Introduction to Distributed Systems (DS)

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Outline

- What is a distributed system?
- Challenges and benefits of distributed systems
- Distribution transparencies
- Pitfalls when developing distributed systems
- Types of distributed systems

What is a distributed system? Many definitions

- [Coulouris]
  - A distributed system is one in which hardware or software components located at networked computers communicate and coordinate their actions only by passing messages.
- [Tanenbaum & van Steen]
  - A distributed system is a collection of independent computers that appears to its users as a single coherent system.
- [Lamport]
  - A distributed system is a system that prevents you from doing any work when a computer you have never heard about, fails.
- The above definitions take different perspectives
  - Operational perspective
  - User perspective
  - DS characteristics perspective

Examples of distributed systems

- Web search
  - Index the entire contents of the Web.
- Massively multiplayer online games
  - Very large number of users sharing a virtual world.
- Financial trading
  - Real time access and processing of a wide rage of information sources.

Implications of distributed systems

- **Concurrency**
  - components execute in concurrent processes that read and update shared resources. Requires coordination
- **No global clock**
  - makes coordination difficult (ordering of events)
- **Independent failure of components**
  - "partial failure" & incomplete information
- **Unreliable communication**
  - Loss of connection and messages. Message bit errors
- **Unsecure communication**
  - Possibility of unauthorised recording and modification of messages
- **Expensive communication**
  - Communication between computers usually has less bandwidth, longer latency, and costs more, than between independent processes on the same computer

Why distributed systems?

- **resource sharing**
  - the possibility of using available resources any where
- **openness**
  - an open distributed system can be extended and improved incrementally
  - requires publication of component interfaces and standards protocols for accessing interfaces
- **scalability**
  - the ability to serve more users, provide acceptable response times with increased amount of data
- **fault tolerance**
  - maintain availability even when individual components fail
- **allow heterogeneity**
  - network and hardware, operating system, programming languages, implementations by different developers

Resource sharing

- The opportunity to use available hardware, software or data anywhere in the system
- **Resource managers** control access, offer a scheme for naming, and control concurrency
- A ***service*** is a software module that manages a collection of related resources and presents their functionality to users.
- A **resource sharing model** describes how
  - resources are made available
  - resources can be used
  - service provider and user interact with each other

Models for resource sharing

- **Client-server** resource model
  - Server processes act as resource managers, and offer services (collection of procedures)
  - Client processes send requests to servers
  - (HTTP defines a client-server resource model)
- **Object-based** resource model
  - Any entity in a process is modeled as an object with a message based interface that provides access to its operations
  - Any shared resource is modeled as an object
  - Object based middlewares (CORBA, Java RMI) defines object-based resource models

Scalability

- A system is **scalable** if it remains effective when there is a significant increase in the amount of resources (data) and number of users
  - Internet: number of users and services has grown enormously
- **Scalability** denotes the ability of a system to handle an increasing future load
- Requirements of scalability often leads to a distributed system architecture (several computers)

Scalability problems (1)

- Often caused by centralized solutions

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

Scalability problems (2)

- Characteristics of **decentralized** algorithms:
  - No machine has complete information about the system state.
  - Machines make decisions based only on local information.
  - Failure of one machine does not ruin the algorithm.
  - There is no implicit assumption that a global clock exists.

Scaling techniques

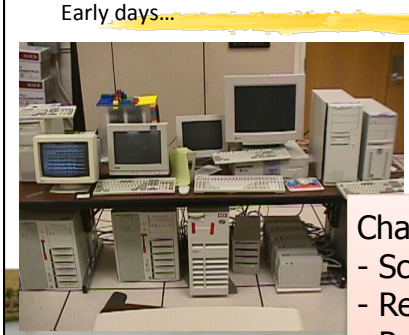
- **Distribution**
  - splitting a resource (such as data) into smaller parts, and spreading the parts across the system (cf DNS)
- **Replication**
  - replicate resources (services, data) across the system
  - increases availability, helps to balance load
  - caching (special form of replication)
- **Hiding communication latencies**
  - avoid waiting for responses to remote service requests (use asynchronous communication or design to reduce the amount of remote requests)

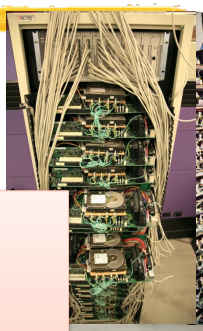
Fault tolerance

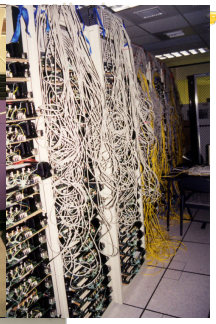
- Hardware, software and network fail!!
- DS must maintain availability even in cases where hardware/software/network have low reliability
- Failures in distributed systems are partial
  - makes error handling particularly difficult
- Many techniques for handling failures
  - Detecting failures (checksum a.o.)
  - Masking failures (retransmission in protocols)
  - Tolerating failures (as in web-browsers)
  - Recovery from failures (roll back)
  - Redundancy (replicate servers in failure-independent ways)

Example: Google File-System

Early days…







Challenges:
- Scalability
- Reliability
- Performance
- Openness

Distribution transparency

- An important goal of a distributed system is to hide the fact that its processes and resources are physically distributed across multiple computers
- A distributed system that is able to present itself to its users and applications as if it were only a single computer system is said to be **transparent**

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 is replicated
Concurrency	Hide that a resource may be shared by several competitive users
Failure	Hide the failure and recovery of a resource

Different forms of transparency in a distributed system (ISO, 1995).
Trade-off between degree of transparency and performance of a system

Pitfalls when Developing Distributed Systems

- False assumptions made by first time developer:
  - The network is reliable.
  - The network is secure.
  - The network is homogeneous.
  - The topology does not change.
  - Latency is zero.
  - Bandwidth is infinite.
  - Transport cost is zero.
  - There is one administrator.

Quality of Service (QoS)

- Non-functional properties of the system:
  - Reliability
  - Security
  - Performance (Responsiveness and throughput)
- *Adaptability* to meet changes is an important aspect of QoS

The role of middleware in distributed systems

- Layer of software offering a single-system view
- Offers transparencies (access, location, …)
- Simplifies development of distributed applications and services

Distributed applications and services

Platform Independent API

DISTRIBUTION MIDDEWARE

- transaction oriented (ODTP XA)
- message oriented(IBM MQSeries)
- remote procedure call (X/Open DCE)
- object-based (CORBA, COM, Java)

Platform Dependent API

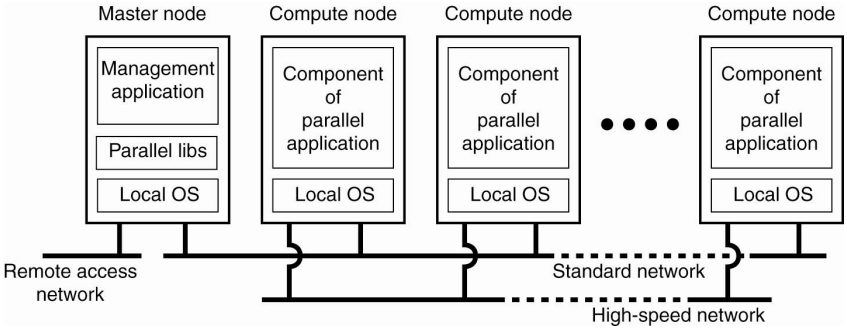
Local OS 1 | Local OS 2 | . . . | Local OS n

Types of distributed system

- Distributed Computing Systems
  - Used for high performance computing tasks
  - Cluster and Cloud computing systems
  - Grid computing systems
- Distributed Information Systems
  - Systems mainly for management and integration of business functions
  - Transaction processing systems
  - Enterprise Application Integration
- Distributed Pervasive (or Ubiquitous) Systems
  - Mobile and embedded systems
  - Home systems
  - Sensor networks

Distributed Computing Systems:
Cluster Computing Systems

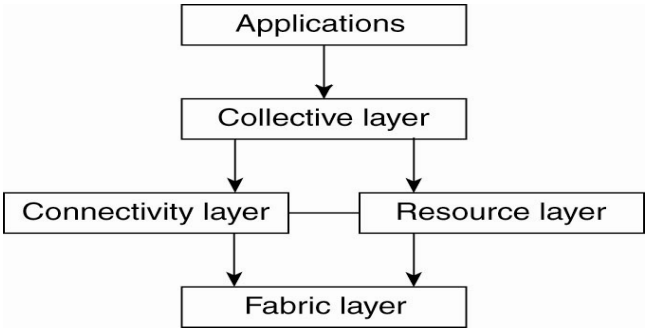
Collection of similar PCs, closely connected, all run same OS



An example of a cluster computing system.

Distributed Computing Systems:
Grid Computing Systems

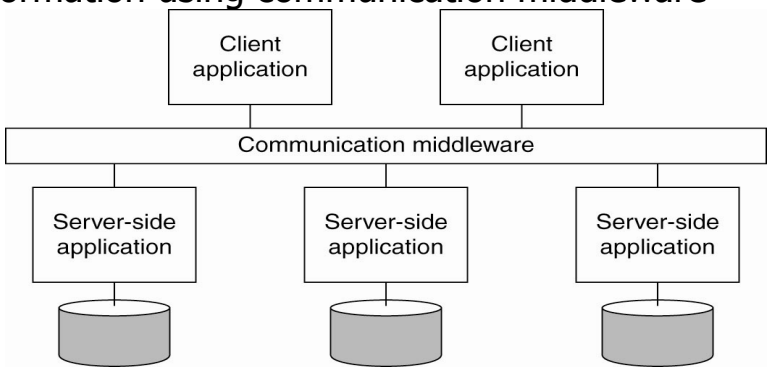
Federation of autonomous and heterogeneous computer systems (HW,OS,...), several adm domains



A layered architecture for grid computing systems.

Distributed Information Systems: Enterprise Application Integration

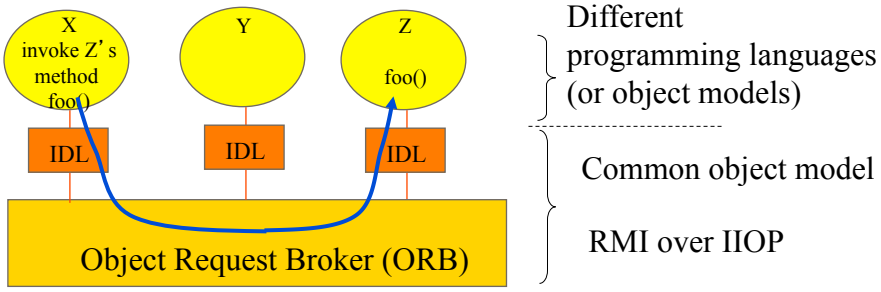
Allowing existing applications to directly exchange information using communication middleware



Middleware as a communication facilitator in enterprise application integration

Example communcation middleware: CORBA

Clients may invoke methods of remote objects without worrying about:
object location, programming language,
operating system platform, communcation
protocols or hardware.



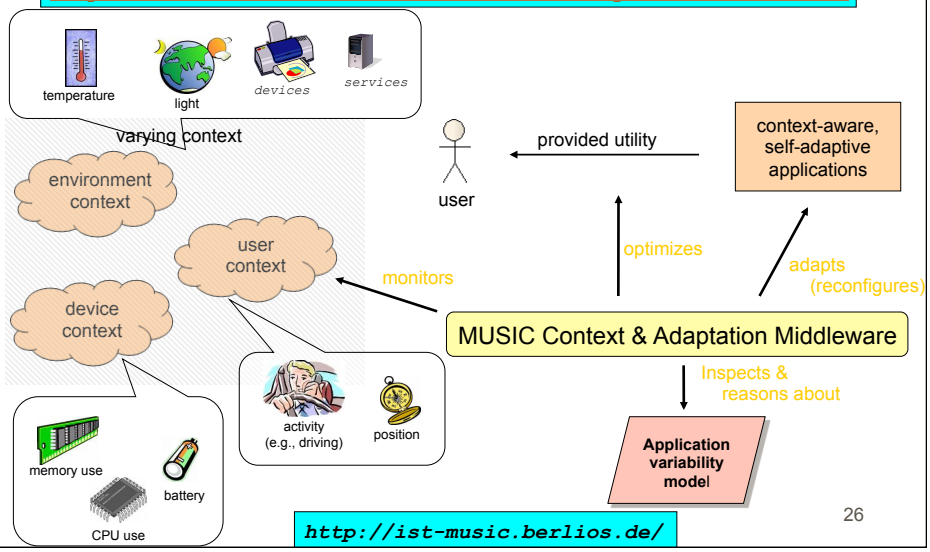
Distributed Pervasive Systems

- Pervasive systems is about exploiting the increasing integration of services and (small/tiny) computing devices in our everyday physical world
- (Mobile) Devices in distributed pervasive systems discovers the environment (its services) and establishes themselves in this environment as best as possible.
- Requirements for pervasive applications
  - Embrace contextual changes.
  - Encourage ad hoc and dynamic composition.
  - Recognize sharing as the default.

Distributed pervasive system :

MUSIC context-aware adaptation middleware

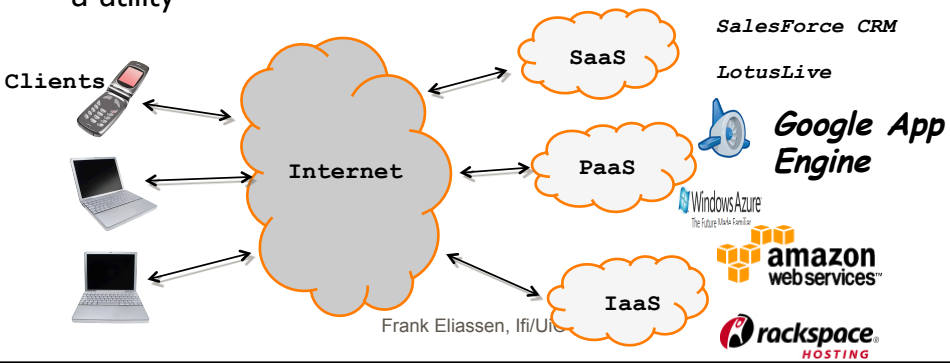
http://www.euronews.net/2010/06/16/music-to-you-mobile-s-ears/



http://ist-music.berlios.de/

Distributed Computing as a Utility

- View: Distributed resources as a commodity or utility
- Resources are provided by service suppliers and effectively rented rather than owned by the end user.
- The term cloud computing capture the vision of computing as a utility



Summary

- Distributed systems:
  - components located in a network that communicates and coordinates their actions exclusively by sending messages.
- Consequences of distributed systems
  - Independent failure of components
  - Unsecure communication
  - No global clock
- Distribution transparency: providing a single computer system view
- Requirements like resource sharing, openness, scalability, fault tolerance and heterogeneity can be satisfied by distributed systems
- Many pitfalls when developing distributed systems