THE UNIVERSITY of EDINBURGH

Distributed Systems
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Today’s Agenda

Architecture (contd..)

Communication

- Fundamentals
- Remote Procedure Calls

Computation vs. Communication

Processes/Threads/VMs/Nodes perform computation

They alone cannot comprise the Distributed System

The interaction between the computational components make any system a distributed system

- Like human beings and society

Some methodology needed to let the computational components interact

Communication

Communication not a prerogative for distributed systems only

- Single node/process can communicate using function calls, IPC, etc.

Communication paradigms describe and classify a set of methods by which computational nodes can interact and exchange data

Communication involves many problems/issues

- Physical transmission to application level
- Need to standardize to make things easy

OSI (Open Systems Interconnection) Reference Model

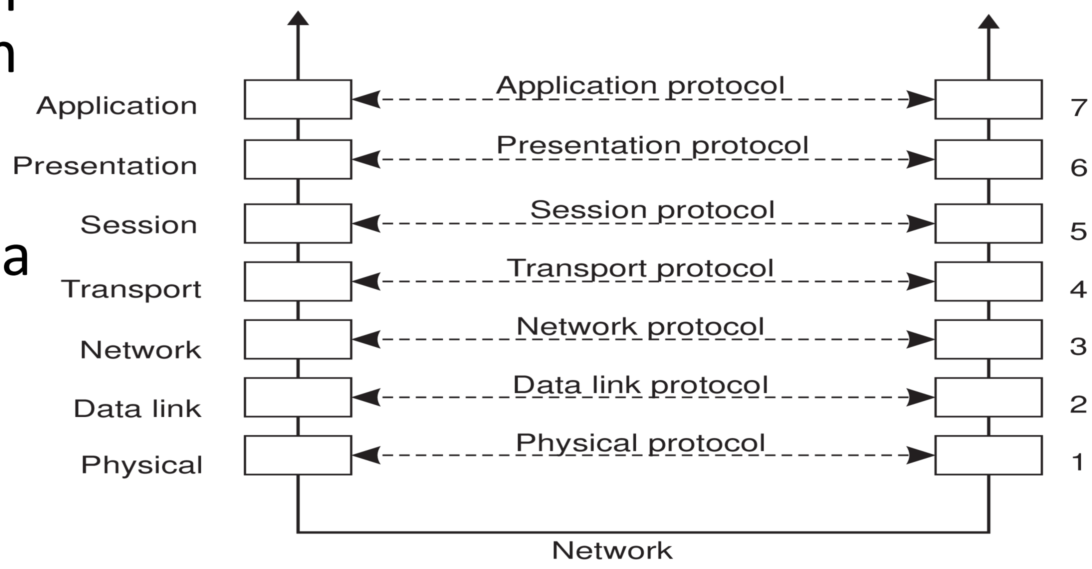
- Designed to allow open systems to communication
- Rules for communications called protocols
- 7 layers

OSI Model

Physical Layer – Contains the specification and implementation of bits and their transmission between sender and receiver

Data Link Layer – Prescribes the transmission of a series of bits into a frame to allow for error and flow control (transmission errors)

Network Layer – Describes how packets in a network of computers are routed

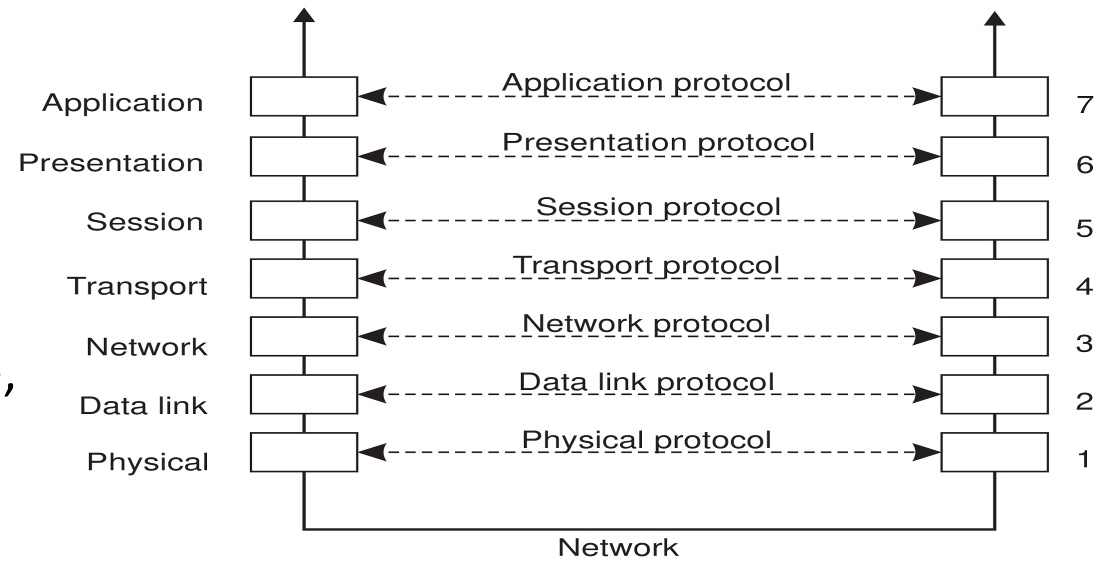


OSI Model

Transport Layer – Contains the protocols for directly supporting applications; establish reliable communication, support real-time streaming of data, etc.

Two standard protocols

- TCP – Connection-oriented, reliable, stream-oriented protocol
- UDP – Unreliable (best-effort) datagram protocol

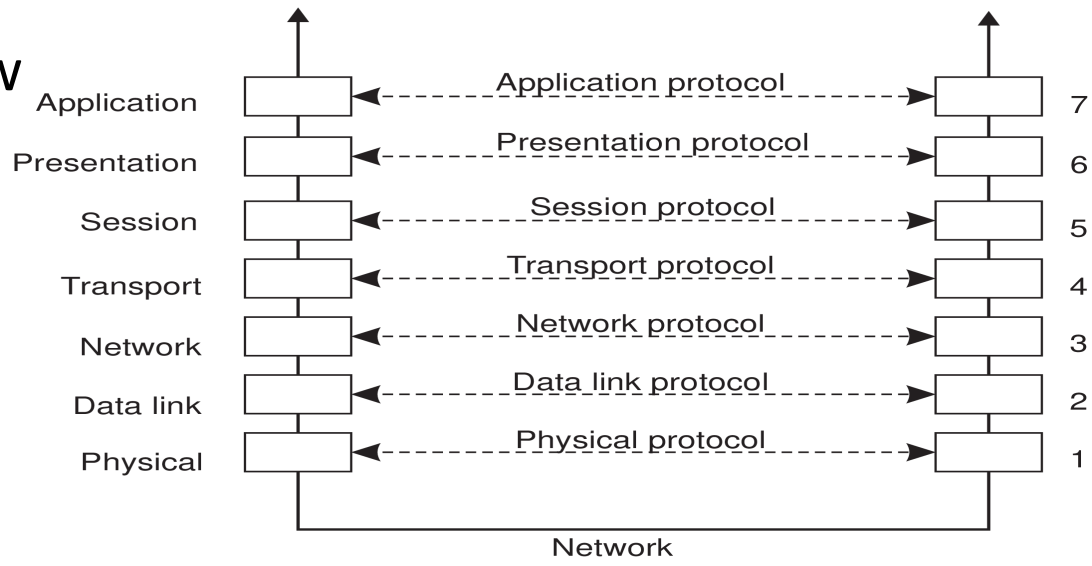


OSI Model

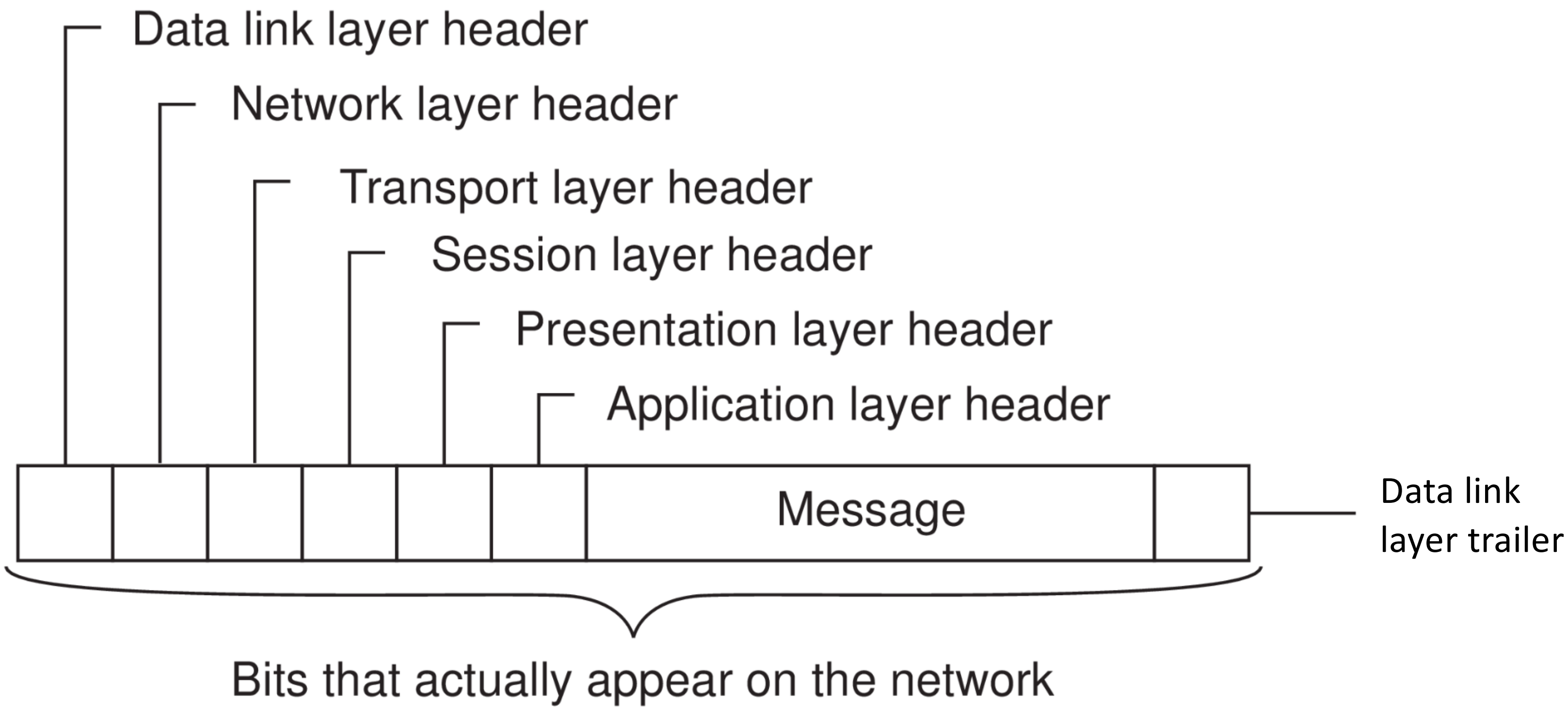
Session Layer – Provides support for sessions between applications

Presentation Layer – Prescribes how data is represented in a way that is independent of the hosts on which communication applications are running

Application Layer – Represents everything else related to the applications (email-protocols, web-access, file-transfer, etc.)



Message in OSI Reference Model



OSI Model ≠ OSI Protocols

OSI Model

- Perfect to understand and describe communication systems through layers
- Problems exists w.r.t middleware layers

OSI Protocols not practical; never successful

TCP/IP dominates over OSI Protocols

Middleware Protocols

Middleware mostly attached to applications

Middleware service protocols different from application-level protocols

Middleware Protocols are application-independent unlike application-level protocols

Session & Presentation layers replaced by middleware layer and is application-independent

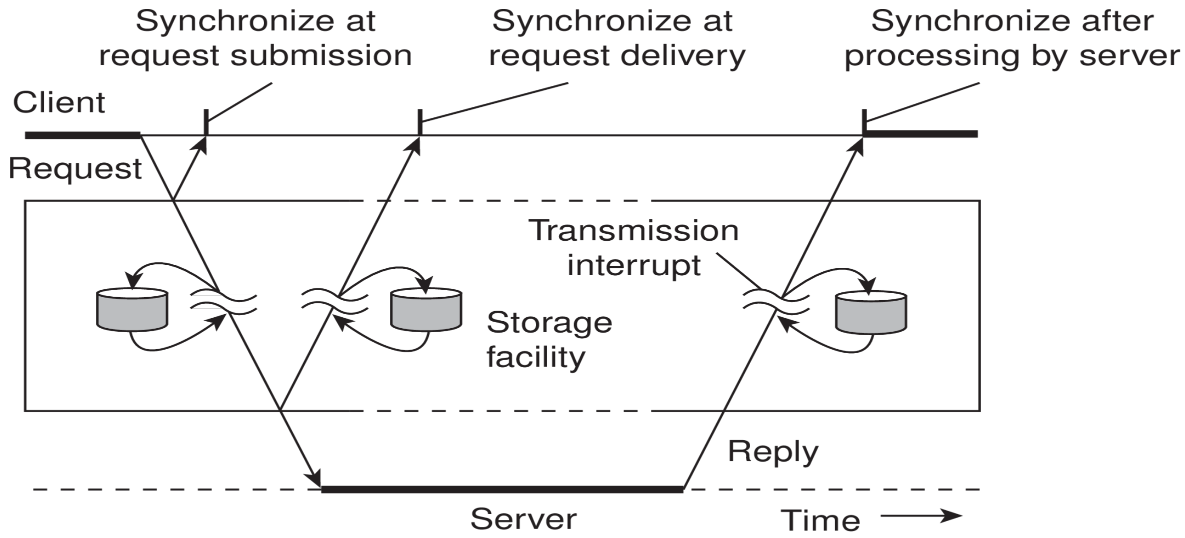
- Transport layer could be offered in the middleware layer

Types of Communication

Persistent vs Transient

Persistent → Message sent is stored by the middleware until it is delivered to the receiver; Example – Email server

Transient → Message sent is stored by the middleware only as long as both the receiver and sender executing; Example – RPC

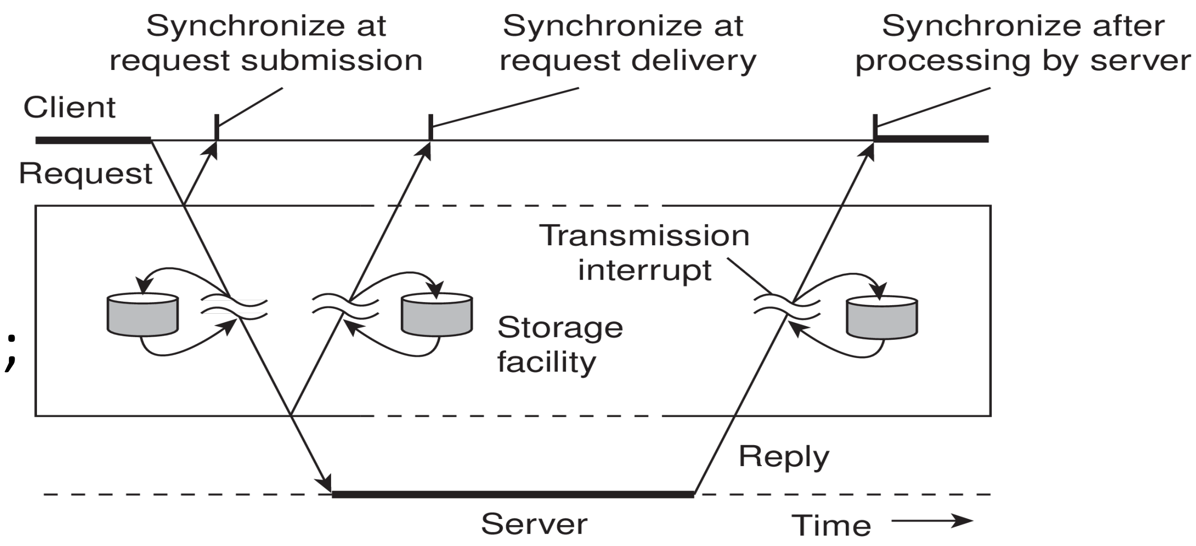


Types of Communication (contd…)

Asynchronous vs. Synchronous

Asynchronous → Sender keeps on executing after sending a message

Synchronous → Sender blocks execution after sending a message and waits for response; 3 levels of responses



Classification of Communication Paradigms

Three categories

- Same address space – Global Variables, Procedure calls
- Different address spaces (Within a computer) – Files, Shared Memory, Signals
- Different address space (Multiple computers) – Shared Memory, Message Passing – RPC, sockets

Distributed Shared Memory

Message Passing

Assume no explicit sharing of data elements in the address space of computational components

Essence of message passing is copying

- Implementation may avoid copying wherever possible

Problem-solving with messages – more active involvement by participants

Send and Receive two main primitives

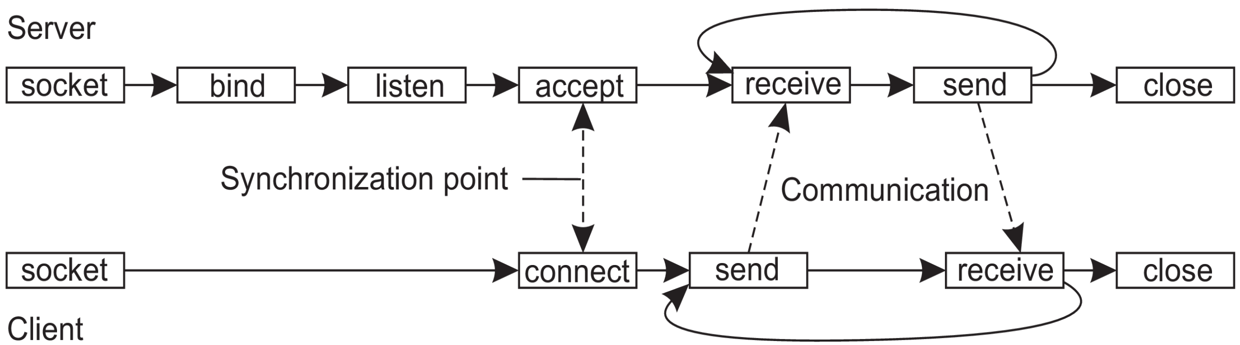
Client<—>Server interaction

Socket Programming

Socket – Software structure that serves as endpoint for sending and receiving data across the network

Several APIs to interact with sockets

Operation	Description
socket	Create a new communication end point
bind	Attach a local address to a socket
listen	Tell OS what is the maximum number of pending connection requests should be
accept	Block caller until a connection request arrives
connect	Actively attempt to establish a connection
send	Send some data over the connection
receive	Receive some data over the connection
close	Release the connection



Socket Code in Python

Server

```
from socket import *

class Server:
   def run(self):
      s = socket(AF_INET, SOCK_STREAM)
      s.bind((HOST, PORT))
      s.listen(1)
      (conn, addr) = s.accept()  # returns new socket and addr. client
      while True:                # forever
         data = conn.recv(1024)  # receive data from client
         if not data: break      # stop if client stopped
         conn.send(data+b"*")    # return sent data plus an "*"
      conn.close()               # close the connection
```

Client

```
class Client:
   def run(self):
      s = socket(AF_INET, SOCK_STREAM)
      s.connect((HOST, PORT)) # connect to server (block until accepted)
      s.send(b"Hello, world") # send same data
      data = s.recv(1024)     # receive the response
      print(data)             # print what you received
      s.send(b"")             # tell the server to close
      s.close()               # close the connection
```

Remote Procedure Call

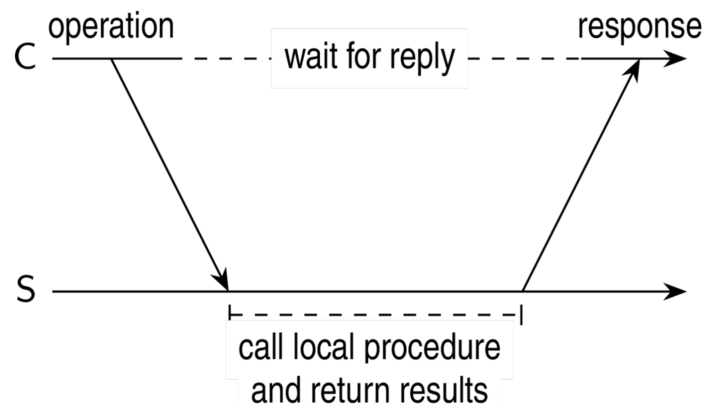
Allow remote services to be called as procedures

- Transparency with respect to location, implementation, language, etc.

Goal is to make distributed computing look like centralized computing

Basic Idea

- Programs can call procedures on other machines
- When process A calls a procedure foo() on machine B, A is suspended
- Execution of foo() takes place on machine B
- After execution of foo(), the result is sent back to A, which resumes execution



Procedure Call to Remote Procedure Call

Procedure Call to Remote Procedure Call

Procedure Call to Remote Procedure Call

RPC – Challenges

Separate callee and caller address space

- How to transfer data?
- Need for a common reference space

Machines may be different

- Parameters and results must be passed and handled correctly

Thousands of procedures exported by servers

- How does client locate a server?

Client and server might fail independently

- How to handle failures?

Parameter Passing

Marshalling/Packing – Parameters passed into a message to be transmitted

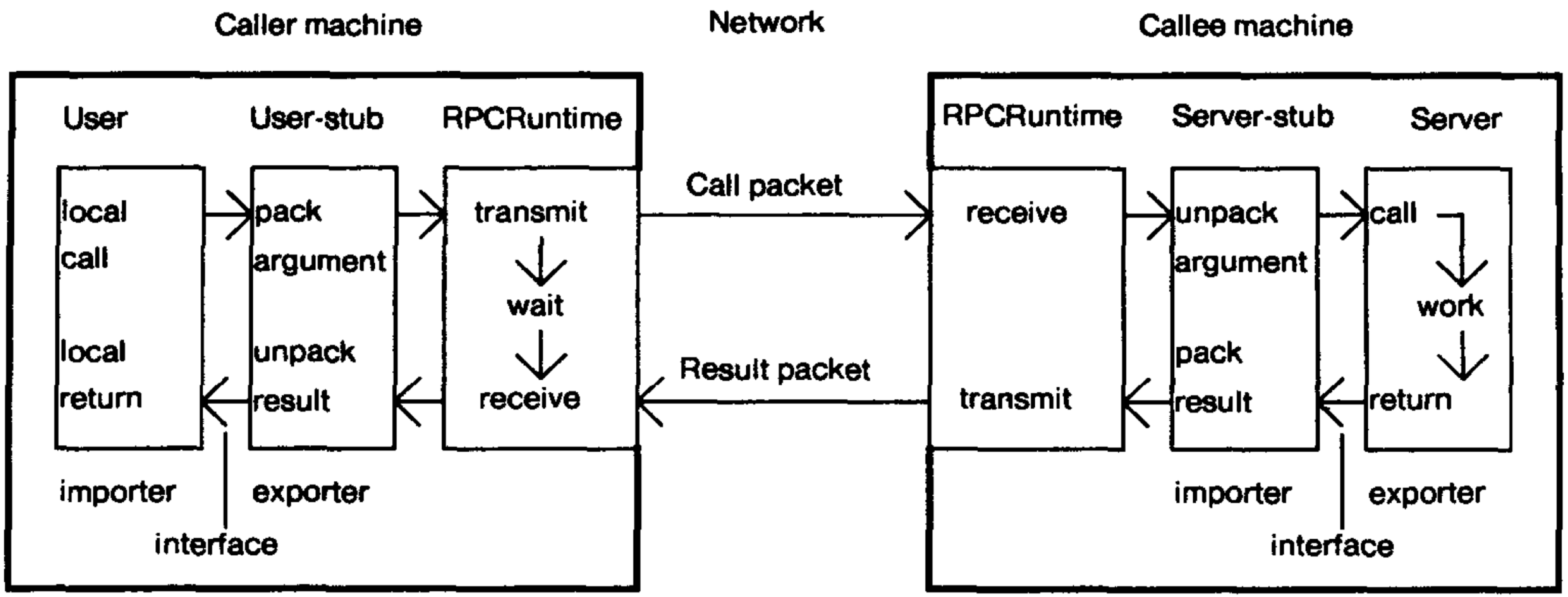
Both parameters and results must be marshalled

Two types of parameters

- Value – directly encoded into the message
- Reference – Can lead to incorrect results (or crash); Solutions???

Client and Server stub takes care of marshalling

Parameter Passing (contd...)



Data Representation

Different micro-architecture and OS

- Size of data-type differs – size of long in 32-bit vs. 64-bit machines
- Format in which data is stored – Little-endian vs. Big-endian

Client and server must agree on how simple data is represented in the message

- Rely on Interface Definition Language (IDL) for the specification
- Stub compiler generates stub automatically from the specification

Binding

Binder

- Use bindings to let clients locate a server

Server

- Export server interfaces during initialization
- Send name, version number, unique identifier, handle to a binder

Client

- Send message to binder to import server interface
- Binder will check to see if a server has exported valid interface
- Return handle and unique identified to client

Binding may incur overhead

- Multiple binders – Replicate binding information; More availability; Load Balancing

Failure Handling

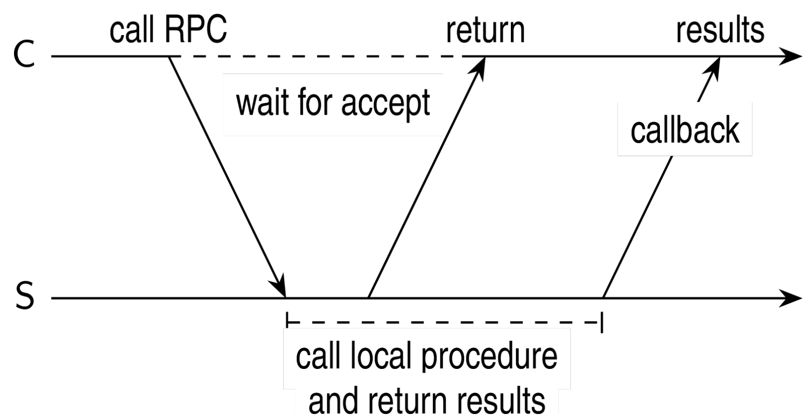
Next Class…

Asynchronous RPC

Request-reply behavior may not be needed

- Blocking may waste resources

Asynchronous behavior – Client continue without waiting for an answer from the server



Demo