Operating Systems

Introduction

Prof. Dr. Oliver Hahm

Frankfurt University of Applied Sciences
Faculty 2: Computer Science and Engineering
oliver.hahm@fb2.fra-uas.de
https://teaching.dahahm.de

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Agenda

- Core Functionalities of Operating Systems
- Generations of Computer Systems and Operating Systems
  - Generation Zero
  - 1st Generation
  - 2nd Generation
  - Batch Processing
  - 3rd Generation
  - Time-sharing
  - 4th Generation
  - 5.Generation

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What do you already know?

Let's go to the survey again:

`https://pingo.coactum.de/977183`

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- Which operating systems do you know?

What do you already know?

Let's go to the survey again:
`https://pingo.coactum.de/977183`

- Which operating systems do you know?
- What are the functionalities of an Operating System?

Some Examples

GNU/Linux

FreeBSD

Microsoft Windows

Be OS

BeOS

macOS

OpenBSD

ORACLE®
Solaris

Zephyr™

AIX

android

RIOT

QNX™

Definition: Operating System

Andrew S. Tanenbaum

An operating system "[provides] application programmers (and application programs, naturally) a clean abstract set of resources instead of the messy hardware ones and managing these hardware resources."

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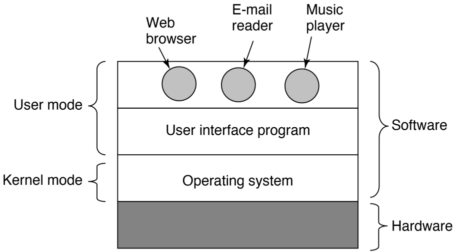
William Stallings

"An OS is a program that controls the execution of application programs, and acts as an interface between applications and the computer hardware. It can be thought of as having three objectives:

- Convenience [. . .]
- Efficiency [. . .]
- Ability to evolve"

Abstraction layer for the applications



Source: Tanenbaum, Modern Operating Systems 4e,

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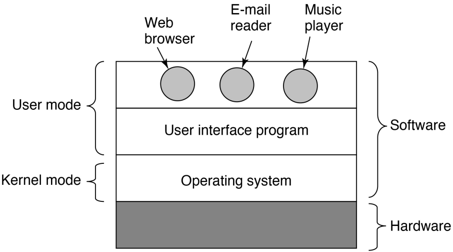
Abstraction layer for the applications



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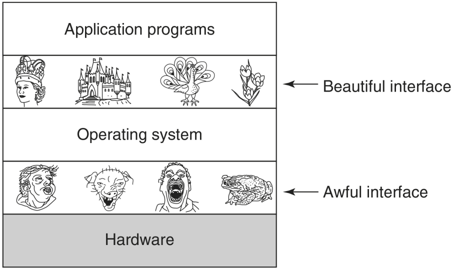

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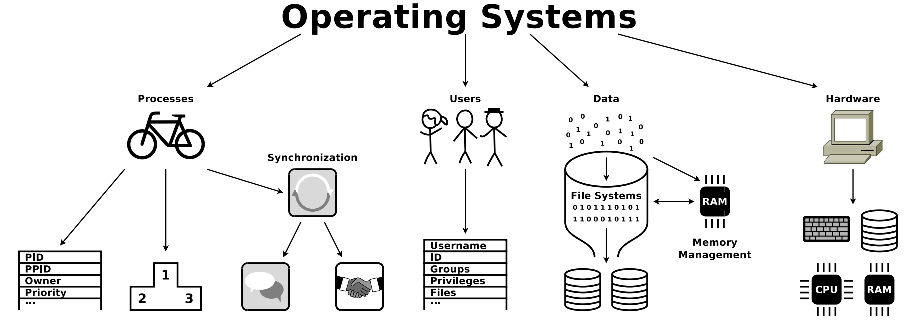
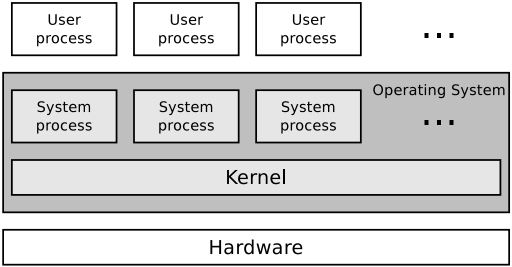
Resource Manager



Source: Baun, Operating Systems

Basic Structure of an Operating System



- User processes process the users' jobs
- System processes provide services of the operating system
- The operating system core ($\Longrightarrow$ kernel) contains all components of the operating system, which are not implemented as system processes

Operating Systems are Part of the System Software

System software controls the operation of a computer, assists users and their applications in making use of the hardware and controls the use and allocation of the available hardware resources

Why do we need an Operating System?

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- Abstract hardware interfaces
- Make software portable
- Share resources and allow for separation
- Efficient usage of resources

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$\Longrightarrow$ Software development without an Operating System is painful

Your Turn

Two Challenges

Your Turn

Two Challenges

- Name an electronic device without a computer!

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- Name a module from your study program that is completely unrelated to Operating Systems!

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Which tasks in software development would be much more cumbersome without an Operating System?

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Generations of Computer Systems and Operating Systems

Generation	Time period	Technological progress
0	until 1940	(Electro-)mechanical calculating machines $\Longrightarrow$ no software!
1	1940 – 1955	Electron tubes, relays, jack panels
2	1955 – 1965	Transistors, batch processing
3	1965 – 1980	Integrated circuits, time sharing
4	1980 – 2000	Very large-scale integration, microprocessors, PCs/Workstations
5	2000 until ?	Distributed systems, *the network is the computer*, virtualization

Quote from the magazine *Popular Mechanics* (1949)

„In the future, computers may weigh no more than 1.5 tonnes.“

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Generation Zero (until 1940)

- Mechanical/Electromechanical calculating machines
- Examples:
  - Mechanical calculator of Wilhelm Schickard (1623)
    - Offers addition, subtraction and carry mechanism („*Zehnerübertragung*“)
  - Mechanical calculator Pascaline of Blaise Pascal (1643)
    - Offers addition, subtraction, $\leq$ 8 digits and carry mechanism
  - Mechanical calculator of Gottfried Wilhelm Leibniz (1673)
    - Offers all 4 basic arithmetic operations, $\leq$ 6 digits and carry mechanism

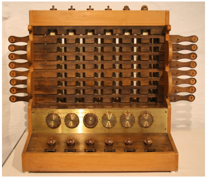


Image Source: Wikipedia (Herbert Klaeren, CC-BY-SA-3.0)

Image Source: Heinz Nixdorf Museum

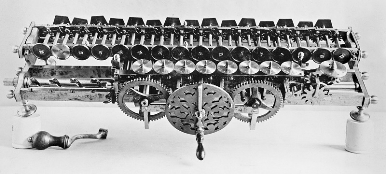


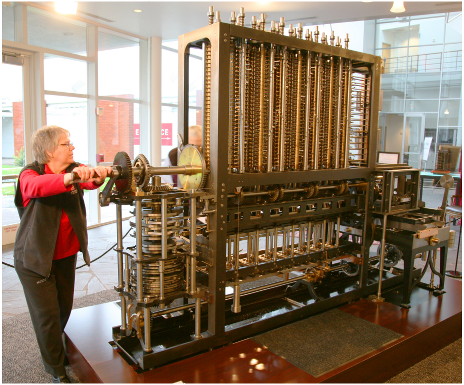
Image Source: Deutsches Museum

No software in this generation $\Longrightarrow$ no operating systems

Generation Zero (until 1940)

Image Source: flickr.com (Jitze Couperus, CC-BY-2.0)

- Another example:
  - Difference Engine No.1 for solving polynomial functions of Charles Babbage (1832)



Generation Zero (until 1940)

- Another example:
  - Hollerith tabulating machine of Herman Hollerith (1888)
    - Includes: Tabulating machine, punch card sorter, key punch (card punch) and punch card reader
    - 1890: The tabulating machine is used to tabulate the US census
    - 1924: The company of Hollerith is renamed to International Business Machines Corporation (IBM)

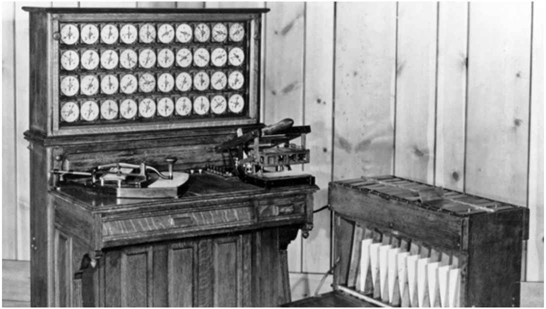


Image source: IBM

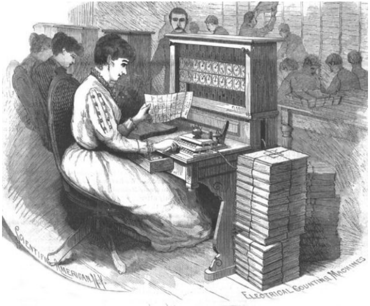


Image source: United States Census Bureau

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1^{st} Generation (1940 – 1955)

- The 1^{st} generation of computer systems was constructed during WW2 $\Longrightarrow$ Konrad Zuse, John von Neumann
- Requirements, a universal computer must satisfy:
  - Stored program
  - Conditional jump (GOTO)
  - Separation of memory and CPU
- Computers were machines with partially $>$ 10,000 tubes or relays, which worked slow and error prone
- **No operating systems and programming languages in this generation**
- Programs were implemented via circuits in patch bays
  - The user/programmer launches **one** program, which directly accesses the hardware

Some systems of the 1st Generation

Image Source: Own work (12.12.2008)

Computer	Development	Storage/CPU separated	Conditional jumps	Programming	Internal encoding	Number representations	Technology
Z1 / Z3	1936-1941	yes	no	SW	binary	floating point	mechanical (relays)
ABC	1938-1942	yes	no	HW	binary	fixed-point	electronic
Harvard Mark 1	1939-1944	no	no	SW	decimal	fixed-point	electronic
ENIAC	1943-1945	no	partially	HW	decimal	fixed-point	electronic
Manchester	1946-1948	yes	yes	SW	binary	fixed-point	electronic
EDSAC	1946-1948	yes	yes	SW	binary	fixed-point	electronic

Computers that operate according to the decimal system?

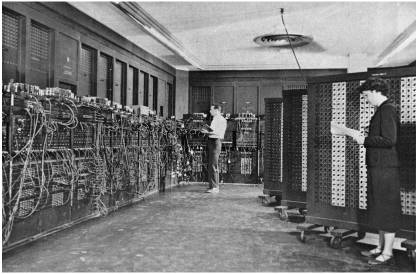
Detailed description of the structure: `http://computer-modell-katalog.de/eniac.htm`

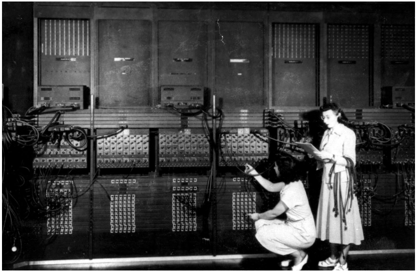
Zuse Z3 (1941)

- The world's first working programmable, digital computer (based on relay technology)
- First computer, which implemented the binary system

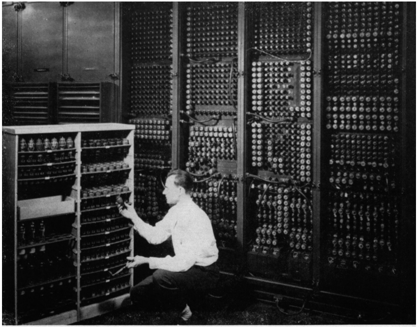
1st Generation: ENIAC (1944)

Image Source: US Army (Public Domain)





- Electronic Numerical Integrator and Computer (ENIAC)
- First electronic general-purpose computer (with electron tubes)



Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

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2nd Generation (1955 – 1965)

Image Source: Flickr (born1945, CC-BY-2.0)

- Early 1950s: Punch cards replace the patchbays
- Mid-1950s: Introduction of the transistors:
  ⟹ Computer systems become more reliable

- Programs were written in early programming languages like FORTRAN or COBOL
  - written down by the programmer on form sheets,
  - punched from coders into punch cards
  - and handed over to the operator (**administrator**)
- The operator…
  - coordinates the order (schedule) of programs (jobs)
  - equips the computer with the punch cards
  - loads the compiler from the magnetic tape
  - hands over the printed out computation result
- Later, for efficiency reasons, programs were collected, stored on magnetic tape and then processed in the machine room

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2nd Generation: Batch Processing (1/4)

- Operating systems of this generation were all batch processing operating systems
- Objective: Maximize CPU utilization

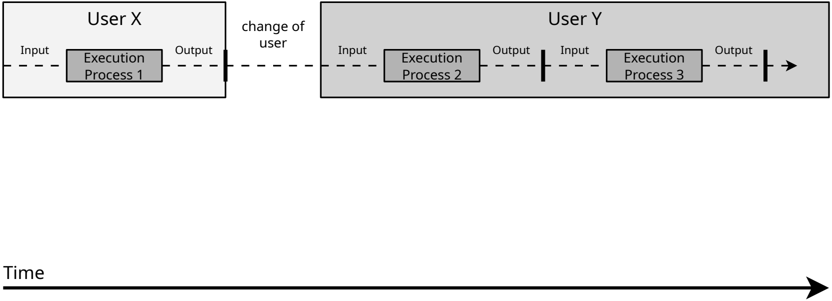
- Each program needs to be provided completely (with all input data!) before the execution may begin
- Batch processing is well suited for the execution of routine tasks

- Today's systems still allow to process program sequences automatically (e.g., non-interactive batch files and shell scripts)

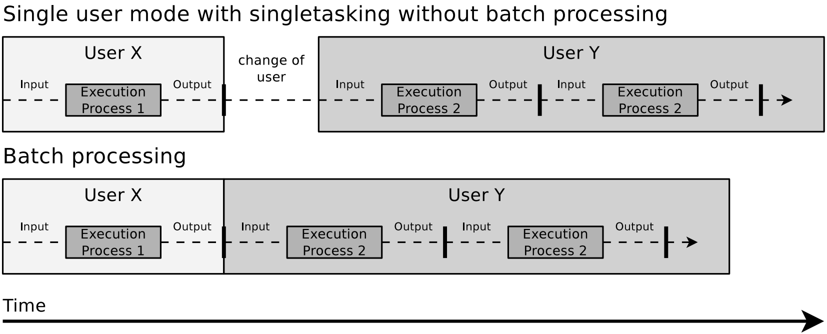
Image Source: IBM (the image shows an IBM 7090 from 1959)
`http://www.computer-history.info/Page4.dir/pages/IBM.7090.dir/images/ibm.7090.jpg`

2^{nd} Generation: Batch Processing (2/4)

Single user mode with singletasking without batch processing

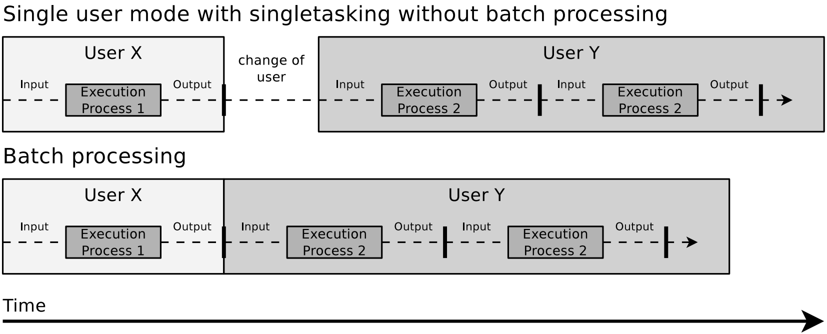


2^{nd} Generation: Batch Processing (2/4)



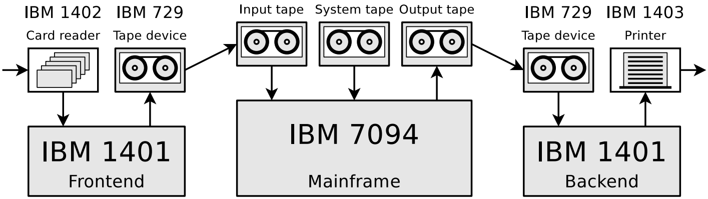
- Batch Processing ⟹ Acceleration via automation

2nd Generation: Batch Processing (2/4)



- Batch Processing ⟹ Acceleration via automation
- **Drawback:** The CPU is still not utilized in an optimal way
  - ⇒ During input/output operations the CPU is idle

2nd Generation: Batch Processing (3/4)



Frontend computer for reading the punch cards and storing their information on tape

Mainframe for program execution

Backend computer for reading the output tapes and printing the results

- Frontend/backend computers free the mainframe from slow I/O operation
  - Data can be read from tape much faster than from punch cards and data can be stored on tape much faster than printed out
- Spooling removes I/O workload from the CPU by using additional HW
  - I/O is carried out concurrently with the processing of other jobs

Today, computers have in addition to the CPU, specific I/O processors with DMA capability (*Direct Memory Access*)

These write data directly into the main memory and fetch the results from there

2nd Generation: Batch Processing (4/4)

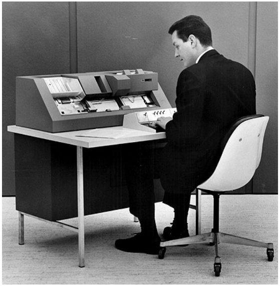


Image source: IBM Archives
https://onfoss.com/a-timeline-of-computer-interface-technology/

- Spooling is still used today
  - e.g., spooling processes for printing
- Batch processing is usually non-interactive
  - A started process is executed without any user interaction until it terminates or an error occurs
- Batch processing operating systems of the 2nd generation only implement singletasking (⟹ slide set 3)
  - The operating system allows only the execution of one program at once
  - Starting a second program is only possible after the first one has finished

Some Operating Systems of the 2nd Generation

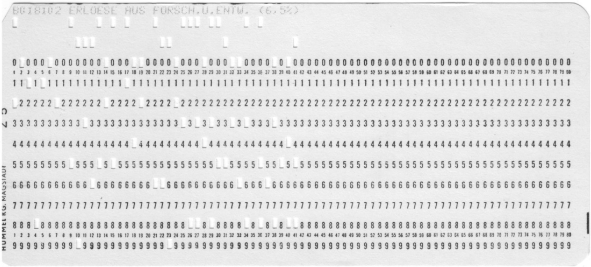
Atlas Supervisor, GM-NAA I/O, UMES, SHARE, IBSYS

„For historic reasons. . . “

Why do many E-mail clients (Mail User Agents (MUAs)) and editors insert line breaks after 80 characters?

2nd Generation: Punch Cards

⇒ The standard line size of ≤ 80 characters in E-mails and text files dates back to the punch card



- Each punch card usually represents a single line of text with 80 characters or a corresponding number of binary data
- 12 punch hole positions for the encoding of each character
  - Digits are encoded with a single hole in the corresponding row
  - Letters and special characters are encoded by punching multiple holes in the column

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3^{rd} Generation (1960 – 1980)

- Early 1960s: Integrated circuits are available
  $\Longrightarrow$ More powerful, smaller and less expensive computers
- 1960s:
  - Improvement of the batch processing systems to allow the execution of multiple jobs during the same period of time $\Longrightarrow$ multitasking
  - First simple memory management (*fixed partitions*) $\Longrightarrow$ slide set 5
- 1970s: Time-sharing (*interactive mode*)
  - One central unit, multiple terminals
  - Each user gets a user process when logging in
- End of the 1970s: Development of the microprocessor
  $\Longrightarrow$ Development of the home computer / personal computer (PC)
  - 1977: Apple II. First home computer
  - 1981: IBM PC. Top selling computer architecture (Intel 80x86)

Some Operating Systems of the 3^{rd} Generation

BESYS, CTSS, OS/360, CP/CMS, Multics, Unics (later Unix), DEC DOS-11, DEC RT-11, Version 6/7 Unix, DEC CP/M, Cray Operating System, DEC VMS

Some systems of the 3rd Generation

Image Source: Clemens Pfeiffer (CC-BY-2.5)

Computer	Development	Special features
CDC 6600	1964	First supercomputer
IBM System/360	1964	8-bit character size. Flexible architecture
PDP-8	1965	First commercial minicomputer from DEC
ILLIAC IV	1969	First multiprocessor computer
CRAY 1	1976	Supercomputer

This generation includes also. . .

- first decentralized computer network (ARPANET)
- computer networks to connect terminals with mainframe computers via serial lines (e.g., IBM Systems Network Architecture)
- proprietary interconnection networks (e.g., DECnet)

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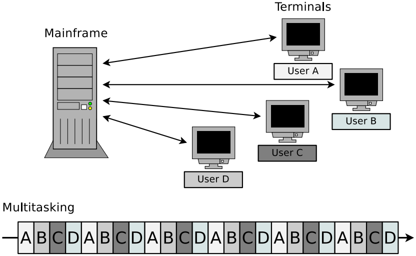
3rd Generation: Time-sharing (1/2)



- Multiple users work with a single computer in a **simultaneous and competitive** way by sharing the available computing time of the CPU
  - Objective: Fair distribution of the computing time

- The computing time is distributed via time slices
  - The distribution can carried out according to different strategies
- Multiple users can work interactively and simultaneously with a computer via terminals $\Longrightarrow$ Multi-user operation ($\Longrightarrow$ next slide set)
- The programs of the individual users are independent of each other
- The pseudo-parallel program or process execution is called multitasking ($\Longrightarrow$ next slide set)
  - **Objective:** Minimizing the response time

3rd Generation: Time-sharing (2/2)

- Because of time-sharing, new concepts were required:
  - Memory protection: The memory is split and running programs are separated from each other
    - This way, a *bug* or crash of a single program does not affect the stability of other programs and the total system
  - File systems, which allow quasi-simultaneous file access
  - Swapping: Process of storing and removing data to/from main memory from/into background memory (HDDs/SSDs)
  - Scheduling: Automatic creation of an execution plan (*schedule*), which is used to allocate time limited resources to users or their processes

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4^{th} Generation (1980 – 2000)

- This generation provides highly integrated circuits and an exponentially growing integration density of electronic components
  - CPUs become more powerful and cheaper
  - The main memory capacity rises
- High computing power can be installed on every workplace
  - Workstations become standard in the in the professional sector
  - Popularity of home computers and personal computers (PC) rises
    - Main objective of operating systems: Intuitive user interfaces for users who do not want to know anything about the underlying hardware

Some Operating Systems of the 4th Generation

QDOS, Xenix, MS-DOS, PC-DOS, QNX, GNU project, SunOS, MacOS, AmigaOS, Atari TOS, Windows, IBM AIX, GEOS, SGI IRIX, MINIX, OS/2, NeXTSTEP, SCO UNIX, Linux, BeOS, Haiku, Google Fuchsia

- Computer networks with open standards became popular
  - Ethernet, Token Ring, WLAN ($\Longrightarrow$ computer networks course)

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5^{th} Generation (2000 – ????)

- Some key words from the 5th generation:
  - *The network is the computer*
  - Distributed systems ⟹ Cluster-, Cloud-, Grid-, P2P-Computing
  - Resources are requested and rent when needed ⟹ on demand
  - Multicore processors and parallel applications
  - Virtualization ⟹ **VMware, XEN, KVM, Docker...**
  - Free Software (OpenSource) ⟹ **Linux (Android), BSD**,...
  - Communication everywhere ⟹ mobile systems
  - Internet of Things ⟹ **RIOT, Zephyr, AWS FreeRTOS**,...
- Keywords for later generations:
  - Quantum computers (maybe 6th or 7th generation)

At the end of the semester you. . .

- know and understand the **functioning** of the **core functionalities** of operating systems
- unterstand the **functioning** of the most important hardware components
- have basic skills in working with **Linux**
- have basic skills in **shell scripting**