2 Introduction to the world of digital data networks

2.1 Comparison of digital data networks with analog technology

Modern technical communication networks, such as robot networks or the Internet, are based almost exclusively on digital techniques. Digital data networks are characterized by a number of advantages compared to analog networks:

- lower susceptibility to interference,
- easy storage of data,
- possibility of sharing different resources (devices, programs, data) in one network,
- high reliability,
- favorable price/performance ratio,
- scalability: adaptation of system resources to the needs in terms of current system performance,
- better protection of data against unauthorized access.

2.2 Characterization of data networks

Digital data networks are often characterized according to their spatial extent:

- **Local area network (LAN)**
  Data networks within an organization (company, university, etc.),

- **Metropolitan area network (MAN)**
  - Networks in inner-city areas or regional networks,
  - applications for high-speed networks,
  - spatial extensions: 1 km ... several hundred kilometers,

- **Long-distance network (Wide Area Network WAN)**
  - national networks,
  - world-wide, global networks (example: Internet).

In addition, digital data networks can roughly be characterized by three basic properties:

- **Network topology**: topological structure of the connections,

- **Network technology**: definition of the transmission media,

- **Access method**: Access to the data.

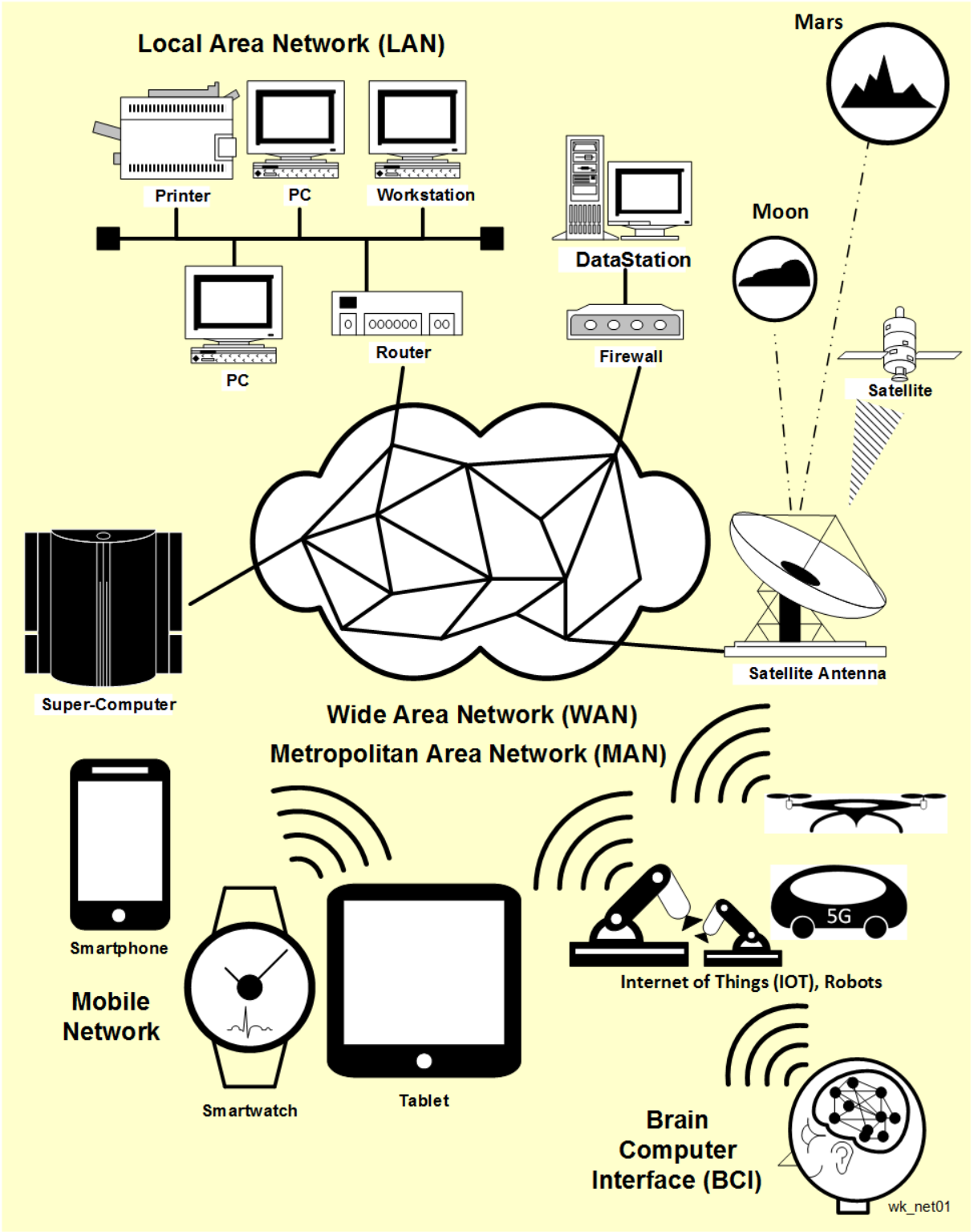

Fig. 2.2-1: Schematic structure of a digital network structure

2.3 Network topologies

2.3.1 Definition of terms

The network topology defines the structure of the connections between the data stations of a communications network, i.e., the architecture of the data network. In modern local data networks (Local area network LAN), four different topologies are mainly in use:

- Bus topology (Ethernet),
- Ring topology (Token Ring, Fiber Distributed Data Interface FDDI),
- Star topology (Ethernet with hub technology),
- Tree topology (Internet).

Topologies are represented as graphs with the data stations as nodes and the transmission links as edges.

Two characterizing classification properties for data networks are introduced, depending on the way the networks are used:

Store and forward network:
Messages travel from the sender to the receiver via one or more partial paths in the network from the sender to the receiver.

Diffusion network:
All stations are connected to a common medium. Sent messages can basically be received by all stations.

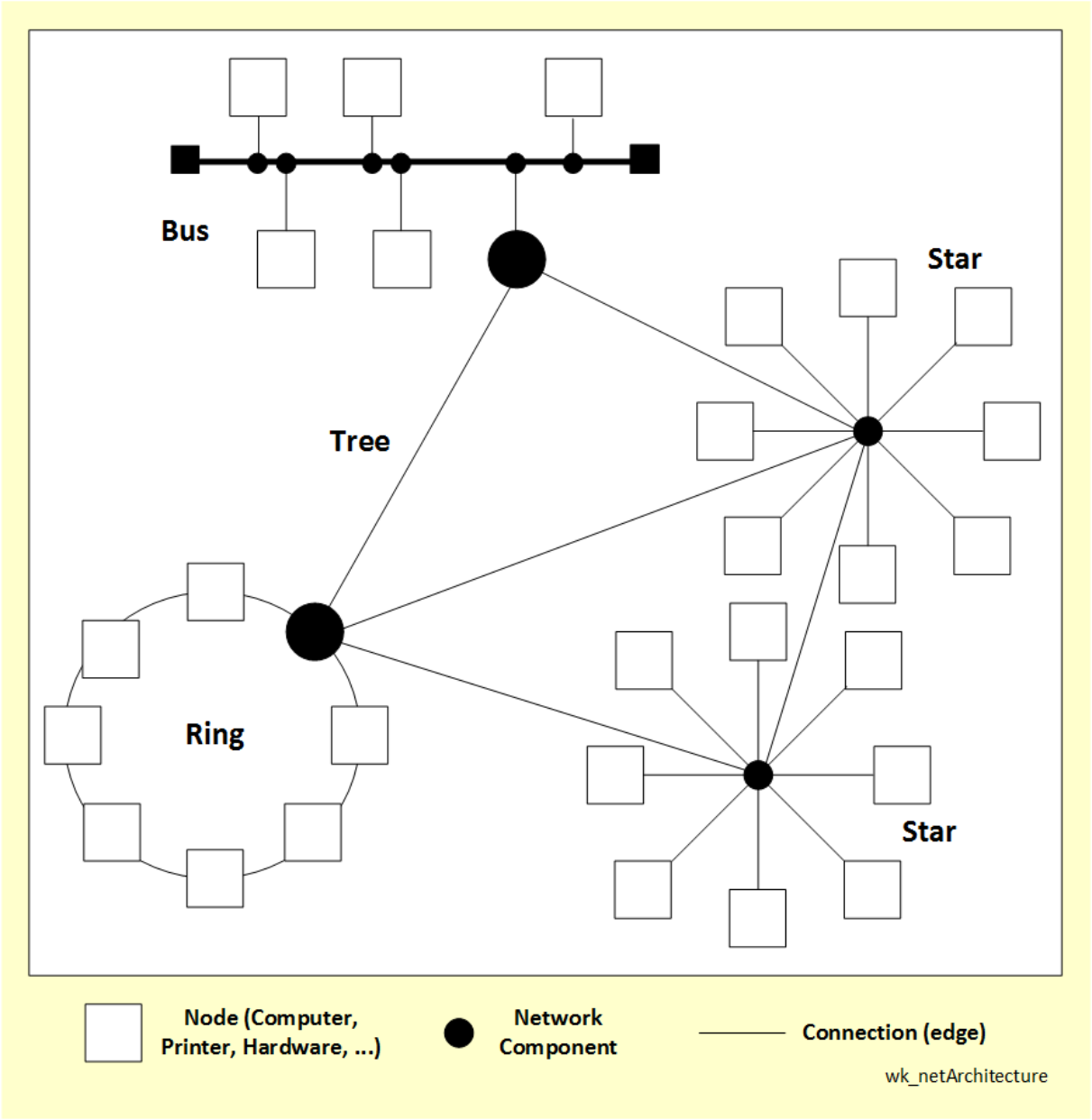

Fig. 2.3.1-1: Schematic representation of the basic network topologies

2.3.2 Bus topology

The **bus topology** consists of a central information channel to which the individual data stations (computers, workstations, IOT) are passively coupled. The ends of the information channel are terminated with the characteristic impedance of the cable to avoid reflections. Networks with bus topology are diffusion networks. Signal propagation occurs in both directions as observed from the transmitter station.

Example: Ethernet-based local area network (LAN).

The bus topology shows various characteristic properties:

- The setup is cheap and easy to install.
- Due to the passive coupling of the data stations, the shutdown or failure of one workstation does not lead to any negative repercussions for the other stations.
- Adding new stations can be done during network operation without shutting down the network.
- All messages sent in the network are sent to all data stations in the network. No routing mechanism is required.
- Passive coupling of the data stations results in a limitation of the bus length and the number of data stations to be integrated if no signal regeneration takes place.
- Data access methods limit the maximum extension of a network.
- Problems with the core data cable lead to failure of the entire network.

2.3.3 Ring topology

A closed loop of point-to-point connections corresponds to the ring topology. The data stations form active components for regeneration and retransmission of incoming data.
In practice, LANs usually use double rings to minimize the susceptibility to errors. In the event of failure of the active ring, the network reconfigures itself independently via the second ring.

Example: FDDI (Fiber Distributed Data Interface)

Characteristic properties of the ring topology:

- Ring topologies require a minimum number of edges.
- Active network stations enable the construction of large networks in terms of the number of data stations as well as the geographical extent.
- The failure of one station leads to the collapse of the entire network if no special safety measures are provided.
- In case of a modification of the network (installation or removal of a node), the entire network must be shut down.
- In general, data is only transported in one direction in the ring. Routing facilities are not required.

- Networks with ring topology are highly unreliable due to the low degree of interconnection.

2.3.4 Star topology

In a network with **star topology**, all network nodes are connected to a facility designated as the central station (e.g., hub). All messages pass through this central node.

Example: Ethernet cabling with UTP-5.

Characteristic properties:

- A network with star topology with N network nodes (without central station) owns exactly N connections.
- Each connection between two nodes passes over two connecting links.
- Each connection is operated bidirectionally.
- Adding additional stations is extremely easy if the central station still has free slots.
- A failure of the central station leads to a failure of the whole network.
- Failures of the non-central nodes have no effect on the rest of the network.

2.3.5 Tree topology

In the **tree topology**, starting from the root of the network, the various data stations are reached via active or passive branching elements. The architectures within tree-topology networks satisfy the concept of structured cabling. They are highly variable, adaptable to a wide variety of spatial and organizational requirements, and they can contain networks with other topologies as substructures.
Tree topologies can also be implemented without a central switching station (root).

Example: Internet.

Characteristic properties:

- Feeding of messages into a "basic node" (root) and feed to all connected stations via distributors (splitter),
- easy adaptation to local and geographical conditions,
- easy expansion of further subnets,
- possibility of interconnection of different network topologies and LAN technologies, even over long distances,
- possible disintegration of the network into individual subnets in case of failure of partial connections.

2.3.6 Mixed network topologies - the normal case in complex networks

Modern digital communication networks usually integrate different network topologies, and their subnetworks extend over geographical areas of different sizes.

As an example, consider the control network of the International Space Station (ISS). The communication networks in the ground station on Earth and the network in the space shuttle have a mutual distance of roughly 400 km. The transmission channel between the two subnetworks uses microwave radiation in the S-band (2 - 4 GHz) as a carrier. The local networks on Earth and in the space station are set up as Ethernet networks based on mixed network topologies.
The ground station is connected to the Earth-wide Internet.

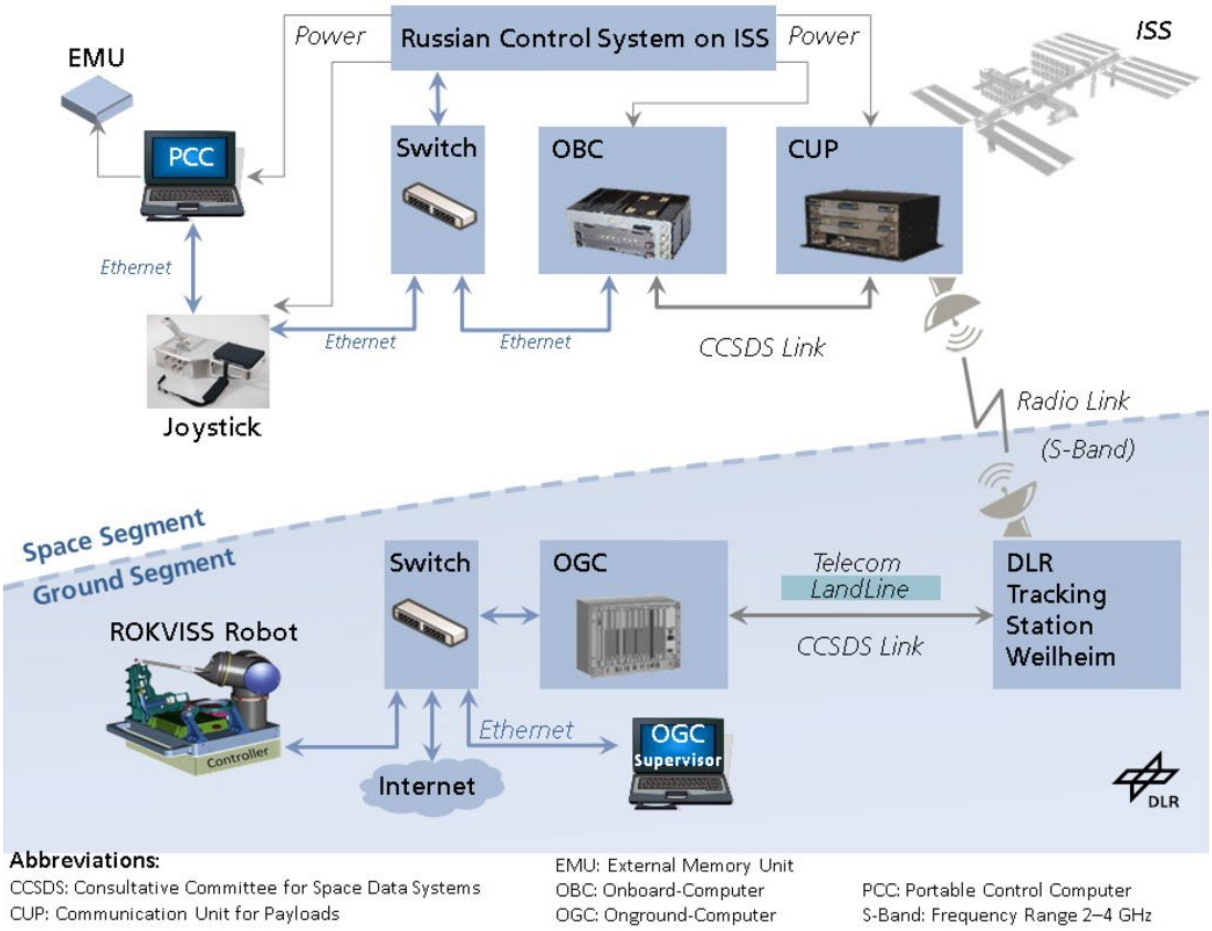

Fig. 2.3.6-1: Control network of the International Space Station (ISS)