MODELS OF DISTRIBUTED SYSTEMS

1. Architectural Models

2. Interaction Models

3. Fault Models

Basic Notions

- *Resources* in a distributed system are shared between users. They are normally encapsulated within one of the computers and can be accessed from other computers by communication.

- Each resource is managed by a program, the *resource manager*; it offers a communication interface enabling the resource to be accessed by its users.

- Resource managers can be in general modelled as *processes*.
  If the system is designed according to an object-oriented methodology, resources are encapsulated in *objects*.

Architectural Models

What are architectural models about?

- ❐ **How are responsibilities distributed between system components and how are these components placed?**

  - **Client-server model**
  - **Peer-to-peer**

And Variations of the above two:

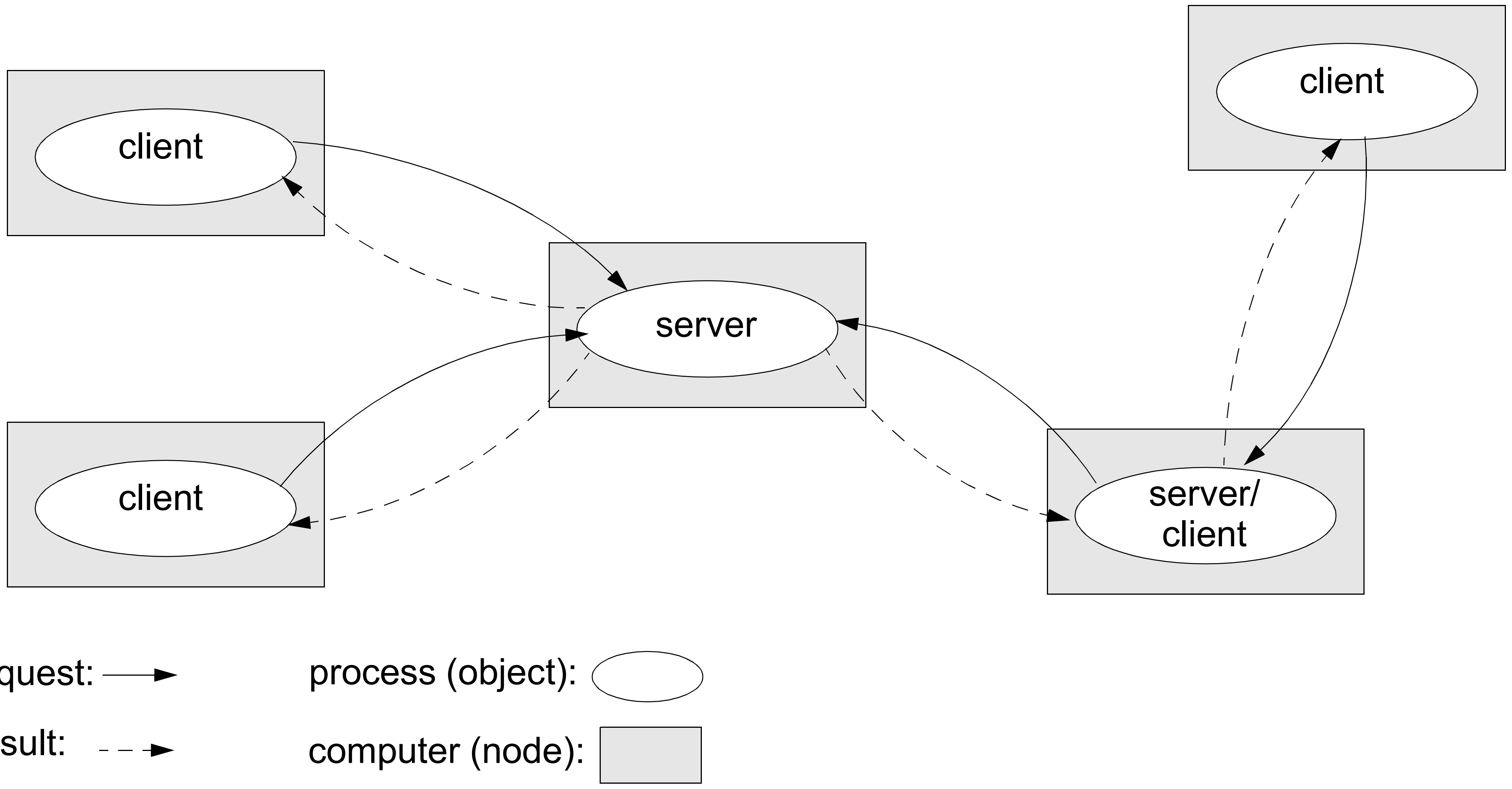
- **Proxy server**
- **Mobile code**
- **Mobile agents**
- **Network computers**
- **Thin clients**
- **Mobile devices**

Client - Server

The system is structured as a set of processes, called *servers*, that offer services to the users, called *clients*.

- **The client-server model is usually based on a simple request/reply protocol, implemented with *send/receive* primitives or using *remote procedure calls* (RPC) or *remote method invocation* (RMI):**
  - **<u>the client</u> sends a request (invocation) message to the server asking for some service;**
  - **<u>the server</u> does the work and returns a result (e.g. the data requested) or an error code if the work could not be performed.**

Client - Server

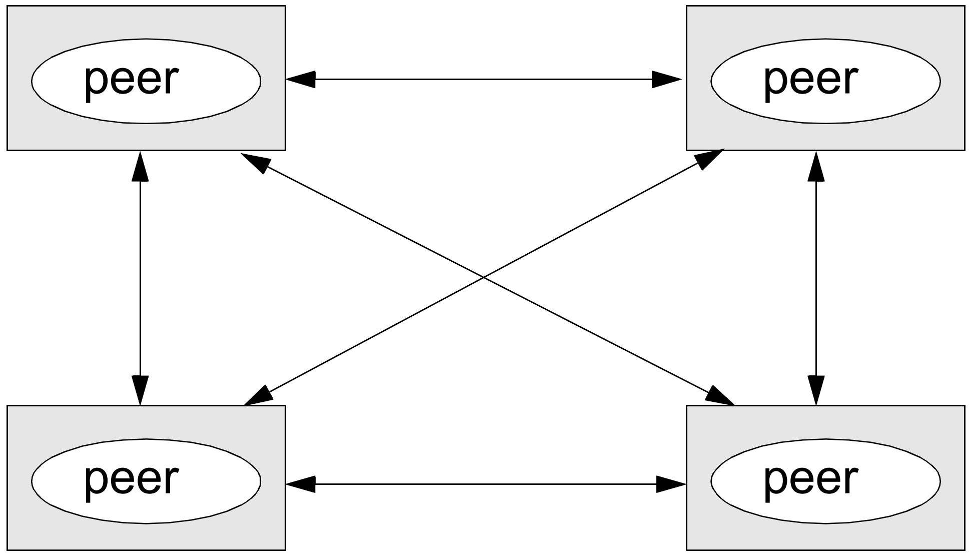


A server can itself request services from other servers; in this new relation, the server itself acts like a client.

Peer-to-Peer

All processes (objects) play similar role:

- Processes (objects) interact without particular distinction between clients and servers.
- The pattern of communication depends on the particular application.
- A large number of data objects are shared; any individual computer holds only a small part of the application database.
- Processing and communication loads for access to objects are distributed across many computers and access links.
- This is the most general and flexible model.



Peer-to-Peer

- **Some problems with client-server:**
  - **Centralisation of service $\Rightarrow$ poor scaling**

    Limitations:

    - **capacity of server**
    - **bandwidth of network connecting the server**

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  - ❒ It distributes shared resources widely

$\Downarrow$

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- Problems with peer-to-peer:
  - High complexity due to
    - cleverly place individual objects
    - retrieve the objects
    - maintain potentially large number of replicas.

Variations of the Basic Models

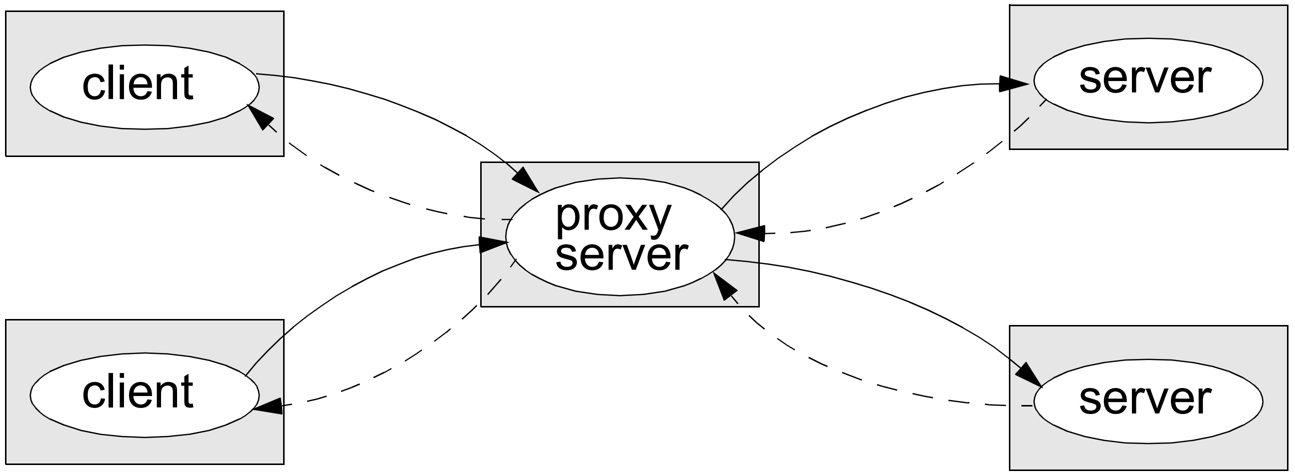
Client-server and peer-to-peer can be considered as basic models.

❒ Several variations have been proposed, with considering factors such as:

- multiple servers and caches
- mobile code and mobile agents
- mobile devices

Proxy Server

A *proxy server* provides copies (replications) of resources which are managed by other servers.



- **Proxy servers are typically used as caches for web resources. They maintain a cache of recently visited web pages or other resources.**
  When a request is issued by a client, the proxy server is first checked, if the requested object (information item) is available there.
- **Proxy servers can be located at each client, or can be shared by several clients.**
- **The purpose is to increase performance and availability, by avoiding frequent accesses to remote servers.**

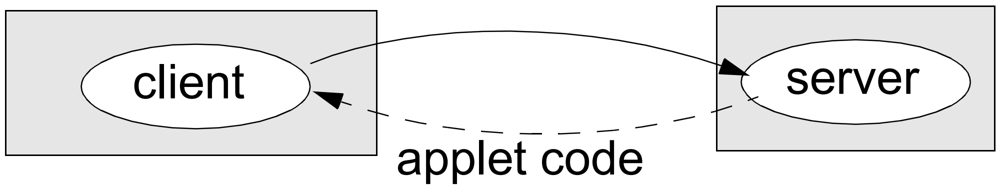
Mobile Code

Mobile code: **code sent from one computer to another and run at the destination.**

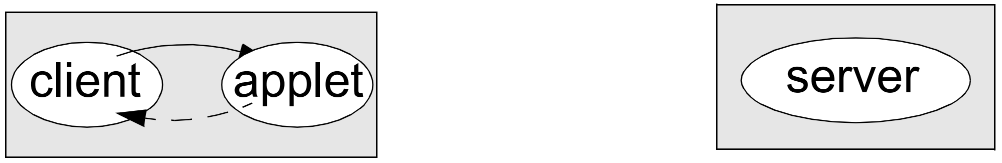
<u>Advantage</u>: remote invocations are replaced by local ones.

Typical example: Java applets.

Step 1: load applet



Step 2: interact with applet



Mobile Agents

Mobile agent: a running program that travels from one computer to another carrying out a task on someone’s behalf.

- A mobile agent is a complete program, code + data, that can work (relatively) independently.
- The mobile agent can invoke local resources/data.

Typical tasks:

- Collect information
- Install/maintain software on computers
- Compare prises from various vendors bay visiting their sites.

Attention: potential security risk (like mobile code)!

Interaction Models

How do we handle time?

Are there time limits on process execution, message delivery, and clock drifts?

- **Synchronous distributed systems**
- **Asynchronous distributed systems**

Synchronous Distributed Systems

Main features:

- Lower and upper bounds on execution time of processes can be set.
- Transmitted messages are received within a known bounded time.
- Drift rates between local clocks have a known bound.

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- Lower and upper bounds on execution time of processes can be set.
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Important consequences:

1. In a synchronous distributed system there is a notion of global physical time (with a known relative precision depending on the drift rate).
2. Only synchronous distributed systems are predictable in terms of timing. *Only such systems can be used for hard real-time applications*.
3. In a synchronous distributed system it is possible and safe to use timeouts in order to detect failures of a process or communication link.

- *It is difficult and costly to implement synchronous distributed systems*.

Asynchronous Distributed Systems

Many distributed systems (including those on the Internet) are asynchronous:

- ❐ **No bound on process execution time (nothing can be assumed about speed, load, reliability of computers).**
- ❐ **No bound on message transmission delays (nothing can be assumed about speed, load, reliability of interconnections)**
- ❐ **No bounds on drift rates between local clocks.**

Asynchronous Distributed Systems

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- ❐ No bounds on drift rates between local clocks.

Important consequences:

1. In an asynchronous distributed system there is no global physical time. Reasoning can be only in terms of logical time.
2. Asynchronous distributed systems are unpredictable in terms of timing.
3. No timeouts can be used.

Asynchronous Distributed Systems

Asynchronous systems are widely and successfully used in practice.

In practice timeouts are used with asynchronous systems for failure detection. However, additional measures have to be applied in order to avoid duplicated messages, duplicated execution of operations, etc.

Fault Models

What kind of faults can occur and what are their effects?

- Omission faults
- Arbitrary faults
- Timing faults

Fault Models

What kind of faults can occur and what are their effects?

- **Omission faults**
- **Arbitrary faults**
- **Timing faults**

- **Faults can occur both in processes and communication channels. The reason can be both software and hardware.**
- **Fault models are needed in order to build systems with predictable behaviour in case of faults (systems which are fault tolerant).**
- **A *fault tolerant* system will function according to the predictions, only as long as the real faults behave as defined by the "fault model". Otherwise ....**

Omission Faults (Fail Stop Model)

A processor or communication channel fails to perform actions it is supposed to do: the particular action is <u>not</u> performed by the faulty component!

- ❐ **With omission faults:**
  - **If a component is faulty it does not produce any output.**
  - **If a component produces an output, this output is correct.**

- ■ **With omission faults, in synchronous systems, faults are detected by timeouts.**
  - ❐ **Since we are sure that messages arrive inside an interval, a timeout will indicate that the sending component is faulty.**
    Such a system has a *fail-stop* behaviour.

Arbitrary (Byzantine) Faults

This is the most general and worst possible fault semantics:

- Intended processing steps or communications are omitted or/and unintended ones are executed. Results may not come at all or may come but carry wrong values.

⇓

Everything, including the worst, can happen!

Timing Faults

Timing faults can occur in synchronous distributed systems, where time limits are set to process execution, communications, and clock drifts.

- **A timing fault results in any of these time limits being exceeded.**