Software layers

Middleware
- applications, services
- middleware
- operating system
- computer and network devices

Middleware is defined as a layer of software whose purpose is to mask heterogeneity and to provide a convenient programming model to application programmers. It hides the complexity of the communication between two or more systems or services.

Major categories of middleware: distributed objects, distributed components, publish-subscribe, web service, peer-to-peer.

Examples are CORBA, Java RMI, DCOM (Microsoft's Distributed Component Object Model).

Middleware services are e.g.: communication facilities, naming of remote entities (objects), persistence (distributed file system), distributed transactions, facilities for security.

System Models

A distributed system can be described in form of descriptive models.

Architectural model defines the interaction between components and the mapping onto the underlying network.

- Software layers
- System architectures

Interaction model
- Failure model
- Security model

The following sections of the course will discuss in more detail various aspects of these system models.
The failure model defines the ways in which failures may occur and how they are handled. Different types of failures:

- Crash faults: the process simply stops due to Hardware failures or Software errors.
- Message loss: messages may be lost due to buffer overflow of routers or network congestion.
- Fail-safe failures: the process fails by crashing; system notifies relevant partners.
- Timing failures: a local clock exceeds the bounds on its rate of drift from real time or transmission takes longer than the specified bound.
- Arbitrary failures (non-malicious Byzantine failure): a process arbitrarily omits intended processing steps, takes unintended processing steps or sends corrupted messages.
- Malicious Byzantine failure: an attacker who has studied the system attempts to break it. Examples are the corruption or replay of messages, or the modification of the program (install hacked version).

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**Architectural model**
- Defines the interaction between components and the mapping onto the underlying network.

**Software layers**
- System architectures

**Interaction model**

**Failure model**

**Security model**

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**Access transparency**

**Problem:** How to access objects in a distributed system.

- Access transparency provides access to local and remote objects in exactly the same way.

```
computer 1
  network
  computer 2
```

**Replication transparency**

**Problem:** For reasons of availability or fast access, resources, e.g., objects may be replicated.

- Replication transparency means that the user is unaware of whether an object is replicated or not. The user accesses replicated objects as if they exist only once.

```
user
  network
  user
computer 1
  network
  computer 2
```

A variety of protocols have been proposed that deal with the problem of consistency among replicated files (Update of replicated files).
**Migration transparency**

**Problem**: Object relocation in distributed systems.

Objects may migrate from one computer to another without influencing the correct behavior of running applications.

**Host migration transparency**

**Problem**: Computer migrates from one subnet to another subnet, e.g., if a user connects his laptop computer to different subnetworks. This requires a dynamic assignment of the IP address (e.g., DHCP), a name server, etc.

- The computer supports the same environment, the same applications, and the same look-and-feel, no matter where the mobile workers are currently connected to the network.

**Types of migration**

- Off-line migration.
- On-line migration.

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**Language transparency**

**Problem**: An application's components are realized by different programming languages.

- Interactions between individual components is independent from the programming language used for implementing the respective components.

**Example: calendar system**

![Diagram of calendar system with C-based system and Lisp-based system](https://example.com/calendar_diagram.png)

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**Other transparencies**

There are a number of other transparencies relevant for distributed systems.

**Failure transparency**

**Problem**: Partial failure in distributed systems, for example computer crashes or network failures.

- Up to a certain degree, failures are masked by the system.

**Concurrency transparency**

- Concurrent access to shared resources by distributed users or application components.

**Problem**: Shared access to objects in distributed systems.

- Several users or application programs can access objects simultaneously (for example shared data) without mutual influence.

**Execution transparency**

Execution transparency implies that processes may be processed on different runtime systems.

**Performance transparency**

- Allows for dynamic reconfiguration of the system to improve the overall system performance when changes in load characteristics are detected.

**Scalability transparency**

- Supports extensions and enhancements of the system or the applications without the need of modifications to the system structure or changes to the application algorithms.
key concept for better exploitation of resources within a distributed, heterogeneous system.

Location transparency
Access transparency
Replication transparency
Migration transparency
Language transparency
Other transparencies

Goal for distributed applications

Interprocess communication (IPC): message exchange between sender and receiver.

Background
Categories of Message Exchange