Introduction to Distributed Systems

Material adapted from *Distributed Systems: Concepts & Design*, George Coulouris, et al. and *Engineering Distributed Objects*, Wolfgang Emmerich

Outline

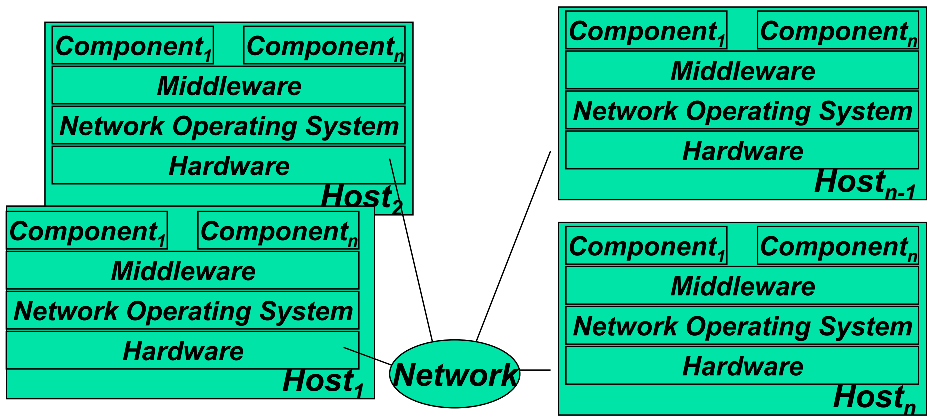
- What is a Distributed System?
- Examples of Distributed Systems
- Distributed System Requirements
- Transparency in Distributed System

What is a Distributed System?

What is a Distributed System?

- A system in which hardware or software components located at networked computers communicate and coordinate their actions only by passing messages. (Coulouris)
- A distributed system is a collection of autonomous hosts that that are connected through a computer network. Each host executes components and operates a distribution middleware, which enables the components to coordinate their activities in such a way that users perceive the system as a single, integrated computing facility. (Emmerich)

What is a Distributed System?



Centralized System Characteristics

- One component with non-autonomous parts
- Component shared by users all the time
- All resources accessible
- Software runs in a single process
- Single Point of control
- Single Point of failure

Distributed System Characteristics

- Multiple autonomous components
- Components are not shared by all users
- Resources may not be accessible
- Software runs in concurrent processes on different processors
- Multiple Points of control
- Multiple Points of failure

Key Terms

- **Resources** – things shared in a distributed system
  - hardware (disks, printers)
  - software (files, databases, data objects)
- **Server** – program or *process* that performs services in response to requests from other processes.
- **Client** – process that makes requests of a server by *invoking* an operation.
- **Remote Invocation** – complete send and response sequence
- Servers & Clients are *software processes*

Examples of Distributed Systems

Boeing 777 Configuration Management

Problems to be solved

- Scale
  - 3,000,000 parts per aircraft
  - Configuration of every aircraft is different
  - CAA regulations demand that records are kept for every single part of aircraft
  - Aircraft evolve during maintenance
  - Boeing produce 500 aircraft per year
  - Configuration database grows by 1.5 billion parts each year
  - Projected life of each aircraft 30 years
  - 45,000 engineers need on-line access to engineering data

Problems to be solved (cont'd)

- COTS Integration
  - Existing IT infrastructure was no longer appropriate
  - Boeing could not afford to build required IT infrastructure from scratch
  - Components were purchased from several different specialized vendors
    - relational database technology
    - enterprise resource planning
    - computer aided project planning
  - Components needed to be integrated

Problems to be solved (cont'd)

Heterogeneity

- 20 Sequent database machines as servers for the engineering data
- 200 UNIX application servers
- NT and UNIX workstations for engineers

Why distributed object technology

- Object wrapping of COTS
- Resolution of distribution at high level of abstraction
- Resolution of heterogeneity
- Scalability

Distributed System Requirements

Requirements

- Integration of new, legacy and components off-the-shelf
  - Legacy components might not need to be re-engineered
  - COTS cannot be modified
- Heterogeneity of
  - hardware platforms
  - operating systems
  - networks
  - programming languages
- Construction of distributed systems

Common Requirements/Challenges

- What are we trying to achieve when we construct a distributed system?
- Certain requirements are common to many distributed systems
  - Heterogeneity
  - Resource Sharing
  - Openness
  - Security
  - Concurrency
  - Scalability
  - Fault Tolerance
  - Transparency

Resource Sharing

- Ability to use any hardware, software or data anywhere in the system.
- Resource manager controls access, provides naming scheme and controls concurrency.
- Resource sharing model (e.g. client/ server or object-based) describing how
  - resources are provided,
  - they are used and
  - provider and user interact with each other.

Openness

- Openness is concerned with extensions and improvements of distributed systems.
- Detailed interfaces of components need to be published.
- New components have to be integrated with existing components.
- Differences in data representation of interface types on different processors (of different vendors) have to be resolved.

Concurrency

- Components in distributed systems are executed in concurrent processes.
- Components access and update shared resources (e.g. variables, databases, device drivers).
- Integrity of the system may be violated if concurrent updates are not coordinated.
  - Lost updates
  - Inconsistent analysis

Fault Tolerance

- Hardware, software and networks fail!
- Distributed systems must maintain availability even at low levels of hardware/software/network reliability.
- Fault tolerance is achieved by
  - recovery
  - redundancy

Scalability

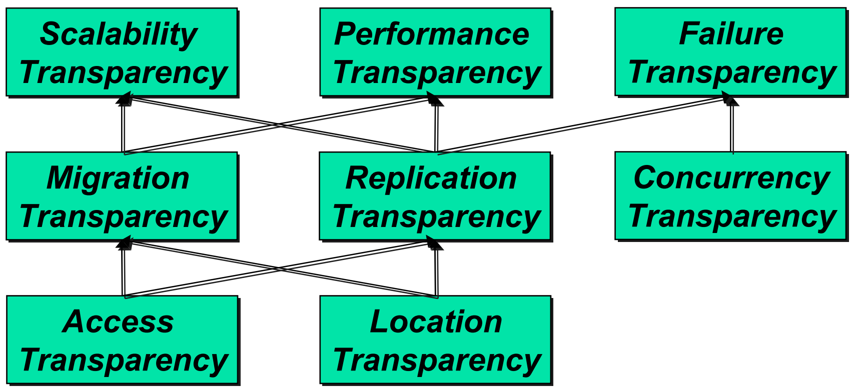
- Adoption of distributed systems to
  - accommodate more users
  - respond faster (this is the hard one)
- Usually done by adding more and/or faster processors.
- Components should not need to be changed when scale of a system increases.
- Design components to be scalable!

Transparency in Distributed Systems

Transparency

- Distributed systems should be perceived by users and application programmers as a whole rather than as a collection of cooperating components.
- Transparency has different dimensions that represent various properties distributed systems should have.

Distribution Transparency



Access Transparency

- Enables local and remote information objects to be accessed using identical operations.
- Example: File system operations in NFS.
- Example: Navigation in the Web.
- Example: SQL Queries

Location Transparency

- Enables information objects to be accessed without knowledge of their location.
- Example: File system operations in NFS
- Example: Pages in the Web
- Example: Tables in distributed databases

Concurrency Transparency

- Enables several processes to operate concurrently using shared information objects without interference between them.
- Example: NFS
- Example: Automatic teller machine network
- Example: Database management system

Replication Transparency

- Enables multiple instances of information objects to be used to increase reliability and performance without knowledge of the replicas by users or application programs
- Example: Distributed DBMS
- Example: Mirroring Web Pages.

Failure Transparency

- Enables the concealment of faults
- Allows users and applications to complete their tasks despite the failure of other components.
- Example: Database Management System

Migration Transparency

- Allows the movement of information objects within a system without affecting the operations of users or application programs
- Example: NFS
- Example: Web Pages

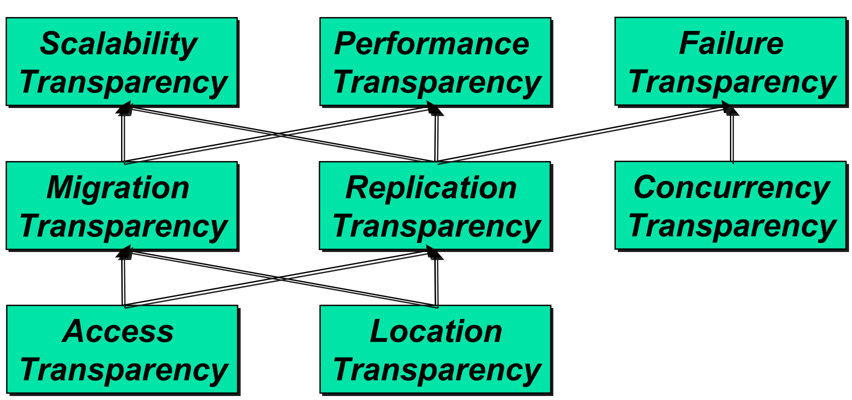
Performance Transparency

- Allows the system to be reconfigured to improve performance as loads vary.
- Example: Distributed make.

Scaling Transparency

- Allows the system and applications to expand in scale without change to the system structure or the application algorithms.
- Example: World-Wide-Web
- Example: Distributed Database

Distribution Transparency



Two Views of Transparency

- The system should hide its distributed nature, programs running on a multiple-computer system appear no different from a single-computer system.
- The system should *not* hide its distributed nature. The programs *are* aware of the multiple computers in the system.
- When designing distributed applications we need to favor the second view.

(see: “A Note on Distributed Computing”, Jim Waldo, et al.)

Key Points

- What is a Distributed System
- Adoption of Distributed Systems is driven by Non-Functional Requirements
- Distribution needs to be transparent to users and application designers
- Transparency has several dimensions
- Transparency dimensions depend on each other