Outline

- Introduction to Distributed Systems
- Clock
- Q&A
Distributed Systems

- Systems Where Components of Networked Computers Communicate and Coordinate Their Actions via Message Passing
  - Concurrency
  - No Global Clock
  - Independent Failures

- Systems Consisting of Collections of Spatially Separated Processes Communicating by Exchanging Messages
  - Sharing States
  - Providing Services
  - Having Global Properties
  - Heterogeneity
  - Unreliable, Insecure, Costly Comm.
  - Scalability
  - Autonomy
Different-Scale Systems

- Systems of Increasing Scale & Decreasing Integration

<table>
<thead>
<tr>
<th>System Type</th>
<th>Heterogeneity, Geographic Distribution</th>
<th>Lack of Centralized Control</th>
<th>Exemplar Computational Model</th>
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<tr>
<td>End (Single) System</td>
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<td>Multithreading</td>
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<tr>
<td>Cluster</td>
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<td>Distributed Shared Memory</td>
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<tr>
<td>Intranet</td>
<td>O</td>
<td></td>
<td>Manager/Worker</td>
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<td>Internet</td>
<td>O</td>
<td>O</td>
<td>Collaborative Systems</td>
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Example of Distributed Systems
Distributed System Goals

**Accessibility**
- As Connectivity and Sharing Increases, Security and Privacy Matter

**Distribution Transparency**
- Access: Regarding Data Representation & Access Method
- Location: Regarding Resource Location
- Migration: Regarding Resource Movement
- Relocation: Regarding Movement in Use
- Replication: Regarding Resource Replication
Distributed System Goals (Cont’d)

- Distribution Transparency (Cont’d)
  - Concurrency: Regarding Competitive Sharing
  - Failure: Regarding Resource Failure and Recovery

- Performance & Comprehensibility Issues

- Openness:
  - Following Standard Rules That Describe the Syntax and Semantics of Services
  - Interoperability
Distributed System Goals (Cont’d)

Openness (Cont’d)
- Portability
- Extensibility

Separating Policy from Mechanism

Scalability
- Limitations
  - Centralized services
  - Centralized data
  - Centralized algorithms
  - Synchronous communication
Distributed System Goals (Cont’d)

- **Scalability (Cont’d)**
  - Decentralized Characteristics
    - No local maintenance of global system state
    - Decision making based only on local information
    - Localized Failure
    - No global clock
  - Scaling Techniques
    - Asynchronous communication
    - Client and Server load balancing
    - Distribution: e.g., DNS & WWW
    - Replication & caching
Distributed System Goals (Cont’d)

- Pitfalls
  - Network Reliability
  - Network Security
  - Network Homogeneity
  - Static Topology
  - Zero Latency
  - Infinite Bandwidth
  - Zero Transport Cost
  - One Administrator
Technical Goals

- Heterogeneity
  - H/W, S/W, and Data Components
- Varying Component Size and Extent
- Network Connection
- Uniform Set of Services
- Certain Global Properties
Distributed Computing Approaches

- Grid
  - Addressing Infrastructure
- Peer-to-Peer
  - Addressing Failure
    - Self-organizing into network topologies
  - w/o a Global Server or Authority
Distributed System Types

- Distributed Computing Systems
  - Cluster Computing Systems
    - Collection of computers connected in a high-speed network
  - Grid Computing Systems
    - Federation of computer systems possibly in different administrative domains

- Distributed Information Systems
  - Transaction Processing Systems
    - Atomic, Consistent, Isolated, and Durable Transaction
Distributed System Types (Cont’d)

- Distributed Information Systems (Cont’d)
  - Enterprise Application Integration
    - Communicating Independent Components
      - Remote procedure call
      - Remote method invocation
      - Message-oriented middleware w/ logical contact points
        - Message queuing model
        - Message brokers as application-level gateway w/ subscription & publication
  - Distributed Pervasive Systems
    - Home Systems Possibly w/ UPnP
    - Electronic Health Care Systems in a BAN
    - Sensor Networks
Issues

- Problem
  - No Global Clock

- Issues
  - How to Determine an Order of Events
  - How to Determine Global States
    - Consistency
Clock

Skew

- Difference between the Readings of Any Two Clocks

Drift

- Divergence of Clocks due to Counting Times at Different Rates
UTC (Coordinated Universal Time)

- **International Time Standard**
  - Formerly, Greenwich Mean Time or GMT
    - Zero hours UTC: midnight Greenwich (0 degrees longitude)
  - Based on Atomic Time (Drift Rate: $1/10^{13}$ Seconds/Second)
    - Signals synchronized and broadcast regularly
      - From land-based radio stations and satellites
Synchronous vs Asynchronous

- **Synchronous Systems**
  - Known Bounds
    - Drift rate of clocks
    - Max message transmission delay
    - Time to execute each step of a process

- **Asynchronous Systems**
  - No Bounds