Course Syllabus

- CMPSCI 677: Distributed and Operating Systems
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  - Office hours: TBD
- **Course web page:** [http://lass.cs.umass.edu/~shenoy/courses/677](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

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

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

<table>
<thead>
<tr>
<th>Concept</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centralized services</td>
<td>A single server for all users</td>
</tr>
<tr>
<td>Centralized data</td>
<td>A single on-line telephone book</td>
</tr>
<tr>
<td>Centralized algorithms</td>
<td>Doing routing based on complete information</td>
</tr>
</tbody>
</table>

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

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

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

Network Operating System
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

<table>
<thead>
<tr>
<th>Item</th>
<th>Distributed OS</th>
<th>Network OS</th>
<th>Middleware-based OS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multiproc.</td>
<td>Multicomp.</td>
<td></td>
</tr>
<tr>
<td>Degree of transparency</td>
<td>Very High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Same OS on all nodes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Number of copies of OS</td>
<td>1</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Basis for communication</td>
<td>Shared memory</td>
<td>Messages</td>
<td>Files</td>
</tr>
<tr>
<td>Resource management</td>
<td>Global, central</td>
<td>Global, distributed</td>
<td>Per node</td>
</tr>
<tr>
<td>Scalability</td>
<td>No</td>
<td>Moderately</td>
<td>Yes</td>
</tr>
<tr>
<td>Openness</td>
<td>Closed</td>
<td>Closed</td>
<td>Open</td>
</tr>
</tbody>
</table>