Distributed and Operating Systems

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UMass Computer Science

http://lass.cs.umass.edu/~shenoy/courses/677

Course Syllabus

- CMPSCI 677: Distributed and Operating Systems
- *Instructor:* Prashant Shenoy
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- *Course web page:* http://lass.cs.umass.edu/~shenoy/courses/677

Course Outline

- Introduction *(today)*
  - What, why, why not?
  - Basics
- Distributed Architectures
- Interprocess Communication
  - RPCs, RMI, message- and stream-oriented communication
- Processes and their scheduling
  - Thread/process scheduling, code/process migration, virtualization
- Naming and location management
  - Entities, addresses, access points

Course Outline

- Canonical problems and solutions
  - Mutual exclusion, leader election, clock synchronization, …
- Resource sharing, replication and consistency
  - DFS, consistency issues, caching and replication
- Fault-tolerance
- Security in distributed Systems
- Distributed middleware
- Advanced topics: web, cloud computing, green computing, multimedia, and mobile systems

Misc. Course Details

- *Textbook:* Distributed Systems, 2nd ed, by Tannenbaum and Van Steen, Prentice Hall 2007 (recommended)
- *Grading*
  - 4-5 Homeworks (15%), 3-4 programming assignments (40%)
  - 1 mid-term and 1 final (40%), class participation + quizzes (5%)
- *Course mailing list*: cs677 @ cs.umass.edu
  - Spire will automatically add you to this list.
- *Pre-requisites*
  - Undergrad course in operating systems
  - *Good* programming skills in a high-level prog. language

Why Distributed Systems?

- Many systems that we use on a daily basis are distributed
  - World wide web, Google
  - Amazon.com
  - Peer-to-peer file sharing systems
  - SETI@Home
  - Grid and cluster computing
  - Modern networked computers
- Useful to understand how such real-world systems work
- Course covers basic principles for designing distributed systems

Definition of a Distributed System

- A distributed system:
  - Multiple connected CPUs working together
  - A collection of independent computers that appears to its users as a single coherent system
- Examples: parallel machines, networked machines

Advantages and Disadvantages

- Advantages
  - Communication and resource sharing possible
  - Economics – price-performance ratio
  - Reliability, scalability
  - Potential for incremental growth
- Disadvantages
  - Distribution-aware PLs, OSs and applications
  - Network connectivity essential
  - Security and privacy

Transparency in a Distributed System

Transparency	Description
Access	Hide differences in data representation and how a resource is accessed
Location	Hide where a resource is located
Migration	Hide that a resource may move to another location
Relocation	Hide that a resource may be moved to another location while in use
Replication	Hide that a resource may be shared by several competitive users
Concurrency	Hide that a resource may be shared by several competitive users
Failure	Hide the failure and recovery of a resource
Persistence	Hide whether a (software) resource is in memory or on disk

Different forms of transparency in a distributed system.

Open Distributed Systems

- Offer services that are described a priori
  - Syntax and semantics are known via protocols
- Services specified via interfaces
- Benefits
  - Interoperability
  - Portability
- Extensibility
  - Open system evolve over time and should be extensible to accommodate new functionality.
  - Separate policy from mechanism

Scalability Problems

Concept	Example
Centralized services	A single server for all users
Centralized data	A single on-line telephone book
Centralized algorithms	Doing routing based on complete information

Examples of scalability limitations.

Scaling Techniques

- *Principles* for good decentralized algorithms
  - No machine has complete state
  - Make decision based on local information
  - A single failure does not bring down the system
  - No global clock
- *Techniques*
  - Asynchronous communication
  - Distribution
  - Caching and replication

Distributed Systems Models

- Minicomputer model (e.g., early networks)
  - Each user has local machine
  - Local processing but can fetch remote data (files, databases)
- Workstation model (e.g., Sprite)
  - Processing can also migrate
- Client-server Model (e.g., V system, world wide web)
  - User has local workstation
  - Powerful workstations serve as servers (file, print, DB servers)
- Processor pool model (e.g., Amoeba, Plan 9)
  - Terminals are Xterms or diskless terminals
  - Pool of backend processors handle processing

Distributed System Models (contd)

- Cluster computing systems / Data centers
  - LAN with a cluster of servers + storage
    - Linux, Mosix, ..
    - Used by distributed web servers, scientific applications, enterprise applications
- Grid computing systems
  - Cluster of machines connected over a WAN
  - SETI @ home
- WAN-based clusters / distributed data centers
  - Google, Amazon, …
- Virtualization and data center
- Cloud Computing

Emerging Models

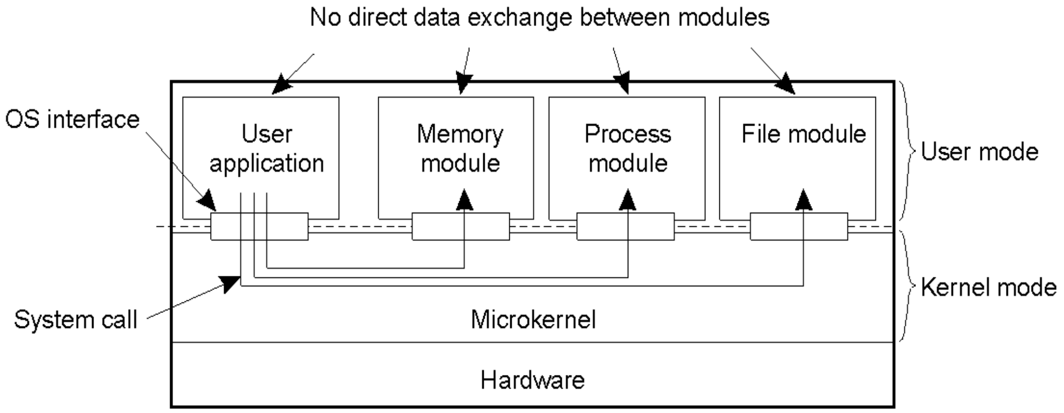
- Distributed Pervasive Systems
  - “smaller” nodes with networking capabilities
    - Computing is “everywhere”
  - Home networks: TiVO, Windows Media Center, …
  - Mobile computing: smart phones, iPODs, Car-based PCs
  - Sensor networks
  - Health-care: personal area networks
- Sustainability as a design goal

Uniprocessor Operating Systems

- An OS acts as a resource manager or an arbitrator
  - Manages CPU, I/O devices, memory
- OS provides a virtual interface that is easier to use than hardware
- Structure of uniprocessor operating systems
  - Monolithic (e.g., MS-DOS, early UNIX)
    - One large kernel that handles everything
  - Layered design
    - Functionality is decomposed into N layers
    - Each layer uses services of layer N-1 and implements new service(s) for layer N+1

Uniprocessor Operating Systems

Microkernel architecture
- Small kernel
- user-level servers implement additional functionality



Distributed Operating System

- 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

Types of Distributed OSs

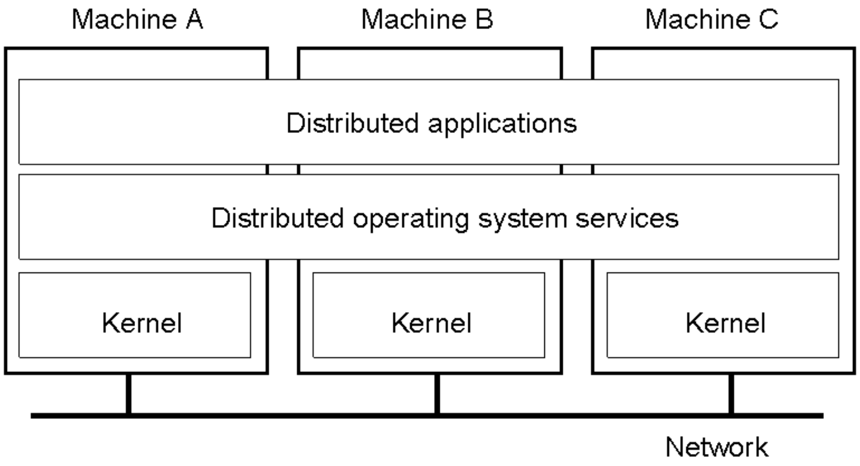
System	Description	Main Goal
DOS	Tightly-coupled operating system for multi-processors and homogeneous multicomputers	Hide and manage hardware resources
NOS	Loosely-coupled operating system for heterogeneous multicomputers (LAN and WAN)	Offer local services to remote clients
Middleware	Additional layer atop of NOS implementing general-purpose services	Provide distribution transparency

Multiprocessor Operating Systems

- Like a uniprocessor operating system
- Manages multiple CPUs transparently to the user
- Each processor has its own hardware cache
  - Maintain consistency of cached data

Multicomputer Operating Systems

Example: MOSIX cluster - single system image



Machine A

Machine B

Machine C

Distributed applications

Distributed operating system services

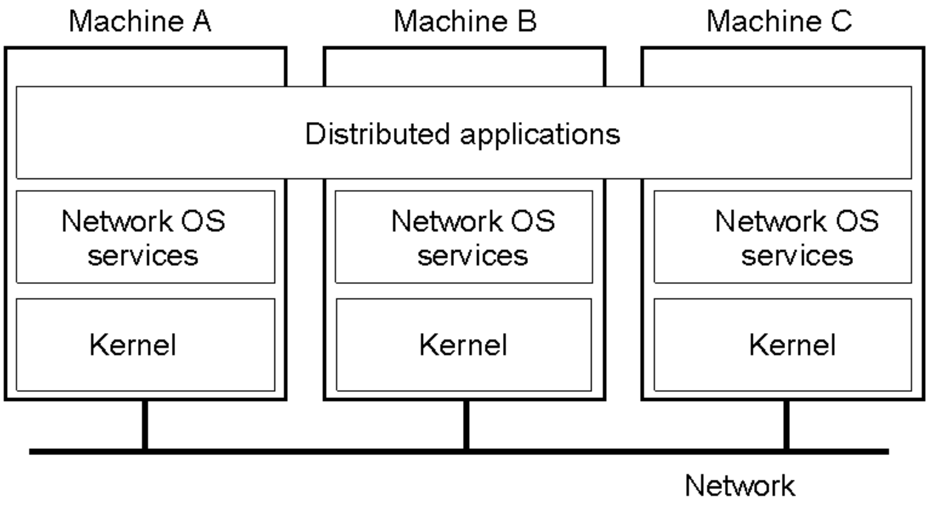
Kernel

Kernel

Kernel

Network

Network Operating System



Machine A

Machine B

Machine C

Distributed applications

Network OS services

Network OS services

Network OS services

Kernel

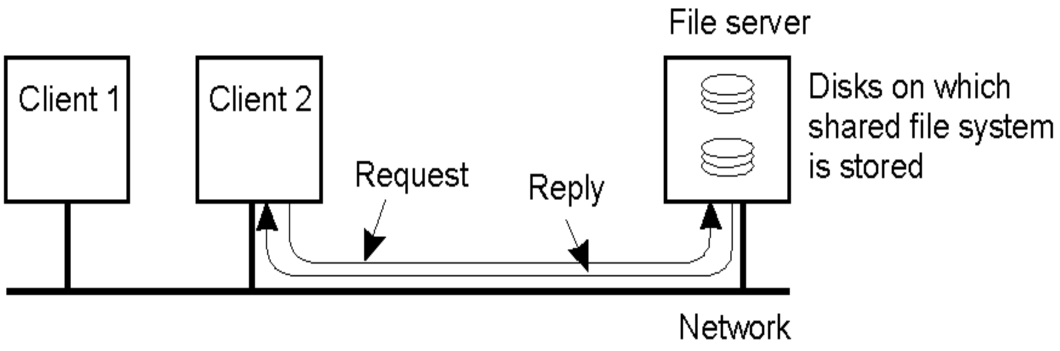
Kernel

Kernel

Network

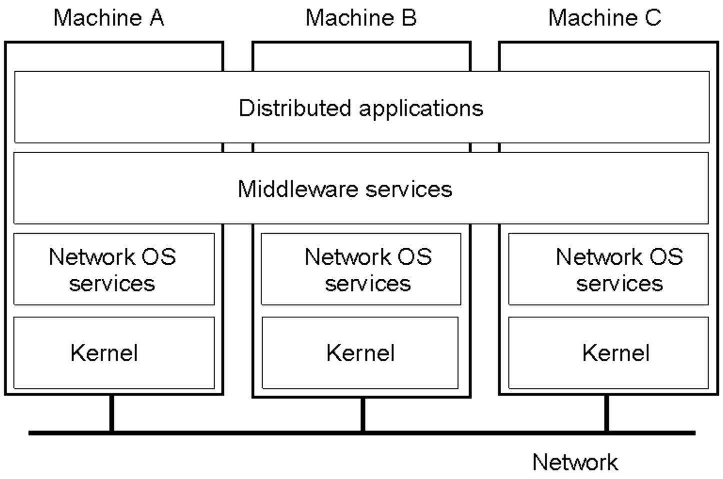
Network Operating System

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



Middleware-based Systems

- General structure of a distributed system as middleware.



Comparison between Systems

Item	**Distributed OS**		**Network OS**	**Middleware-based OS**
	Multiproc.	**Multicomp.**		
Degree of transparency	Very High	High	Low	High
Same OS on all nodes	Yes	Yes	No	No
Number of copies of OS	1	N	N	N
Basis for communication	Shared memory	Messages	Files	Model specific
Resource management	Global, central	Global, distributed	Per node	Per node
Scalability	No	Moderately	Yes	Varies
Openness	Closed	Closed	Open	Open