Institute of Computer Science
Department of Mathematics and Computer Science

Freie Universität Berlin

Algorithms and Programming IV

Introducing the Concepts of Distributed Programming

Summer Term 2023 | 14.06.2023

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Our Topics

1 Defining Distributed Systems

2 Possible Application Domains

3 Our Distributed System Model

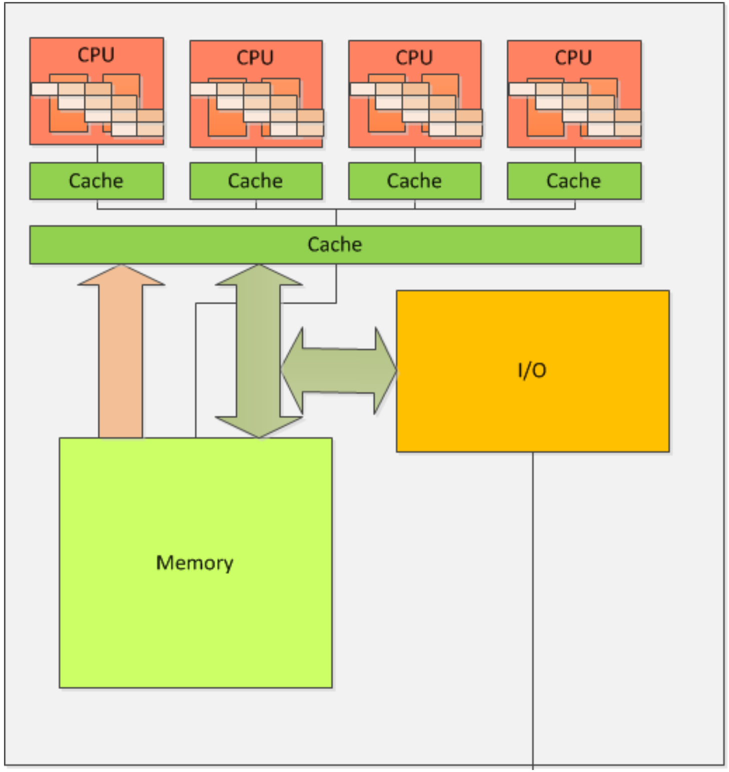
4 An Architectural Model of Distributed Systems

- Communicating entities
- Communication paradigm
- Roles and responsibilities
- Placement

Characteristics of a Centralized System Model

- One component with non-autonomous parts
- Component shared by users all the time
- Homogenous architecture – all execution units are from the same kind
- All resources accessible
- A running application is based on a single program

- Single point of control
- Single point of failure

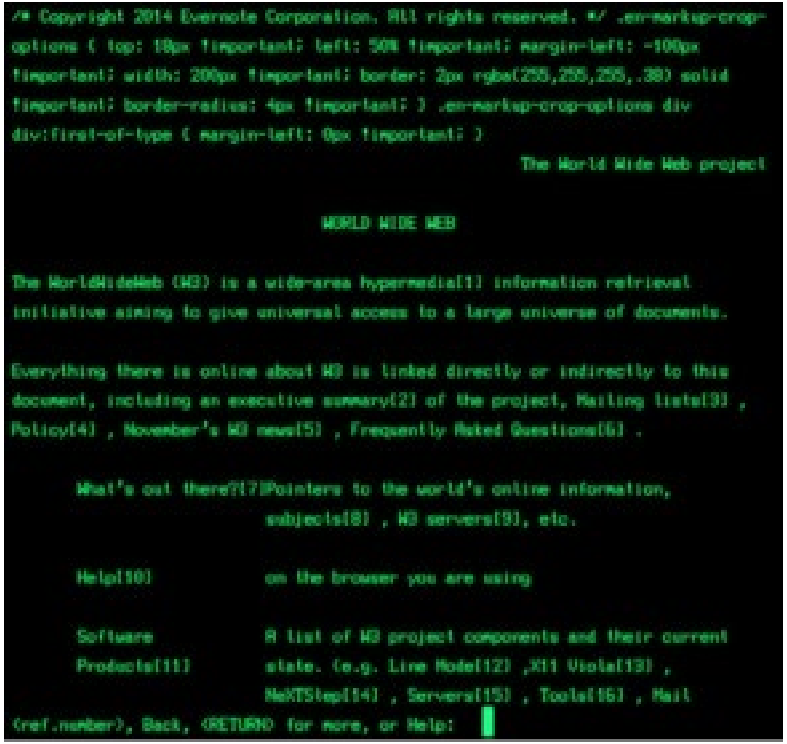


Exchange Information between CERN-Laboratories

- In 1989, Tim Berners-Lee proposed a project to address this problem. The underlying idea was based on the hypertext to create a world-wide scientific network for information sharing

- Tim Berners Lee developed the following concepts: Hyperlinks, URL, HTTP, HTML, the Webbrowser WorldWideWeb and the Webserver NeXTSTEP

- Christmas 1990: the first website info.cern.ch



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/* Copyright 2014 Evernote Corporation. All rights reserved. */ .en-markup-crop-
options { top: 18px !important; left: 50% !important; margin-left: -100px
!important; width: 200px !important; border: 2px rgba(255,255,255,.38) solid
!important; border-radius: 4px !important; } .en-markup-crop-options div
div:first-of-type { margin-left: 0px !important; }
                                                     The World Wide Web project

                              WORLD WIDE WEB

The WorldWideWeb (W3) is a wide-area hypermedia[1] information retrieval
initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this
document, including an executive summary[2] of the project, Mailing lists[3] ,
Policy[4] , November's W3 news[5] , Frequently Asked Questions[6] .

       What's out there?[7]Pointers to the world's online information,
                           subjects[8] , W3 servers[9], etc.

       Help[10]            on the browser you are using

       Software            A list of W3 project components and their current
       Products[11]        state. (e.g. Line Mode[12] ,X11 Viola[13] ,
                           NeXTStep[14] , Servers[15] , Tools[16] , Mail
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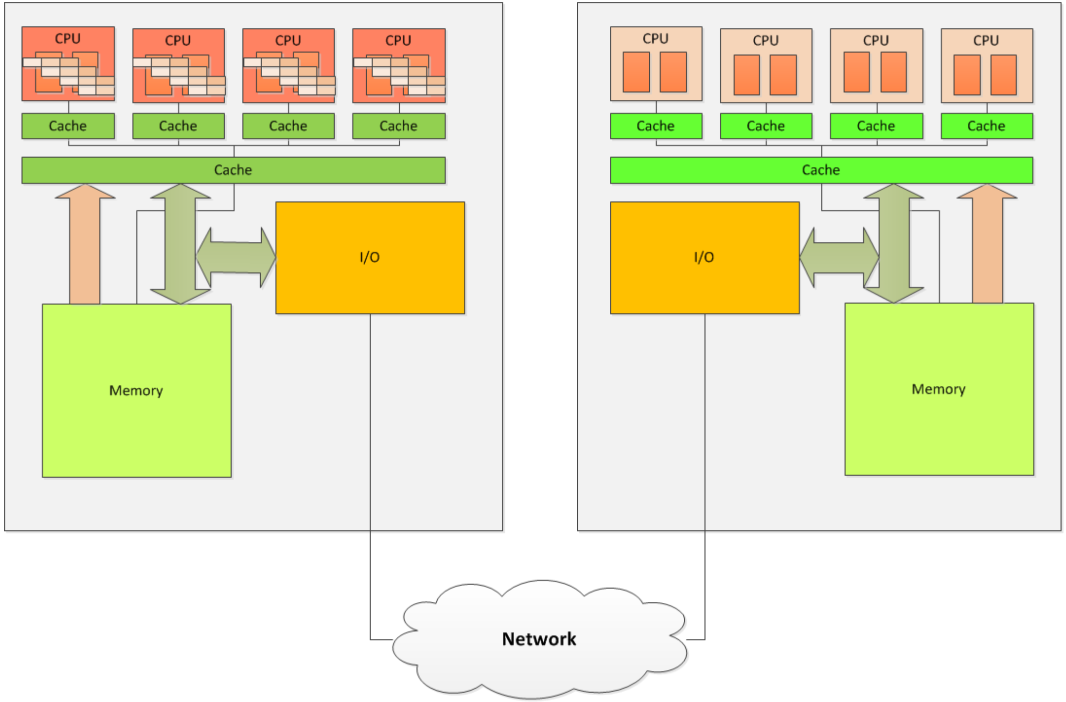
Distributed System Model



Distributed System

- Multiple autonomous components
- Components are not shared by all users
- Resources may not be accessible
- Software runs in concurrent processes on different processors
- Multiple points of control
- Multiple points of failure

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

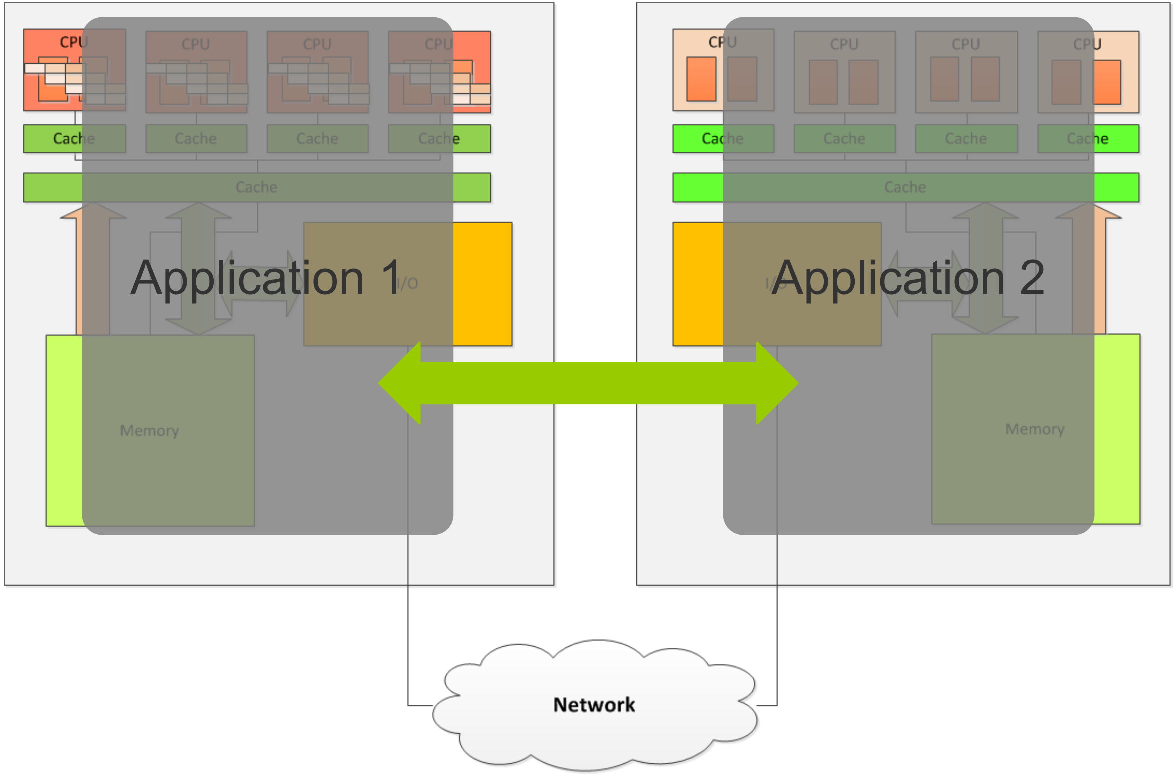
Email message sent to a DEC SRC bulletin board at 12:23:29 PDT on 28 May 87

Let’s have a bit more detail…

“A distributed system consists of a *collection of autonomous computer* linked by a *computer network* and equipped with distributed system software. Distributed system *software enables* computers *to coordinate their activities* and *to share the resources* of the system – hardware, software, and data […] so that users perceive the system as a single, integrated computing facility.”

(Coulouris et al., 1994)

Distributed System Model



Possible Application Domains

Finance and commerce	eCommerce Application, e.g. Amazon and eBay, PayPal, and online banking and trading
Information Systems & Social Media	Web information and search engines, ebooks, Wikipedia; social networking: Facebook, Twitter.
Entertainment	Online gaming, music and film in the home, user-generated content, e.g. YouTube, Flickr
Healthcare	Health informatics, online patient records, monitoring patients
Education	E-learning, virtual learning environments; distance learning
Transport and logistics	GPS in route finding systems, map services: Google Maps, Google Earth
Science	Grid as an enabling technology for collaboration between scientists
Environmental management	Sensor technology to monitor earthquakes, floods or tsunamis

Defining Computer Supported Cooperative Work (CSCW)

- CSCW describes the cooperation in teams with the help of groupware to fulfill a shared task. Groupware especially supports the communication, the coordination, the making of group decisions, and the joint processing of information objects.

- Groupware is computer-software and related computer networks that enable collections of people to cooperate distributed.

Source: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/computer-supported-cooperative-work

A two-dimensional Collaboration Framework

	Real time	Asynchronous
Communication	•Telephone •Video conferencing •Instant messaging •Texting	•Email •Voice mail •Blogs •Social networking sites
Information sharing	•Whiteboards •Application sharing •Meeting facilitation •Virtual worlds	•Document repositories •Wikis •Web sites •Team workspaces
Coordination	•Floor control •Session management •Location tracking	•Workflow management •Project management •Calendar scheduling

Source: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/computer-supported-cooperative-work

Using People Aktivities to feed Systems

facebook

twitter

Social Computing

- has to do with digital systems that support online social interaction.
- is concerned with **how** digital systems support social interaction.

$$PR(u) = \sum_{v \in B_u} \frac{PR(v)}{L(v)}$$

AN ARCHITECTURAL MODEL OF DISTRIBUTED SYSTEMS

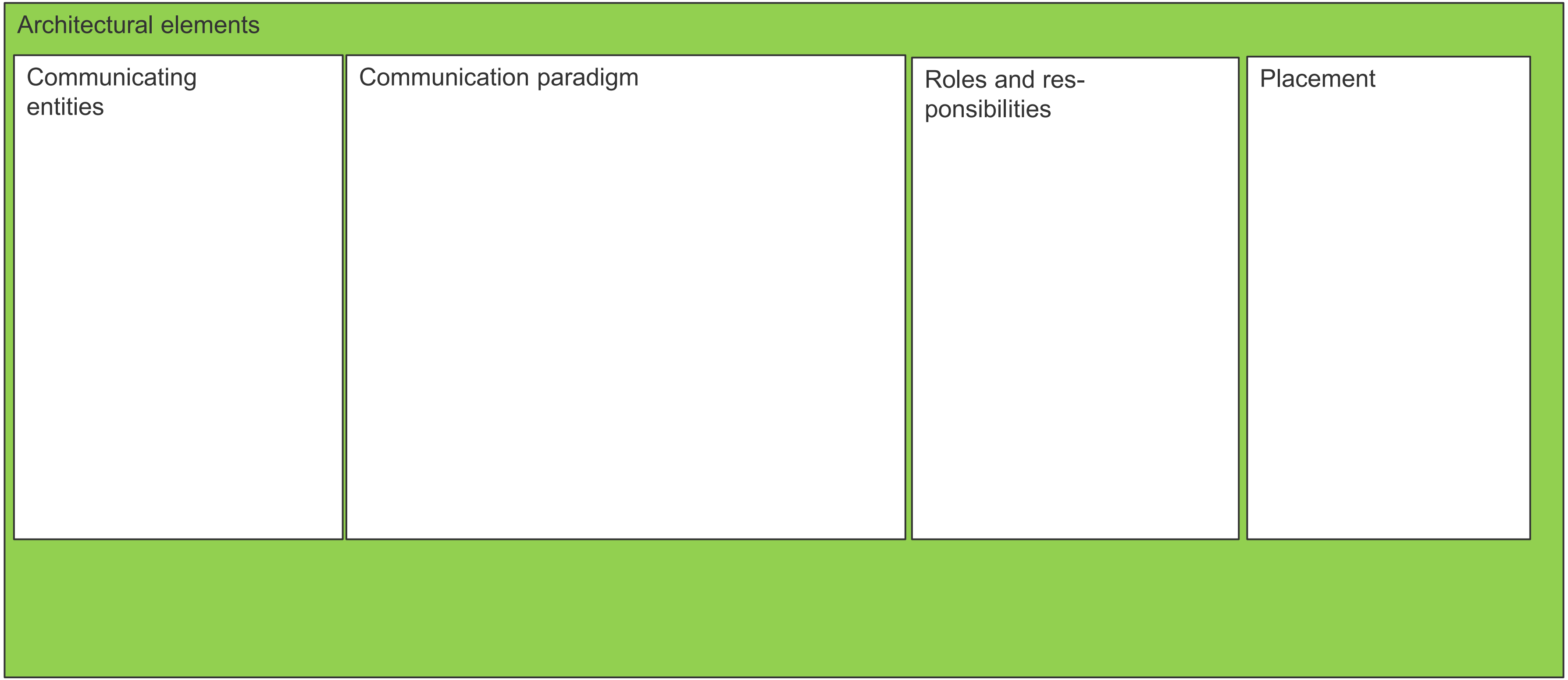
Architectural Model

An architectural model of a distributed system simplifies and abstracts the functions of the individual components of a distributed system.

It deals with the

- organization of components across the network of computers, and
- their interrelationship, i.e., how these components communicate with each other.

An Architectural Model of Distributed Systems



Architectural elements

Communicating entities

Communication paradigm

Roles and responsibilities

Placement

An Architectural Model of Distributed Systems

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What are the **entities** that are communicating in the distributed system?

System-oriented Perspective

In distributed systems the entities that communicate are typically processes.

Exceptions:

- In primitive environments such as sensor networks, there are no operating systems that provide any abstractions, therefore nodes communicate directely.
- In most environments processes are supplemented by threads, so threads are the endpoints of communications.

Problem-oriented perspective

Objects

- Computation consists of a number of interacting objects representing units of decomposition for a problem domain
- Objects are accessed via interfaces

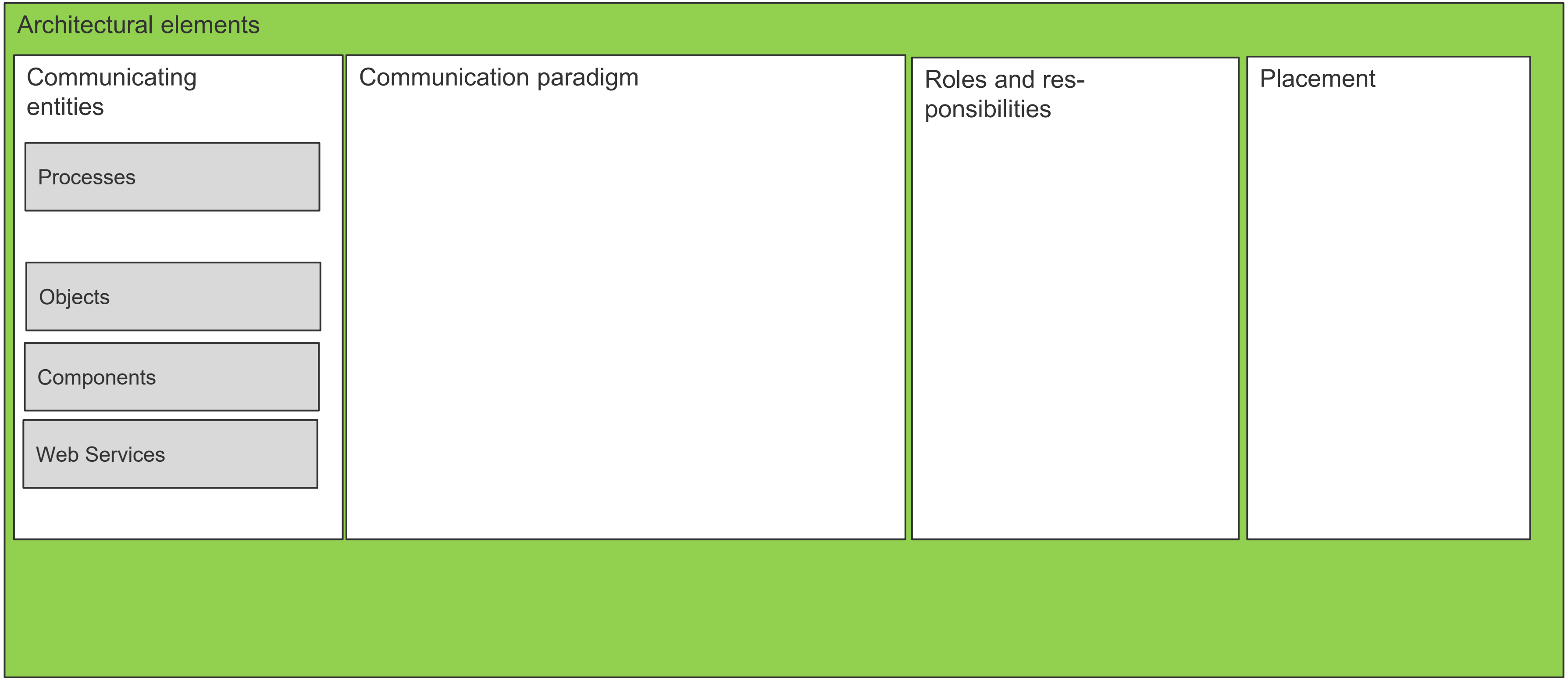
Components

- Resemble objects in that they offer problem-oriented abstractions, also accessed via interfaces
- Specify not only their interfaces but also the assumptions they make in terms of other components/interfaces that must be present for a component to fulfil its function

Web services

- A software application which is identified via Uniform Resource Identifier (URI)
- Supports direct interactions with other software agents

An Architectural Model of Distributed Systems



Architectural elements

Communicating entities

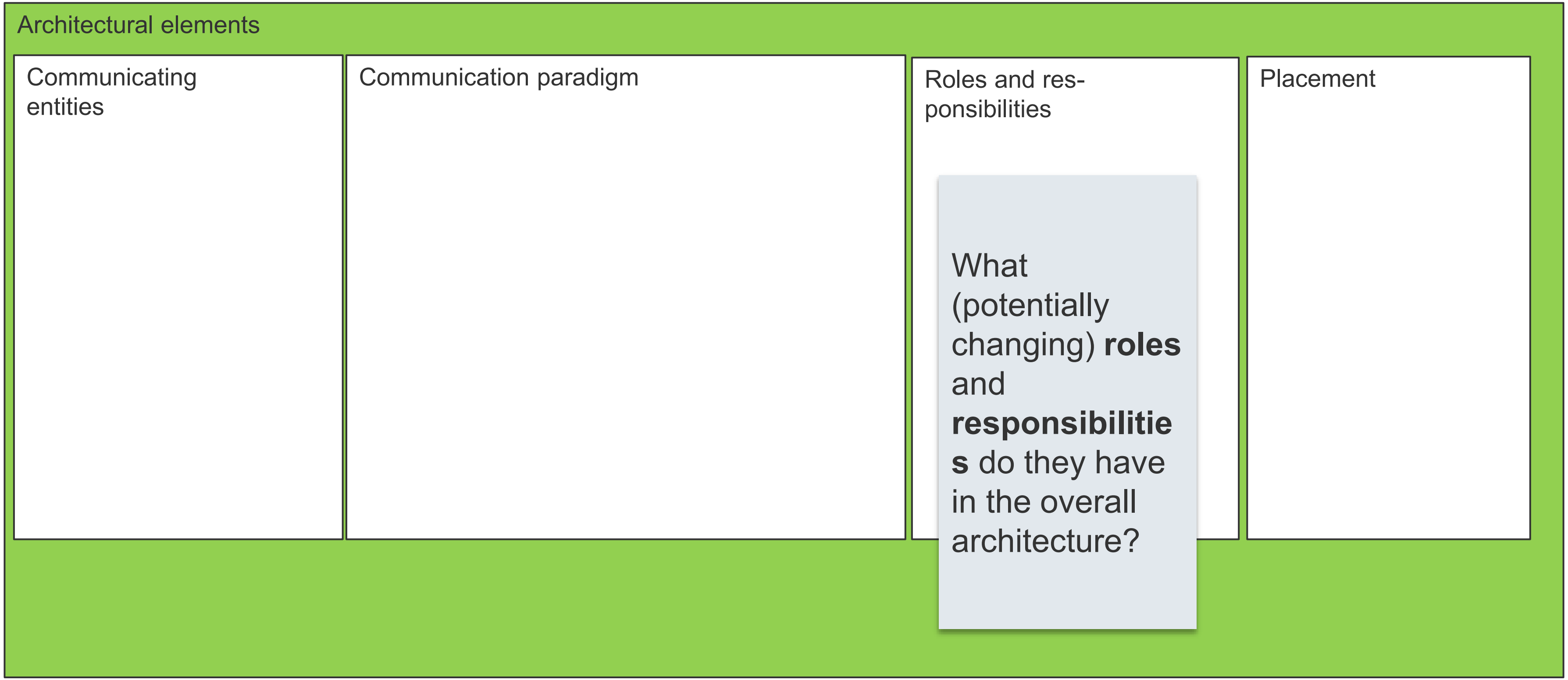
- Processes
- Objects
- Components
- Web Services

Communication paradigm

Roles and responsibilities

Placement

An Architectural Model of Distributed Systems



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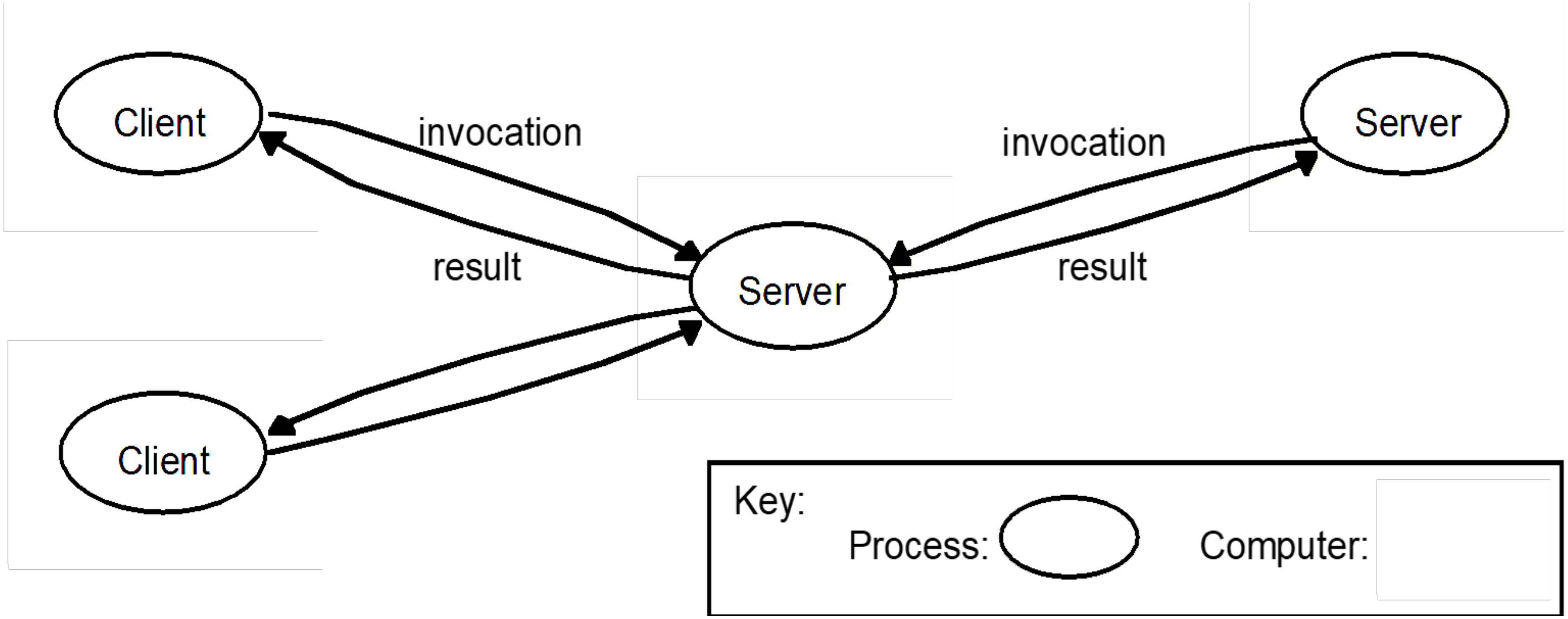
What (potentially changing) **roles** and **responsibilities** do they have in the overall architecture?

Architectural Styles

client-server

peer-to-peer

Client-Server

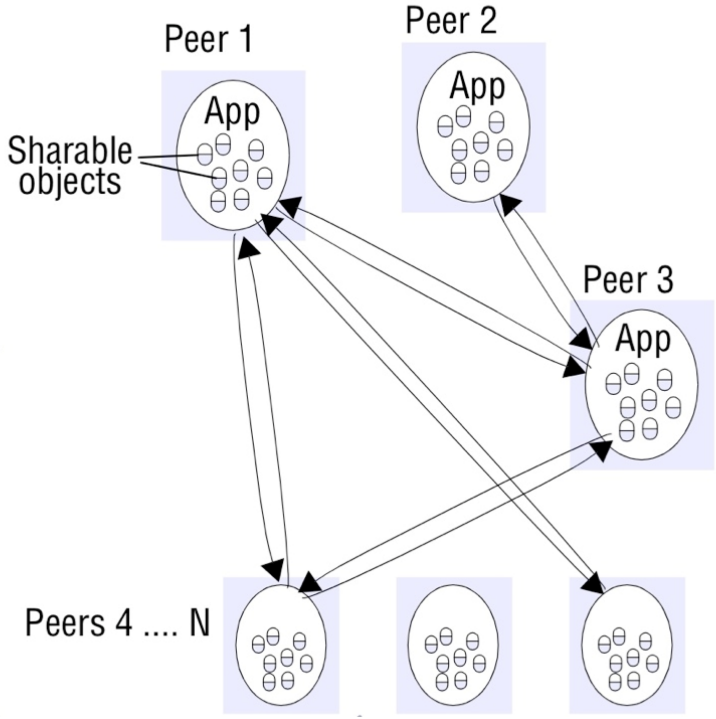


Fundamental Issue with Client-Server

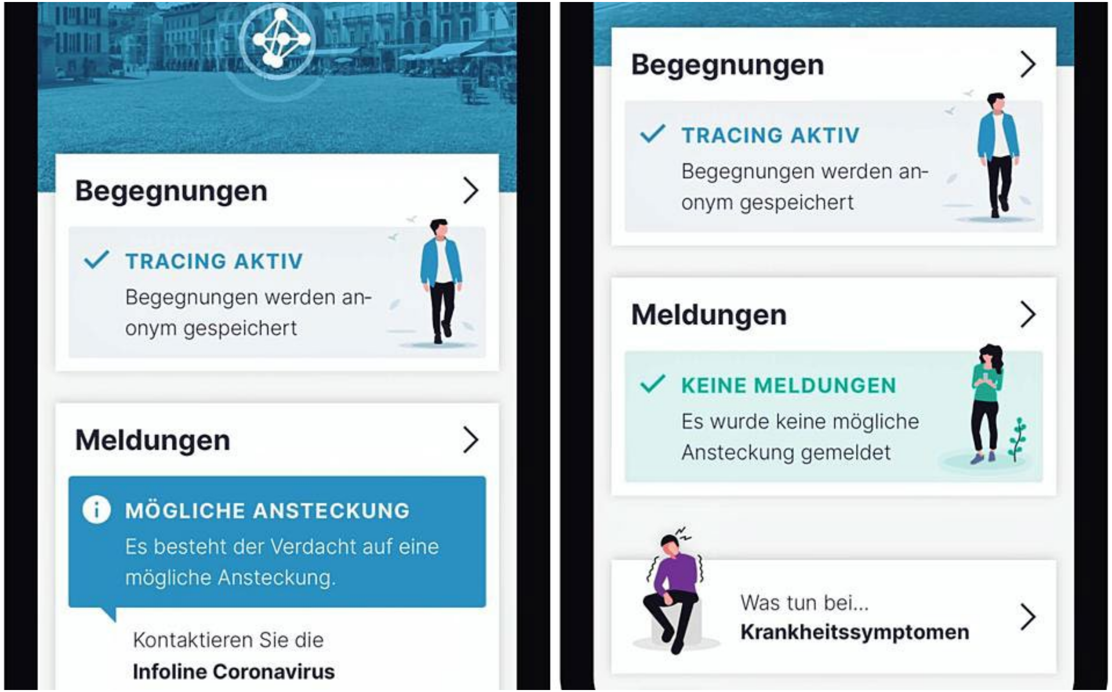
- Client-server offers a direct, relatively simple approach to the sharing of data and other resources, but it scales poorly.
- The centralization of service provision and management implied by placing a service at a single address does not scale well beyond the capacity of the computer that hosts the service and the bandwidth of its connections.
- Even though, there a several variations of the client-server architecture to respond to this problem but none of them really solve it.

Peer-to-Peer

- Is composed of a large number of peer processes running on separate computers
- All processes have client and server roles: servent
- Patterns of communication between them depends entirely on application requirements
- Need to place and retrieve individual computers is more complex then in client-server architecture



Example: Corona Tracing App



Begegnungen

✓ TRACING AKTIV

Begegnungen werden anonym gespeichert

Meldungen

MÖGLICHE ANSTECKUNG

Es besteht der Verdacht auf eine mögliche Ansteckung.

Kontaktieren Sie die **Infoline Coronavirus**

Begegnungen

✓ TRACING AKTIV

Begegnungen werden anonym gespeichert

Meldungen

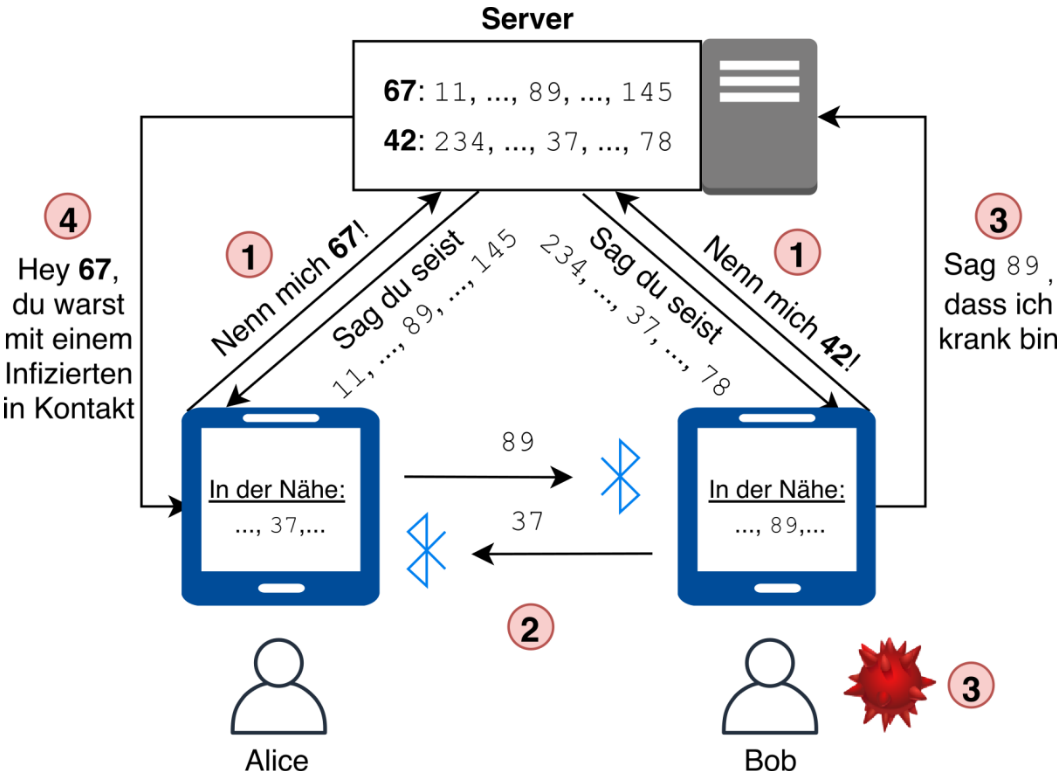
✓ KEINE MELDUNGEN

Es wurde keine mögliche Ansteckung gemeldet

Was tun bei... **Krankheitssymptomen**

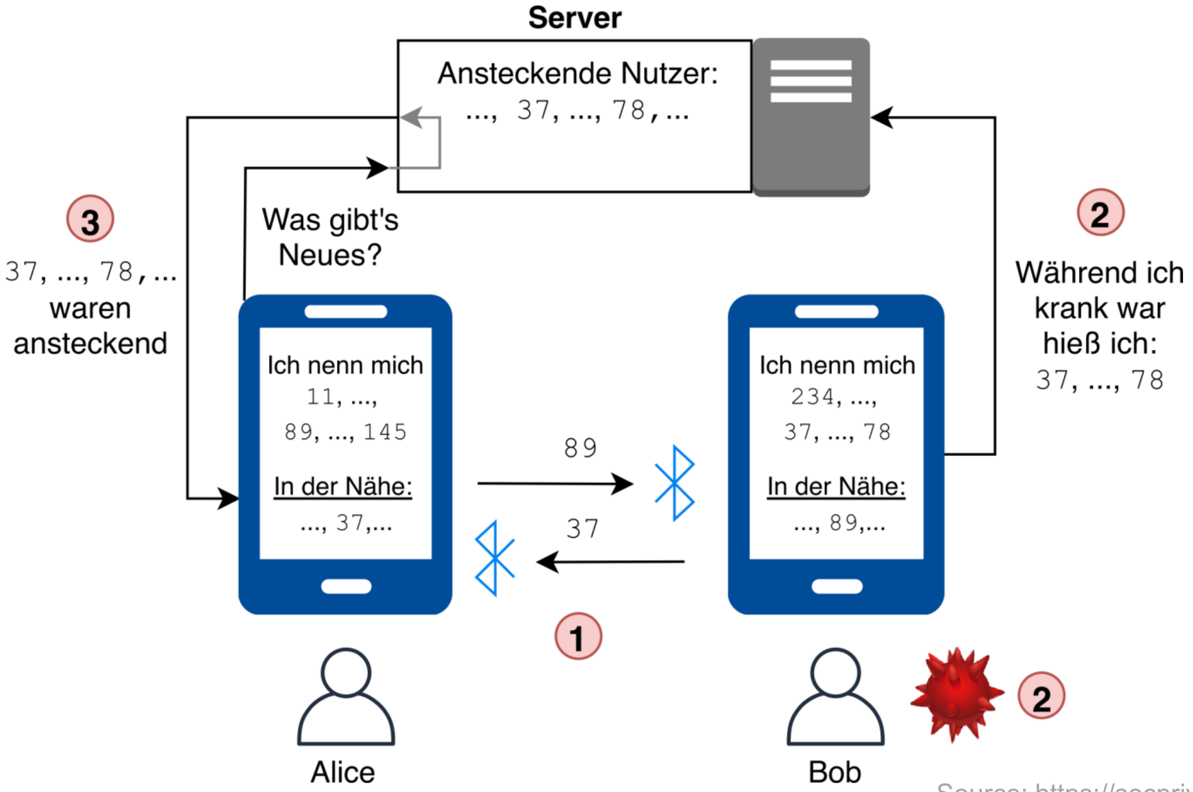
Source https://www.suedkurier.de/baden-wuerttemberg/warum-sind-die-schweizer-so-schnell-corona-tracing-app-der-eidgenossen-soll-bald-verfuegbar-sein;art417930,10518170

Example: Corona Tracing App (Central)



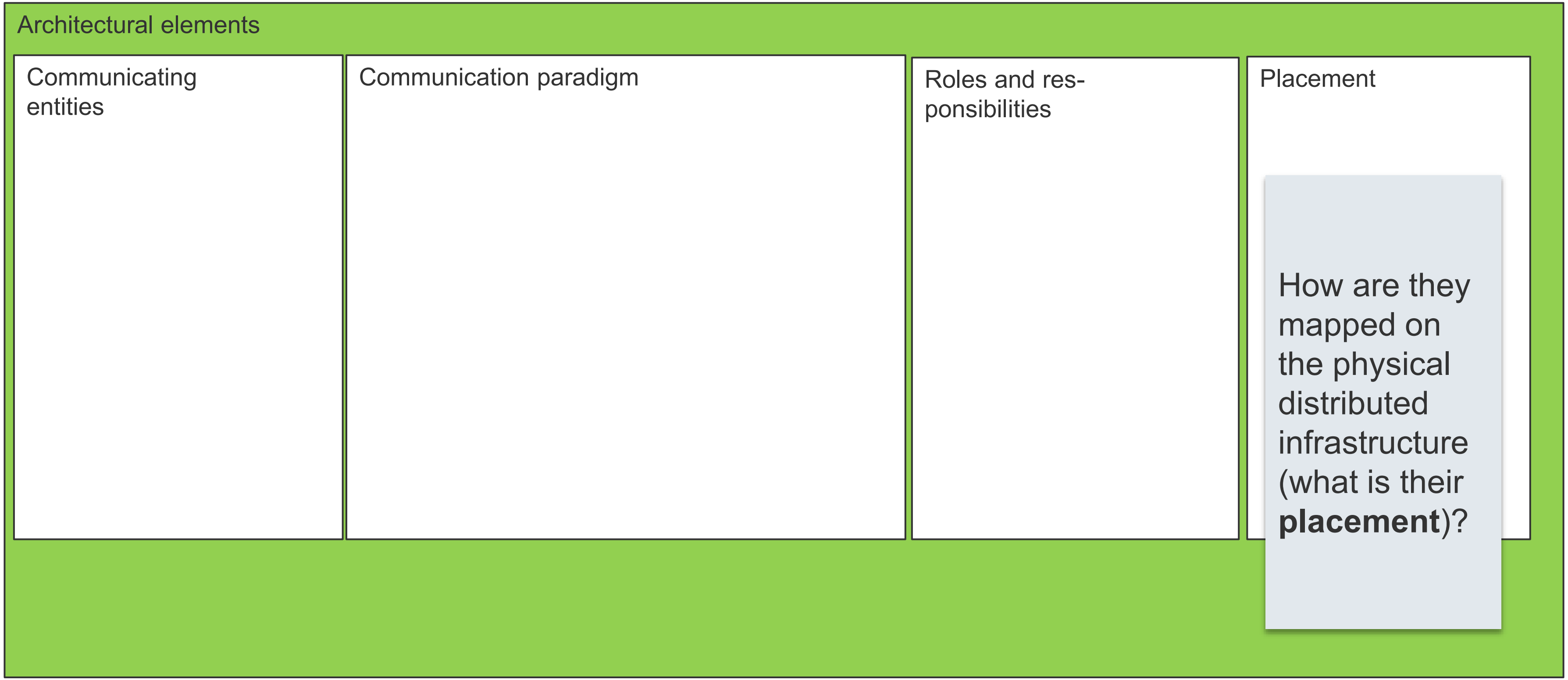
Source: https://secpriv.wien/blog/de/tracing-app/overview/

Example: Corona Tracing App (Decentral)



Source: https://secpriv.wien/blog/de/tracing-app/overview/

An Architectural Model of Distributed Systems



Architectural elements

Communicating entities

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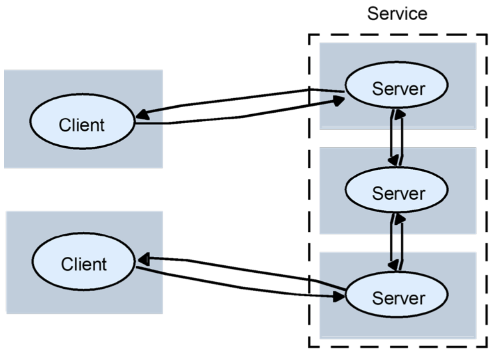
Roles and responsibilities

Placement

How are they mapped on the physical distributed infrastructure (what is their **placement**)?

Services provided by multiple servers



A service provided by multiple servers

Option 1

- Servers partition a set of objects in which the service is based and distribute them between themselves
- Example
  - In the Web in which each webserver manages its own set of resources
  - User can employ a browser to access a resource at any one of the servers

Option 2

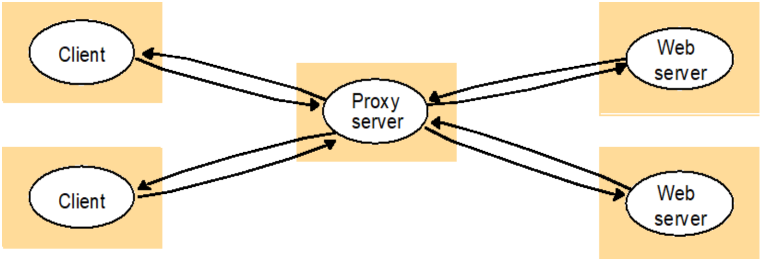
- Server maintain replicated copies of them on several hosts
- Example:
  - Network Information Service (NIS) used by computers on a LAN

Proxy server and caches

A cache is a store of recently used data objects that is closer to the objects themselves. Caches might be co-located with each client or may be located in a proxy server that can be shared by several clients.

How does it work?

- If a new object is received at a computer, it is added to the cache store, replacing some existing objects if necessary.



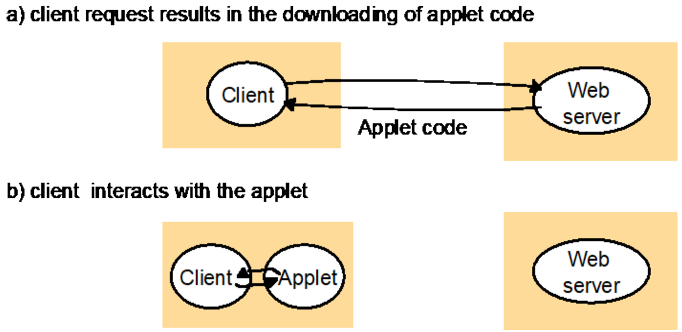
Web proxy server

- If an object is requested by a client process, the caching service checks the cache for an up-to-date copy.
- If copy is not available this copy is fetched.

Mobile code/agents

A typical well-known and widely-used example for **mobile code** are applets.

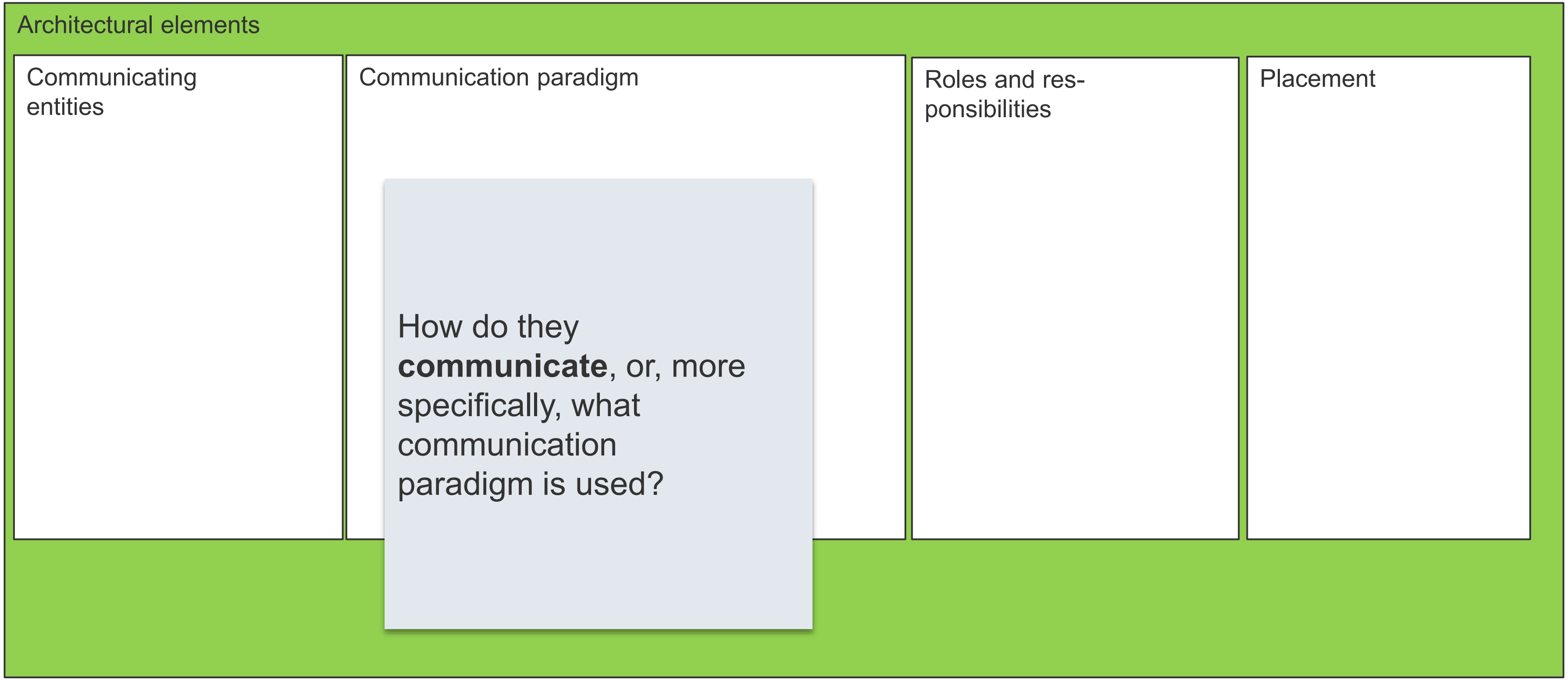
- Example: Javascript-widgets


a) client request results in the downloading of applet code
Client
Web server
Applet code
b) client interacts with the applet
Client
Applet
Web server

A **mobile agent** is a running program (both code and data) that travels from one computer to another in a network carrying out a task on someone’s behalf, e.g. collecting information.

- Example: web crawler

An Architectural Model of Distributed Systems



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How do they **communicate**, or, more specifically, what communication paradigm is used?

Types of Communication Paradigms

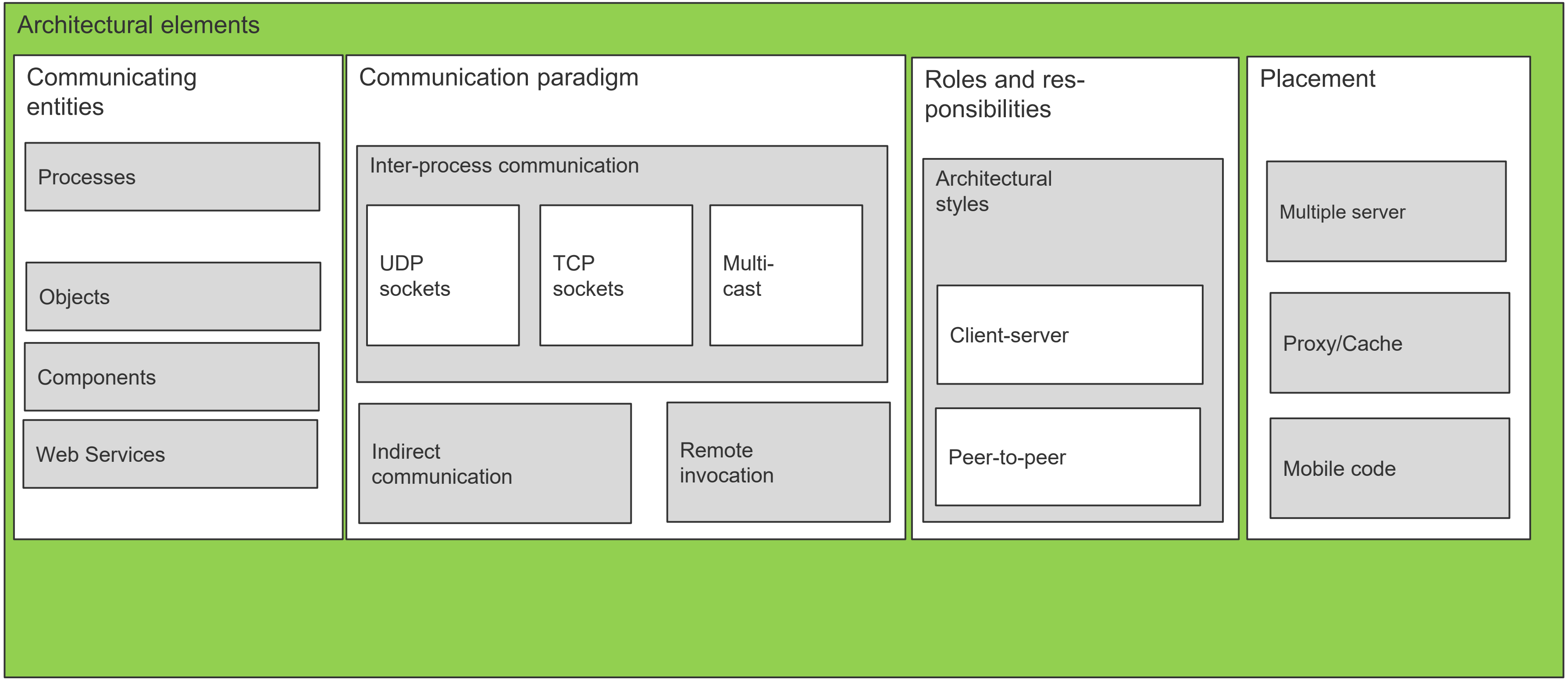
Interprocess communication

Remote invocation

Indirect communication

Next Lecture ☺

Summary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Processes
Objects
Components
Web Services
Communication paradigm
Inter-process communication
UDP sockets
TCP sockets
Multi-cast
Indirect communication
Remote invocation
Roles and res-ponsibilities
Architectural styles
Client-server
Peer-to-peer
Placement
Multiple server
Proxy/Cache
Mobile code

References

- Dennis, B. Haley Wixom, D. Tegarden: *Systems Analysis and Design with UML Version 2.0: An Object-Oriented Approach*, John Wiley & Sons, 2004
- George Coulouris, Jean Dollimore, Tim Kindberg: *Distributed Systems: Concepts and Design*. 4th edition, Addison Wesley, 2005
- Frank Buschmann, Kevlin Henney, Douglas C. Schmidt: *Pattern-Oriented Software Architecture Volume 4: A Pattern Language for Distributed Computing*, Wiley, 2007

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Communication Paradigms in Distributed Systems

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