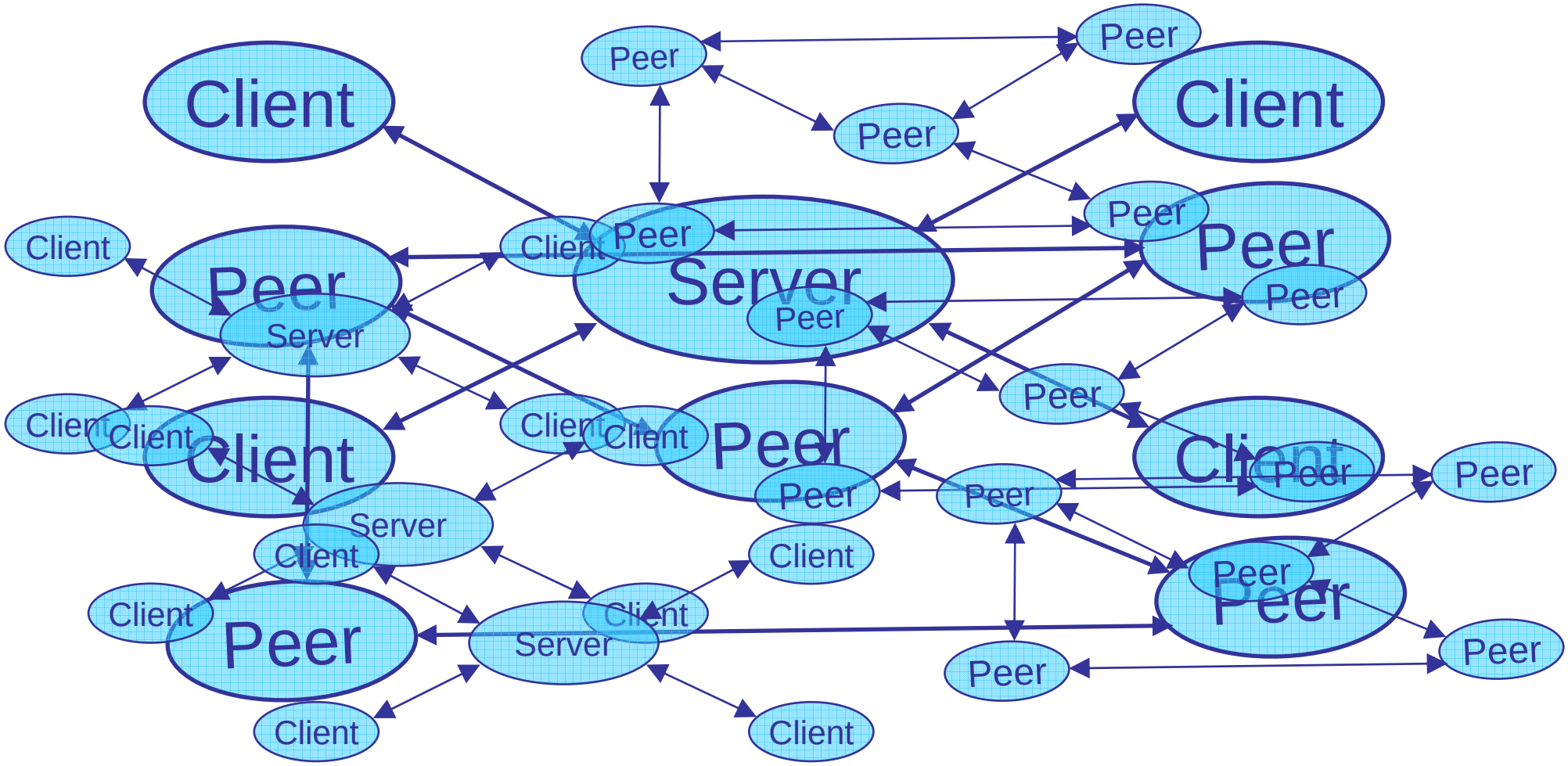
Middleware

Till G. Bay, May 18th, 2006

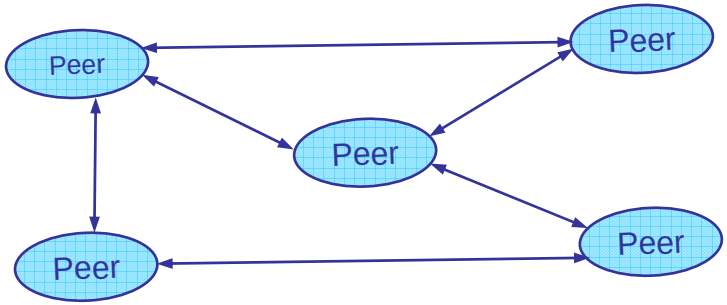
Looking back…

- Input- and output streams
- Sockets
- Threads
- Client-Server

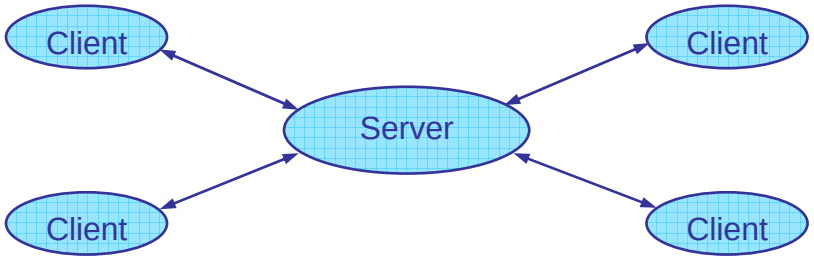
Distributed Systems



Same needs



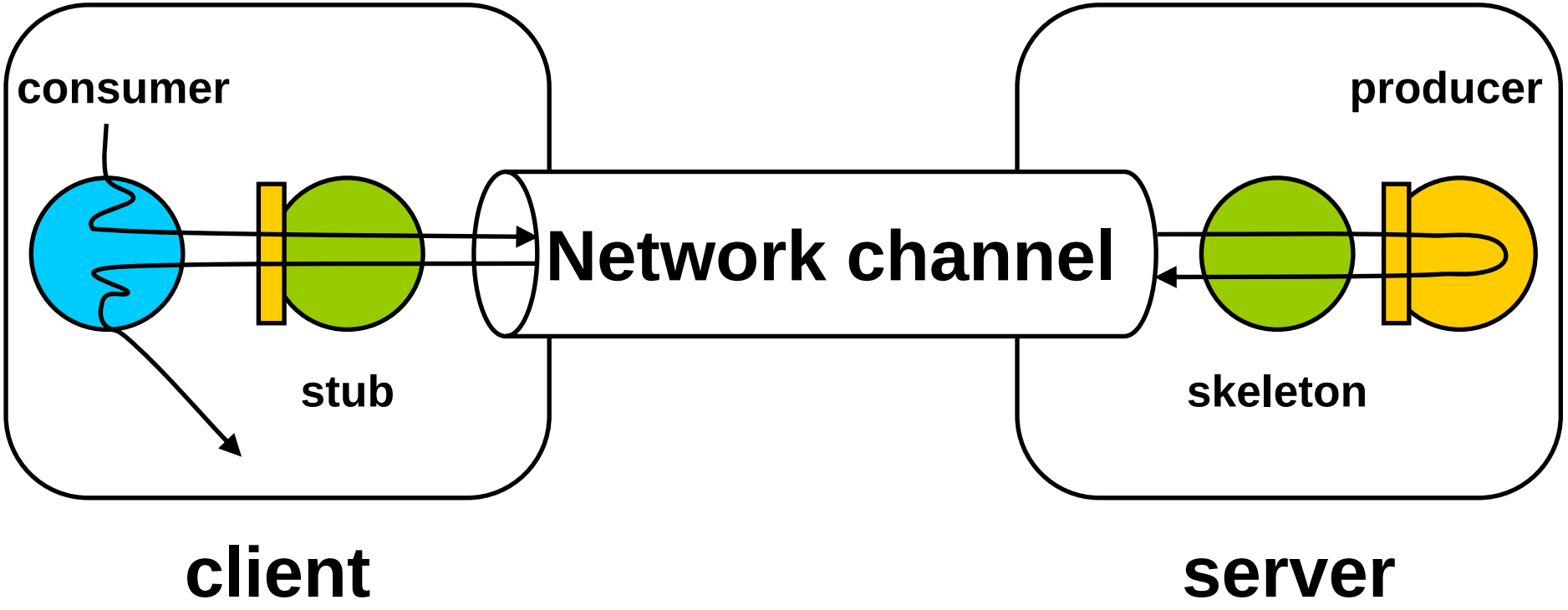
- Communication of data over the network
- Calling methods on remote object



Middleware

- Abstraction
  - *Proxy* (*stub*) for the remote object, mimics it and redirects invocations to it
  - Globally unique object reference/name
  - Communication handling (most commonly a TCP socket)

Interaction Scheme



Invocation

- Transform messages and send to the «other side»
  - Marshalling
- The «other side»: skeleton
  - Serverside counterpart to stub
  - Extracts request arguments from message (*unmarshaling*) and invokes the server object
  - Marshals return value and sends it to the invoker side, where stub unmarshals it and returns the result to invoker

Stubs and Skeletons in Perspective

- Client side: Stub
  - Offers same interface than server object: mimics the server
  - Usually bound to a single server
  - Marshals the request into a stream of bytes
    - Method id (e.g., name)
    - Arguments
  - Additional features:
    - Caching of values
    - Load balancing
    - Statistics
    - …
- Server side: Skeleton
  - Represents the server objects
  - Bound to a single server
  - Sometimes several proxies for a server
  - Unmarshals the request and calls the corresponding Method on the server object
  - Additional features:
    - Persistence
    - …

Distributed Objects in perspective

- Object has
  - Interface (abstract type)
  - Implementation (concrete type)
  - Local reference, e.g., value of a monotonically increased counter, memory address
- «Remote» object has
  - Interface for remote invocations
  - Implementation
  - Global reference, e.g., *(host id, process id, obj id)*

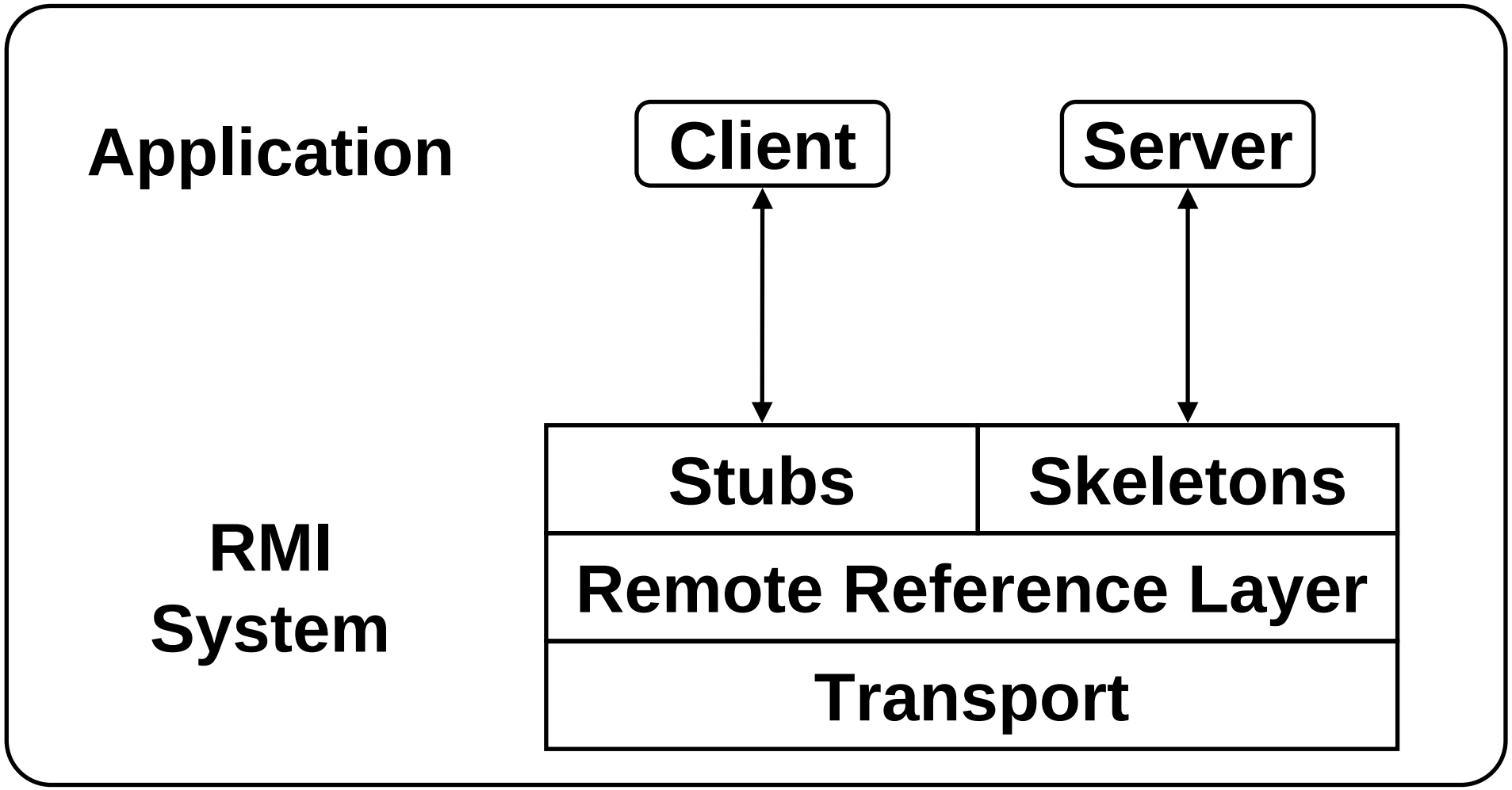
Preview: Further Concepts

- Repositories
  - Reference Repository
    - *Find* new remote *objects* (locate objects, i.e., bootstrapping)
  - Interface Repository
    - *Discover* new remote object *types* (browse remote types)
- Advanced concepts
  - Dynamic invocations
  - Threading

Java RMI Overview

- Allow distributed Java Objects to interact
  - Through (remote) method invocations
  - Invocations are synchronous (even if there is no reply)
  - Fully integrated into Java language
  - Remote interfaces described though Java interfaces
- Separate compilation
  - Generate Stubs and Skeletons according to interfaces
  - Compile application

Java RMI Architecture



Stub Skeleton Layer

- Stub
  - Has same interface than remote object
  - Initializes call to remote object
  - Marshals arguments to stream
  - Passes stream to remote reference layer
  - Unmarshals the return value
  - Informs the remote reference layer that call is complete
- Skeleton
  - Unmarshals arguments from the stream
  - Makes up-call to the remote object implementation
  - Marshals the return value or an exception onto the stream

Example

1. Write the interfaces of the remote (i.e., remotely accessible) objects: coarse grained
2. Write the implementations of the remote objects
3. Write other classes involved: fine grained
4. Compile the application with **`javac`**
5. Generate stubs and skeletons with **`rmic`**

Example: Declaring a remote interface

- Objects are remotely accessible through their remote interface(s) only.
- Methods to be exported are declared in an interface that extends the **`java.rmi.Remote`** interface
- Remote interfaces
  - Must be public
  - All methods must declare **`java.rmi.RemoteException`** in throws list: represent exceptions due to distribution

A HelloWorld Remote Interface

```
import java.rmi.*;

public interface Hello extends
  Remote {
  public void print() throws
  RemoteException;
}
```

Implementing a Remote Interface

- Implement the **`Remote`** interface
  - Abstract class **`java.rmi.server.RemoteObject`** implements **`Remote`**
    - Remote behavior for **`hashCode()`**, **`equals()`** and **`toString()`**
  - Abstract class **`java.rmi.server.RemoteServer`** extends **`RemoteObject`**
    - Functions to export remote objects

Implementing a Remote Interface

- Concrete class
  - **`java.rmi.server.UnicastRemoteObject`** extends **`RemoteServer`**
    - Non-replicated remote object
    - Support for point-to-point active object references (invocations, parameters, and results) using TCP
    - Inheritance: subclass **`UnicastRemoteObject`**
- Note
  - Own exceptions must not subtype **`RemoteException`**

HelloWorld Implementation

```
import java.rmi.*;
import java.rmi.server.*;

public class HelloImpl extends
  UnicastRemoteObject
  implements Hello {

  public HelloImpl() throws RemoteException
    { super(); }
  public void print() throws RemoteException
    { System.out.println("Hello World"); }
}
```

Constructing a Remote Object

- The Constructor
  - Calls the no-argument constructor of the **`UnicastRemoteObject`** class (implicitly or explicitly)
  - Which exports a **`UnicastRemoteObject`**, meaning that it is available to accept incoming requests by listening to calls from clients on an anonymous port
  - Throws **`RemoteException`**, since the constructor of **`UnicastRemoteObject`** might do so, if the object cannot be exported
    - Communication resources are unavailable
    - Stub class cannot be found, …
- Alternative: Delegation
  - Explicitly export the object **`UnicastRemoteObject.exportObject()`**

Starting a Server

```
public class HelloServer {

  public static void main(String[] args) {
    …
    Hello hello = new HelloImpl();
    // Register object (e.g., naming service)
    // What's up doc?
    …
  }
}
```

Starting a Client

```
public class HelloClient {

  public static void main(String[] args) {
    …
    // Lookup object (e.g., naming service)
    Hello hello = …;
    // Invoke the remote object
    hello.print();
    // That's all folks…
  }
}
```

CORBA Overview

- Object model (with calling convention etc.)
- IDL with generators and compilers
- Object Request Broker (ORB)
- System functions as Object Services
- Application support through Common Facilities / Application Domains
- Conventions (for interfaces and protocols etc.)

- **http://www.omg.org**

Exercise 1: Mini Discussion

- Discuss the following 2 questions each for 3 minutes with your neighbor:

1. Which features of RMI are Java specific?
2. What should be changed to make RMI programming language independant?

RMI vs. CORBA

- RMI
- Java only
- Platformindependence due to Java
- Easy to use

- Using RMI

1. Define java interfaces for remote classes
2. Create and compile implementation of the remote classes
3. Create stub and skeleton classes using the **rmic**
4. Create and compile server application
5. Create and compile client to access remote objects
6. Start RMI registry and server app.
7. Test client

CORBA

- Heterogeneous Systems
- Platformindependence due to language independance
- More elaborate architecture

Using CORBA

1. Define IDL interfaces of remote classes
2. Create stub and skeleton classes using **idl***
3. Create and compile implementation of the remote classes
4. Create and compile server application
5. Create and compile client to access remote objects
6. Start server
7. Test client

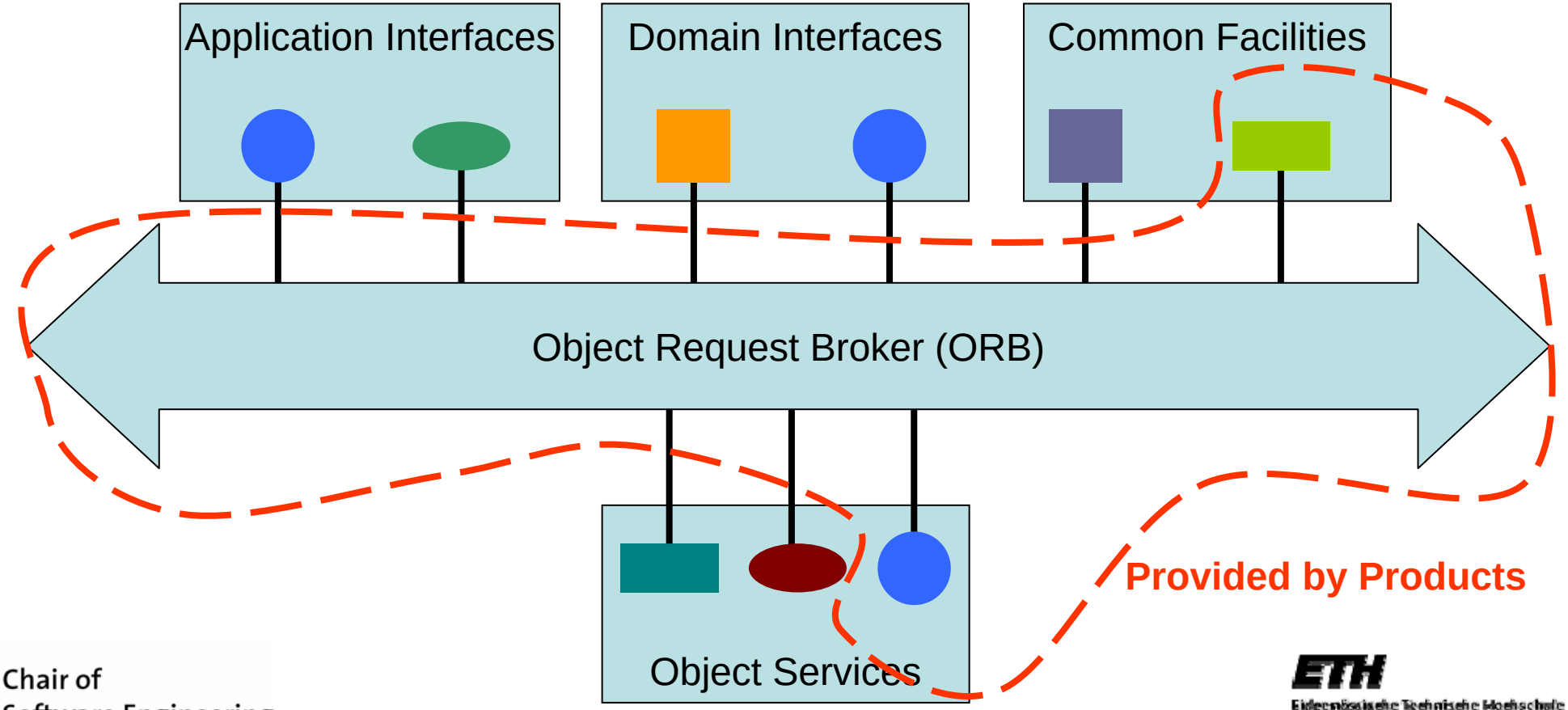
Exercise 2: Mini Discussion

Discuss the following question for
3 minutes with your neighbor

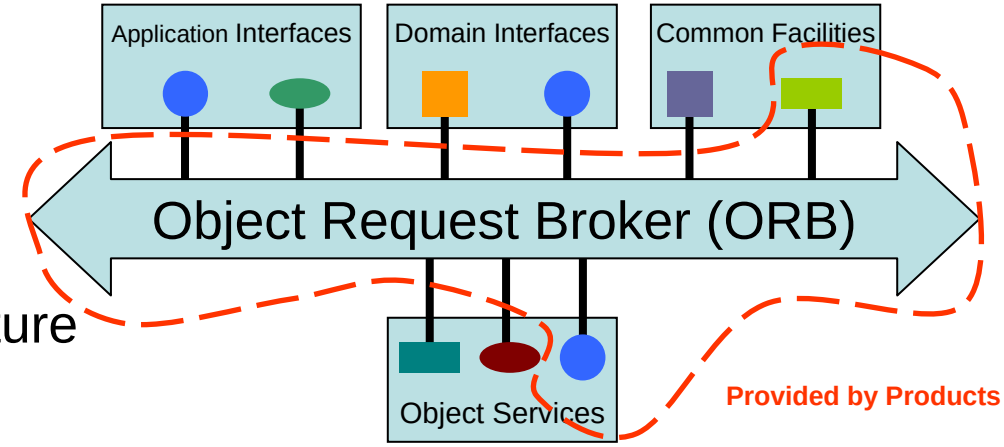
What are the advantages of a technology independant component model for distributed applications?

Object Model Architecture: OMA

- OMG's reference architecture:
  Object Management Architecture



OMA



Application Interfaces
Developed for specific
application not part of CORBA infrastructure

Object Services
Domain independent interfaces used by many distributed applications.
Examples: Naming Service, Trading Service

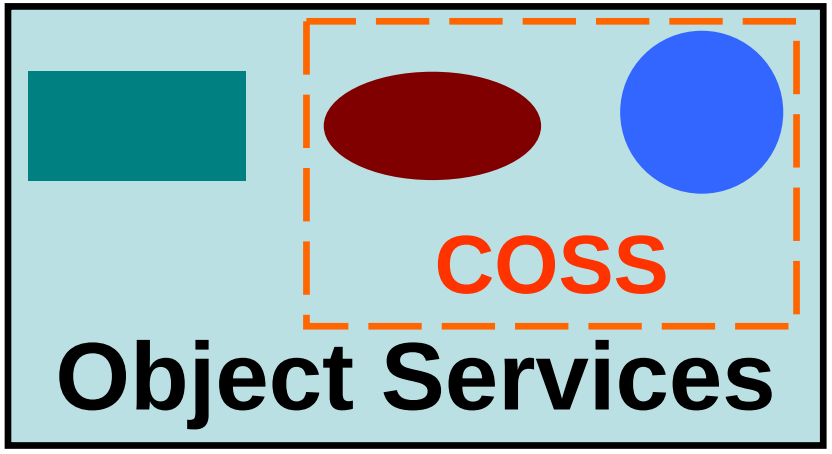
Common Facilities
Commonly used facilities used in end-user applications.
Examples: GUI Library, Internationalization framework

Domain Interfaces
Like Object Services and Common Facilities but targeted to a specific application domain
Examples: Telecommunication, Medical, Financial

ORB
Infrastructure propagating method calls, relating objects to each other.

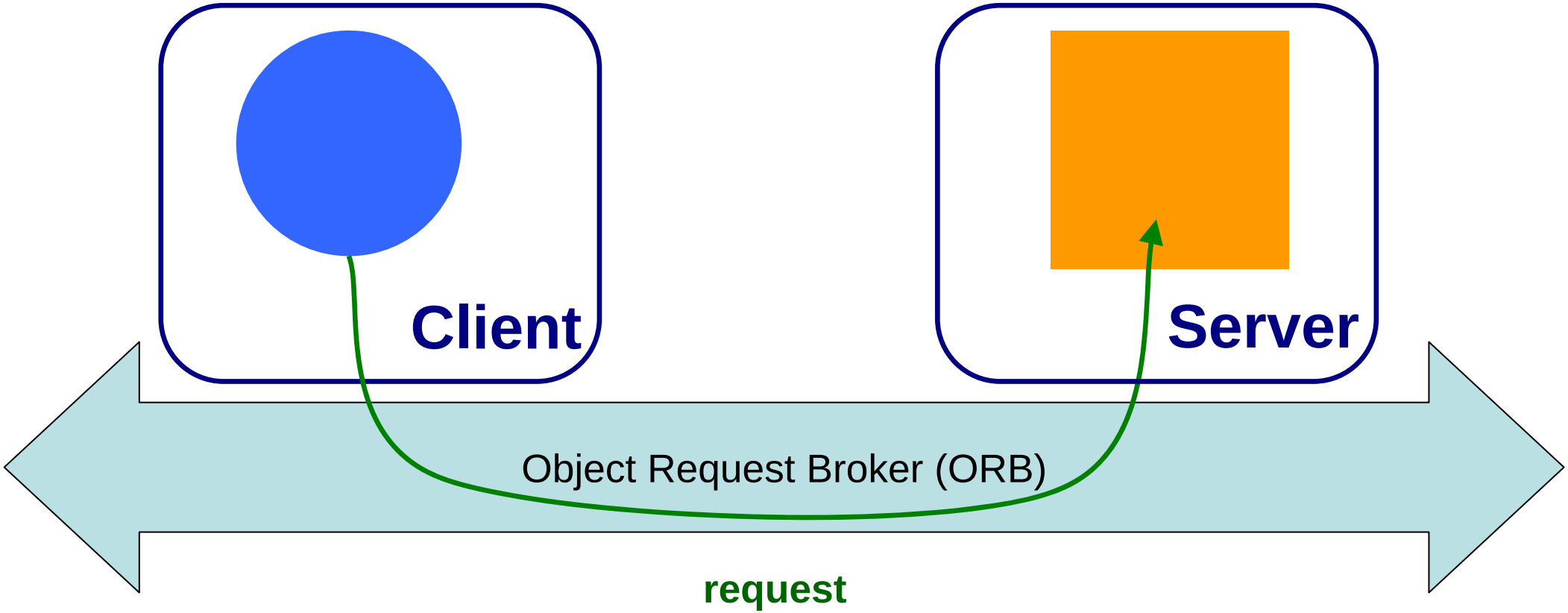
Object Services

- Base Services as system-wide infrastructure
  (not all implemented and not all fully specified)
- **COSS** (Common Object Services Specification)
  (CORBA conforming products must provide these)
- **Eventhandling**, **Persistence**,
- **Naming**, **Lifecycle**,
- Transactions, Time,
- Security, Licensing,
- Trading, Replication,
- Concurrency, Externalization

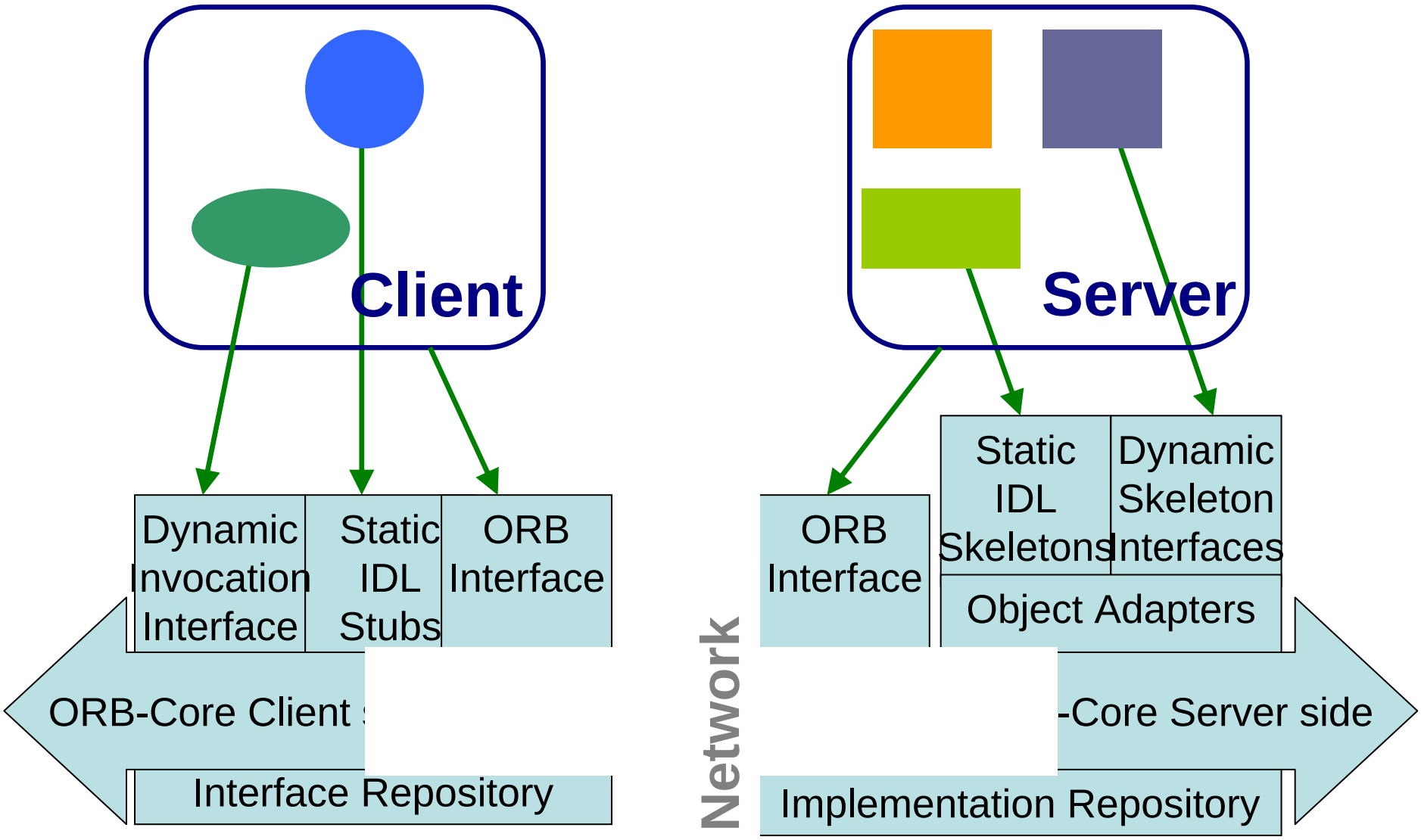


Communication of Objects

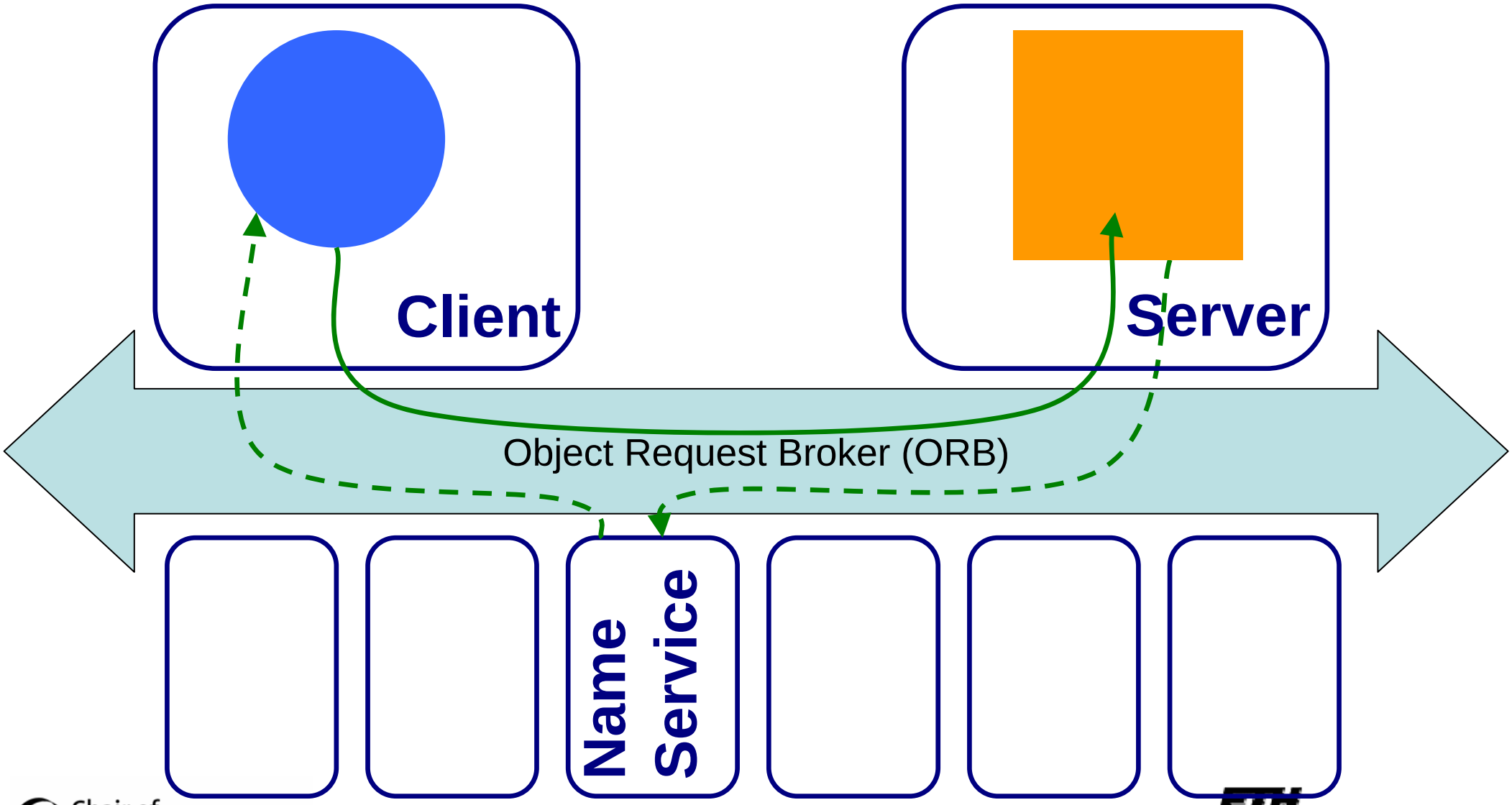
- ORB Core



ORB: Object Request Broker



NameService



Other initial Services

- Collection service
- Concurrency service
- Event service
- Externalization service
- Licensing service
- Life cycle service
- Notification service
- Persistent state service
- Property service
- Query service
- Relationship service
- Security service
- Telecoms log service
- Time service
- Trading object service
- Transaction service

Need a Semester or Master Thesis?

SEmasters: May 30. 2006, IFW E42, 16.00

The Chair of Software Engineering presents the Thesis topics that are available

Article to read

- TSpaces
  http://www.almaden.ibm.com/cs/TSpaces/papers/ComputerNetworks.pdf