AI: Internet Computing

Lecture 1 — Introduction

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- PhD in 2010, Master's degree (diploma) in Computer Science, Technical University of Munich (TUM).
- Visiting faculty member at Harvard University.
- Spokesperson of the BISE division in the German Informatics Society (GI).
- Research work has been appreciated numerous times and is featured in a variety of media outlets.
- Several editorial responsibilities | research and executive education for a number of organizations | mentor of several start-ups.

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DFG Deutsche Forschungsgemeinschaft
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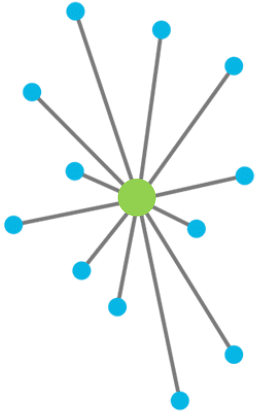
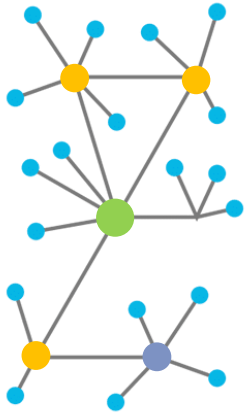
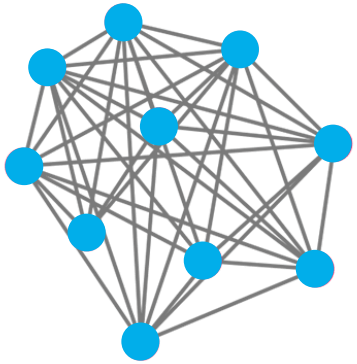
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES
RSF Russian Science Foundation
Federal Ministry of Education and Research
Federal Ministry for Economic Affairs and Energy
Federal Ministry of Justice and Consumer Protection

Internet Computing
Distributed Systems vs. Decentralized Systems







Centralized Network
(e.g., Web-Services)

Partially
(De-)Centralized Network
(e.g., Domain Name Systems)

Decentralized Networks
(e.g., Peer-to-Peer Networks)

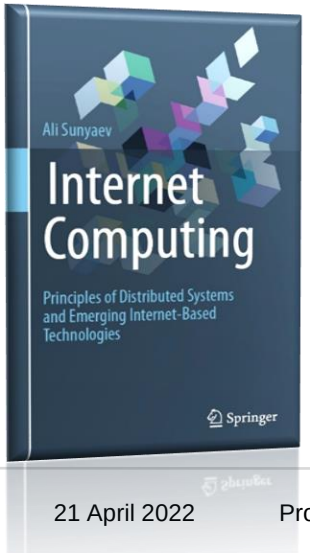
Degree of Decentralization

Client Server (3rd Level) Server (2nd Level) Server (1st Level)

Figures align with Baran P. (1964) On Distributed Communications Networks. IEEE Transactions on Communications Systems 12(1):1–9.

Learning Goals of the Lecture

In this course you will learn key architectures and technologies for the design and implementation of **Internet Computing** applications.



Textbook: Internet Computing

- Principles of Distributed Systems and Emerging Internet-Based Technologies
- Introduces students and young professionals to the fundamentals of contemporary, emerging and future technologies and services in Internet computing

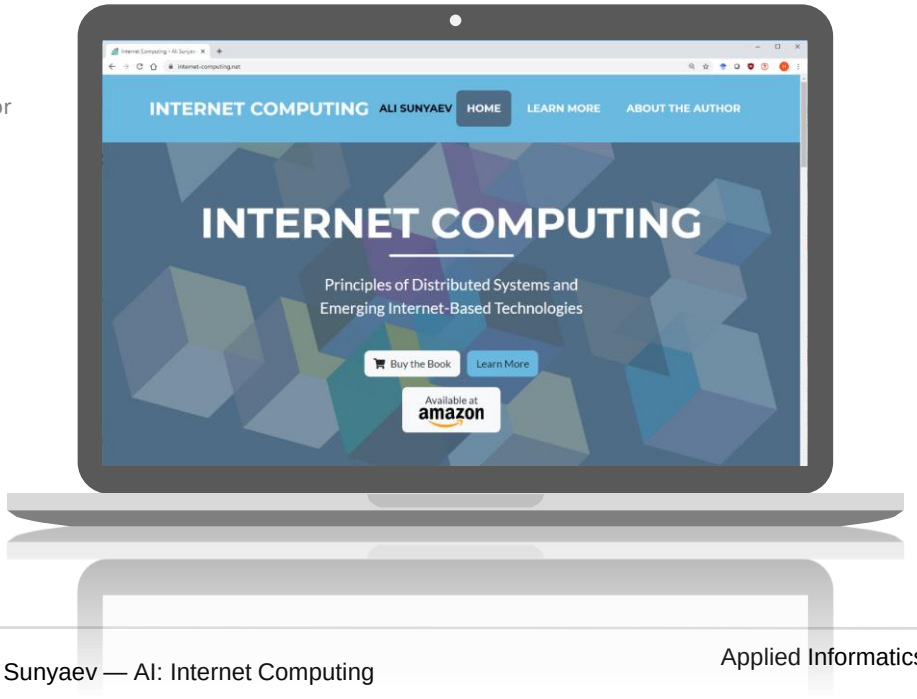
Textbook: Internet Computing

Learning goals and summary for each chapter

Website: www.internet-computing.net

Available online

A wealth of examples for every chapter



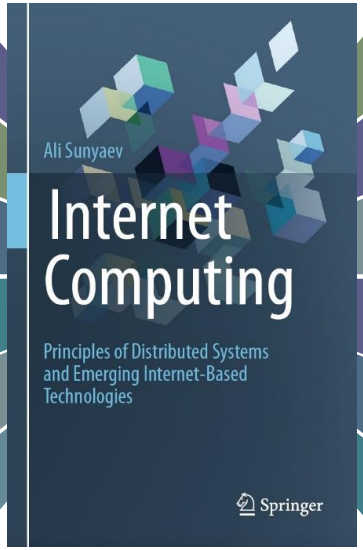
12 Chapters

Recommendations for further readings at the end of each chapter

Questions for checking students' comprehension at the end of each chapter

Textbook: Internet Computing—Chapters

1. Introduction to Internet Computing
2. Information Systems Architecture
3. Design of Good Information Systems Architectures
4. Internet Architectures
5. Middleware
6. Web Services



7. Cloud Computing
8. Fog and Edge Computing
9. Distributed Ledger Technology
10. The Internet of Things
11. Critical Information Infrastructures
12. Emerging Technologies

Textbook: Internet Computing—Chapters

01

Introduction to Internet Computing

- A Brief History of the Internet
- Defining Internet Computing
- Distributed Information Systems for Internet Computing
- Application Examples of Internet Computing

02

Information Systems Architecture

- Defining Information Systems Architecture
- The Principles of Information Systems Architecture
- Architectural Views
- Architectural Patterns

03

Design of Good Information Systems Architectures

- Architecture Design
- IS Architectures' Quality
- The Information Systems Architecture Design Process

04

Internet Architectures

- History of the Internet
- Today's Internet Network Infrastructure
- The Internet Protocol
- Content Delivery Networks
- Emerging Internet Network Architecture

Textbook: Internet Computing—Chapters

05

Middleware

- Introduction to Middleware
- Remote Procedure Call
- Middleware Categories

06

Web Services

- Introduction to Web Services
- Basic Web Technologies
- Web Service Architectures

07

Cloud Computing

- An Introduction to Cloud Computing
- Essentials to the Provision of Cloud Services
- Chances and Challenges of Cloud Computing
- Security and Data Protection in Cloud Environments

08

Fog and Edge Computing

- Fog and Edge Computing Fundamentals
- Challenges and Opportunities of Fog and Edge Computing
- Fog and Edge Computing in Practice

Textbook: Internet Computing—Chapters

09

Distributed Ledger Technology

- Background of Distributed Ledger Technology
- Technical Foundation
- The Bitcoin Blockchain
- Smart Contracts
- Applications of Distributed Ledger Technology

10

The Internet of Things

- Introduction of the Internet of Things
- The Internet of Things: Technologies and Architectures
- Internet of Things Applications
- Challenges and the Future of the Internet of Things

11

Critical Information Infrastructures

- Foundations of Critical Information Infrastructures
- Properties of Critical Information Infrastructures
- Functions of Critical Information Infrastructures
- Operation of Critical Information Infrastructures

12

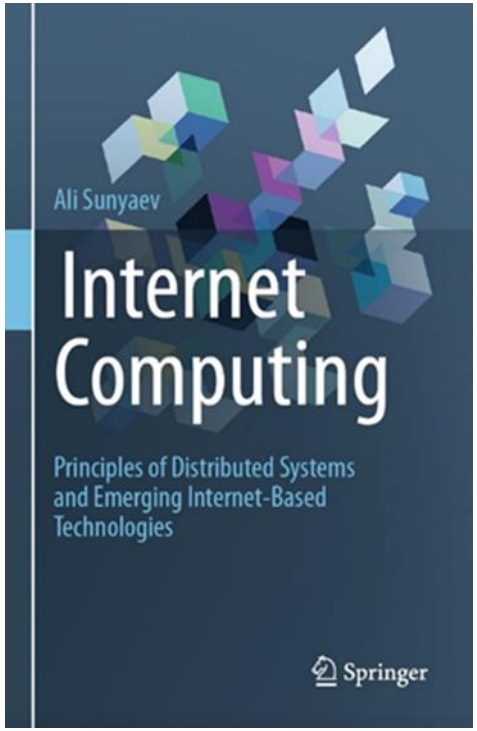
Emerging Technologies

- Emergence and Emerging Technology
- Immersive Technologies
- Virtual Assistant
- Artificial Intelligence

Learning Goals of the Lecture

- Know the most important historical developments of the Internet
- Understand the definitions of information systems and distributed systems
- Get to know examples of Internet-based applications
- Get to know challenges of distributed information systems

Reference to the Teaching Material Provided



Chapter 1
Introduction to Internet Computing

Abstract
Over the past decades, the Internet has fundamentally influenced almost all areas of our everyday lives. It has profoundly changed the ways in which we communicate, gather information, and consume media, and has led to the emergence of Internet companies that are based on fundamentally new business models. This chapter introduces Internet computing as a scientific field that is concerned with applications provided via the Internet, the underlying architectures and technologies necessary to build such applications, and systemic matters that inform the design of such applications. Based on these foundations, this chapter outlines this book's structure. In addition to defining Internet computing and briefly presenting the chapters, an overview of the historical background and development of the Internet is provided. This chapter also introduces the concepts of information systems (IS) and distributed systems as important related scientific fields that shaped the ways Internet-based applications have been designed. To round off this introduction, several common Internet-based applications are presented.

The Learning Objectives of this Chapter
This chapter's main learning objective is to provide a basic understanding of the concept of Internet computing. This chapter also gives readers a brief impression of the major contents of this book and how it is structured. After having read this

Introduction

Image source: [William (Bill) H. Gates, founder, technology advisor of Microsoft Corporation visits The Department of Energy on October 8, 2013] by United States Department of Energy. 2013. Public Domain.

The History of the Internet

- Today, we can hardly imagine a life without the Internet
- College students spend 3 to 6 hours per day online (Saikia et al., 2019)
- Most important activities: direct communication, social networking, information gathering, media streaming, and gaming
- The Internet has become the basis for various innovative business models

The History of the Internet

- The Internet, as we know it today, has not existed for very long

- The history of the Internet can be divided into three main phases:
  1. Development of technological fundamentals from the mid-1960s
  2. Growth and internationalization of the Internet from the mid-1970s
  3. Commercialization of the Internet from the early 1990s

The History of the Internet: Development of Technological Fundamentals

- **4th of October, 1957:** The USSR is the first state to succeed in launching an artificial earth satellite called “Sputnik 1” into the orbit
- **7th of February, 1958:** The USA founds the Advanced Research Project Agency (ARPA)
  - Purpose: executing research projects to expand the frontiers of technology and science
  - J.C.R. Licklider becomes the first head of the Information Processing Techniques Office
- **From 1960s:** Paradigm shift from circuit-oriented to packet switching concepts

Image source: [Sputnik 1 Satellite] by Van ravenswaay, Detlef. May 8th 2013. Public Domain.

The History of the Internet: Development of Technological Fundamentals

- **1967:** The ARPANET project starts
  - Stanford Research Institute (SRI) writes the specifications of the network
  - Network measurement system is prepared by University of California, Los Angeles (UCLA)
  - Bolt, Beranek and Newman (BBN) develops packet switching techniques

- **Fall of 1969:** The first four computers were connected at UCLA, SRI, the University of California at Santa Barbara (UCSB), and the University of Utah

- **29th of October, 1969:** ”I” and “O” are the first successful messages that UCLA sends to SRI

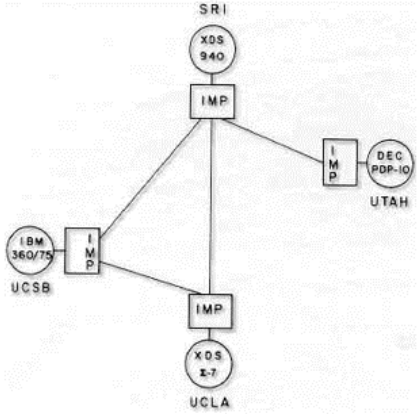


Image source: [The initial four-node ARPANET (1969)] by Kleinrock, Leonard. August 2010. Public Domain.

The History of the Internet: Development of Technological Fundamentals

- **October 1972:** First public presentation of the ARPANET at the International Computer Communications Conference (ICCC)
  - Connected to 40 machines all over the US
  - Interactive chess games and the simulation of an air traffic control system
- **December 1974:** The first version of the internetwork Transmission Control Protocol/ Internet Protocol (TCP/IP) is presented
- **From early 1980s:** Several other computer networks are being created all over the world
- **3rd of August, 1984:** The first email in Germany is received at KIT
- **1986:** NSFNET is created by the National Science Foundation (NSF) and interlinked with the ARPANET
- **1990:** ARPANET is decommissioned

Image source: [Logo NSF] by National Science Foundation. n.d. Public Domain.

The History of the Internet: Development of Technological Fundamentals

- **From mid-1980s:** Internet Service Providers (ISPs) are formed to provide network access to commercial customers
- **1990:** Tim Berners-Lee develops the fundamental technologies for the World Wide Web
- **1992:** U.S. Congress passed the Scientific and Advanced-Technology Act, 42 U.S.C. § 1862(g)
  - Allows NSFNET to support access to computer networks which were not used exclusively for research and educational purposes
- **1999:** Darcy DiNucci coins the term Web 2.0
- **2000:** The dot-com bubble ends with a real stock market crash

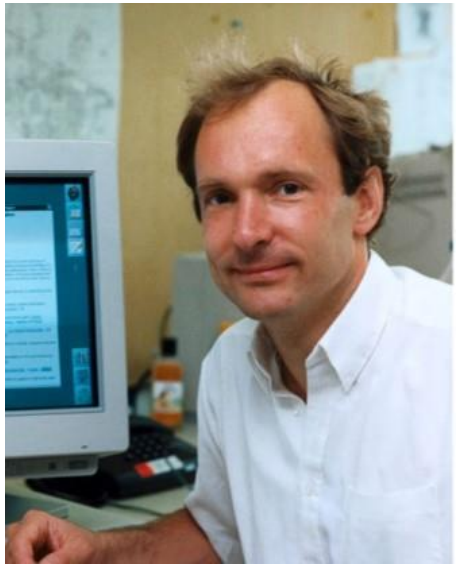
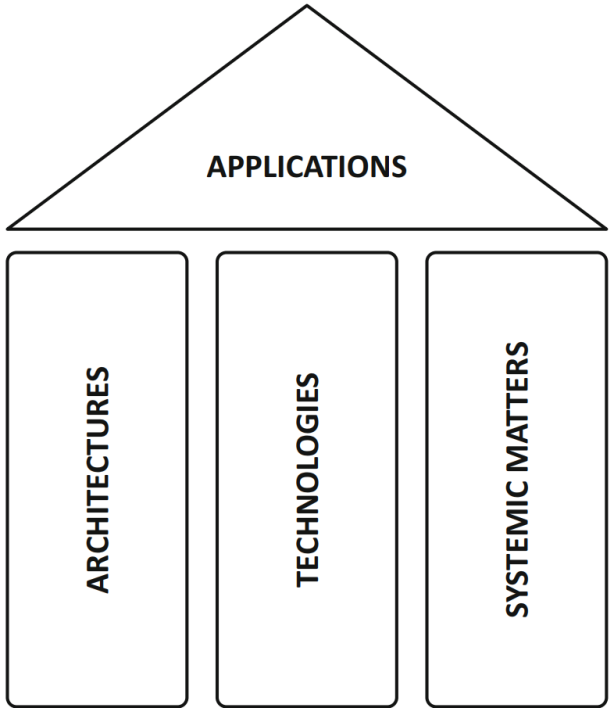


Image source: [Tim Berners-Lee] by Cern, July 10th 1994. Licensed © CERN.

Internet Computing

Definition

Internet computing is concerned with the *applications* provided on the Internet, the *architectures* and *technologies* used in applications on the Internet, and the *systemic matters* that shape the design of such applications. Internet computing encompasses all applications irrespective of whether they are built for the general public (e.g., social network services) or solely used within a single organization (e.g., enterprise-resource-planning systems) or a closed group of organizations (e.g., supply-chain management systems).



Internet Applications

- **Internet applications** can come in many different forms and manifestations
  - Designed for the general public vs. specific organizations
  - Private use vs. commercial use
  - Open-source vs. proprietary

- Due to the inherent distributed nature of the Internet infrastructure, nearly all Internet computing applications are **distributed information systems**

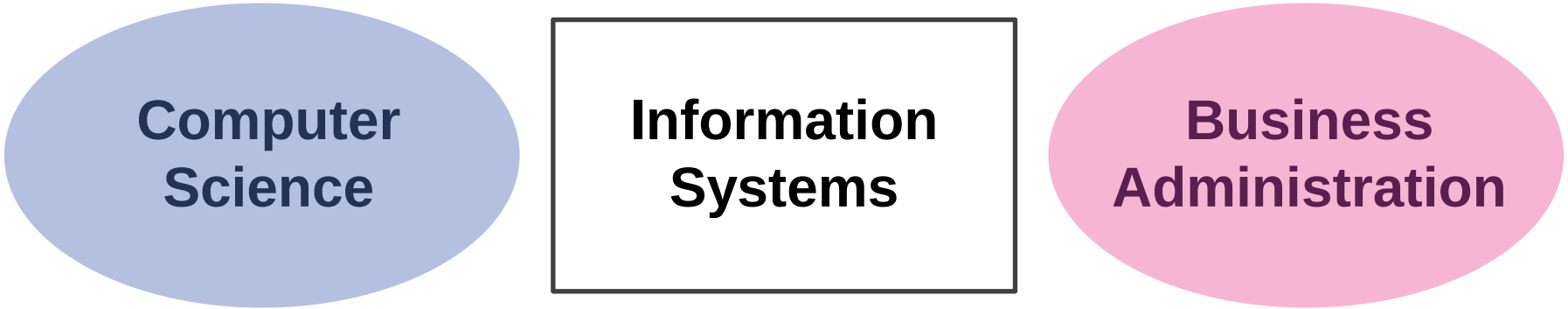
Information Systems

Definition

Information systems are interrelated components working together to collect, process, store, and disseminate information to support decision making, coordination, control, analysis, and visualization in an organization.

Kenneth C. Laudon, Jane P. Laudon

Where CS Meets BA…



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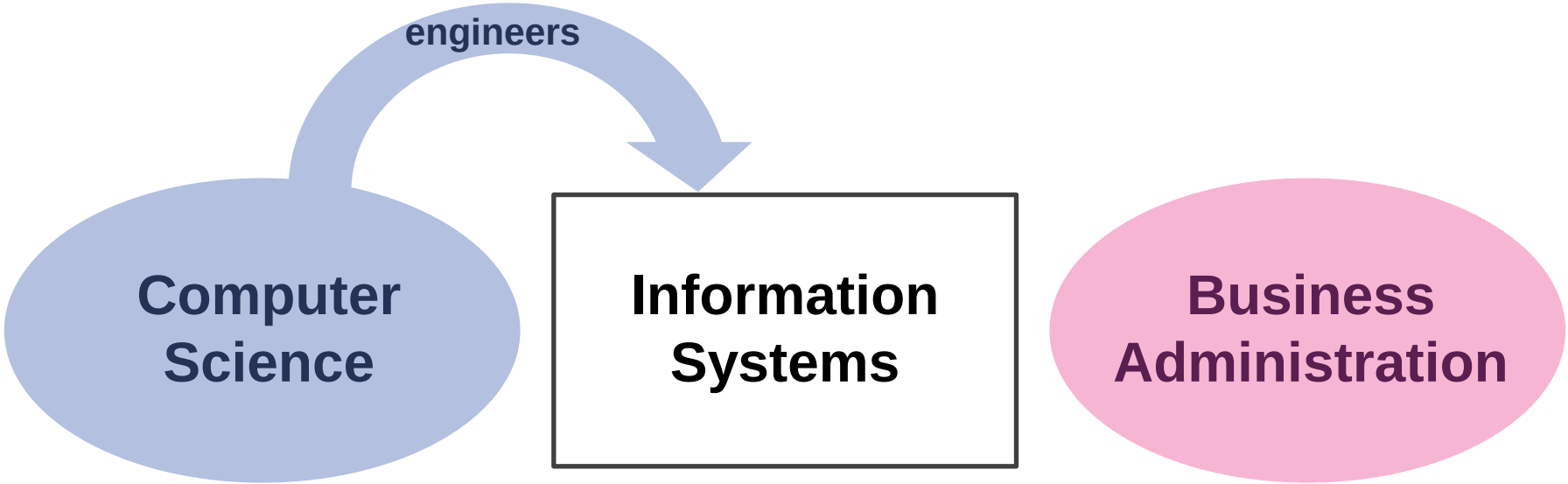

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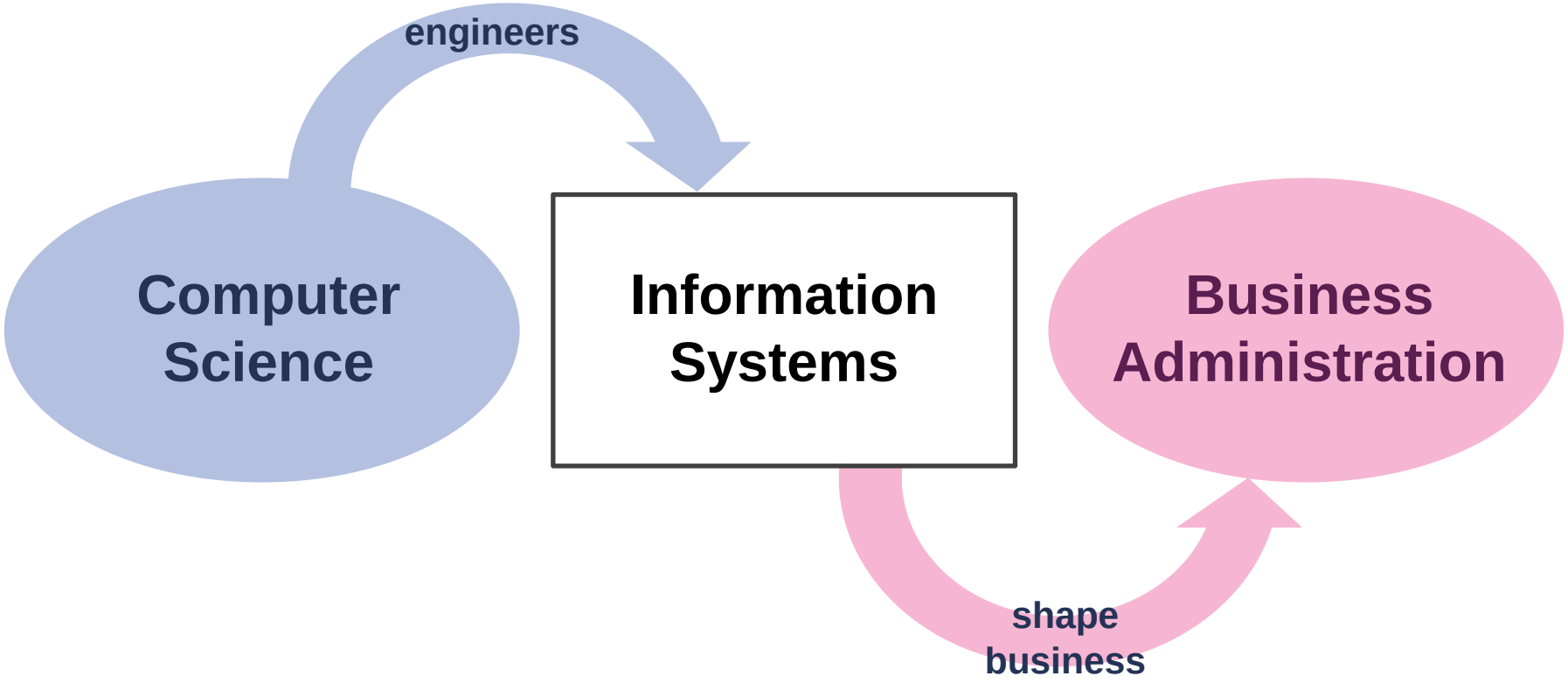

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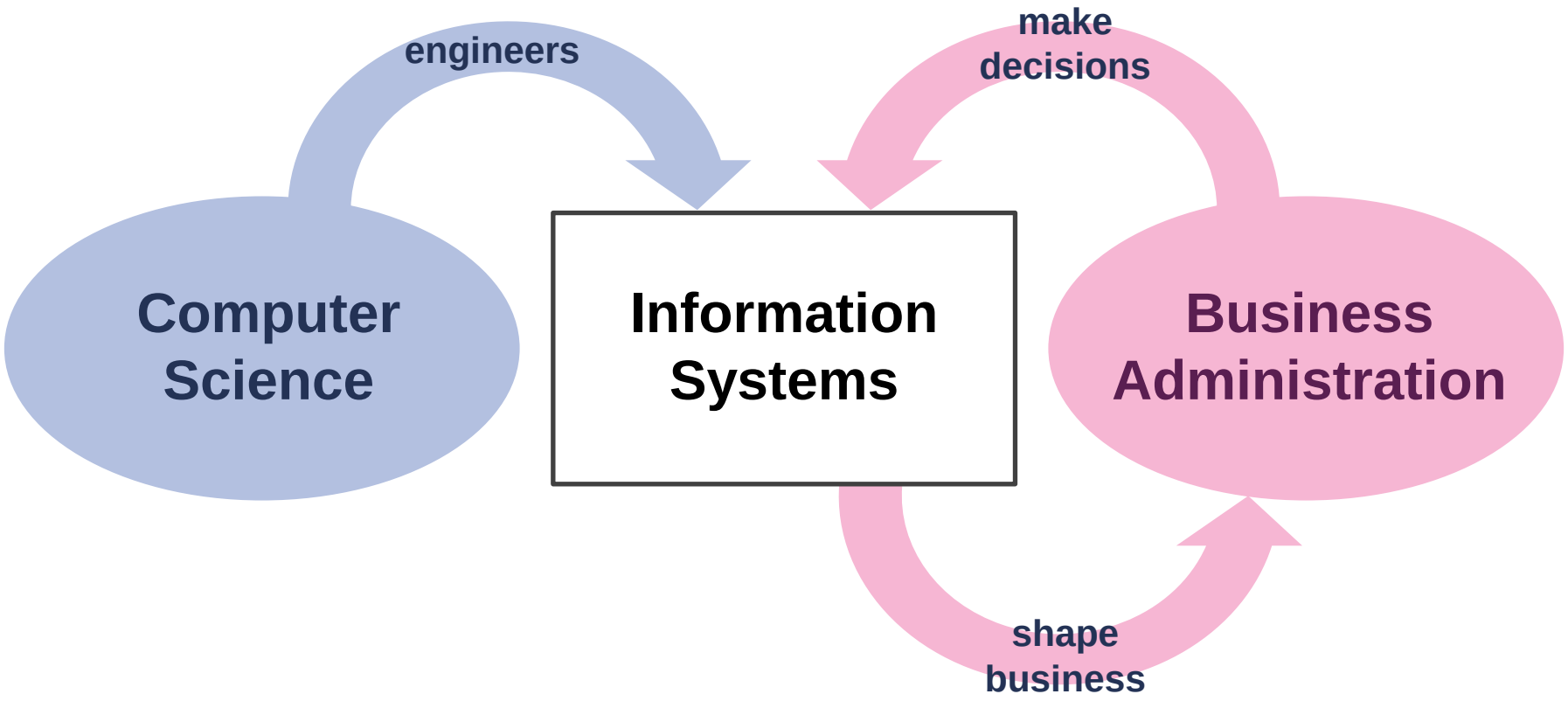

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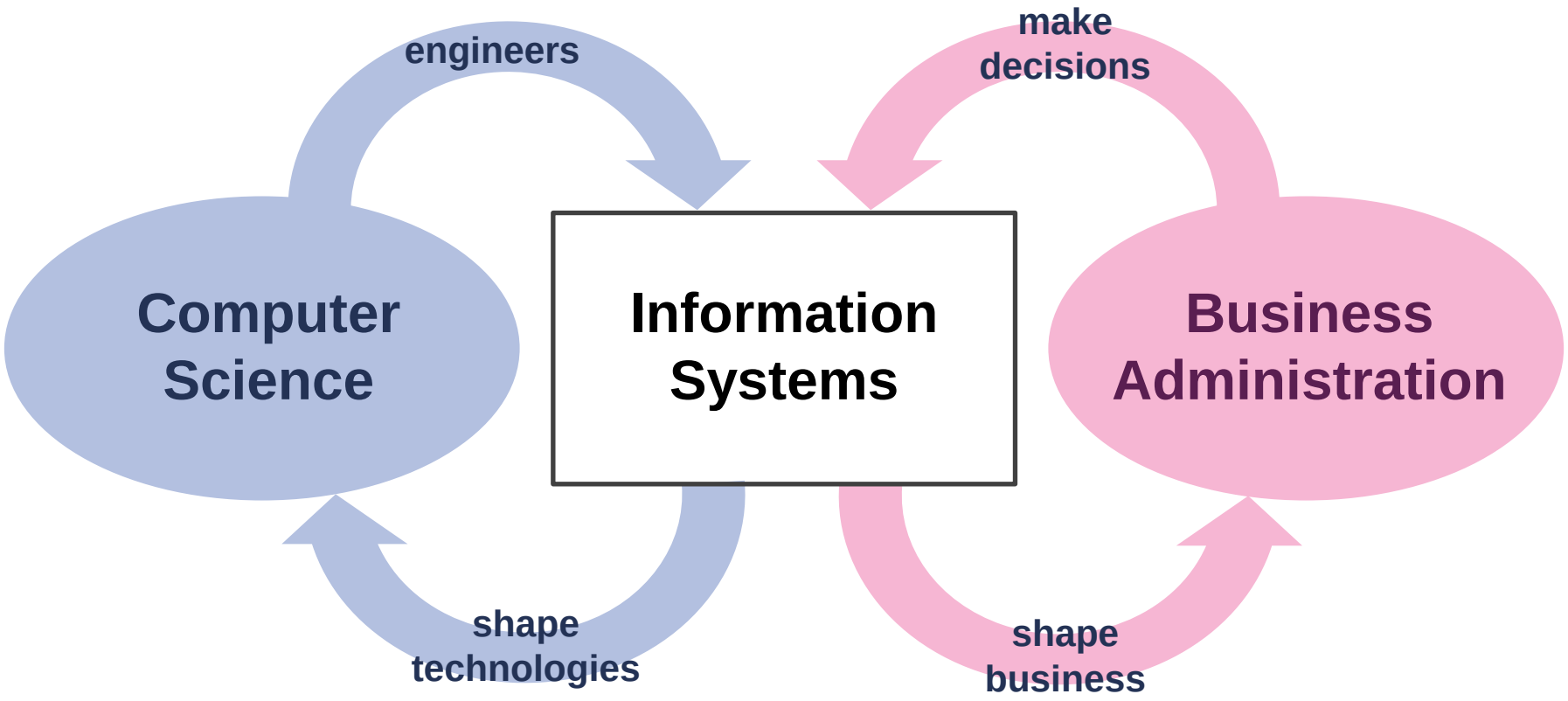

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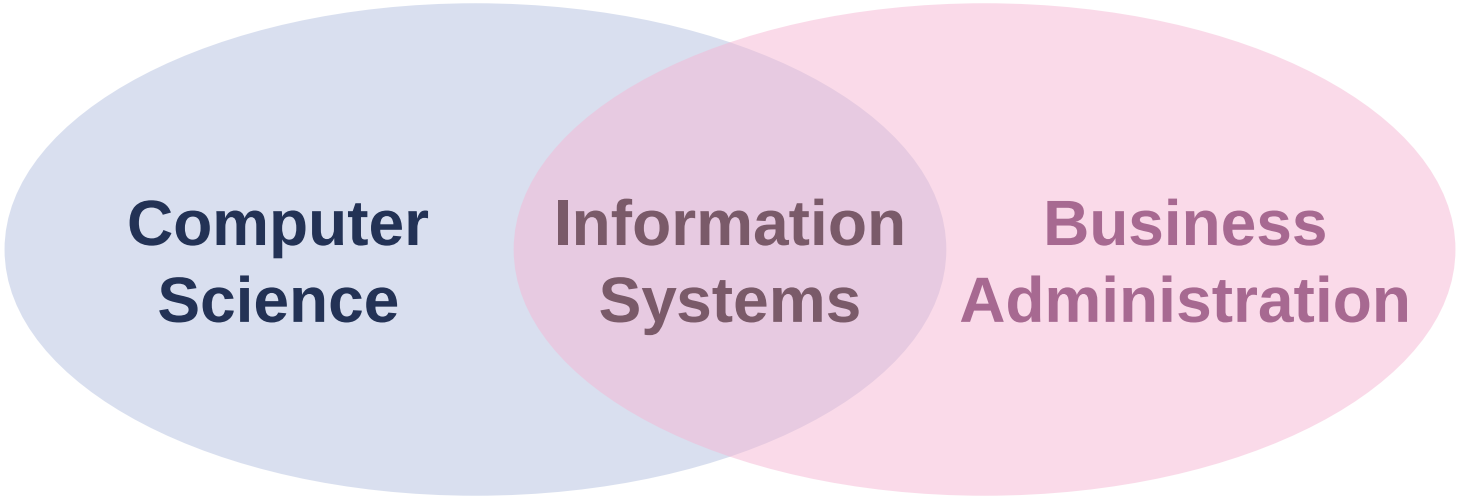

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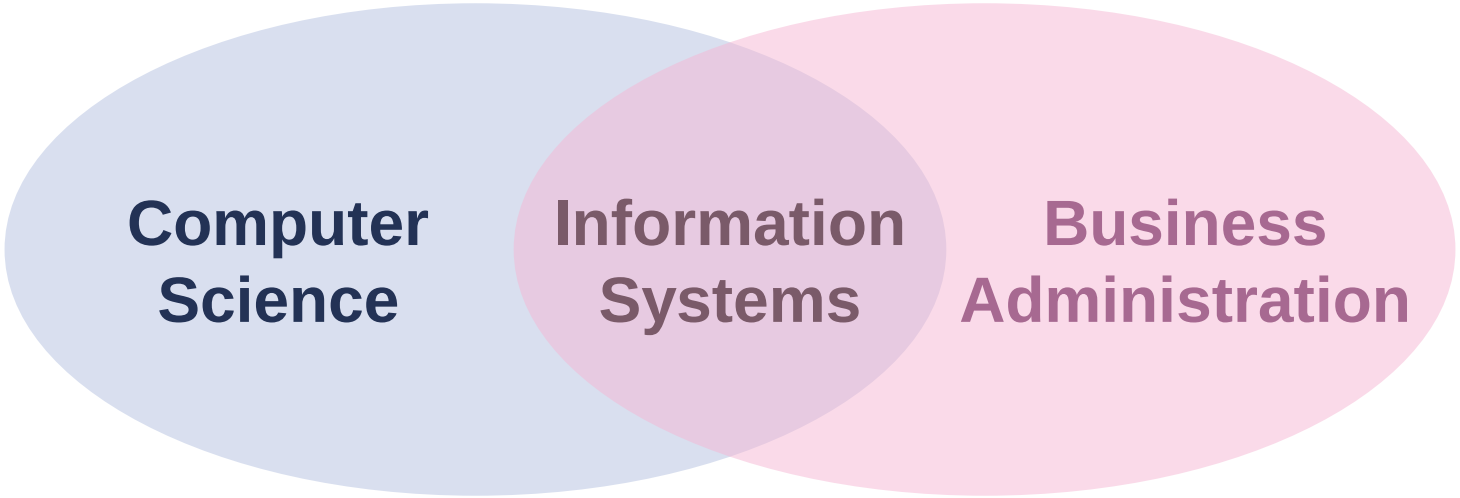


We will take a **computer science view**:
design principles and Internet technologies

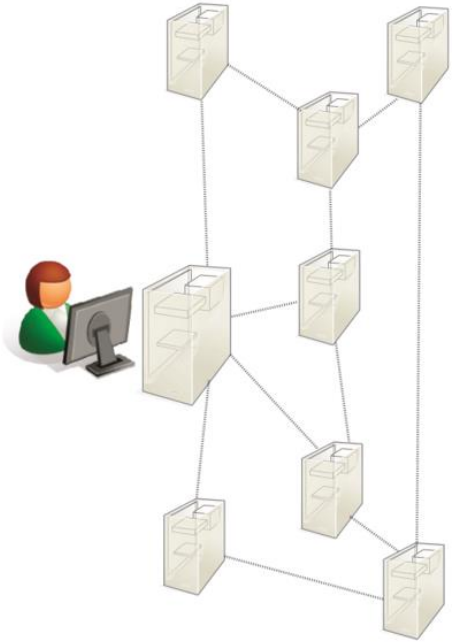
Distributed Information Systems

Distributed Systems

- In previous courses you have learned how **computer systems** work, how **algorithms** are designed and how **software** is engineered

Distributed Systems

- In previous courses you have learned how **computer systems** work, how **algorithms** are designed and how **software** is engineered
- Most information systems are **distributed systems**



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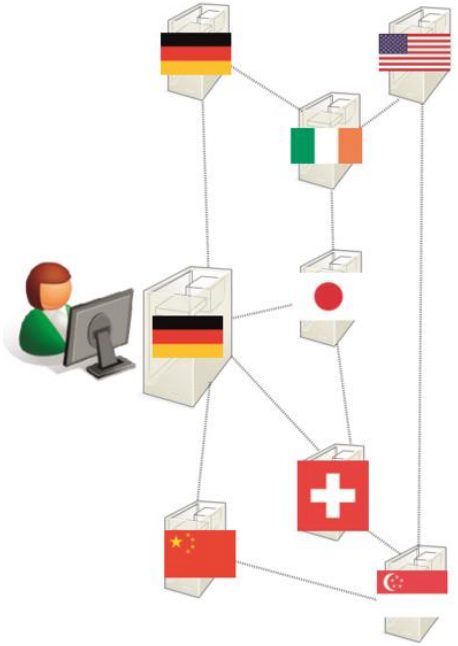

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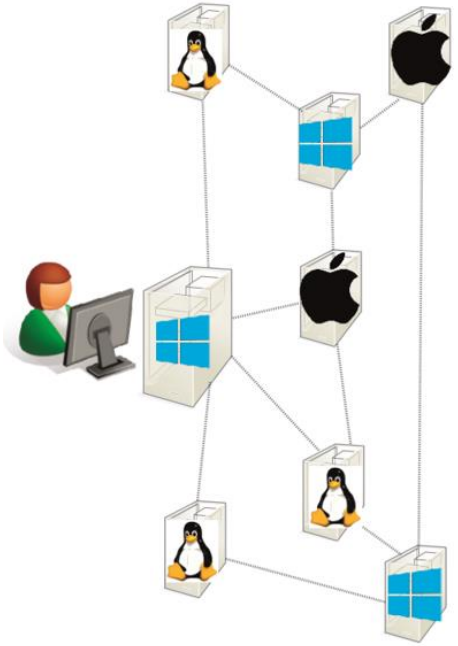

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Definition

A **distributed system** is a collection of independent computers that appears to its users as a single coherent system.

Andrew Tanenbaum, Maarten van Steen

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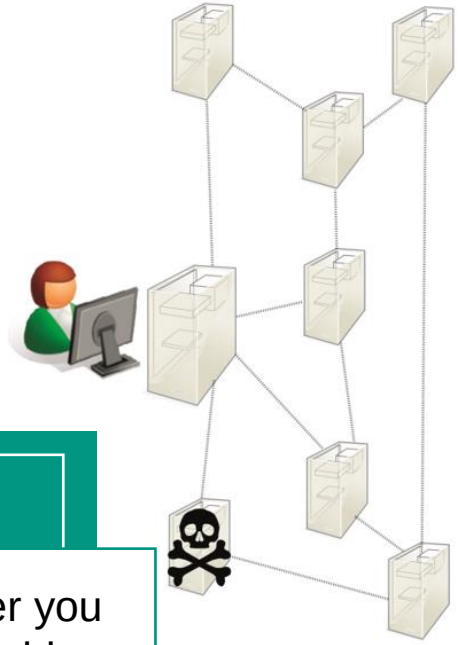

Definition

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

Distributed Information Systems

- Most Internet applications are **distributed information systems**
  - Distributed storage and retrieval of data
  - Distributed processing of information geographically
  - Distributed users

Distributed Information Systems

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- **Distributed information systems** used in ...
  - Enterprises (CRM, ERP, data warehouses, expert systems, etc.)
  - Search engines and digital libraries
  - E-commerce

eCommerce: Amazon

Image source: Anderson, T. (Writer), & Lawrence L. (Director). (1999, February 3). Nerd of the Amazon/The Case Against Jake Beard/Classic (Season 1, Episode 4) [TV series episode]. In Hewitt Don, Fager Jeff, Owens Bill (Executive Producers), *60 Minutes II*. CBS News Production.

eCommerce: Amazon

- **Functionality**
  - Largest online retail store
  - Provision of payment services and sales platform
  - Cloud storage and computing services
  - Audio and video streaming services

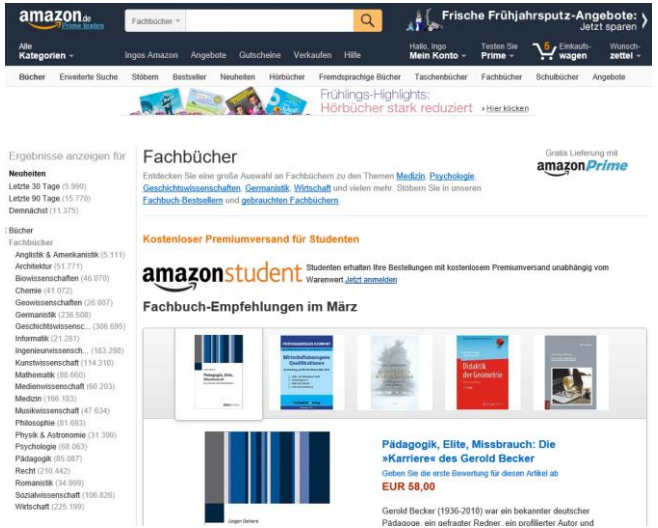

Image source: amazon.de

eCommerce: Amazon

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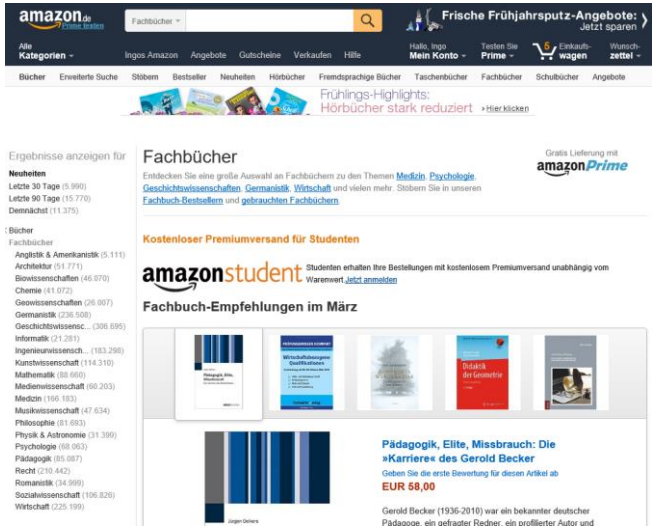
Adoption and Impact

- > 150 mn active amazon prime accounts
- > 60% of units sold by third-parties
- > $125 bn revenue in 4th quarter 2020



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- **Backend Technology**
  - Hundreds of distributed services
  - Mix of C++, Perl and JAVA code

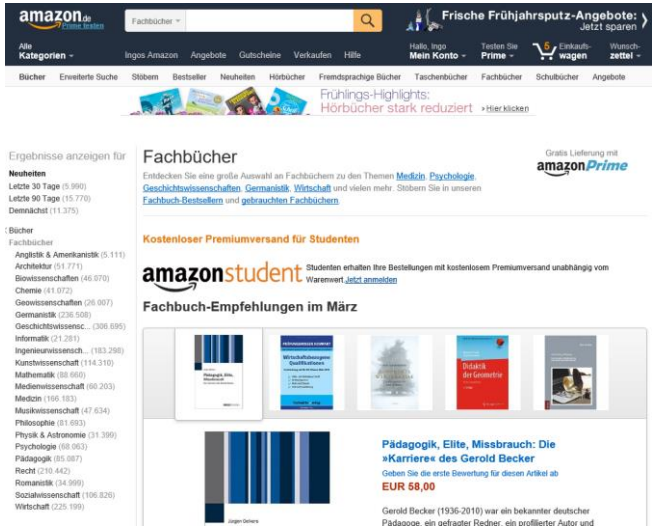

Image source: amazon.de

Enterprise Systems: Salesforce

- **Functionality**
  - Provides Cloud Computing solutions for enterprises
  - Specialized on provision of customer relation management software
  - Contact and task management, support of HR workflows, internal feedback, etc.
  - Biggest competitor of SAP

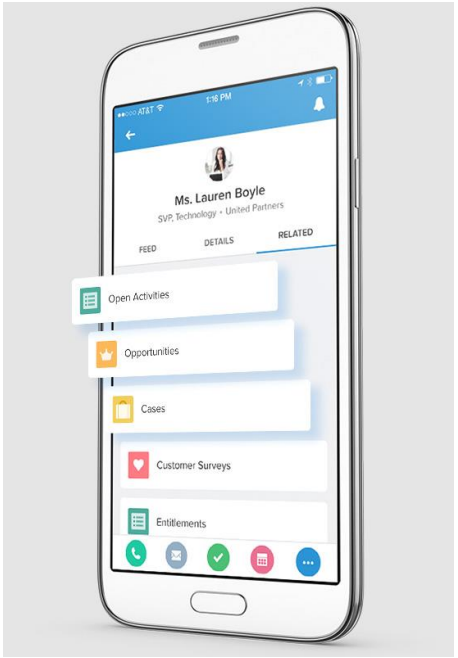

Image source: salesforce.com

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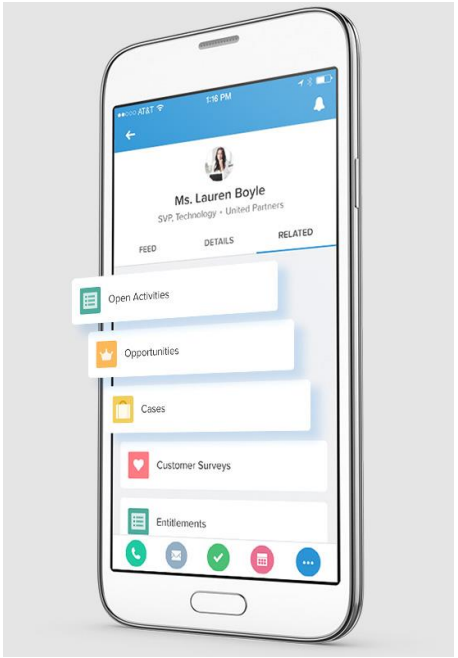
Adoption and Impact

- > 150k business customers
- > 49k employees
- > USD 17.1 bn annual revenue



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Backend Technology

- Mix of JAVA, Perl and Python code
- Jetty web and application server

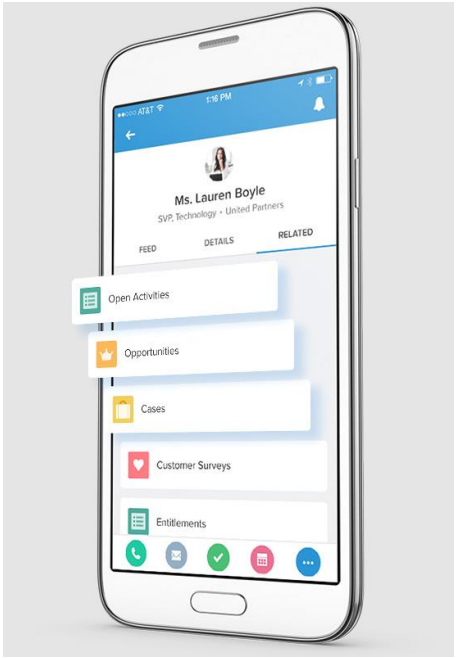

Image source: salesforce.com

Enterprise Systems: SAP ERP

- **Functionality**
  - Enterprise Resource Planning solution
  - Sales, accounting, supply chain management, production management, payroll, recruiting, etc.
  - Main product of SAP SE

Image source: sap.com

Enterprise Systems: SAP ERP

- **Functionality**
  - Enterprise Resource Planning solution
  - Sales, accounting, supply chain management, production management, payroll, recruiting, etc.
  - Main product of SAP SE
- **Adoption and Impact**
  - > 400k customers in > 180 countries
  - > 102k employees in > 140 countries
  - > EUR 27.3 bn annual revenue

Image source: sap.com

Enterprise Systems: SAP ERP

Functionality

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Adoption and Impact

- > 400k customers in > 180 countries
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Backend Technology

- Based on SAP NetWeaver platform
- ABAP, C/C++, supports JAVA and C#
- SAP NetWeaver Application Server
- Oracle, SAP ASE, SAP HANA database

Image source: sap.com

Search Engines: Google

- **Functionality**
  - Web, product and price search, news platform
  - Personal information management (mail, calendar, contacts)
  - Online collaboration tools
  - Cloud apps, storage and computing

Image source: google.de

Search Engines: Google

- **Functionality**
  - Web, product and price search, news platform
  - Personal information management (mail, calendar, contacts)
  - Online collaboration tools
  - Cloud apps, storage and computing
- **Adoption and Impact**
  - > 86% global market share in desktop web search
  - > 5.5 bn search requests per day
  - > 63k search requests per second
  - > $146 bn annual revenue

Image source: google.de

Search Engines: Google

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  - > $146 bn annual revenue
- **Backend Technology**
  - Mix of C++, Java, Python and Go code
  - Custom-built web servers, distributed file system and storage services

Image source: google.de

Social Media: Instagram

- **Functionality**
  - Social photo sharing

Image source: https://www.facebook.com/brand/resources/instagram/instagram-brand/

Social Media: Instagram

- **Functionality**
  - Social photo sharing
- **Adoption and Impact**
  - Founded in 2010
  - > 1 bn users
  - > 0.5 bn daily users
  - > $ 20 bn annual revenue
  - Acquired by Facebook in 2012

Image source: https://www.facebook.com/brand/resources/instagram/instagram-brand/

Social Media: Instagram

- **Functionality**
  - Social photo sharing
- **Adoption and Impact**
  - Founded in 2010
  - > 1 bn users
  - > 0.5 bn daily users
  - > $ 20 bn annual revenue
  - Acquired by Facebook in 2012
- **Backend Technology**
  - Python/Django
  - Apache Solr
  - PostgreSQL
  - Amazon S3

Image source: https://www.facebook.com/brand/resources/instagram/instagram-brand/

GIS: OpenStreetMap

- **Functionality**
  - Online mapping and route planning
  - Allows upload of GPS data and editing of map data

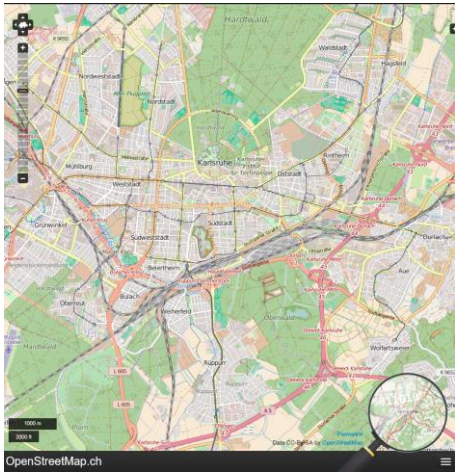
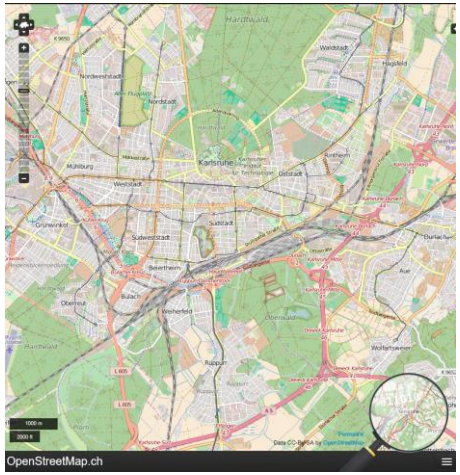


Image source: openstreetmap.org

GIS: OpenStreetMap

- **Functionality**
  - Online mapping and route planning
  - Allows upload of GPS data and editing of map data
- **Adoption and Impact**
  - > 7 mn registered users
  - > 1.5 mn contributors
  - > 4.5 mn map changes per day
  - Support of NGOs in crisis response (e.g., Haiti earthquake and Ebola pandemic)



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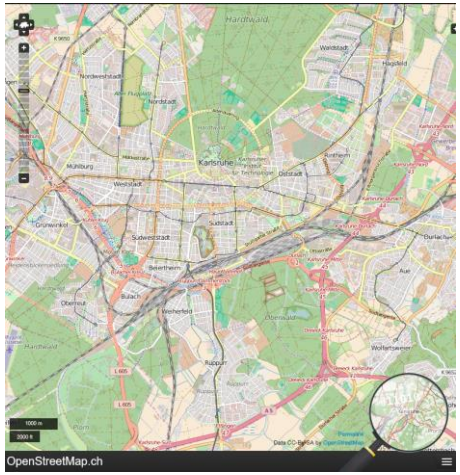
- **Backend Technology**
  - Ruby on Rails
  - Apache web server with custom mod tile module to serve map tiles
  - PostgreSQL database



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Public Administration: Ilias

- **Functionality**
  - University information systems
  - Learning, knowledge, and collaboration platform
  - Management of courses and exams

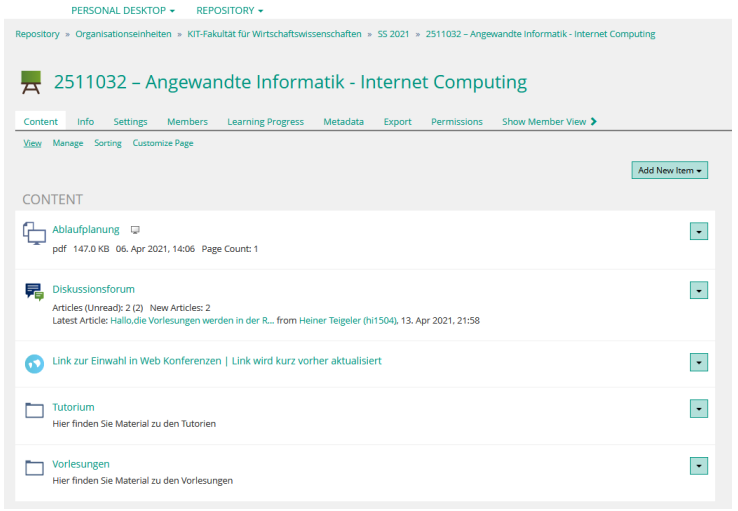

Image source: https://ilias.studium.kit.edu

Public Administration: Ilias

Functionality

- University information systems
- Learning, knowledge, and collaboration platform
- Management of courses and exams

Adoption and Impact

- Used by many German universities
- > 50k commits in GitHub
- Open source (GPL-3.0 License)

Image source: https://ilias.studium.kit.edu

Public Administration: Ilias

- **Functionality**
  - University information systems
  - Learning, knowledge, and collaboration platform
  - Management of courses and exams
- **Adoption and Impact**
  - Used by many German universities
  - > 50k commits in GitHub
  - Open source (GPL-3.0 License)
- **Backend Technology**
  - MySQL or MariaDB database
  - Apache webserver
  - Written in PHP (w/ PEAR)

Image source: https://ilias.studium.kit.edu

Blockchain: Bitcoin

- **Functionality**
  - Pseudonymous payments
  - Micropayments
  - Cross-border payments

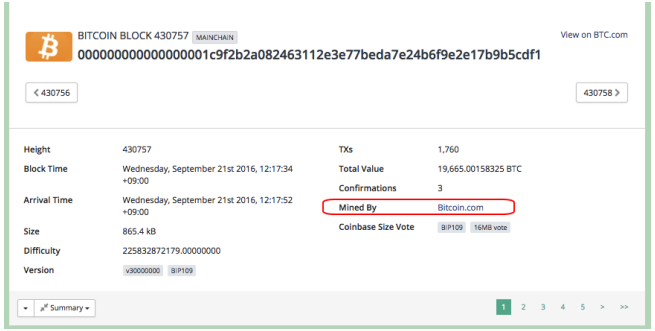

Image source: bitcoinforum.com

Blockchain: Bitcoin

- **Functionality**
  - Pseudonymous payments
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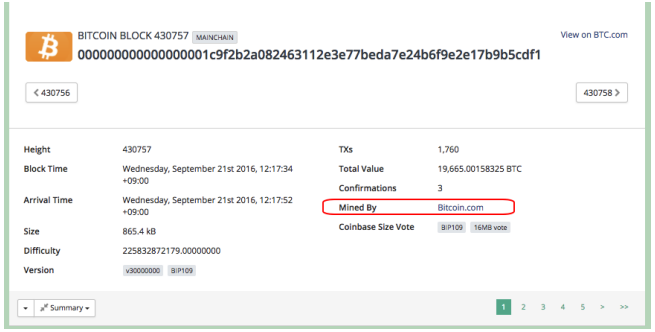
  - Cross-border payments
- **Adoption and Impact**
  - > 70 mn Bitcoin wallets
  - > $ 790 bn Bitcoin capitalization
  - > 41% of the cryptocurrency market



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Blockchain: Bitcoin

Functionality

- Pseudonymous payments
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- Cross-border payments

Adoption and Impact

- > 70 mn Bitcoin wallets
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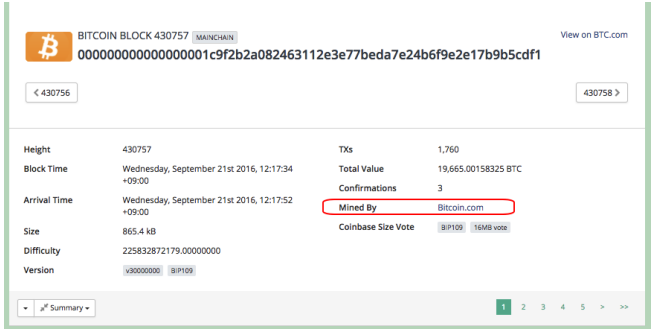
Backend Technology

- Blockchain
- Proof-of-Work consensus mechanism
- Public-key cryptography
- Timestamp server



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Cloud Computing: Dropbox

- **Functionality**
  - Cloud storage
  - File synchronization
  - Version history

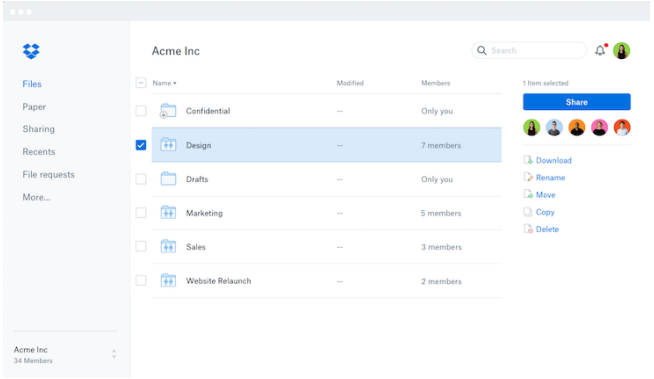
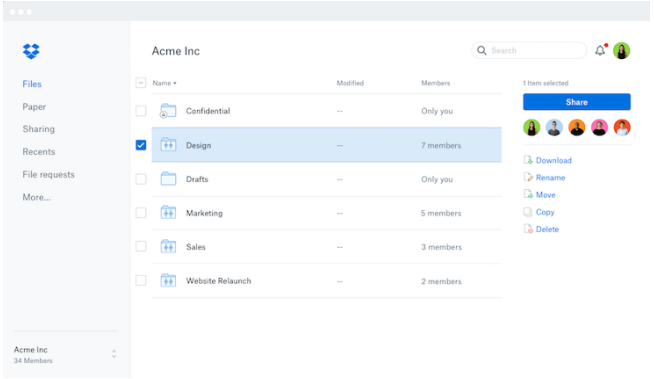


Image source: dropbox.com

Cloud Computing: Dropbox

- **Functionality**
  - Cloud storage
  - File synchronization
  - Version history
- **Adoption and Impact**
  - > $ 1.8 bn annual revenue
  - > 800k files uploaded every minute
  - > 15.25 mn paying customers



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Cloud Computing: Dropbox

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- **Adoption and Impact**
  - > $ 1.8 bn annual revenue
  - > 800k files uploaded every minute
  - > 15.25 mn paying customers
- **Backend Technology**
  - Amazon S3 (2014-2016, now: Magic Pocket)
  - CoffeeScript
  - (AES)-256 encryption
  - SSL transfers
  - API for third-party applications

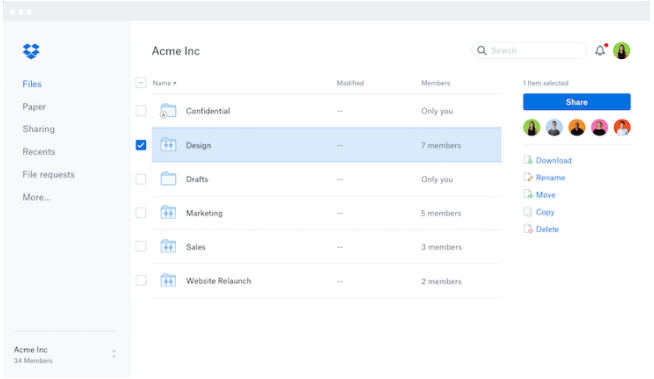

Image source: dropbox.com

Distributed Information Systems: Challenges

Challenge 1: Reliability

- Software or hardware errors can lead to **transient** or **persistent** failures
  - Transient: can be solved by restarting or replacing failed component
  - Persistent: involves unrecoverable loss of data

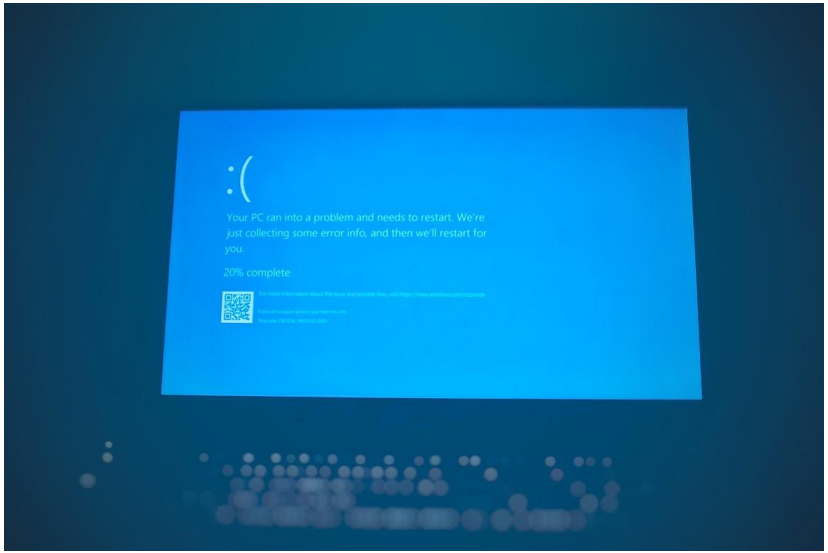

Image source: [Windows Blue Screen of Death on Laptop] by Hoene Joshua, May 15th 2020. Unsplash License.

Challenge 1: Reliability

- Software or hardware errors can lead to **transient** or **persistent** failures
  - Transient: can be solved by restarting or replacing failed component
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- **Downtime is expensive!**
  - Downtime on Black Friday: $ 833k loss per minute at Amazon.com!

Image source: [Obverse of United States one-dollar bill, series 2009] by Kameron Chia, December 16th 2019. Public Domain.

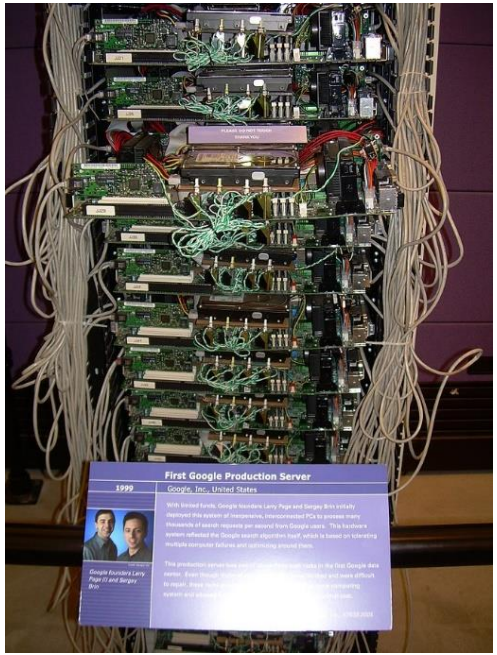
Challenge 1: Reliability

- Software or hardware errors can lead to **transient** or **persistent** failures
  - Transient: can be solved by restarting or replacing failed component
  - Persistent: involves unrecoverable loss of data
- **Downtime is expensive!**
  - Downtime on Black Friday: $ 833 k revenue per minute at Amazon.com!
- **Partial failures** in distributed systems
  - Accept order of product X
  - Debit credit card
  - Decrease stock quantity of product X
  - Trigger shipping

Image source: [Obverse of United States one-dollar bill, series 2009] by Kameron Chia, December 16th 2019. Public Domain.

Challenge 2: Scalability

- Today's popular web applications handle **tens of thousands of requests per second**



Google's server infrastructure mid 1990s

Image source: [Google's First Production Server (1999)] by Carlo Nardone, November 10th 2007. Licensed under CC BY-SA 2.0.

Challenge 2: Scalability

- Today's popular web applications handle **tens of thousands of requests per second**
- Need to (quickly!) **scale up** startup to millions of users or customers

Part of Google's server infrastructure 2014

Image source: [Sonnenuntergang über unseren Wassertanks und Kühltürmen in St. Ghislain (Belgien)] by Google, at n.d.

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- **Flexibility:** need to incorporate new functionality and business models
- Requires understanding of **software architecture** and **systems engineering**
- Solid knowledge of **middleware technologies** crucial

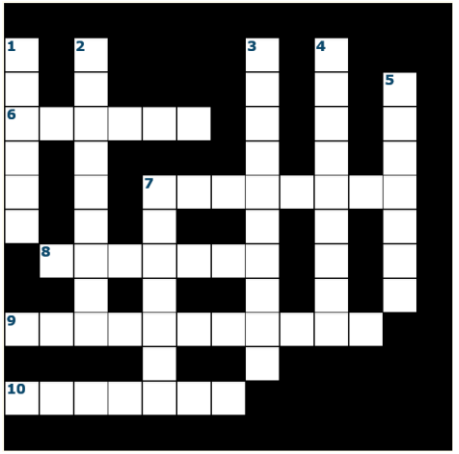
Part of Google's server infrastructure 2014

Image source: [Sonnenuntergang über unseren Wassertanks und Kühltürmen in St. Ghislain (Belgien)] by Google, at n.d.

Challenge 3: Information Security

- Storage of **highly sensitive information** (personal details, credit card numbers, financial statements, exam grades, etc.)

The “Adobe Crossword”



Hints for 6-across:
food; mouse; dairy; cheddar; ...

Image source: [Crossword] by zed0.

Challenge 3: Information Security

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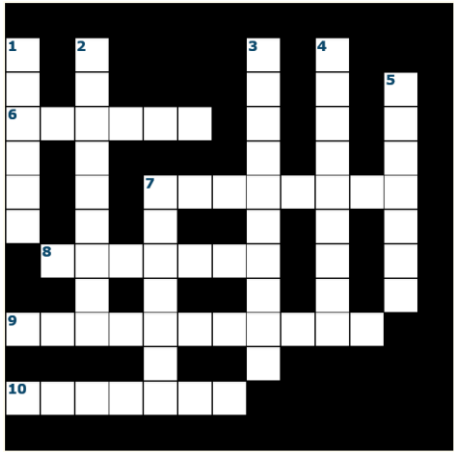

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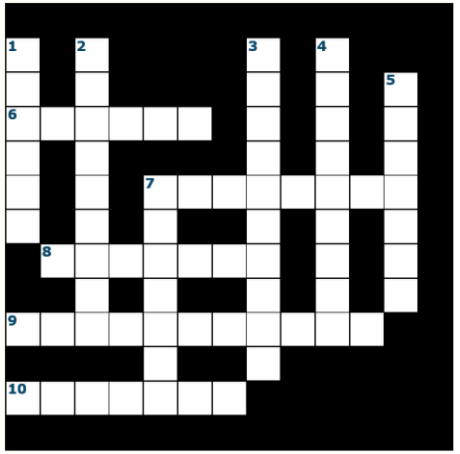
- Protection against **external attacks** (code injection, privilege escalation, (distributed) Denial of Service, etc.)
- **Multitenancy**: guarantee separation of information between different users/customers

The “Adobe Crossword”



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Challenge 4: Integration

- **No one-stop solution** for the development of information systems
- Popular services **integrate a mix of technologies and components**

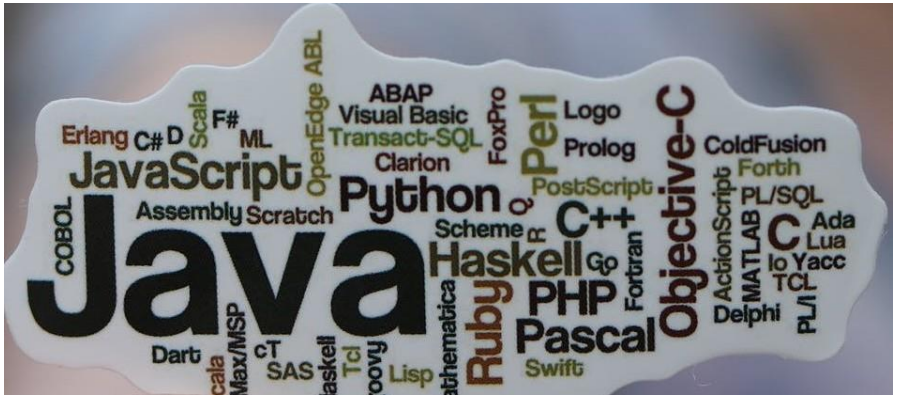

Image source: [Cloud of many programming languages] by RTC, November 11th, 2018. Pexels Linzenz.

Challenge 4: Integration

- **No one-stop solution** for the development of information systems
- Popular services **integrate a mix of technologies and components**
- Different **programming languages**: C++, Java, C#, Python, Perl, JavaScript, Ruby, Go, PHP, ...

Image source: Bruegel, Pieter, the Elder (1563). *The (Great) Tower of Babel* [Painting]. Kunsthistorisches Museum, Vienna.

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- Different **programming languages**: C++, Java, C#, Python, Perl, JavaScript, Ruby, Go, PHP, ...
- Different **database technologies:** postgresql, mysql, MongoDB, Redis
- Integration of **loosely coupled** systems favoured over a single, monolithic solution

Image source: Bruegel, Pieter, the Elder (1563). *The (Great) Tower of Babel* [Painting]. Kunsthistorisches Museum, Vienna.

Challenge 5: Interoperability

- Modern information systems support **heterogeneous clients**
- Customers use **web, mobile, or workstation clients** with different interfaces, screen sizes, operating systems, etc.

Image source: Rehn, Ben Simon (2020). *Urban chameleon* [Photograph]. Instagram. https://www.instagram.com/p/B8BwIUfockv/

Challenge 5: Interoperability

- Modern information systems support **heterogeneous clients**
- Customers use **web, mobile, or workstation clients** with different interfaces, screen sizes, operating systems, etc.
- Incorporate **services from other businesses** via the web (payment, logistics, data storage, etc.)
- Need to provide **interfaces for business-to-business (B2B) relations**

Image source: Rehn, Ben Simon (2020). *Urban chameleon* [Photograph]. Instagram. https://www.instagram.com/p/B8BwIUfockv/

Challenge 6: Usability

- Customers/users need to **understand intuitively** how the system works
- User interface should be **rich and responsive**

Image source: [Baby on Laptop] by PublicDomainPictures, February 10th, 2013. Pixabay License.

Challenge 6: Usability

- Customers/users need to **understand intuitively** how the system works
- User interface should be **rich and responsive**
- Information should be **easy to find** and **arranged in a logical way**
- System may need **to proactively recommend** information

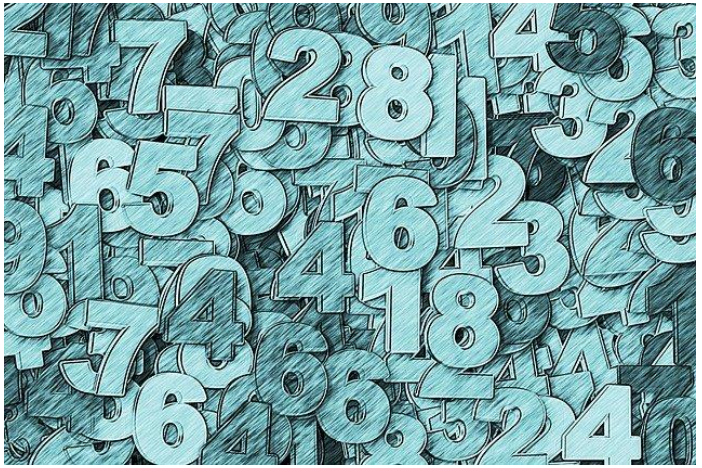

Image source: [Numbers] by Altmann Gerd, April 4th, 2019. Pixabay License.

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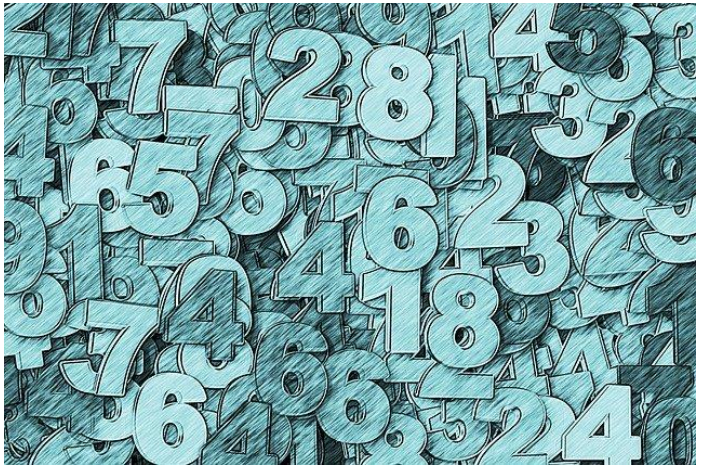
- User interface should be **rich and responsive**
- Information should be **easy to find** and **arranged in a logical way**
- System may need **to proactively recommend** information
- Support of **collaborative authoring/curation of information**



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Information Systems Are Complex!

- Information systems are **large, complex and mission-critical** software systems
- We need **structured approaches to manage their complexity**
- Scalable, reliable and secure technological basis is **key success factor**
- Foresighted managerial decisions require solid understanding of
  - **System architectures**
  - **Middleware technologies**
  - **Data formats and standards**
  - **History and trends**

Software Engineering at Large …

Software engineering

Image source: [Fire Base Salerno] by Eli J. Medellin, June 29th, 2008. Public Domain.

Software Engineering at Large …

Software engineering

(Distributed) systems engineering

Image source: Google Maps
Image source: [Fire Base Salerno] by Eli J. Medellin, June 29th, 2008. Public Domain.

Conclusion

- Information systems are complex socio-technical systems
- This course covers strategies and technologies to cope with this complexity
- Practice-oriented approach
  - No detailed coverage of a single framework
  - Focus on integration of many different technologies

- Questions?
- Suggestions?

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Questions

Questions

1. What role did ARPANET play in the creation of the Internet?
2. How is Internet computing defined?
3. What are the key characteristics of distributed IS?
4. Why are distributed IS important for Internet-based applications?
5. What are core design challenges of distributed IS?
6. What are examples of Internet-based applications?