Communication Networks 2

Introduction

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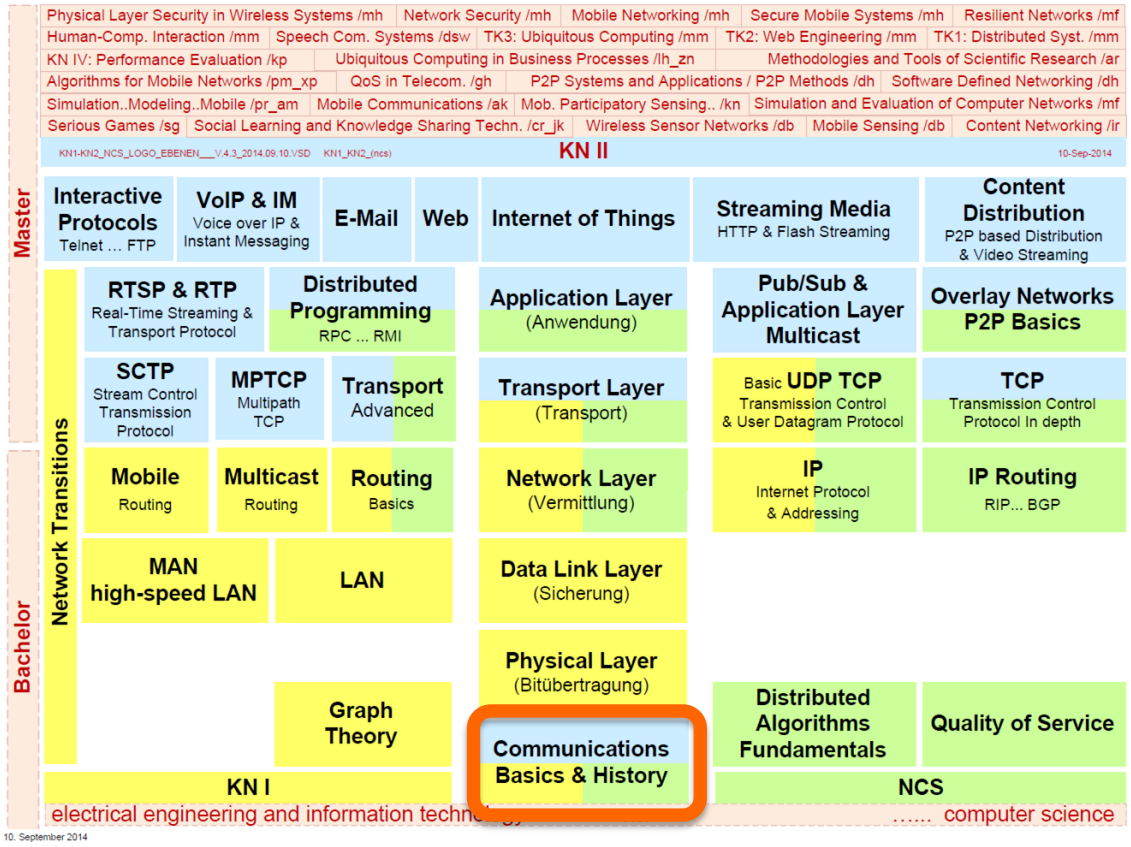

Prof. Dr.-Ing. **Ralf Steinmetz**
KOM - Multimedia Communications Lab

Our real networked World
Networking Protocol Map … (Source www.javvin.com)

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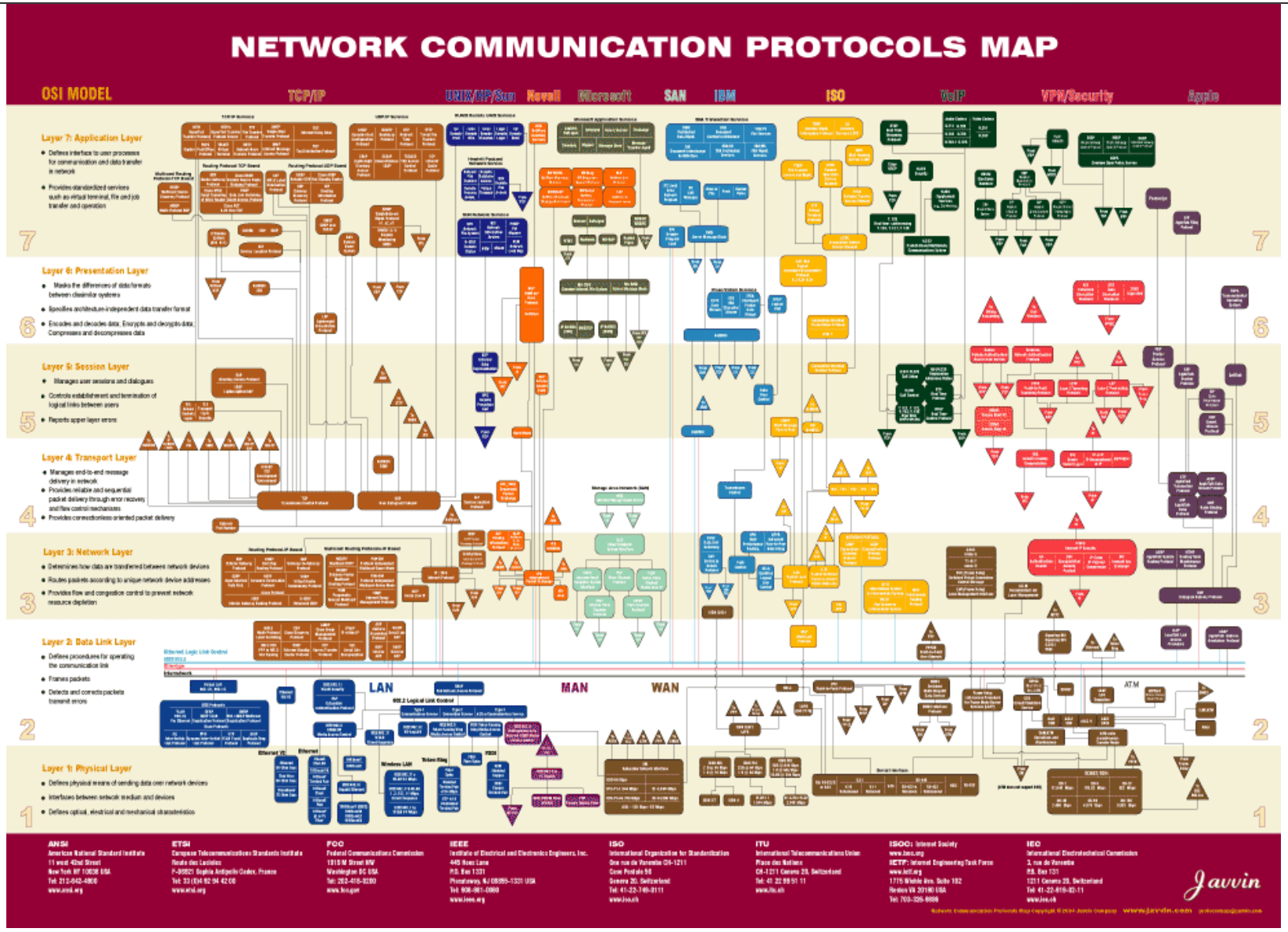

Overview

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History

1 Telegraphy

2 Telephony
3 Telegraphy vs. Telephony

4 Television
5 Television vs. Telephony and Telegraphy

6 The Internet
- 6.1 Forefather of the ARPANET (1965)
- 6.2 The ARPANET (here: ~1967 - 1972)
- 6.3 Standardization (1969 onwards)
- 6.4 Internetworking (~1972 onwards)

7 Since 1980

Basics

8 Network Structures, Types and Components

9 Basic Terminology and Concepts
- 9.1 Layered Architecture
- 9.2 Layer Concept
- 9.3 Protocol: Communication between same Layers

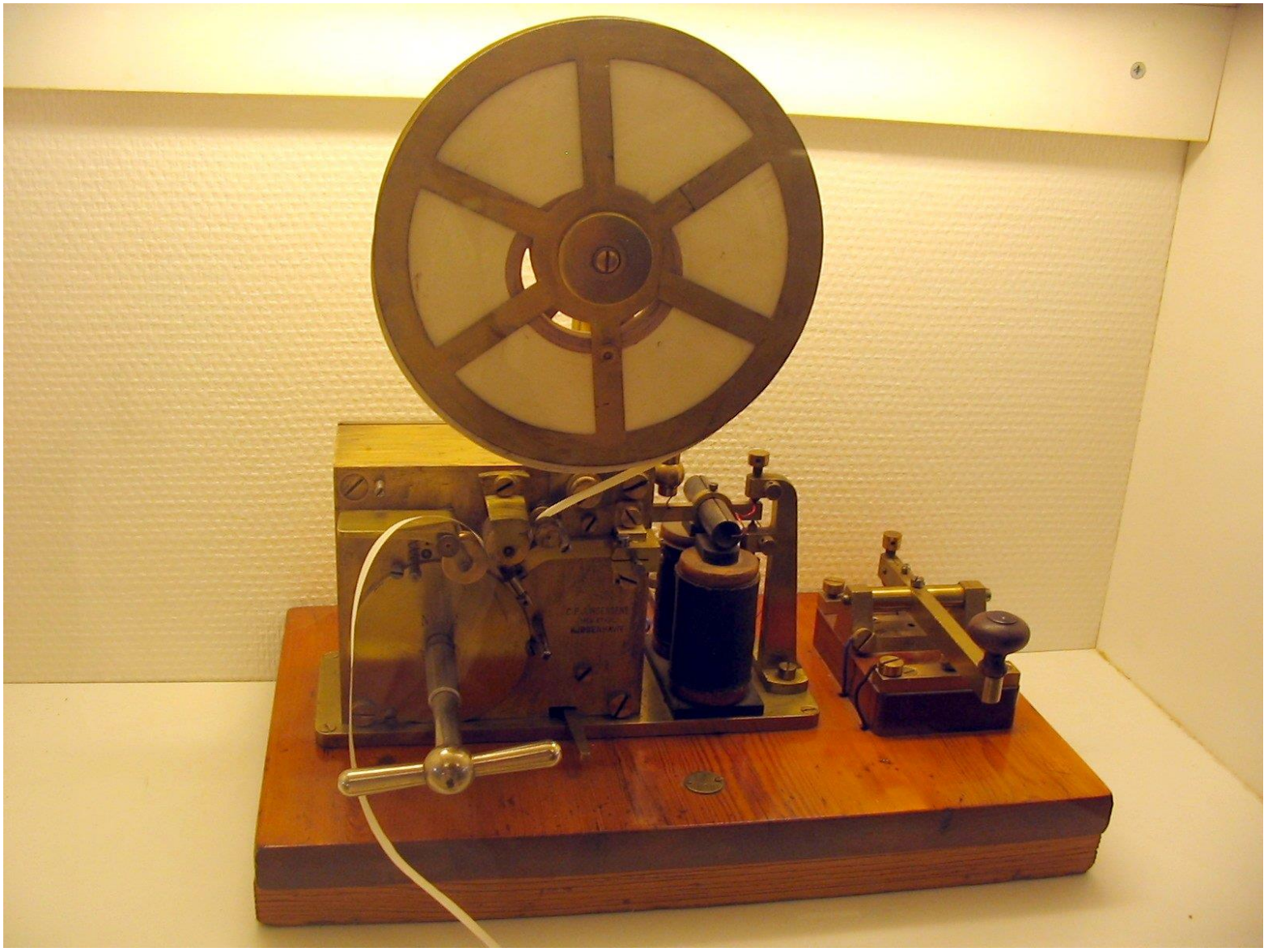
10 Connections and Connectionless Services

11 Reference Model for Open Systems Interconnection
- 11.1 Architecture
- 11.2 Layers and theirs Functions
- 11.3 Data Units

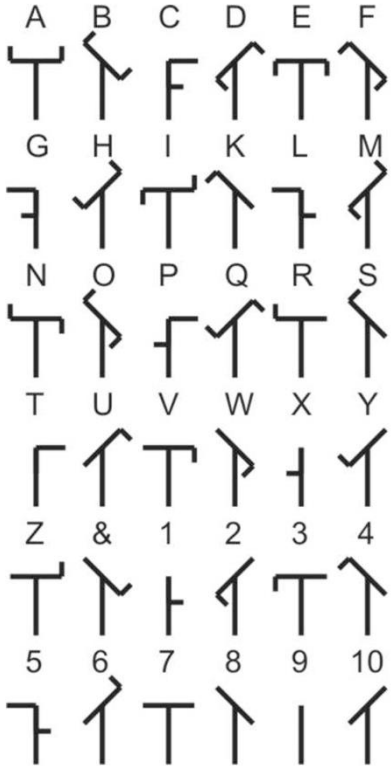
12 Five Layer Reference, Internet Reference Model and a Comparison
13 Example: Layers in Action

14 History und Basics - Summary

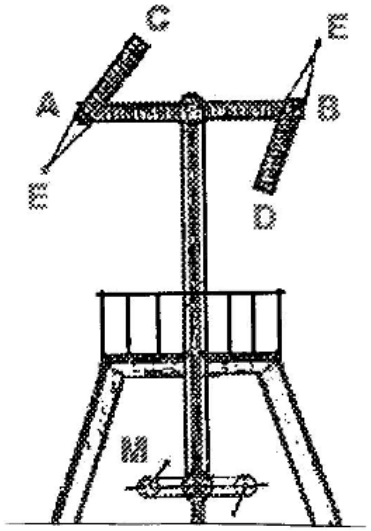
1 Telegraphy



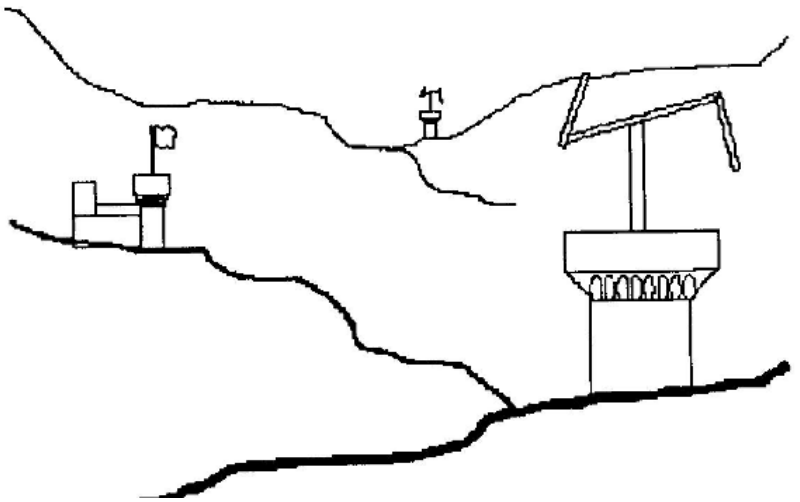
and before



Chappe-Code



Source: www.mathematik.uni-muenchen.de



e.g. 18th century

1791: Semaphoric Telegraph (Chappe)

Brief History of Electronic Communications

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Telegraphy

~1750: first experiments with electrostatic telegraphs

~1804: first experiments with electrochemical telegraphs

- Voltaic pile (1800 by Volta) used as power source

~1830: first experiments with electromagnetic telegraphs

- Electromagnet (1825 by Sturgeon) used as basis for receiver

1844: first Morse telegraph line between Washington and Baltimore

- Telegraph network then grew rapidly
  - 1846: 40 miles, 1850: 12000 miles

1866: first operational transatlantic telegraph cable

- Connecting North America and Europe

1874: Baudot multiplex system

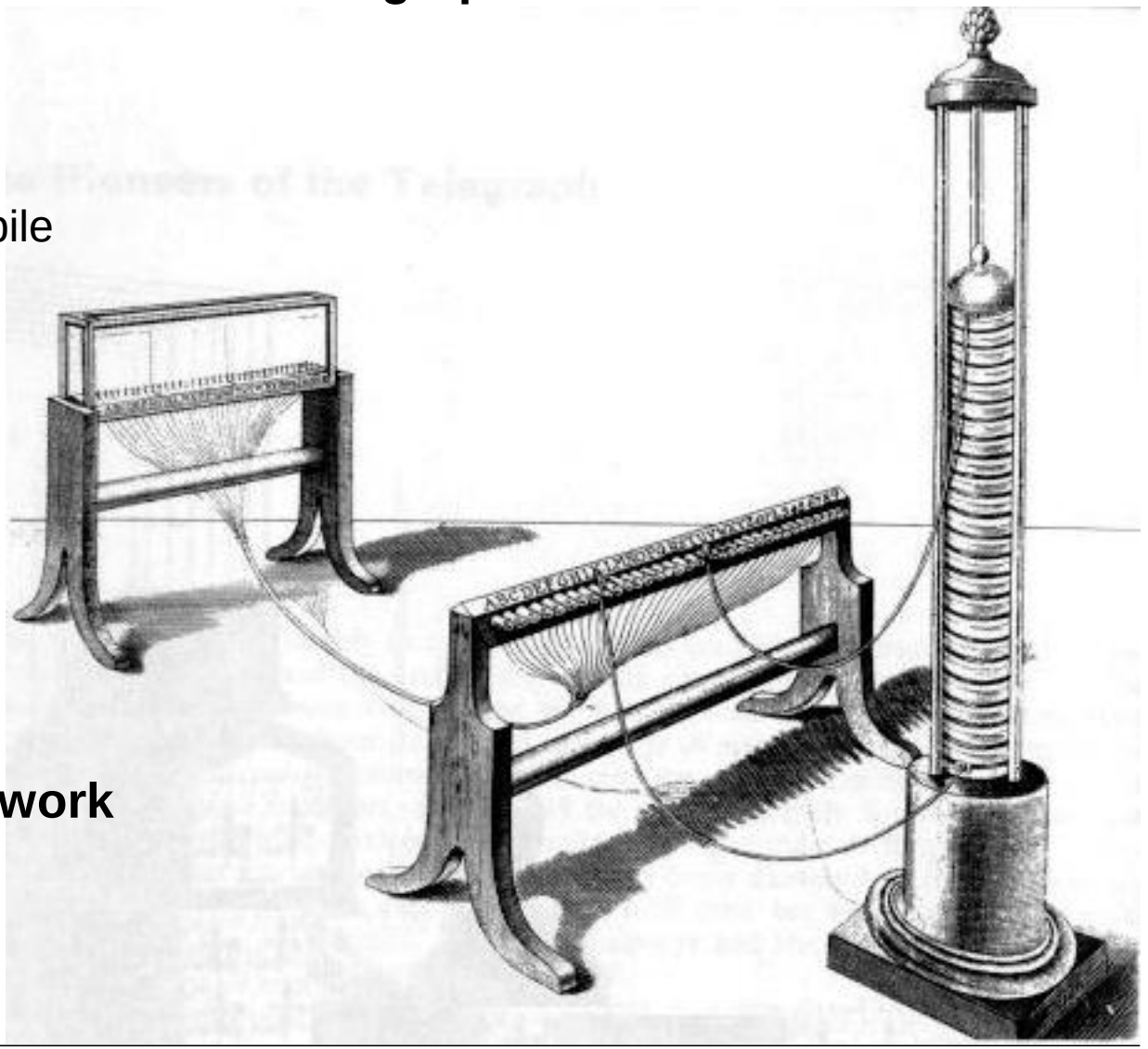
- Time multiplexing with fixed length code

- to be continued…

Early Experiments

Von Sömmering's electrochemical telegraph

- Presented 1809
- Sender:
  - 35 switches (a-z,1-9) connected to voltaic pile
- Network:
  - 35 wires (2000 ft)
- Receiver:
  - 35 electrodes in acid bath



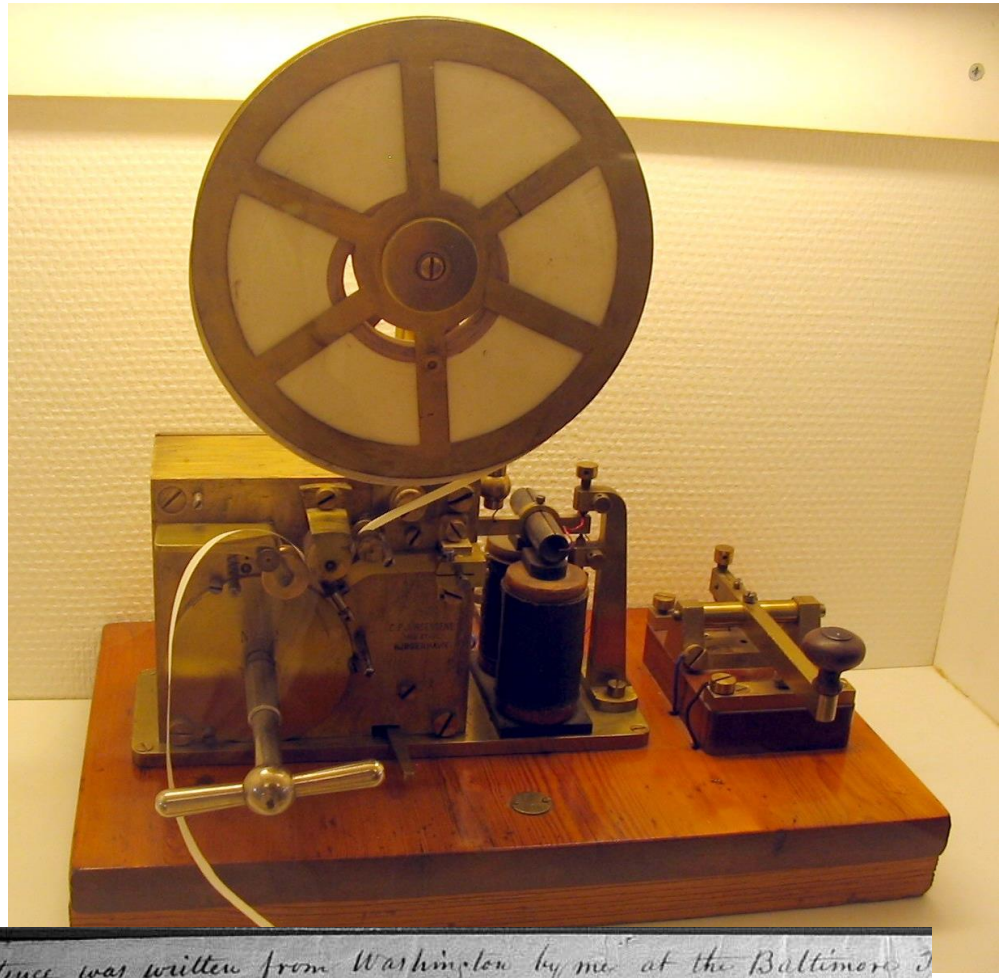
→ Communication network is point to point line

Image source: From Semaphore to Satellite, ITU, 1965

Morse Telegraph

Morse transceiver

- One switch to send long and short impulses at sender
  - dahs and dits or
  - dashes and dots
- Dashes and dots
  - punched into paper strip at receiver
- See beginning of first telegraph ‘What hath God wrought’ (Num 23,23) sent in 1844 from Washington to Baltimore
- Communication network?



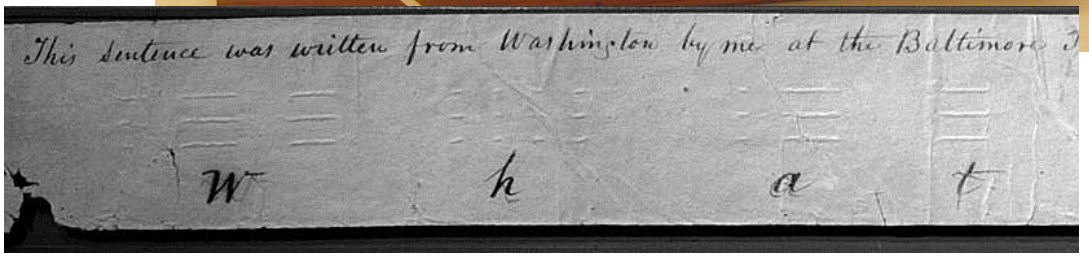


Image source: Wikimedia Commons

Morse Telegraph

Telegraph Network in United States 1916

- Similarities to today's Internet?
- Signal coding?
- Type of switching?
  - Packet?
  - Message?
  - Circuit?
- Type of service?
  - Connection oriented?
  - Connectionless?
- Repeaters?
- Routers?

Image source: Wikimedia Commons

Morse Telegraph

Morse Code

- Variable length
- Short code for frequently used letters

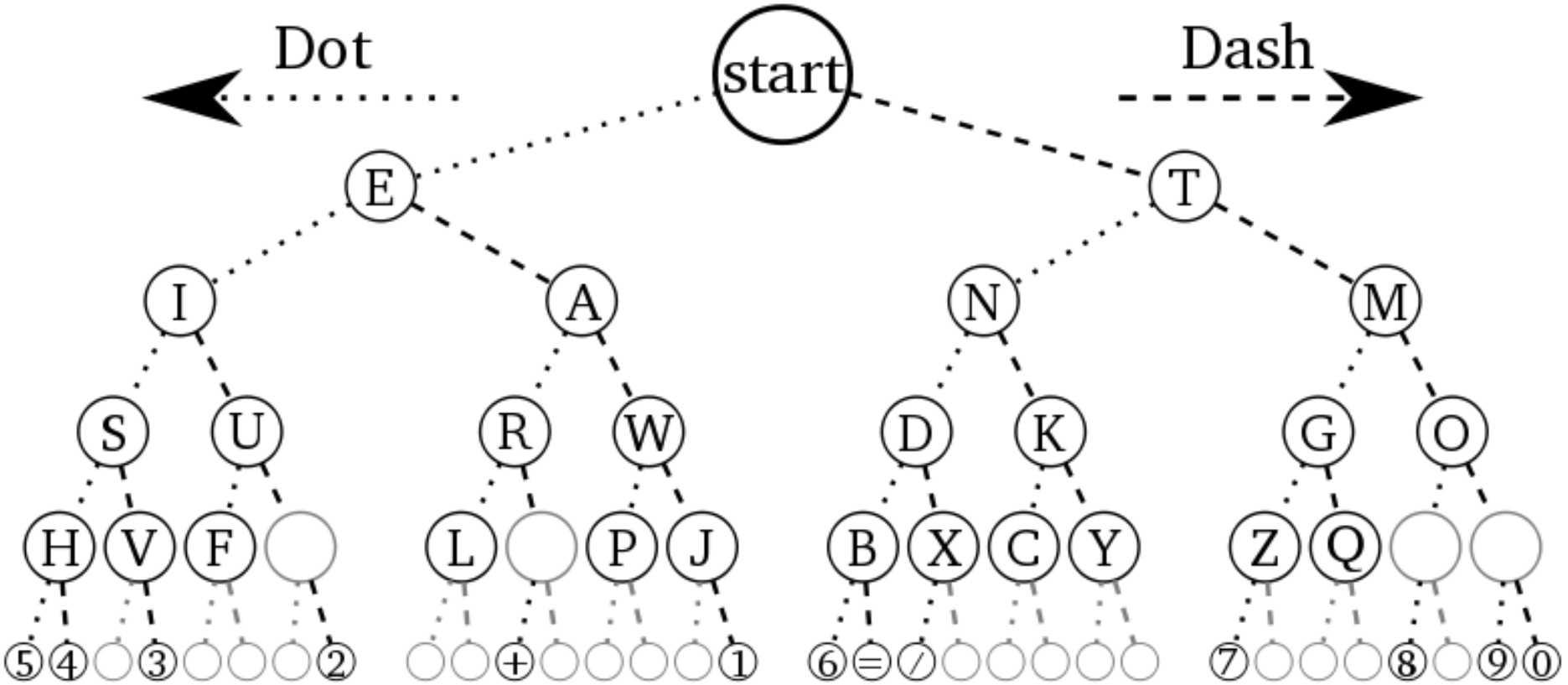


Image source: Wikimedia Commons

Baudot Telegraph

Baudot time multiplex system

- Forefather of teletypewriters (TTYs)
- Baud rate (symbol rate) of transmission named after Baudot
- Challenge:
  - to increase number of telegraph messages
- Solution:
  - time multiplexing
  - To connect multiple telegraphs over same line
- First attempts failed
  - Problems with synchronization of sender and receiver
  - Reason:
    - variable length morse code
- Baudot solved problem
  - Fixed length (5 bit) code
  - Synchronized time multiplexing

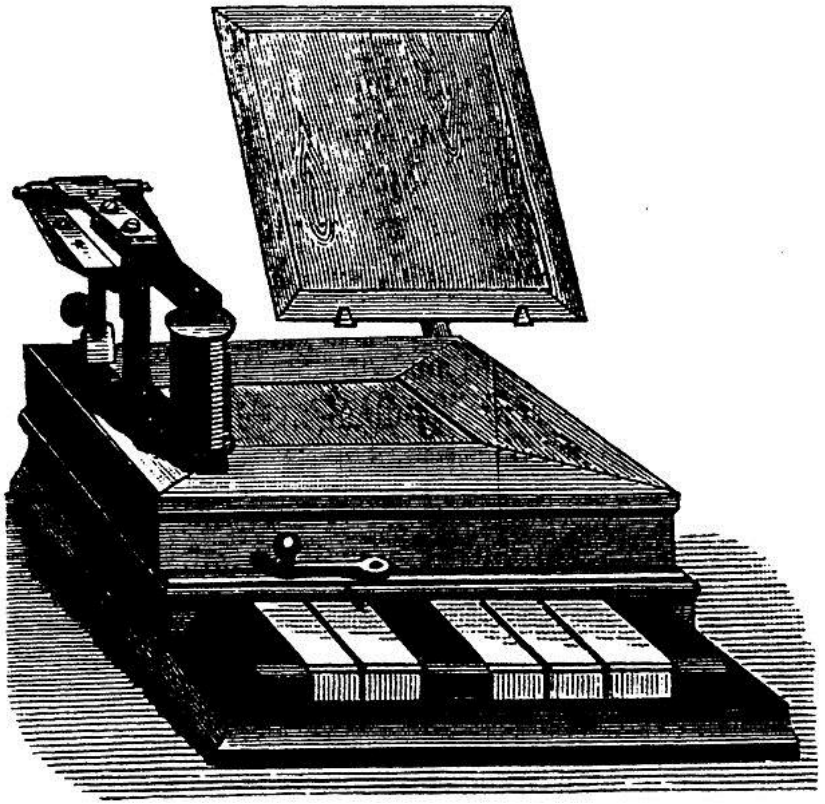


Image source: Wikimedia Commons

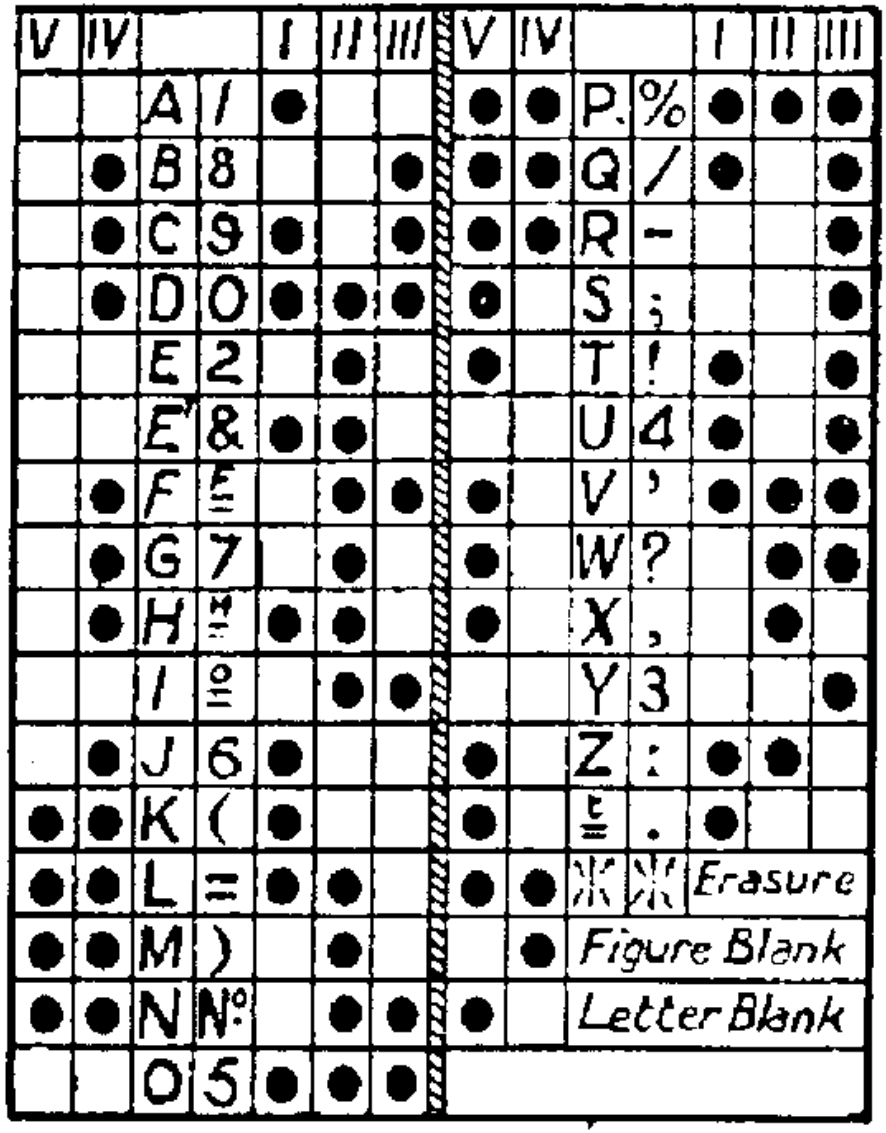
Baudot Telegraph

Baudot code

- Fixed length 5 bit code
  - Allows for 2^5=32 symbols
  - Restricted to five bits due to hardware constraints
    - Workaround by shifting alphabet to represent more characters
- Later standardized by CCITT (ITU-T)
  - International telegraph alphabet 1
  - Forefather of ASCII code

Baud rate vs. bit rate

- Early systems operated at ~2 Characters per second = 2 Baud
- Corresponds to (assuming Baudot code) 10 bit per second



Baudot Telegraph

Baudot time multiplex system

- Multiple senders/receivers connected to distributor
  - Copper segments with rotating brushes
- Distributors
  - at sender and
  - receiver side synchronized
- Serialization of characters typed on Baudot keyboard
- Time multiplexing of input from multiple keyboards

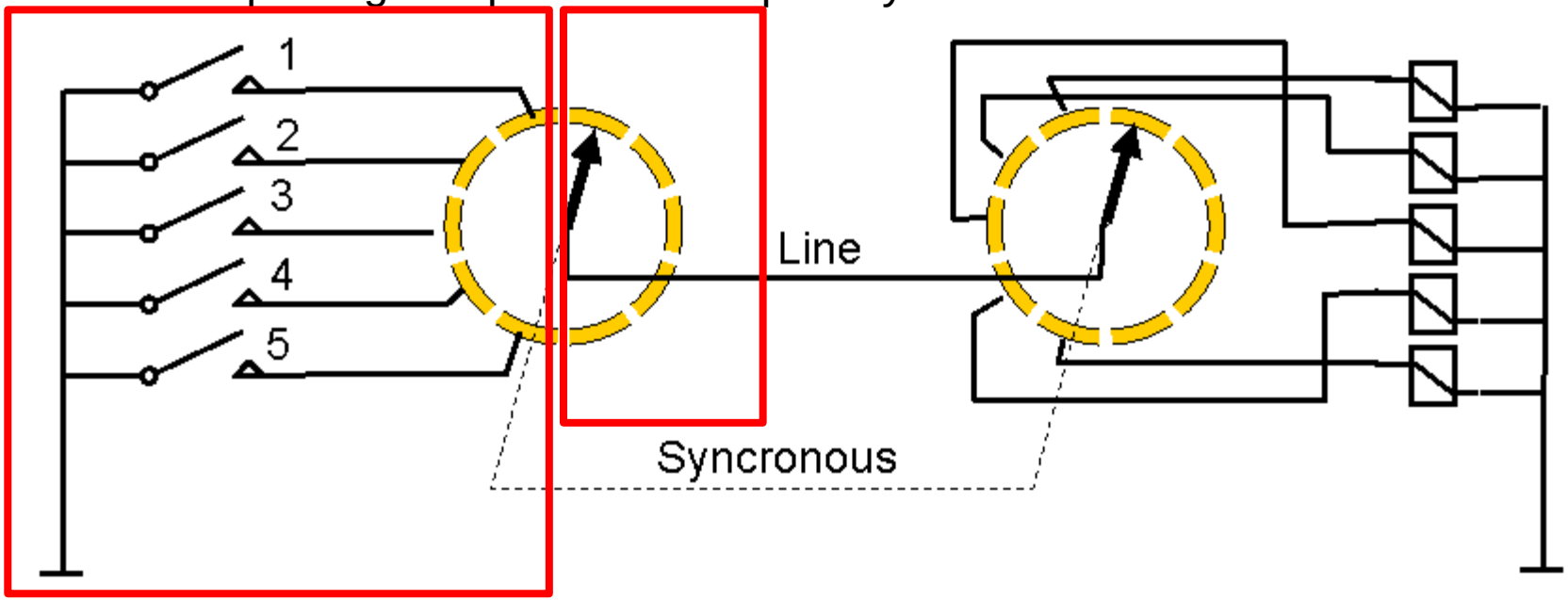


Image source: Wikimedia Commons

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Telephony

~1860: first successful electronic sound (nearly voice) transmission

- Make and break transmitter by Johann Philipp Reis

1876/77: first patents for telephone technology granted in US

- Elisha Gray, Alexander Graham Bell, Thomas Edison
- Different approaches for voice conversion / reproduction

1877: first manually switched phone exchange in US

1892: first automatic telephone exchange patented in US (Strowger)

- Driving factor was competition in undertaker business …
- Dial pulse sent by telegraph keys
- Stepping switch with two degrees of freedom at phone exchange

To be continued…

Telephony

First telephones in 1870s sold pairwise

- With dedicated, direct line

Assuming a full mesh

- Each customer can call any other customer

→ Each customer has n-1 phones

→ $\frac{n \times (n-1)}{2}$ lines required for n customers

Scalability?

- O(?) phones required?
- O(?) lines required?

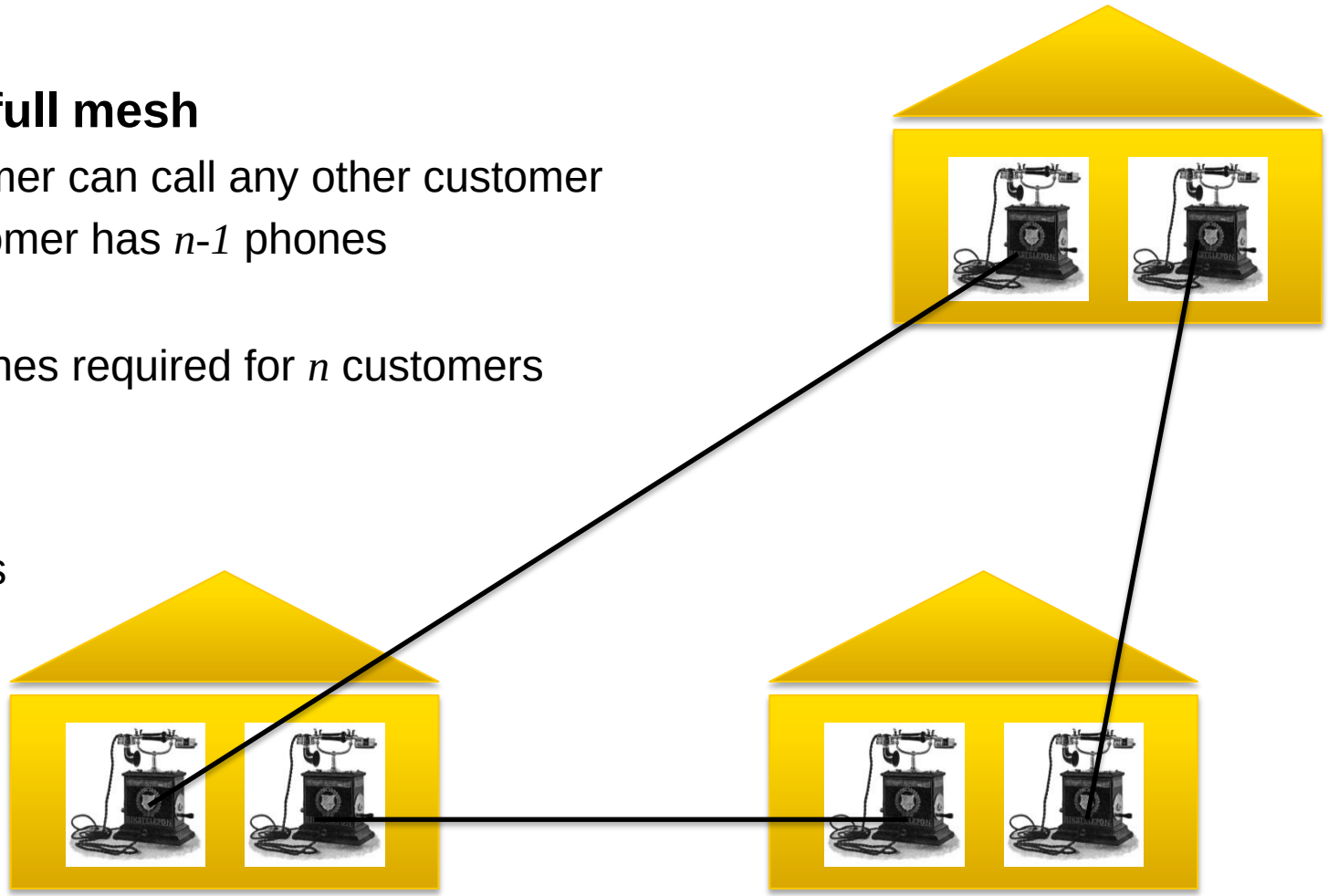

Image source: Wikimedia Commons

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Telephone switches reduced complexity of phone network

- Line from each phone to central switchboard
- Long distance lines between switchboards
- First switches manually operated
- Complexity?
  - O(?) phones required?
  - O(?) lines required?
- Basic principle in use till today

Image source: Wikimedia Commons

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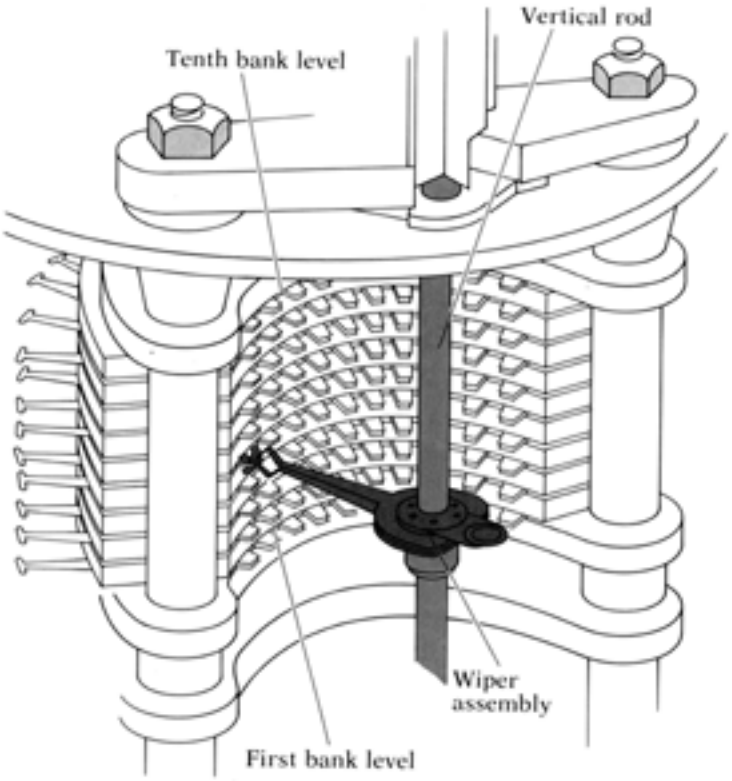
Strowger switches automated phone exchange

- Stepping switch with two degrees of freedom
- Used in former GDR until 1995



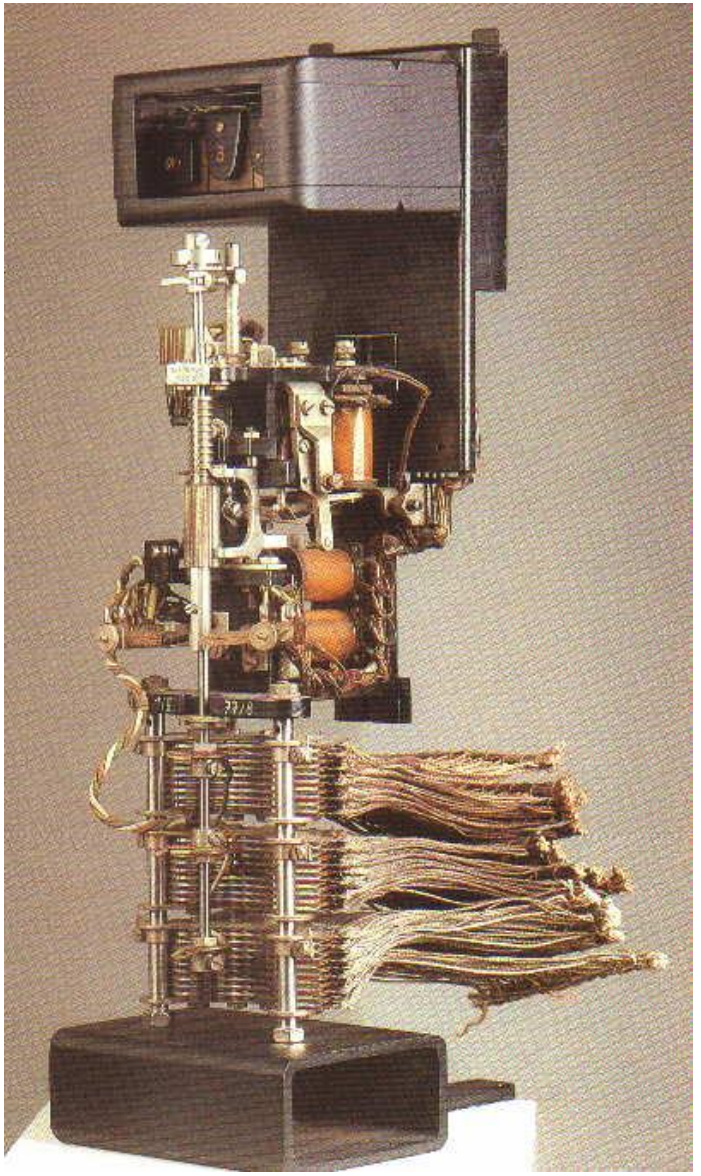
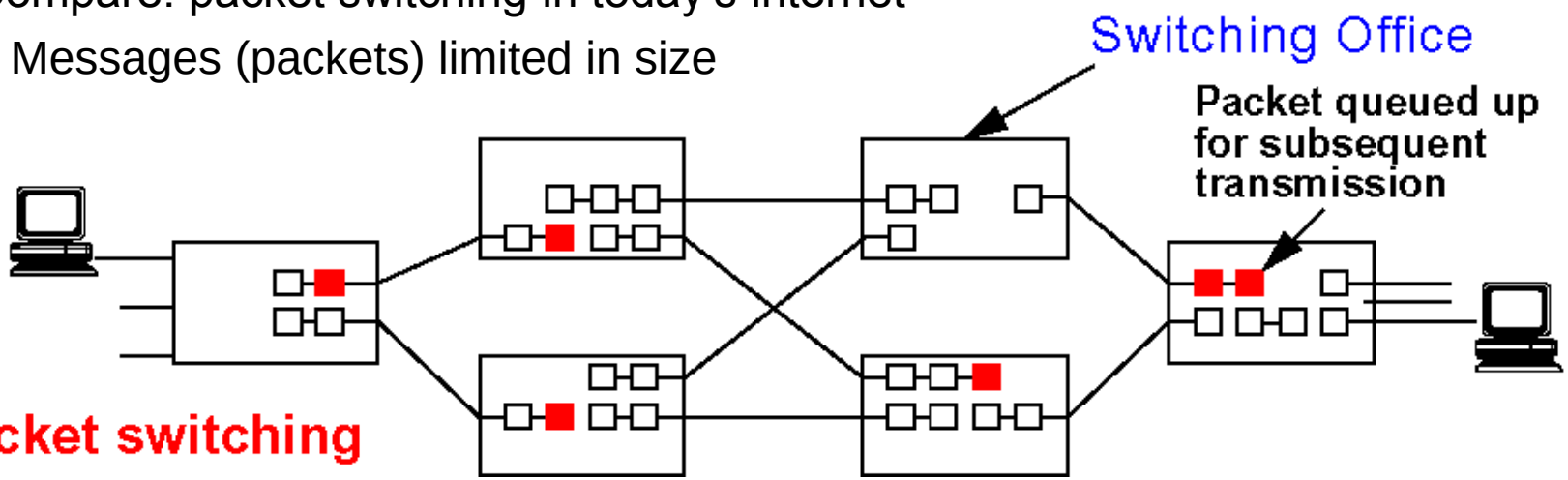


Image source: harvard.edu

Concepts of early telegraphy and telephony systems still in use today

Telegraph networks

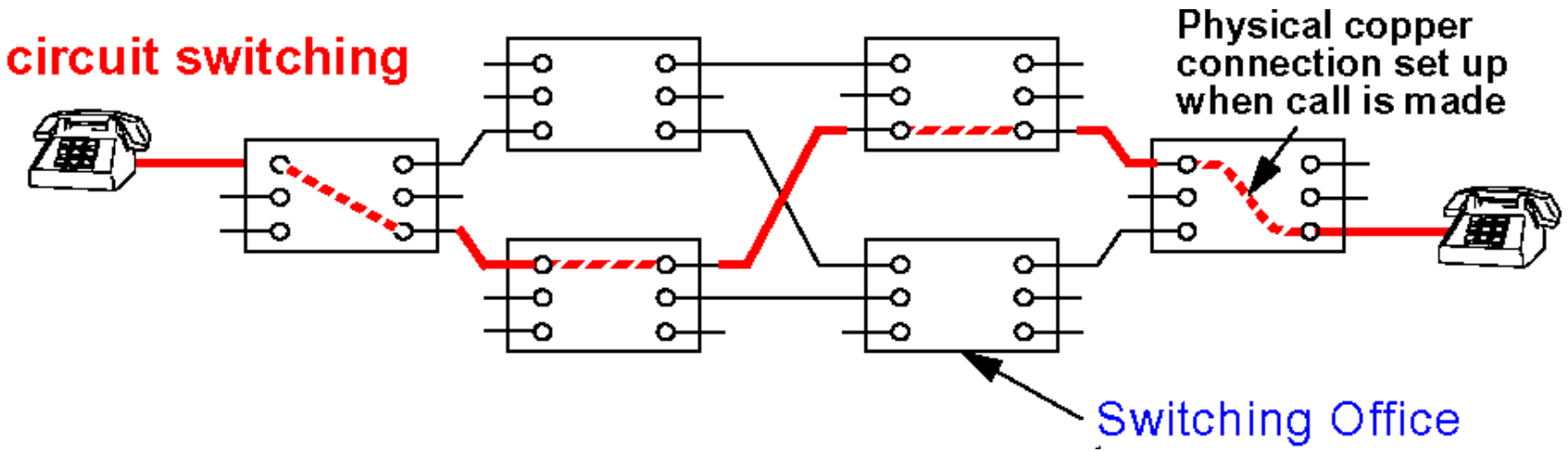
- Message switching
  - Telegram as discrete unit forwarded from sender to receiver via relay stations
  - No dedicated line between Sender S and Receiver R
- Connectionless service
  - Subsequent telegrams from S to R may use different lines
  - E.g. in case of line failures
- Compare: packet switching in today's internet
  - Messages (packets) limited in size



Telegraphy vs. Telephony

Telephone networks

- Circuit switching
  - Dedicated line between Sender S (caller) and Receiver R (callee)
  - Reserved exclusively for entire call duration
- Connection oriented service
  - Communication always follows same path
  - Three phases: connect (dial), talk (data exchange), disconnect (hang up)
- Concepts still in use in today
  - No dedicated lines but reserved resources
  - E.g., connecting an ISDN call reserves 64kbit/s between caller and callee




TELEFUNKEN

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Television

~1831 - 1890: Basics of radio transmission

- Electromagnetic induction (Faraday)
- Theory of electromagnetic fields (Maxwell)
- Wave character of wireless electrical transmissions (Hertz)

1895: Wireless telegraphy demonstrated by Marconi

- Long wave transmission, high transmission power >200kW

1926: First demonstration of transmission of moving images (Baird)

- Electromechanical television
- 12.5 frames per second, 30 lines resolution

1928: First (wireless) TV broadcast stations appear

1996: First commercial digital TV station (DirecTV, US)

To be continued…

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Schematic representation of mechanical TV

- Strong light beam scans object through rotating disc with holes (Nipkow Disc)
  - Photoelectric cells detect light reflections
- Output of photoelectric cells reproduced at receiver side
  - Light source with varying intensity watched through Nipkow Disc

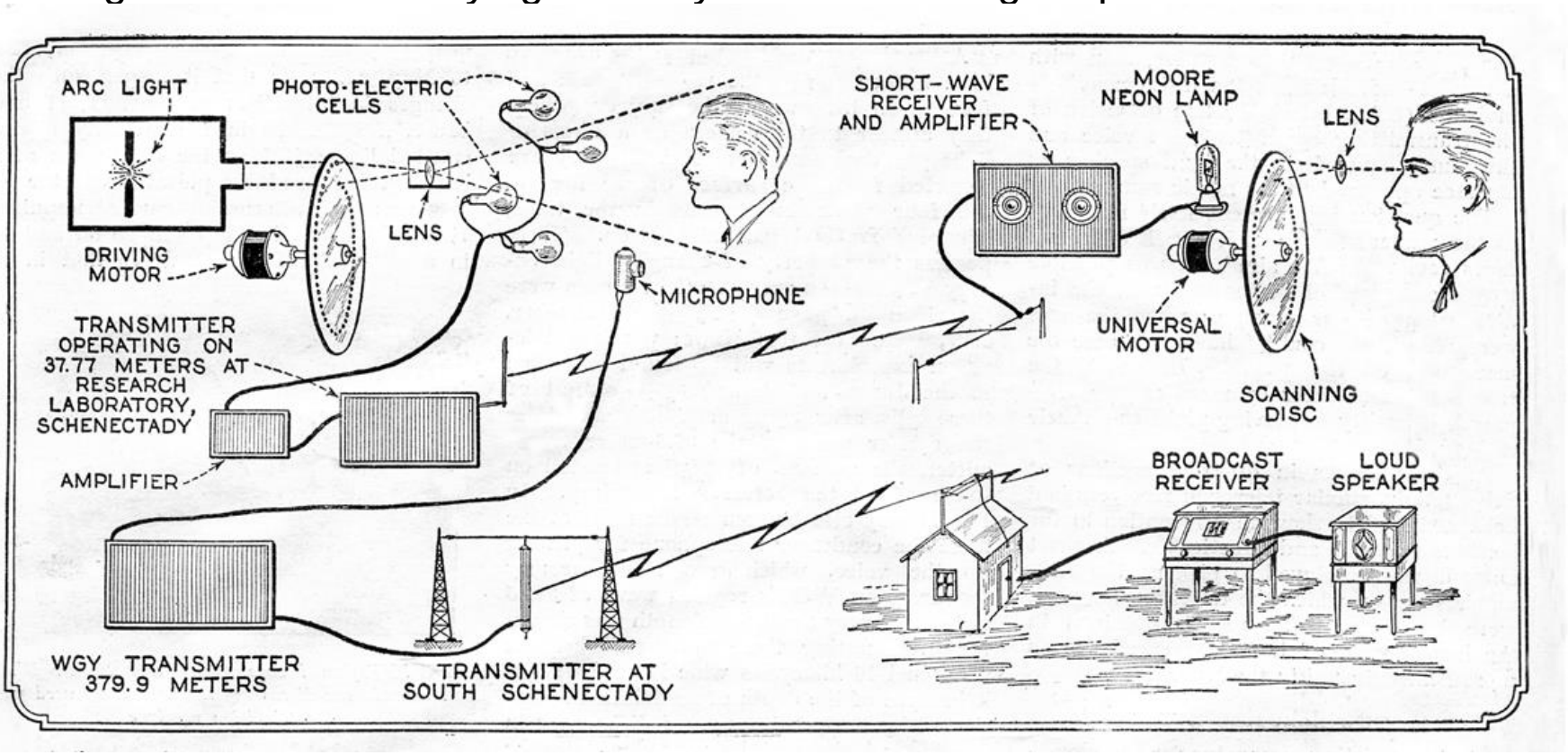

Image source: Wikimedia Commons

Television

TV is broadcast medium

- One sender
- Many Receivers
- E.g., coverage of WABC TV station, New York
  - Covers ~9 million households

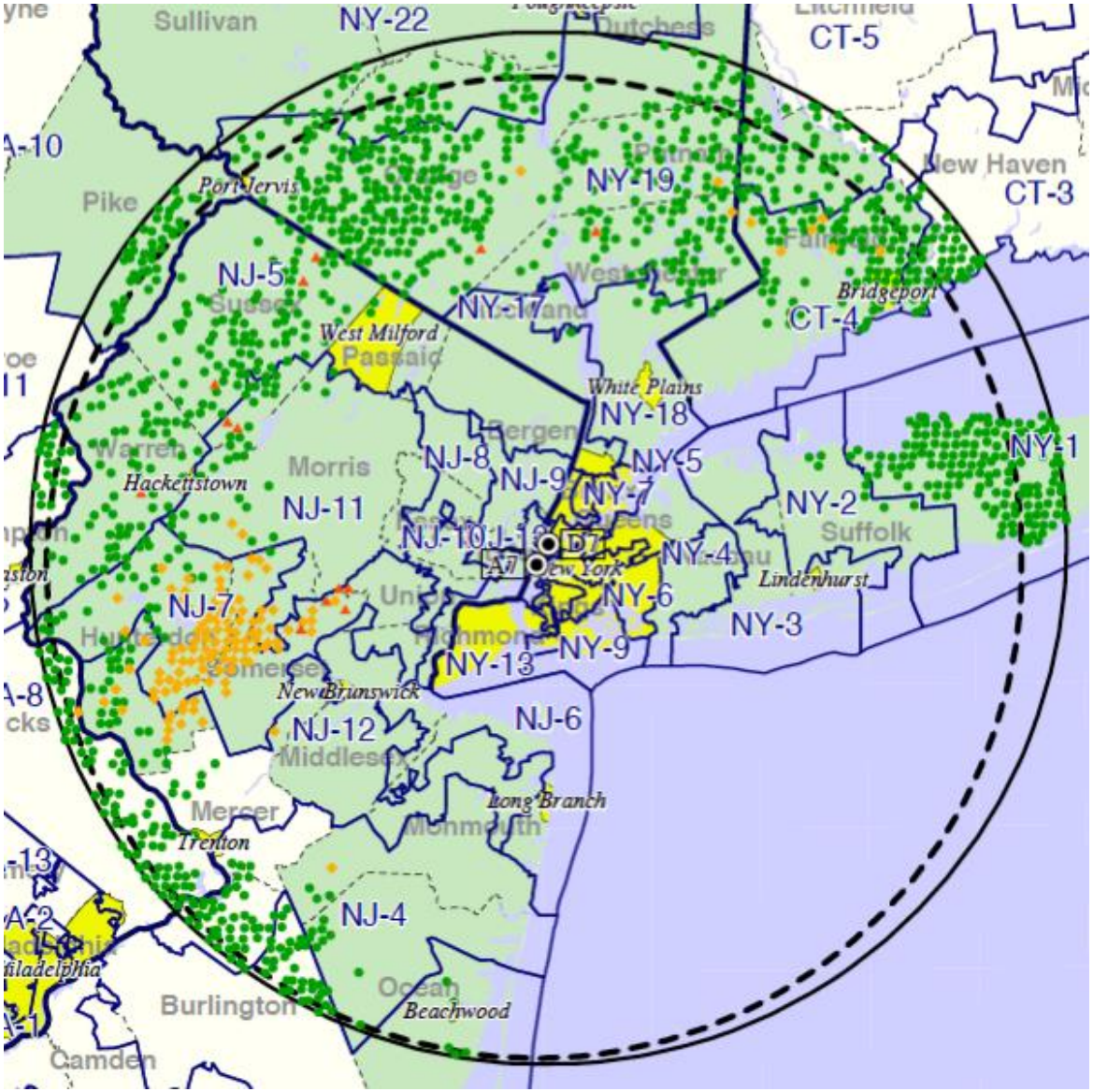

Image source: fcc.gov

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Terrestrial digital TV broadcast - DVB-T

- Terrestrial analogue TV replaced completely by DVB-T in 2009
  - Satellite and cable TV will follow
- Closest stations at Feldberg, Frankfurt, Wiesbaden
  - Cover ~2 million households

Sample calculation

- DVB-T data rate is ~4 Mbit/s
- ~2 million households in Rhine/Main area

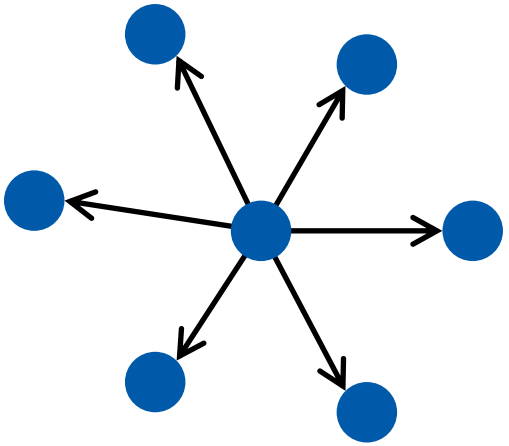
→ ~8 Tbit/s (Terabit per second) received during primetime

- Compare: global average Internet traffic was ~46 Tbit/s in 2010
  - (source: Cisco visual networking index)

Image source: ueberallfernsehen.de

Television developed as broadcast medium

- One sender, many receivers
  - In order of millions for TV stations
- Inherent property of radio transmission



Telephony (and telegraphy) developed as unicast medium

- One sender, one receiver
- Inherent property of circuit switched network

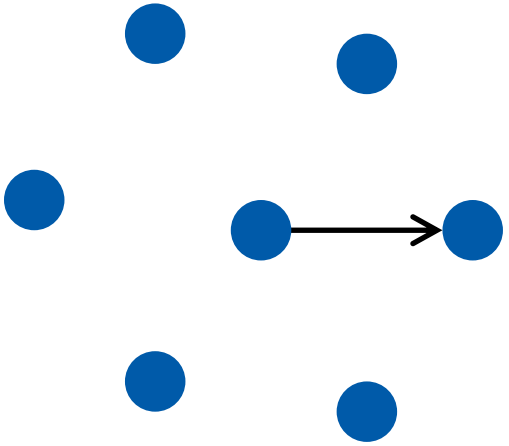


Image source: Wikimedia Commons

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The Internet

1961: Packet switching theory described by Kleinrock at MIT

- Shows performance of packet switching (compared to circuit switching)

1962: “Galactic Network” idea presented by Licklider at MIT

- Vision of possibilities achieved by globally interconnected computers

1965: First computer network by Roberts and Marill

- Two computers at MIT and UCLA connected by dial-up telephone line

1967: ARPANET concept published by Roberts

1969: First IMP (Interface Message Processor) installed at UCLA by BBN

- First host connected to ARPANET
- Three more followed at Stanford, UC Santa Barbara, University of Utah
- Research on network itself as well as on network applications

1969: Request for Comments (RFC) established by Crocker at UCLA

- First RFC describes IMP architecture

Source: http://www.isoc.org/internet/history/brief.shtml

Brief History of Electronic Communications

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The Internet (cont'd)

1970-1972: First communication protocol implemented in ARPANET

- Network Control Protocol (NCP) for host-to-host communication
- Basis for application development

1971: 23 hosts connected

1972: First application presented – electronic mail by Tomlinson

1972: Open architecture internetworking idea presented by Kahn at DARPA

- Motivation: Connecting different networks

1973: Initial TCP/IP idea presented by Cerf and Kahn at Stanford and BBN

- ARPANET's NCP does not meet internetworking requirements

1983: Cutover from NCP to TCP/IP in ARPANET

Source: http://www.isoc.org/internet/history/brief.shtml

6.1 Forefather of the ARPANET (1965)

First wide-area network built by Marill and Roberts in 1965

- ‘Toward a Cooperative Network of Time-shard Computers’
  - American Federation of Information Processing Systems conference 1966
- Connecting a TX-2 at MIT to a PDP-1 at Santa Monica
  - TX-2 built at MIT, spin-off: Digital Equipment Corporation (DEC)
  - PDP-1 built by DEC
- Connection via telephone line at 1200 bits per second

Motivation: connecting heterogeneous systems

- Early software highly specialized for machine it ran on
  - Software written in assembler code
  - Platform independent languages yet to come
- Using software written for machine A on machine B required high effort
  - Porting code or rewriting from scratch equally complex tasks

Forefather of the ARPANET

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Elementary approach

- In general: connect remote computer instead of local terminal
  - Remote computer looks like local terminal for local computer
  - No changes to hardware or operating system required
- User program handles all networking tasks
  - Communication with user and remote computer

Remember: we are in the age of mainframe computers

Image source: Wikimedia Commons

6.2 The ARPANET (here: ~1967 - 1972)

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Concept proposed by Roberts

- Based on preceding experiment on connecting computers in 1965
- Funded by Advanced Research Projects Agency (ARPA)
  - US military research agency (now DARPA – Defense Advanced …)
  - Why? Because Roberts moved from MIT to ARPA.

Goals

- Load sharing
  - Send program and data for processing to remote machine
  - Required identical computers at that time
- Message service

Had been tried before

- Data sharing
  - Send program for processing to remote data
- Program sharing
  - Send data for processing to remote program
- Remote service
  - Send query to remote program and data
  - Harness specialized hardware and software

Extended goals of ARPANET for heterogeneous environments

The ARPANET

Core component: network connections

- 50 kbit/s full-duplex leased telephone lines (AT&T)
- Min. two paths between any two IMPs

Topology as planned in 1970

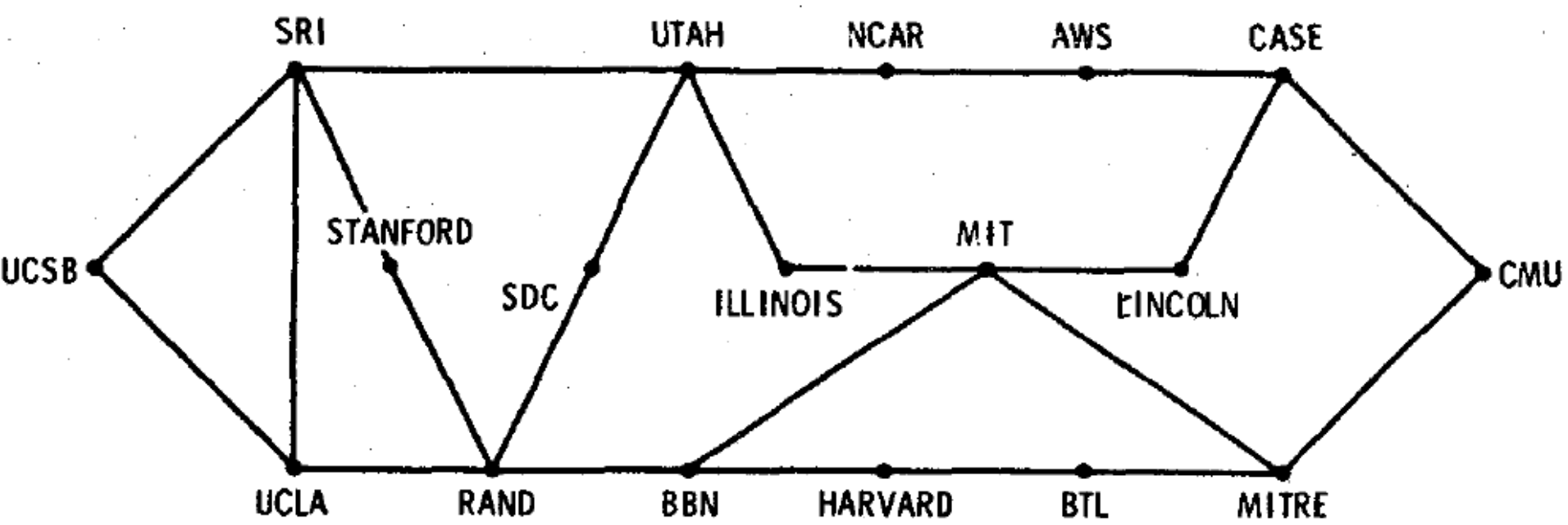

Image source: Computer network development to achieve resource sharing, AFIPS 1970

6.3 Standardization (1969 onwards)

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Problem: developing communication protocols requires consensus

- Different locations, institutions, manufacturers, operators … involved
  - → Standards required
- But:
  - scientific publication process too slow
  - industrial standardization process too slow and to expensive
- Remember: ARPANET was research project with restricted funding

Solution: request for comments (RFCs)

- At first: memos, minutes of meetings
  - Circulated by mail
    - (standard old fashioned, not electronic)
- Later: published electronically
  - FTP, HTTP

request for comments (RFCs)

- Provide fast and open access to

RFC Index

Num	Information
0001	**Host Software** S. Crocker [April 1969] (TXT = 21088) (Status: UNKNOWN) (Stream: Legacy)
0002	**Host software** B. Duvall [April 1969] (TXT = 17145) (Status: UNKNOWN) (Stream: Legacy)
0003	**Documentation conventions** S.D. Crocker [April 1969] (TXT = 2323) (Obsoleted-By RFC0010) (Status: UNKNOWN) (Stream: Legacy)
0004	**Network timetable** E.B. Shapiro [March 1969] (TXT = 5933) (Status: UNKNOWN) (Stream: Legacy)
0005	**Decode Encode Language (DEL)** J. Rulifson [June 1969] (TXT = 26408) (Status: UNKNOWN) (Stream: Legacy)
0006	**Conversation with Bob Kahn** S.D. Crocker [April 1969] (TXT = 1568) (Status: UNKNOWN) (Stream: Legacy)
0007	**Host-IMP interface** G. Deloche [May 1969] (TXT = 13408) (Status: UNKNOWN) (Stream: Legacy)
0008	**ARPA Network Functional Specifications** G. Deloche [May 1969] (PDF = 750612) (Status: UNKNOWN) (Stream: Legacy)
0009	**Host Software** G. Deloche [May 1969] (PDF = 722638) (Status: UNKNOWN) (Stream: Legacy)
0010	**Documentation conventions** S.D. Crocker [July 1969] (TXT = 3348) (Obsoletes RFC0003) (Obsoleted-By RFC0016) (Updated-By RFC0024, RFC0027, RFC0030) (Status: UNKNOWN) (Stream: Legacy)
0011	**Implementation of the Host - Host Software Procedures in GORDO** G. Deloche [August 1969] (TXT = 46971, PDF = 2186431) (Obsoleted-By RFC0033) (Status: UNKNOWN) (Stream: Legacy)
0012	**IMP-Host interface flow diagrams** M. Wingfield [August 1969] (TXT = 177, PS = 1489750, PDF = 1163721) (Status: UNKNOWN) (Stream: Legacy)
0013	**Zero Text Length EOF Message** V. Cerf [August 1969] (TXT = 1070) (Status: UNKNOWN) (Stream: Legacy)

Internet standardization

- http://www.rfc-editor.org/rfc-index.html

Who is behind RFCs?

- Started in 1969 by ARPANET working group (WG)
- International Internet growth demanded for more coordination
  - International Cooperation Board (ICB)
  - Internet Research Group (IRG)
  - Internet Configuration Board (ICB)
- Continuing growth demanded for restructuring organizational institutions
  - Task forces (TFs) founded for particular technology areas
    - Routers, protocols, …
  - Internet Architecture Board (IAB) coordinates task forces

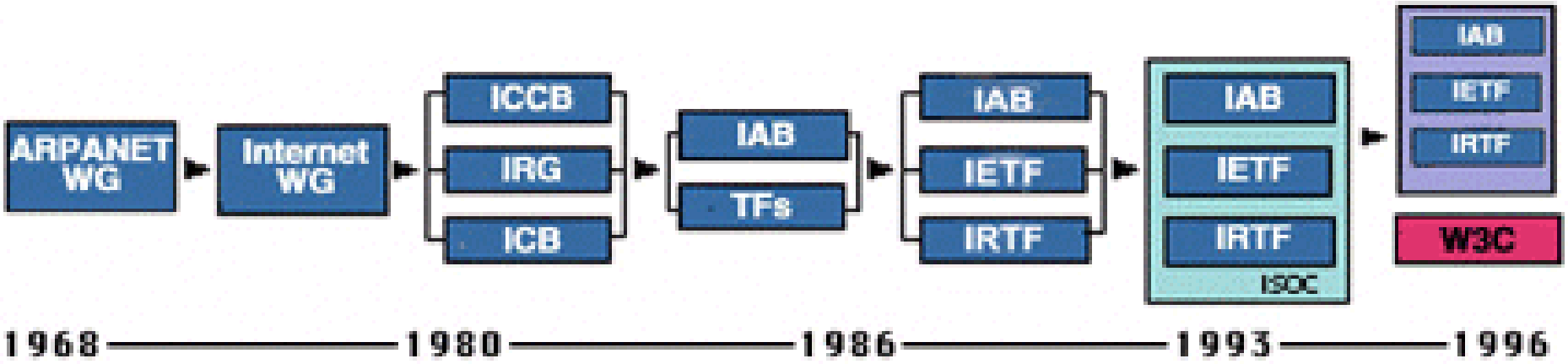

Image source: http://www.isoc.org/internet/history/brief.shtml

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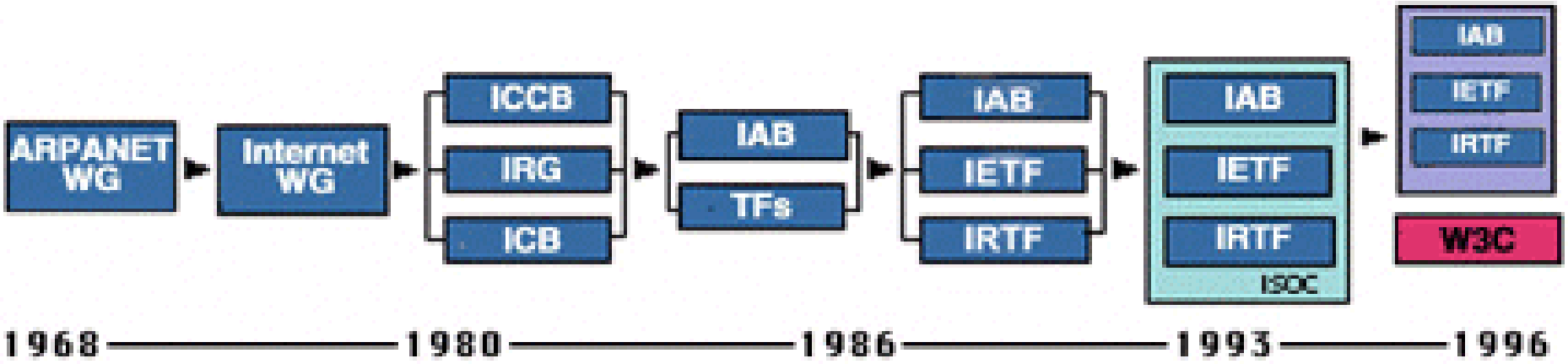
Who is behind RFCs?

- Strong activities in practical/engineering aspects
  - Internet Engineering Task Force (IETF) became major player
  - Other task forces combined into Internet Research Task Force (IRTF)

- Commercialization of the Internet led to shifted interests
  - Internet Society (ISOC) coordinates business and research efforts

Development of Word Wide Web (WWW / W3)

- World Wide Web Consortium (W3C) founded
  - Responsible for protocols and standards of the web



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Besides ARPANET many other networks appeared in/after 1970s

- E.g. NSFNET by US National Science Foundation
  - Advanced research and education networking
- E.g. JANET by UK government
  - Research and education network
- E.g. German DATEX-P by Deutsche Bundespost
  - Commercial packet switched service

Internetworking concepts proposed by Kahn in 1973

- Goal: to connect different networks
- Ground rules valid until today
  - No internal changes required to connect a network to the Internet
  - Best effort communication
  - Stateless gateways/routers used for connection of networks
  - No global control
  - Also:
    - dealing with packet loss, pipelining, fragmentation, global addressing, flow control, …

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ARPANET's NCP does not meet internetworking requirements

- TCP/IP presented by Cerf and Kahn at Stanford and BBN in 1974
- Concept of byte streams
- Flow control by sliding window with cumulative acknowledgements
- First only TCP (nearly as we know it today) implemented
- Research on packet voice demanded for more simple protocol → UDP
- Other applications:
  - File and disk sharing, mobile agents
- Not foreseen:
  - proliferation of LANs and PCs
  - Considered were national level networks
  - 32 bit IP addresses with 8 bit network address, 24 bit host address

TCP/IP evolved to deployment version until 1981

- IPv4 as used today
  - Details see forthcoming lectures
- ARPANET switched to TCP/IP in 1983

Brief History of Electronic Communications

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The Internet (cont'd)

- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control
- early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: Web
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web
- late 1990's – 2000's:
  - more killer apps: instant messaging, P2P file sharing
  - network security to forefront
  - est. 50 million host, 100 million+ users
  - backbone links running at Gbps
- 2010:
  - ~750 million hosts
  - voice, video over IP
  - P2P applications: BitTorrent (file sharing) Skype (VoIP), PPLive (video)
  - more applications: YouTube, gaming, Twitter
  - wireless, mobility

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Mobile telephony

and

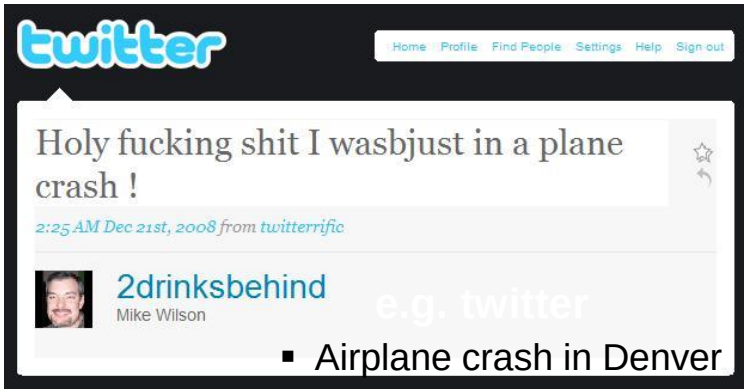
- SMS

Web

Peer-to-Peer

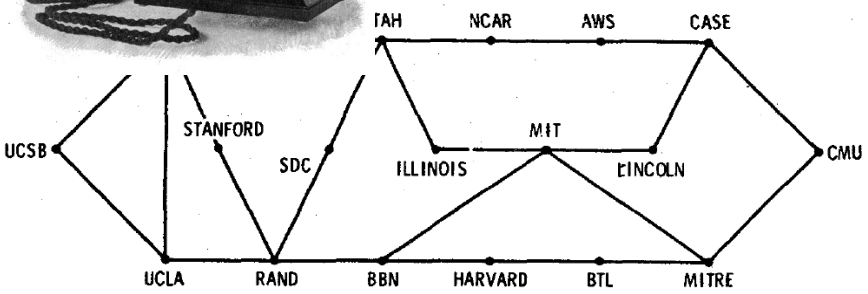
and

- Web services
- …
- Twitter
- Online social networks
- …



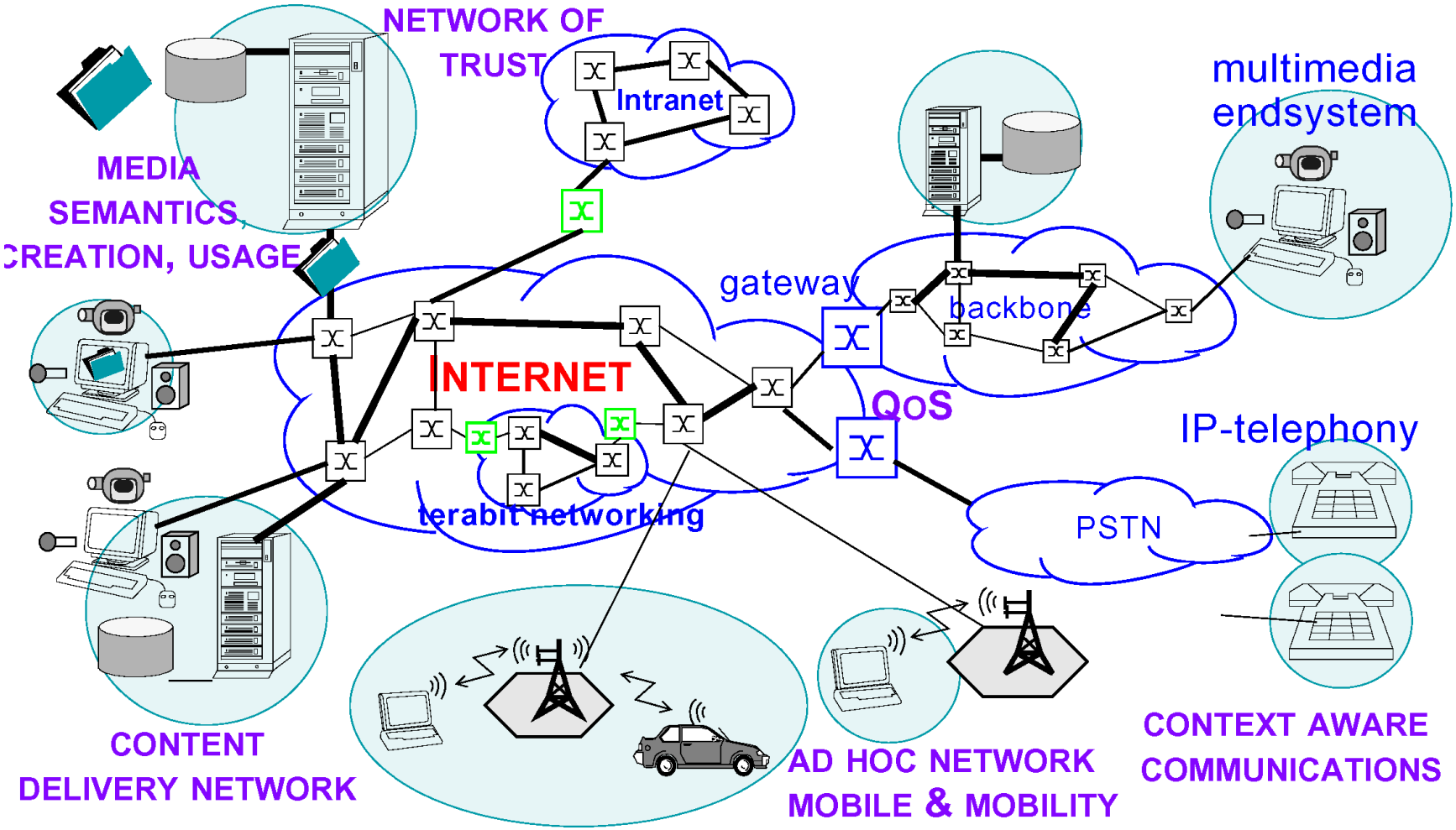
Part I → Part II

Part I – History

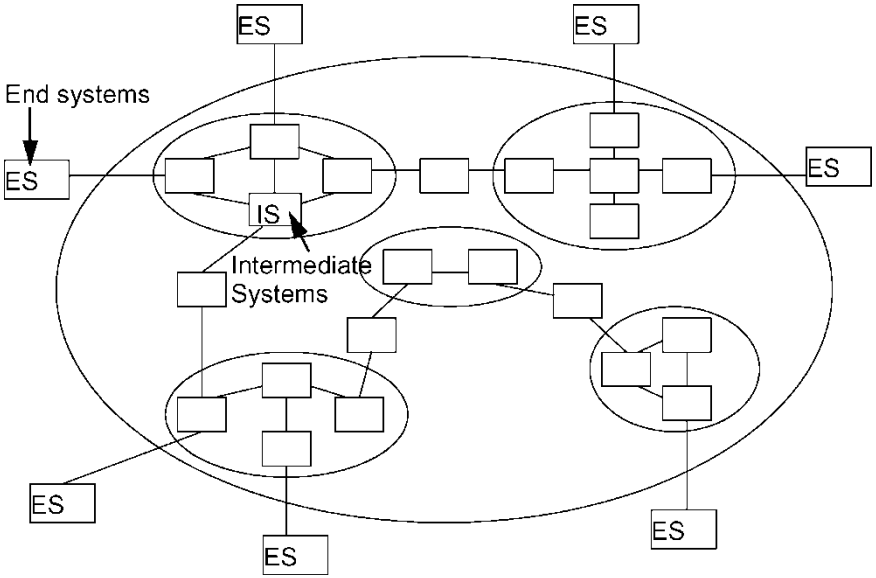


Part II – Basics

- Network Structures
- Architecture
- Layers
- Protocol
- Service
- Connection, connection oriented, connectionless
- Terminology


NETWORK OF TRUST
Intranet
MEDIA SEMANTICS, CREATION, USAGE
multimedia endsystem
gateway
backbone
INTERNET
QoS
IP-telephony
PSTN
terabit networking
CONTENT DELIVERY NETWORK
AD HOC NETWORK MOBILE & MOBILITY
CONTEXT AWARE COMMUNICATIONS

Network Components



Data transfer from end system to end system

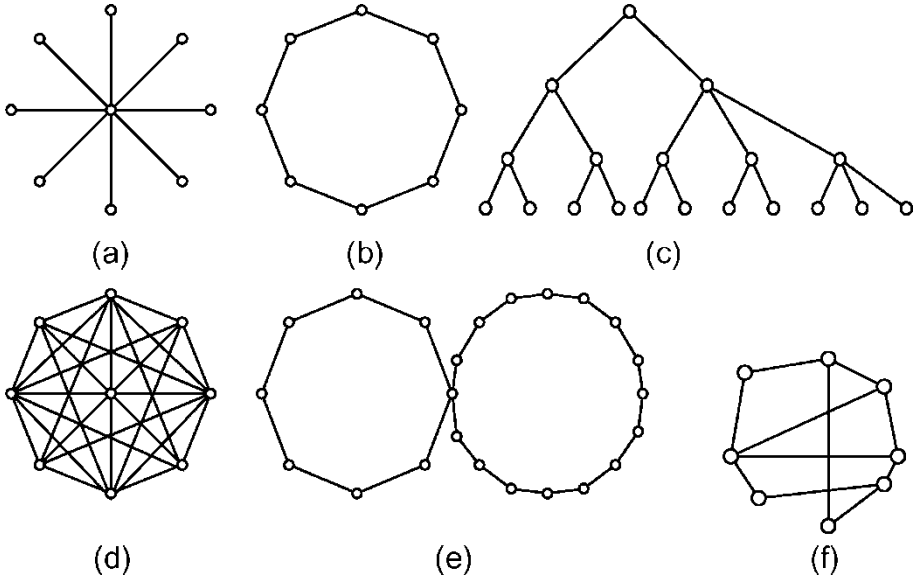
- END-SYSTEM (ES) also known as Data Terminal Equipment (DTE)
  - e.g. terminal, computer, telephone
  - and Data Circuit terminating Equipment (DCE) and Data transfer equipment
    - e.g: modem, multiplexer, repeater
- INTERMEDIATE SYSTEM (IS) also called Data Switching Exchange (DSE)
  - e.g. router

Network Structures

Point-to-point channels

- net = multitude of cable and radio connections often also called a network
- whereby a cable always connects two nodes
- more prevalent in wide area domains (e. g. telephone)

Topologies:



Network Structures

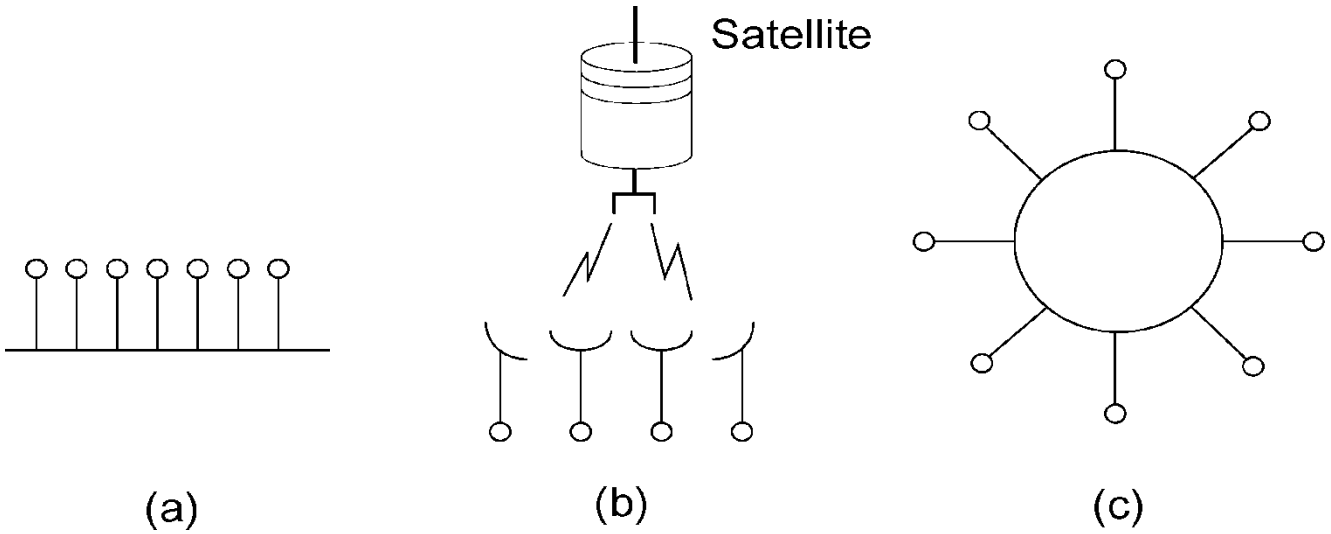
Broadcasting channels

- systems share one communication channel
- one sends, all others listen

Used for

- wide area: radio, TV, computer communication
- local area: local networks

Topologies:



Network Types

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Distance between Processors	CPUs jointly located on/in..	Example
<= 0,1 m	Boards	usually tightly coupled multi-processor system
1 m	Systems	e.g. body area network e.g. sensor area network e.g. storage area network
10 m	Rooms	LAN
100 m	Buildings	
1 km	Campuses	
10 km	Cities	MAN
100 km	Countries (national)	WAN
1.000 km	Continents (intern.)	
>= 10.000 km	Planets	

- Local Area Network (LAN) e.g. IEEE 802.3 = Ethernet, IEEE 802.11
- Metropolitan Area Network (MAN):
  - (being replaced by LAN + WAN) e.g. FDDI
- Wide Area Network (WAN): example SDH, ATM, all optical networks
- Inter-Planetary Internet: http://www.ipnsig.org/

Network Types: Mobile Communication

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Expansion

- with the areas: LAN, MAN and WAN

Examples for "Wireless"

- GSM, UMTS, lte ..
- wireless telephony: DECT, ..
- LANs: Bluetooth, WiFi, ..

wireless communication mobile communication

		Wired or Radio Connection	
		Wired	**Wireless**
Connection to network either static or dynamic (at different locations)	**Mobile**	**mobile IP** **e.g. laptop in the hotel**	**mobile telephony** **e.g. laptop in the car** **PDA at customer's site**
	Fixed	**POTS** **Existing LANs** **e.g. workstation in the office**	**wireless LAN** **cordless telephone** **e.g. wireless "last mile"**

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Problem: engineering communication means

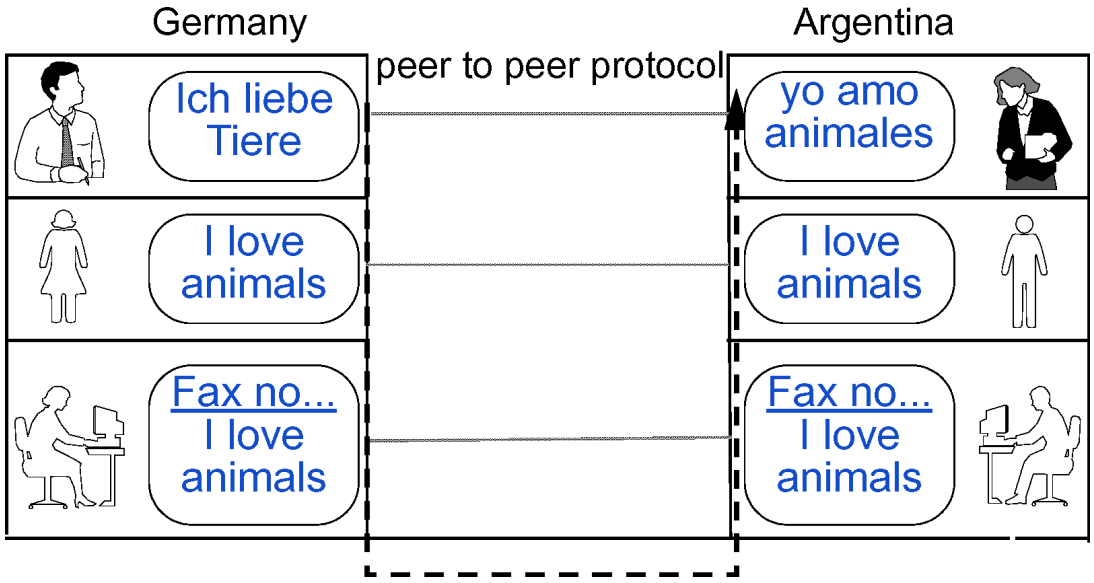
- multitude of partially very complex tasks
- interaction of differing systems and components

Simplification:

- to introduce abstraction levels of varying functionalities
- general module, preferable: layer, level

Example (here using ISO-OSI reference model, later 5 layers

- biologists with translator and e.g. secured encrypted FAX-office



Layer content („service“)

- may be exchanged at any layer independently

Use protocol

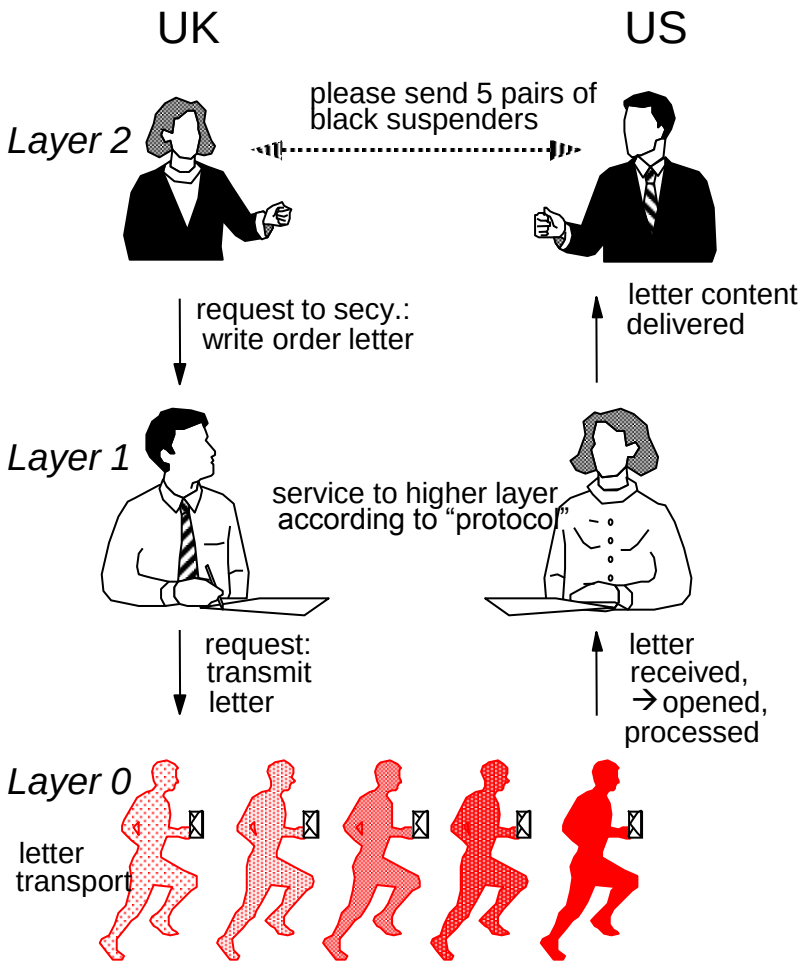
- to ensure peer entities interoperate correctly

Tradeoff:

- overhead (SW/msg) vs. exchangeability, clarity, simplicity

Note:

- open question remains: what is going to happen? (“presentation syntax”)



Layered Architecture

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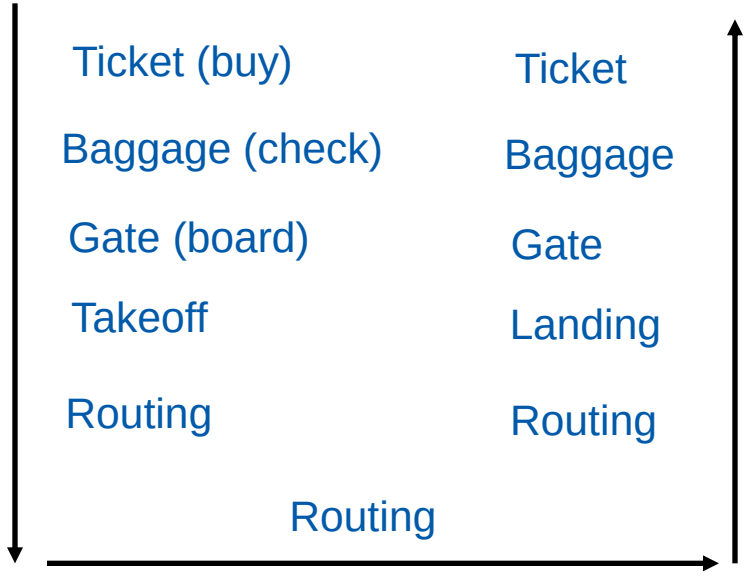
How would you describe the airline system?

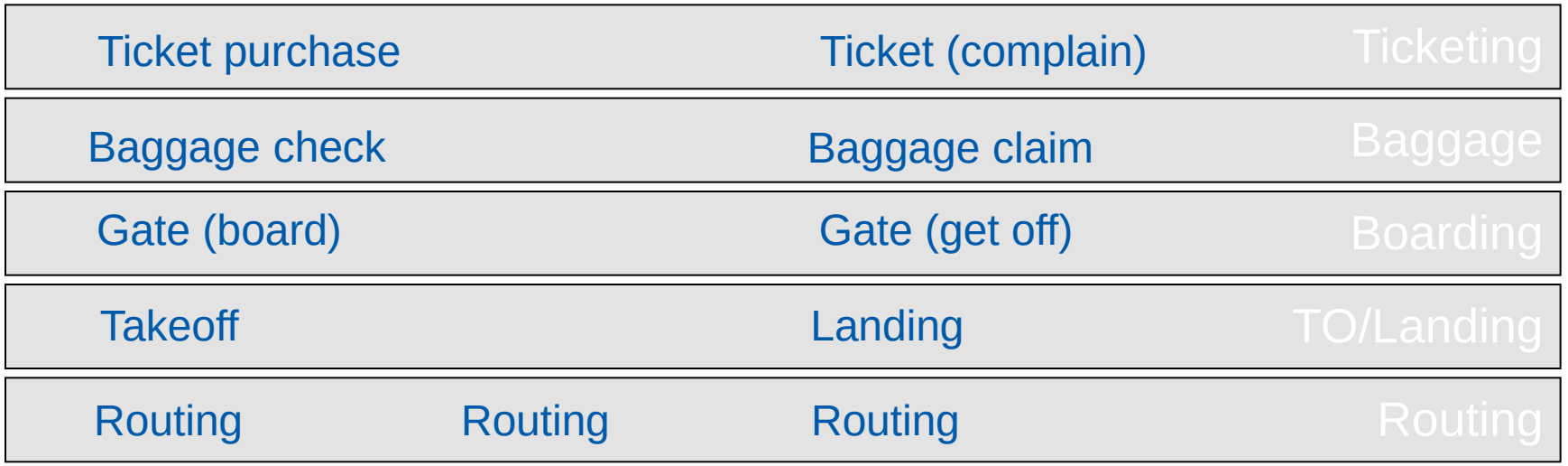
- Ticketing, baggage, gates, pilots, routing, …

Describe by actions:

- Buy ticket
- Check in with baggage
- Go to gate for boarding
- Plane takes off
- Plane is routed to destination
- Plane lands
- Arrive at gate
- Claim bags
- (Complain to airline)



Layered Architecture



Layers provide services by:

- Performing actions on its own layer
- Using services from a layer **directly below**
- Realizing a distributed abstract machine

Is above a good example? No!

- good layered architectures are great art & science!

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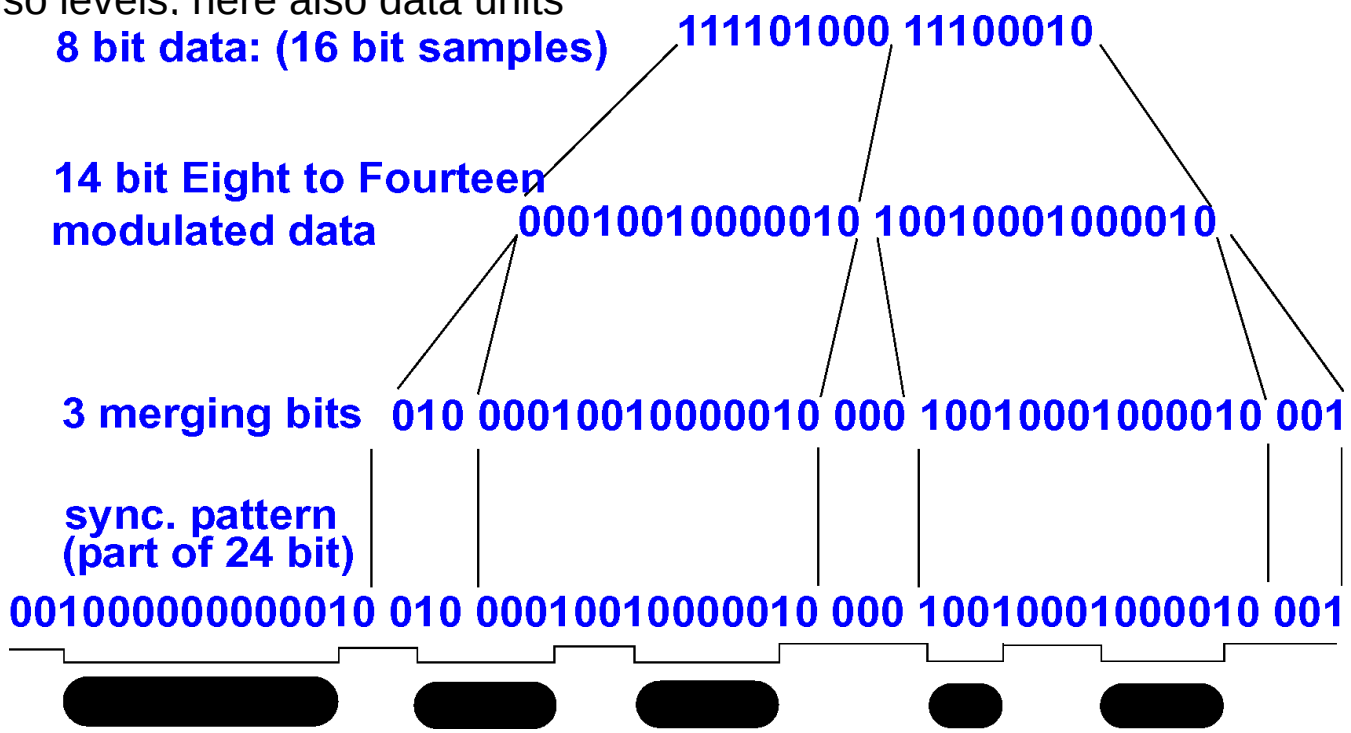
(only in communication?) layers exist in various areas

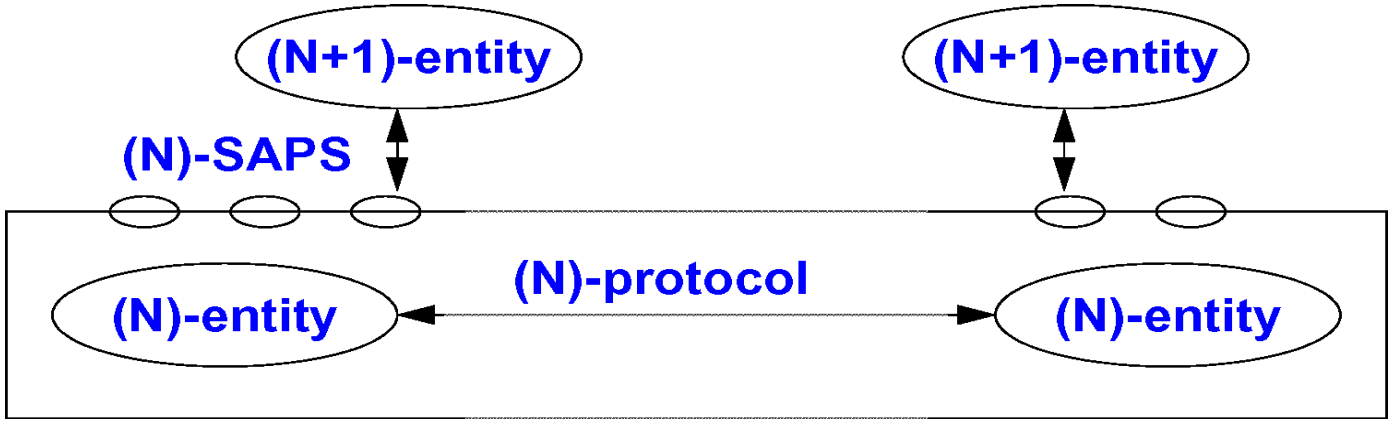
- e. g.
  - compression: MPEG
  - CD technology

Example: CD Digital Audio

- here also levels, here also data units



Layers in General



N-Layer

- abstraction level with defined tasks

N-Entity

- active elements within a layer
- process or intelligent I/O module
- peer entities: corresponding entities on different systems

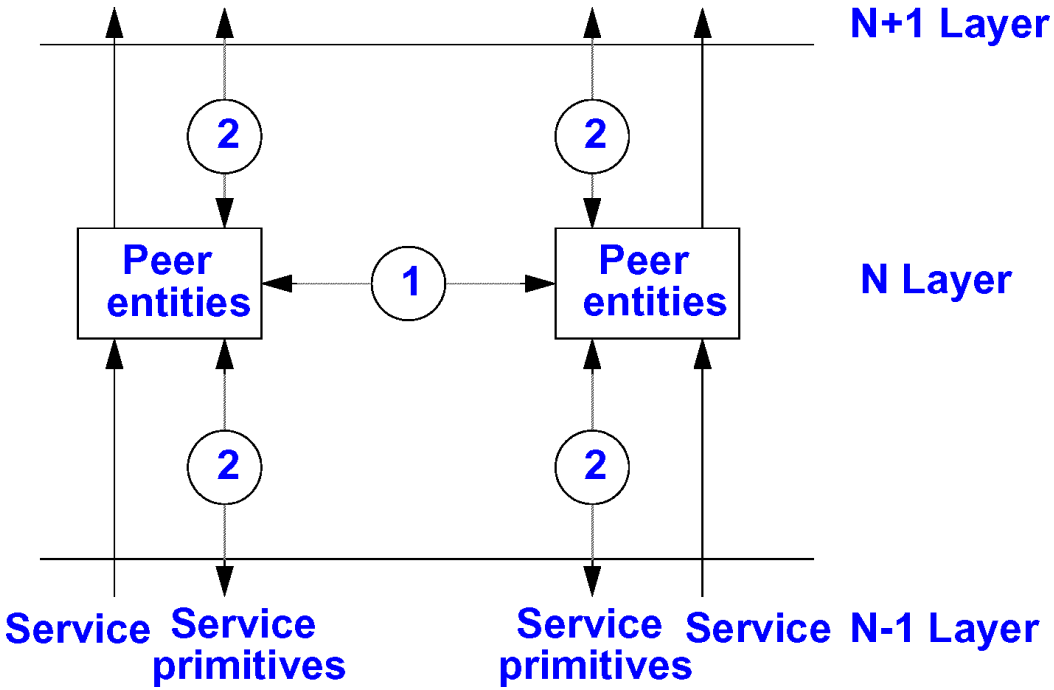
N-Service Access Point, N-SAP

- service identification

N-Protocol:

- a multiple of rules for transferring data between N-entities

9.3 Protocol: Communication between same Layers



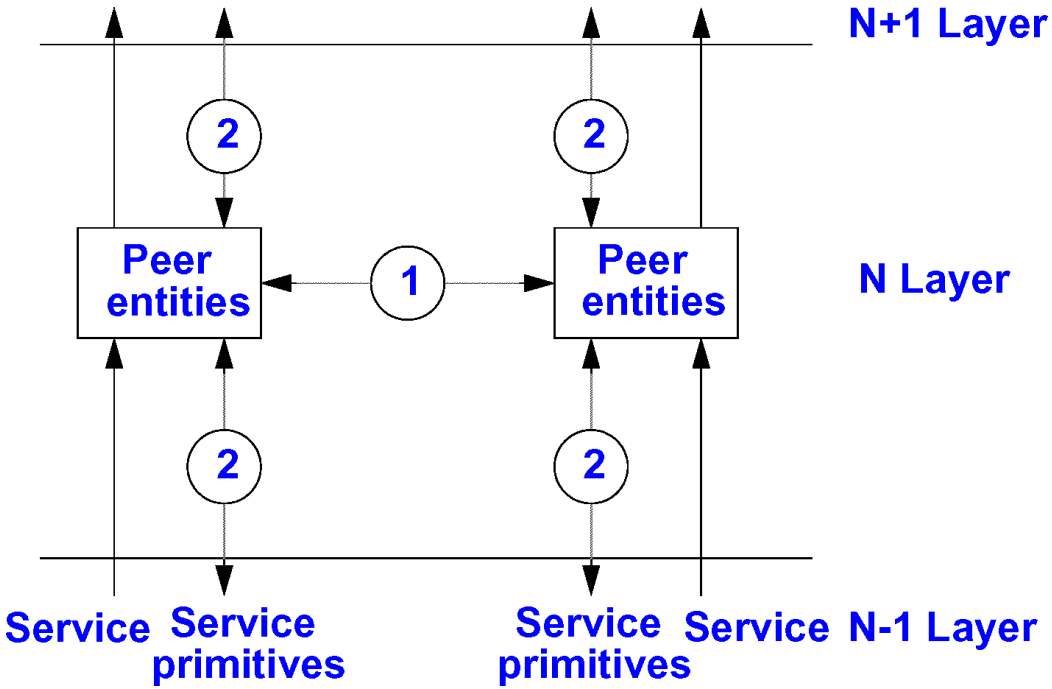
Definition of protocol:

- A protocol defines
  - the format and
  - the order of messages
- exchanged between two or more communicating entities,
- as well as the actions taken on transmission and/or reception of a message or other event

Protocol

- rules for syntax (format) and semantics (contents)
  - of the data transfer (frames, packet, message) occurring
  - between the respective, active peer entities
- analogy: programming, protocol corresponds to
  - realization of the data type (procedures, etc.)
  - the "interior" of the object

Service: Communication between adjacent Layers



Service

- multiple of primitives/operations/functions
  - which one layer offers to the upper next layer
- characterized by the "interface"
- does not reveal anything about the implementation
- analogy: programming, service corresponds to
  - abstract data type
  - object

Fundamental distinction between connection-oriented and connectionless

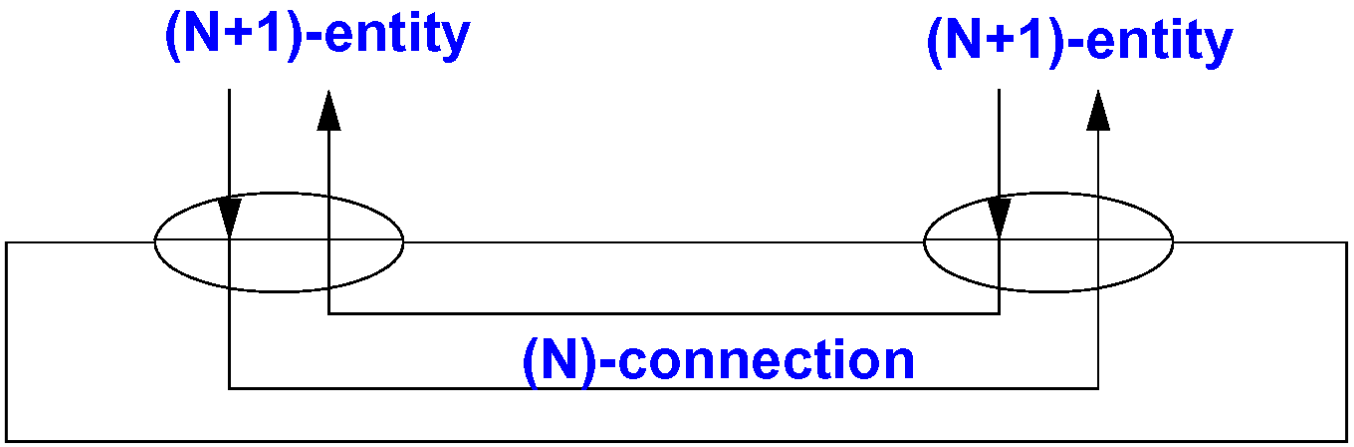
Rough analogies:

- **Connection-oriented ≈ telephone service**
- **Connectionless ≈ postal service**

...how many calls can she handle?

...what kind of guarantee do you get?

Connections: Connection Oriented Service



Connection oriented:

- 3 phases:
  - to connect (also called handshake)
  - to transfer data
  - to disconnect

Note: "Connection-oriented" does not imply any additional properties of the connection

- No reliability, flow control, or congestion control is required
- TCP (Internet's connection-oriented protocol) implements them

BUT: "Connections" are nothing but a distributed "state", held at both end points

- this is the *basis* for almost all additional properties
- … and for overhead (IP golden role: *no* state in routers)

Connectionless Service

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Connectionless networks have no connection establishment phase

- transfer of isolated unit data
- Go straight to data transfer phase
- Also, no connection teardown phase

No need to maintain connection state

Communication partner might not be ready for receiving

Connectionless networks do not implement:

- Reliability, flow control, congestion control
- Applies also to UDP (Internet's connectionless protocol)

So, Which Is Better?

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Overhead of handshake in connection-oriented

- Can be significant in short communications
- Insignificant in long communications

What happens when network is congested:

- Connection-oriented: Busy, no connection
- Connectionless: Can communicate, but may be stalled

Possible to build connection-oriented service on top of a connectionless service

Pro Connection-oriented: Better service (at cost of state)

Pro Connectionless: Stateless → Scalable

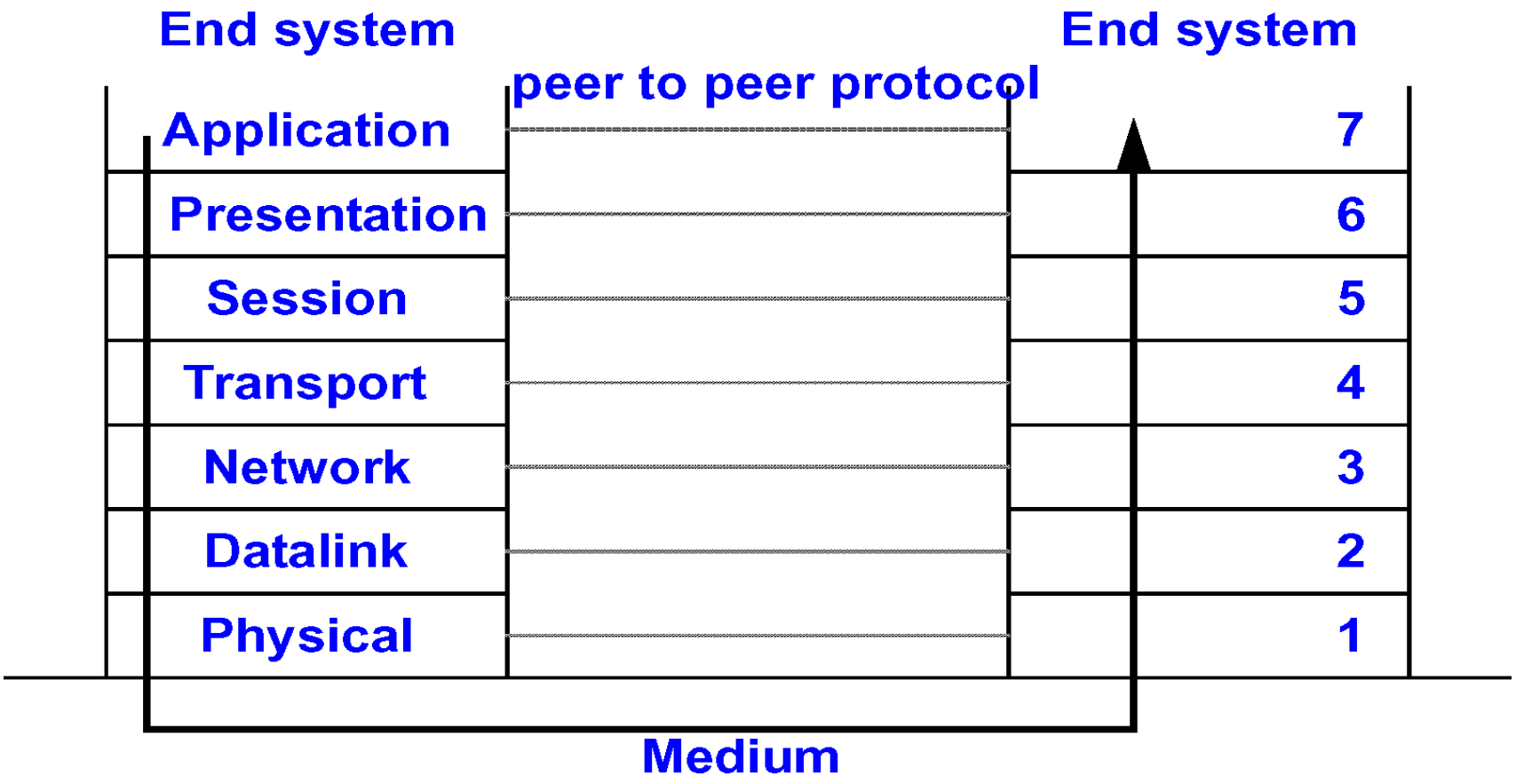
Applications for both types of networks

ISO OSI (Open Systems Interconnection) Reference Model

- model for layered communication systems
- defines fundamental concepts and terminology
- defines 7 layers and their functionalities

7	**Application Layer**
6	**Presentation Layer**
5	**Session Layer**
4	**Transport Layer**
3	**Network Layer**
2	**Data Link Layer**
1	**Physical Layer**

Actual data flow between two systems:



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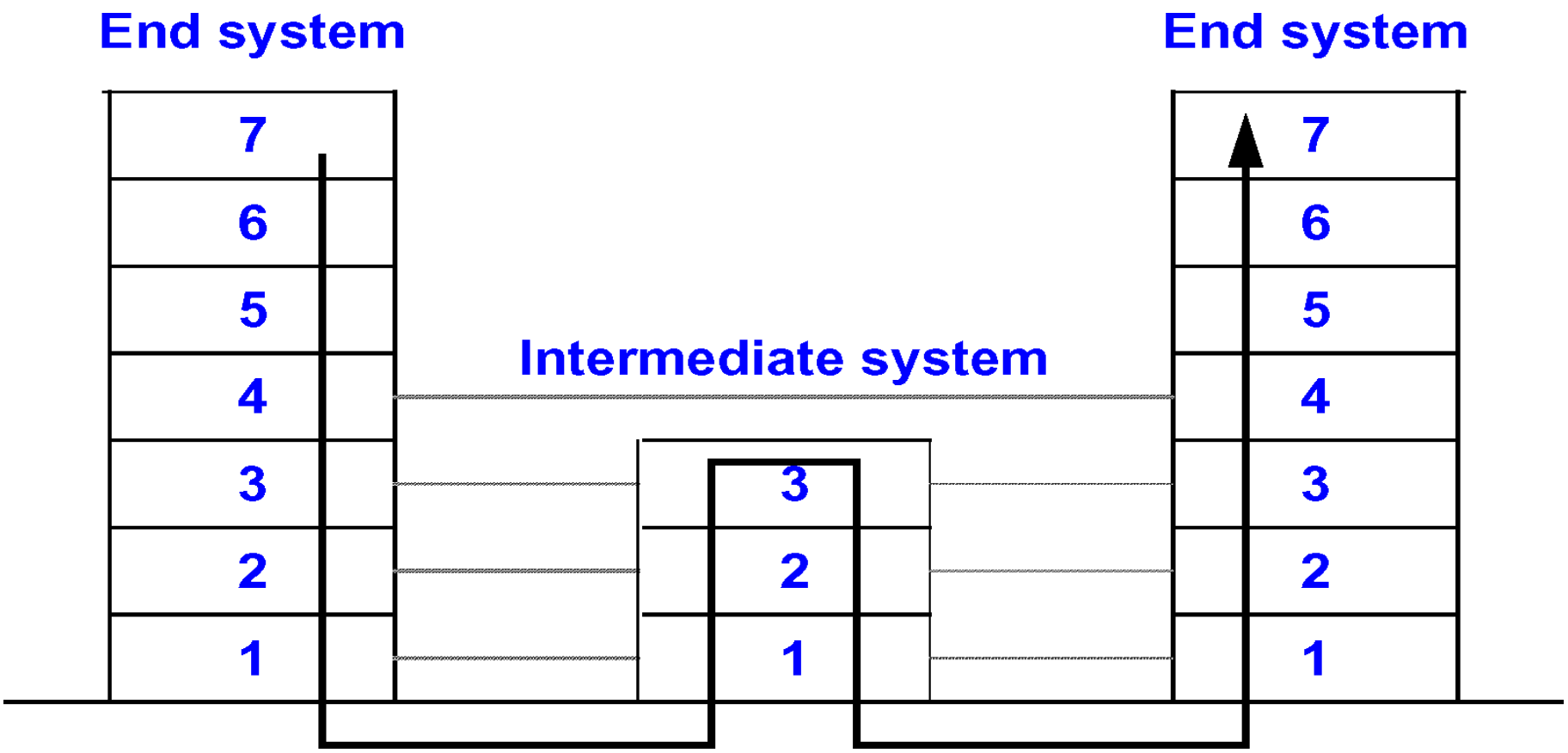
Real data flow with intermediate systems:



11.2 Layers and theirs Functions

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Layer	Function

1 Physical	**Signal representation of bits: sending bit 1 is also received as bit 1 (and not as bit 0):**
	▪ mechanics: connector type, cable/medium,..
	▪ electronics: voltage, bit length,..
	▪ procedural:
	  ▪ unidirectional or simultaneously bidirectional
	  ▪ initiating and terminating connections
	
	Protocol example: RS232-C = ITU-T V.24; other: ITU-T X.21

2 Data Link	**Reliable data transfer between adjacent stations with frames**
	▪ introducing data frames and acknowledgement frames
	▪ error recognition and correction within the frame:
	  ▪ manipulation, loss, duplication
	  ▪ Residual & “severe” errors deferred to higher layers
	▪ fast sender, slow receiver:
	  ▪ flow control
	▪ distribution network requires access control:
	  ▪ Medium Access Control (MAC)

ISO-OSI Layers: Functions

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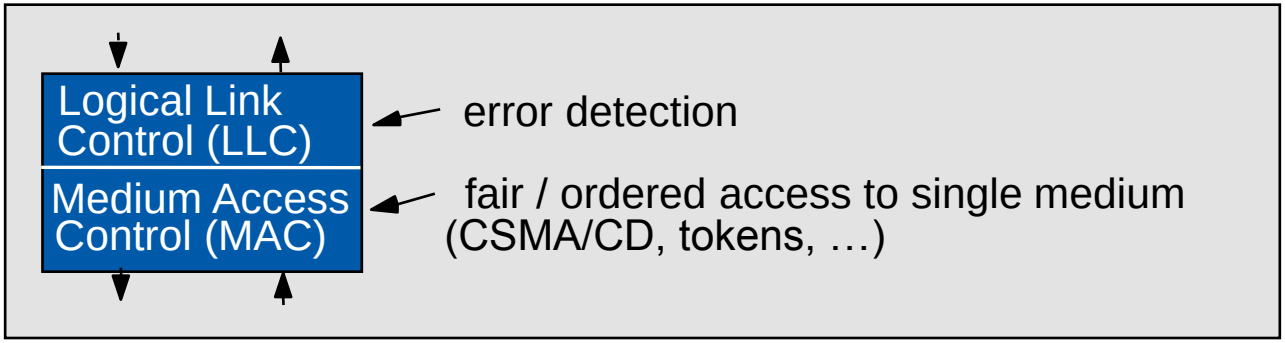
Layer	Function
2 **Data Link**	Layer 2 may already include some flow control Goal: protect slow receiver Flow control can be sophisticated (sliding window protocol), For example, avoid slow stop-and-go for satellite connections Broadcast networks (LAN) often with two sublayers Logical Link Control (LLC) Medium Access Control (MAC) 

ISO-OSI Layers: Functions

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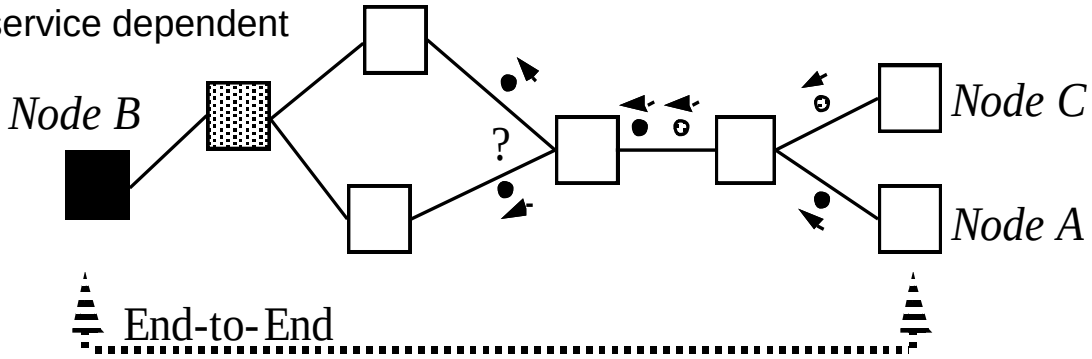
Layer	Function
3 Network	**connection (as relationship between entities)** **end system to end system** ▪ (subnets) with packets ▪ routing, i. e. among others ▪ fixed, defined during connect, dynamic ▪ congestion control (too many packets on one path) ▪ quality of service dependent  ▪ varying subnets, Internetworking, ▪ i. e. among others ▪ addressing, packet size ▪ comment: at broadcast networks: ▪ routing often simplified or non-existent, i. e. this layer does often not exist here ▪ example: IP (connectionless), X.25 (connection-oriented)

ISO-OSI Layers: Functions

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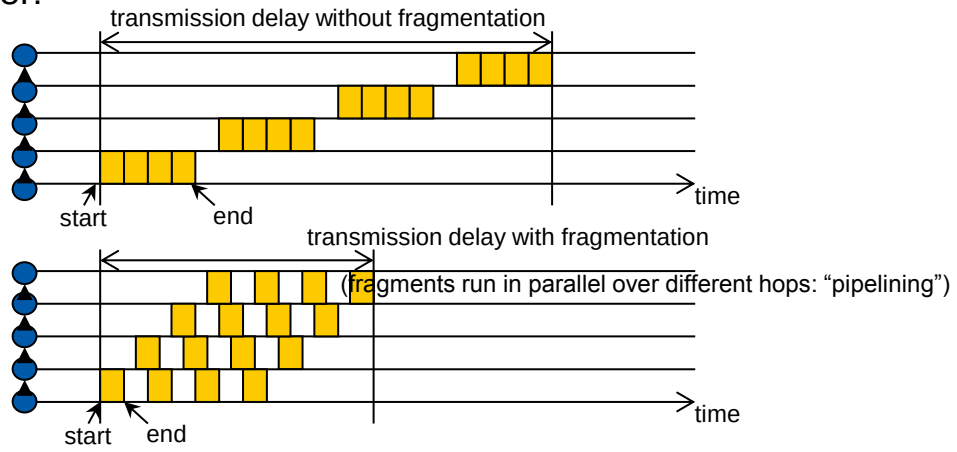
Layer	Function

4 Transport	**Connection (as relationship between entities)**
	From source (application/process) to destination (application/process)
	▪ optimize required quality of service and costs
	  ▪ 1 L4 connection corresponds to 1 L3 connection
	▪ increase throughput:
	  ▪ 1 L4 connection uses several L3 connections (splitting)
	▪ minimize costs:
	  ▪ several L4 connections multiplexed onto 1 L3 connection
	▪ process addressing, connection management, error correction
	▪ fast sender, slow receiver:
	  ▪ flow control
	▪ protocol example: TCP
	 

ISO-OSI Layers: Functions

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Layer	Function
5 Session	**support a "session" over a longer period** ▪ synchronization (during interrupted connection) ▪ token management (coordinate the simultaneous processing of different applications)

6 Presentation	**data presentation independent from the end system**
	▪ negotiating the data structure,
	▪ conversion into a global data structure
	▪ examples:
	  ▪ data types: date, integer, currency,
	  ▪ ASCII, Unicode, …

7 Application	**application related services**
	▪ examples:
	  ▪ electronic mail, directory service
	  ▪ file transfer, WWW, P2P, …

Comment:

- layer does not necessarily correspond to the process of the implemented unit
  - otherwise loss of efficiency

OSI 7-Layer Architecture Summary

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7. Application Layer A: cooperating entities
6. Presentation Layer P: exchange of data (semantics!)
5. Session Layer S: structured dialogue
4. Transport Layer T: end2end msg. stream betw. individual processes
3. Network Layer N: packet stream between end systems
2. Data Link Layer D: error-recovering frame stream, adjacent sys.
   - LAN comprises
     - L.2b: Logical Link Control
     - L.2a: Media Access Control
1. Physical Layer PH: unsecure bitstream between adjacent systems

Note:

- Many service functions carried out in several layers / services
  - i.e. Overhead, even reversal in part due to net homogeneity

Application level “messages” are processed as data units.

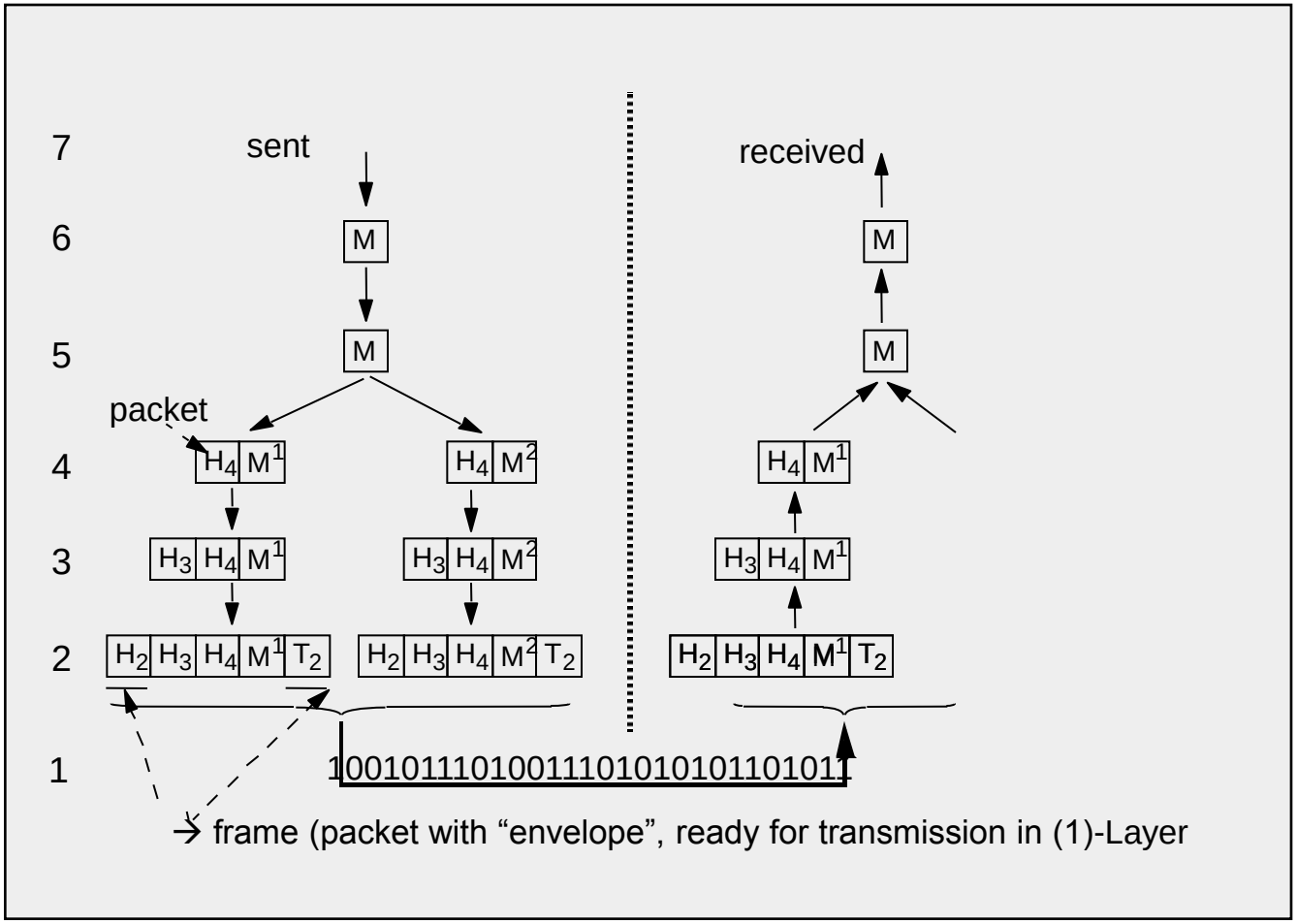
Following notions for data units have become common:

- packet: “unit of transportation” (may contain fragments)
- datagram: instead of packet if sent individually (connectionless)
- frame: with final envelope, ready to send (next to lowest layer)
- cell: small packet of fixed size

OSI terminology: „message“ is a PDU

- PDU: Protocol Data Unit
  - (N)-PDU: semantics understood by peer entities of (N)-service
  - (N)-PDU = (N)-PCI plus (N)-SDU; (N)-SDU = (N+1)-PCI plus (N+1)-SDU
- PCI: Protocol Control Information: only used by peers
- SDU: Service Data Unit = payload - optionally carried in PDU for user

OSI Model: Data Units



Header H_n (plus maybe Trailer T_n) in (N)-layer carries (N)-PCI

Protocol Control Information PCI: checksums, msg no., …

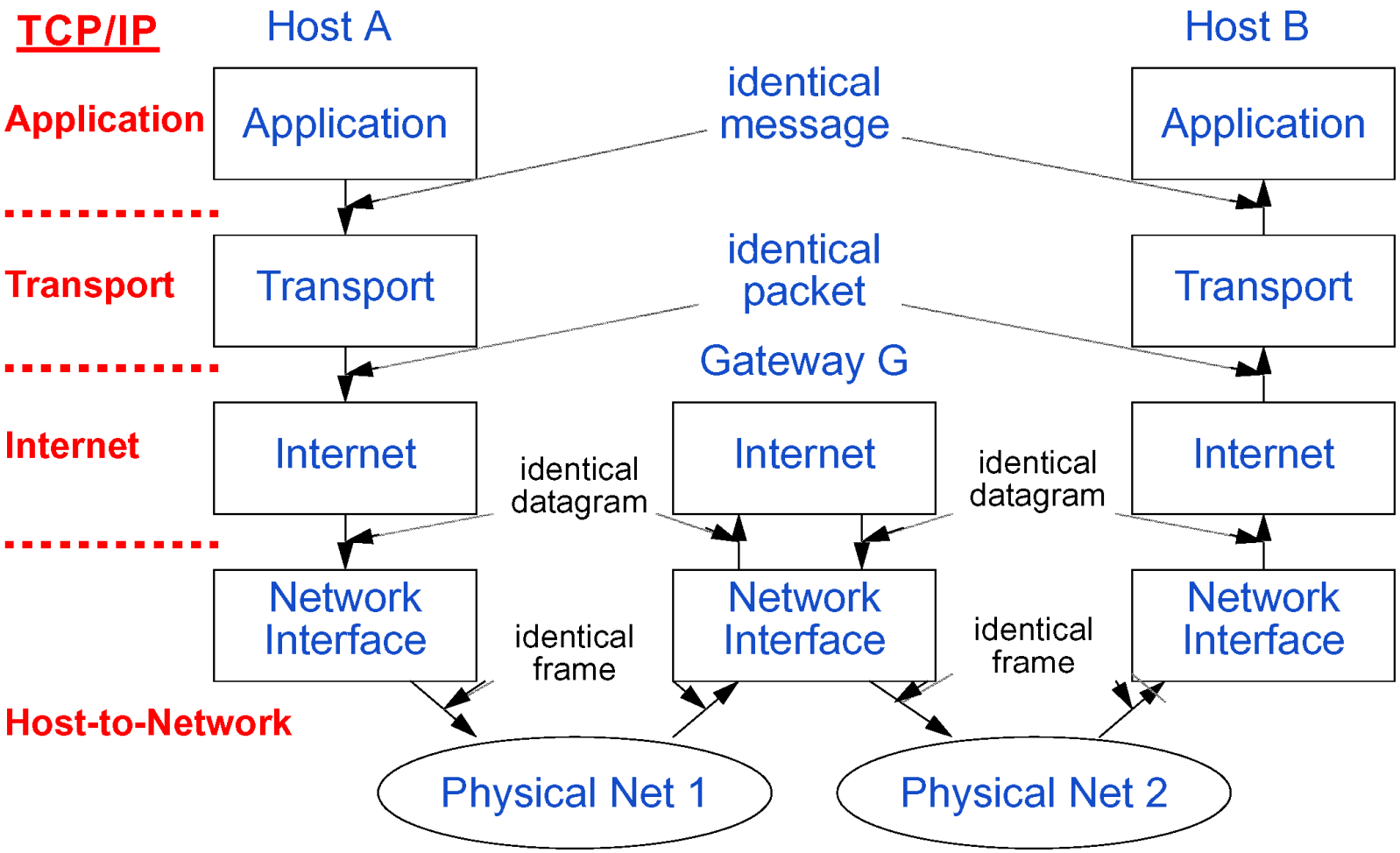
OSI (Open Systems Interconnection) Reference Model

7	Application Layer
6	Presentation Layer
5	Session Layer
4	Transport Layer
3	Network Layer
2	Data Link Layer
1	Physical Layer

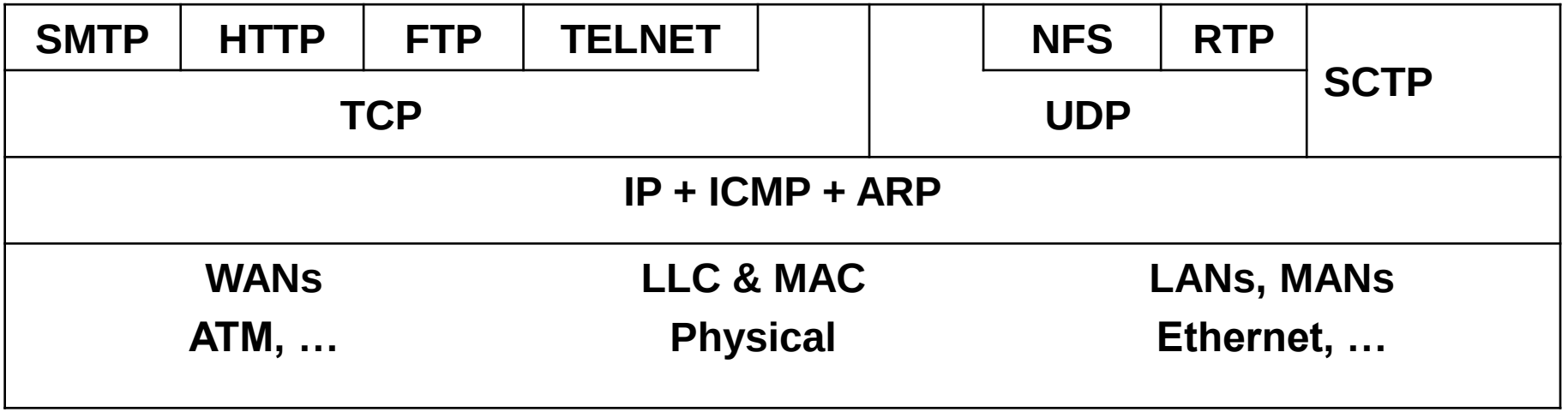
TCP/IP Reference Model Internet Architecture

- ISO-OSI presentation, session and application layer merged
- ISO-OSI data link layer and physical layer merged to form Network Interface

TCP/IP Reference Model: Internet Architecture



Well-Known Internet Protocols



ARP = Address Resolution Protocol
FTP = File Transfer Protocol
HTTP = Hypertext Transfer Protocol
IP = Internet Protocol
ICMP = Internet Control Message Protocol
LLC = Logical Link Control
MAC = Media Access Control
NFS = Network File System
SMTP = Simple Mail Transfer Protocol
TELNET = Remote Login Protocol
TCP = Transmission Control Protocol
UDP = User Datagram Protocol
SCTP = Stream Control Transmission Protocol

Comparing the Reference Models: 5-Layer Model Used Herein

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ISO-OSI: standardized too late

- implementations usually worse than those of Internet protocols
- in general, however, mainly good concepts

TCP/IP (Internet)

- TCP/IP already prevalent, SMTP too, now e. g. WWW
- integrated into UNIX

Considered here:

Layer		Function
5	Application	application related services incl. ISO-OSI L5 and L6 (as far as necessary)
4	Transport	connection end/source (application/process) to end/destination (application/process)
3	Network	connection end-system to end-system
2	Data Link	reliable data transfer between adjacent stations
1	Physical	sending bit 1 is also received as bit 1

Example: Layers in Action

What happens in different layers when you use your browser to access a website?

Remember: **Internet has only 5 layers**

- Layers 5, 6, and 7 implemented in a single application layer

In Internet, layers 3 and 4 are somewhat confused

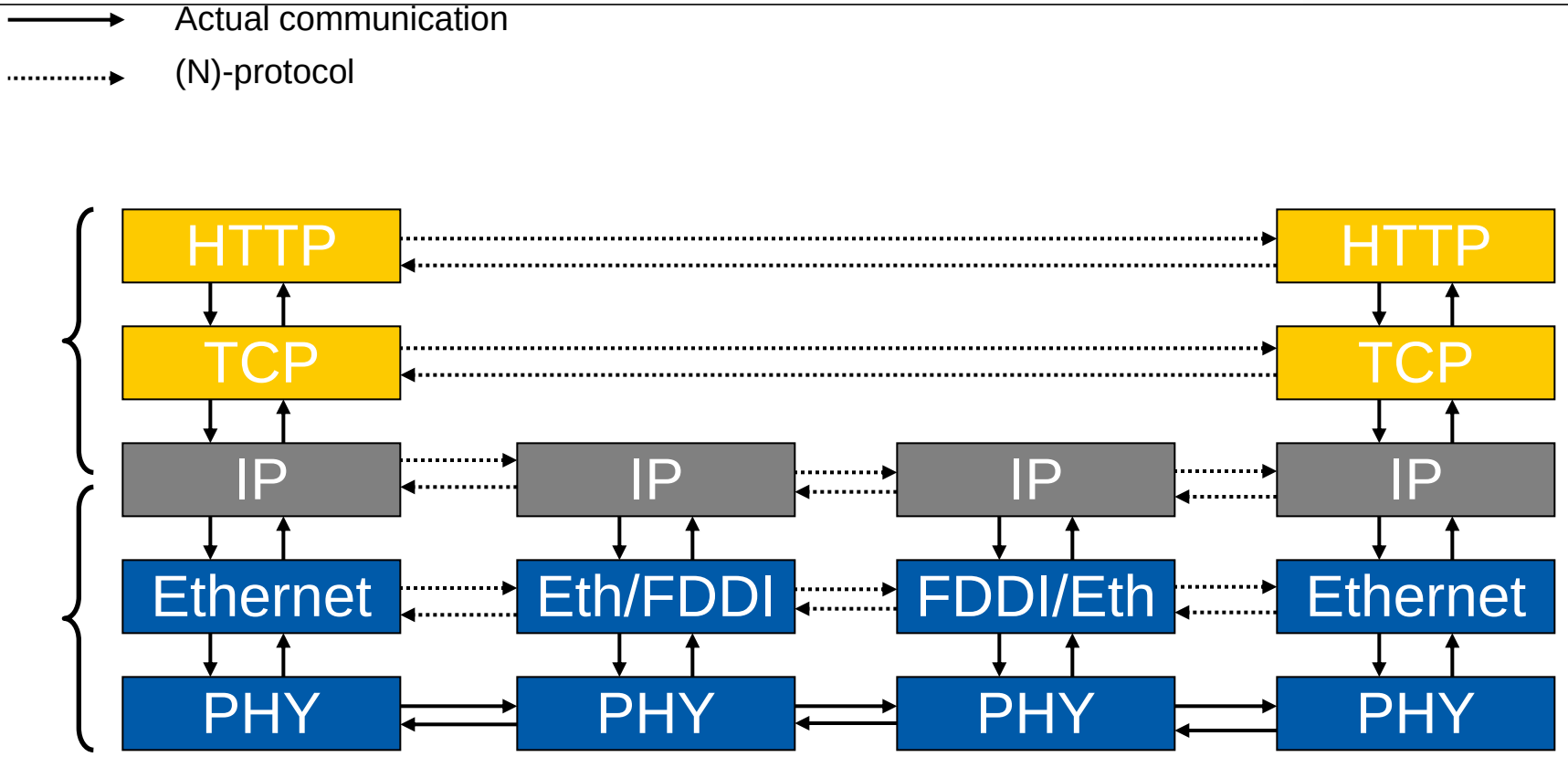
- Transport protocol TCP (or UDP) and network protocol IP
- Sometimes hard to draw a clear line where TCP ends and IP begins
- **But:** Basic functionality is clearly separated

So, what happens?

Sidenote: 7-layer model has been extended… :-)

- Layer 8: Financial layer
- Layer 9: Political layer

Layers in Action



Request goes down on layers at browser

Physical layer handles actual sending of message to next (neighbor) node

Network protocol (IP) takes care of routing message to destination

- Possibly several hops from one router to another
- At each router, message goes up to IP-layer for processing

Transport and application layers converse end-to-end

Functionality Recap

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Layer 5,6,7

- Create HTTP request
- Invoke layer 4 (= TCP)
- Process reply (= web page)

Layer 4

- Open reliable connection to web server
- Make sure data arrives in the order it was sent
- Do not saturate network
  - Congestion control

Layer 3

- Route message from client to web server
- Message passed from router to router
- Layer 3 provides end-to-end service through hop-by-hop actions

Layer 2

- Put data from layer 3 in frames
- Send frames to immediate neighbor

Layer 1

- Actual transmission of a frame as a bitstream

Each layer performs some critical function

Layering not always “clean”

- Where congestion control or reliability is handled ?

14 History und Basics - Summary

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History

Basic terminology and concepts

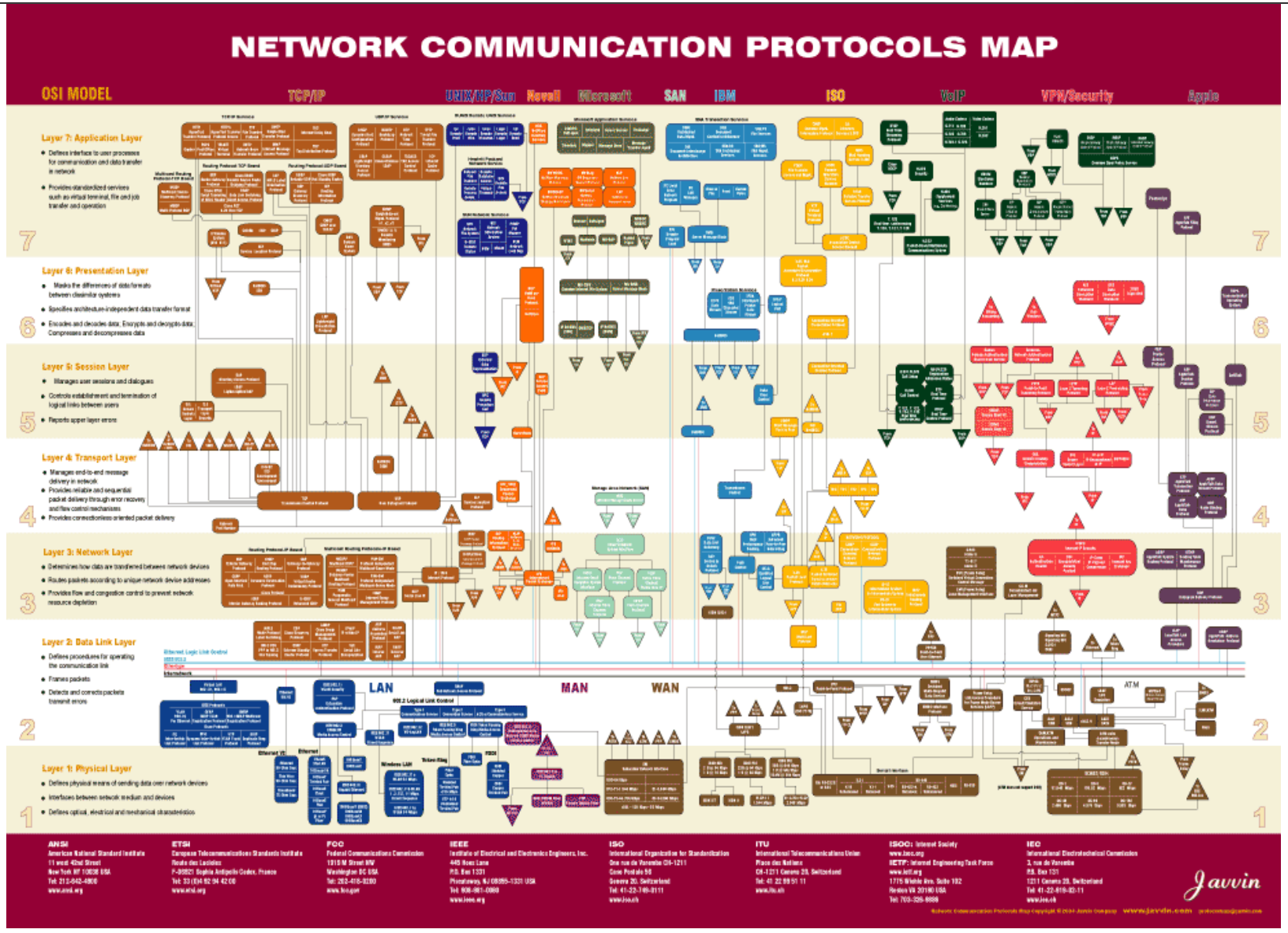
- Protocol
- Service
- Layer

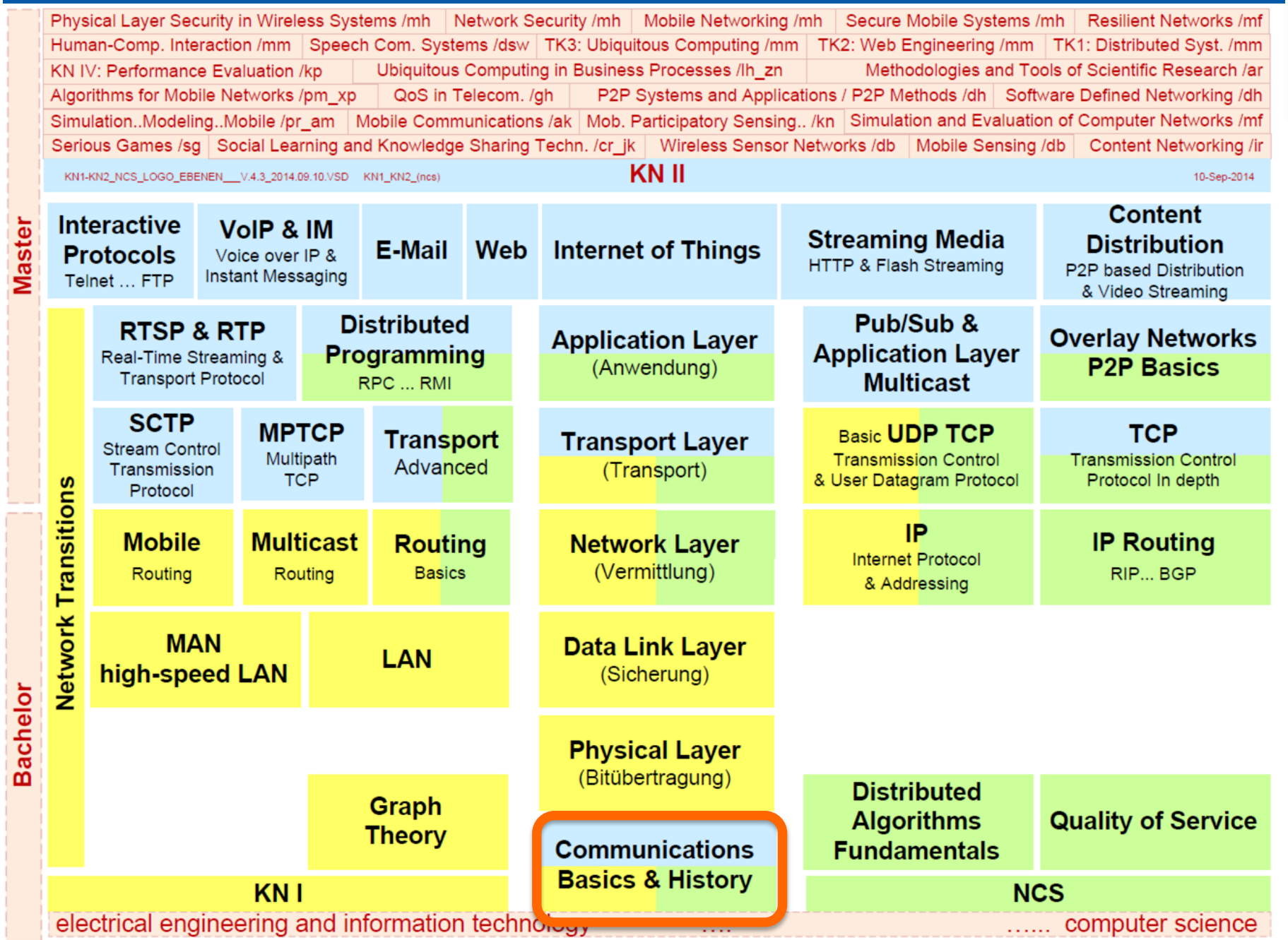
OSI and Internet layer models

Connection-oriented and connectionless networks

Example of layers in practice

Networking Protocol Map … (Source www.javvin.com)





10. September 2014