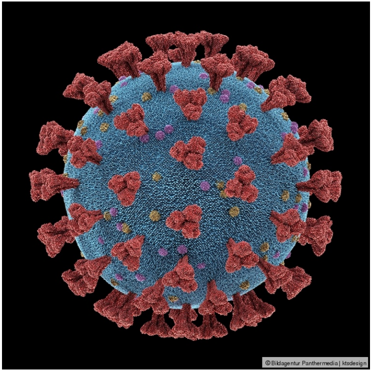
FRANKFURT UNIVERSITY OF APPLIED SCIENCES

COVID-19 Measures

- Wear a mask (medical or FFP2) until you have taken a seat
- When seated you may take off the mask if you can maintain an interpersonal distance of 1,5 m
- Open the windows periodically whenever possible
- Behave reasonable and use common sense



Distributed Systems
Basics of Communication

Prof. Dr. Oliver Hahm
Frankfurt University of Applied Sciences
Faculty 2: Computer Science and Engineering
oliver.hahm@fb2.fra-uas.de
https://teaching.dahahm.de

Agenda

1 Introduction

2 Basics of Communication
- Number of Communication Peers
- Addressing
- Buffering
- Communication Pattern
- Semantics of Messages

Agenda

1. Introduction

2. Basics of Communication
   - Number of Communication Peers
   - Addressing
   - Buffering
   - Communication Pattern
   - Semantics of Messages

Goals

- Getting accustomed to a **generic message-oriented communication service** with a very high practical relevancy → the Internet and the TCP/IP protocol suite
- Getting to know **sockets** as a common API for network programming
- Communication services on higher layers (e.g., remote procedure calls (RPCs), web services) are based on these basic services

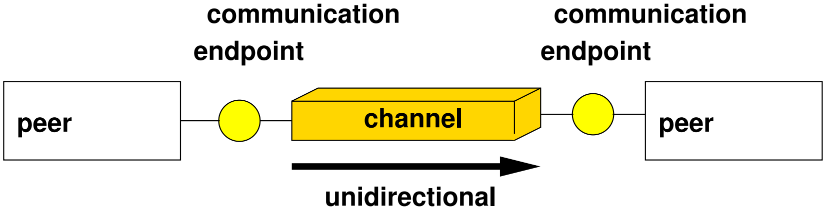
Layering

Higher layer communication services and middleware platforms offer a more abstract interface which is aligned with the corresponding cooperation paradigm. They are based internally on these fundamental concepts of the underlying communication system

Agenda

Basics of Communication

- All interaction between any participants requires an underlying communication capability
- Communication channel
  - The facility that allows for the connection/coupling of communication partners is called **communication channel** or simply **channel**
- Direction of the message flow of a channel
  - A channel is called **directed** or **unidirectional** if one process takes exclusively the sender role and the other process takes exclusively the receiver role
  - Otherwise the channel is called **undirected** or **bidirectional**



Aspects of Communication

1. The number of communication peers
2. Addressing
3. Buffering
4. Communication pattern
5. Message structure

Agenda

Number of Peers of a Channel

- Exactly two:
  - Most simple (and most common) case
- More than two:
  - For certain applications group communication may be appropriate
  - $\rightarrow$ **multicast** service
  - Special case: Broadcast

Agenda

1 Introduction

2 Basics of Communication
- Number of Communication Peers
- Addressing
- Buffering
- Communication Pattern
- Semantics of Messages

Direct Addressing

- Each communication partner have a distinct, unambiguous (potentially globally unique) address
- Addressing can be explicit and symmetrical
  - → The sender must explicitly name the receiver – and vice versa

  Example:

  `SEND ( P, message )` - Send a message to process *P*

  `RECEIVE ( Q, message )` - Receive a message from process *Q*

- Asymmetrical variant (e.g., for server processes):
  - → Only the sender names the receiver, the receiver (server) gets to know the identity of the sender only on reception

  Example:

  ```
  SEND ( P, message )
  RECEIVE ( sender_id , message )
  ```

Indirect Addressing

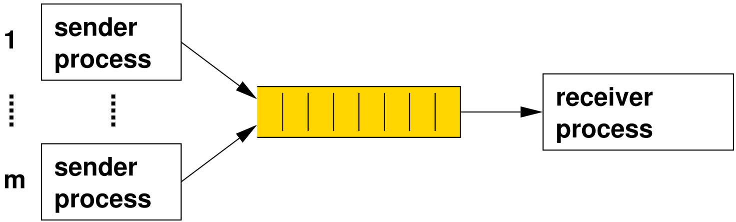
- Communication happens indirectly via intermediary instances
- Advantages:
  - Improved modularity
  - The number of communication partners can be restructured in a **transparent** manner, e.g., after a node failed
  - Extend options of group communication, like, for example, $m : 1$, $1 : n$, $m : n$
  - Intermediary instance may ...
    - only forward
    - store and forward
    - transform/translate messages

Example for Indirect Addressing

Mailbox:

`SEND ( mbox, message )` - Send a message to a mailbox `mbox`.

`RECEIVE ( mbox, message )` - Receive a message from a mailbox `mbox`.



Agenda

Buffering

- **Capacity** of a channel:
  The number of messages which can be stored temporarily in a channel to **decouple** sender and receiver in time
- The channel's capability for buffering messages is typically implemented by a (waiting) **queue**
- In distributed systems the waiting queue is typically realized on the receiver site (rendezvous site)
- Buffering can be used to restore the message order or to modify the sending order

No Buffering (Capacity Zero)

- Unbuffered communication
- Sender and receiver are very closely coupled in time
- Also called Rendezvous
- Often considered to be too inflexible
- Example:
  - A sender is blocked when a `SEND` operation happens before a corresponding `RECEIVE` operation
  - As soon as the corresponding `RECEIVE` operation is executed the message is copied directly without any buffering from the sender process to the receiver process
  - If vice versa a `RECEIVE` operation happens at first, the receiver is blocked until the `SEND` operation is executed
- Example: Communication between threads in various microkernels such as RIOT or L4

Limited Capacity

- A channel can contain at any point of time a maximum of N messages (waiting queue with **capacity N**)
- `SEND` operation during a non-full waiting queue
  - The message is stored in the queue
  - The sender process resumes its normal operation
- Waiting queue is full (it contains N sent but not yet received messages):
  - The sender process blocks until free space in the queue is available again or the message is discarded
  - Analogously a receiver is blocked on a `RECEIVE` operation if the waiting queue is empty

Consequences

- **Buffered** communication enables **loose coupling** of the communication partners in terms of time
- Passing the message to the communication system does not imply that the receiver has received the message
- Typically the sender won't even know a maximum duration until a message is received
- If this knowledge is of importance for the sender an explicitly communication between sender and receiver is required:

Process P (Sender):		Process Q (Receiver):
...		...
`send ( Q, `*message*` );`	⟶	`receive ( P, `*message*` );`
`receive ( Q, `*reply*`);`	⟵	`send ( P, "'acknowledgement"' );`
...		...

Agenda

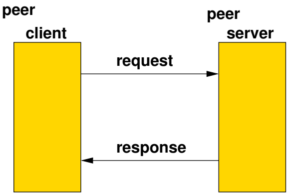
Communication Pattern

One-Way

- Single message without response or acknowledgement

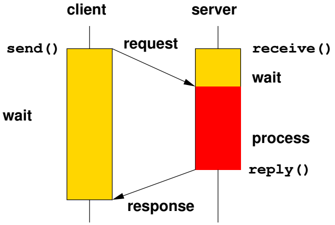
Request/Response

- Client role (consumer)
- Server role (producer)
- Often blocking on the client site ($\rightarrow$ standard RPC)

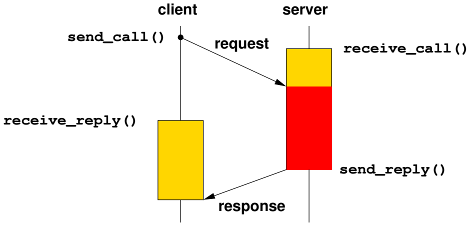


Differing Synchronicity for Request/Response:

- **Synchronous call**: The sender process blocks until the end of the communication process ($\rightarrow$ arrival of the response)
  $\Rightarrow$ no parallelism
- **Asynchronous call**: Sender is only delayed for the initiation of the communication process ($\rightarrow$ passing the message to the communication system)



(a) synchronous



(b) asynchronous

Publisher/Subscriber Model

- Message classified by **topics** or event channels
- Receiver subscribe topics (subscriber)
- Sender publishes messages or events (publisher)
- Model allows for transparent sending of messages to multiple receivers!
- Examples: CORBA Notification Service, OMG DDS, MQTT

More Complex Communication Patterns

- Not very common in simple communication systems
- Exception: Three-way handshake between two participants for reliable connection establishment
- More complex patterns emerge by group communication
- Very common on the upper layers
- Example: business process

Agenda

Semantics of Messages

Byte stream

- Passed messages of various `SEND` operations cannot be identified as individual units any more ⇒ message borders get lost
- The receiver (and the communication system) observe only sequence of characters (byte stream)
- Example: UNIX pipes

Message container

- Messages can be identified by sender and receiver
- The messages have either a fixed length or the length can be derived on both sides

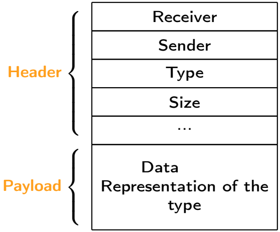
⇒ The message borders remain intact

- The correct interpretation of the internal structure of a message is the responsibility of the communication peers
- Example: UNIX message queues

Message Structure

Typed messages

- Messages have a typed structure
- The type is know to the sender and receiver and partly by the communication system
- The type is used as part of the operations
- Exemplary structure of a message:



- Message body may contain typed objects ($\rightarrow$ object-orientation)

Message Serialization

Example

- Java object serialization transforms an object into a bytestream and vice versa (deserialization)
  - The header contains information about type, layout etc., the body contains the actual data
  - Java class implements the interface `java.io.Serializable`
  - All attributes of the class must be `serializable` themselves or marked as `transient`
  - Operations are `writeObject()`, `readObject()`

Messages of a Documental Nature

- Example: HTML over HTTP
- XML-Documents
  - Very popular today
  - Type description via scheme
- Example: SOAP (Simple Object Access Protocol)

```
<soap-env:Envelope
xmlns:soap-env="http://schemas.xmlsoap.org/soap/envelope/"
soap-env:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
<soap-env:Body>
<tns:getFlaeche xmlns:tns="urn:tns:beispiel">
<tns:seite1 xsi:type="xsd:double">8.0</tns:seite1>
<tns:seite2 xsi:type="xsd:double">4.0</tns:seite2>
</tns:getFlaeche>
</soap-env:Body>
</soap-env:Envelope>
```

Important takeaway messages of this chapter

- For all higher layer services in a distributed system an underlying communication system is required
- The facility that enables the communication between the peers is called channel
- Important characteristics of a communication system are the number of participants, the addressing style, its capacity, the used communication pattern, and the semantics of the message