THE UNIVERSITY of EDINBURGH

Distributed Systems
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Disclaimer: Slides prepared using multiple sources (UW-Madison – Remzi, Andrea, Mike; Cambridge – Martin Kleepman; Distributed Systems book by MVS/ AST); University of Edinburgh – Yuvraj Patel

Today’s Agenda

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

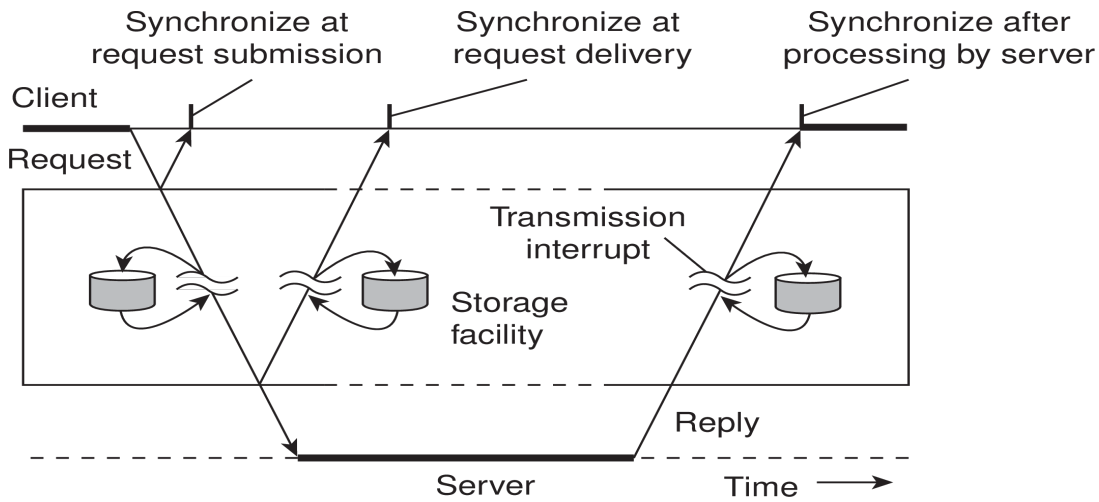
- Physical transmission to application level
- Need to standardize to make things easy

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

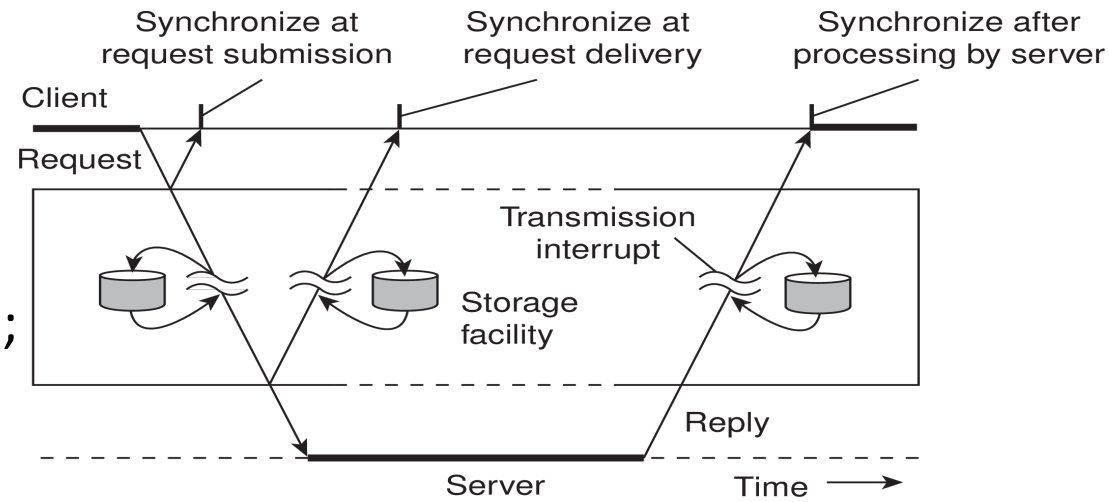


Types of Communication (contd…)

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

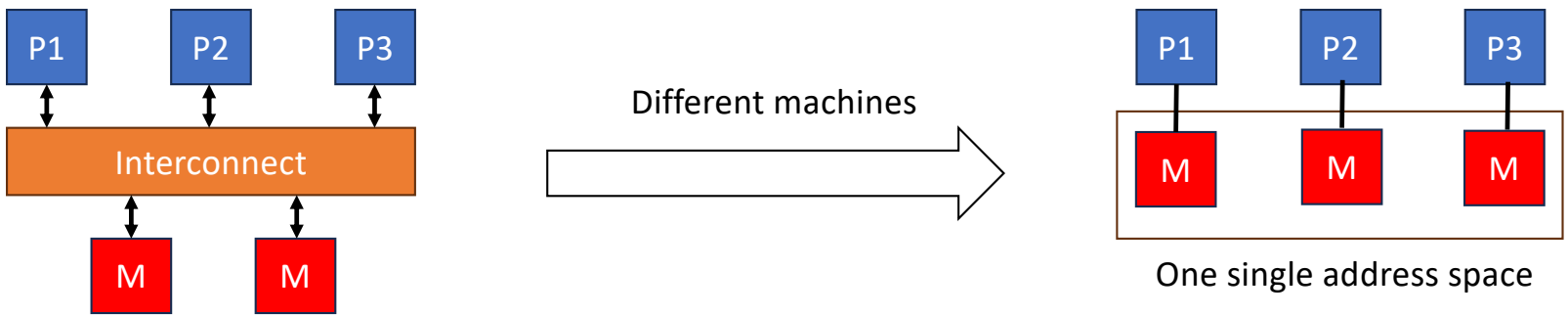


Classification of Communication Paradigms

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

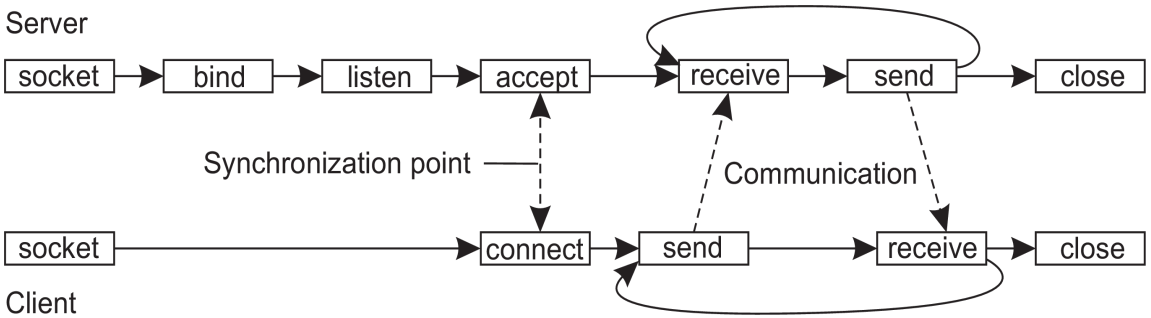
Client<—>Server interaction

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

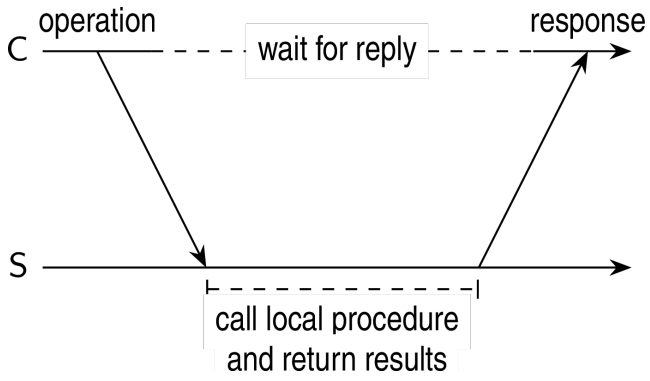
Allow remote services to be called as procedures

- 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

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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

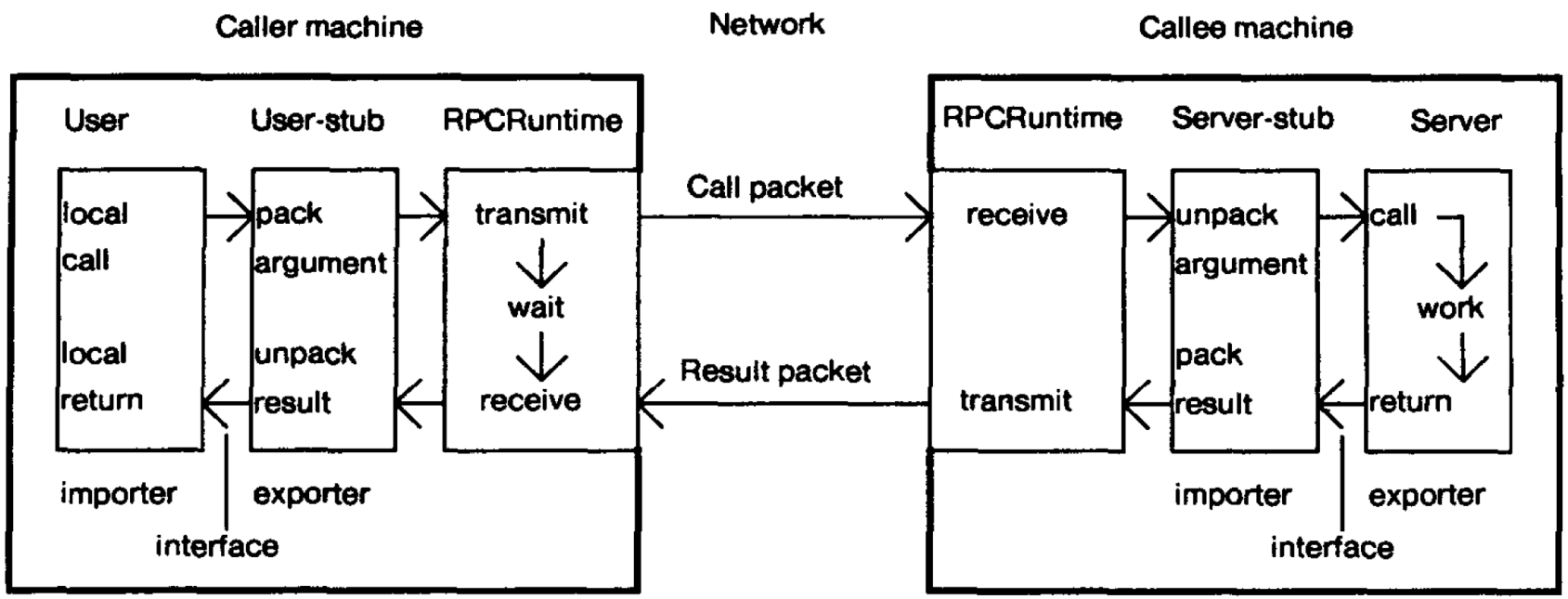
Both parameters and results must be marshalled

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

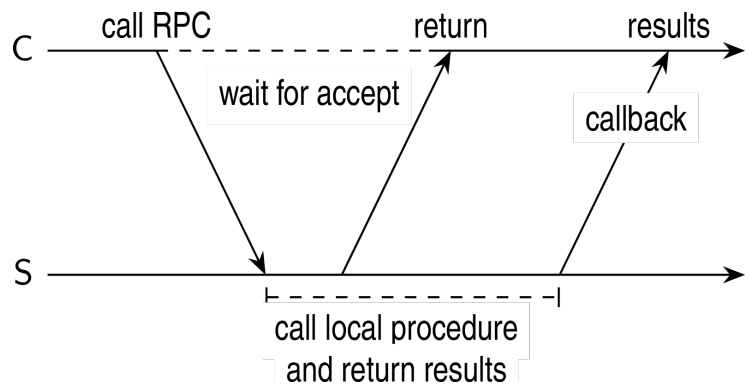
- Multiple binders – Replicate binding information; More availability; Load Balancing

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

Next Class…

Failure Handling

Next Class…