

Course Organization & History of Telecommunications

Unit 01 - Hands-On Networking - 2018

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HON | Team



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Introduction

Telecommunications

Definition (Wikipedia): *Telecommunication is the **transmission of signs, signals, writings, images and sounds or intelligence of any nature** by wire, radio, optical or other electromagnetic systems, as defined by the International Telecommunication Union (ITU).*

Telecommunication occurs when the exchange of information between communication participants **includes the use of technology**. It is transmitted either electrically over physical media, such as cables, or via electromagnetic radiation. Such transmission paths are often divided into **communication channels** which afford the advantages of **multiplexing**.

Telecommunication Networks

Definition ([Wikipedia](#)): A telecommunications network is a collection of **terminal nodes**. Links are connected so as to enable telecommunication between the terminals.

The transmission links connect the nodes together. The nodes use **circuit switching**, **message switching** or **packet switching** to pass the signal through the correct links and nodes to reach the correct destination terminal.

Each terminal in the network usually has a **unique address** so messages or connections can be routed to the correct recipients. The collection of addresses in the network is called the **address space**.



Source



Source

21st Century Computer Networking



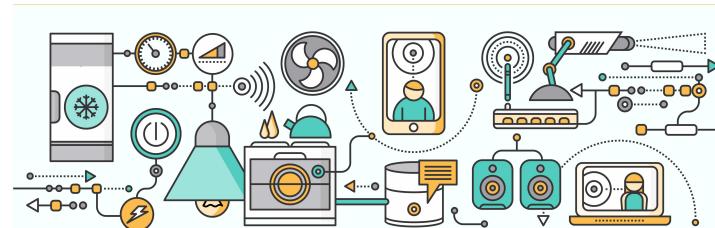
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Introduction

Telecommunications History

Greek Telecommunication Systems

🔥 Troy (1194 BC)

- Signal "Troy has fallen".
- Eight fire signal stations in use.
- First documented (although not proved) case of long-distance communication.

驲 Marathon (490 BC)

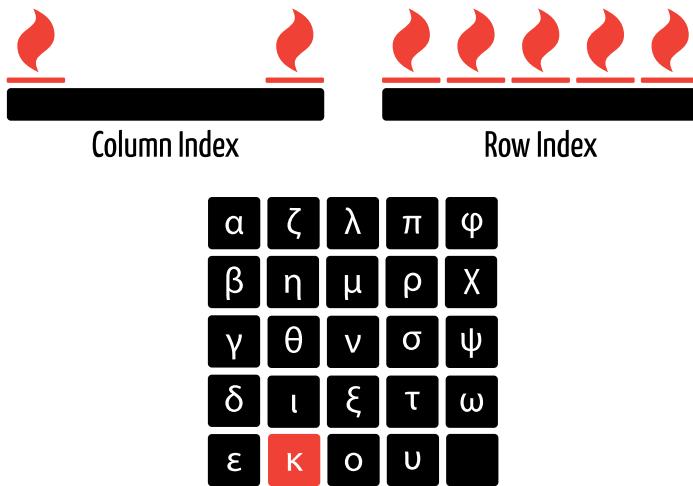
- Signal "We won".
- Runner Pheidippides sent to transmit the message on foot.
- Allegedly died after transmitting.

⚡ Problems

- Single, distinct piece of information conveyed.
- Limited capabilities / special or even single-purpose systems.

Fire Signals++

🔥 Fire Code of Polybios



💡 Approach

- Encode symbols of an alphabet instead of fixed messages.
- Expressiveness of communication system = expressiveness of Greek.

⚡ Problems

- Tell fire signals apart from a distance.
Binoculars not yet invented, hence practical distance ~100m.
- Number of fires is important.
Position does not carry information.

Quiz

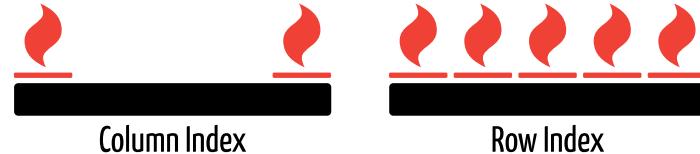
➊ How many torches do we need in case we encode optimally?

A: All 10

B: 5

C: 6

D: 4



Column Index

Row Index

| | | | | |
|------------|----------|-----------|----------|----------|
| α | ζ | λ | π | ϕ |
| β | η | μ | ρ | χ |
| γ | θ | ν | σ | ψ |
| δ | ι | ξ | τ | ω |
| ϵ | K | O | U | |

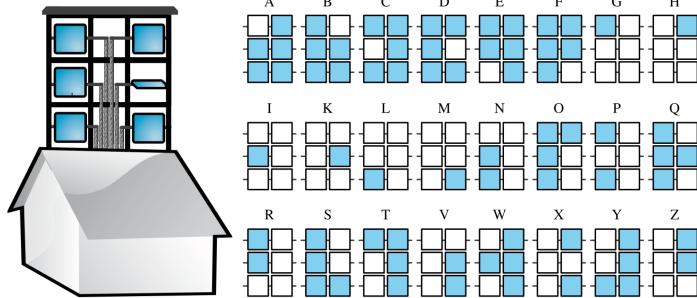
⚠ Answer:

- ✖ A: False.
- ✖ C: Improvement, by keeping the row/col index in place. But we could do better.

✓ B: True. Consider position of torch as relevant and encode binary ($2^5 = 32$).
 Note: $32 - 23 = 9$ symbols left for other symbols.

✖ D: Not possible, as 25 symbols cannot be expressed by 4 bits ($2^4 = 16$).

Lord-Murray Telegraph



💡 Approach

- Shutter open or not (binary).
- Shutter scheme (3×2) transferred to symbol (no row/col association).

Source: Dirk Hoffmann - "Einführung in die Informations- und Codierungstheorie"

See also: [The Clacks](#)

❓ Which important symbols are missing?

The letters **J** and **U** are missing as well as spaces, periods and all other special characters... and numbers.

❓ How would you add these missing characters?

e.g.: All claps off or other unused combinations.

Electric Transmission

⚡ Electricity / Electromagnetism

- **Thales, 550 BC:** First findings.
- **Gilbert, 16th century:** Systematic investigations.
- **Volta, 1800:** Predecessor of the battery invented.
- **Oersted, Ampere, Sturgeon, Ohm, 1820 - 1824:** Foundations for electromagnetism.

≠ Telegraphs

- **Samuel von Soemmering, 1809:** First text message transmitted via electricity.
- **Gauß, Weber, ~1830:** Created first electromagnetic telegraph.
Used another binary code (mirror moving left/right).

Telegraph to Telephone

⌚ Goal: Create a "harmonic" telegraph - able to transmit multiple streams of morse data in parallel.

💡 Invention of Modulation Schemes

- Amplitude Modulation
- Phase Modulation

👤 Alexander Bell and Thomas Watson

- Created first* harmonic telegraph.
- Transmitted primitive tones.



Source

⚡ Still took some time until **recognizable speech** could be transmitted.

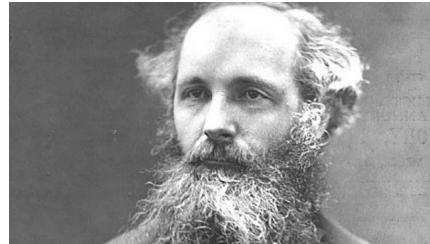
Patent War I

- Patent "*Improvement in transmitters and receivers for electric telegraphs*" submitted by Bell and granted in 1875.
- Elisha Gray developed a similar approach and it is *still* not known who the intellectual father of telephony is.
- Led to first patent war over a technological innovation.
- Struggling Parties:
 - Elisha Gray and the Western Union Telegraph Company.
 - Alexander Graham Bell.
- Argument took **11 years** and consisted of about **600 trials**.

Going Wireless

- All electric communication at that time cable-bound.
- **Maxwell 1865:** "A Dynamical Theory of the Electromagnetic Field".
 - Maxwell equations to understand fields.
 - Theoretical foundations for electromagnetic waves.

James Maxwell (1831 - 1879)



[Source](#)

$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

Communications Unplugged

Heinrich Hertz (1857 - 1894)

- Proof of Maxwell's theories using a experimental setup in 1886.
- First implementation of wireless transmission of messages.



[Source](#)

Guglielmo Marconi (1874 - 1937)

- First practical use of electromagnetic waves for communication.
 - Patent and company founded (Wireless Telegraph & Signal Company).

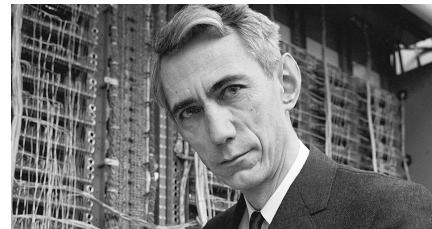


[Source](#)

Information Theory

- "A Mathematical Theory of Communication" (1948).
- Definition of a *Bit* (see later).
- Theoretical bounds on a *channel's data transmission rate*.
- Non-constructive proof that transmissions *error rate* can be reduced arbitrarily close to zero if using an appropriate *coding scheme*.
- Codes (Hamming, Reed-Solomon, ...)
 - Error Detection
 - Error Correction
 - Compression

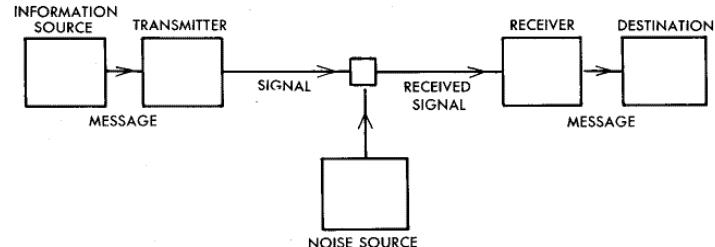
Claude Elwood Shannon (1916 - 2001)



[Source](#)

Shannon-Weaver Communication Model

- First *formalization* of communication systems.



Introduction

Telecommunications Present & Future

The Internet

- Invented as a network to connect:
 -  Academia (exchange research results, etc.)
 -  Military (exchange intelligence, reliable communication infrastructure, ...)
- Evolved into the ...
 - largest (51% of the world's population could access it in June 2017),
 - most ubiquitous,
 - most versatile (services from Facebook to remote maintenance) and
 - cheapest to access (no extra fee for international connections, ...)
- ... network of mankind.

Quiz

➊ What is the *Cloud*?

A: An aerosol comprising a visible mass of minute liquid droplets or frozen crystals.

B: The Solution-as-a-Service to all your current, past and future computer-related problems.

C: Someone else's computer.

D: A fantasy game protagonist.

⚠ Answer:

✗ A: True, if only we were meteorologists.

✓ C: Yes, although cloud providers don't want you to believe that.

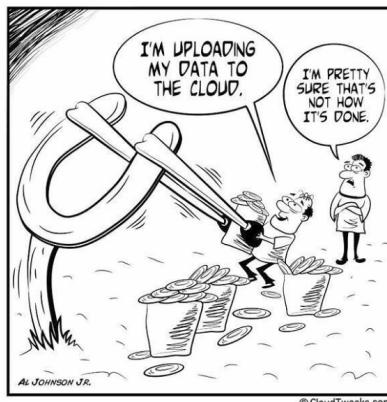
✗ B: Unfortunately, no.

✗ D: Technically yes, but... you know.

Cloud and Internet of Things (IoT)

Nomenclature

- Cloud := someone else's computer (nothing more and nothing less)
- XaaS := X-as-a-Service (everything can be bought)
 - IT Trinity:
 - Compute
 - Store
 - Communicate (Network)



Internet-of-Things

- Sensors and actuators on all physical devices.
 - Detect aspects of the world.
 - Interact with the world.
- Measure lots of data.
- Analyze data.
- Make clever decisions and act.
- Hopefully learn something about this world.
- But also: Internet-of-Threats.

Multimedia Internet

Voice-over-IP (VoIP)

- Already replacing most in-company phone networks and services.
- Commonly used by people staying in contact across the globe (e.g. Skype).
- Starting to be used in mobile phone networks (LTE).

IP-TV

- Broadcasting television using the Internet (but with the same experience as before).

Games

- Need for high interactivity and high reliability to be entertaining.

All-IP / Next-Gen Networks (NGN)

Special purpose networks are migrated to shared infrastructure.

Applications (broadcast media, telephone, industry, medical services...) with custom solutions are now using IP, TCP and other Internet protocols.

Software-Defined Networking

- Raised interest since "OpenFlow: enabling innovation in campus networks" (2008).
- Gained traction with industry and academia since then.
- We have our own SDN testbed and research going on [here](#).
- Market to surpass \$1.4bn in 2015 ([Source](#)).
- Main driving factors for SDN rise:
 - Cloud / Fog Computing.
 - Big Data and Analytics.
 - Mobility.

Future Internet

⌚ Tactile Internet

- Term coined by [ITU](#).
- Goal: End-to-end latency below 1ms.
- Requires rethinking of:
 - Network infrastructures.
 - Network protocols.
 - Execution environments (operating systems, hardware platforms).
 - Control algorithms.
 - Network models.

↳ Industry 4.0

- Industry has long used custom communication solutions (CANBUS, OPC-UA, etc.).
- Reasons were:
 - Unreliability of Internet technologies.
 - Different requirements (more reliability > high data rates).
- Today: Demands have changed, Internet technology got better and most importantly cheaper.
- But also: Exploit 4.0.

Wanted Alive: Network Engineers

Definition

network engineer

[net-wurk en-juh-neer]

noun. A person solving problems you didn't know existed in the first place using methods you don't understand.

see also: magician, voodoo master

Facts

- Few people know how networks and telecommunications really work.
- Significant demand for new systems to be built, including new paradigms and approaches.
- Old systems to be maintained and migrated to and integrated with new solutions.
- Concepts of data networks are applicable in other domains (e.g. energy networks).



Networking is an important topic and you should learn more!

Course Organisation

Outline

- Theoretical foundations of communication systems and networks.
- Top-down tour through the network stack (for instance OSI model):
 - Application Layer: HTTP, DNS, Email, SSH, Telnet, ...
 - Transport Layer: TCP, UDP, RTP, ...
 - Network Layer: IPv4, IPv6, ICMP, ...
 - Data Link Layer: Ethernet, 802.11, ...
- Practical skills:
 - Socket Programming / Network Software Design
 - Network Design and Architecture Considerations
 - Troubleshooting Methodology

Prerequisites

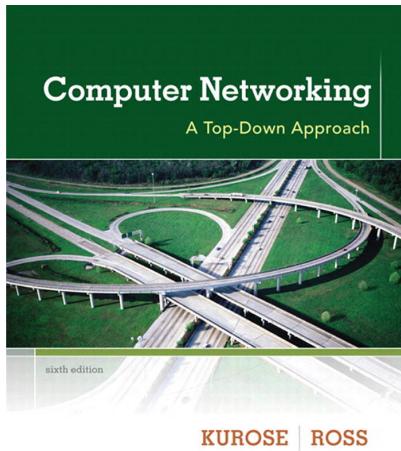
- Enough **motivation and drive** for taking part in a short but intensive course with many new concepts.
- No networking knowledge required.
- Elementary programming skills required (e.g. Programmierung 1+2, Programmieren für Ingenieure).
- **Python** skills are beneficial, but there will be a tutorial on that later.

Which content is explicitly not taught?

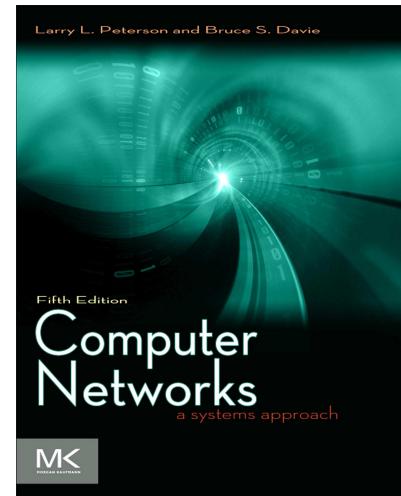
- Routing Protocols, Queueing Theory, ...
 - Advanced topics dealt with in the *Data Networks* core lecture.
- Advanced Network Security:
 - Security is important, but incorporating it makes simple things very complex.
 - There is an extra course for that (*Network Security*, next iteration SS18).
- In-Depth Physical Layer:
 - Attend our lecture TC1, TC2 to get more details.
- Advanced Multimedia Communications:
 - Attend our lecture FMI to get more details.

Primary Literature

Computer Networking - A Top-Down Approach (*Kurose / Ross*)



Computer Networks - A Systems Approach (*Peterson / Davie*)



- Approach similar to ours.
- Read along to dive deeper into concepts.
- Methodology different.
- Read to get another perspective on certain topics.

How should I rework the lectures?

We meet from 08:30 - 15:00 each day...

⚠ This is not all the time you should spend on this course (if you consider passing).

Instead you **MUST** ([RFC2119](#)):

- Give the slides another pass and check if you understood all concepts.
- Read the material mentioned under *Further Reading* at the end of each lecture.
- Lookup concepts in the mentioned literature to get a different view.
- Experiment with the code and software we provide you.
- Raise questions in class or lab, so that gaps can be filled.
- Have a look at RFCs like the one above to find out how things exactly work.

Furthermore, you **MAY**:

- Start developing network software on your own.
- Explore protocols we do not cover, but which are related to things we cover.

You **SHOULD NOT** waste time to idle... even though it's semester break.

Regulations

Learning Units

- Presence Period: Feb. 19th - Mar. 02nd
- Three slots per day (all times sharp, s.t.):
 - 08:30 - 10:00
 - 10:00 - 12:00
 - 13:00 - 15:00
 - Irregular breaks (as necessary, matching the content)
- Lectures and Labs with irregular pattern.
 - See preliminary schedule in CMS.
 - Final lecture on Mar. 02nd

Examination

Written Exam

- Written on March, 27th
 - Reexam on May, 8th
- Covering all content from the lectures.
- Duration: ca. 60 - 90 minutes.
- Passing Criteria: 50% of achievable points.

Projects

- Period: Mar. 02nd (Release) - Mar. 16th (Deadline UTC/GMT +1)
- Passing Criteria:
 - **Single** submissions (no groups).
 - **One** project **must** be passed.
 - For passing **both** projects you get **+10%** on **your** exam points.
 $30P \rightarrow 33P$

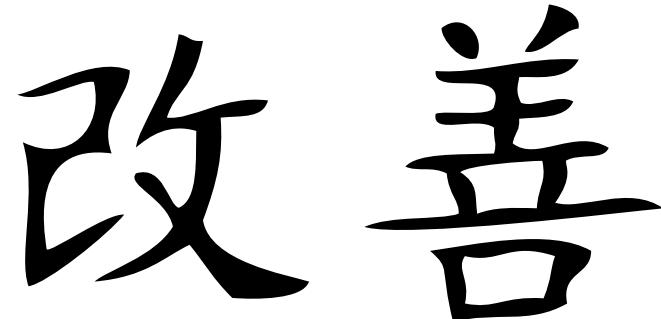


Course only passed if **exam and projects** are passed.

Continuous Improvement

If you have problems with some aspect of the lecture, **please tell us.**

We have updated the course material to **Python 3.6** instead of 2.x, so tell us in case you find any leftovers!



[Source](#)

Bug Bounties: If you point out bugs / provide good suggestions, you get a bounty (or snickers... whatever is available).



[Source](#)

⚠ Careful: You are not awarded with a bounty when raising the doubt *during the lecture*, as this might be *disturbing*.

Questions?

Wrap-Up

🏡 Take-Home Messages

- Telecommunications and Networking are old fields, but **still highly relevant**.
- Transmission system face **new challenges** and need **new solutions**.
- HON has three parts: **Lecture/Tutorials, Exam, Projects**.
- Designing telecommunication systems well can **save your life!**

📘 Further Reading

- <https://cms.nt.uni-saarland.de/hon18/> (if you have doubts about orga)
- Kurose-Ross "Computer Networking" (Sec. 1.1., 1.7)
- Dirk W. Hoffmann - "Einführung in die Informations- und Codierungstheorie" (optional, for more historic trivia)