Internet of Things
Networking Protocols and Standards
Introduction

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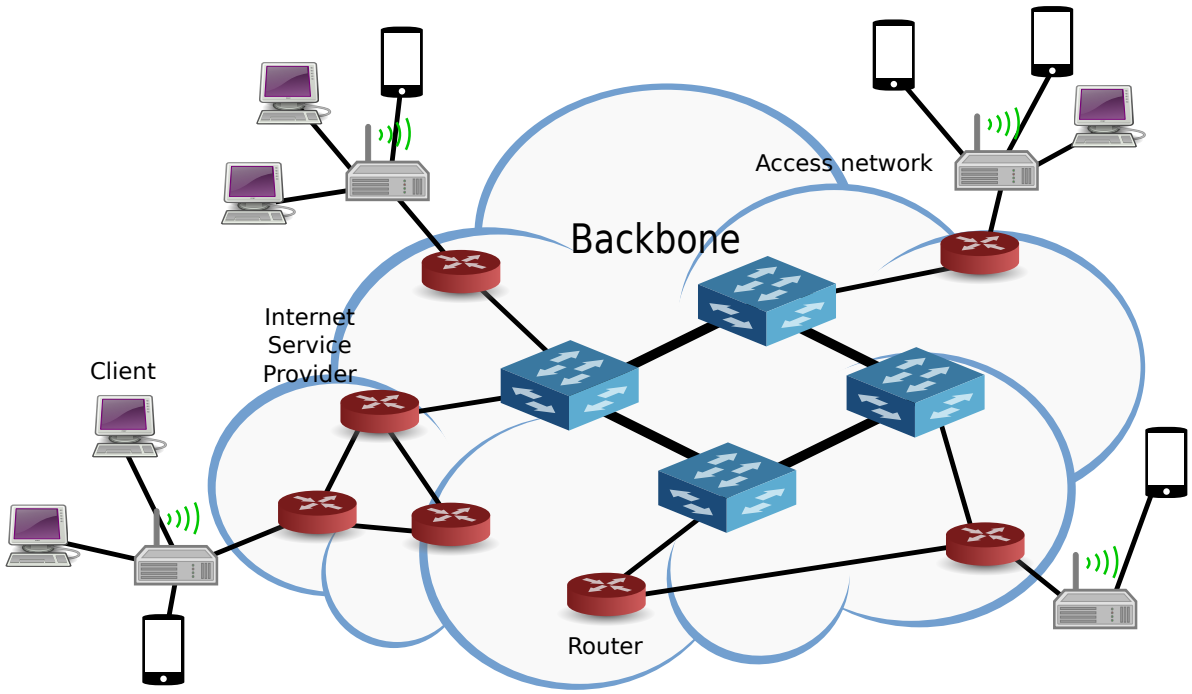
http://robot.unipv.it/toolleeo

What is a network

A **network** is a system to connect humans, places and objects



A large network has a hierarchical structure

Packet communication

In a data network, information is cut into chuncks called **packets**

Packets are composed by two parts:

- **Payload**: containing the data to exchange.
- **Header**: for network and control purpose.

Packet communication

Rules are necessary to correctly and uniquely interpret a packet

$\Rightarrow$ PROCOTOLS

Protocol specification:

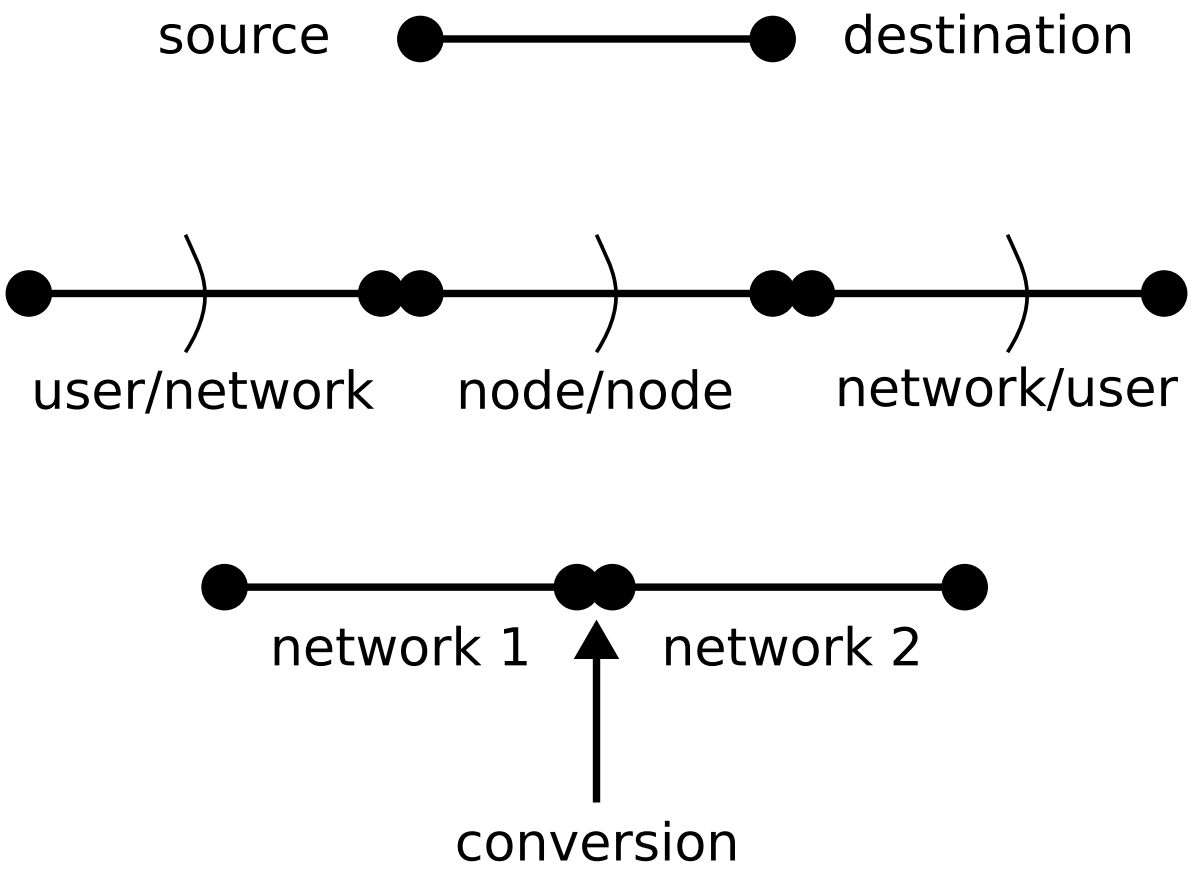
- Operates between the same layer on two systems.
- May involve different operating system.
- Protocol specification must be precise:
  - Format of data units.
  - Semantics of all fields.

Service definition:

- Functional description of what is provided.

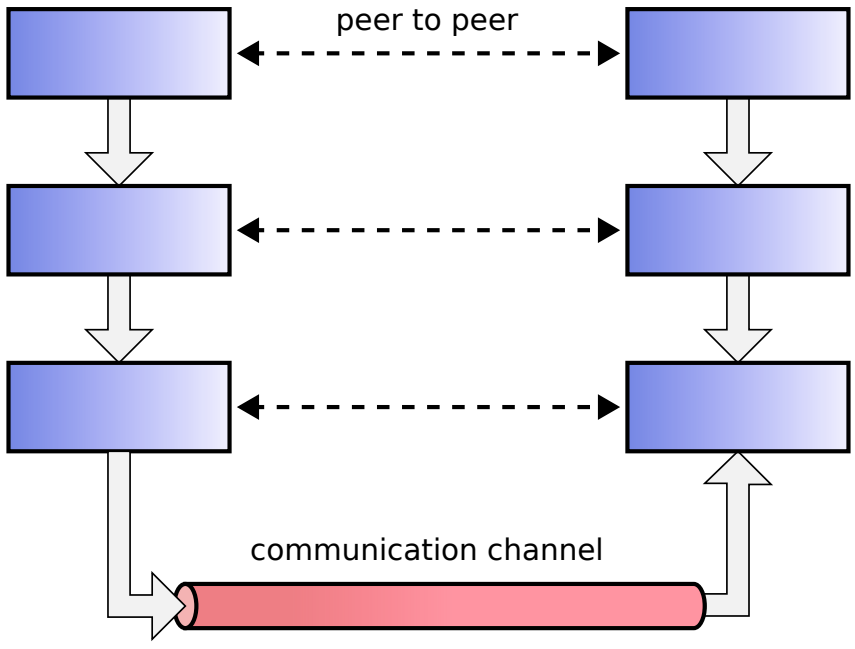
Protocols define interfaces

Between nodes



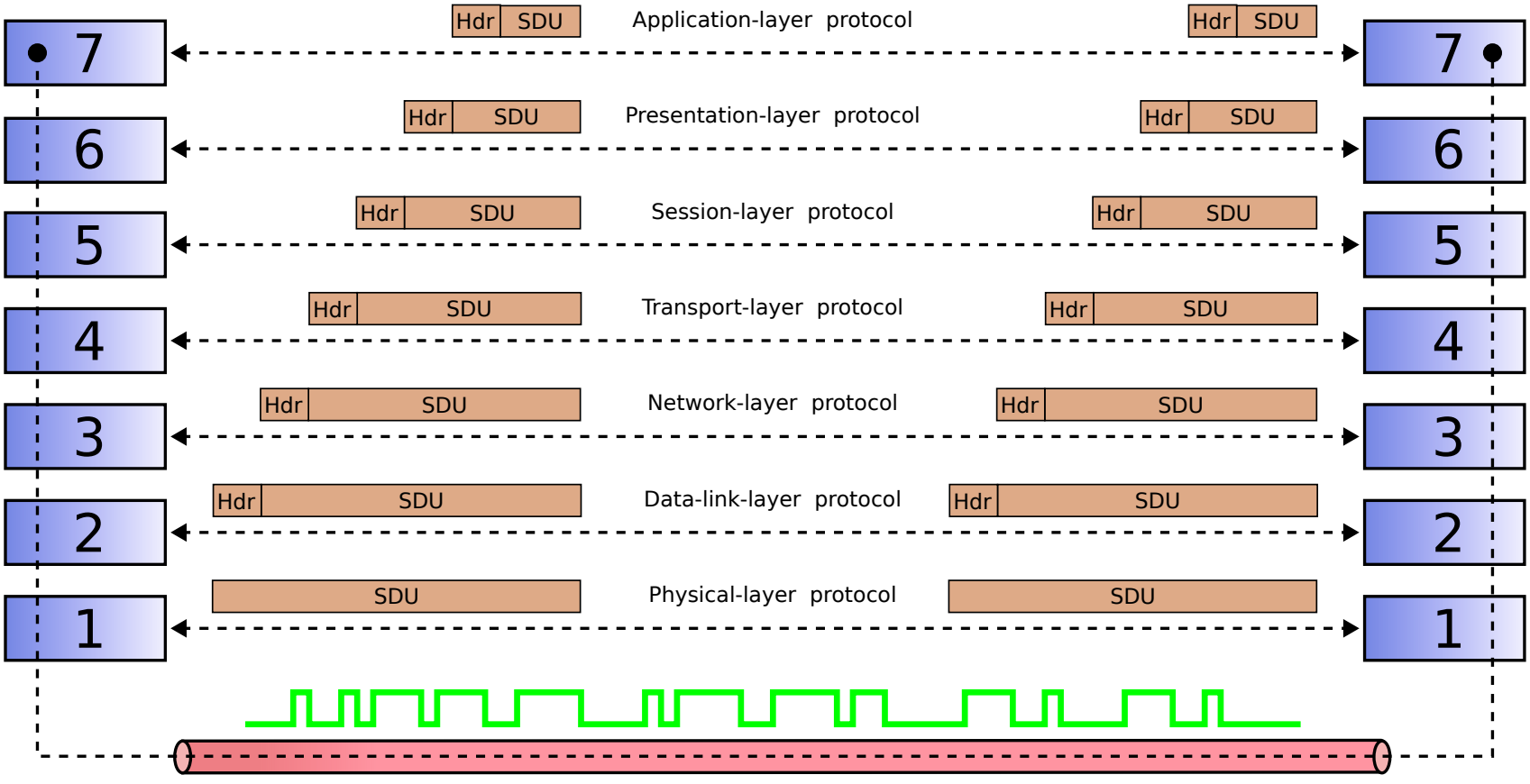
Protocols define interfaces

Between functions and services



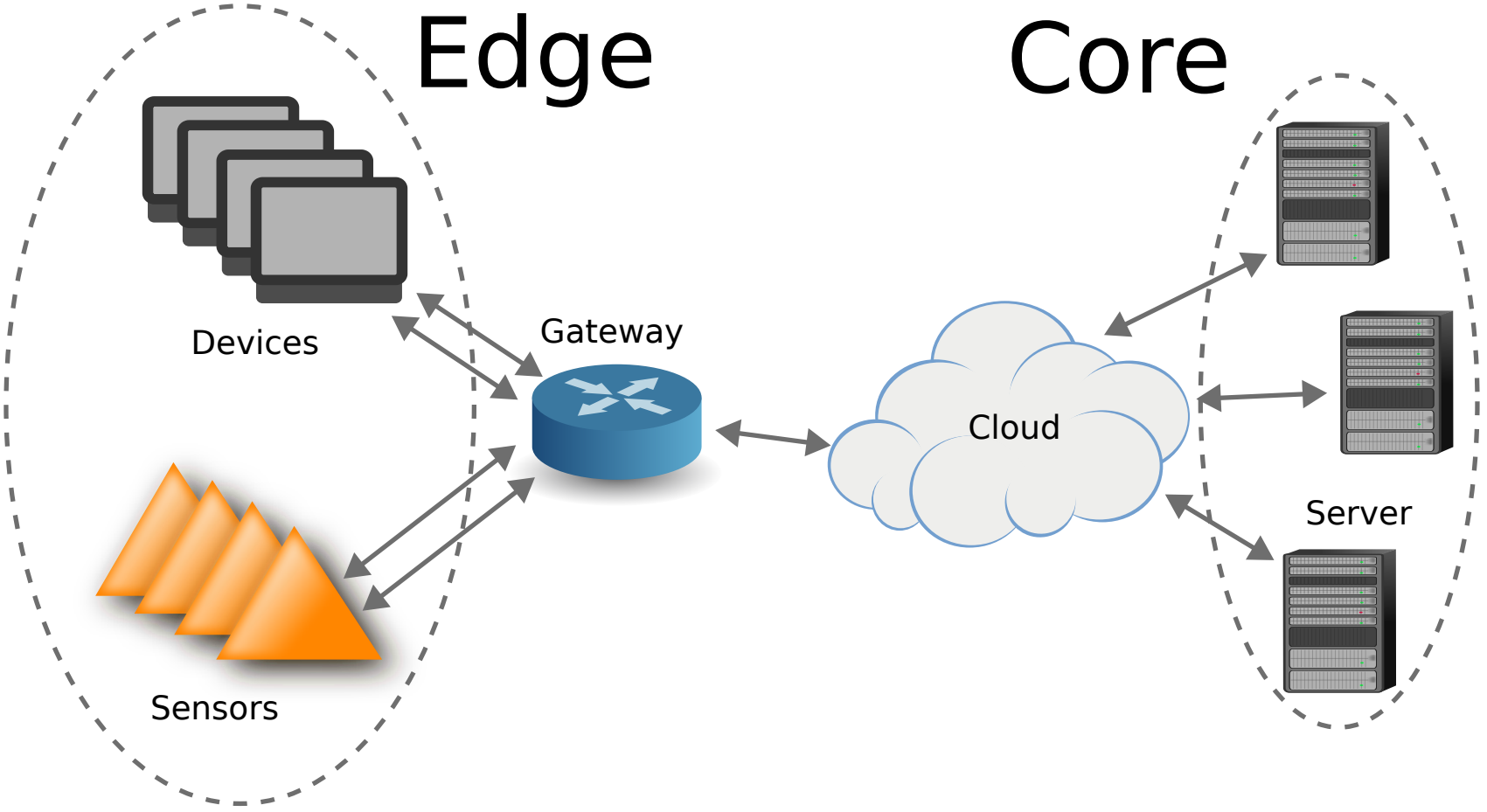
- All functions required to set up and maintain a connection are split into different **layers**.
- Each layer is characterized by its own rules and features.

Layers at work



SDU = Service Data Unit : a unit of data that has been passed down from a layer or sublayer to a lower layer.

Core vs Edge



Edge has devices
Core has servers

System model

Client

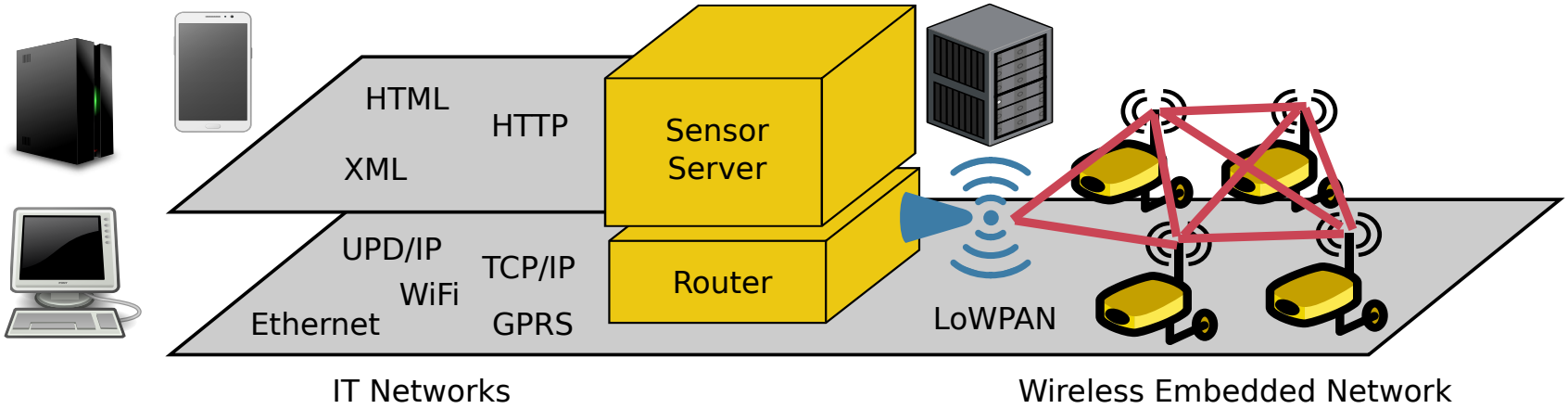
- Issues requests
- Consumes/presents responses
- Receives alerts

Server

- Manages embedded devices
- Collects and processes readings and events
- Presents embedded services
- Services requests

Wireless Sensor Device

- Takes measurements and actions
- Application-specific local processing
- Communicates over LoWPAN
- Routes (for others)
- Processes commands



Standards for machine communication

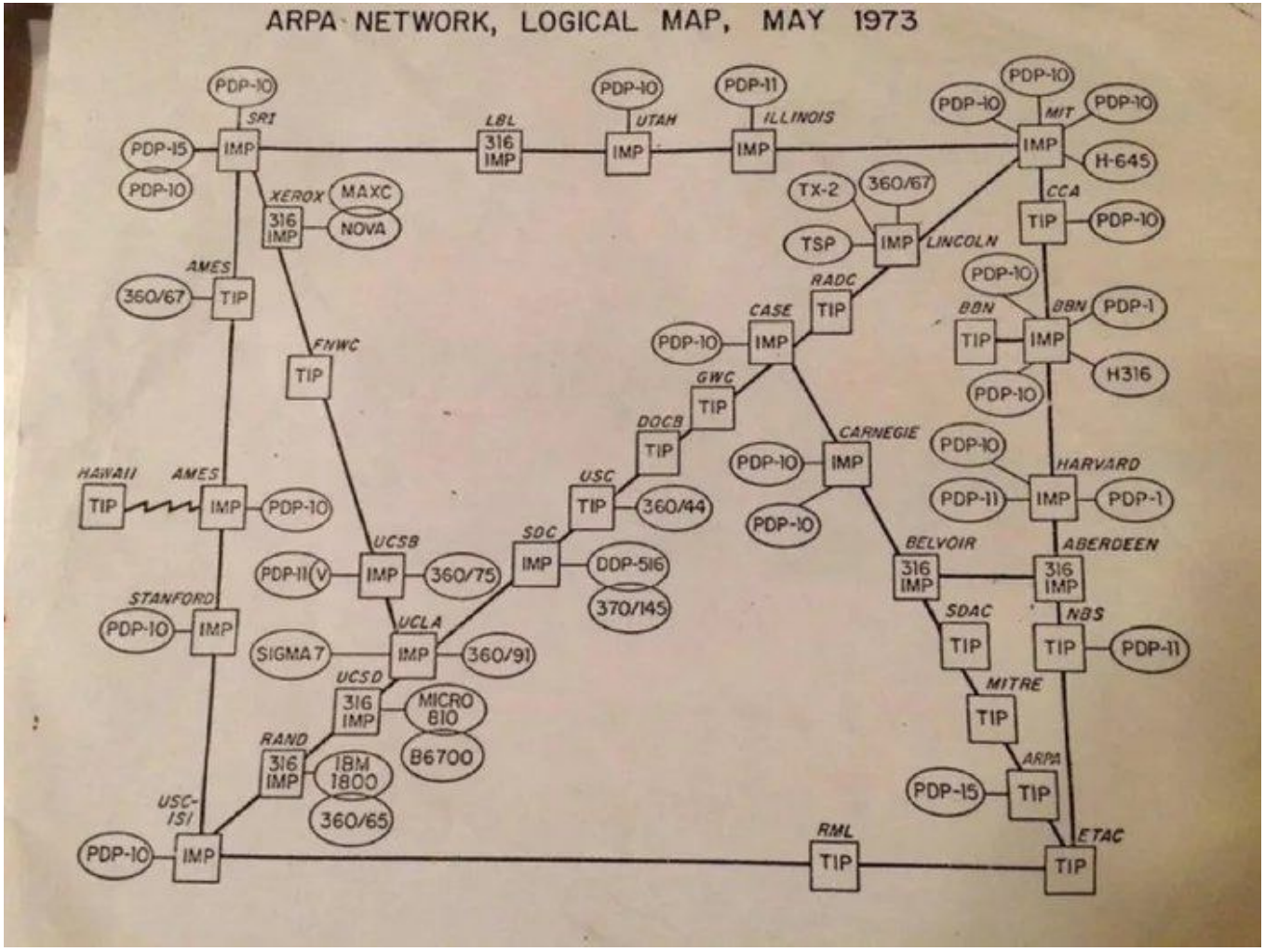
- **Cabled Networks**: Ethernet (32 variants!), HomePlug, HomePlugAV
- **Point-to-Point**: DisplayPort, DVI, FireWire, HDMI, SCART, USB
- **Field Buses**: Ethercat, PROFIbus, BACnet, BatiBUS, EHS, KNX / EIB, LON, X10
- **Wireless Networks**: WLAN, Bluetooth, DECT, HomeRF ZigBee, Z-Wave, EnOcean
- **Network Protocols**: AFP, BitTorrent, Bonjour/Zeroconf, CalDAV, CUPS, DHCP, DNS, DPWS, DynDNS, FTP, HTTP, IMAP, IPP, IRC, JetDirect, LDAP, LPR, NAT-PMP, NFS, OMA DM, POP3, RTP, RTSP, SIP, SMB, SMTP, SNMP, SSDP, SSH, TFTP, TR-069, UPnP, WebDAV, CHAIN/AIS, SML
- **Medical**: aECG, CCD, CCR, CDA, DICOM, EDF, EDIFACT, HL7, IHE, ISO/EN 13606, ISO/IEEE 11073, PHMR, SCP-ECG, xDT, XPHR, ICD-10, ICHI, ICPM, LOINC, OPS, SNOMED, UCUM, UMLS
- **Runtime**: OSGi, MIDP
- **Middleware**: URC, UniversAAL, oneM2M

About all such options...

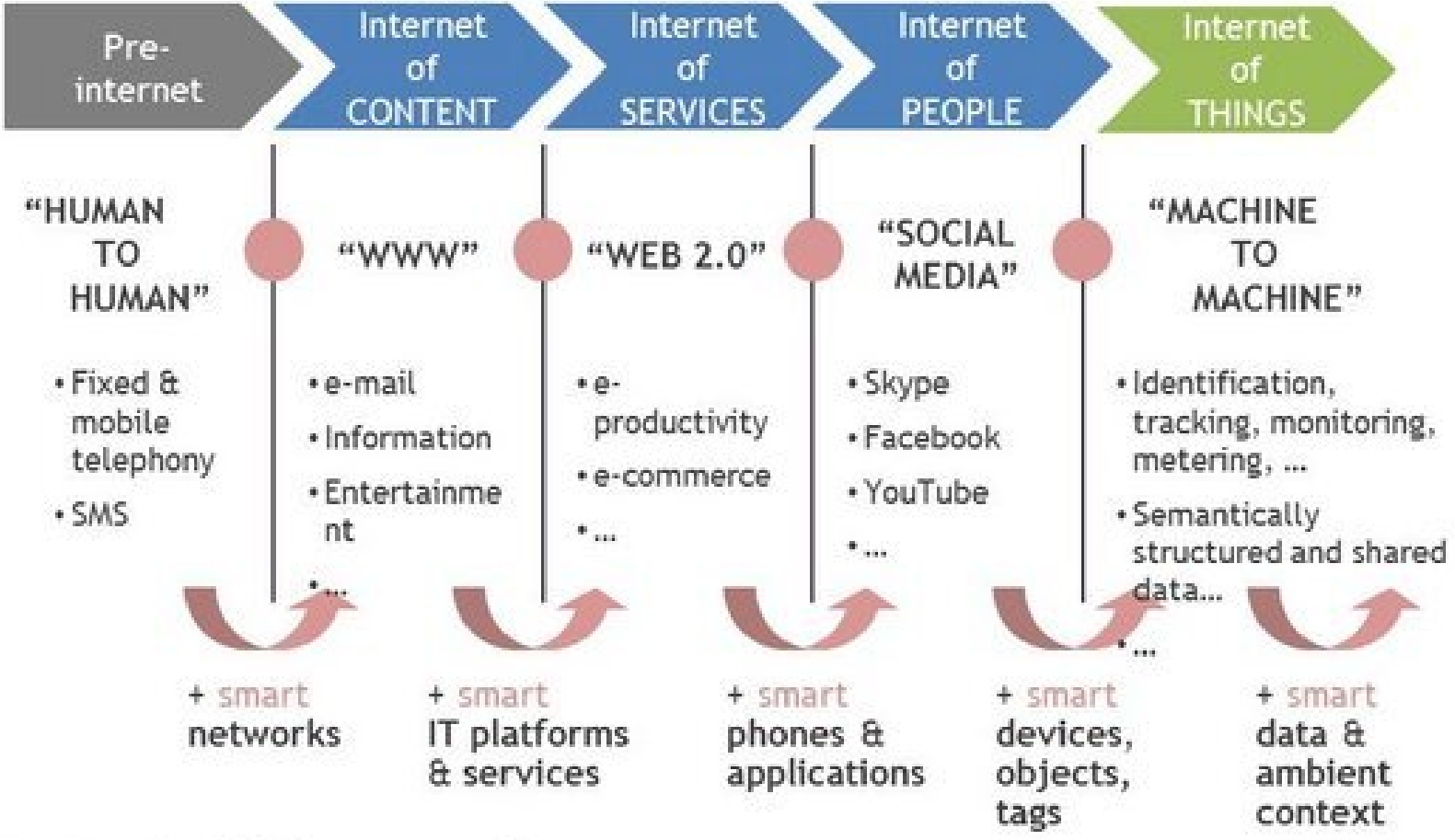
"the nice thing about standards is that
there are so many to choose from."

Andrew S. Tanenbaum

Internet (Arpanet) in 1973



Evolution of the Internet



Key characteristics

- All nodes have computation and communication capabilities of varying degrees
- There are several intermediaries between communication end points who may use different protocols across all layers of the OSI stack
- Any node is uniquely addressable from any other system
- Any node can offer a service. Additionally it can discover and consume any service offered by another node
- Nodes and services do not exist in isolation
- Any node can align itself with a logical network

The ISO OSI model

Application
Presentation
Session
Transport
Network
Data link
Physical

ISO: International Standards Organization
OSI: Open Systems Interconnection Reference Model (1984)

Layer 1: Physical Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- Defines the physical interface between devices
- Handles the transmission of raw bits

Issues:

- mechanical and electrical interfaces
- time per git
- distance

Layer 2: Data Link Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- Manages the reliable transfer of information between **adjacent** nodes
- Frame-level error control
- Control of flow

Issues:

- framing (dividing data into chuncks with header and trailer bits)
- addressing

Layer 3: Network Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- Path selection between end systems (dynamic/fixed routing)

Issues:

- fragmentation and reassembling
- translation between different network types

Layer 4: Transport Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- virtual end-to-end links between peers
- end-to-end flow control

Issues:

- headers
- error detection
- reliable communication

Layer 5: Session Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- establishes, manages and terminates a communication session between systems
- groups several user-level connections into sessions

Issues:

- several protocols do not include a session layer

Layer 6: Presentation Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

- represents data properly
- data encryption
- data compression
- data conversion

Issues:

- several protocols do not include a presentation layer

Layer 7: Application Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

Responsibilities:

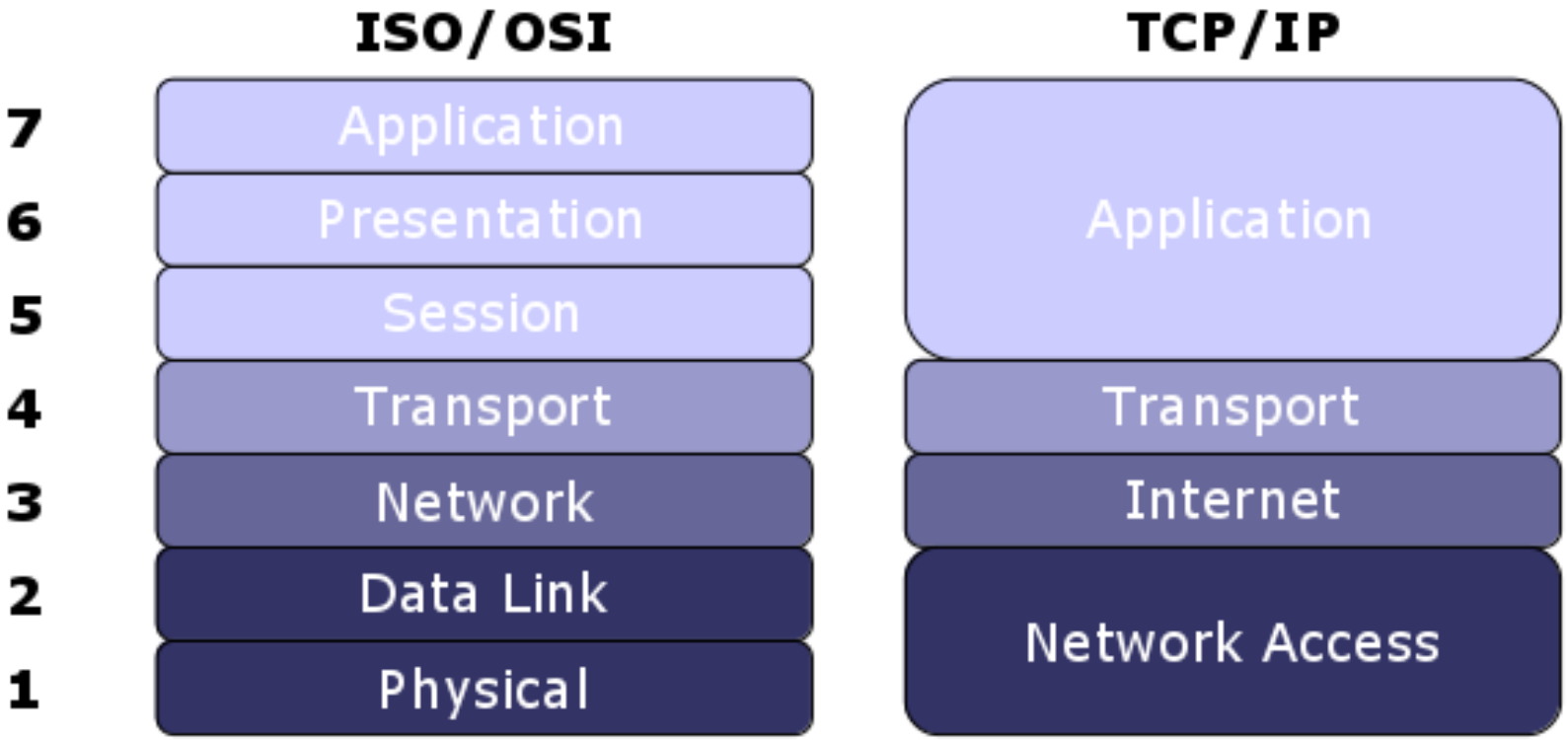
- anything not provided by other layers
- implement communications between two applications of the same type

Examples:

- HTTP, FTP, SMTP/POP3/IMAP

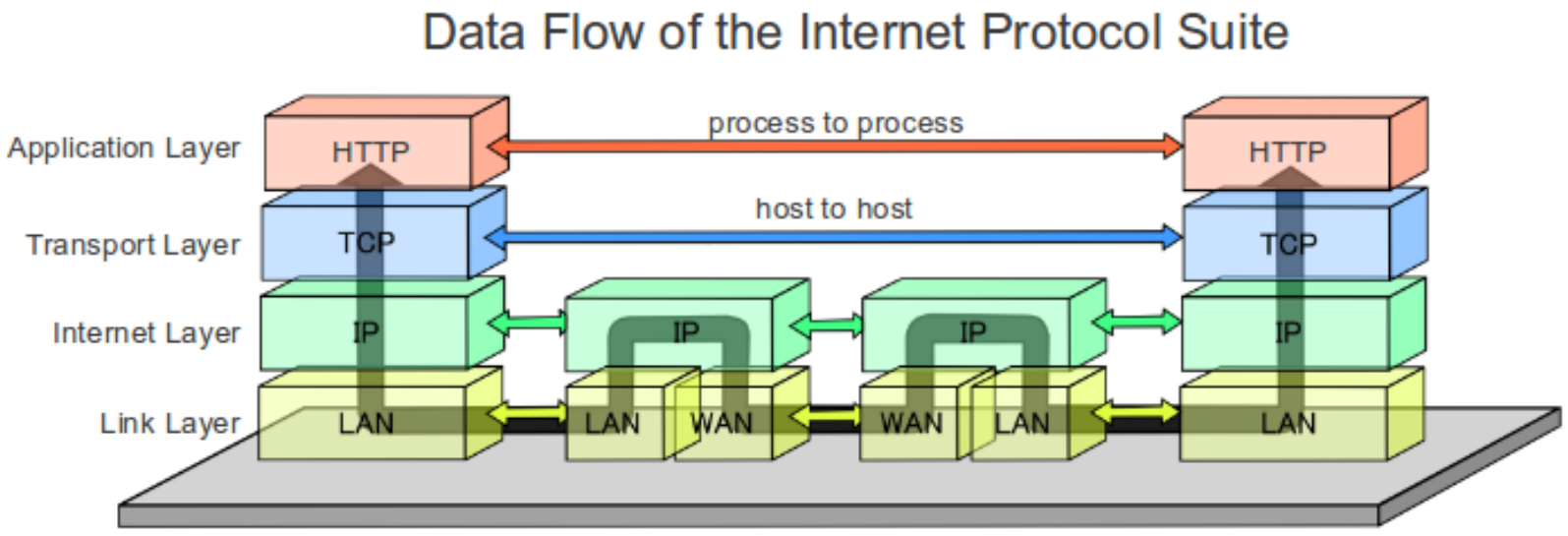
ISO OSI model vs TCP/IP model

Some protocol stacks have a simplified organization w.r.t. the full ISO OSI model



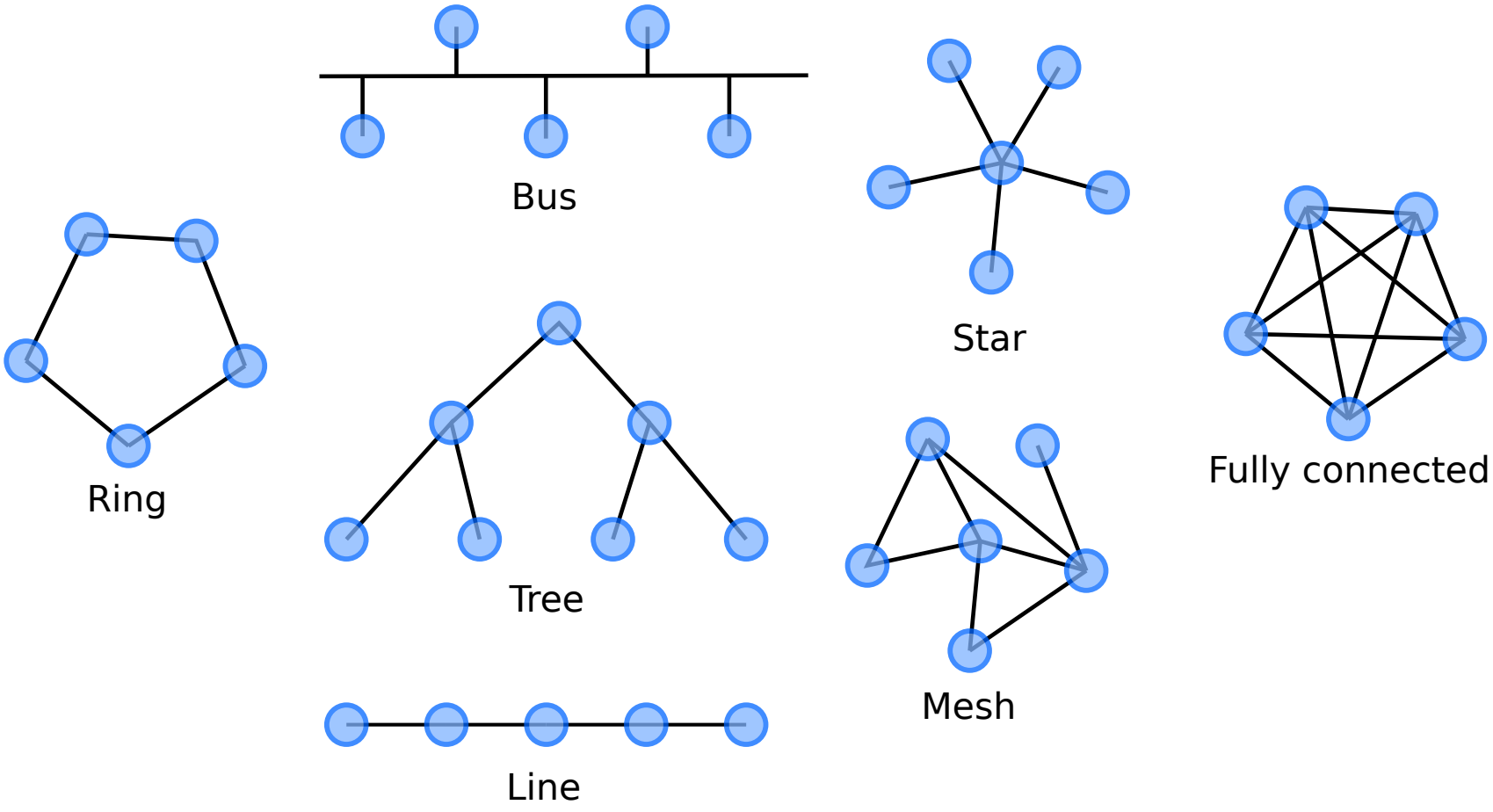
Source:
https://networkengineering.stackexchange.com/questions/24360/what-is-the-osi-session-layer-5-used-for

Data flow of the Internet Protocol Suite

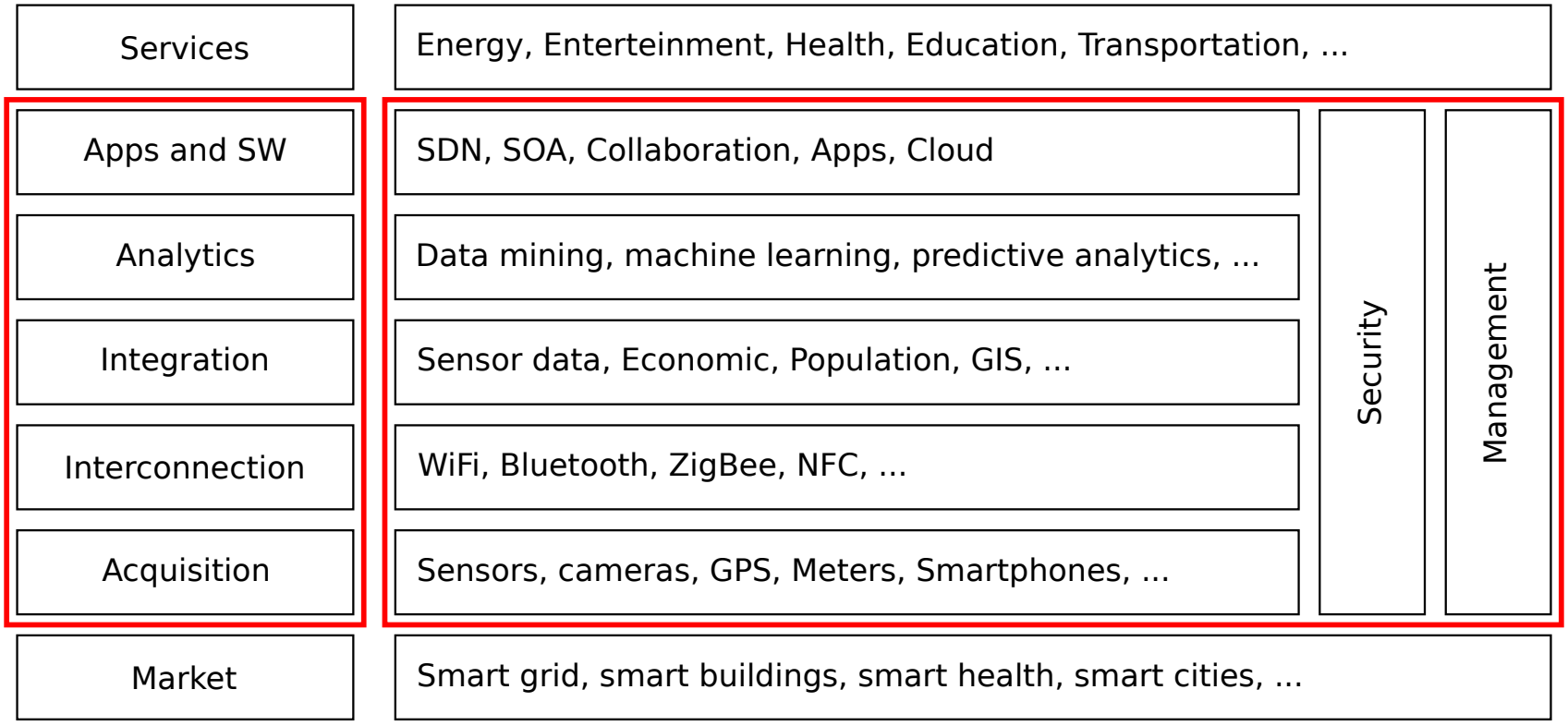


Source: `https://commons.wikimedia.org/wiki/File:Data_Flow_of_the_Internet_Protocol_Suite.PNG`

Network topology



The IoT ecosystem



The focus of the course is on the **interconnection layer**

IoT layers

IoT protocols operates at different layers of the networking stack. The following ones will be considered:

- Medium Access Control (MAC) layer
- Network layer
- Session layer

IoT protocols

Session		MQTT, SMQTT, CoRE, DDS, AMQP, XMPP, CoAP, ZeroMP, ...	**Security**	**Management**
Network	**Encapsulation**	6LowPAN, 6TiSCH, 6Lo, Thread, ...	TCG, Oauth 2.0, SMACK, SASL, ISASecure, ace, DTLS, Dice, ...	IEEE 1905, IEEE 1451, ...
	Routing	RPL, CORPL CARP, ...		
Datalink		WiFi, Bluetooth Low Energy, Z-Wave, ZigBee Smart, DECT/ULE, 3g/LTE, 5G, NFC, Weightless, HomePlug, GP, 802.11ah, 802.15.4e, G.9959, WirelessHART, DASH7, ANT+ LTE-A, LoRaWAN, ...		