Sistemas Distribuídos

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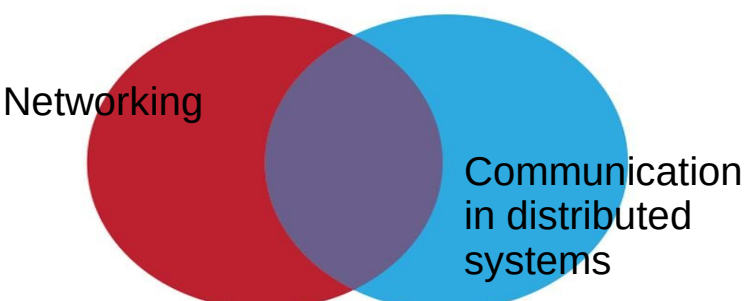
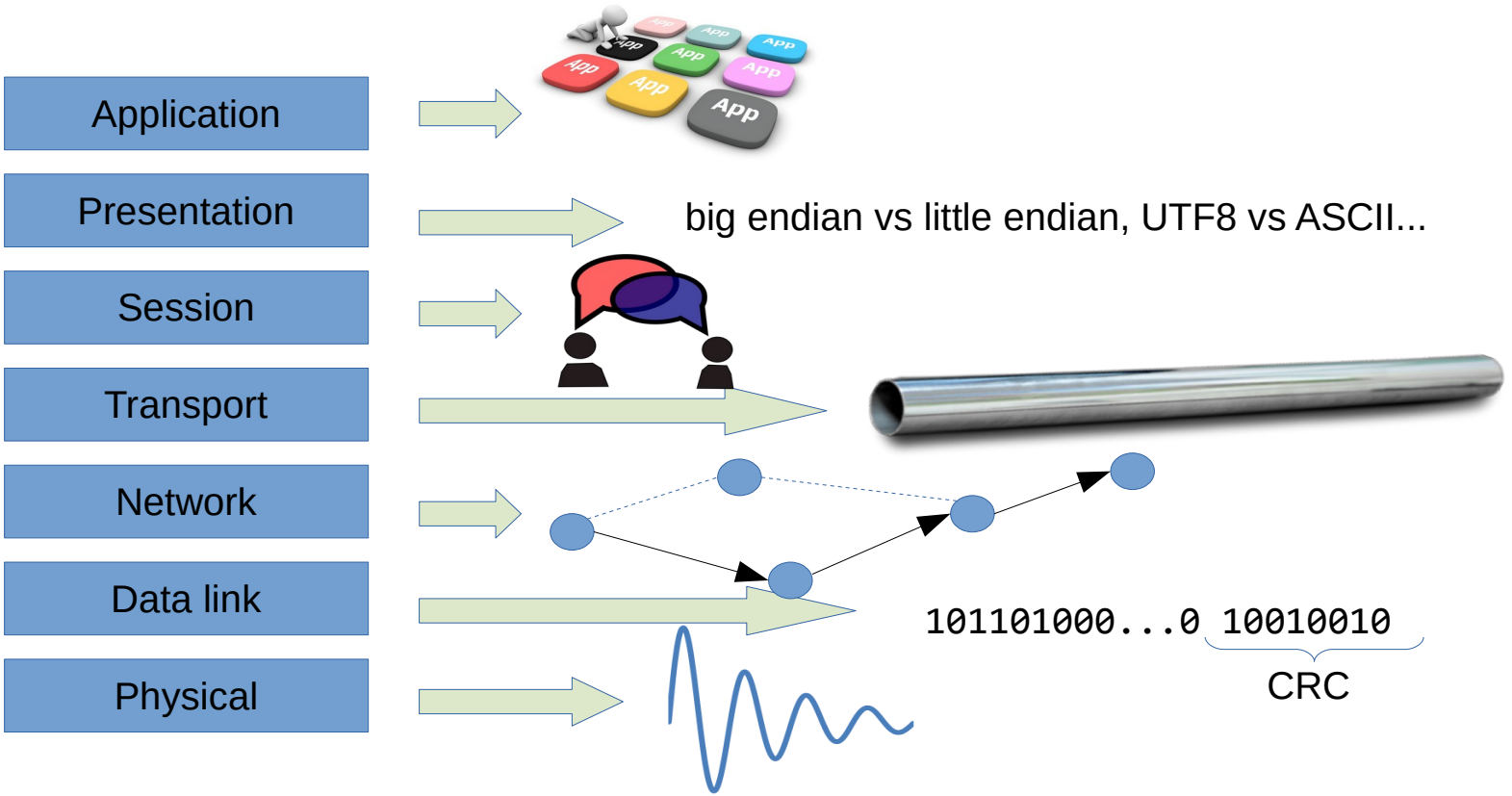
Communication

- Networking is used for communication in distributed systems
- What aspects of networking are relevant to distributed systems?
- How does communication in distributed systems goes beyond networking?



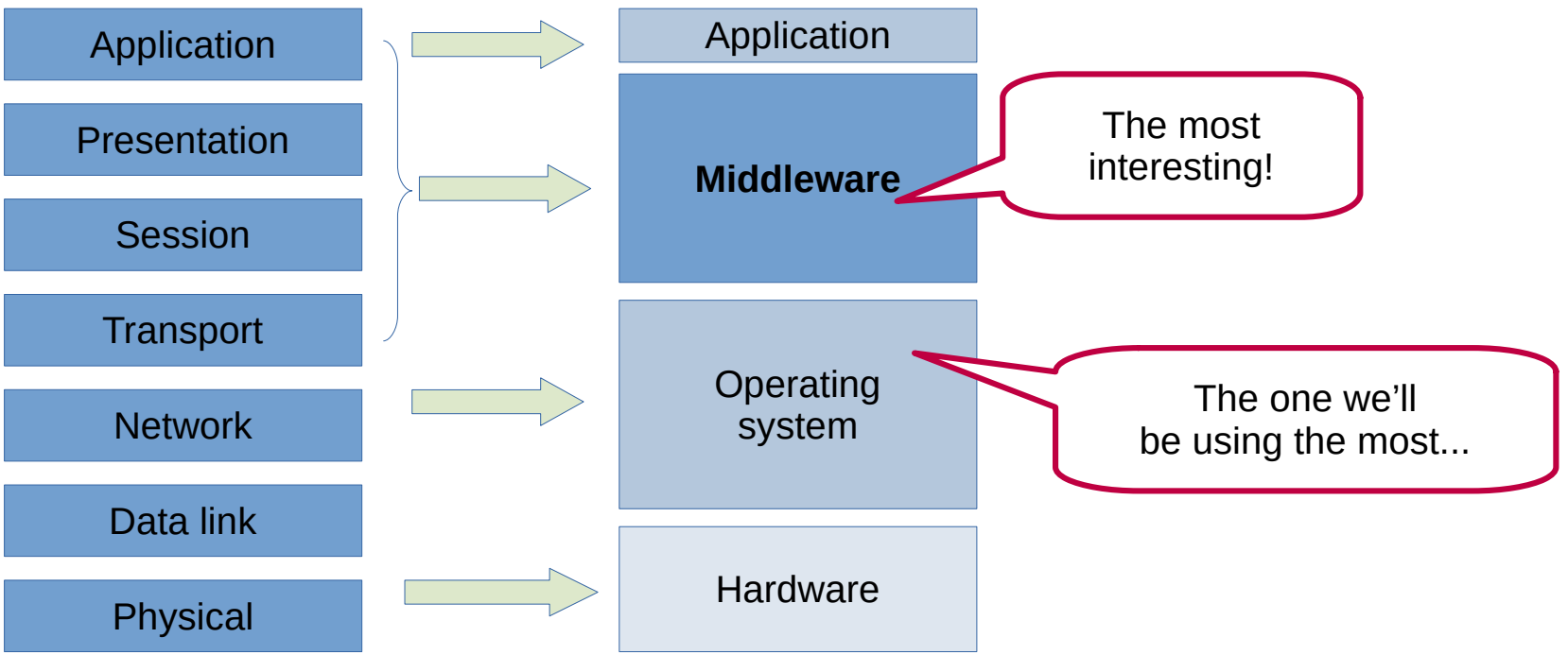
Networking 101: OSI model



Networking 101: OSI model

- Layers as implementation modules
  - Standard interfaces
  - Interchangeable alternatives
  - No longer used
- Layers as abstractions
  - Different ways to interpret the same thing
    - E.g. electric signal vs bits vs channel
  - Still useful

Simplified model



Simplified model

- The hardware is not very interesting…
- The operating system is standard:
  - TCP/IP (mainly…)
  - Sockets API
- The middleware layer encapsulates solutions to hard problems:
  - Much more than session/presentation layers
  - More than just communication (e.g. persistence)
  - Determines how applications are developed

Operating system

- A simplified understanding of TCP/IP
  - What do we need to know for distributed systems?
- The Sockets application programming interface

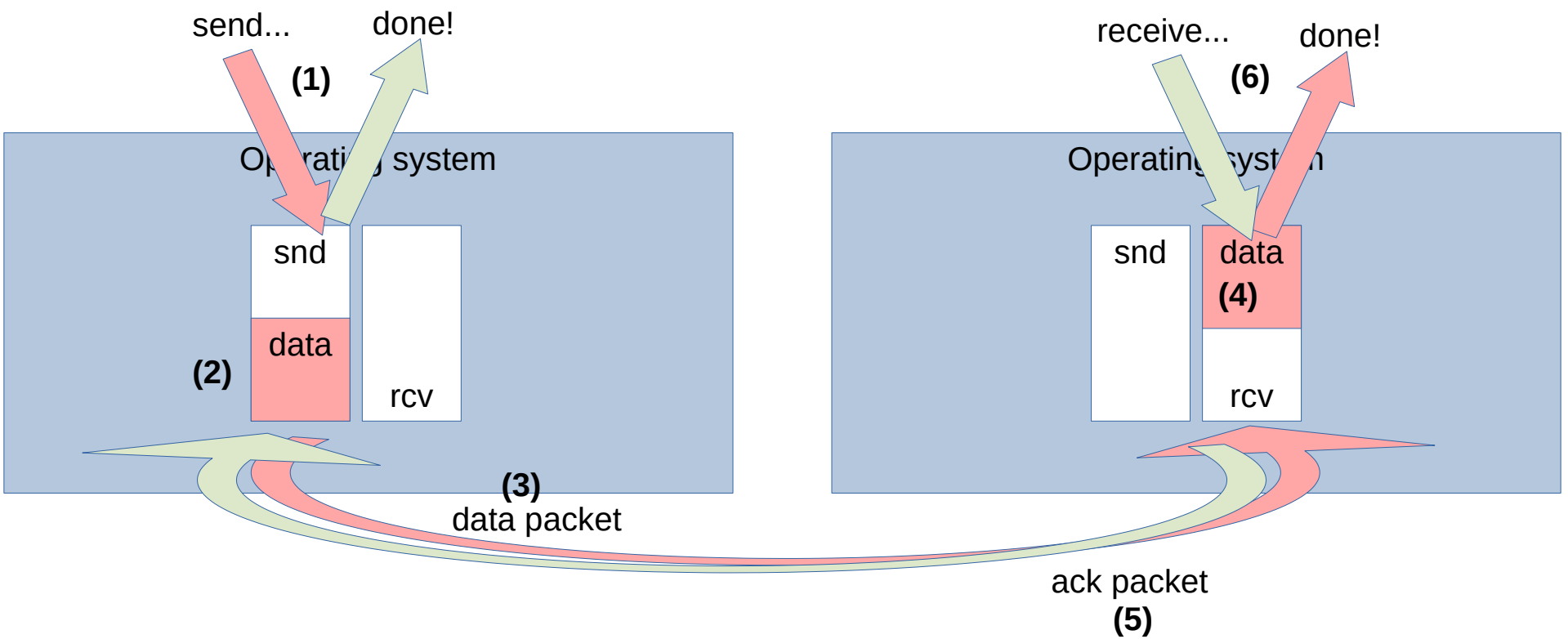
TCP/IP

- A bi-directional reliable FIFO connection:
  - Bi-directional: both participants send and receive
  - Reliable: no data is lost or corrupted
  - FIFO: data is received in the same order as sent
- When the connection is broken:
  - A prefix of data sent has been received
    (“Prefix” includes possibly all or none)

TCP/IP

- A connection is identified at each participant by:
  - A local IP address
  - A local port
  - A remote IP address
  - A remote port
- It is possible to have more than one connection on the same port
- It is possible that addresses and ports are different in participants due to Network Address Translation (NAT)

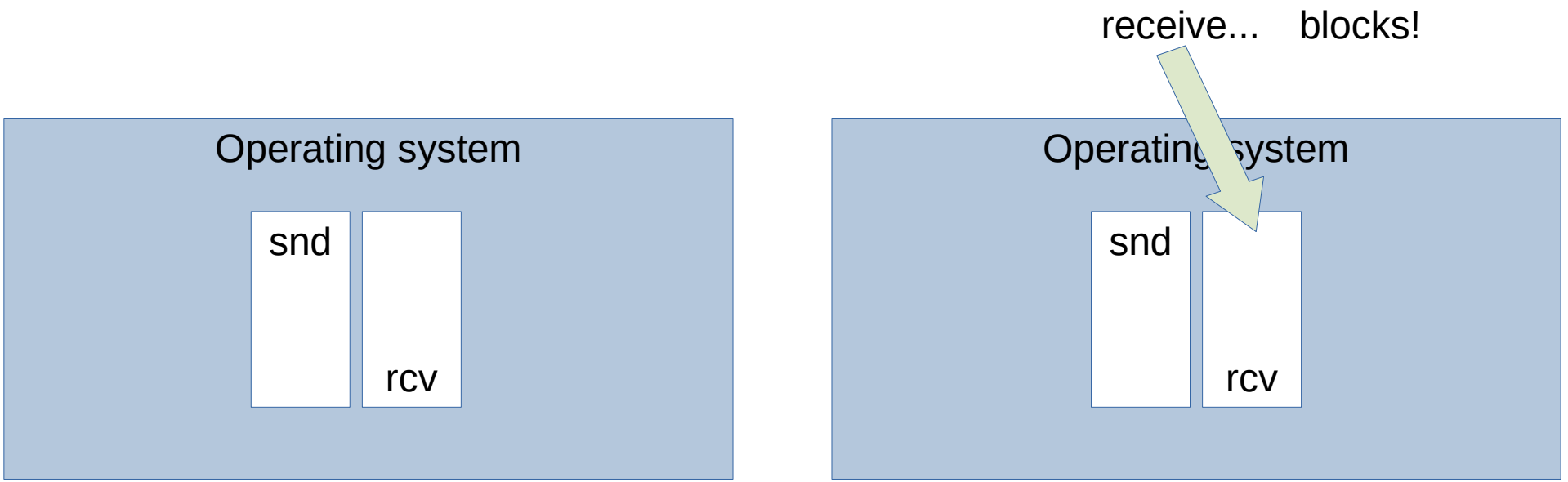
TCP/IP


send...
done!
(1)
snd
data
(2)
rcv
receive...
done!
(6)
snd
data
(4)
rcv
(3)
data packet
ack packet
(5)

TCP/IP

- The protocol controls when to send packets
  - (2)→(3) and (4)→(5)
  - Important for efficient/safe use of network
  - Limited by network capacity
- Consuming data (6) makes receiver buffer space available for more packets
- Acknowledgment (5) makes sender buffer space available for more data

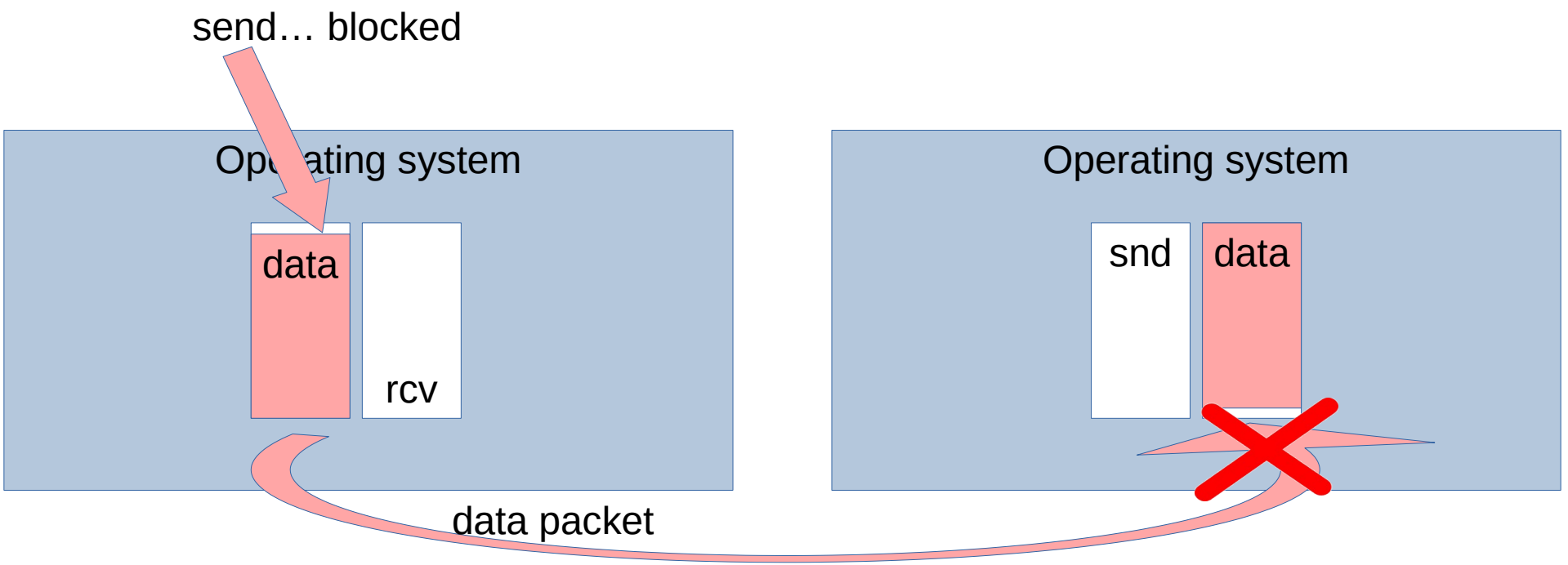
TCP/IP


receive... blocks!
Operating system
snd
rcv
Operating system
snd
rcv

TCP/IP

- When the sender does not write:
  - Sender buffer becomes empty
  - Stops sending packets
  - Receiver buffer becomes empty
- The receiver is also blocked

TCP/IP


send… blocked
Operating system
data
rcv
Operating system
snd
data
data packet

TCP/IP

- When the receiver does not read:
  - Receiver buffer fills up
  - Stops accepting new data
  - Stops sending acknowledgments
  - Sender buffer fills up
- The sender is also blocked

TCP/IP Summary

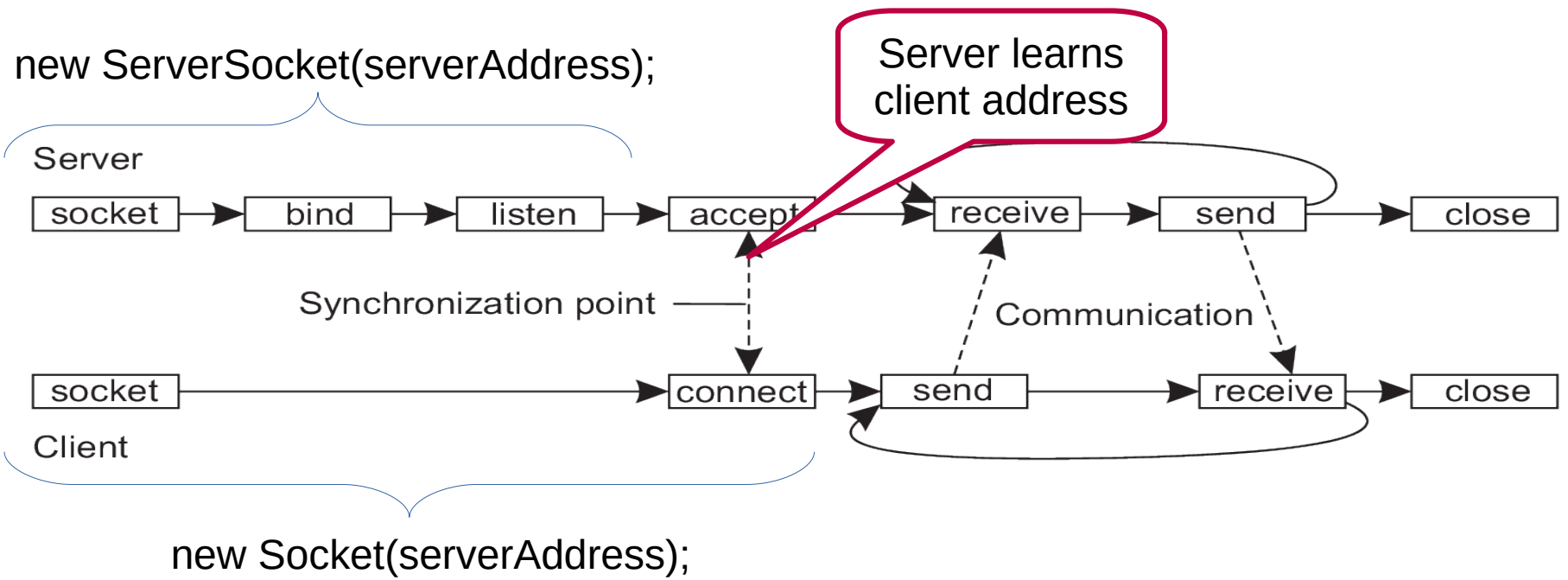
- Connection behaves like:
  - a pair of operating system pipes
  - a pair of bounded buffer concurrency constructs
- It is both a communication and a distributed synchronization primitive
  - Allows waiting for other processes/threads in different hosts
  - (Think await()/signal()...)

Sockets

- Interface for setting up a new connection
- Interface for sending and receiving data
- Interface for closing an existing connection

Sockets: Connecting

- How to discover the peer address?
- Asymmetric interface:
  - “Server” is well known and is contacted by “Client”



Sockets: Sending and receiving

- In the Unix tradition:
  - An open connection is a file descriptor
  - Sending and receiving with read() and write()
- In Java, it is wrapped in I/O streams:
  - Socket sock = …
  - sock.getOutputStream() → for writing
  - sock.getInputStream() → for reading
- Closed connection equivalent to EOF (read doesn’t block and returns 0 bytes)

Sockets: Sending and receiving

- Sending and receiving lines of text in Java:
  - BufferedWriter pw = new BufferedWriter(
    new OutputStreamWriter(sock.getOutputStream())
    );
  - rw.write(…);
  - BufferedReader br = new BufferedReader(
    new InputStreamReader(sock.getInputStream())
    );
  - br.readLine();

Sockets: Disconnecting

- In the Unix tradition, by closing the file descriptor. In Java, wrapped as:
  - sock.close();
  - sock.getInputStream().close();
  - sock.getOutputStream().close();
- Can be partially closed:
  - sock.shutdownOutput();
  - sock.shutdownInput();

Middleware: Synchrony and persistence

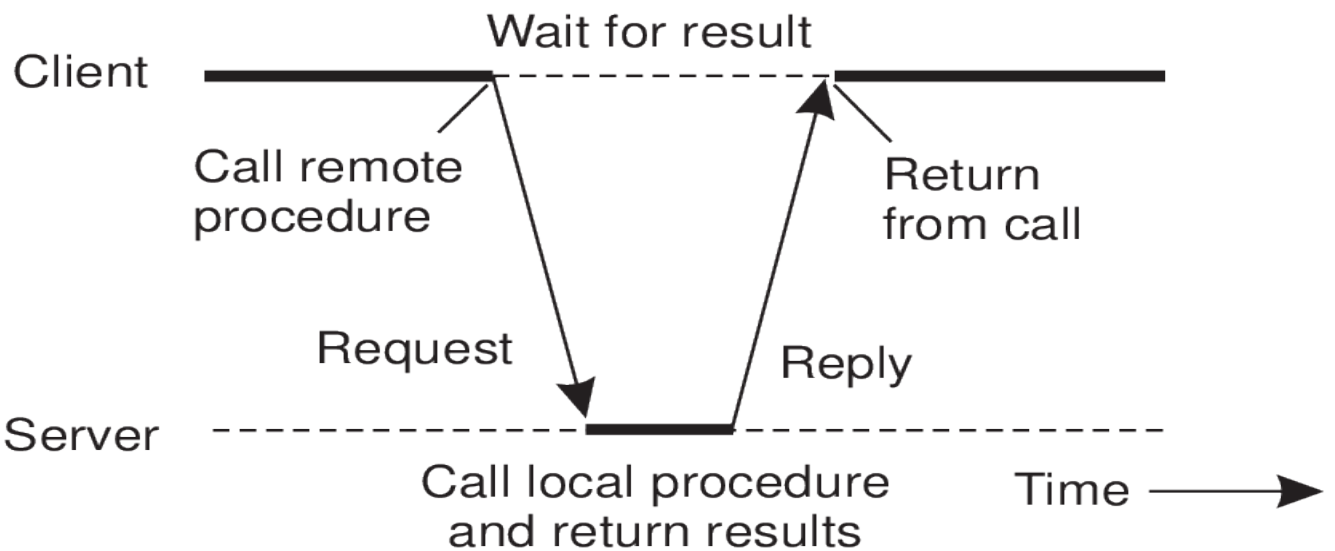
- Asynchronous vs synchronous:
  - Thread not blocked while interacting
  - Thread blocked only until...
  - To thread blocked until reply received
- Transient vs persistent:
  - Persistent messages stored on disk at various stages of processing
  - Used to restart interaction

Middleware: Destination and addressing

- Point-to-point vs multipoint:
  - Interaction between two vs multiple participants
- Explicit vs implicit:
  - Explicit addressing: Join group, send to group
  - Implicit addressing: Subscribe to interest, publish content

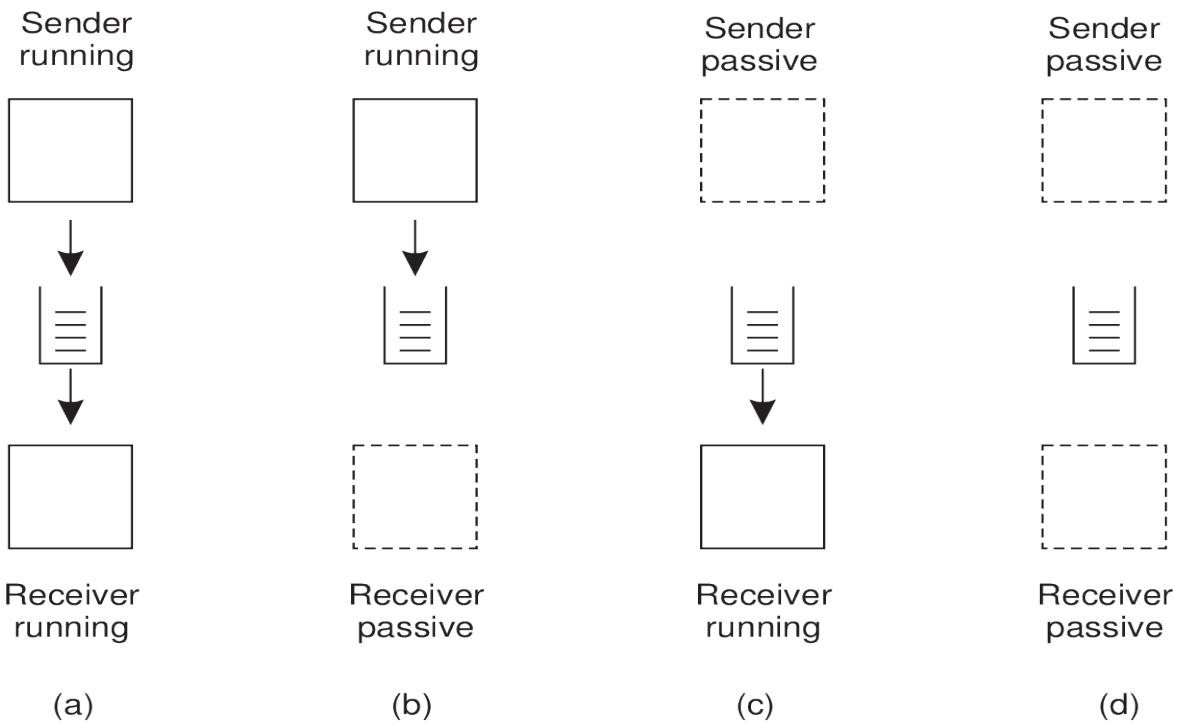
Example: Client/server RPC

- Synchronous / transient / point-to-point /explicit
- Interaction looks like a local method/procedure invocation



Example: MoM

- Asynchronous / persistent / * / *
- Loosely coupled communication:

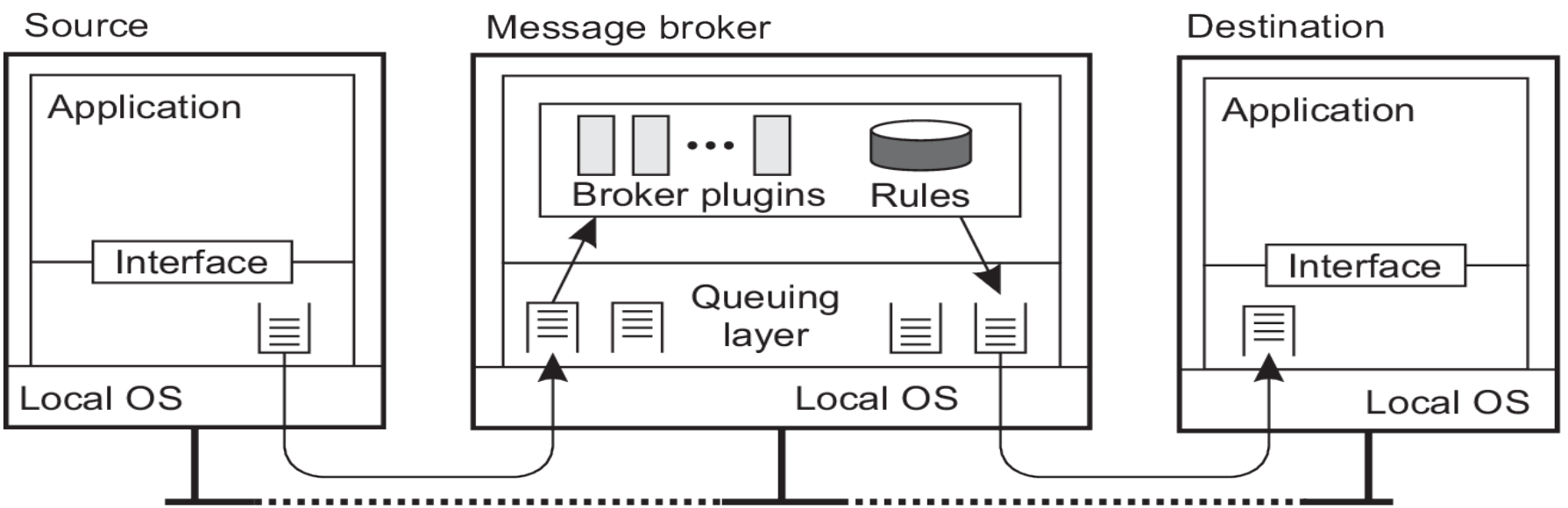


Example: MoM

- Point-to-point:
  - Send to named queue
  - Receive from named queue
- Topic based multipoint:
  - Subscribe to topic
  - Publish to topic
- Content based multipoint:
  - Subscribe to expression: “stock=’IBM’ and price>10”
  - Publish data: “(stock=’IBM’, …, price=11.5, ...)”

Example: MoM

- Use with a message broker / application bus component:



Example: Group communication

- Asynchronous / transient / point-to-multipoint / explicit
- Expects a variable group of processes
- Targets fault-tolerant systems
- Provides notifications of current group composition and predictable delivery context

Example: MPI

- * / transient / multipoint / explicit
- Expects a fixed group of processes
- Targets parallel processing
- Provides a spectrum of asynchronous/ synchronous send and receive operations:
  - Asynchronous needed for parallelism
  - Synchronous needed to wait for completion of interim stages

Summary

- Operating system provides the basic communication primitive:
  - TCP/IP + Sockets
- Various middleware layers provide communication primitives tailored for different applications
- Our next goal: Build useful middleware on TCP/IP + sockets