1 Communication Networks – Examples and attempt of a definition

1.1 Ubiquitous diversity

Communication networks connect two or more entities with the aim of exchanging information. Participating entities can be living beings (humans, animals, plants), organizations (states, cities, companies, universities, etc.) and/or technical devices (machines, computers, robots).

The classic example of a simple communication network is a conversation between two people. They generate speech signals with their voice and transmit information to their counterpart by means of sound waves (Fig. 1.1-1).

Fig. 1.1-1: Communication network with Russian President Vladimir Putin (left) and German Chancellor Olaf Scholz (right) in the Kremlin, Moscow, Russia, on February 15, 2022

Universities can also join together to form communication networks. One such example is “Hochschule Bayern e.V.”, an association of all Bavarian state and church universities of applied sciences. The association communicates the goals and activities of the universities to the ministry, politicians and the public. Here, too, people are the sources of information (Fig. 1.1-2).

Fig. 1.1-2: Map of the "Hochschule Bayern e.V." communication network

In addition to these human-dominated communication networks, technical communication networks are increasingly move into the foreground. Multiple computers are connected to form computer networks and supercomputers (Fig. 1.1-3).

Fig. 1.1-3: Supercomputer Frontier (HPE), Oak Ridge National Laboratory, USA
(currently (March 2023) world's most powerful computer, processors: AMD Optimized 3rd Generation EPYC 64C 2 GHz, 8 730 112 cores,
computing power: $1.102 \cdot 10^{18}$ flop/s)

Computers and industrial robots are connected to each other in industrial plants in communication networks (Fig. 1.1-4).

Fig. 1.1-4: Industrial robots in the automotive industry

Humans cooperate with so-called cooperative robots to achieve a common goal or work hand in hand with collaborative robots on a common task. Different types of human-machine interfaces enable the simultaneous integration of humans and robots in novel network structures (Fig. 1.1-5).

Fig. 1.1-5: Human-machine interfaces that had been developed as functional demonstrators developed at the Institute of Medical Engineering Schweinfurt (IMES)

Of particular interest is the communication between humans and humanoid robots. As an example, consider the humanoid robot lady *Sophia* from the Hong Kong company Hanson Robotics (Fig. 1.1-6).

sophia1

Fig. 1.1-6: Interview of the robot lady *Sophia* (left) by the Deputy Secretary General of the United Nations Ms. Amina J. Mohammed (right) at the UN meeting on October 11, 2017.

According to the manufacturer, the humanoid robot *Sophia* possesses artificial intelligence, is equipped with speech processing and the ability to visually process data and recognize faces. It imitates human gestures and facial expressions, can answer certain questions and hold simple conversations about predefined topics.

Sophia became the first humanoid robot to receive the citizenship of Saudi Arabia in 2017 at the Future Investment Initiative international conference in Riyadh.

Technical specifications of *Sophia*:
Size: 167 cm,
Weight: 20 kg,
Sensors: Wide-angle chest camera (Intel RealSense, 1080p), 2 HD-Kameras (720p, one for each eye), external USB microphone, joint angle sensors and force sensors in arm joints, touch sensors in fingers, audio localization array, inertial measurement unit (IMU),
Aktuators: Head and neck: 5 Dynamixel XM430 servos und 23 Xpert servos; Eyes: Hitec HS-65MG servos; Neck: 3 Dynamixel XM430 servos; Arms und hands: 2 Dynamixel MX64 servos, 1 Dynamixel MX106 servo, 4 Dynamixel XM 430 servos, 6 Xpert servos, 2 MKS servos (per arm/hand),
Degrees of freedom: 83 (head and neck: 36, arm and hand: 15, torso: 3, mobile base: 14),
Electrical power: 110/220 V or 24 V-lithium-polymer battery,
CPU: 3 GHz Intel i7, 32 GB RAM, integrated GPU,
Software: Ubuntu Linux OS, Ethernet, Wi-Fi,
Materials: Frubber (actuated skin), carbon fiber, CNC aluminum, steel, spektra fiber, Delrin thermoplastic, acrylic, polycarbonate, 3D-printed parts and other mixed materials.

The three future technologies that will most shape the 21st century are genetics, nanotechnology and robotics (GNR technologies), according to Ray Kurzweil, futurist and Google's head of engineering development. The combination of these three fields of technology will open up entirely new opportunities for humans, while at the same time creating profound problems when misused.

The technologies will have a particularly positive impact in the field of medical technology. One example is the development of a nanorobot for functional medical imaging in a collaborative project between the Chair of Experimental Physics V - Biophysics, the University of Würzburg and the Institute of Medical Engineering IMES at THWS.

A nanorobot swarm of superparamagnetic iron oxide molecules (magnetite Fe_3O_4) surrounded by a polymeric protective shell is injected into the body of a living being (human, animal). The nanoparticles move autonomously through the body and attach to biological target molecules. Excited by external magnetic fields, they transmit information about their position and the internal biochemical function of tissues and organs in a contactless manner by means of emitted electromagnetic fields. Figure 1.1-7 below shows the nanoparticle, schematic structure of the Transmit/Receive magnetic system, working prototype and results of an examination of the heart muscle of a mouse.

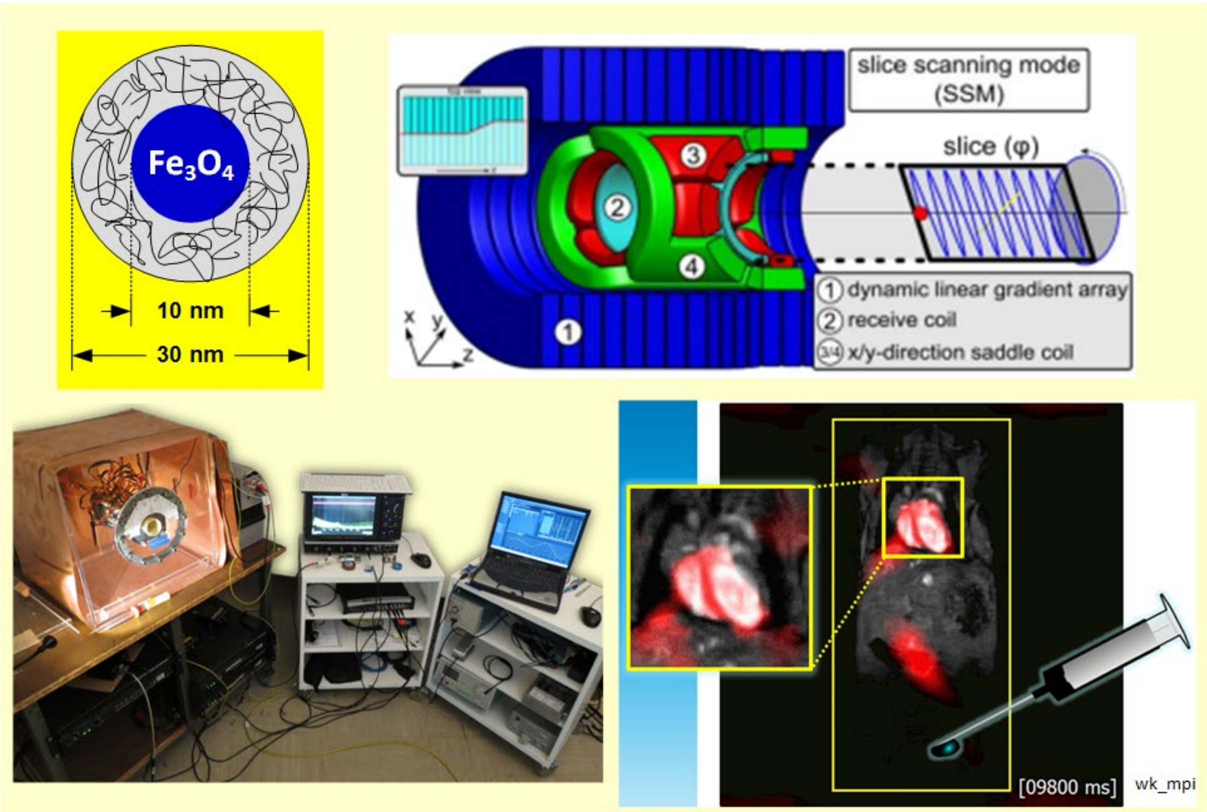

Fig. 1.1-7: ***Magnetic Particle Imaging*, a new medical imaging technique using superparamagnetic nanorobots for functional diagosis**

The most complex and fascinating communication network on earth is the human brain. It contains about 100 billion neurons, each of which is interconnected with neighboring neurons via up to 10,000 synapses.

Reading this script involves a large number of neurons in different activity centers inside the human brain (Fig. 1.1-8).

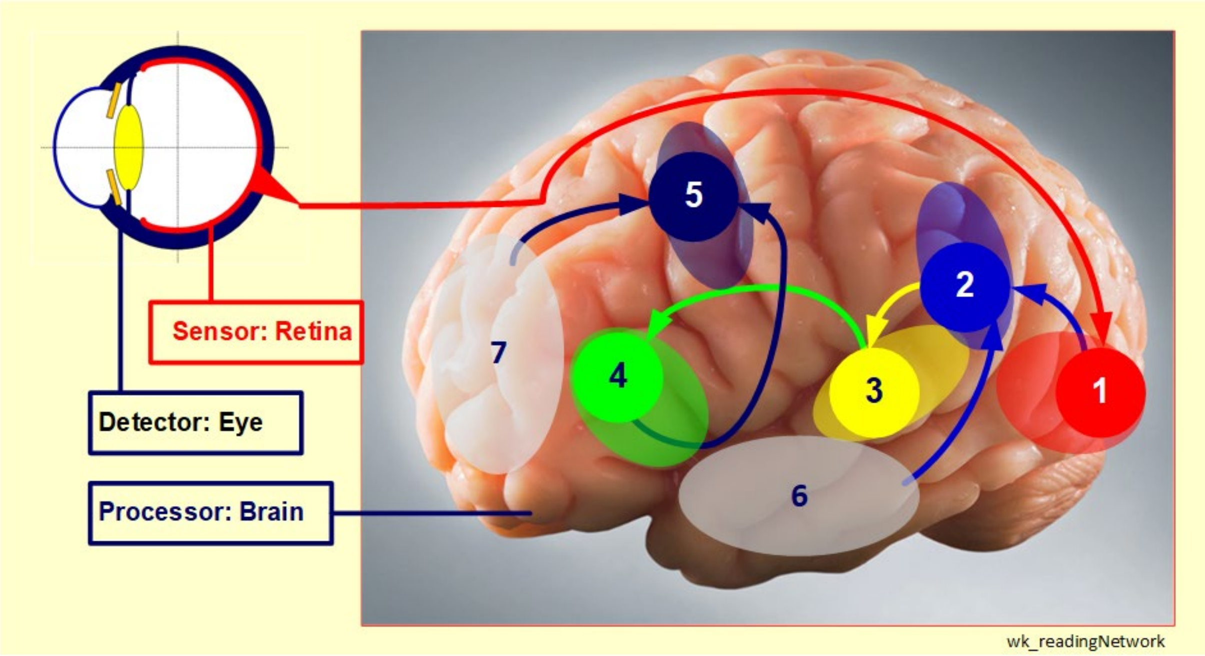

Fig. 1.1-8: Schematic of the "reading network" as part of the neural communication network in the human brain

Explanation of the "reading network":

Detection of letters with the eye, transformation into electrical signals in the retina.

1: **Visual center**: Signal transmission to the visual center (visual cortex) in the occipital lobe of the brain, recognition of the shape of the letters,

2: **"Reading center"** in the angual gyrus (in the parietal lobe): translation of the visual form into an auditory code,

3: **Wernicke's area**: formation of words from the letters,

4: **Broca's center**: analysis of word meaning,

5: **Motor cortex**: readiness to speak,

6: **Inferotemporal cortex**: storage of memories of visual perceptions,

7: **Prefrontal cortex**: memory for temporal sequence of events.

1.2 General communication model according to Claude E. Shannon

In 1948, the American mathematician and electrical engineer Claude E. Shannon published a general information model that has since served as a fundamental building block for modern digitization.

The model consists of two abstract communication partners, the sender and the receiver, as well as an external interference source, the so-called noise source (Fig. 1.2-1).

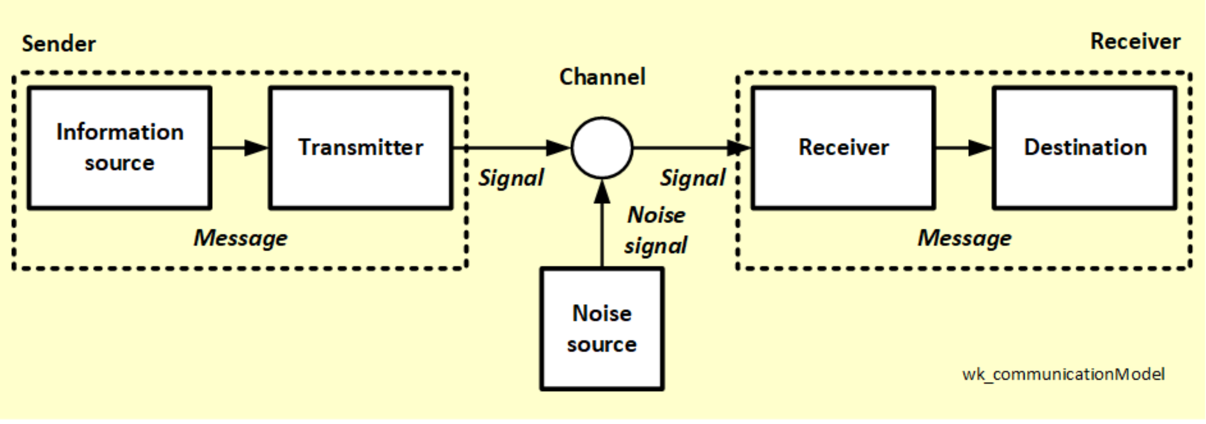

Fig. 1.2-1: General communication model according to Claude E. Shannon

The **information source** generates a message, which can occur in different forms:

- static string of characters,
- time-dependent sequence of characters,
- spatio-temporal sequence of 2D or multidimensional character sets,
- multimodal information (image, sound, ...).

The **transmitter** transforms the message into a signal that can transported to the receiver via the transmission channel.

Different physical media can serve as a **channel** (transmission channel): electric line, optical fiber, electromagnetic waves, sound waves in the air, etc.

On the transmission channel, unpredictable interfering signals can mix with the actual working signal to be transmitted. Noise sources (electromagnetic interference, natural phenomena (lightning), noise, etc.) serve as the **noise source**.

The **receiver** shows the inverse behavior to the transmitter. It detects the signal from the transmission channel and reconstructs the message of the transmitter.

The **destination** represents the human or the thing (machine, robot, etc.) for which the message of the sender is addressed.

All technical communication systems can be modeled with this basic model.

Exercises

E.1.1-1: Which possibilities does a human have to communicate with an appropriately built robot?

Identify at least five different techniques.

E.1.2-2: A human "talks" to a humanoid robot.

Assign the corresponding properties or system components of humans and robots to the subcomponents of the general communication model according to C.E. Shannon.