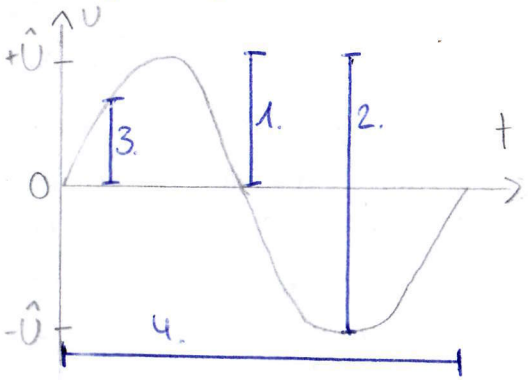
Signaling



1. Amplitude
2. Peak-to-Peak Amplitude
3. Root mean square
4. Single period

Signal Bandwidth

- 300 Hz - 3400 Hz = 3100 Hz Bandwidth

Sampling

- Scan signal wave to digitalise it
- Sampling freq (f_s) > 2 · Bandwidth
- $f_s = 1 / T_s$

Quantisation

- Signal amplitude can reach infinite lvls.
  ↳ Only up to certain points measured
- Q = 2^n steps

Seconds

- 1 s = 1000 ms = 1000000 µs
- 1 ms = 1000 µs

High/Low-Pass Filter

- Only freq. higher/lower than x can pass
- Lower / Higher freq. are rolled off
  ↳ Rolloff: Every octave, dB is lowered by 4

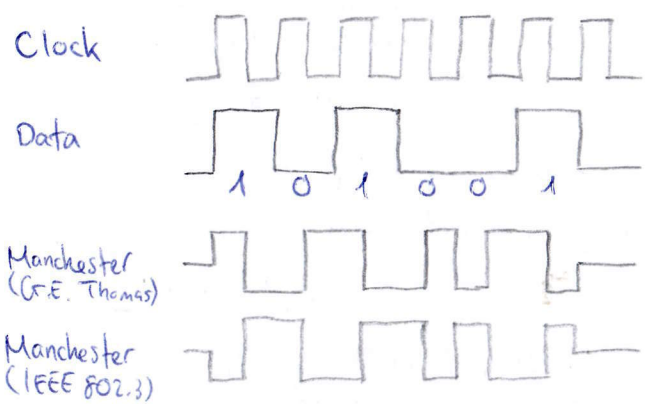
Symbol

- Every significant change in voltage lvl. = symbol
- Symbol ≠ 1 bit
- No standard

Baud / Non return to Zero (NRZ)

- Symbol per second
- Standard: 9600 symbol per second
- Voltage lvl. doesnt change until new symbol

Manchester Code



Klassifizierung von Netzwerke

- Personal Area Network (PAN) < 1m
- Local Area Network (LAN) < 1km
- Metro Area Network (MAN) < 10km
- Wide Area Network (WAN) < 1000 km
- Internet > 1000 km

Start Bit

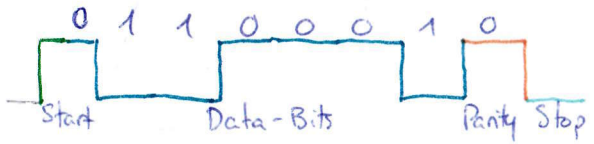
- Signs can be transmitted anytime
  ↳ Start bit announces transmission
- SPACE indicates start of transmission

Parity Bit

- Optional bit after communicated signal
- Failure Detection
- Can be set to odd or even
  ↳ - Odd: Total nr. of 1 → odd number
  - Even: —"— → even number
- No match = refusal of received signal

Stop Bit

- Sent after Parity bit if present
- At least 1 Stop Bit expected by receiver
- Stays in MARK until new transmission



Bit Order

- LSB: Start from right
- MSB: Start from left

MSB → 1 0 0 1 0 ← LSB

Filters

low pass: 
high pass:
band pass: 
band stop: 
low band pass: 
band high pass: 
low band high pass: 

Layer 1 Basics

CSMA / CD
- Only used if NIC in Half Duplex
- Help prevent collision and recovery
- Ethernet Standard
- Procedure
  - Listen to medium if idle
    - Start transmission and listen for collision
    - If collision, send jam signal to all
    - Every device get random backoff timer
    - If max attempts → Abort

Bit / Slot Time
- 1 / NIC speed (Network Interface Card)
- Time to travel entire network and back

Local Collision
- Collision before (512 bits) 64 B are sent
- Receiving bits while sending
- Too little data to detect collision

Late Collision
- Collision after 512 bits
- Indicative of network design problem
  - Full duplex / Half Duplex mismatch etc.

Signal Propagation
- 0.2 m / ns → 200 km / ms (2)

Auto-Negotiation (automatic MDIX)
- Occurs when cables are connected
- Speed, Duplex, Pins are negotiated
- Highest common denominator selected

Duplex Mismatch
- Configured duplex method are different
  - e.g. manually configured wrong
- Very low throughput

Hub
- Detect and regenerate bit seq.
- Detect collision and announce
- Connect different Ethernet networks
- Only in Half-Duplex

Half Duplex / Full Duplex
- HD
  - One pair of wire to send / receive
    - Lower throughput
- FD
  - 1 or 2 wire (each) to send / receive
    - No collisions possible
    - CSMA / CD disabled when FD

RJ-45 Connector
- Straight-through: 1→1, 2→2, 3→3, 6→6
- Crossover: 1→3, 3→1, 2→6, 6→2

Layer 2 ARP, MAC, Ethernet

Broadcast Domain
- Sending to all in network
  ↳ MAC: FFFF.FFFF.FFFF
- Routers seperate Broadcast domain

Collision Domain
- Domain where devices can interfere with each other
- Router/Switch/Bridge seperate Collision domain

Address Resolution Protocol (ARP)
- PCA wants to send to PCB but IPv4 unknown
  ↳ - ARP request -> Who has IP x
    - Switch broadcast floods request
    - PCB sends reply to PC A
    - Switch puts MAC in own table
- ARP Table deletes entry after some time
- Overhead / Security issues (Man in the middle)

Bridge
- Manage traffic on LAN
- Splits workgroup and reduce traffic
- Smaller collision domain
- Has ARP table

Switch
- Uses MAC for switching decisions (MAC Table)
- Intelligent Forwarding

Router
- Connects Layer 2 networks

Difference Switch, Bridge, Hub
- Hub: - Multiport Repeater
  - Only Layer 1
- Bridge: - Only 2 Ports
  - Cannot error check
- Switch: - A lot of ports
  - Can error check

Logical Link Layer (LLC)
- Interface between L2 and L3
- Adds control info to help deliver packet

Media Access Control (MAC)

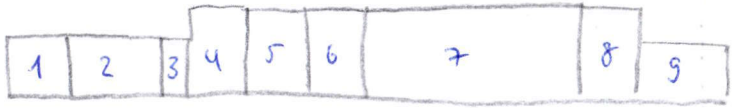
Organisationally unique identifier (OU) 24Bits	Vendor assigned (NIC) 24 Bits

- Individual / Group (I/G)
  ↳ - I/G = 0 => Unicast, I/G = 1 => Multi
    - First bit of first octet
- Universally / Locally Administered Addr. (U/L)
  ↳ - U/L = 0 => Globally adm.
    - U/L = 1 => Locally adm.
    - First bit in second place

0 1

00**1**1 0101 01**1**1 1011 etc.
U/L
I/G

Ethernet II Frame



1.19. Interframe spacing (IFG)
2. Preamble (7B)
   ↳ Identify initiation of frame by 10101011
3. Start Frame Delimiter (SFD) (1B)
   ↳ Single 1 to signal next byte is DA
4.15. Destination / Source MAC Address (6B each)
6. Type (2B) => IPv4 = 0x0800, ARP = 0x0806
7. Data and Padding (1500B)
   ↳ Holds data from higher Layer
   Min. 46B required (Padding)
8. Frame Check Seq. (FCS) (4B)
   ↳ Receiver NIC check for transmission errors

PDU
- Current layer is PDU
- Min. 64B to detect collisions

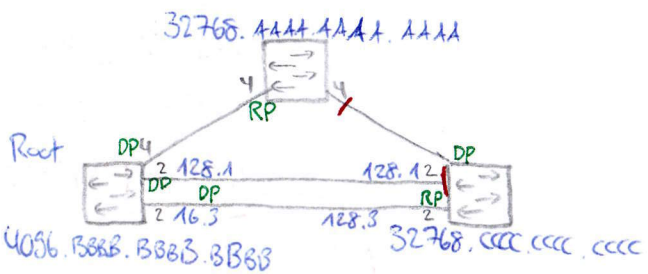
SDU
- When data gets passed to lower layer
  ↳ PDU becomes SDU

MTU
- Maximum Transmission Unit

Layer 2 STP

Spanning Tree Protocol (STP)

- BPDU
  - ↳ - Hello / configuration BPDU sent by root bridge
    - Topology change notification (TCN)
    - Source MAC of port
    - Destination MAC: 01-80-c2-00-00-00 (multicast)
- Electing Root Bridge (Lower is better)
  - ↳ 1. Bridge ID (Bridge Priority + MAC Address)
    2. If equal, only MAC are compared



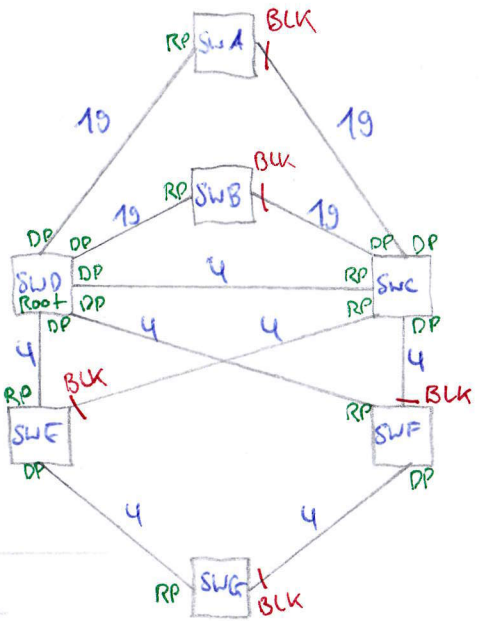
- Port States
  - ↳ - Blocking => Drops all packets and BPDU (20s)
    - Listening => Process BPDU, discards data frames (15s)
    - Learning => Update MAC table with frames no forwarding (15s)
    - Forwarding => Process everything

Disabled → Blocking → Listening → Learning → Forwarding

- Hello / Config. BPDU (Every 2s from root sw)
- Max age: Last BPDU > 20s
  - ↳ Find new path to root
- Forward delay: 15s between switching states
- Direct topology change (2x forward period = 30s)
  - ↳ Port between switch goes down
    - Root bridge sends TCN
    - All MAC Timeout set to 15s (Def. 300s)
- Indirect topology change (52s)
  - ↳ - Port not down, but link failure
    - Switch waits 20s for BPDU + 2s next BPDU
    - Listening + Learning state (30s)
- Insignificant topology change
  - ↳ - PC connected to Switch turns off
    - STP Port Fast
      - ↳ Define ports that don't send TCN

Comparison Algorithm

1. Lowest bridge ID
2. Lowest root path cost
3. Lowest sender bridge ID
4. Lowest sender port ID
   - ↳ Port Priority + Port nr.
     - Lowest port is cut



SW A = 32768 f4ac.c1c4.2b80
SW B = ——— " ——— 81
SW C = ——— " ——— 82
SW D = 4096 ——— " ——— 83
SW E = 32768 ——— " ——— 84
SW F = ——— " ——— 85
SW G = ——— " ——— 86

Layer 2 VLAN

Port Aggregation

- Multiple links combined to 1
  ↳ STP doesn't block any link

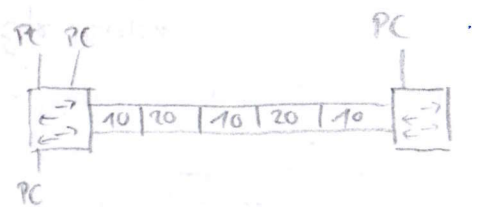
Link Aggregation Protocol (LACP)

- LACP active : Switch negotiates EtherChannel
- LACP passive : Only negotiates if asked to
- 16 potential links per EtherChannel
  ↳ - 8 lowest port priority active
    - 8 on standby

VLAN

- Multiple broadcast domain in 1 switch
- Broadcast / STP domain (not collision)

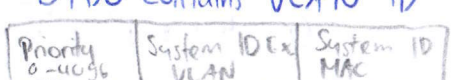
Trunk



- 1 link between 2 switches but 2 domains
- Ethernet packet tagged with VLAN ID
- Multiple MAC Table per Switch
- Max 4096 VLAN (12 bit)

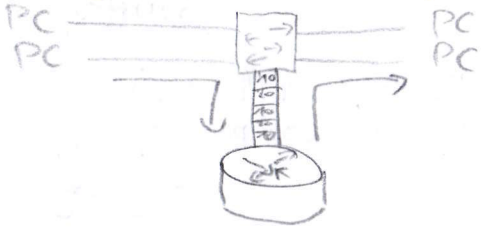
PVST (Per VLAN Spanning Tree)

- BPDU contains VLAN ID



InterVLAN

- Sending data between VLAN requires Router



- Router on a Stick

Layer 3 Basics

Classful networks

- A: 0.0.0.0/8 - 127.0.0.0/8
- B: 128.0.0.0/16 - 191.255.0.0/16
- C: 192.0.0.0/24 - 223.255.255.0/24

Private addresses

- 10.0.0.0 - 10.255.255.255
- 172.16.0.0 - 172.31.255.255
- 192.168.0.0 - 192.168.255.255
- Not routable

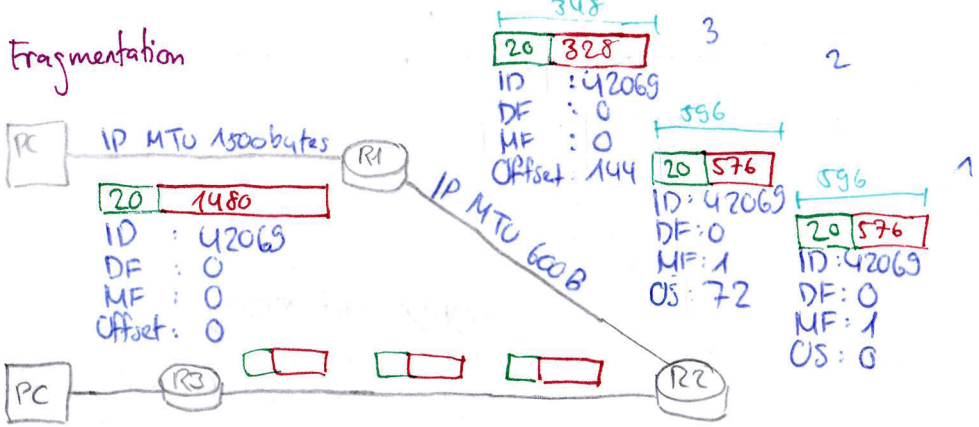
Reserved IP addresses

- Loopback: 127.0.0.0/8 or 127.0.0.1
- Linklocal: 169.254.0.0/16 or 192.254.0.1

IPv4

- Network portion + Host portion
- 32 bits in 4 octets
- 192.168.10.0/24 (Network address)
  - 192.168.10.1/24 (First host address)
  - 192.168.10.254/24 (Last host address)
  - 192.168.10.255/24 (Broadcast address)

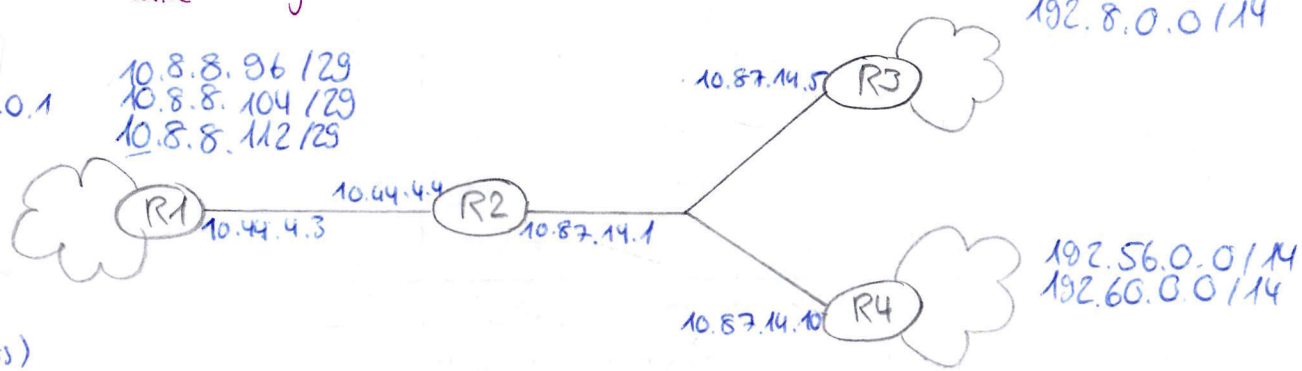
Fragmentation



- Offset needs to be divisible by 8
  - ↳ 72 · 8 = 576

    144 · 8 = 576 + 576
- DF: 0 = Frag. allowed, 1 = Not allowed

Static Routing



R1: 192.0.0.0. 255.192.0.0 10.44.4.4

R2: 192.0.0.0. 255.192.0.0 10.87.14.1

10.8.8.96 255.255.255.224 10.44.4.3

R3: 10.8.8.96 255.255.255.224 10.87.14.1

R4↗

Balanced Workload

ip route 0.0.0.0 0.0.0.0

↳ for all routes

Layer 3 Subnetting

CIDR	Dotted Decimal Notation	Bin. Mask	Nr. of Hosts without -2
/32	255.255.255.255	...1111'1111	1
/31	254	10	2
/30	252	100	4
/29	248	1000	8
/28	240	10000	16
/27	224	100000	32
/26	192	1000000	64
/25	128	10000000	128
/24	255.255.255.0	..11111111.0	256
/23	254	10	512
/22	252	100	1024
/21	248	1000	2048
/20	240	10000	4096
/19	224	100000	8192
/18	192	1000000	16384
/17	128	10000000	2^{15}
/16	255.255.0.0	11111111.0.0	2^{16}
/15	254	10	2^{17}
/14	252	100	2^{18}
/13	248	1000	2^{19}
/12	240	10000	2^{20}
/11	224	100000	2^{21}
/10	192	1000000	2^{22}
/9	128	10000000	2^{23}
/8	255.0.0.0	11111111.0.0	2^{24}
/7	254	10	2^{25}
/6	252	100	2^{26}
/5	248	1000	2^{27}
/4	240	10000	2^{28}
/3	192	100000	2^{29}
/2	192	1000000	2^{30}
/1	128	10000000	2^{31}

8 16 24

11111111.11111111.11111111.11111111

128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1 128 64 32 16 8 4 2 1

1 1 1

1 1 1 1 1

1 1 1

Subnetting

- Reduce 2 from nr. of host because of network /broadcast address

Examples

1. 192.168.1.0/24 Create 50 host networks
   - 62 (2^6) min => 8 - 6 = 2 subnet bits
   - 192.168.1.0/24, 192.168.1.64/24
   - 192.168.1.128/24, 192.168.1.192/24
2. 192.168.1.0/24 8 equal sized subnets
   - $2^3 = 8$, 3 bits for subnets
   - 192.168.1.0/27, 192.168.1.32, ..., 192.168.1.224
3. 172.16.0.0/16 Create subnets of /23
   - /16 → /23 = 7 bits => 128 subnets
   - 172.16.0.0/23, 172.16.2.0/23, ..., 172.16.254.0/23

Variable Length Subnet Mask (VLSM)

- Subnet a subnet even further
- 192.168.20.0/24
  - ↳ 192.168.20.0/27, 192.168.20.32/27, ..., 192.168.20.224/27
    - ↳ 192.168.20.4/30, 192.168.20.8/30, ..., 192.168.20.28/30

IP Route command

- Default Route 0.0.0.0/0
- Everything that isn't local ~~dst~~ is over Def. Route reachable

ip route 0.0.0.0 0.0.0.0 [name]

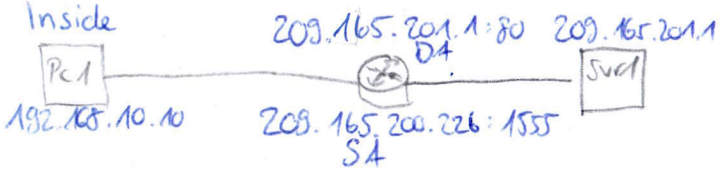
Layer 3 NAT, IPv6

Network address Translation (NAT)

- Private address in home network / organisation
- NAT translate private IP to public to route over internet
- Static Routing
  - ↳ - 1 public IP for a private IP
    - Used for Webserver / Hosting / Datacenter
- Dynamic Routing
  - ↳ - Assigns a public IP from a pool
    - Needs as many public IP as devices connected

Port Address Translation (PAT)

- 1 public IP for devices (~Desk)
- Use port number to track session



- Overlapping ports => Increment 1 port by 1

IPv6

- Next Header can contain Extension Header
- Fragmentation by Host rather than router
  - ↳ MTU by "ICMPv6 package too big" response
- Convert Base 16 number to base 10
  - ↳ $0F3E \Rightarrow 0 \cdot 16^3 + 15 \cdot 16^2 + 3 \cdot 16^1 + 14 \cdot 16^0 = 3904$
    $16^3 = 4096$, $16^2 = 256$

IPv6

- FE80 prefix only within 1 router
- FC00::HostID Unique Local addr
- Multicast start with FF0X::/8 (X: 112)
- Second octet defines lifetime / scope
  - ↳ 8-bit 4-bit 4-bit 112 bit
    1111 1111 Lifetime Scope GroupID
    FF
    First octet
  - Lifetime: 0 = permanent, 1 = temp.
  - Scope: 1 = Node, 2 = Link, 5 = Site
    8 = Org. E = Global
- Solicited Multicast
  - ↳ - Search for IP with same last 24 bits
    - Replacement for ARP / Duplicate Address Detection
    - FF02::1:FF:+24 bits
- Anycast
  - ↳ Same IP in internet for like datacenter

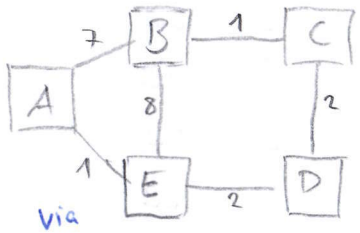
ICMPv6

- Replaces IPv4 ARP
- New ICMPv6 roles
  - ↳ - Router Solicitation / Advertisement
    - Neighbor " / "
- Duplicate Address Detection (DAD)

Layer 3 DVP

Distance Vector Protocol (DV Protocol)

- Hop count as distance
- $D^x(y, z)$ ⇒ Distance from x to y via z
  ↳ $c(x,z) + \min_w(D^z(y,w))$



destination	via A	via B	via D
A	1	14	5
start B	7	8	5
C	6	9	4
D	4	11	2

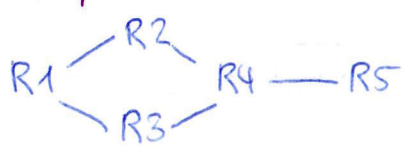
- Link cost changes
  ↳ - Link cost reduction cause no problem
  - Cost increase can cause infinity problem
- Split Horizon: Routes not sent back to where it came
- Poison Reverse: Routes sent back but distance = 16
  ↳ unreachable
- Holddown Timer
  ↳ - Receive info and pass on but don't do anything
  - 3 times update time (default 90s)
  - If no news after 90s, change something
- Triggered Updates
  ↳ Instantly send new info instead of update timer
  - Faster info propagation
  - Holddown timer + Triggered update = optimum
- Problems with DV Protocol
  ↳ - Slow convergence
  - Router sends entire routing table every update
    ↳ Significant bandwidth consumption
  - Routers vulnerable to accidental / inten. misdirections

RIP

(IPv6 not supported)

	RIPv1	RIPv2
Routing Protocol	Classful	Classless
VLSM	No	Yes
Addressing Type	Broadcast	Multicast
Send subnet mask with outing update	No	Yes
Auth	No	Yes

Example



- R4-R5 goes down
  ↳ Poison Reverse / Trigg. updates / Split Horizon on
- All routers receive info with trigg. updates and informs source with poison reverse
- Hold down timer (120s) → After, routing entry deleted
- During 120s → ICMP Destination unreachable

Layer 4 WLAN

WLAN (802.11)

- 2.4GHz = 2400MHz - 2483.5MHz
- 22 MHz = 3 channels (1, 6, 11),
- 20 MHz = 4 channels (1, 5, 9, 13)
- 40 MHz with Channel Bonding (3, 11)
- 5GHz = 5170MHz - 5330MHz, 5490 - 5710 MHz
- 20, 40, 80, 160 MHz bandwidth possible

Signal Dampening (dB)

- $P(dBm) = 10 \cdot \log(P(mW))$, $P(mW) = 10^{\frac{P(dBm)}{10}}$
- Power change: $\pm x2$ => dB value: ± 3 dB
  $\pm x10$ => dB value: ± 10 dB
- Path loss d: $100 + 20 \log(d)$, d in km
- RSSI: Focus on expected signal, all other are noise
- SNR: Signal to noise ratio (higher is better)

Modulation

- $s(t) = A \cdot \sin(2\pi ft \cdot \varphi)$
  (A: Amplitude, f: Frequency, φ: Phase)
- ASK Modulation (Amplitude Shift Keying)
  ↳ Easy to use and robust against distortion
- FSK Modulation (Freq. shift Keying)
  ↳ "Waste" of freq., needs a lot of bandwidth
- PSK Modulation (Phase SK)
  ↳ Complex demodulation, strong against distortions
- QAM (Quadrature Amplitude Mod.) = ASK + PSK

MiMo (Multiple Input Multiple output)

- Multiple paths from transmitter to receiver
- Maximal ratio combining
  ↳ - Multipath signal received by Digital Signal proc. (DSP)
    - Adjusts and combines signal → Transmit stronger signal
- Transmit Beam Forming
  ↳ - Multiple antenna send with different phase modulation
    - Signal overlap at receiver for best possible bandwidth
- Spatial multiplexing
  ↳ - Multiple antenna send different signal parallel
    - Increase bandwidth but requires MIMO client
- MIMO only works with reflections

IEEE 802.11 Standards

802.11 protocol	Freq. (GHz)	Bandwidth (MHz)	Stream data rate (Mbit/s)	Allowable MIMO stream	Modulation	Range Indoor (m)
ac	5	20	400ns GI: x · 7.2 up to 72.2 800ns GI: x · 6.5 — 11 — 65	8	MIMO-OFDM	35
		40	400: x · 15 to 150, then 180, 200 800: x · 13.5 to 135, then 162, 180			
		80	400: x · 32.5 to 325, 390, 433 800: x · 29.2 to 292.5, 351, 390			
		160	400: x · 65 to 650, 780, 866 800: x · 58.5 to 234, etc., 780			
ad	60	2160	Up to 6.75 Gbit/s	N/A	OFDM single carrier	3.3
ax	2.4 5	?	Up to 13.53 Gbit/s	N/A	MIMO-OFDM	N/A

EIRP

- EIRP = Pt + Gt - At
  ↳ - Pt = Output power
    - Gt = Antenna gain
    - At = Antenna loss
- EIRP = 20 dBm Standard

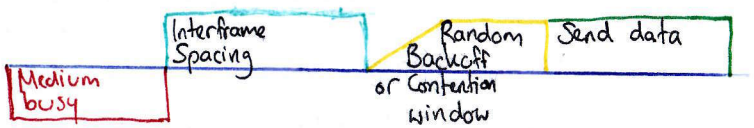
5GHz Requirements

- Dynamic Freq. Selection (DFS)
  ↳ Prüft ob Freq. von Radar besetzt ist und schaltet aus um
- Threaded Power Control (TPC)
  ↳ Reduziert Ausgangsleistung um Störung zu verhindern

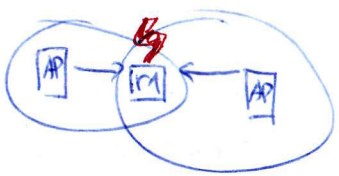
Layer 4 ULAN

CS MA / CA - DCF (Distributed Coordination Function)

- Listen before transmitting, transmit if no one is
- If occupied, wait 1 Inter Frame Spacing + Random Backoff

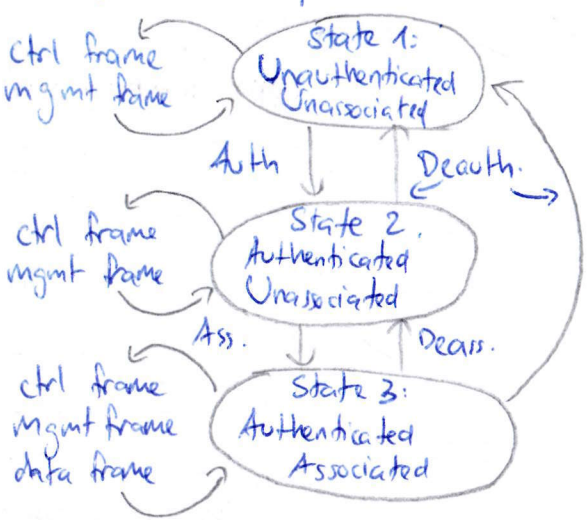


- Problem if 2 transmitting devices too far from each other



Probe Request

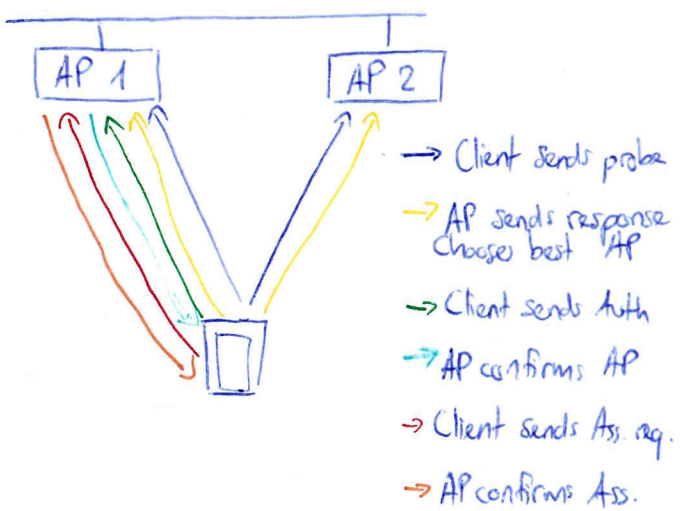
- Client sends probe request to AP to find out its capabilities
- Router send Probe response



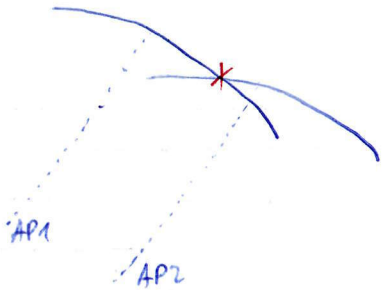
Connection establishment

- Authentication
  - ↳ Auth request to AP containg pw
- Association
  - ↳ Ass. request (Client MAC, BSSID, ESSID)
- Active Scanning
  - ↳ - Receive multiple probe resp. from AP's
    - Repeat Ass. if already auth.
    - Disassociation if possible
- Handoff - Threshold
  - ↳ Change AP if signal is weak
    - New AP > 10 dB
- AP automatically reduce bandwith to reach further

Association Process

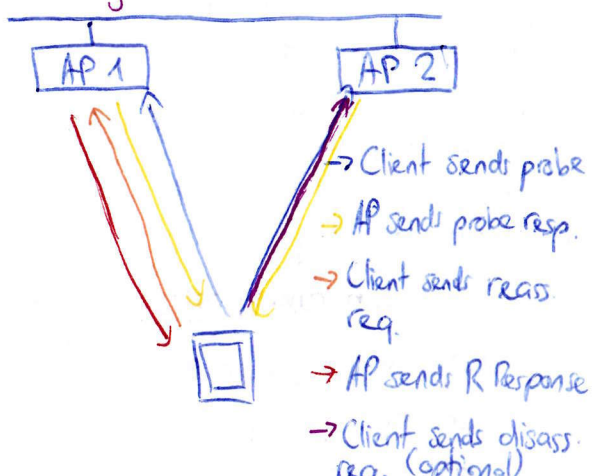


Positive Interference



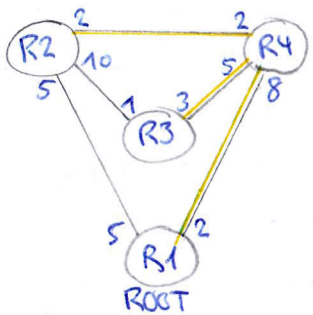
- Beamforming / Maximal Ratio Combining
- Send same frame in 2 diff. antenna
- Overlapping at client => Stronger SNR

Roaming Process



Layer 3 OSPF

Shortest Path First (Dijkstra)



- Build Link State Database (LSDB)

RouterID	NeighborID	Cost
R1	R2	5
R1	R4	2
R2	R1	5
R2	R3	10
R2	R4	2
R3	R2	1
R3	R4	3
R4	R1	8
R4	R2	2
R4	R3	5

Link Failure

- Changes instantly announced with LSA
- SPF calculates new shortest way

- Dijkstra Algorithm

Candidate LSA	Cost to root	Tree
(R1, R2, 5)	5	
→ (R1, R4, 2)	2	
(R1, R2, 5)	5	(R1, R4)
× (R1, R2, 5)	5	(R1, R4)
→ (R4, R2, 2)	4	
(R4, R3, 5)	7	
(R4, R3, 5)	7	(R1, R4) (R4, R2)
→ (R4, R3, 5)	7	(R1, R4) (R4, R2)
× (R2, R3, 10)	14	
		(R1, R4) (R4, R2) (R4, R3)

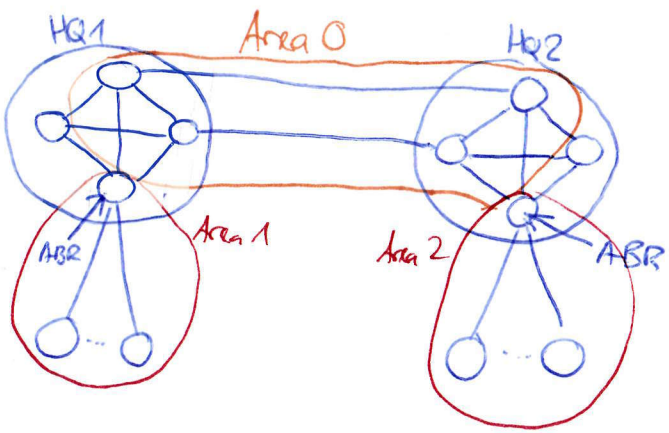
OSPF

- Overcomes limitations of dv routing protocol

1. Establish neighbor adjacencies
   - OSPF neighbors send Hello to find neighbors
   - If present, router tries to establish adjacency
   - Area, MTU, Timer, Auth must match etc.
2. Exchange LSA
   - LSA contains state/cost of direct neighbors
   - Router flood to adjacent neighbor
3. Build LSDB
   - After LSA exchange, routers build LSDB
   - Important that everyone holds same data
4. Execute SPF
5. Build routing table

- Works with IP (protocol nr. 89)
- Doesn't rely on TCP/UDP
- New neighbor = Sends full update (all known LSA)
- Default cost on Cisco
  - 100 MBit/s = 1, 10 MBit/s = 10
- 224.0.0.5 to send info to all OSPF router
- 224.0.0.6 to send info to DR/BDR router
- Classless protocol + VLSM
- Not more than 50 router recommended

Hierarchical structure of OSPF



- ABR = Area Border Router
  - Have LSDB of both areas and calculate SPF
  - Broadcast address summary to other area
- ASBR: Autnomous System boundary router
  - Marks router that go to an external network

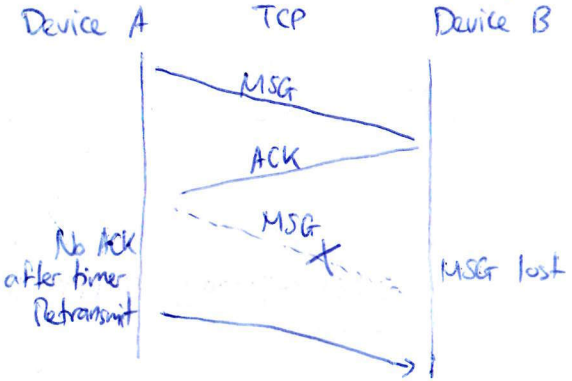
Eigenschaften

- Auth. of Routing Msg.
- Classless routing upd.
- Dynamic Link Cost
- Type of Service Routing
- Support Multi Access Network

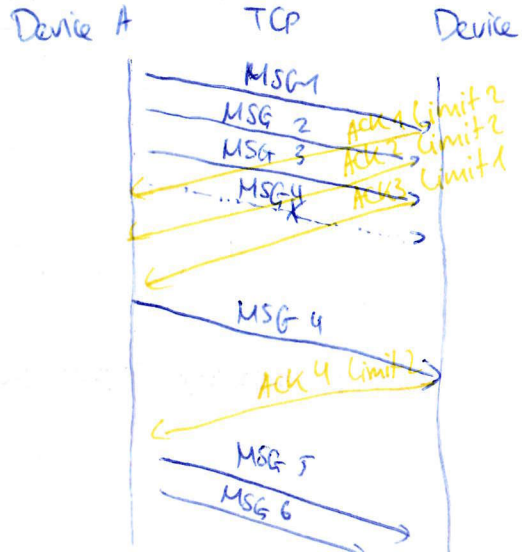
Layer 4 TCP/UDP

TCP/UDP

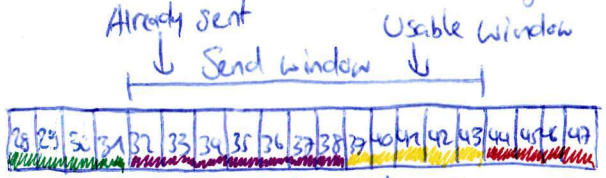
- Source port and dest. port in 16 bits
- Range 0 - 65535 ← max window size in header
- TCP/UDP use same range but are independent
- 0 - 1023 reserved for universal TCP/IP appl.
- 1024 - 49151 for TCP/IP appl at IANA
- 49152 - 65535 for private / dynamic range



- Improved PAR (Positive Acknowledgement with Retransmission)

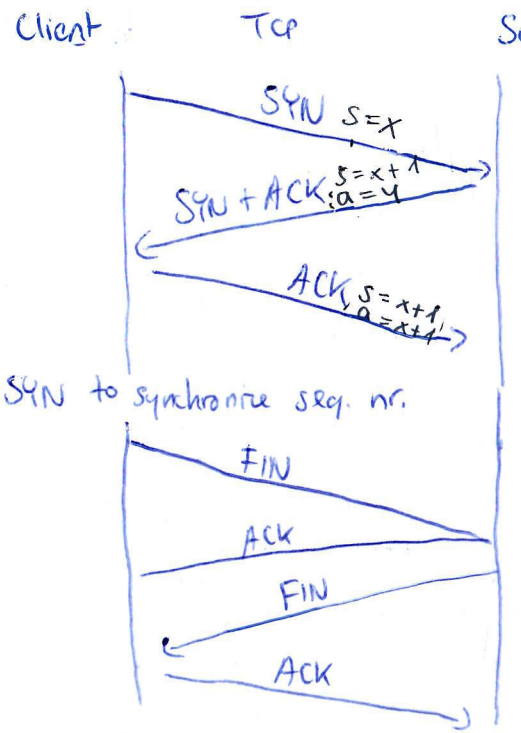


- Division of TCP transmission Stream into categories



Category 1	Category 2	Category 3	Category 4
Sent Acked	Sent Not Acked	Not sent Recipient rdy to receive	Not sent Recipient not rdy to receive

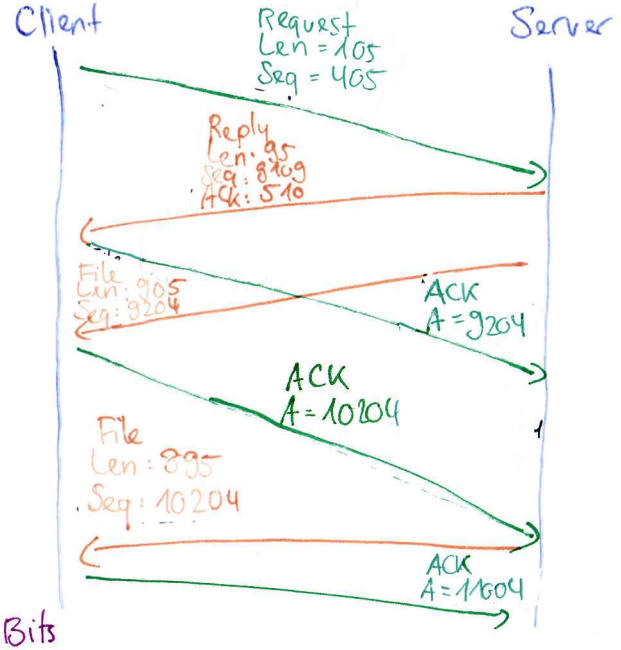
- Dealing with missing ACK
  - ↳ Window stucks on missing ACK until resend
- Connection Establishment



TCP/UDP Port Nr.

FTP	21	HTTPS	443
SSH	22		
HTTP	80		

- Congestion window
  - ↳ Slow start of transmission

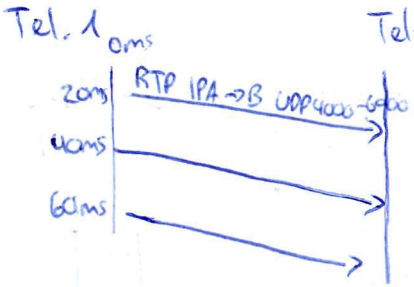


TCP Control Bits

- PSH: Immediately send to receiver
- URG: Priority data transfer
- RST: Reset the connection

Layer 7 SIP / RTP

Real Time Protocol (RTP)



- Header Content
  - ↳ Timestamp: Time of Recording
    - SSRC: Differentiate between streams
    - CSRC: For video conf. for mixer
    - PT: Payload type => Codec
- Every 20 ms = 8000Hz = 160 Bytes

Realtime Control Protocol (RTCP)

- Sender Report (SR)
  - ↳ - Report transmission stats (Packet loss, jitter)
- Receiver Report (RR)
  - ↳ - For passive participants (Not sending RTP)

Session Description Protocol (SDP)

- Information exchange for multimedia transmission
- Type (video), protocol (UDP, H.320), format (MPEG)
- Not a transport protocol
- <type> = <value>
- Defines Endpoints (IP / Port of streams)

Session Iniation Protocol (SIP)

- 5 facets of establishing/terminating multimedia comm.
  - ↳ - User Loc.: Where to send data to
    - User Avail.: Something like discord status
    - User Capabi.: What is device capable of (Camera?)
    - Session setup: Dial number, ringing, take phone
    - Session manag.: Redirect
- Uses existing IETF protocols like HTTP, DNS, URL
- SIP components
  - ↳ User agent = End user device
    - ↳ Client makes call, Server takes call
    - Gateway: Translation SIP and non-SIP
    - Registrar: Knows where device is (Presence)
    - Proxy: Handle routing of SIP signaling msg.
      - ↳ Stateful ver.: Check validity, TCP connection
    - Redirect: Returns redirected UAC for new dest.

SIP Adressing

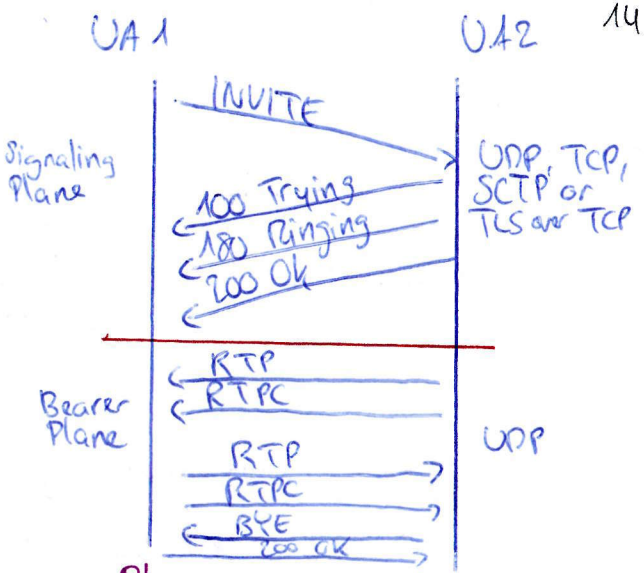
- Used to identify communication resources
- Sip: password@host:port;uri-param?headers

SIP Message

- Header contains info about msg
- Optional body contains payload

Out of order delivery

- Packets take diff. routes and have to be reordered
- Not ordered => Quality loss
  - ↳ Jitter



Plane

- Transport (Bearer) Plane
  - ↳ - Übertragung von Multimediadaten
    - QoS, Routing
- Call-Control Plane
  - ↳ - Signalling and Call-Control
    - Billing
- Service Plane
  - ↳ - Application (Voicemail)
    - Address Resolution

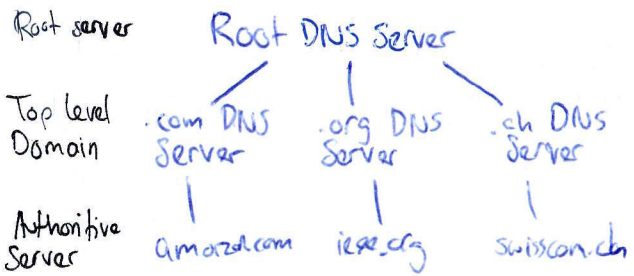
Centralized / Decentralized Intelligence

- SIP / H.323 (intelligent)
  - ↳ Feature in device, server for finding callee
- MGCP (dumb)
  - ↳ Media Gateway Contr. controls device
- Diff.: update, server conn.,

Layer 7 DNS, DHCP

DNS

- Get IP by quering by name
- DNS reachable by any cast



- Root Servers
  - ↳ - 13 org manage root server in multiple location
    - Contain root zone db (Details of TLD like .ch)
- Top Level Domain (TLD)
  - ↳ - Contains authoritative server
- Authoritative server (Every company has one)
  - ↳ - Provides auth, hostname - IP mapping (Mail / Web)
    - Master server contains original data, slave a copy
- Recursive query: Auth. Server queries other DNS for you
- Iterative query: Returns referral to other DNS, Client queries
- UDP port 53 for lookups
- TCP port 53 for zone transfer
- ICANN manages IP for Root-Server

DNS Caching

- DNS Client/Server cache to speedup lokup
- Req. query: Server cache TLD server, is not auth.
- Iter. query: Host caches DNS for a time
- Root / TLD server not often visited

DNS Resource Record (RR)

- Contains info requested by DNS in universal format
- (name, [pref.], value, type, [TTL]) []: optional

Type	Name	Value	Description
A	Hostname	IP	host - IP mapping
NS	Domain	auth. server	routing function
CNAME	Alias	origin	alias to origin
MX	Domain	Mail server	

- (abc.com, dns.ispcom, NS)
  (dns.ispcom, 1.1.1.3, A)
- (alias.com, example.com, CNAME)
  (example.com, 1.1.1.4, A)
- (abc.com, 2.2.2.2, A)
  (abc.com, 10, mail.abc.com, MX)
  (abc.com, 10, mail.def.com, MX)
  (mail.abc.com, 2.2.2.3.com, A)
  (mail.def.com, 2.2.2.4.com, A)
- Zone file describes DNS zone stored in auth DNS

Reverse DNS (rDNS)

- Determine hostname by IP
- Email Anti Spam
  - ↳ Check if mail comes from legit domain
- Network troubleshoot (traceroute)

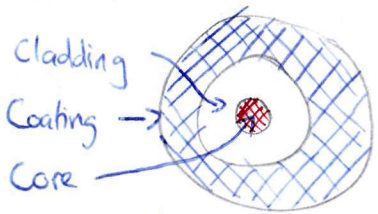
DHCP

- Lease an IP for some time
- Procedure
  - ↳ 1. Discover (Broadcast)
    Sent by client to willing DHCP
  - 2. Offer
    Sent by server
  - 3. Request
    Sent by client to take request
  - 4. Acknowledgement
    Sent by server to assign address / mask
- Client: DHCPDISCOVER, DHCPREQUEST
- Server: DHCPOFFER, DHCPACK

Optical Network

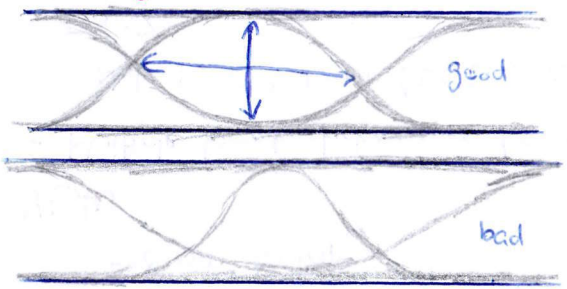
Optical Spectrum

- Comm. wv: 850, 1310, 1550 nm
- Specialty wv: 980, 1480, 1625 nm



- Fibre ~ 1 µm (0.000001 m)

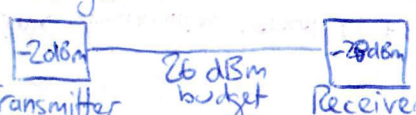
Eye Diagram



- Vertical eye shows ability to see 0/1
- Horizontal eye shows sampling acc. over time

Optical Power Budget

- Budget: Power sent - Receiver sensitivity



- Around 3 dBm for reserve

Attenuation in Fibre

- Absorption through fibre mat. Higher wv len. = less absorption
- Micro-/Macrobends, Reflection, Fibre Splices

Types of Dispersion

- Chromatic Dispersion (CD)
  - ↳ Diff. wv → Diff travel speed
    - Pulse Broadening and ISI

    - Higher freq. suffer more
    - $d(km) = \frac{\text{Spec. of Transponder (ps/nm)}}{\text{Coeff. of Disp. of Fib. (ps/nm·km)}}$
    - Compensator in cable against disp.
      - ↳ Slows down only high freq.
- Polarisation Mode Dispersion
  - ↳ Caused by manufacturing, intlect stress etc.
    - Solution: Improve fiber, regeneration,
    - No problem for 10G cable or < 1600 km

3R of Optical Networking

- Re-Gen
  - ↳ - Optically amplify signal (eg. EDFA)
    - Do as early as possible
- Re-Shape
  - ↳ - Use Dispersion Shift Fiber to counter CD
- Re-Time
  - ↳ - Read and retransmit signal
    - Opto-Elektro-Opto Konverter

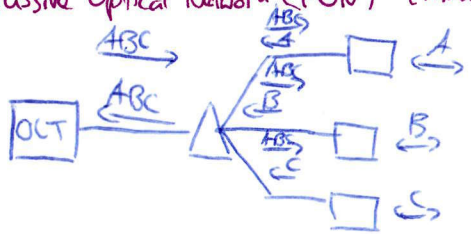
Scattering

- Change light direction by atom/particle in glass
  - ↳ Higher wv len. = less scattering

Wave Division Multiplexing (WDM)

- Multiple cables with diff signal combined into 1 cable
- Coarse WDM
  - ↳ - Cost optimized, big spectrum (-) → 20 nm space
    - Re-Gen not possible, Max 2.5 Gbps, Max 20 channels
- Dense WDM
  - ↳ - Bandwidth optimised, low spectrum → 0.4 nm spaced
    - Re-Gen, 80 channels

Passive Optical Network (PON) [PON JAPAN: YO !! I]



- Fibre Saving between Splitter and CO/PCP
- No deployment of active equipment
- Data sent to everyone
- Jamming is easy / No resiliance (1 point of fail. = entire tree)

Four Wave Mixing (FWM)

- Channels die "kollidieren" ergeben neue Wellen
- In-band crosstalk kann nicht gefiltert werden
  - ↳ - Optisch oder elektrisch nicht

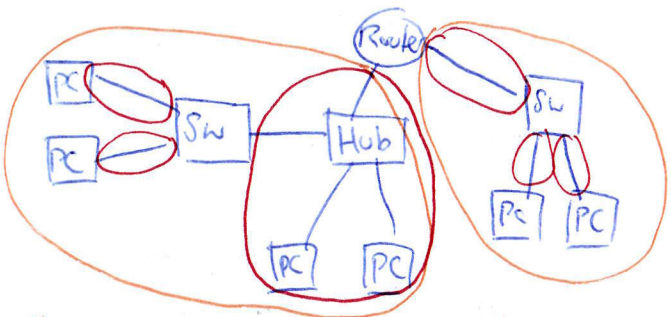
Types

Wavelength	Diameter		Refraction	Typ
650 nm	980/1000 µm	Plastik	Stufenindex	Multimode
850 nm	50/125 µm	Glass	Gradientindex	"
1300 nm ≤	65/125 µm	"	"	"
1550 nm ≤	9/125 µm	"	Stufenindex	Monomode

Signalling

↳ 0111 0001

Domains

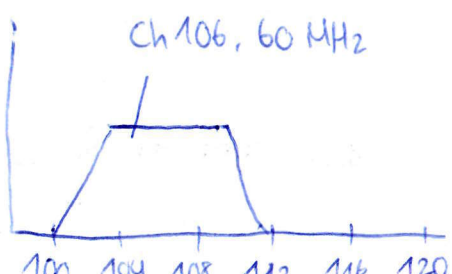


- Broadcast Domain
- Collision Domain

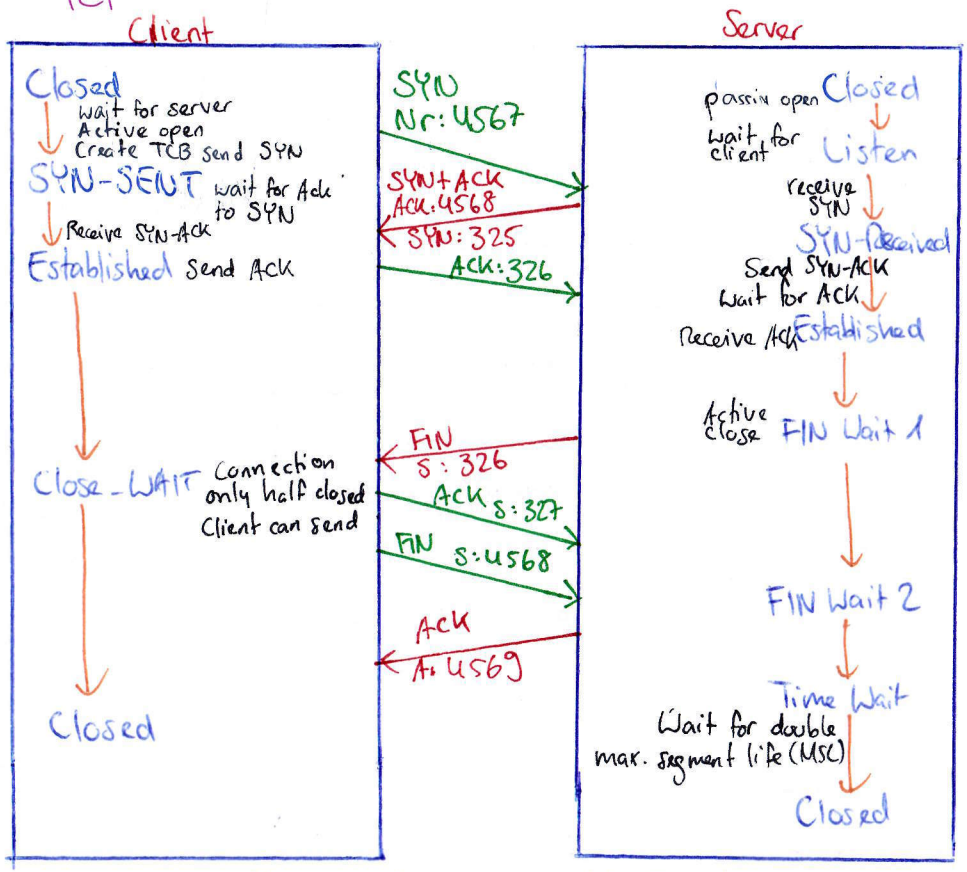
Ethernet II vs 802.3

- 802.3 has Length field
- II has Type field

WLAN 5GHz



TCP



3 Way Handshake

- Each device sends a SYN and receive ACK

Initial Sequence Number Selection

- 32 bit ISN chosen through timed counter

TCP Sequence Nr Sync

- Establishment involves SYN-ACK of SYN contains received n+1

4 Way Handshake Close

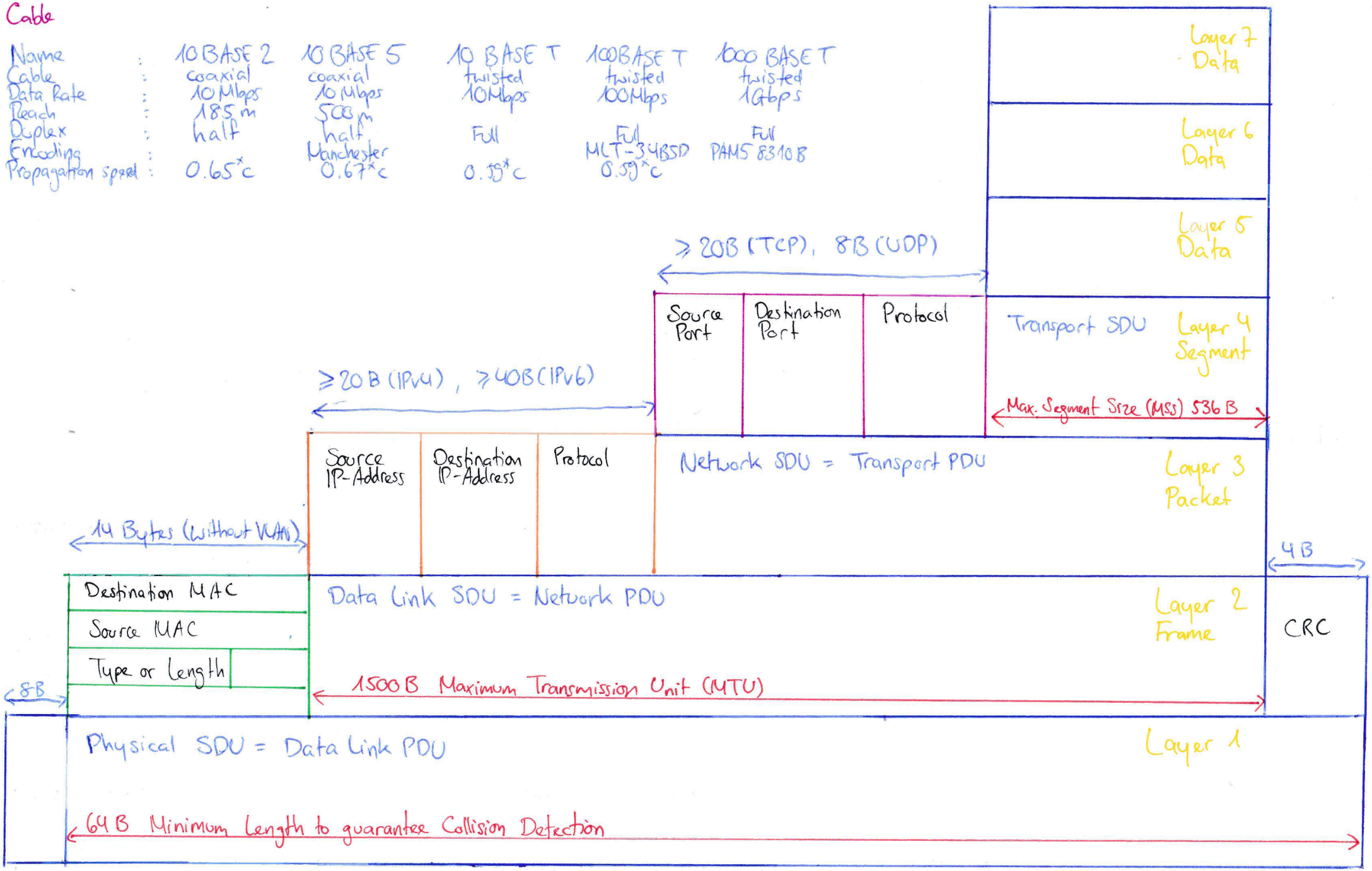
- Each device sends FIN and receive an ACK

	Classic Telephony	IP Telephony
Vermittlung	Leistungsvermittlung	Packetvermittlung
Bandwidth	N x 64 kbps	Beliebig (deshalb auch video)
QoS	Fixe Bandwidth	Best effort
Devices	Analoge Telefone, ISDN	IP Phones, PC, Routers
Protocol	DSS1, SS7	SIP
Tarif	Mostly per min.	Flat
Mobility	Keine (Tel = Anschluss)	Mobil dank dynamic registration

Standards

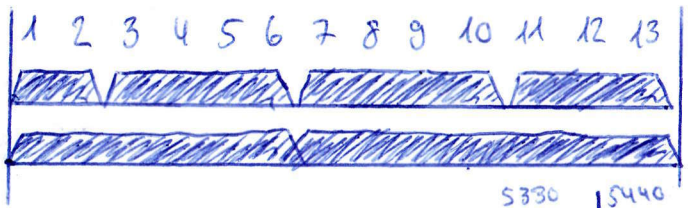
Cable

Name	10BASE2	10BASE5	10BASET	100BASET	1000BASET
Cable	coaxial	coaxial	twisted	twisted	twisted
Data Rate	10 Mbps	10 Mbps	10 Mbps	100 Mbps	1 Gbps
Reach	185 m	500 m			
Duplex	half	half	Full	Full	Full
Encoding		Manchester		MLT-3 4B5B	PAM5 8B10B
Propagation speed	0.65*c	0.67*c	0.59*c	0.59*c	

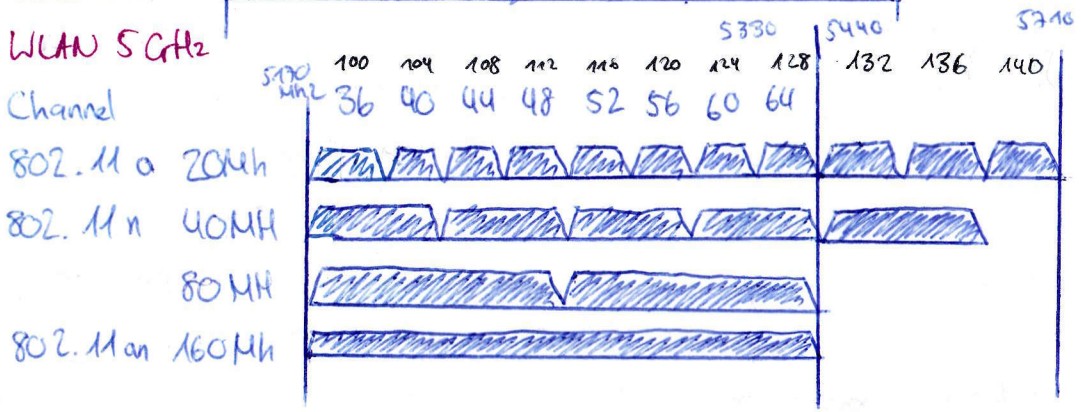


Standards II

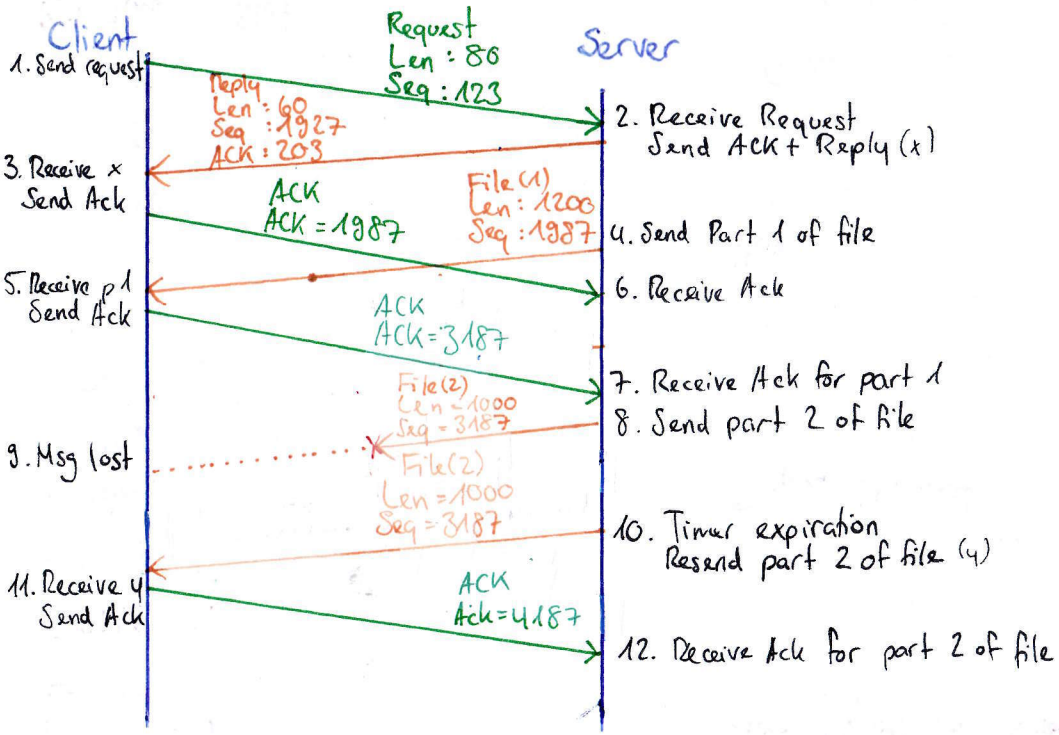
WLAN 2.4 GHz



WLAN 5 GHz

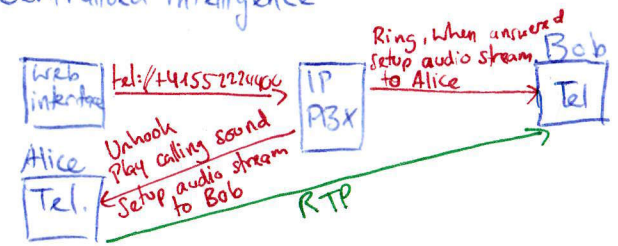


More TCP

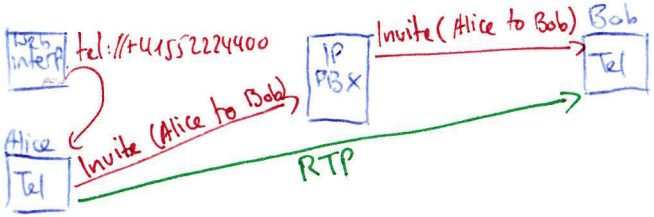


SIP

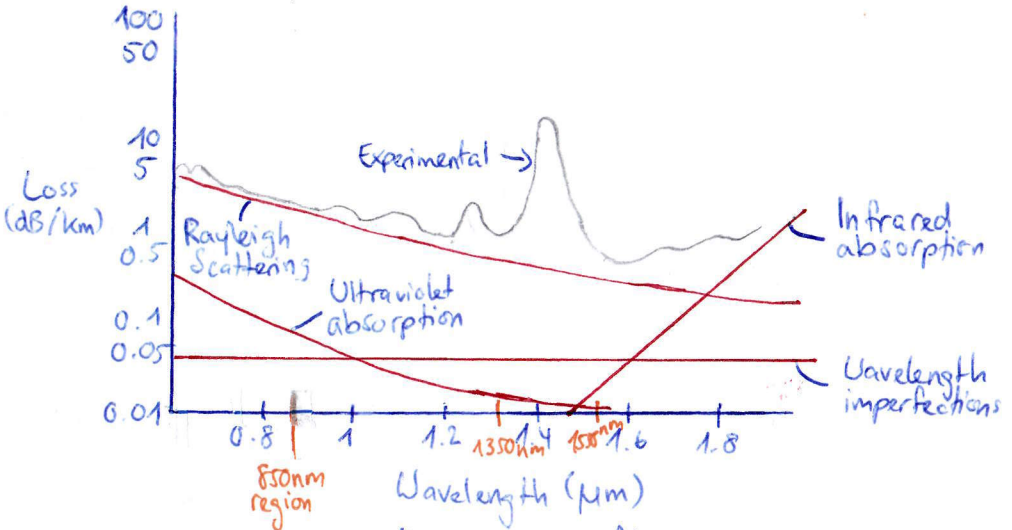
Centralised intelligence



Decentralised intelligence



Attenuation Response



- Rayleigh Scattering: Absorption by fiber material
  Scattering of light from fiber

OSI

7	Application	– Message	– Anwendung
6	Presentation		Darstellung
5	Session		Sitzung
4	Transport	– Segment	– Transport
3	Network	– Packet	– Vermittlung
2	Data Link	– Frame	– Datensicherung
1	Physical	– Bits	– Bitübertragungs

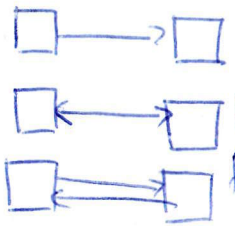
1. Bluetooth, PON, IEEE 802.11
2. ARP, STP, Ethernet, ASCII
3. IPv4, IPv6
4. TCP, UDP
5. NetBios, SDP, iSCSI
6. JPEG, MPEG
7. Telnet, DNS, HTTP

1 Übertragung von Bits über physisches Medium
2. Lokale Verbindung
3. Weltweite Addressierung / Verbindung
4. Logische Ende-zu-Ende Verbindung
5. Kontrolliert Verbindungen zwischen PC
6 Darstellung von Information
7. Anwendungen

Multiplexing

- 4 dimensions (space, time, freq, code)
- Goal: Multiple use of shared medium
- Freq. multiplex
  - ↳ – Seperation in small freq. bands
    - Channel gets whole band for whole time
    - Waste of bandwidth if traffic uneven
- Time multiplex
  - ↳ – Channel gets whole spectrum for time
    - High throughput for many users
    - Precise sync necessary → difficult
- Time / Freq. multiplex
  - ↳ – Channel gets freq. band for time
    - Freq. Hopping
    - Protection against tapping / selective interfer.
- Code multiplex
  - ↳ – All channels use same spectrum at same time
    - Channel has unique code
    - Bandwidth efficiency, No coord. / sync. needed
    - Protection against tapping / selective interference
    - Varying data rates
    - More complex signal regeneration

Duplex

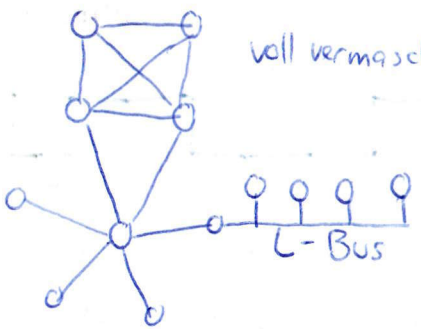


Simplex, only in 1 direction

half-duplex, 1 cable for both direction

full-duplex, 2 cable

Topology



voll vermascht

Stern