Introduction to Distributed Systems

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Objectives

- Introduction to distributed systems and middleware
- Conceptual and practical aspects of distributed systems and middleware
- Illustration through current distributed systems, e.g. web systems, database systems

Agenda

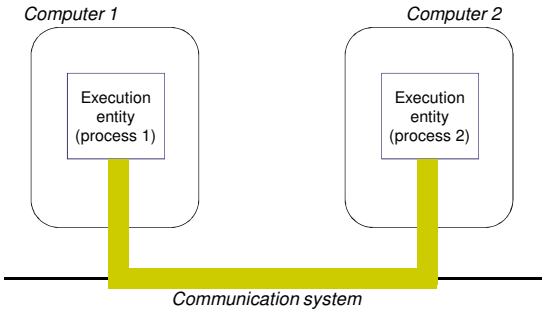
Lecture, Tuesday, 09:45 – 12:45	Lab, Tuesday, 09:45 – 12:45
Introduction to distributed systems	
	Distributed applications with RMI (Part I)
Distributed Web applications	
	Distributed applications with RMI (Part II)
Interruption week	
Event-based systems & MapReduce systems	
	Distributed Web applications with Servlets (Part I)
Cloud computing	
	Distributed Web applications with Servlets (Part II)
Advanced techniques for efficient distributed systems	
	Caching with Memcached
Event-based systems & MapReduce systems	
Interruption week	
Advanced techniques for dependable distributed systems	
	Evaluation

What is a distributed system

- "*A distributed system is one in which the failure of a computer you didn't even know existed can render your own computer unusable.*"

  Leslie Lamport, 1987.

Distributed system

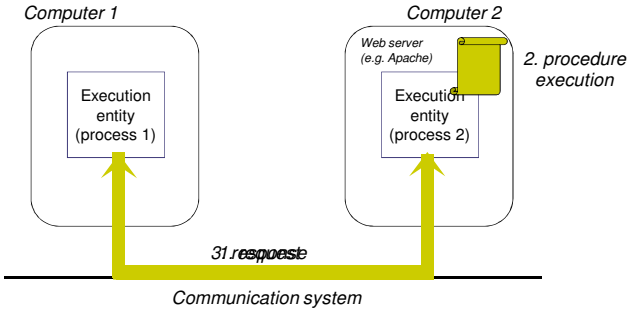


Communication mechanisms in a distributed system

- Direct (i.e. Synchronous) communication
  - Program to program
    - E.g. remote procedure call
  - Program to database
    - E.g. distributed transaction processing
- Indirect (i.e. Asynchronous) communication
  - Message passing

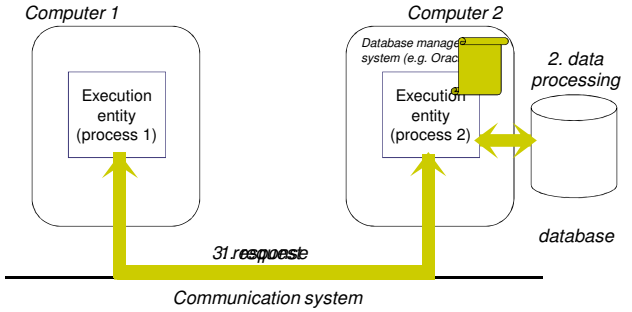
Communication mechanisms in a distributed system

- Remote procedure call (e.g. a web application)



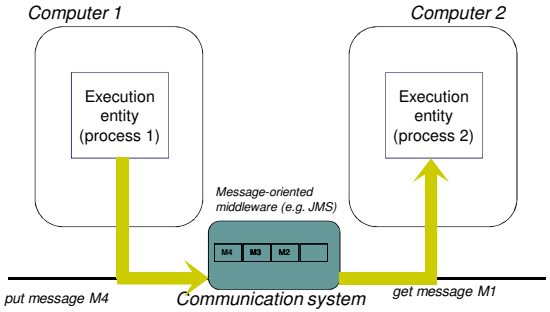
Communication mechanisms in a distributed system

- Distributed transaction processing (e.g. a database server)



Communication mechanisms in a distributed system

- Message passing (e.g. a chat system)



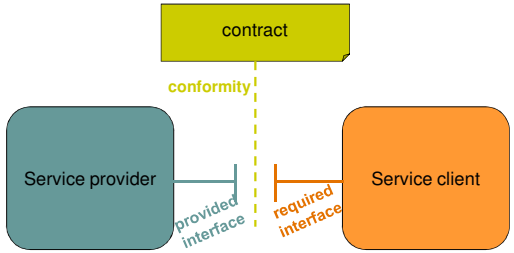
Outline

1. What is a distributed system
   - Communication mechanisms in distributed systems
   - **Services and interfaces in computing systems**
   - Client/server architecture
2. What is a middleware
3. References

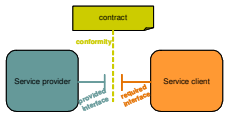
Services and interfaces in a computing system

- Service definition
  - A computing system is a set of (hardware and software) components
  - A component provides a service
  - "A service is a contractually defined behavior that can be implemented and provided by any component for use by another component, based solely on the contract",
    Bieber et. al., Service oriented programming, http://www.openwings.org/
- Interface definition
  - A service is accessible via one or several interfaces
  - An interface defines the possible interaction between a service provider and its client

Interfaces (1/2)

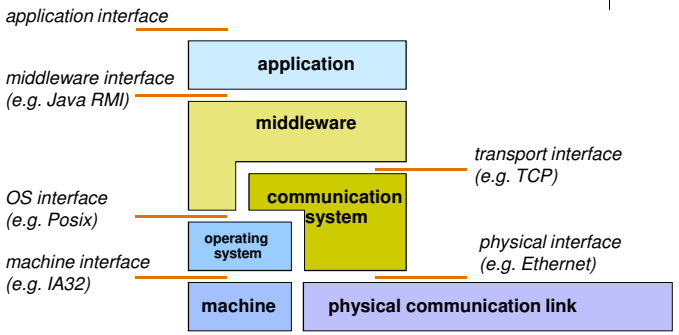


Interfaces (2/2)



- A service relies on two interfaces
  - Required interface (from the service client point of view)
  - Provided interface (from service provider point of view)
- Contract
  - The contract specifies the conformity between the provided and required interfaces
  - The service client and the service provider are considered as black-boxes; they might be replaced by other implementations as long as the contract is respected
- The contract may specify aspects that are not related to the interfaces
  - Non-functional properties related to QoS requirements

Examples of important interfaces in computing systems



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   - Services and interfaces in computing systems
   - **Client/server architecture**
2. What is a middleware
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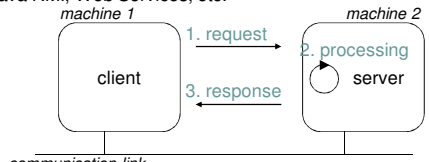
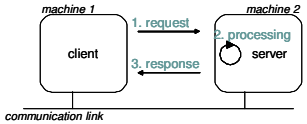
Client/server architecture (1)

- Definitions
  - The client/server architecture is a general interaction model
  - The server provides a service
  - The client requests that service
  - The client and the server are usually (but not necessarily) hosted by two distinct machines
  - Examples of protocols based on the client/server architecture: RPC, Java RMI, Web Services, etc.



Client/server architecture (2)



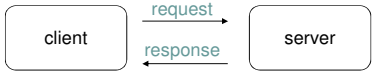
- Request message:
  - Sent by the client to the server
  - Specifies the requested service (a server may provide several services)
  - Contains parameters of the requested service
- Response message:
  - Sent by the server to the client
  - Results of service execution, or error message
- Synchronous communication between the server and the client:
  - When the client sends a request, it waits (it is blocked) until the server replies to its request

Client/server architecture (3)

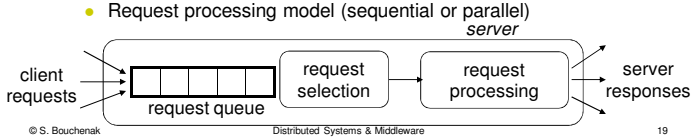
- Advantages of the client/server architecture
  - Structuring
    - Separation between the interface of a service and the implementation of that service
    - Based on this separation, the client and server implementations can be modified as long as the interface is kept unchanged
  - Protection/security
    - The client and server run in different protection domains
  - Resource management
    - A server may be shared by several clients

Client/server architecture (4)

- A server shared by several clients
  - The client point of view



  - The server point of view
    - Selecting a request among client requests
    - Request processing model (sequential or parallel)



Client/server architecture (5)

- Request selection (i.e. scheduling) model
  - First, the server selects one of the waiting (i.e. queued) client requests
  - Then, it process the client request and builds its response
  - Before it returns it to the client
- Different request selection strategies
  - First-In First-Out (FIFO)
  - Shortest first
  - Priority-based scheduling

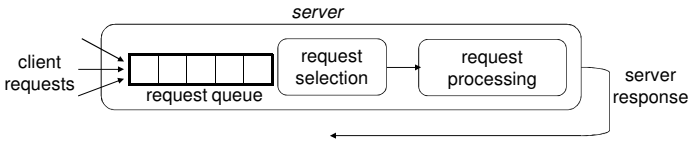
Client/server architecture (6)

- Request processing model (resource management)
  - The client and server are executed by two distinct processes (asynchronous call)
  - The client waits untils it receives a response to its request
  - Several requests may be processed concurrently by the server
    - real parallelism (e.g. multiprocessors, I/O)
    - pseudo-parallelism
  - Concurrency may take the form of:
    - multiple processes, or
    - multiple threads

Client/server architecture (7)

- Server resource management – A unique process

```
while (true) {
        receive(client_id,message);
        extract(message, service_id, params);
        results = do_service(service_id, params);
        send(client_id, results);
}
```

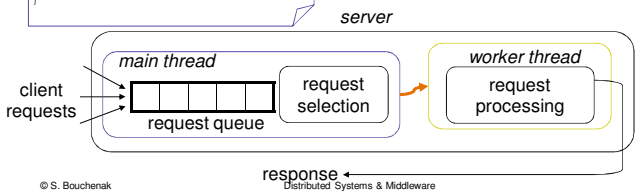


Client/server architecture (8)

- Server resource management – Multiple processes

```
while (true) {
   receive(client_id,message);
   extract(message, service_id,
      params);
   thr = create_thread(client_id,
      service_id,params);
}
```

```
Program executed by thread thr:
   results = do_service(
      service_id, params);
   send(client_id, results);
   exit
```



Client/server architecture (9)

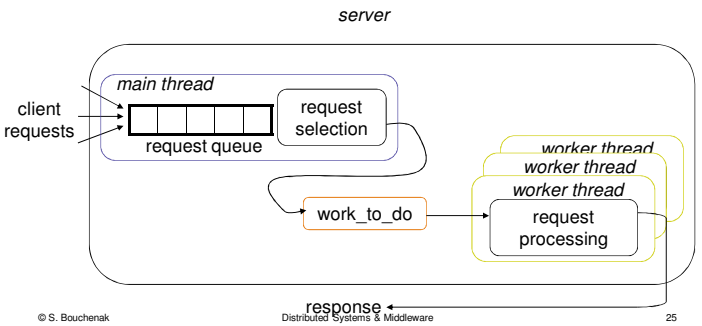
- Server resource management – A pool of processes

```
while (true) {
   receive(client_id,message);
   extract(message, service_id,
      params);
   work_to_do.put(client_id,
      service_id,params);
}
```

```
Pool of processes:
while (true) {
   work_to_do.get(
      client_id, service_id,
      params);
   results = do_service(
      service_id, params);
   send(client_id, results);
}
```

Client/server architecture (10)

- Server resource management – A pool of processes



Client/server architecture (11)

- Application of the client/server architecture
  - With low level operations
    - Using functions of the communication system
    - Example: Sockets
      - TCP, connected mode
      - UDP, unconnected mode
  - With high level operations
    - Using a middleware
    - Example: RMI in object-oriented middleware
      - Remote method invocation

Outline

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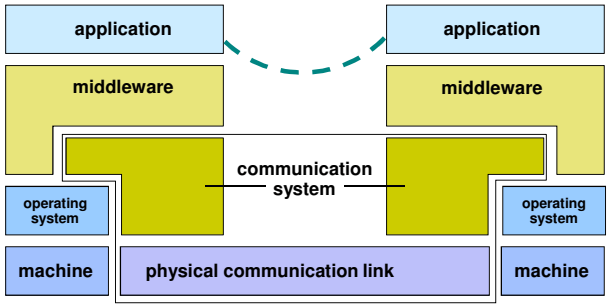
   - Communication mechanisms in distributed systems
   - Services and interfaces in computing systems
   - Client/server architecture
2. **What is a middleware**
3. References

What is a middleware



Functions of a middleware

- A middleware has mainly four functions
  - Make distribution as invisible (transparent) as possible
  - Provide a homogeneous view of underlying heterogeneous hardware and software systems
  - Provide services of common use for distributed systems
  - Provide a high-level interface or API (*Applications Programming Interface*) for programming distributed applications

Middleware for distributed systems

- Middleware aims at simplifying programming distributed systems
  - Implementation, evolution and reuse of applications code
  - Inter-platform portability of applications
  - Interoperability between heterogeneous applications

Examples of middleware solutions

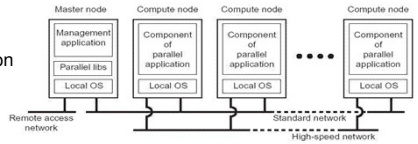
- Sun JVM
- CORBA
- Microsoft .NET
- Sun J2EE / EJB
- …

Types of distributed systems

- Distributed computing systems
- Distributed information systems
- Distributed pervasive systems

Distributed computing systems

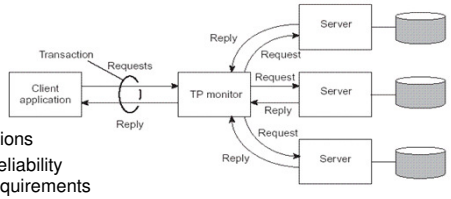
- Objective
  - Distributed systems configured for high performance computing
- Cluster computing
  - A group of high-end systems connected through a LAN
  - Homogeneous, i.e. same OS, hardware
  - Single managing node
- Grid computing
  - Heterogeneity
  - Geographical dispersion
- Applications
  - Video streaming
  - Web services
  - Scientific computing



M. van Steen, Lecture on Distributed Systems, Chapter 1, http://www.cs.vu.nl/~steen/

Distributed information systems

- Objective
  - Providing consistent access to (shared) data that can be distributed and accessed concurrently
- Observation
  - Transactions
  - ACID properties
- Applications
  - Streaming applications
  - Data access with reliability and consistency requirements



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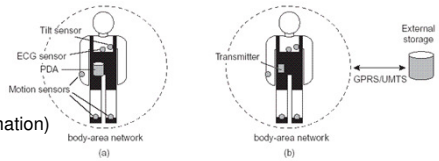
Distributed pervasive systems

- Objective
  - Providing consistent access to (shared) data that can be distributed and accessed concurrently
- Observation
  - Contextual change
  - Ad-hoc composition
- Applications
  - Domotics (home automation)



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Outline

1. What is a distributed system
2. What is a middleware
   - What is a middleware
   - Functions of a middleware
   - Middleware for distributed systems
   - Examples of middleware solutions
   - Types of distributed systems
3. **References**

References

- Chris Britton, Peter Bye. *IT Architectures and Middleware: Strategies for Building Large, Integrated Systems (2nd Edition)*. Addison-Wesley, 2004.
- George Coulouris, Jean Dollimore, Tim Kindberg. *Distributed Systems: Concepts and Design (4th Edition)*. Addison Wesley, 2005.
- Arno Puder, Kay Römer, Frank Pilhofer. *Distributed Systems Architecture: A Middleware Approach*. Morgan Kaufmann, 2005.
- Andrew S. Tanenbaum, Maarten van Steen. *Distributed Systems: Principles and Paradigms (2nd Edition)*. Prentice Hall, 2006.
- This lecture is partly based on lectures given by Sacha Krakowiak, http://sardes.inrialpes.fr/people/krakowia/