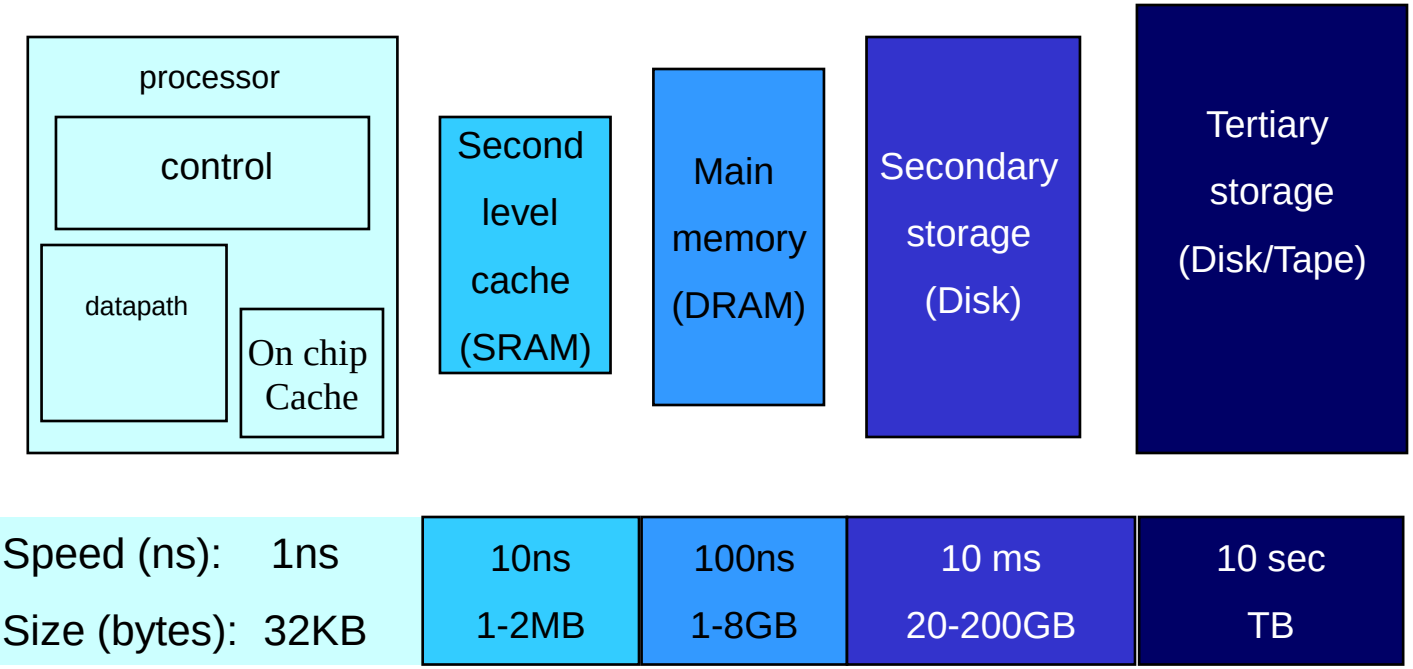


- Multiple levels of memory hierarchy
- Level closer to the CPU is faster to access
- Cache memories work well if spatial and temporal locality exists among data accesses

Memory Hierarchy

Deeper levels of cache memory

Large memories are slow, fast memories are small.



The Principle of Locality

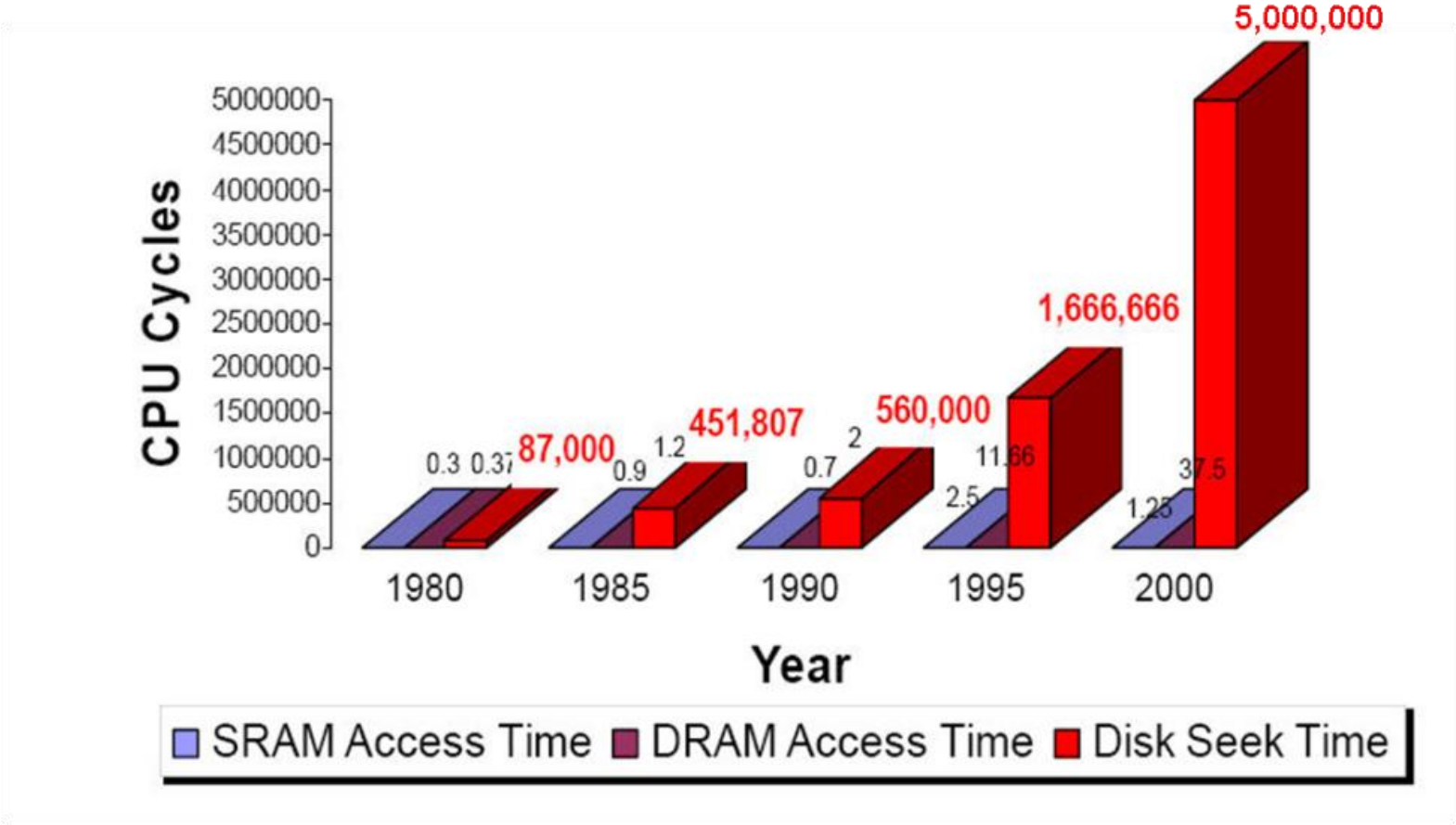
- The Principle of Locality:
  - Programs access a relatively small portion of the address space at any instant of time.
- Two Different Types of Locality:
  - **Temporal Locality** (Locality in Time): If an item is referenced, it will tend to be referenced again soon (e.g., loops, reuse)
  - **Spatial Locality** (Locality in Space): If an item is referenced, items whose addresses are close by tend to be referenced soon (e.g., straight line code, array access)
    - Cache Block or Cache Line
- ~~Last 30 years, HW relied on locality for speed~~

Technology Impacts (cont'd)

- Disk (I/O wall)
  - large capacity, slow access time
  - was the most expensive item in computers
  - file system – file storage
- Storage is one of those technologies that we tend to take for granted. And yet, if we look at the true status of things today, storage is king. One can even argue that servers, which have become commodities, are now becoming peripheral to storage devices.

  --Michael Vizard

I/O Bottleneck

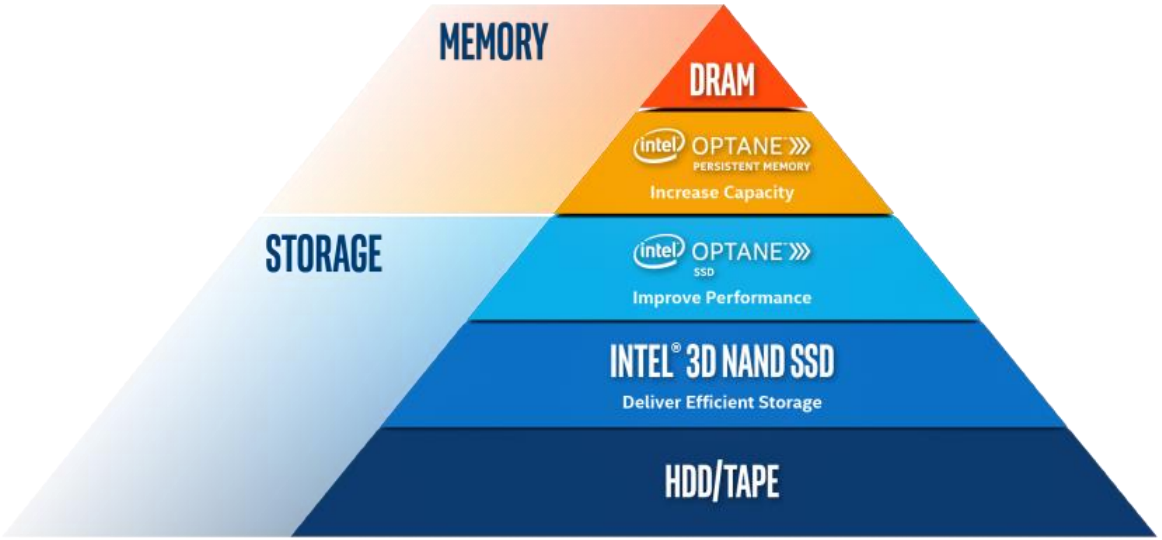


Bryant and O'Hallaron, "*Computer Systems: A Programmer's Perspective*", Prentice-Hall 2003

New Memory – Storage Devices

Memory or storage

- Quite open with new opportunities
- Challenges
  - Interface with cache and storage
  - Measurement and Simulator
  - Controllers
  - OS
- ***Infrastructure ?***



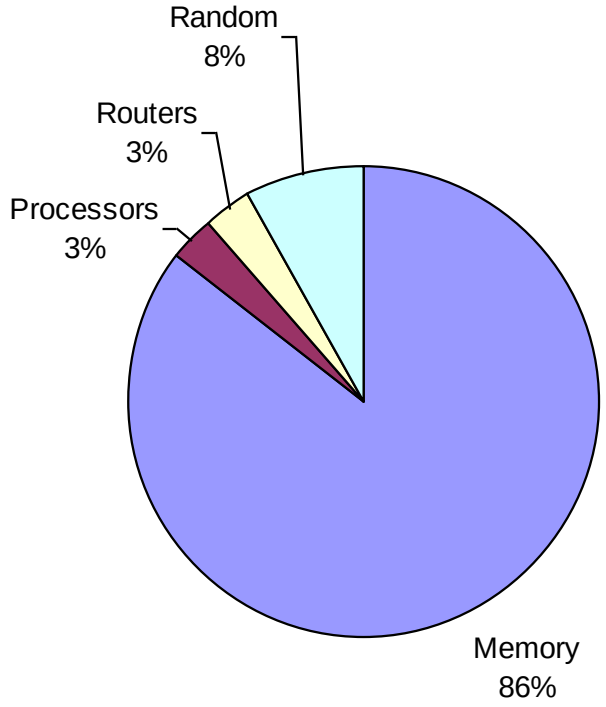
N. Zhang, B. Toonen, X-H. Sun, B. Allcock, "Performance Modeling and Evaluation of a Production Disaggregated Memory System," International Symposium on Memory Systems (MEMSYS'20), Sept. 2020 (accepted to appear)

Technology Impacts (cont'd)

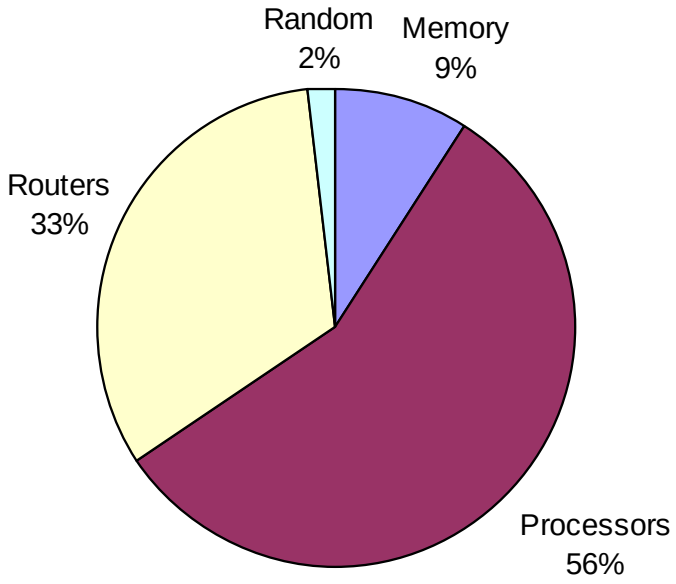
- Power Consumption (power wall)
  - Moore's law
  - Green computing
- Networking (local area networks)
  - Speed increases faster than computing speed
  - diskless workstations
  - memory/disk sharing rather than CPU sharing
  - Remote data access

What Are We Doing with the Total System Silicon?

Silicon Area Distribution



Power Distribution

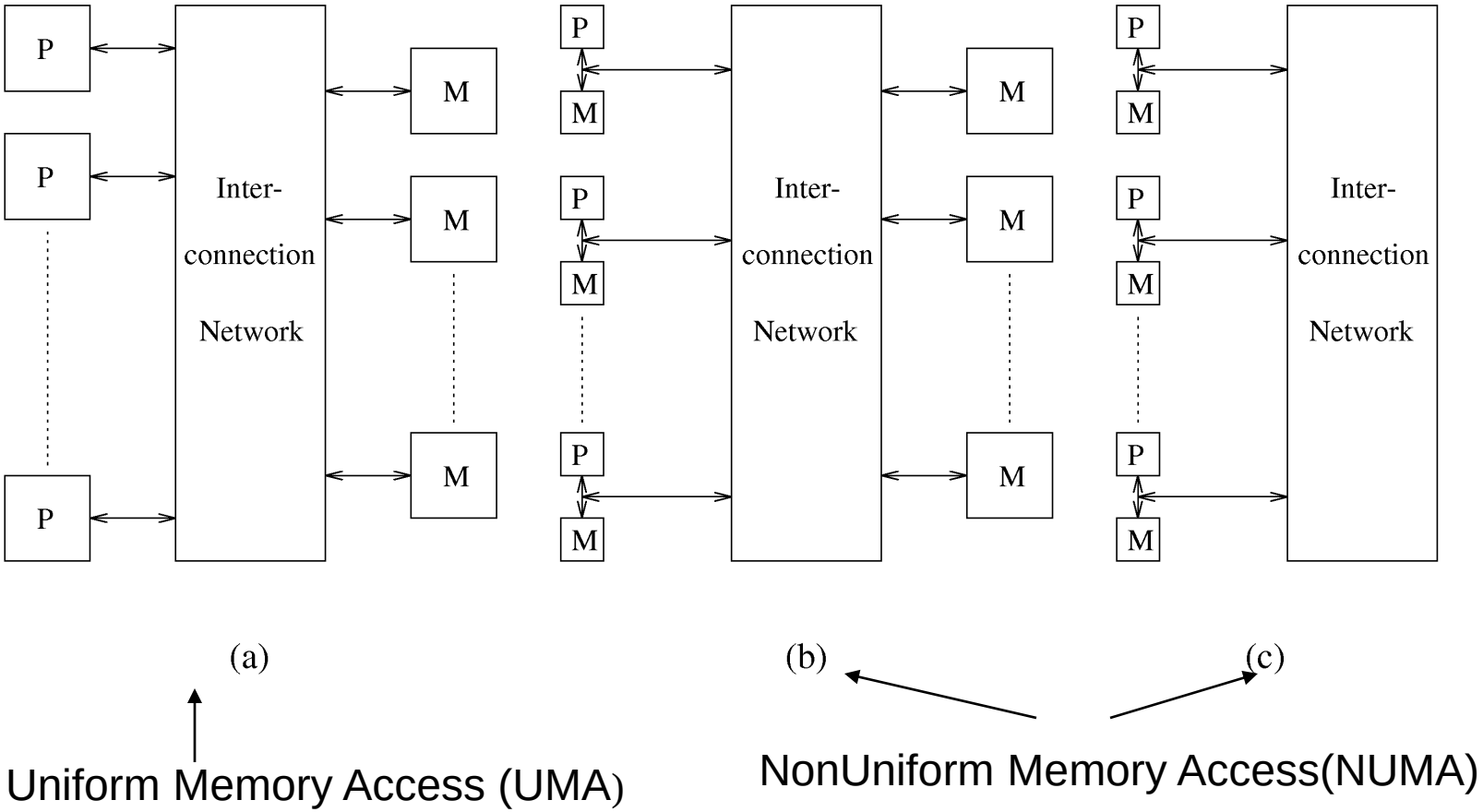


Courtesy of Peter Kogge, UND

Parallel Processing

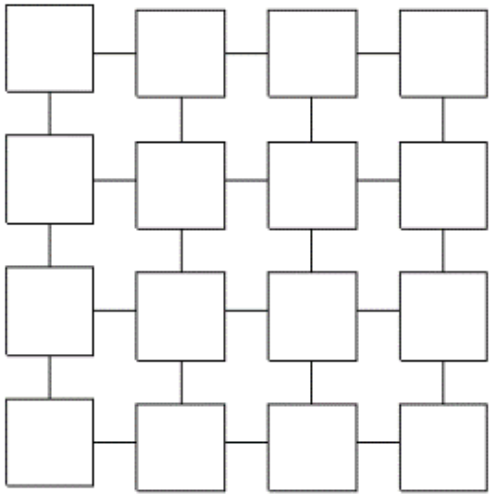
- Parallel Processing
  - Several working entities work together toward a common goal
- Parallel Processing
  - A kind of information processing that emphasizes the concurrent manipulation of data elements belonging to one or more processes solving a single problem
- Parallel Computer
  - A computer designed for parallel processing

Multiprocessors: Shared-Memory Multiprocessors



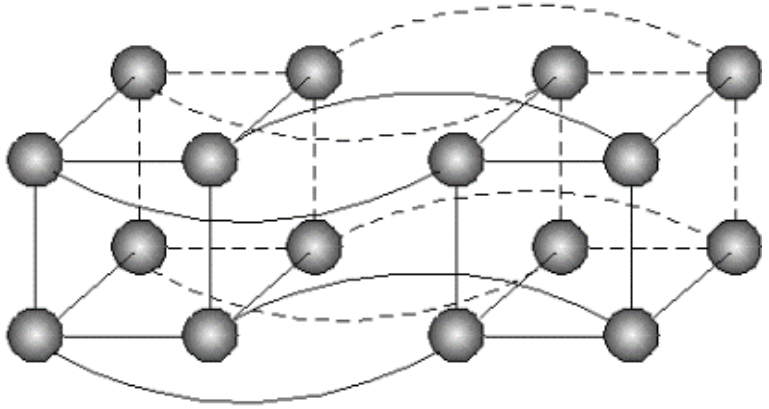
Homogeneous Multicomputer Systems

a) 2D-mesh



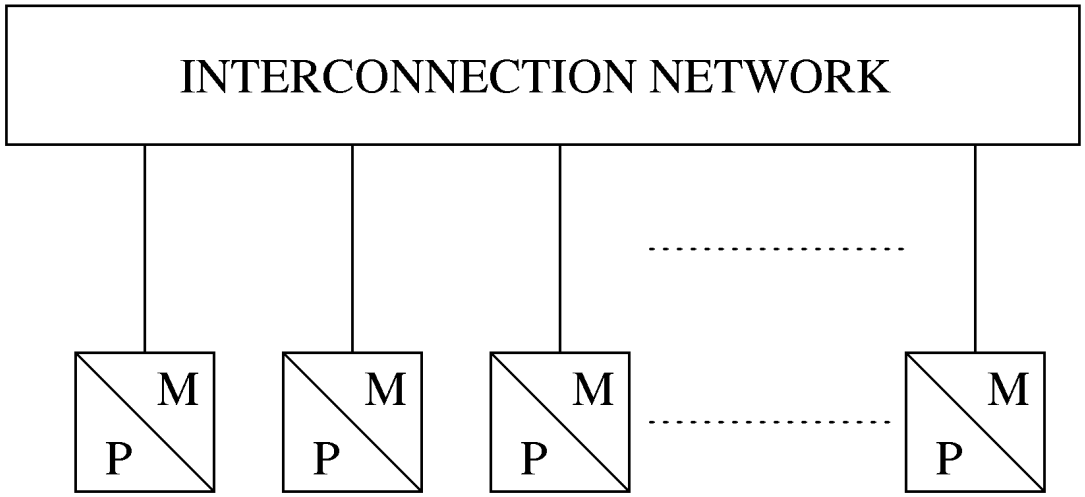
(a)

b) Hypercube



(b)

Multiprocessors: Distributed-Memory Multiprocessors

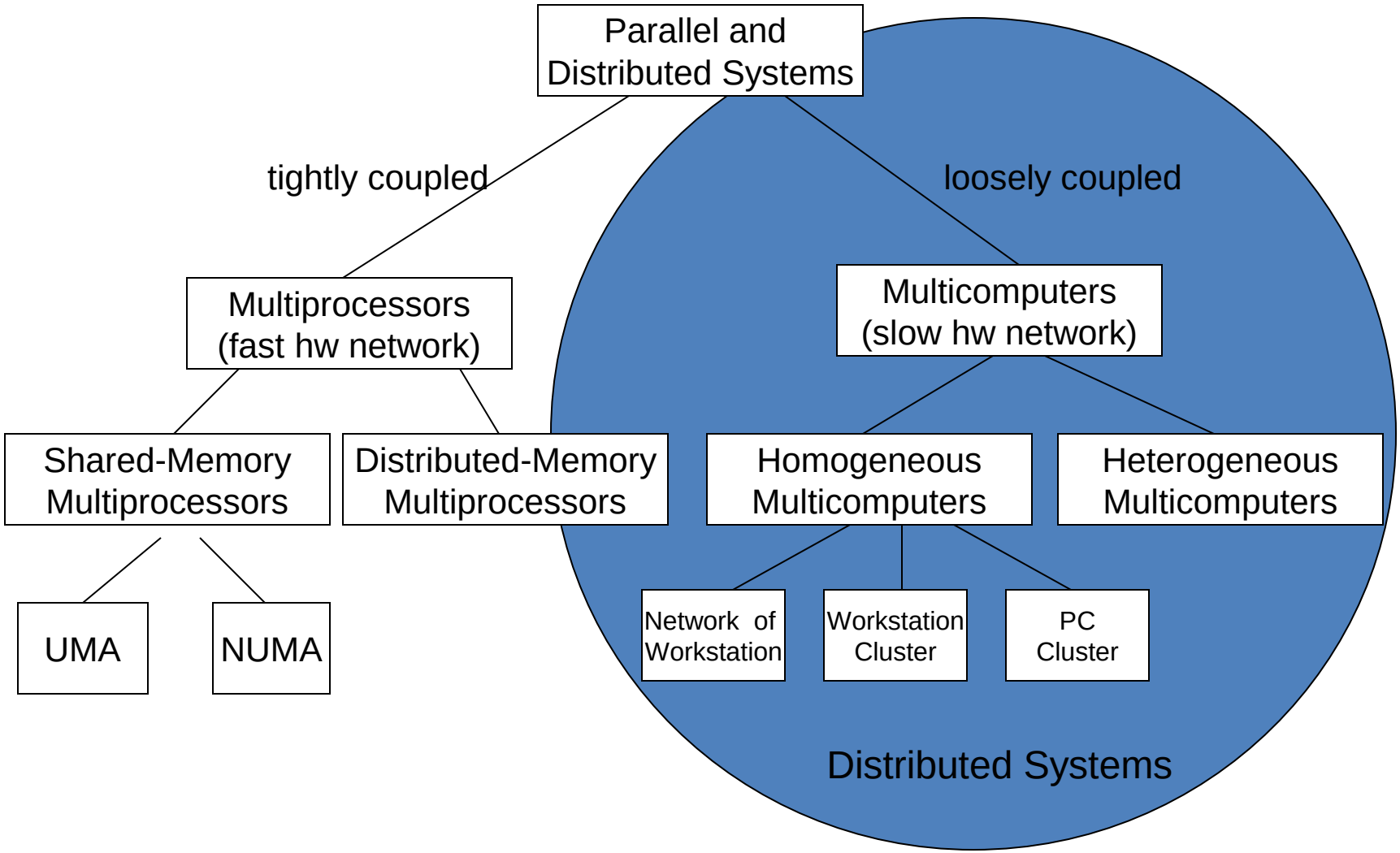


Note: NO HARDWARE SUPPORT FOR REMOTE MEMORY ADDRESSING

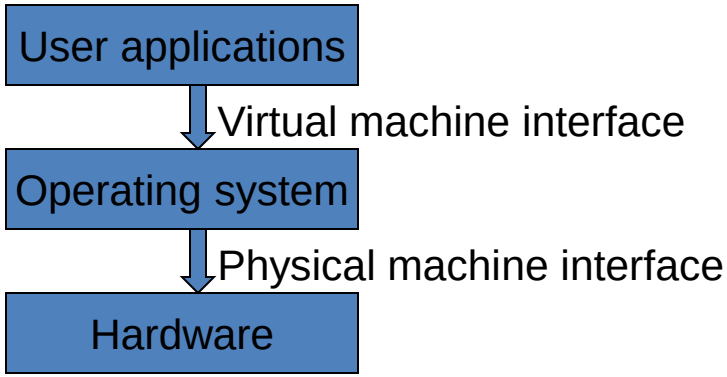
Distributed Systems (Networking)

- A *distributed* system is a collection of processors that do not share memory or a clock. Each processor has its own local memory.
- The processors in the system are connected through a *communication network*.
- A distributed system provides user access to various system resources.
- Access to a shared resource allows:
  - Computation speed-up
  - Increased data availability
  - Enhanced reliability

Hardware Concepts



Software Concepts

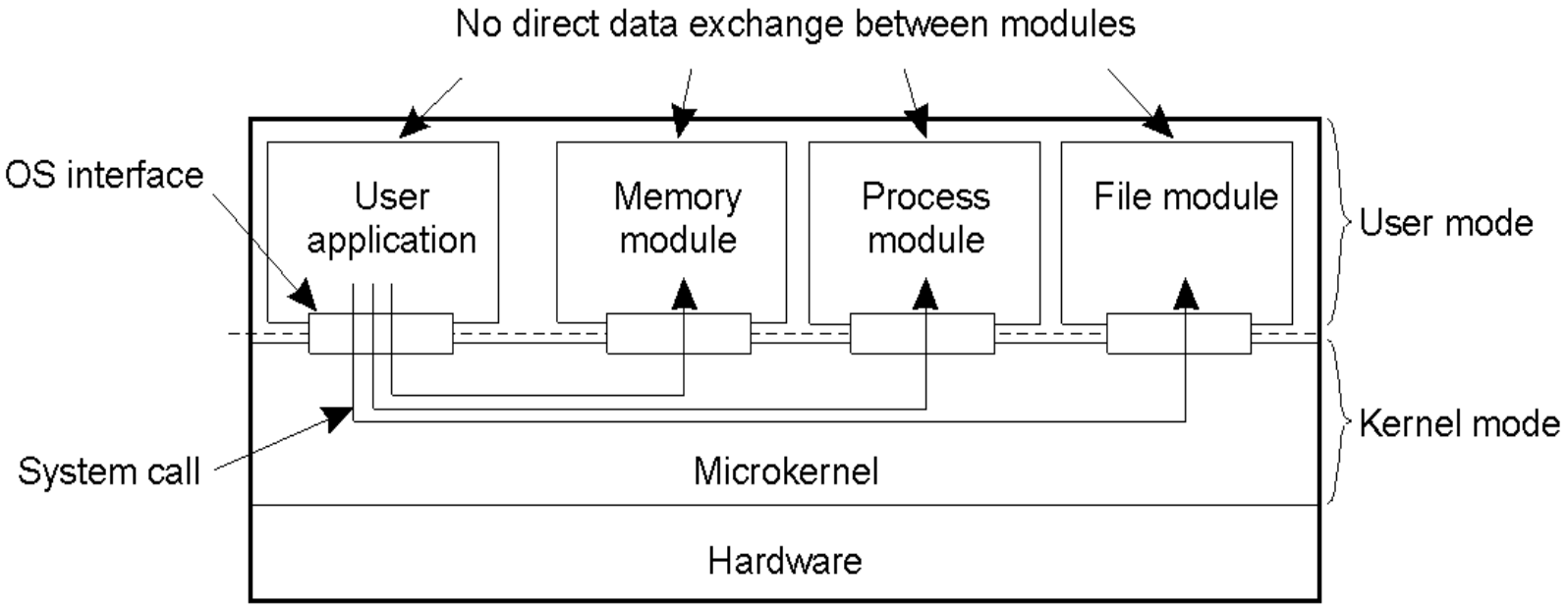


- Operating system:
  - Interface between users and hardware
  - Implements a virtual machine that is easier to program than raw hardware
- Primary functions:
  - Services: file system, virtual memory, networking, CPU scheduling, …
  - Coordination: concurrency, memory protection, security, networking,…

Uniprocessor Operating Systems

Microkernel architecture

- Small kernel
- user-level servers implement additional functionality

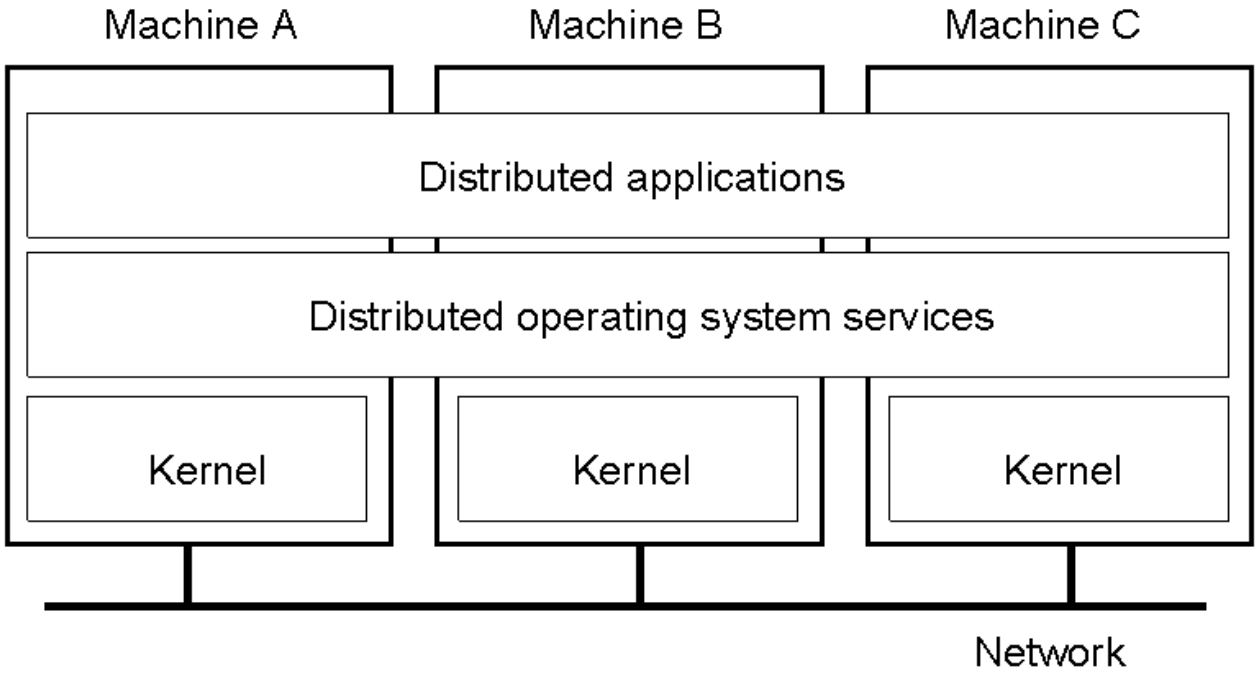


Multiprocessor Operating Systems

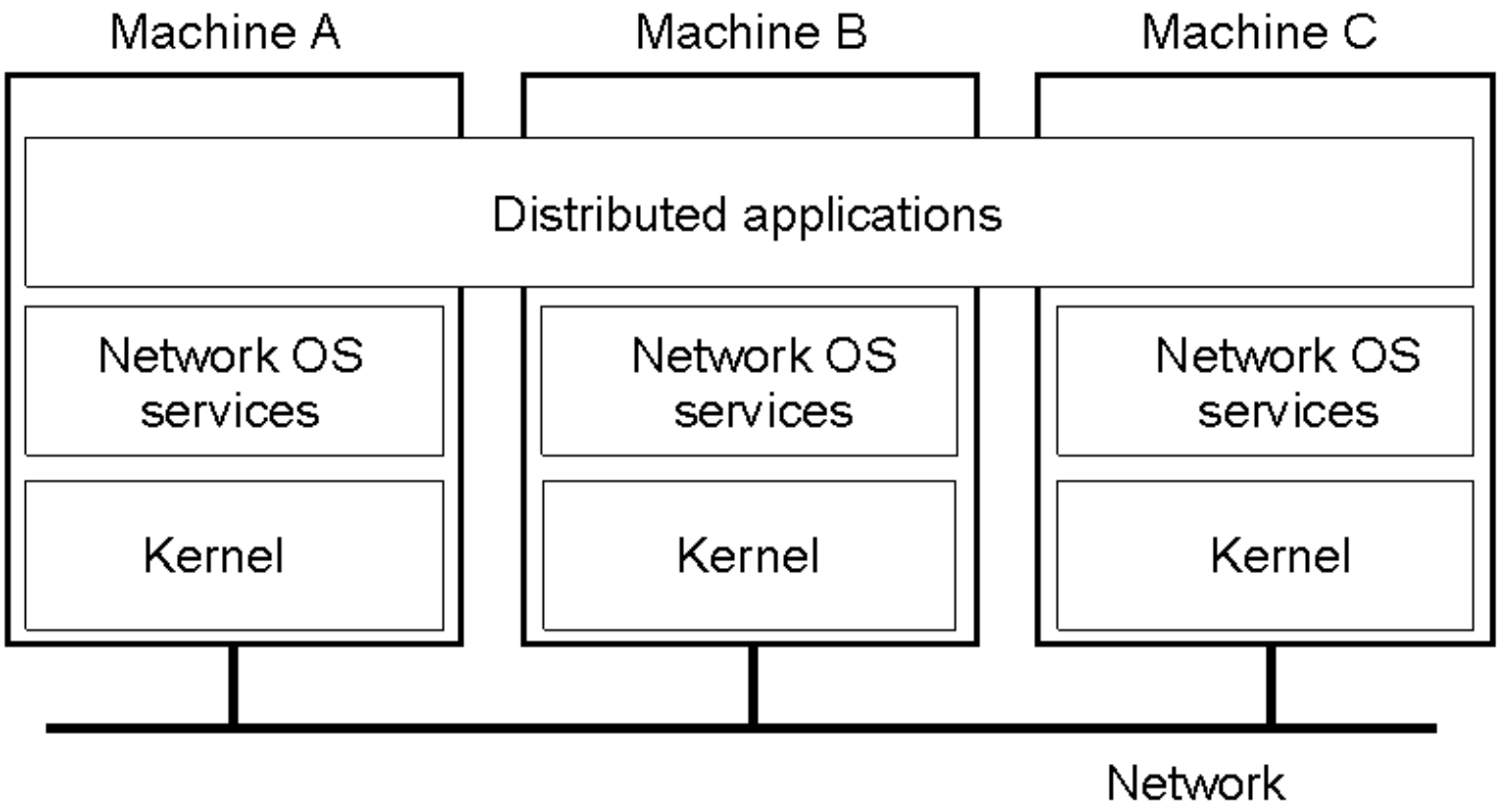
- Like a uniprocessor operating system
- Manage multiple CPUs transparently to the user
- Each processor has its own hardware cache
  - Maintain consistency of cached data
  - Scalability issues
- Shared variable versus message passing

Multicomputer Operating Systems

- More complex than multiprocessor OS
  - Because communication must be through explicit message passing

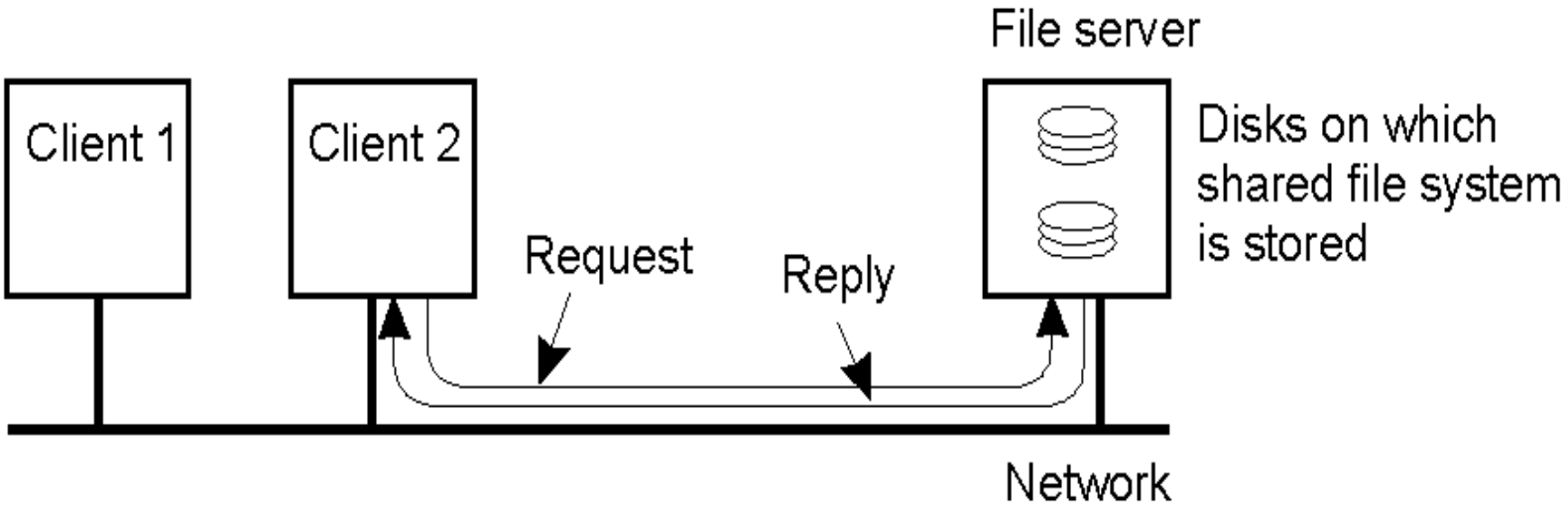


Network Operating System



Network Operating System

- Employs a client-server model
  - Minimal OS kernel
  - Additional functionality as user processes



Network-Operating Systems

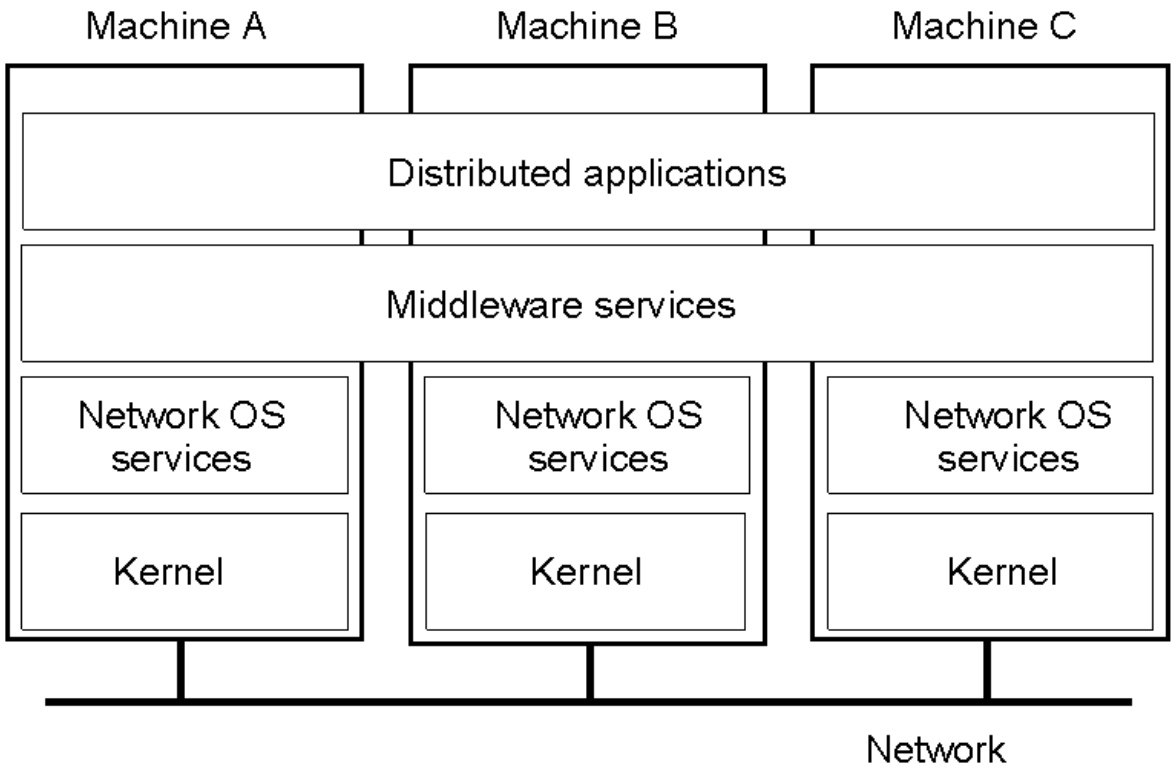
- Users are aware of multiplicity of machines. Access to resources of various machines is done explicitly by
  - Remote logging into the appropriate remote machine.
  - Transferring data from remote machines to local machines, via the File Transfer Protocol (FTP) mechanism.

Distributed Operating System

- Users not aware of multiplicity of machines.
- Manages resources in a distributed system
  - Seamlessly and transparently to the user
- Looks to the user like a centralized OS
  - But operates on multiple independent CPUs
- Provides transparency
  - Location, migration, concurrency, replication,…
- Presents users with a virtual uniprocessor

Middleware-based Systems

- General structure of a distributed system as middleware.



Any Questions?