DISTRIBUTED HETEROGENEOUS APPLICATIONS AND CORBA

Heterogeneity in Distributed Systems

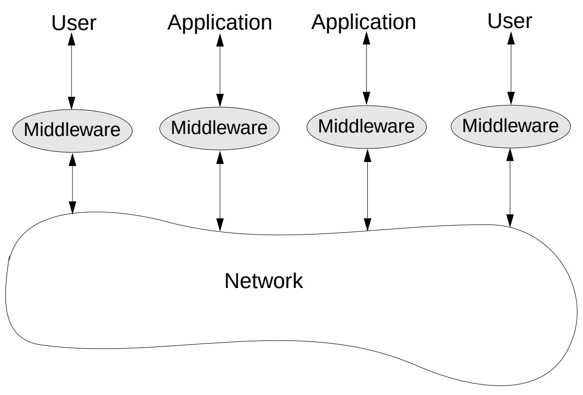
☞ Distributed applications are typically heterogeneous:
- different hardware: mainframes, workstations, PCs, servers, etc.;
- different software: UNIX, MS Windows, IBM OS/2, Real-time OSs, etc.;
- unconventional devices: teller machines, telephone switches, robots, manufacturing systems, etc.;
- diverse networks and protocols: Ethernet, FDDI, ATM, TCP/IP, Novell Netware, etc.

☞ Why?
- Different hardware/software solutions are considered to be optimal for different parts of the system.
- Different users which have to interact are deciding for different hardware/software solutions/vendors.
- **Legacy systems**.

Middleware

☞ A key component of a heterogeneous distributed client-server environment is *middleware*.

- *Middleware* is a set of services that enable applications and end users to interact with each other across a heterogeneous distributed system. Middleware software resides above the network and below the application software.

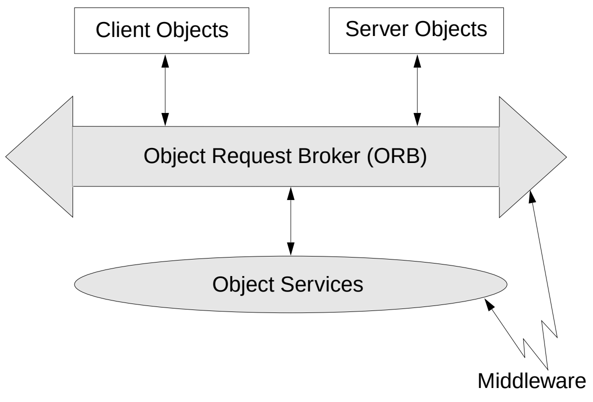


Middleware (cont'd)

- Middleware should make the network transparent to the applications and end users ⇒ users and applications should be able to perform the same operations across the network that they can perform locally.
- Middleware should hide the details of computing hardware, OS, software components across networks.
- Different kind of software qualifies, to certain extent, as middleware:
  - File-transfer packages (FTP) and email;
  - Web browsers;
  - CORBA

Objects in Distributed Systems

- A distributed application can be viewed as a collection of objects (user interfaces, databases, application modules, customers).



Objects in Distributed Systems (cont'd)

- Objects are data surrounded by code; each one has its own attributes and methods which define the behavior of the object; objects can be clients, servers, or both.

- Middleware:

  - Object brokers allow objects to find each other in a distributed system and interact with each other over a network; they are the backbone of the distributed object-oriented system.

  - Object services allow to create, name, move, copy, store, delete, restore, and manage objects.

- Modeling in terms of OO concepts does not necessarily imply use of OO programming languages for implementation or the use of OO database managers as part of the system.

Objects in Distributed Systems (cont'd)

If we relate to the picture in Lecture 3, slide 10, which explains RMI, we can recognize some components:

- We have the client and server objects.

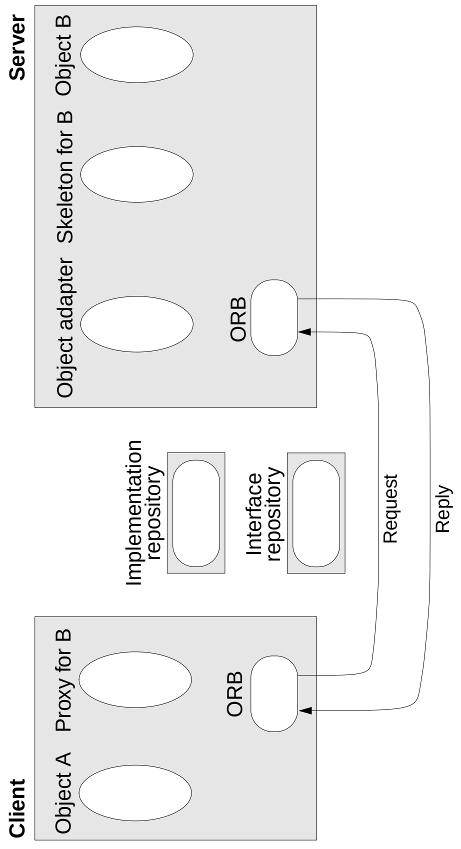
- We have the skeleton and proxy, which are on the border between middleware and application.

- The *communication module* and the *remote reference module* are part of the ORB.

☞ Additional components which are part of the middleware:

- Object adapter
- Implementation repository
- Interface repository.

Objects in Distributed Systems (cont'd)



Interface Definition Language

☞ An **interface** specifies the API (Application Programming Interface) that the clients can use to invoke operations on objects:
- the set of operations
- the parameters needed to perform the operations.

- One or more interfaces can be defined for an object. Such, different interfaces can be defined for different classes of users of the same object.
- Interfaces are defined by using an **interface definition language** (IDL).
  CORBA IDL is an example of such a language.

Interface Definition Language (cont'd)

☞ Middleware products (such as CORBA) provide interface compilers that parse the IDL description of the interface. Such a compiler produces the code which represents:
- the classes corresponding to the *proxies* (in the language of the client).
- the classes corresponding to the *skeletons* (in the language of the server).

- If the client or the server are not in an object oriented language, the compiler generates a client stub (instead of proxy class) respectively server stub (instead of skeleton class).

☞ IDLs are declarative languages; they do not specify any executable code, but only declarations.

☞ IDLs should be implementation language independent ⇒ the interface is defined independent of the language in which the server and its clients are implemented.

Language mappings have to be defined which allow to compile the IDL interface and to generate proxies and skeletons in the implementation languages of the clients and of the server respectively.

CORBA

☞ Object Management Group (OMG): a non-profit industry consortium formed in 1989 with the goal to develop, adopt, and promote standards for the development of distributed heterogeneous applications.

☞ One of the main achievements of OMG is the specification of a Common Object Request Broker Architecture (CORBA).

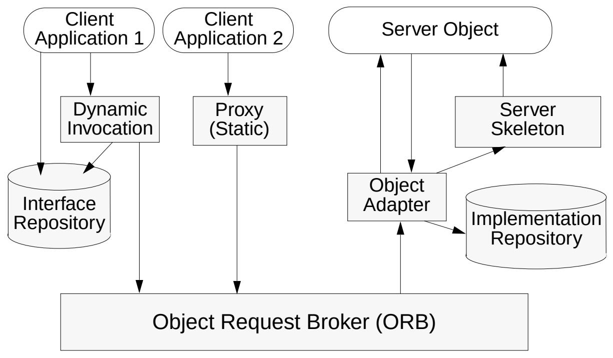
- The *CORBA specification details the interfaces and characteristics of the Object Request Broker*; it practically specifies the middleware functions which allow application objects to communicate with one another no matter where they are located, who has designed them and in which language they are implemented.
- OMG only provides a specification; there are several products which, to a certain extent, implement the OMG specification.

CORBA (cont'd)

- Key concepts:
  - CORBA specifies the middleware services used by the application objects.
  - An object can be a client, a server or both.
  - Object interaction is through requests: the information associated with a request is
    1. an operation to be performed
    2. a target object
    3. zero or more parameters.
  - CORBA supports *static* as well as *dynamic binding*; dynamic binding between objects uses run-time identification of objects and parameters.
  - The *interface* represents the contract between client and server; an IDL has been defined for CORBA; proxies and skeletons (client and server stubs) are generated as result of IDL compilation.
  - CORBA objects do not know the underlying implementation details; an *object adapter* maps the generic model to a specific implementation.

CORBA (cont'd)

Components of a CORBA environment:



Interface and Implementation Repository

Interface Repository

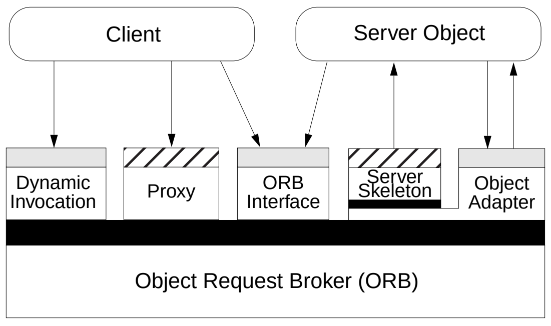
- The interface repository provides a (standard) representation of available object interfaces for all objects in the distributed environment. It corresponds to the server objects' IDL specification.
- The clients can access the interface repository to learn about the server objects, determine the types of operations which can be invoked and the corresponding parameters. This is used for *dynamic invocation* of objects.

Implementation Repository

- Implementation details for the objects implementing each interface are stored in the implementation repository:
  - the main information is a mapping from the server object's name to the file name which implements the respective service;
  - there is information concerning the object methods and information needed for method selection.
- Information stored in the implementation repository can be specific to the operating system running on the respective server object's computer.
- The representation in the implementation repository can be specific for a certain CORBA implementation.
- The implementation repository is used by the *object adapter* in order to solve an incoming call and activate the right object method (via a *server skeleton*).

The Object Request Broker (ORB)

ORB and its interfaces:



■	ORB implementation dependent interface
▭	Interface identical for all ORB implementations
▨	Proxies and skeletons for each server interface

The Object Request Broker (cont'd)

☞ The ORB, through its interfaces, provides mechanisms by which objects transparently interact with each other.

- Issuing of a request from a client can be dynamic or static; it is performed through the *proxies (client stubs)* or the *dynamic invocation interface*.
- Invocation of a specific server method is performed by the server skeleton which gets the request forwarded from the *object adapter.*
- The *ORB interface* can be accessed also *directly* by clients and object implementations for certain services: e.g. directory services, services connected to naming, manipulation of object references.

Static and Dynamic Invocation

☞ CORBA allows both *static and dynamic invocation* of objects. The choice is made depending on how much information, concerning the server object, is available at compile time.

Static Invocation

- Static invocation is based on compile time knowledge of the server's interface specification. This specification is formulated in IDL and is compiled into a *proxy (client stub)*, corresponding to the programming language in which the client is encoded.
- For the client, an object invocation is like a local invocation to a proxy method. The invocation is then automatically forwarded to the object implementation through the ORB, the object adapter and the skeleton.
- Static invocation is efficient at run time, because of the relatively low overhead.

Static and Dynamic Invocation (cont'd)

Dynamic Invocation

- Dynamic invocation allows a client to invoke requests on an object without having compile-time knowledge of the object's interface.
- The object and its interface (methods, parameters, types) are detected at run-time. CORBA provides, through the *dynamic invocation interface*, the mechanisms in order to inspect the *interface repository*, to dynamically construct invocations and provide argument values corresponding to the server's interface specification.
- Once the request has been constructed and arguments placed, its invocation has the same effect as a static invocation.
- The execution overhead of a dynamic invocation is huge.
- From the server's point of view, static and dynamic invocation are identical; the server does not know how it has been invoked.
  The server invocation is always issued through its skeleton, generated at compile time from the IDL specification.

The Basic Object Adapter

☞ The object adapter (OA) is the primary interface between the server object implementation and the ORB.

Services provided by the OA:

- Object registration: OA provides operations by which certain entities, specified in a given programming language, are registered as *CORBA objects*.
- Object reference generation: OA generates object references to CORBA objects.
- Object upcalls: OA dispatches incoming requests to the corresponding registered objects.
- Server process and object activation: if needed, OA starts up server processes and activates objects as result of incoming invocations.

Other CORBA Services

These services, and others, have been specified by the CORBA documents; current products implement only some of them.

☞ Naming and Trading Services:
- The basic way an object reference is generated is at creation of the object when the reference is returned.
- Object references can be stored together with associated information (e.g. names and properties).
- The *naming service* allows clients to find objects based on names.
- The *trading service* allows clients to find objects based on their properties.

☞ Transaction Management Service: provides two-phase commit coordination among recoverable components using transactions.

☞ Concurrency Control Service: provides a lock manager that can obtain and free locks for transactions or threads.

☞ Security Service: protects components from unauthorized users; it provides authentication, access control lists, confidentiality, etc.

☞ Time Service: provides interfaces for synchronizing time; provides operations for defining and managing time-triggered events.

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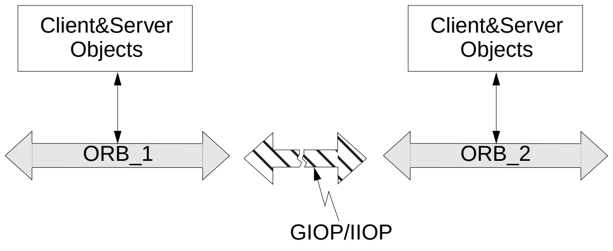
Inter-ORB Architecture

☞ Implementations of ORBs differ from vendor to vendor ⇒ how do we solve interaction between objects which are running on different CORBA implementations?



- General Inter-ORB Protocol (GIOP): GIOP is defined in CORBA 2.0; it specifies a set of message formats and common data representations for interactions between ORBs and is intended to operate over any connection oriented transport protocol.
- Internet Inter-ORB Protocol (IIOP): IIOP is a particularization of GIOP; it specifies how GIOP messages have to be exchanged over a TCP/IP network.

Summary

- Distributed systems are typically heterogeneous. Middleware is the set of services which enable the components to interact with each other without taking notice of the distributed and heterogeneous character of the environment.
- The API visible for the user of a service is defined in an IDL. The IDL compiler generates proxies and skeletons (client and server stubs). IDLs should be implementation language independent.
- CORBA is the OMGs specification for an Object Request Broker (ORB). Several vendors provide different (partial) implementations consistent with this specification.
- The ORB, through its interfaces, provides mechanisms by which objects transparently interact with each other.
- Objects in CORBA can be invoked statically and dynamically. Static invocation is based on compile time knowledge of the server's interface specification. Dynamic invocation allows a client to invoke requests on an object without having compile-time knowledge of the object's interface.
- The object adapter is the interface between the object implementation and the ORB. It provides services for registration of objects and their activation.
- CORBA 2.0 defines protocols for interaction between ORBs implemented by different vendors.

PEER-TO-PEER SYSTEMS

1. Characteristics of Peer-to-Peer Systems

2. The Napster File System

3. BitTorrent

Basic Characteristics

☞ Main characteristics of peer-to-peer systems:

- Each user contributes resources to the system.
- All the nodes have the same functional capabilities and responsibilities (although they may differ in the resources they contribute).
- Correct operation does not depend on the existence of any centrally-administered system.

☞ Key issues:

- Choice of strategy for
  - the placement of data and their replica across many hosts;
  - the access to data.

  Such that
  - workload of nodes and communication lines is balanced;
  - availability of data is provided.

☞ Anonymity of providers and users is offered (at least to a certain degree).

Why Do We Need It?

☞ If only particular servers which are centrally managed, can provide services/data, then scalability is limited:
- server capacity
- network bandwidth provided to a server

☞ To avoid the scaling problem
- Peer-to-peer systems use the data and computing resources available in the personal computers and workstations present on the Internet and other networks.
- Instead of separately managed servers, services are provided by all these resources together.

☞ Important!
- Availability of individual processes/computers in a peer-to-peer system is unpredictable

⇩

Services cannot rely on guaranteed access to a host.

- Availability can be improved by replication on several hosts.

Peer-to-Peer Systems

First Pioneer:
Napster (1999)

☞ The index is centralised!

Later Systems:
Freenet
Gnutella
Kazaa
BitTorrent

☞ Only semi-centralised or completely distributed.
☞ Better anonymity, scalability, fault tolerance.

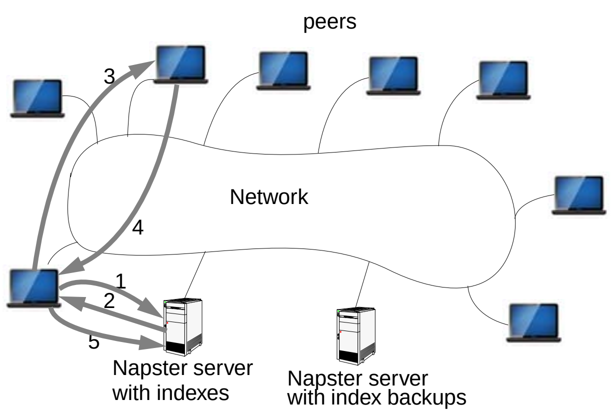
The Napster File Sharing System

☞ Napster provides a globally-scalable information storage and retrieval service for digital music files.

☞ Napster was the first to demonstrate the feasibility of a peer-to-peer solution on large scale.

☞ Napster, as an open service, was shut down July 2001, as result of lawsuits on copyright issues.

The Napster File Sharing System (cont'd)


peers
3
Network
4
1
2
5
Napster server with indexes
Napster server with index backups

Step 1: File location request;
Step 2: List of peers offering the files;
Step 3: File request;
Step 4: File loading;
Step 5: Index update (user adds own files to pool of shared resources).

The Napster File Sharing System (cont'd)

☞ Napster uses a centralised index (with replicas for increased availability).

☞ The whole pool of files is distributed over the personal computers of the peers.

☞ In order to achieve load balancing:

- When creating and sending the list of peers offering the file (step 2), Napster takes into account locality (the distance between the requesting client and the potential servers).

Problems with Napster

☞ Centralised index:
- Scaling problem (server capacity and network bandwidth).
- Anonymity of operators is not possible: for example, legal responsibility for copyright issues can be put on operators maintaining the central index.

☞ A completely distributed index can both provide better scaling and anonymity.

☞ Napster did not provide particular solutions for consistency of replica updates or for guaranteed availability. This was no problem because of the particular application, music files:
- Music files are immutable (they don't change after being created) ⇒ there is no need to maintain replicas consistent.
- If a file is unavailable at a certain moment it can be downloaded later.

☞ Second generation systems (see slide 26) have tried to solve some of the above problems by applying various specific, ad hoc solutions.

BitTorrent

☞ Similar to Napster, BitTorrent is a peer-to-peer file-sharing application; much more decentralized as Napster.

☞ Designed by Bram Cohen; first release 2001; several versions followed.

☞ Main problems considered:
- Files are very large and if the *whole* file has to be downloaded from the *same* peer this leads to poor performance, processor overload, network congestion.

  ⇓

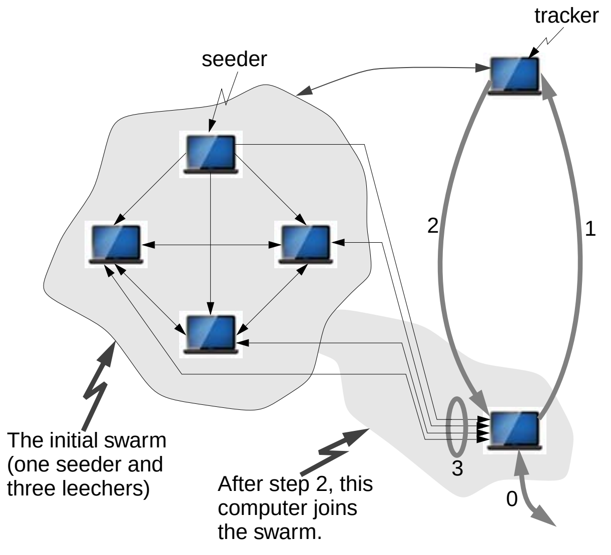
  So, why not *divide the file into chunks* and download different chunks from *different* peers, *in parallel*?

- Centralised indexing creates problems with scalability and availability.

  ⇓

  Avoid the need for centralised indexing.

BitTorrent (cont'd)


tracker
seeder
2
1
3
0
The initial swarm (one seeder and three leechers)
After step 2, this computer joins the swarm.

Step 0: Search for the .torrent file and save it;

Step 1: The BitTorrent client on the computer contacts the tracker identified in the .torrent file;

Step 2: The tracker identifies the corresponding swarm and helps the computer join it;

Step 3: The computers in the swarm trade pieces of the file to be downloaded; the computer receives multiple pieces of the file in parallel.

BitTorrent (cont'd)

☞ A swarm is composed of several computers interested in downloading/uploading a given file:

- *seeders*: have the complete file;
- *leechers*: have only a part of the file and are in the process to get the whole file.

A swarm consists of, at least, one seeder ⇒ for a download of a file to operate, at least one seeder is needed to be available.

☞ A download begins with identifying and downloading a .torrent file; the .torrent file is created and made available by a user wanting to share a file;

- the *.torrent* file contains metadata needed for downloading a certain file: name of the shared file, file size, chunk size, checksum for each chunk of the file (checked for integrity at download), URL of the tracker.

BitTorrent (cont'd)

☞ Before being made available, a file to be distributed is broken into pieces (chunks); the *chunk* size can be between 64KB and 4MB.

- BitTorrent downloads different chunks of the file simultaneously from multiple computers.
- As more computers in the swarm as faster the download; BitTorrent is particularly useful for files that are large and *popular* (many simultaneous downloads).
- Chunks are typically received non-sequentially and rearranged into the correct order (based on the information from the .torrent file) by the receiving client.

☞ The *tracker* is the computer in charge of managing the transfer of a particular file:

- The tracker's URL is extracted from the .torrent file.
- It keeps track of the connected computers; it facilitates the computers in the swarm to connect to each other by sharing their IP addresses.
- Attention: the file is not downloaded from the tracker! The tracker only coordinates the swarm.

☞ The concrete way how you identify the .torrent file corresponding to the actual file you are interested in, is not part of the protocol. You can google, or go to specialised pages (e.g. PiratBay, but also many other less controversial ones), etc.

BitTorrent (cont'd)

Tit-for-tat reward system

The reward system tries to avoid peers only downloading but not contributing with uploading:

- In order to receive files, you also have to give; clients reward other clients who upload, preferring to send data to clients who contribute more upload bandwidth ⇒ the more files you share with others, the faster your downloads are.
- After you have got the whole file, you should continue to run the client ⇒ you stay as a potential seeder which others can use ⇒ your rates improve in the tit-for-tat system.

BitTorrent: Scaling, Availability, Developments

☞ Napster:

- centralized indexing service (if it fails ⇒ 💣);
- the whole file is downloaded (sequentially) from the same peer (if it fails ⇒ 💣).

⇩

Potentially reduced scalability and availability.

☞ BitTorrent:

- no indexing system (you just need a .torrent file);
- pieces of the file are downloaded (in parallel) from multiple seeders and leachers from the swarm.

⇩

Increased scalability, availability, performance.

BitTorrent: Scaling, Availability, Developments (cont'd)

☞ A potential point of failure is the tracker supervising the swarm!

Two alternative solutions are proposed in later versions:

- A decentralized, trackerless torrent system:
  Clients communicate to each other without a central tracker; a distributed hash table (DHT) technique is used, by which nodes identify other nodes to build the swarm. The swarm is managed collectively by its members.

- Multi-tracker implementations:
  Multiple trackers can be used for one torrent; they are specified on the .torrent file.

Summary

- Peer-to peer systems are a possible solution for the scaling problems with traditional client-server systems.

- Scaling in peer-to-peer systems is solved by exploiting the resources available on the personal computers and workstations available in the network, instead of using dedicated and centrally maintained servers.

- Napster has been the first widely used peer-to-peer system. While the pool of files is completely distributed over the personal computers of the hosts, Napster is still using a centralised index. This has consequences with regard to both scaling and anonymity.

- BitTorrent has solved some of Napster's shortcomings and increased both availability and performance. There is no centralised indexing system and downloads are performed in cooperation and in parallel by members of a swarm.