Kommunikationssysteme

<u>Computer Network</u>: a set of autonomous computer exchanging information

<u>System</u>: a regularly interacting or interdependent group of items forming a unified whole

<u>Distributed System</u>: a set of geographically distributed, autonomous, and interconnected computers, offering services based on cooperation

<u>Application</u>: service on single host

<u>Distributed Application</u>: service in a distributed system

<u>End-Systems</u> (hosts), <u>Intermediate systems</u> (routers), <u>Links</u> (cables)

- Personal Area Net. (PAN)
- Storage Area Net. (SAN)
- Local Area Net. (LAN)
- Metropolitan Area Net. (MAN)
- Wide Area Net. (WAN) / Global Area Net. (GAN)

Networks provide infrastructure for:
- connectivity   - resource sharing
- load balancing   - reliability

<u>Information</u>: Knowledge on subjects depends on humans

<u>Data</u>: characters or continuous functions which represent
(digital)   (analog)
information to be processed in a well-defined manner

Signals / Messages / Communications
↳ Physical representation of data

Standardization for global compatibility

ITU/ISO/IEEE/IETF

Dialog: o←→o   Broadcast: Anycast:

Multicast: Unicast: o——→o

Serial VS Parallel Transmission

Simplex / Duplex / Half-Duplex

Quality of communication

USER-Adequacy - Subjective Opinion

TECHNICAL - Performance   - Security   - Costs

- Reliability   - Safety

OSI Layers

1	Physical	/	Bitübertragungsschicht
2	Data	/	Sicherungsschicht
3	Network	/	Vermittlungsschicht
4	Transport	/	Transportschicht
5	Session	/	Kommunikationssteuerungsschicht
6	Presentation	/	Darstellungsschicht
7	Application	/	Anwendungsschicht

Layers/protocols Horizontal

Service   Vertical
→ Request
→ Indication
→ Response   SAP-Service Access Point
→ Confirmation

Connectionless service: each transfer separate, no state
Connection-oriented service: set up between users, states, protocol
setup→exchange→teardown dependant negotiation, (evtl.) tear-down

Point-to-Point / Broadcast/Shared Medium   Channels

Network topologies: Bus, Ring, Star, Tree, Full-Mesh, Mesh

Resource Sharing -Multiplexing: space-division, frequency-division,
                                time-division, code-division

              -Switching: circuit, packet, message

signal delay v: light= $3 \cdot 10^8$ m/s, copper=$2,3 \cdot 10^8$ m/s, fiber = $2 \cdot 10^8$ m/s
      Length · Bandwidth = const

Modulation   A/A, A/D - D/A Transformation, Recoding D/D

Link Encoding: -Source coding: reduction of redundancy
   (Layer 1)   -Channel coding: detect and correct errors
                -cable coding: assign bits to signals

 NRZ ($\underline{0}\,\overline{1}$), NRZI (change when 1 encountered), Manchester ($\overline{0}\underline{1}$)

Framing Approaches: -Sentinel: special patterns to delineate fram
   (Layer 2)   -Counter: length in header
                     -Clock: time-frames

Reliable Transmission: - error detection (and correction)
                       -flow control
                          →avoid bursts @ sender
                          →avoid buffer overflow @ receiver
                        credit-/window-based schemes
                        rate-based schemes
                        ⇒ Sliding Window Protocols

Error Control : -sequence numbering
  - acknowledgement
  - retransmission
  - forward Error Correction   (Parity Check)
  - checksums   (CRC   )

Distributed access to same shared medium

- co-ordination   - pre-allocation
- constant / variable   frame lengths

Contention -based ⇒ Aloha Net., send, then check ACK,
(no availability check)   if collision/lost, repeat after random

Carrier Sense Multiple Access (CSMA)
  → check availability before sending data
    1-persistent, p-persistent, non-persistent
  → if collision, repeat after random wait

  CSMA/CD, with Collision Detection

    → jamming signal to everyone, increases backoff

LAN IEEE 802.3

MAC (Medium Access Control) ⇒ 48-bit unicast address
                              assigned to physical adapter
LLC (Logical Link Control)   Broadcast: F:F:F:F:F:F
                              Multicast: first bit 1

Fast Ethernet - 100 Mbit/s

Gigabit Ethernet - 1 Gbit/s

  Token Ring (token moves around, needed to send)
    FDDI

Internetworking

L1, Repeater   L2, Bridge   L3, Router   L>4, Gateway
   Hub   Switch

Source routing bridges (host-driven)
Transparent bridges (self-sufficient, forwarding table)
  ⇒ Redundant Paths, duplicate packets, loops
      → Spanning Tree Algorithm
Remote Bridges (2 LANs encapsulated through WAN)

Switches: -cut-through (direct, as soon as dest. known)
           - store-and-forward (store full packet first, then anal
           - hybrid-switching (combination)
           - predictive switching

Virtual LANs (VLANs) IEEE 802.10

Layer 3/4 switching, IP Switching

Routers, Layer 3, ~~////////////~~ IP: Internet Protocol

IPv4 Header

4b: Version	4b: Header Length (32bit Words)	8b: Type of Service
16b: Length	16b: Ident	16b: Flags/Offset
8b: TTL	8b: Protocol (TCP=6, UDP=17)	16b: Checksum
32b: source Addr.	32b: dest. Addr.	

Address Translation

- IP/Subnet   -Default Router   -DNS server
- DHCP(new IP)   -ARP (IP→Mac)

NAT   ICMP (ping, traceroute)

Routing Algorithms

adaptive / non-adaptive

→ determine shortest path

→ transport the packets throug inter-network

paths based upon metrics (delay, bandwidth, access,...)
- Static routing (simple, non-adaptive)
- Broadcast routing: Flooding (everything to anyone, minus origin)
- Hot Potato: (shortest queue selected)
- Distance Vector Routing (periodically updated table, take
  → used in RIP   better routes from neighbors)
- Link State Routing (routers distribute their local view
  → OSPF   to others)

IPv6 Header

4b: Version   8b: Traffic Class   20b: Flow Label |

16b: Payload length   8b: Next Header   8b: Hop Limit |

16 B: source Addr | 16 B: dest. Addr |

AS: Autonomous System (16 bit number), administrative dom

Stub AS, Multi-homed AS, Transit AS

Subnets

Classless Inter-domain Routing (CIDR)

prefix used for inter-domain, network ID for intra-domain

Route Propagation   Interior GW Protocols

     -RIP   —OSPF

     Exterior GW Protocols

     (peers exchange routing tables)

     — BGP-4

End-to-End Protocols

⇒ Transport Layer (conn set-up, data transfer, tear-down)

   -error control   -Flow control   -sequential order

   3way-Handshake   IP/Port, globally unique

                             Socket (on host)

UDP (User Datagram Protocol)

-connectionless   -unreliable   -message-based   -unorde

Header: 16b: source port   16b: dest. port |

        16b: length   16b: checksum | data

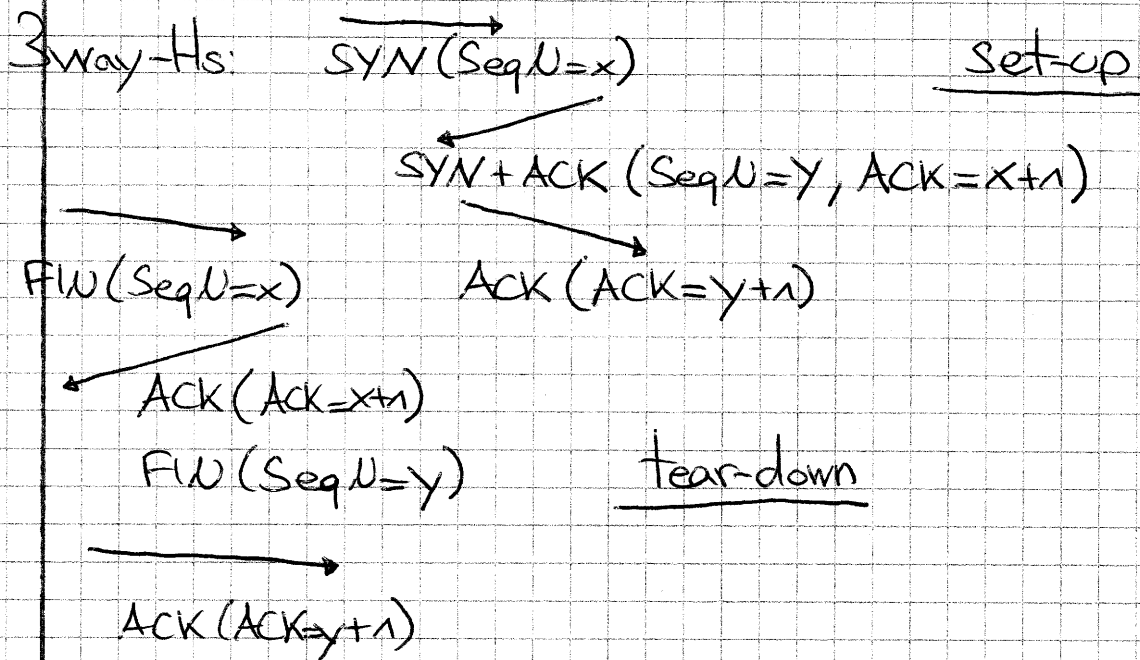### TCP (Transmission Control Protocol)

-connection-oriented -reliable   -ordered

-Flow-control   -congestion-control   -error-control

-sequence numbering -ACKs/numbers   -retransmission

Header: 16b: source port   16b: dest. port |

       32b seq. number | 32b: ACK | ...

Flags: URG, SYN, ACK, FIN, RST, EOM/PSH

3way-Hs: $\longrightarrow$ SYN(SeqN=x) Set-up

SYN+ACK (SeqN=Y, ACK=X+1)

FIN(SeqN=x) ACK (ACK=y+1)

ACK(ACK=x+1)

FIN(SeqN=y) tear-down

ACK(ACK=y+1)

checksumming, acknowledgement

retransmission, Go-Back-N (selective repeat, selective ack.)
$\rightarrow$ Timeout (RTT, Karn/Partridge, Jacobson/Karels)

Flow-control, sliding-window (ACK + advertised window)

Congestion-control, window-based (Slow-start, AIMD)

Implementations: Tahoe, Reno, Vegas

Distributed Applications E-Mail, DNS

SMTP/POP/IMAP
$\downarrow$
HELO
MAIL FROM   MIME (Multipurpose Internet Mail Extensions)
RCPT TO $\rightarrow$ adds content type and encoding
DATA   7/8 bits, base64
QUIT

DNS, recursive resolution