

Netze und verteilte Systeme I

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Diese Unterlagen sind ausschließlich für Teilnehmerinnen und Teilnehmer an obiger Lehrveranstaltung gedacht und Weiterverteilung ist nur nach Zustimmung des Autors erlaubt.

Überblick

VO Netze und verteilte Systeme I + II
PS Netzwerke und Betriebssysteme in der Praxis 2st

LA 6. Sem.

VO Netze und verteilte Systeme I
(STEOP) 3st bis 21.5.2021

BSc 2. Sem.

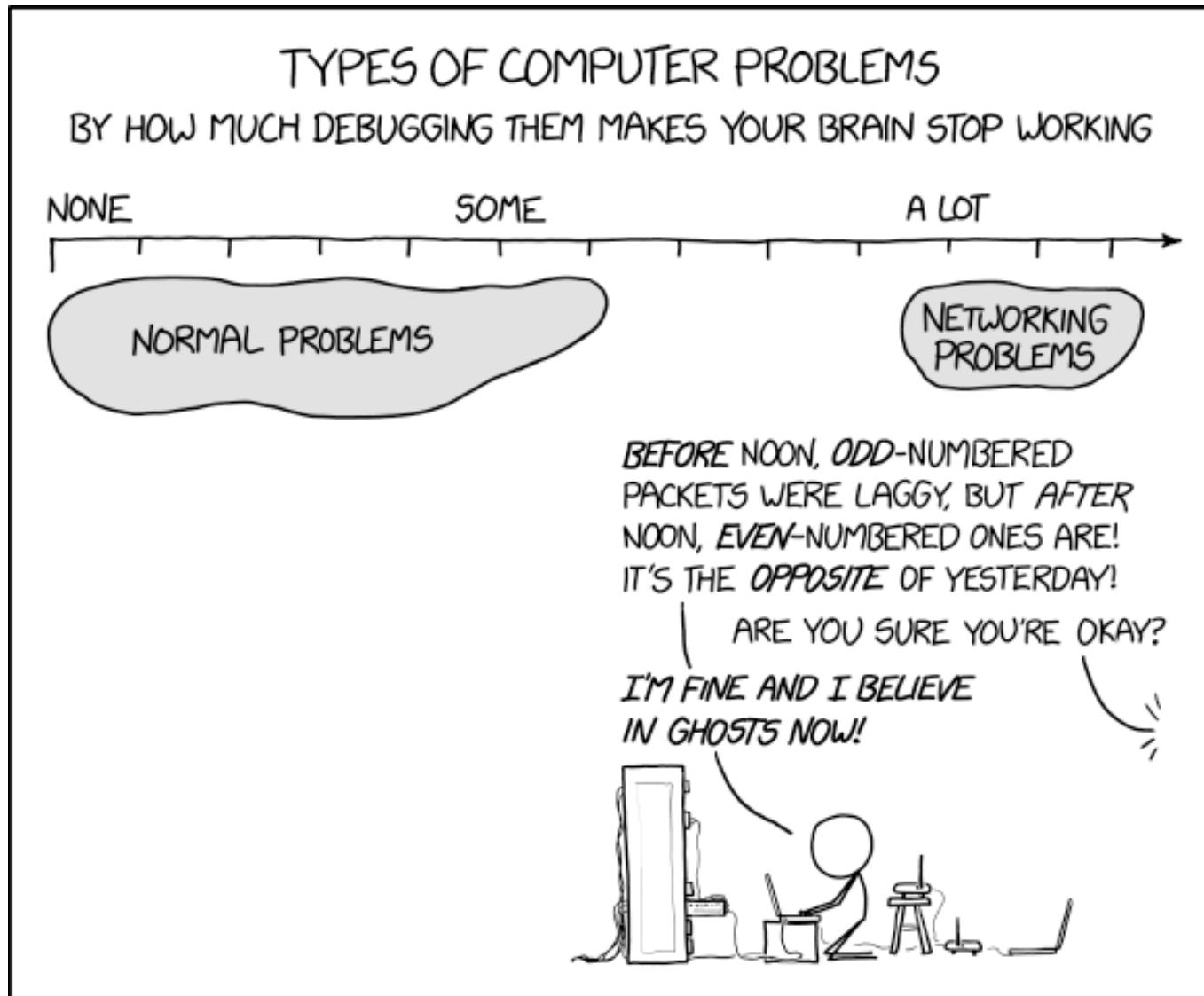
VO Netze und verteilte Systeme II
3st. ab 27.5.2021

BSc 4. Sem.

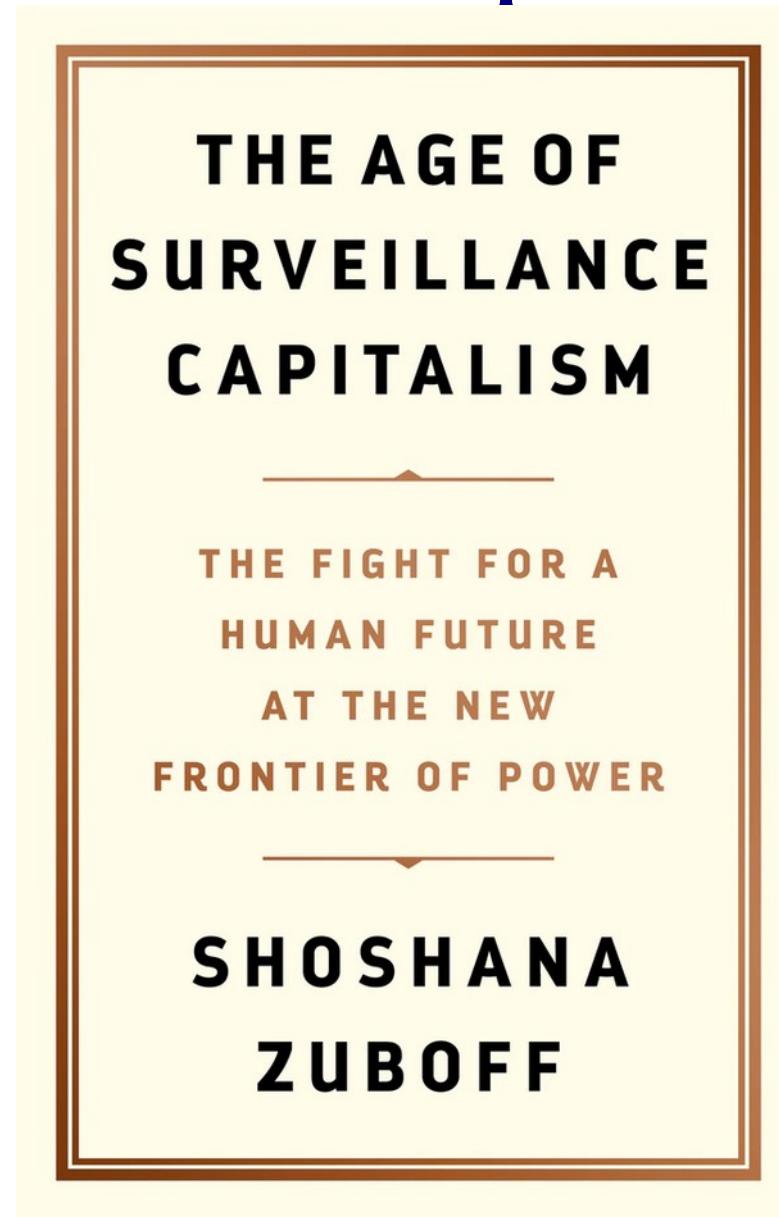
PS Netze und verteilte Systeme 2st

BSc 4. Sem.

Xkcd.com



Surveillance Capitalism (2019)



G-MAFIA,(BAT,...)



<https://theconversation.com/amazon-facebook-and-google-dont-need-to-spy-on-your-conversations-to-know-what-youre-talking-about-108792>

NSA



DNS 1.1.1.1-9.9.9.9

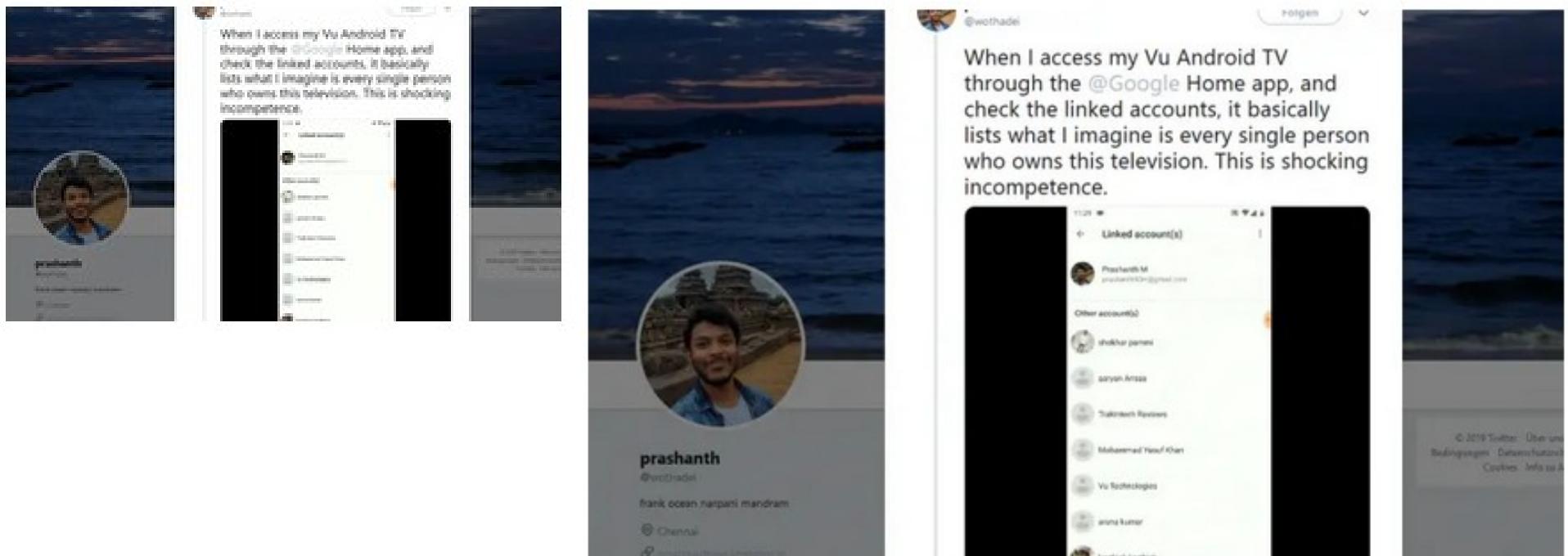


Networked = Hacked

Android TV zeigte fremde Nutzerkonten an

Die Google Home App zeigte einem Nutzer eine Liste mit fremden Konten an. Google kappte daraufhin die Verbindung zwischen Google Photos und Android TV.

07.03.2019 16:06 Uhr 2



(Bild: Twitter / prashanth)

<https://www.heise.de/newsticker/meldung/Android-TV-zeigte-fremde-Nutzerkonten-an-4328513.html>



EFF.org 28.2.19

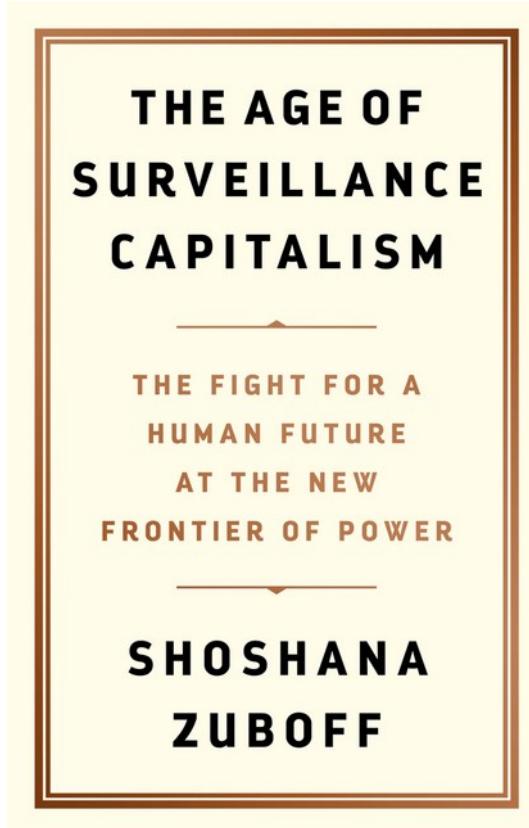
<https://www.eff.org/deeplinks/2019/02/announcing-fix-it-already>



- Android should let users deny and revoke apps' Internet permissions.
- Apple should let users encrypt their iCloud backups.
- Facebook should leave your phone number where you put it.
- Slack should give free workspace administrators control over data retention.
- Twitter should end-to-end encrypt direct messages.
- Venmo should let users hide their friends lists.
- Verizon should stop pre-installing spyware on its users' phones.
- WhatsApp should get your consent before you're added to a group.
- Windows 10 should let users keep their disk encryption keys to themselves.

It's 2019. We have the technology to fix these problems, and companies are running out of excuses to neglect security and privacy best practices. We hope that with a little more attention, these companies will take these issues seriously and fix them already.

Surveillance Capitalism



“Start-up Rezept”:

- Übergriff
- Gewöhnung
- Anpassung
- Neuausrichtung

Artikel 25, DSGVO

Datenschutz durch Technikgestaltung und durch datenschutzfreundliche Voreinstellungen

Privacy by design/default

Artikel 5 DSGVO

Grundsätze für die Verarbeitung personenbezogener Daten

(1) Personenbezogene Daten müssen

- a) auf rechtmäßige Weise, nach Treu und Glauben und in einer für die betroffene Person nachvollziehbaren Weise verarbeitet werden („Rechtmäßigkeit, Verarbeitung nach Treu und Glauben, **Transparenz**“);
 - b) für festgelegte, eindeutige und legitime Zwecke erhoben werden und dürfen nicht in einer mit diesen Zwecken nicht zu vereinbarenden Weise weiterverarbeitet werden; eine Weiterverarbeitung für im öffentlichen Interesse liegende Archivzwecke, für wissenschaftliche oder historische Forschungszwecke oder für statistische Zwecke gilt gemäß Artikel 89 Absatz 1 nicht als unvereinbar mit den ursprünglichen Zwecken („**Zweckbindung**“);
 - c) dem Zweck angemessen und erheblich sowie auf das für die Zwecke der Verarbeitung notwendige Maß beschränkt sein („**Datenminimierung**“);
 - d) sachlich richtig und erforderlichenfalls auf dem neuesten Stand sein; es sind alle angemessenen Maßnahmen zu treffen, damit personenbezogene Daten, die im Hinblick auf die Zwecke ihrer Verarbeitung unrichtig sind, unverzüglich gelöscht oder berichtigt werden („**Richtigkeit**“);
 - e) in einer Form gespeichert werden, die die Identifizierung der betroffenen Personen nur so lange ermöglicht, wie es für die Zwecke, für die sie verarbeitet werden, erforderlich ist; personenbezogene Daten dürfen länger gespeichert werden, soweit die personenbezogenen Daten vorbehaltlich der Durchführung geeigneter technischer und organisatorischer Maßnahmen, die von dieser Verordnung zum Schutz der Rechte und Freiheiten der betroffenen Person gefordert werden, ausschließlich für im öffentlichen Interesse liegende Archivzwecke oder für wissenschaftliche und historische Forschungszwecke oder für statistische Zwecke gemäß Artikel 89 Absatz 1 verarbeitet werden („**Speicherbegrenzung**“);
 - f) in einer Weise verarbeitet werden, die eine angemessene Sicherheit der personenbezogenen Daten gewährleistet, einschließlich Schutz vor unbefugter oder unrechtmäßiger Verarbeitung und vor unbeabsichtigtem Verlust, unbeabsichtigter Zerstörung oder unbeabsichtigter Schädigung durch geeignete technische und organisatorische Maßnahmen („**Integrität und Vertraulichkeit**“);
- (2) Der Verantwortliche ist für die Einhaltung des Absatzes 1 verantwortlich und muss dessen Einhaltung nachweisen können („**Rechenschaftspflicht**“).

Art. 32: Sicherheit der Verarbeitung!

(1) Unter Berücksichtigung des **Stands der Technik**, der **Implementierungskosten** und der **Art, des Umfangs, der Umstände und der Zwecke der Verarbeitung** sowie der unterschiedlichen **Eintrittswahrscheinlichkeit und Schwere des Risikos** für die Rechte und Freiheiten natürlicher Personen treffen der Verantwortliche und der Auftragsverarbeiter **geeignete technische** und organisatorische **Maßnahmen, um ein dem Risiko angemessenes Schutzniveau zu gewährleisten**; diese Maßnahmen schließen unter anderem Folgendes ein: %

Art. 32: Sicherheit der Verarbeitung?

(1) Unter Berücksichtigung...

- a) **Pseudonymisierung und Verschlüsselung** personenbezogener Daten
- b) **Vertraulichkeit, Integrität, Verfügbarkeit** und Belastbarkeit der Systeme und Dienste im Zusammenhang mit der Verarbeitung auf Dauer sicherzustellen
- c) **Verfügbarkeit** der personenbezogenen Daten und den Zugang zu ihnen bei einem physischen oder technischen Zwischenfall rasch wiederherzustellen
- d) **regelmäßigen Überprüfung, Bewertung und Evaluierung** der Wirksamkeit der technischen und organisatorischen Maßnahmen zur Gewährleistung der Sicherheit der Verarbeitung

Entwicklungen

- Web
- P2P
- Mobile
- M2M
- Ad-hoc
- Deep Web
- Dark Web
- IoT
- 5G



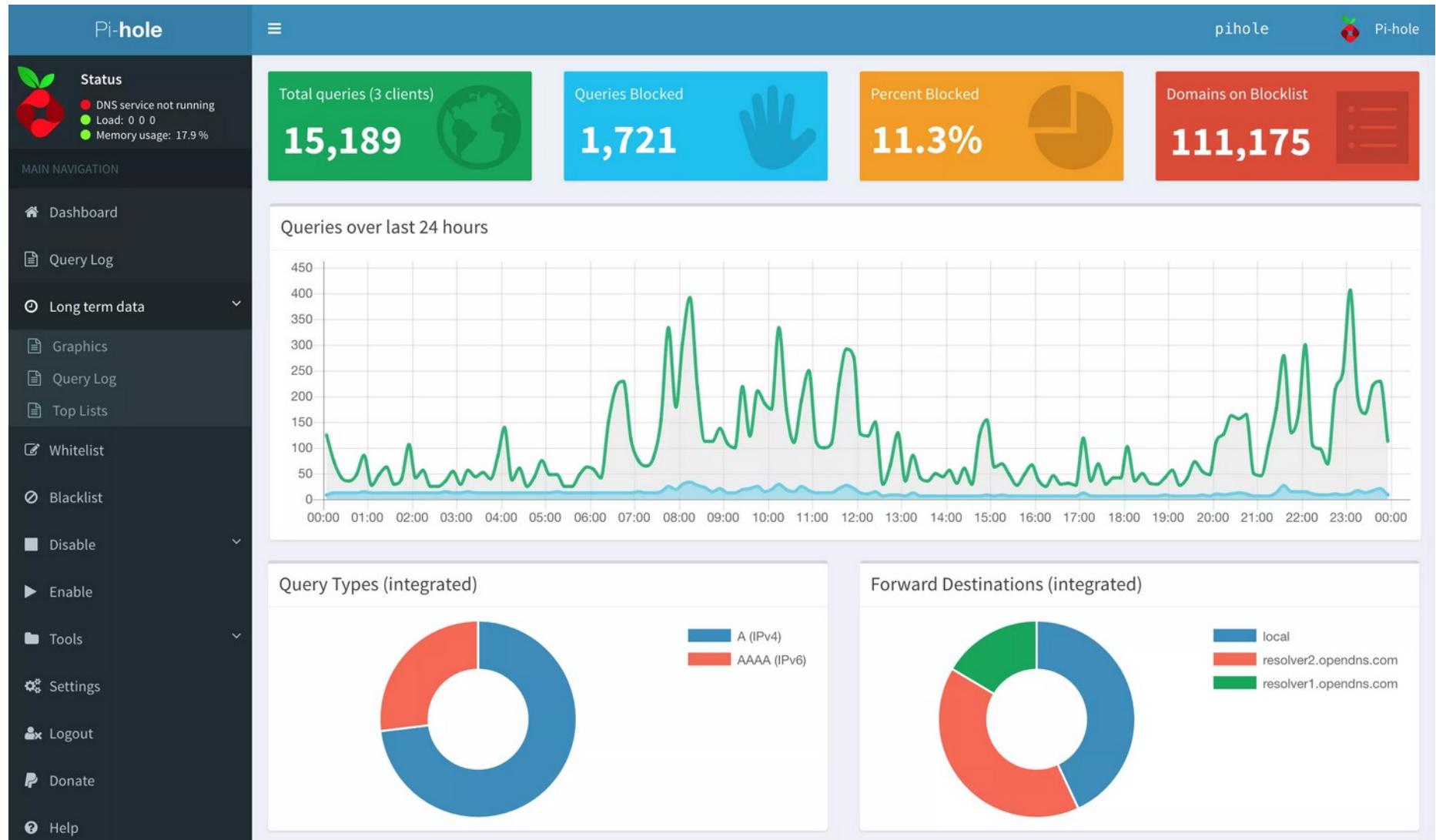
Smartphone oder PC?



Hilfe oder Spionage?



Selbstverteidigung?



Zum Vor- und Nachlesen

- Andrew S. Tanenbaum,
“Computernetzwerke”, v5, 2012
bis ca Seite 563 v 1032
- James F. Kurose, Keith W. Ross,
„Computernetzwerke”, v6, 2014
- Institutsbibliothek
- IEEE, ACM, IETF, Wikipedia



Abgrenzung

- Kein “Internet-Kurs”
 - SEO?
- Wenig Nachrichtentechnik
 - Hohlleiter?
- Viele englische Fachbegriffe
 - Safety = Security?

Altertum

- Fackeltelegraphie bereits im 5. Jhd. v. Chr. (Griechenland)
- **Protokoll** von Polybius (2. Jhd. v. Chr., Griechenland):
- Einteilung/**Kodierung** des Alphabets in 5 Gruppen zu 5 bzw. 4 Zeichen
- 2 Gruppen von je 5 Fackeln (hinter einer Wand)
- **Verbindungsauftbau:**
 - 1. Sendeabsicht: Heben von 2 Fackeln
 - 2. Empfangsbereitschaft: Heben von 2 Fackeln
 - 3. Senken der Fackeln
- **Datenübertragung** für jedes Zeichen:
 - 1. Heben von Fackeln über die linke Hälfte der Wand zur Bekanntgabe der Zeichengruppe
 - 2. Senken der Fackeln
 - 3. Heben von Fackeln über die rechte Hälfte der Wand zur Bekanntgabe des Zeichens
 - 4. Senken der Fackeln

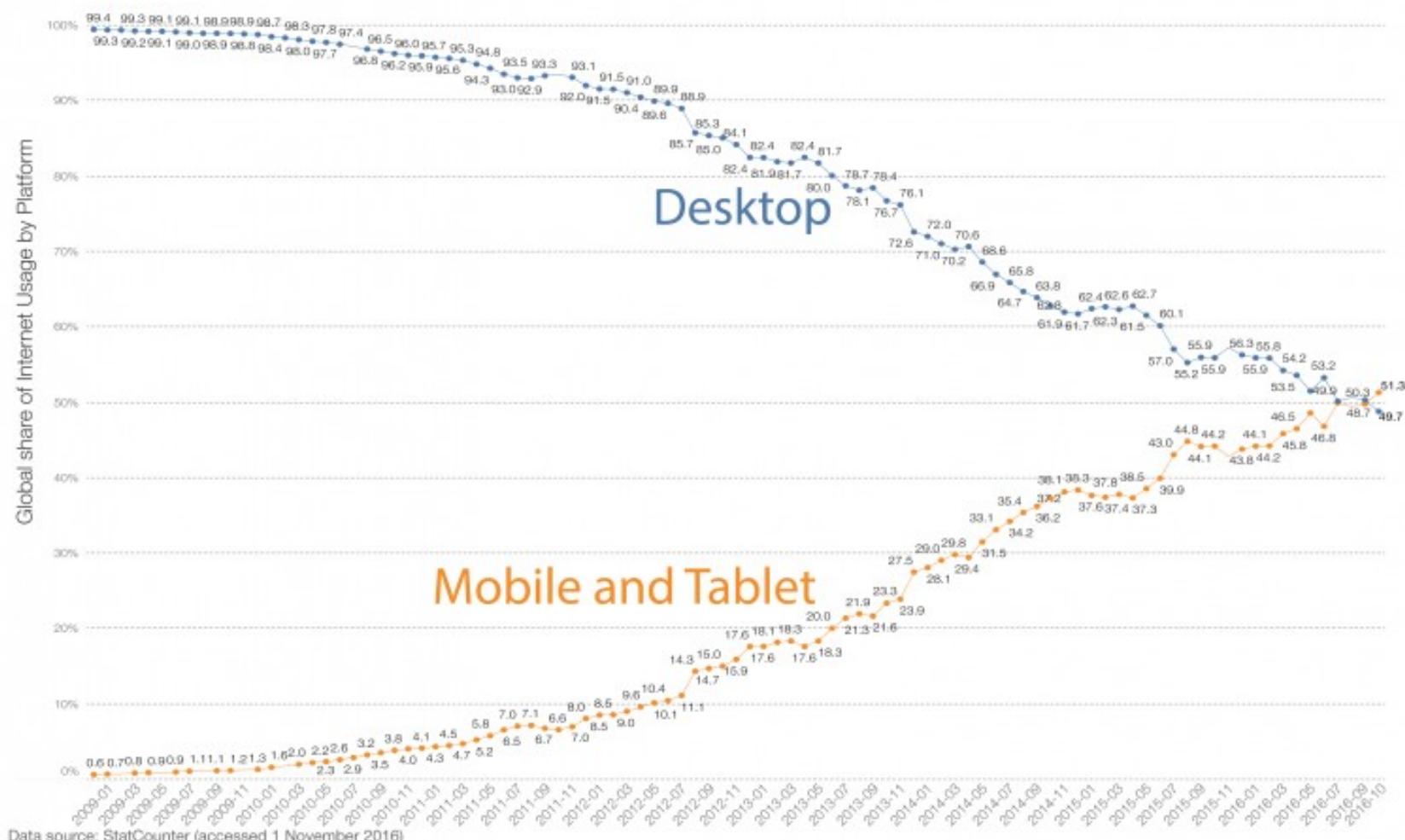
Geschichte der elektr. Komm.

- 1843 erste elektrische Telegraphen-Leitung in Deutschland
- 1851 London - Paris
- 1852 bereits 6'400km Kabel in England
- 1857 erstes Seekabel: Telegrafie-Verbindung Irland-Neufundland
- 1866 London - New York
- 1876 Bell: "This 'phone' has way to many shortcomings for us to consider it as a serious way of communicating. The unit is worthless to us."
- 1870 London – Bombay in 4 Minuten 22 Sekunden
- 1880 erste öffentliche Telefonnetze
- 1889 Erfindung der automatischen Vermittlung
- 1900-1907 Transatlantik Verbindung
- 1914 erst ca. 3% Selbstwählende Anschlüsse in Deutschland
- 1923 Rundfunk
- 1924 in 80 Sekunden um die Welt
- 1960 digitale Übertragung analoger Signale
- 1964 Nachrichtensatelliten
- 1966 Glasfaser
- Beginn des Internet: ~1980
- Anfang der Entwicklung in Europa: ~1990
- .com überholt .edu um ca. 1994
- [http://de.wikipedia.org/wiki/Chronologie_des_Internets ;\)](http://de.wikipedia.org/wiki/Chronologie_des_Internets)

Desktop vs Mobile devices

Global share of internet usage by platform worldwide (2009 to October 2016)
These estimates are published by StatCounter.com

OurWorld
in Data



Data source: StatCounter (accessed 1 November 2016)

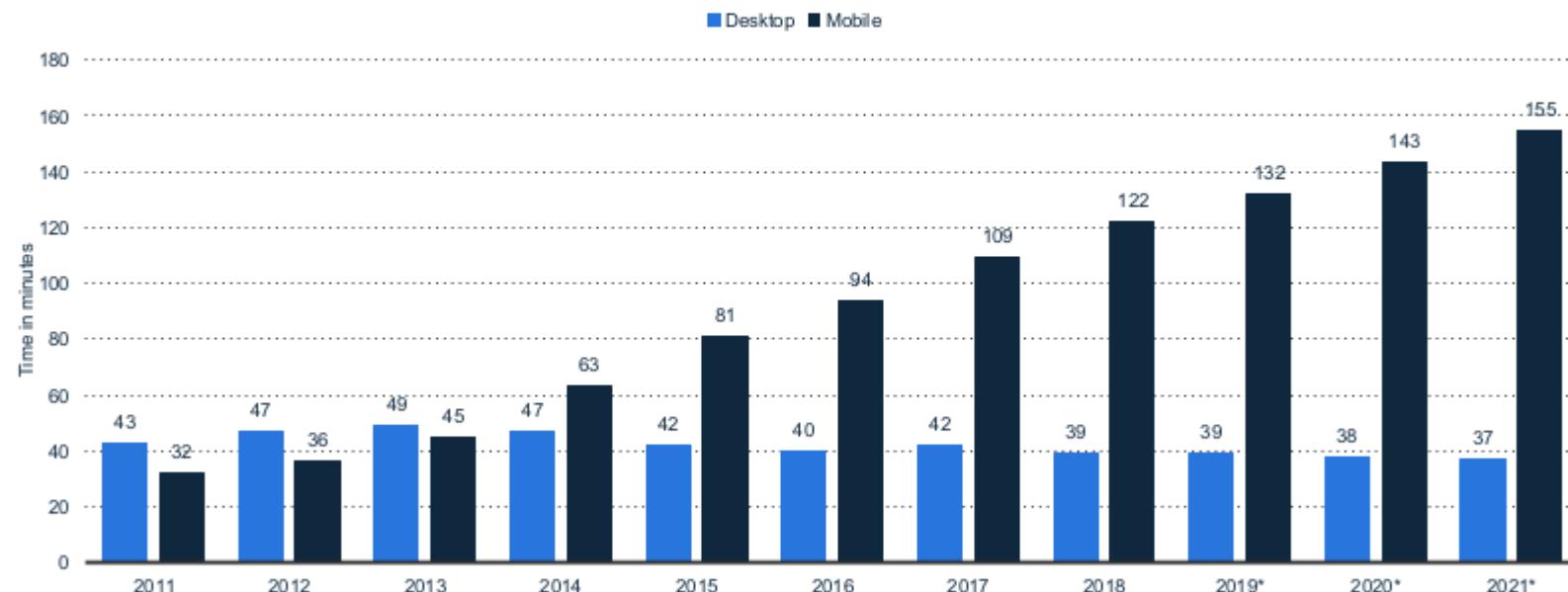
The interactive data visualization is available at OurWorldInData.org. There you find the raw data and more visualizations on this topic.

Licensed under CC-BY-SA by the author Max Roser.

Desktop vs Mobile usage

Daily time spent with the internet per capita worldwide from 2011 to 2021, by device (in minutes)

Daily internet usage per capita worldwide 2011-2021, by device



Note: Worldwide; 2011 to 2018

Further information regarding this statistic can be found on [page 103](#).

Source(s): Zenith; [10.319732](#)

36

Online usage statista

Computer Network

- **Computer network:**

1. A **network of data processing nodes that are interconnected for the purpose of data communication.**
 2. A **communications network in which the end instruments are computers.**
- **American National Standard T1.523-001**
<https://glossary.atis.org/home/>

Ziele von Rechnernetzen

- Gemeinsame Nutzung von Ressourcen
- Hohe Zuverlässigkeit
- Kosteneinsparung
- Skalierbarkeit
- **Kommunikation!**
 - Zugriff auf entfernte Informationen
 - Interpersonelle Anwendungen
 - Interaktive Unterhaltung

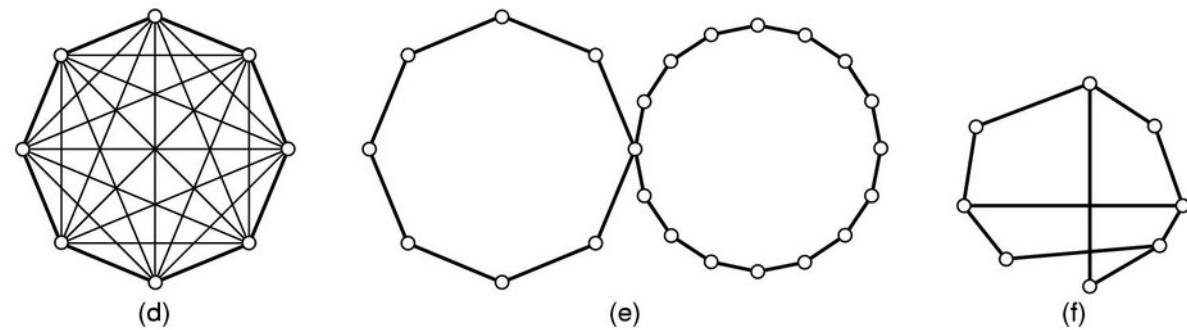
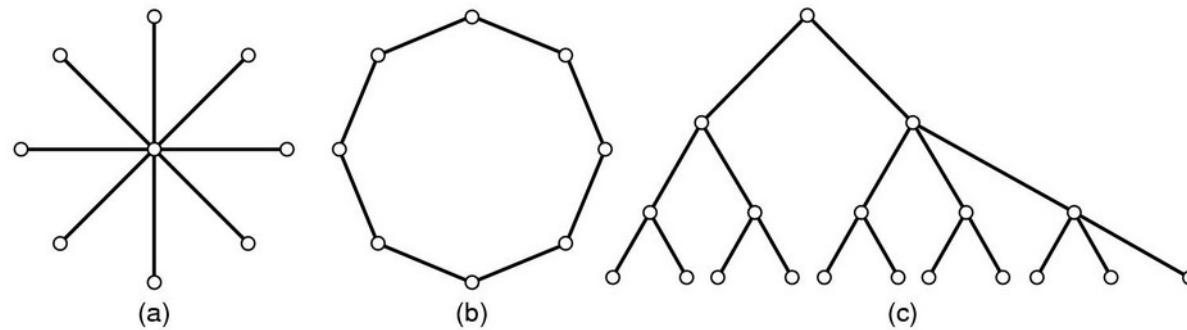
Netze: Übertragungsart

- Rundfunk (broadcast)
-
- Punkt-zu-Punkt (point-to-point)

Netze: Reichweite

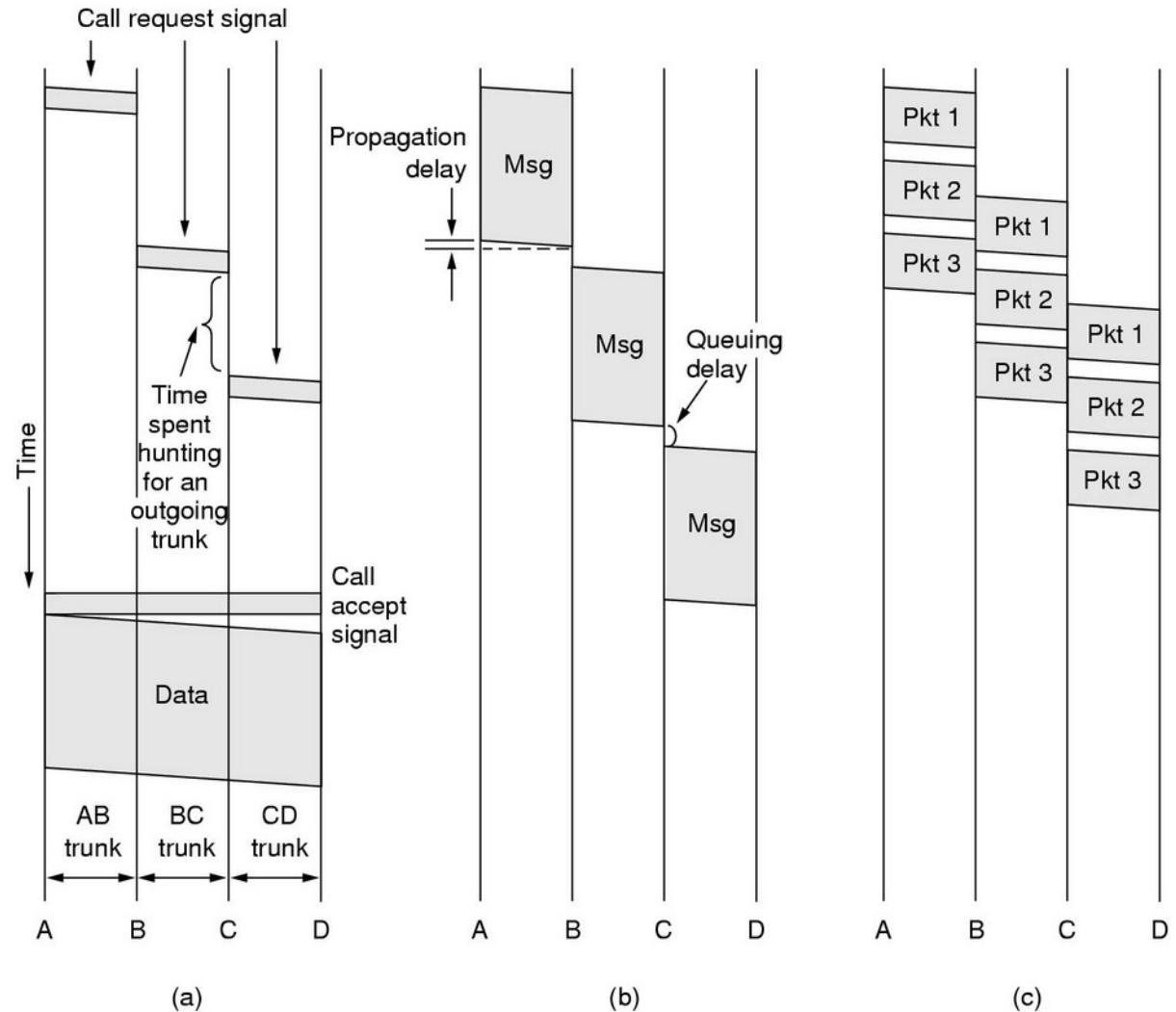
Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	
1,000 km	Continent	
10,000 km	Planet	The Internet

Netze: Topologien



Netze: Vermittlung

- Leitung
- Paket
- Nachrichten



Netze: Zugang

- dynamisch
 - Kanalzugang (Ethernet, WiFi, ...)
 - Netzwerkzugang (Dial-up, VPN, ...)
 - Dienstzugang (Socket, NAPI, ...)
 - **SDN**
- statisch

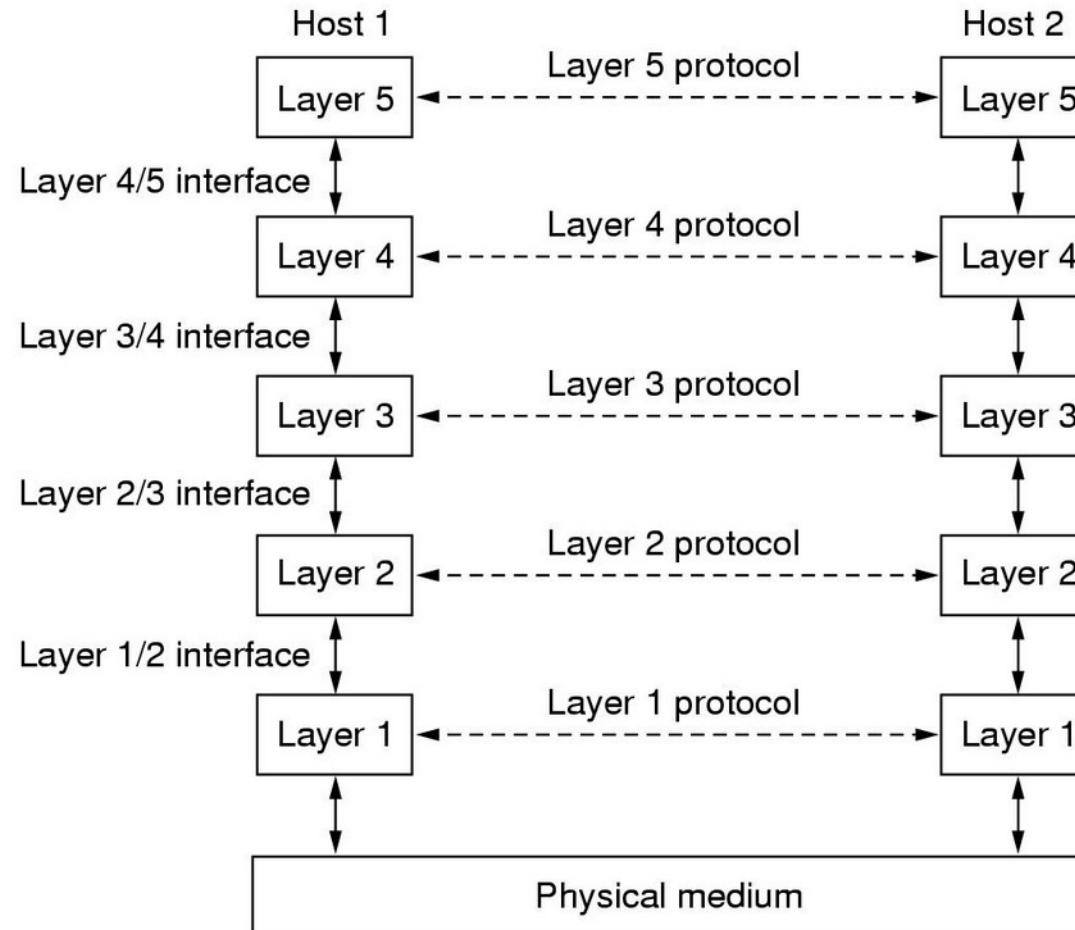
Netze: Übertragungsart

- synchron
 - Taktgeber, Uhr, GPS, NTP, ...
 - SONET, SDH, ISDN, ...
 - Multimedia, IPTV, IPTel, ...
- asynchron
 - Statistical Mux, ATM, Ethernet, ...
 - IP, file transfer

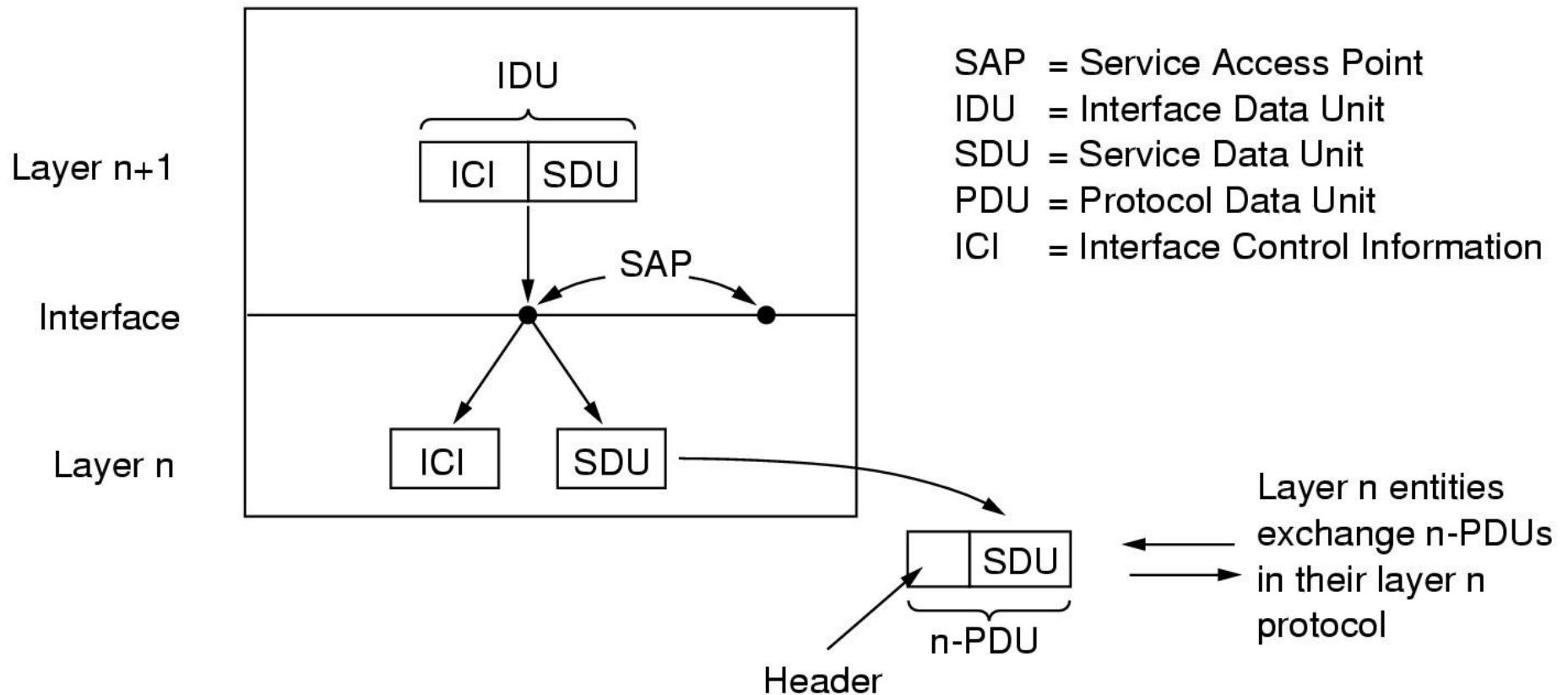
Netze: Entwurfsaspekte

- Geschwindigkeit
- Medium
- Ausfallssicherheit
- Fehlerhäufigkeit
- Ausdehnung
- Kosten

Schichten und Protokolle



Schichten und Schnittstellen



Dienstarten

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
Connection-less	Unreliable connection	Digitized voice
	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

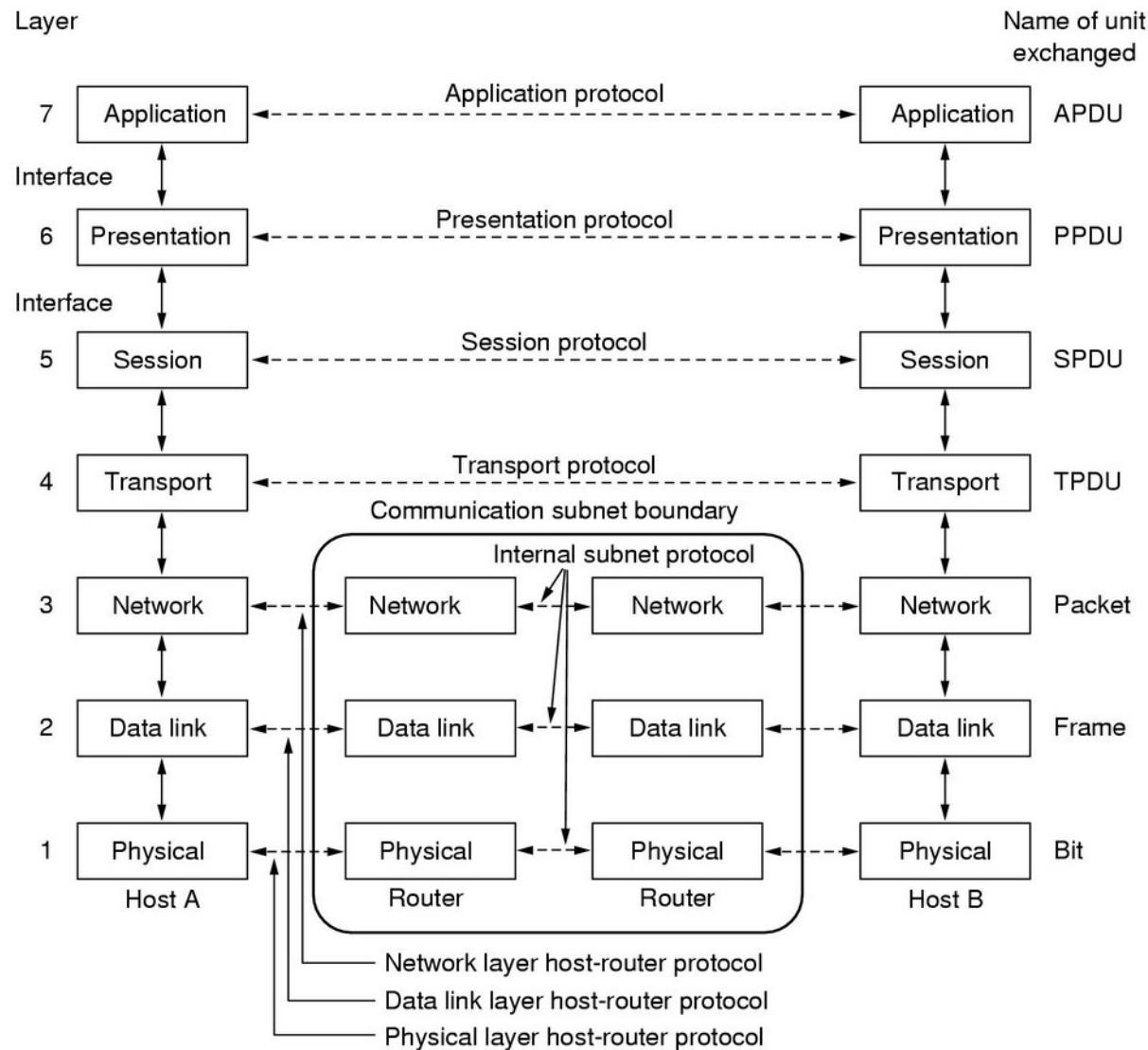
Dienstprimitive

- Anfrage (request)
- Anzeige (indication)
- Antwort (response)
- Bestätigung (confirm)

Dienst: Beispiel

- CONNECT.request
- CONNECT.indication
- CONNECT.response
- CONNECT.confirm
- DATA.request
- DATA.indication
- DISCONNECT.request
- DISCONNECT.indication

ISO/OSI-Referenzmodell

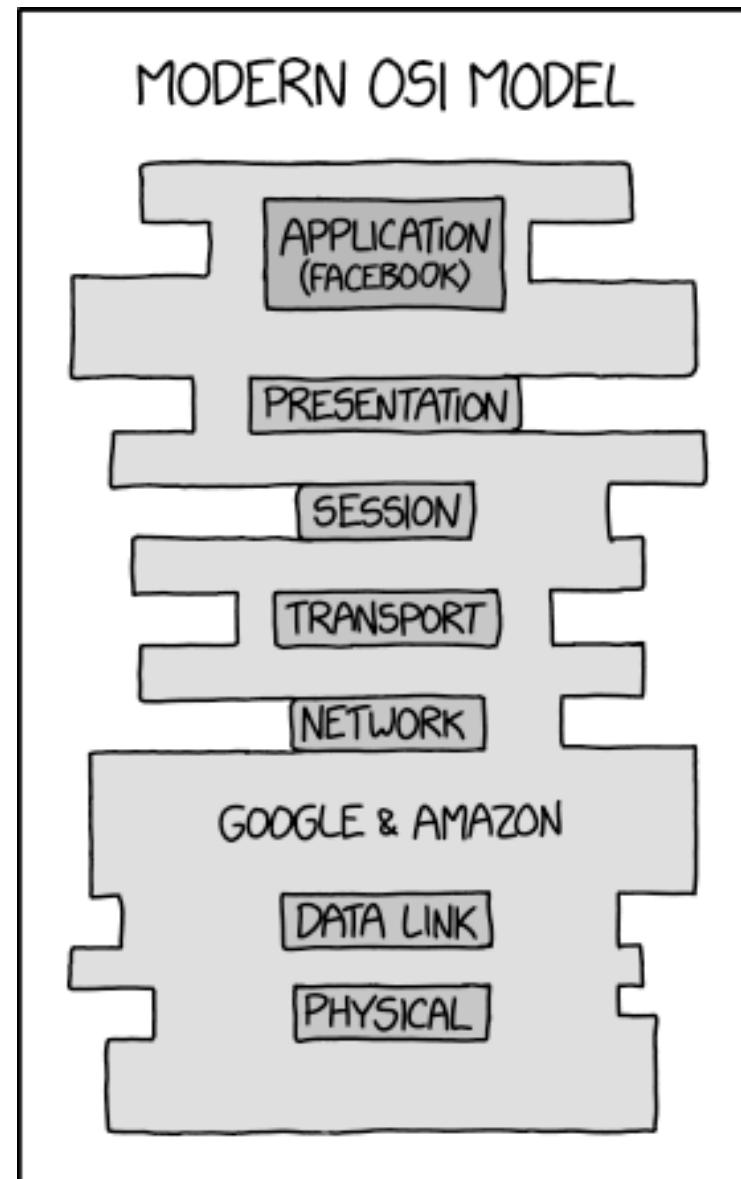


Protocol Stacks

RFC 1122 , Internet STD 3 (1989)	Cisco Academy ^[30]	Kurose, ^[31] Forouzan ^[32]	Comer, ^[33] Kozierok ^[34]	Stallings ^[35]	Tanenbaum ^[36]	Mike Padlipsky's 1982 "Arpanet Reference Model" (RFC 871)	OSI model
<i>Four layers</i>	<i>Four layers</i>	<i>Five layers</i>	<i>Four+one layers</i>	<i>Five layers</i>	<i>Five layers</i>	<i>Three layers</i>	<i>Seven layers</i>
"Internet model"	"Internet model"	"Five-layer Internet model" or "TCP/IP protocol suite"	"TCP/IP 5-layer reference model"	"TCP/IP model"	"TCP/IP 5-layer reference model"	"Arpanet reference model"	OSI model
Application	Application	Application	Application	Application	Application	Application/Process	Application Presentation Session
Transport	Transport	Transport	Transport	Host-to-host or transport	Transport	Host-to-host	Transport
Internet	Internetwork	Network	Internet	Internet	Internet		Network
Link	Network interface	Data link	Data link (Network interface)	Network access	Data link	Network interface	Data link
		Physical	(Hardware)	Physical	Physical		Physical

https://en.wikipedia.org/wiki/TCP/IP_model

xkcd.com ;)



Pedagogic cybersecurity framework

Layer	Vulnerability
1. Physical	Cut the wire; stress equipment; wiretap
2. Data link	Add noise or delay (threatens availability)
3. Network	DNS and BGP attacks; false certificates
4. Transport	Man in the middle
5. Session	Session splicing (Firesheep); MS SMB
6. Presentation	Attacks on encryption; ASN-1 parser attack
7. Application	Malware; manual exploitation of vulnerabilities; SQL injection; buffer overflow
8. Organization	A: Insider attacks; poor training or policies B: Sub-contractors with weak cybersecurity; lack of information sharing C: Weak technical or organizational standards
9. Government	A: Laws prohibiting effective cybersecurity (for example, limits on encryption); weak laws for IoT or other security B: Badly drafted cybercrime laws (for example, prohibiting security research) C: Excessive government surveillance
10. International	A: Nation-state cyberattacks B: Lack of workable international agreements to limit cyberattacks C: Supranational legal rules that weaken cybersecurity (for example, some International Telecommunications Union proposals)

Physical - Bitübertragung

- Schnittstellen
 - Mechanische (Stecker)
 - Elektrische (Pegel)
 - Prozedurale (Verfahren)
- Signale
- Laufzeiten

Data Link – Sicherung/Leitung

- Rahmen (data frames)
- Fehlererkennung
- Fehlerkorrektur
- Flusssteuerung
- Kanalzugriff (**MAC**, nicht **MAC** oder **MAC**)

Network - Vermittlung

- Paket (packet)
- Auswahl von Routen
 - Statisch/dynamisch
 - Kosten/Geschwindigkeit
- Abrechnung
- Behandlung von Überlast
- Adresswandlung

Transport – End-zu-End

- Verbindungsorientiert/-los
- Fehlererkennung/-korrektur
- Flusssteuerung
- Multiplex
- Mehrfachnutzung

Session - Sitzung

- An-/Abmeldung, Auf-/Abbau
- Dialogsteuerung
- Token-Management
- Synchronisation

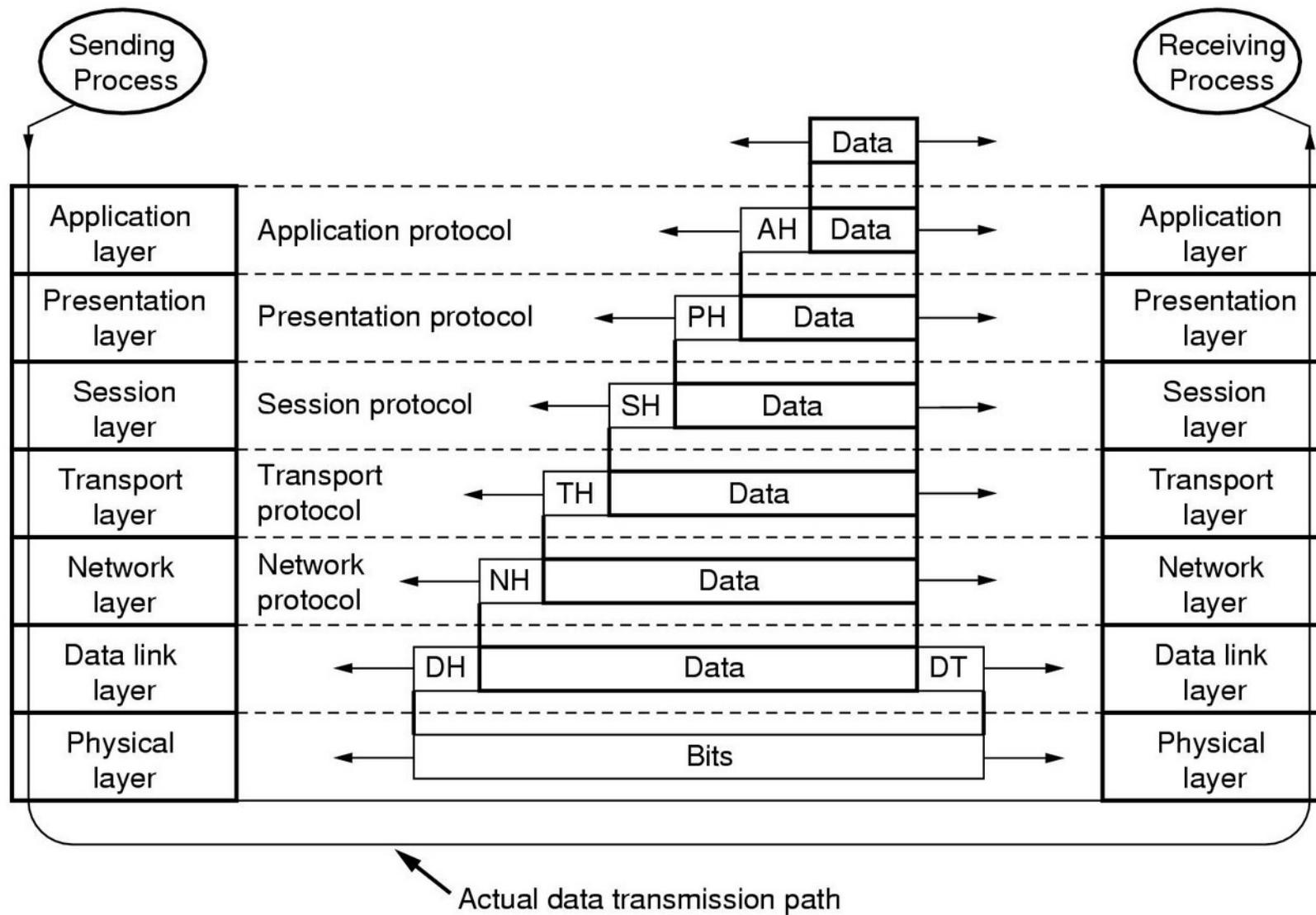
Presentation - Darstellung

- Syntax und Semantik
- Kodierung
- Standarddarstellung
- Zeichenwandlung
- Bytereihenfolge

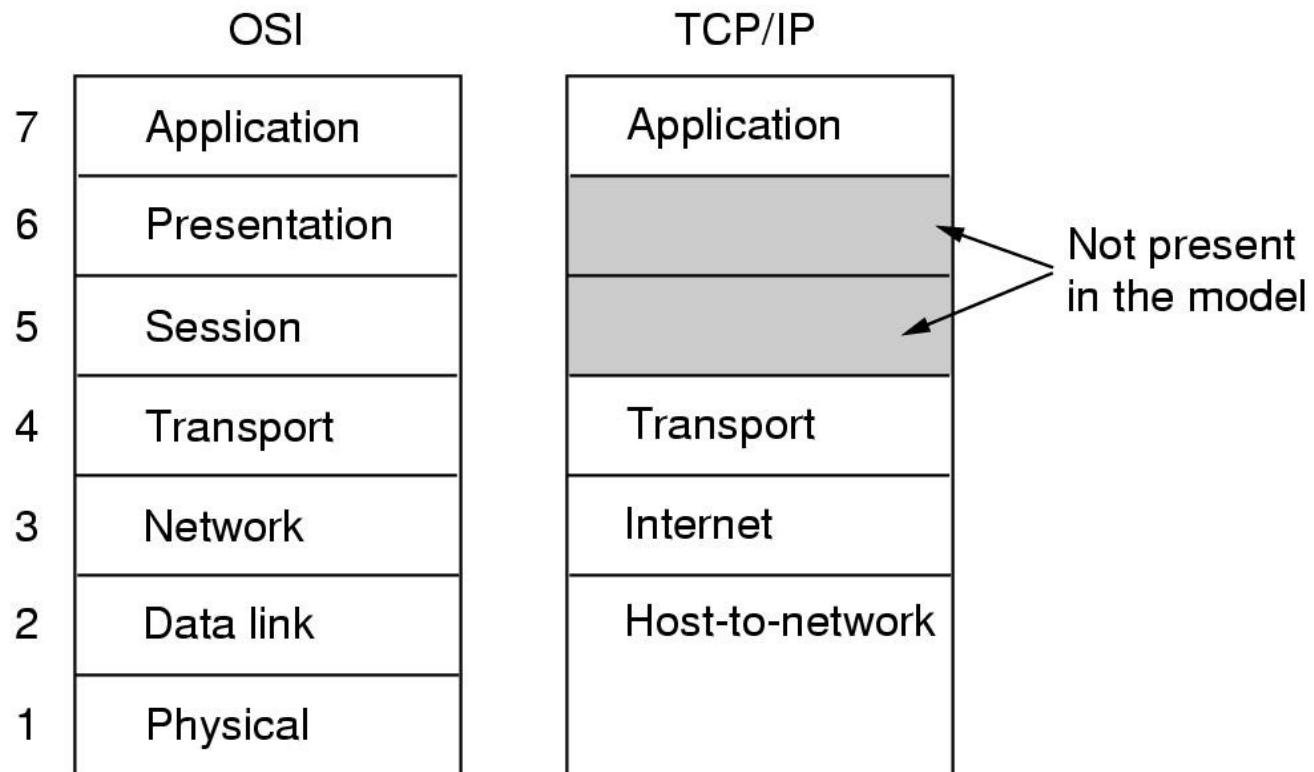
Application - Anwendung

- Abstraktion von Diensten
 - Terminal: Cursor, Textzeilen
 - Dateitransfer: Dateinamen
 - E-mail: Adressen
 - Entfernte Ausführung: Aufgabenverteilung

ISO/OSI-RM Beispiel



OSI vs TCP/IP



Protokolle der TCP/IP Suite

Internet protocol suite

Application layer

BGP • DHCP • DNS • FTP • HTTP • HTTPS
• IMAP • LDAP • MGCP • MQTT • NNTP •
NTP • POP • ONC/RPC • RTP • RTSP • RIP •
SIP • SMTP • SNMP • SSH • Telnet •
TLS/SSL • XMPP • *more...*

Transport layer

TCP • UDP • DCCP • SCTP • RSVP •
more...

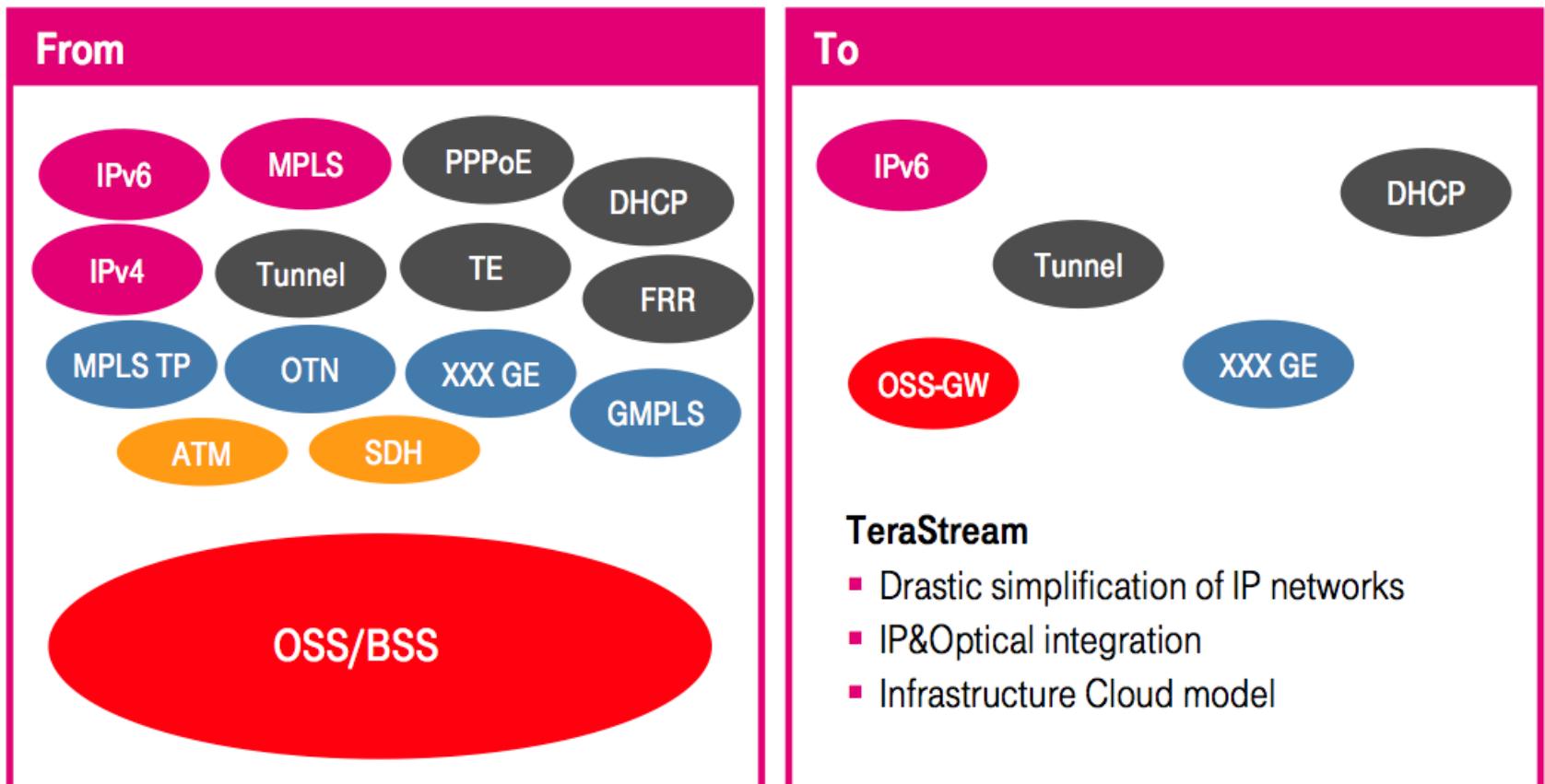
Internet layer

IP (IPv4 • IPv6) • ICMP • ICMPv6 • ECN •
IGMP • IPsec • *more...*

Link layer

ARP • NDP • OSPF • Tunnels (L2TP) • PPP
• MAC (Ethernet • Wi-Fi • DSL • ISDN •
FDDI)
more...

Einfach(er)?!

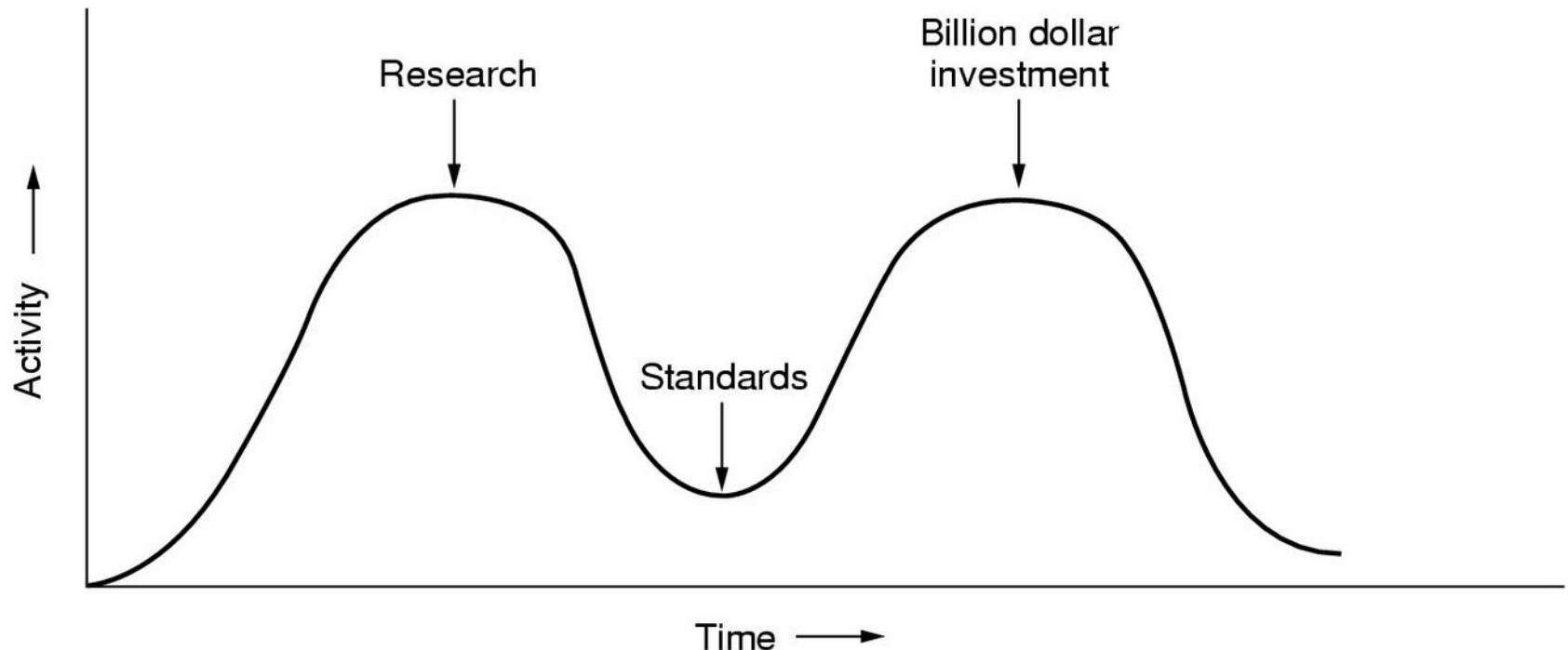


OSS

OSS

OSS/BSS

Dilemma



“Gremien”

- ISO (ANSI, BSI, DIN, ...)
- ITU-T
- ETSI

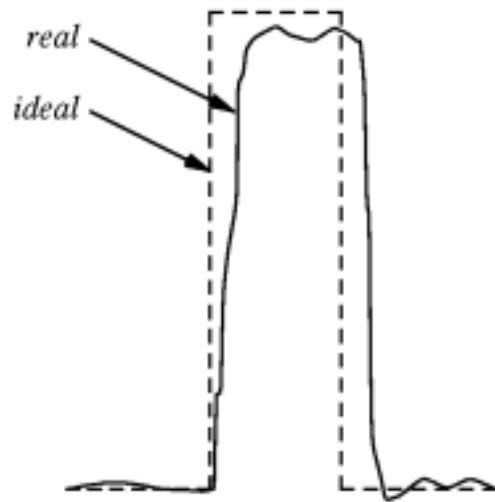
IEEE

- IAB, Internet Society
- IETF, IRTF
- IANA, ICANN, RIPE, ...

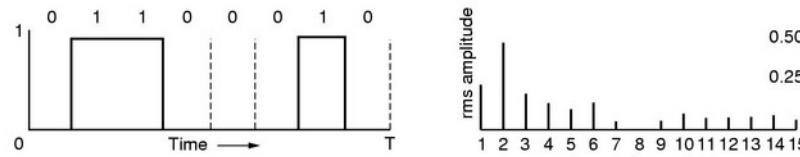
Physische Medien

- Twisted Pair
- Coax
- Glass Fiber
- Radio
- Satellites
- Microwave
- Infrared
- Laser

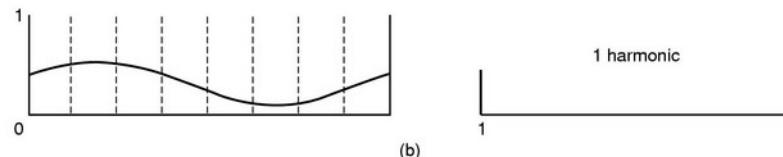
Signalbeschränkung



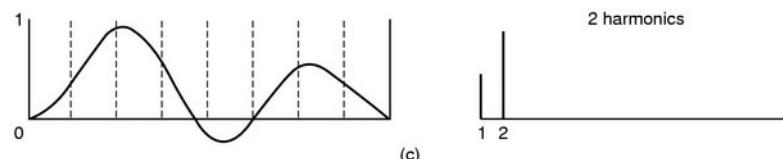
Fourier-Analyse



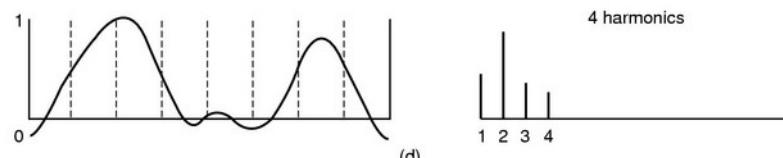
(a)



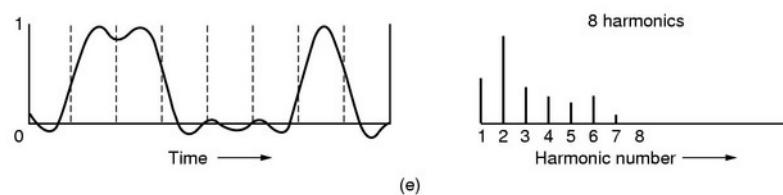
(b)



(c)



(d)



(e)

Nyquist 1924

- Nyquist's theorem: A theorem, developed by H. Nyquist, which states that an **analog signal waveform** may be uniquely reconstructed, without **error**, from samples taken at equal **time intervals**. The **sampling rate** must be equal to, or greater than, twice the highest **frequency component** in the analog signal. **Synonym sampling theorem.**
- Satz von Nyquist: Die Wellenform eines analogen Signals kann eindeutig und fehlerfrei aus Abtastungen an gleichen Zeitintervallen rekonstruiert werden. Die Abtastrate muss dabei mindestens doppelt so groß wie die höchste Frequenzkomponente des analogen Signals sein.
- $C = 2W \log_2 M$

Claude Shannon 1948

- "The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point."
- Shannon's law: A statement defining the theoretical maximum rate at which error-free digits can be transmitted over a bandwidth-limited channel in the presence of noise, usually expressed in the form $C = W \log_2(1 + S/N)$, where C is the channel capacity in bits per second, W is the bandwidth in hertz, and S/N is the signal-to-noise ratio. Note: Error-correction codes can improve the communications performance relative to uncoded transmission, but no practical error correction coding system exists that can closely approach the theoretical performance limit given by Shannon's law.
- Gesetz von Shannon: Definiert die theoretisch mögliche maximale Rate mit der fehlerfreie Zeichen über einen bandbreitenlimitierten verrauschten Kanal übertragen werden können, mathematisch ausgedrückt in der Form: $K = B * \log_2(1 + S/R)$, wobei K die Kanalkapazität in Bits pro Sekunde, B die Bandbreite in Hertz und S/R der Signal-Rauschabstand ist. Beachte: Fehlerkorrigierende Kodes können die Kommunikationsgeschwindigkeit zwar relativ zu unkodierten Übertragungen verbessern, aber kein praktikables Fehlerkorrekturverfahren kann das theoretische Limit von Shannon erreichen.
- **$C = W \log_2(1 + S/N)$**

Errors

- **error:** **1.** The difference between a computed, estimated, or measured value and the true, specified, or theoretically correct value. **2.** A deviation from a correct value caused by a malfunction in a **system** or a **functional unit**. *Note:* An example of an error is the occurrence of a wrong **bit** caused by an equipment malfunction.
- **Fehler:** **1.** Die Differenz zwischen einem berechneten, geschätzten oder gemessenen Wert und dem wahren, spezifizierten oder theoretisch richtigen Wert. **2.** Eine Abweichung von einem richtigen Wert verursacht von einer Fehlfunktion in einem System oder einer funktionellen Einheit. Beachte: Ein Fehler ist z.B. das Auftreten eines falschen Bits verursacht durch einen Gerätefehler.

Noise

- **noise:** 1. An undesired disturbance within the frequency band of interest; the summation of unwanted or disturbing energy introduced into a communications system from man-made and natural sources. 2. A disturbance that affects a signal and that may distort the information carried by the signal. 3. Random variations of one or more characteristics of any entity such as voltage, current, or data. 4. A random signal of known statistical properties of amplitude, distribution, and spectral density. 5. Loosely, any disturbance tending to interfere with the normal operation of a device or system.

Hertz

- **hertz (Hz):** 1. The SI unit of frequency, equal to one cycle per second. Note: A periodic phenomenon that has a period of one second has a frequency of one hertz. 2. A unit of frequency which is equivalent to one cycle per second.

Bit

- **bit:** *Abbreviation for binary digit.* 1. A character used to represent one of the two digits in the numeration **system** with a base of two, and only two, possible states of a physical entity or system.
2. In **binary notation** either of the characters 0 or 1. 3. A unit of **information** equal to one binary decision or the designation of one of two possible and equally likely states of anything used to store or convey information.

Serial transmission

- **serial transmission:** The sequential transmission of the signal elements of a group representing a character or other entity of data. Note: The characters are transmitted in a sequence over a single line, rather than simultaneously over two or more lines, as in parallel transmission. The sequential elements may be transmitted with or without interruption. *Synonym sequential transmission.*

Parallel Transmission

- **parallel transmission:** 1. The simultaneous transmission of the signal elements of a character or other data item. 2. In digital communications, the simultaneous transmission of related signal elements over two or more separate paths. Note: Protocols for parallel transmission, such as those used for computer ports, have been standardized by ANSI.

Baud

- **baud (Bd):** 1. A unit of **modulation rate**. *Note:* One baud corresponds to a rate of one **unit interval** per second, where the modulation rate is expressed as the reciprocal of the duration in seconds of the shortest unit interval. 2. A unit of **signaling speed** equal to the number of discrete **signal** conditions, variations, or events per second. *Note 1:* If the duration of the unit interval is 20 milliseconds, the signaling speed is 50 bauds. If the signal transmitted during each unit interval can take on any one of n discrete states, the **bit rate** is equal to the rate in bauds times $\log_2 n$. The technique used to **encode** the allowable signal states may be any combination of amplitude, **frequency**, or **phase modulation**, but it cannot use a further **time-division multiplexing** technique to subdivide the unit intervals into multiple subintervals. In some **signaling** systems, non-**information**-carrying signals may be inserted to facilitate **synchronization**; e.g., in certain forms of **binary modulation coding**, there is a forced inversion of the **signal** state at the center of the **bit** interval. In these cases, the synchronization signals are included in the calculation of the rate in bauds but not in the computation of **bit rate**. *Note 2:* **Baud** is sometimes used as a synonym for **bit-per-second**. This usage is deprecated.

Signal

- **signal:** 1. Detectable transmitted energy that can be used to carry **information**. 2. A **time**-dependent variation of a characteristic of a physical phenomenon, used to convey information. 3. As applied to electronics, any transmitted electrical **impulse**. 4. Operationally, a type of **message**, the text of which consists of one or more letters, words, characters, signal flags, visual displays, or special sounds, with prearranged meaning and which is conveyed or transmitted by visual, acoustical, or electrical means.

Message

- **message:** 1. Any thought or idea expressed briefly in a plain or secret **language**, prepared in a form suitable for **transmission** by any means of communication. *Note:* A message may be a one-unit message or a multiunit message. 2. [In telecommunications,] **Record information** expressed in plain or encrypted language and prepared in a **format** specified for intended transmission by a telecommunications **system**. 3. An arbitrary amount of information whose beginning and end are defined or implied.

Format

- **format:** 1. The arrangement of bits or characters within a **group**, such as a **word**, **message**, or **language**. 2. The shape, size, and general makeup of a document.

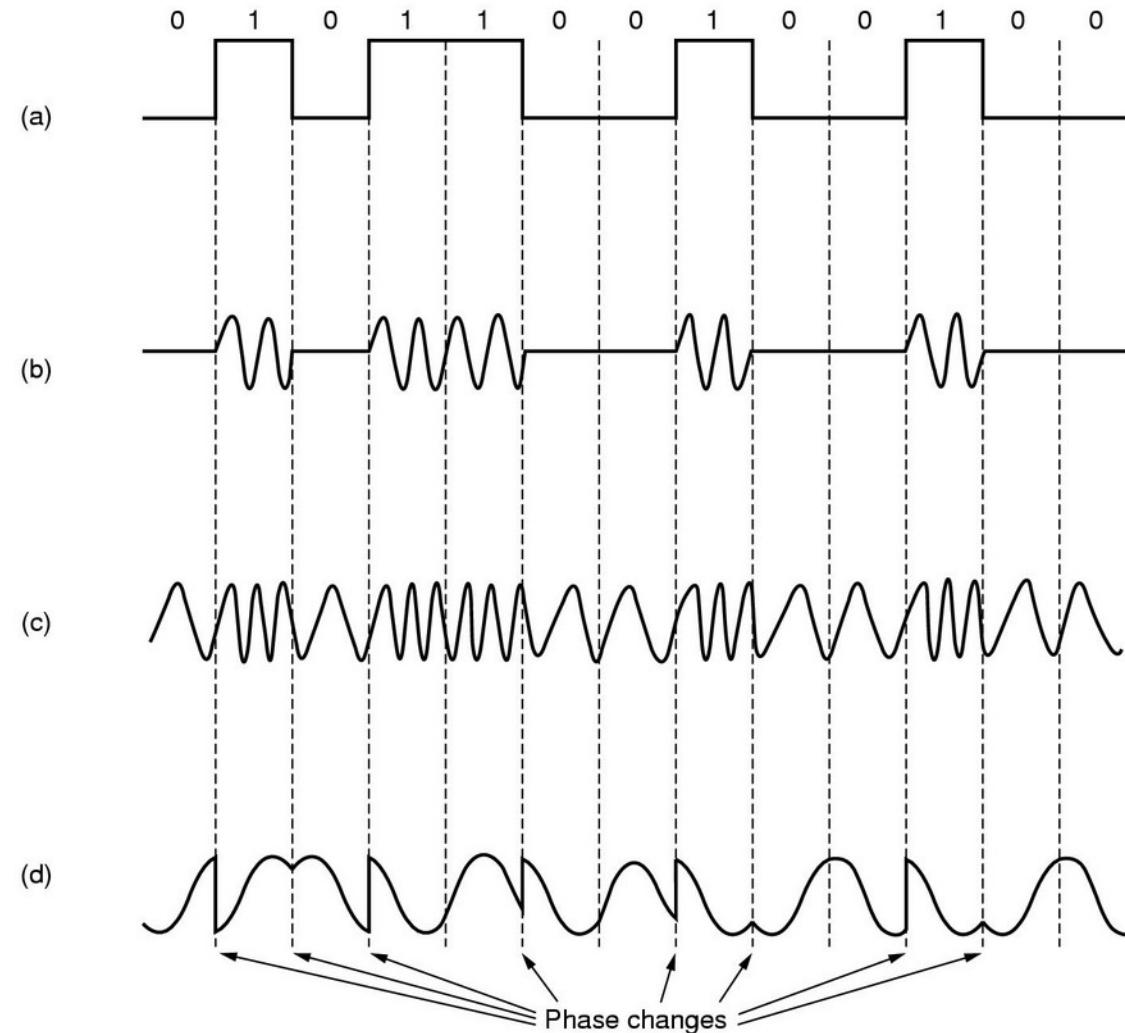
Language

language: A set of characters, conventions, and rules that is used for conveying information.

Einfache Modulationsarten

- Amplitudenmodulation
- Frequenzmodulation
- Phasen-/Winkelmodulation

Modulation Types



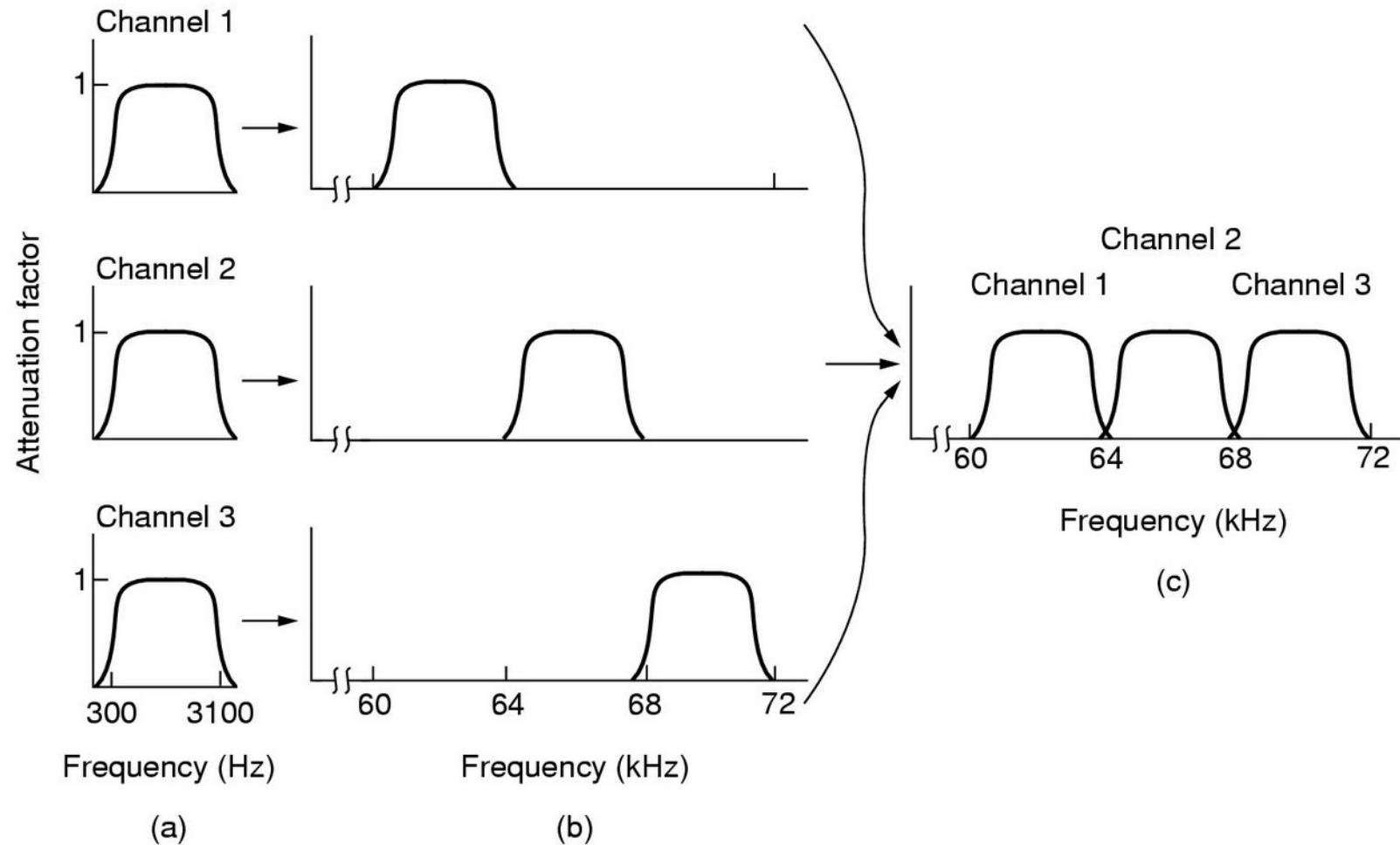
Multiplexing

- **multiplexing (MUXing)**: The combining of two or more **information** channels onto a common transmission medium. **Note:** In electrical communications, the two basic forms of multiplexing are **time-division multiplexing (TDM)** and **frequency-division multiplexing (FDM)**. In optical communications, the analog of FDM is referred to as **wavelength-division multiplexing (WDM)**.

Frequency-division Muxing

- **frequency-division multiplexing (FDM):**
The deriving of two or more simultaneous, continuous channels from a transmission medium by assigning a separate portion of the available frequency spectrum to each of the individual channels.

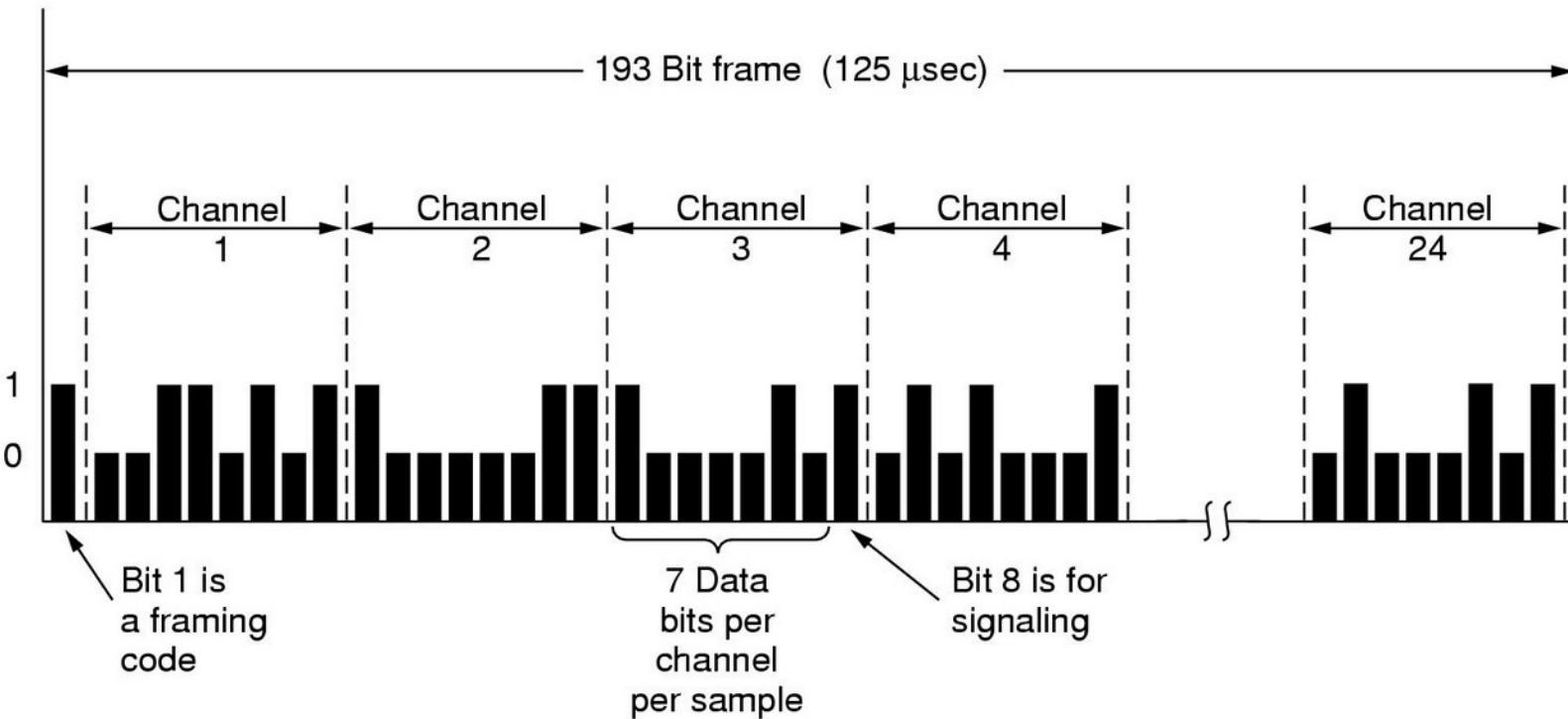
Frequency-division Muxing



Time-division Muxing

- **time-division multiplexing (TDM)**: Digital multiplexing in which two or more apparently simultaneous channels are derived from a given frequency spectrum, i.e. , bit stream, by interleaving pulses representing bits from different channels. Note: Successive pulses represent bits from successive channels, e.g., voice channels in a T1 system.

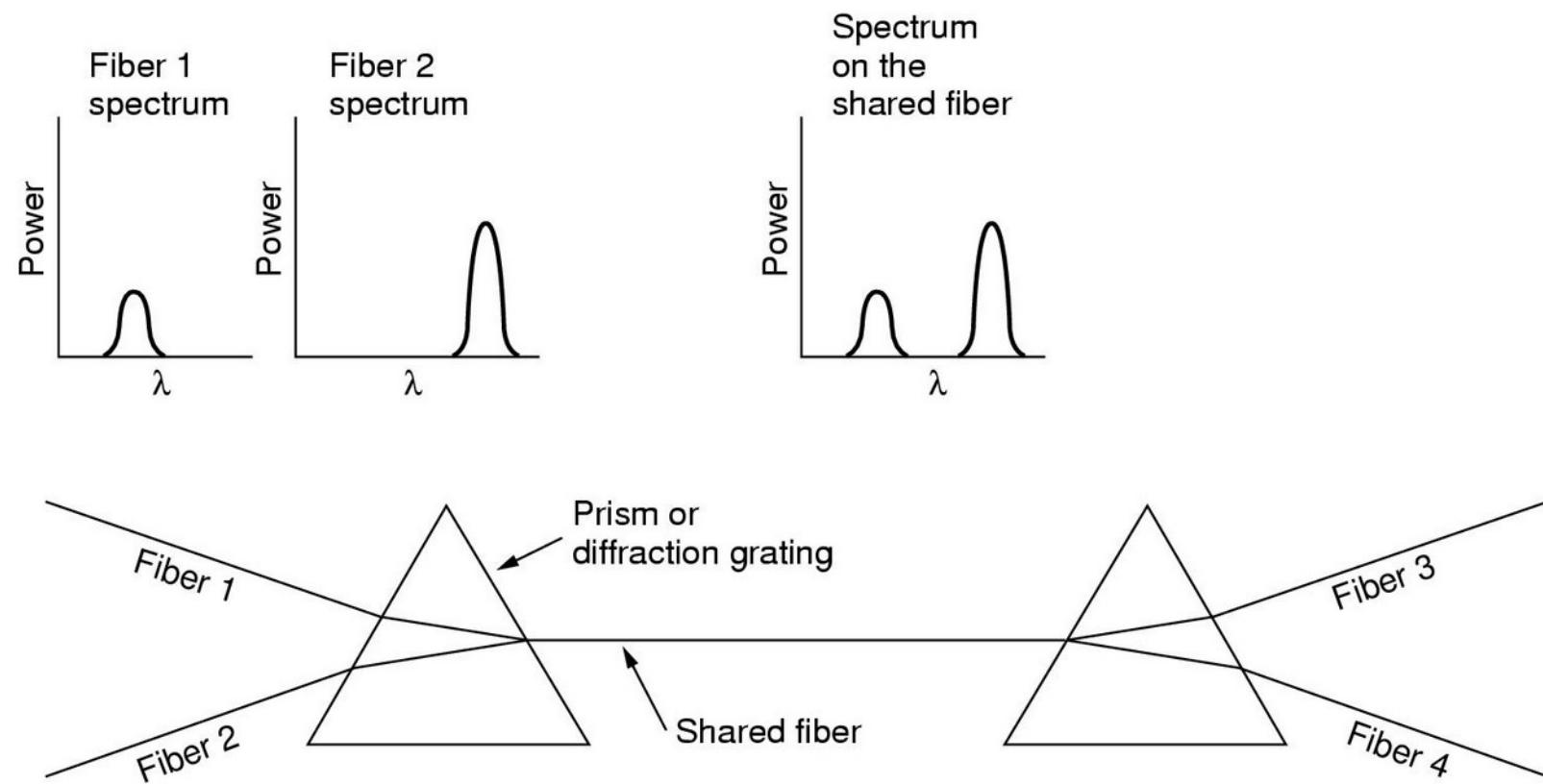
Time-division Muxing



Wavelength-division Muxing

- **wavelength-division multiplexing (WDM)**: In optical fiber communications, any technique by which two or more optical signals having different wavelengths may be simultaneously transmitted in the same direction over one fiber, and then be separated by wavelength at the distant end.

Wavelength-division Muxing



Moderne Modulationsarten

- **QAM** - zB Kabel-TV (DVB-C)
- **QPSK** - zB Satelliten-TV (DVB-S)
- **APSK** - zB DVB-S2
- **OFDM** - zB Antennen-TV (DVB-T),
LTE

Synchronization

- **synchronization:** 1. The attaining of **synchronism**. 2. The obtaining of a desired fixed relationship among corresponding significant instants of two or more signals. 3. A state of simultaneous occurrences of significant instants among two or more signals.

Signaling

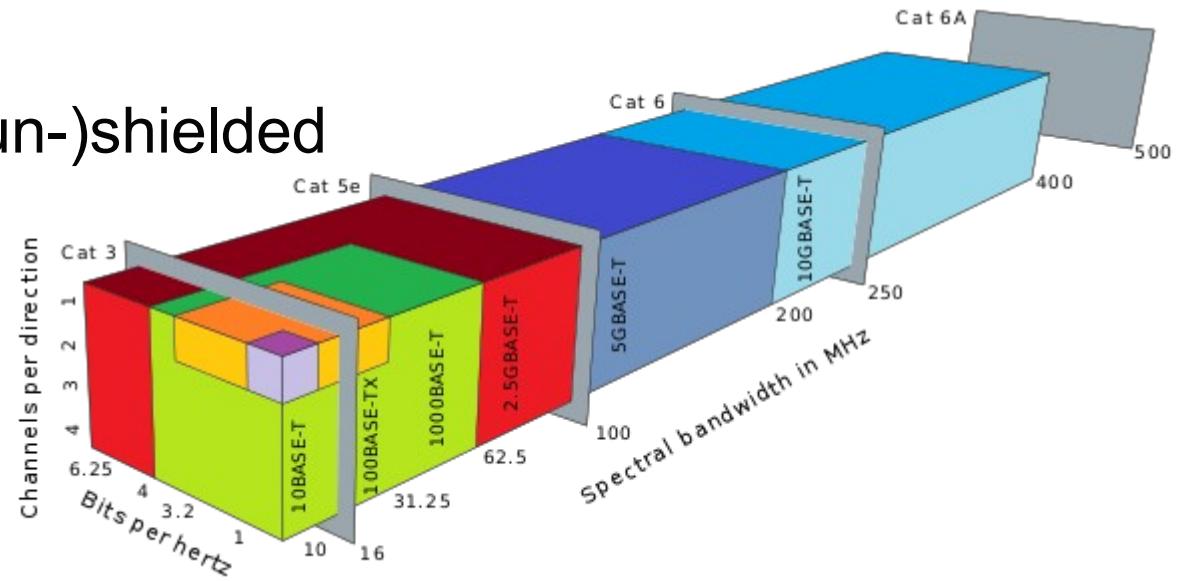
- **signaling:** 1. The use of signals for controlling communications. 2. In a telecommunications network, the information exchange concerning the establishment and control of a connection and the management of the network, in contrast to user information transfer. 3. The sending of a signal from the transmitting end of a circuit to inform a user at the receiving end that a message is to be sent.

Transmission Medium

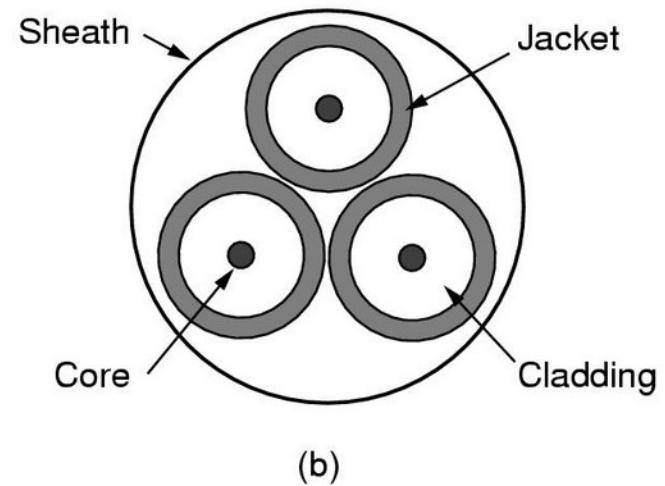
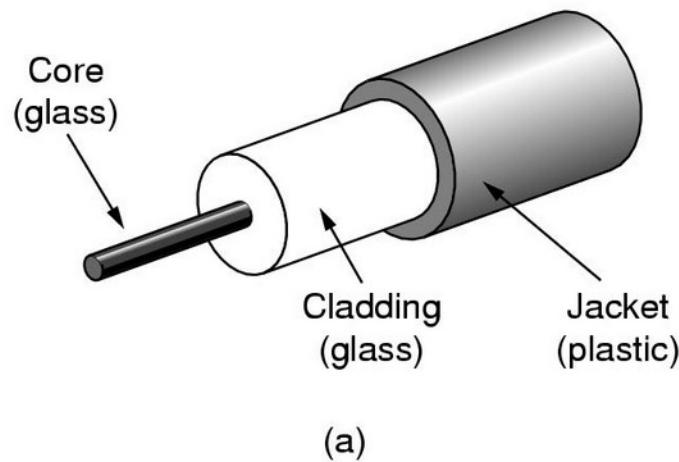
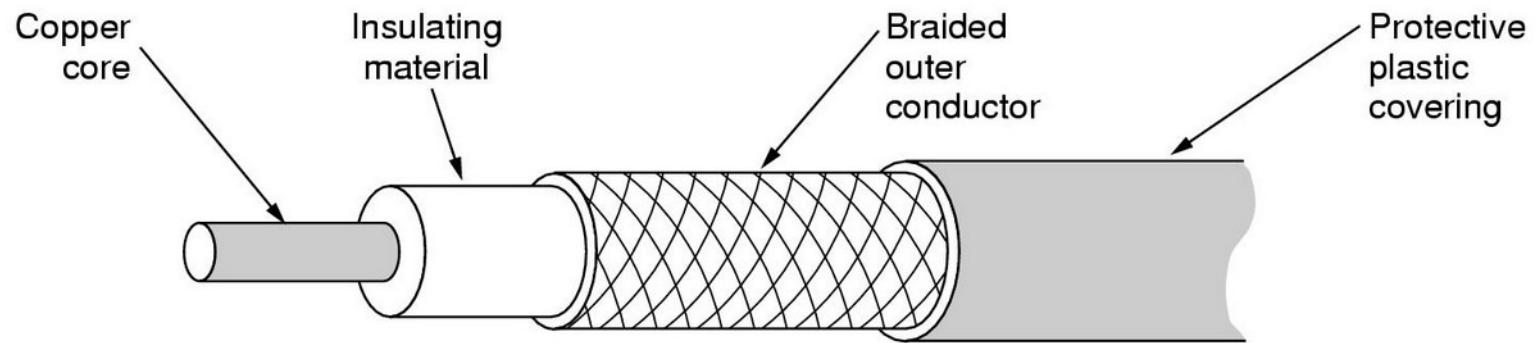
- **transmission medium:** Any material substance, such as fiber-optic cable, twisted-wire pair, coaxial cable, dielectric-slab waveguide, water, and air, that can be used for the propagation of signals, usually in the form of modulated radio, light, or acoustic waves, from one point to another.
Note: By extension, free space can also be considered a transmission medium for electromagnetic waves, although it is not a material medium.

Kabel

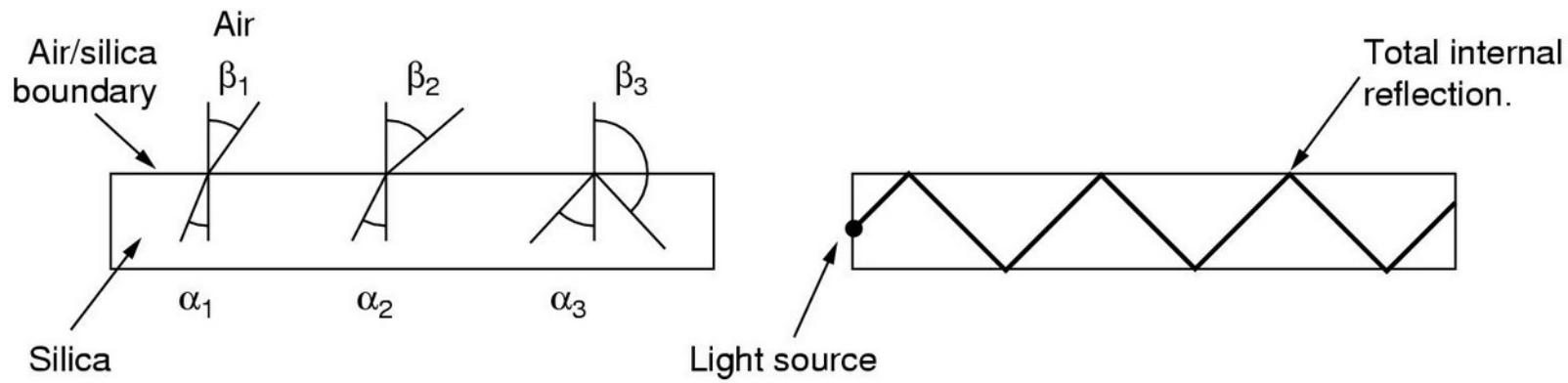
- Kupfer
 - Twisted pair, (un-)shielded
 - Kat3
 - Kat5
 - ...
 - Kat8
- Koaxialkabel
- Glas
 - LED
 - Laser, single-/multi-mode



Kabelaufbau

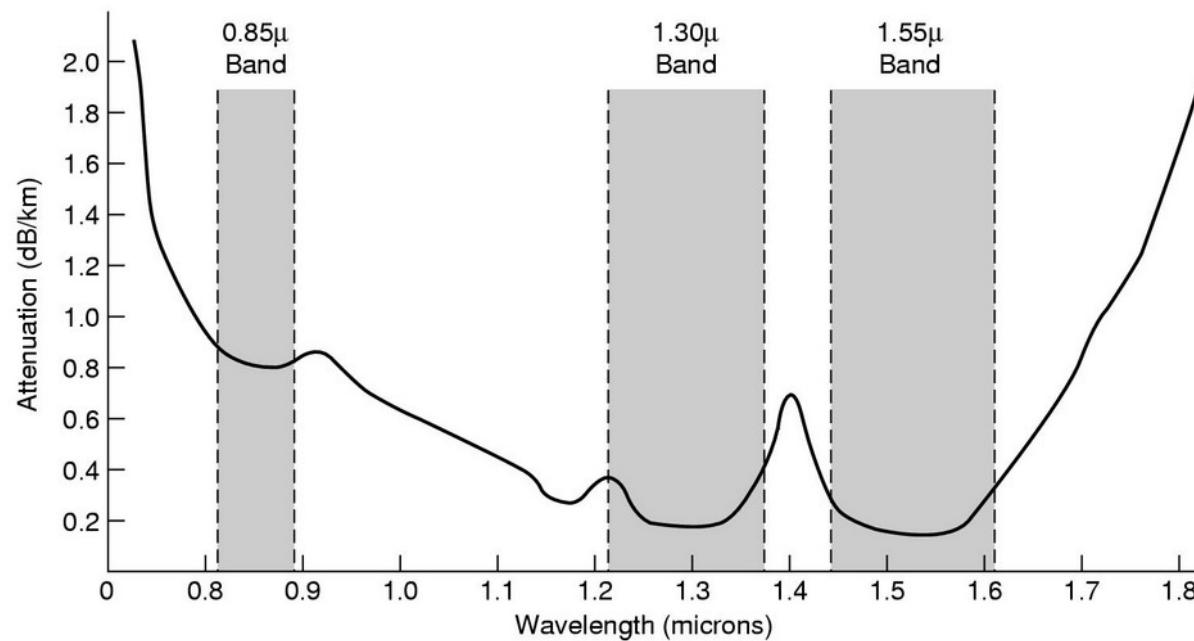


Glasfaser



(a)

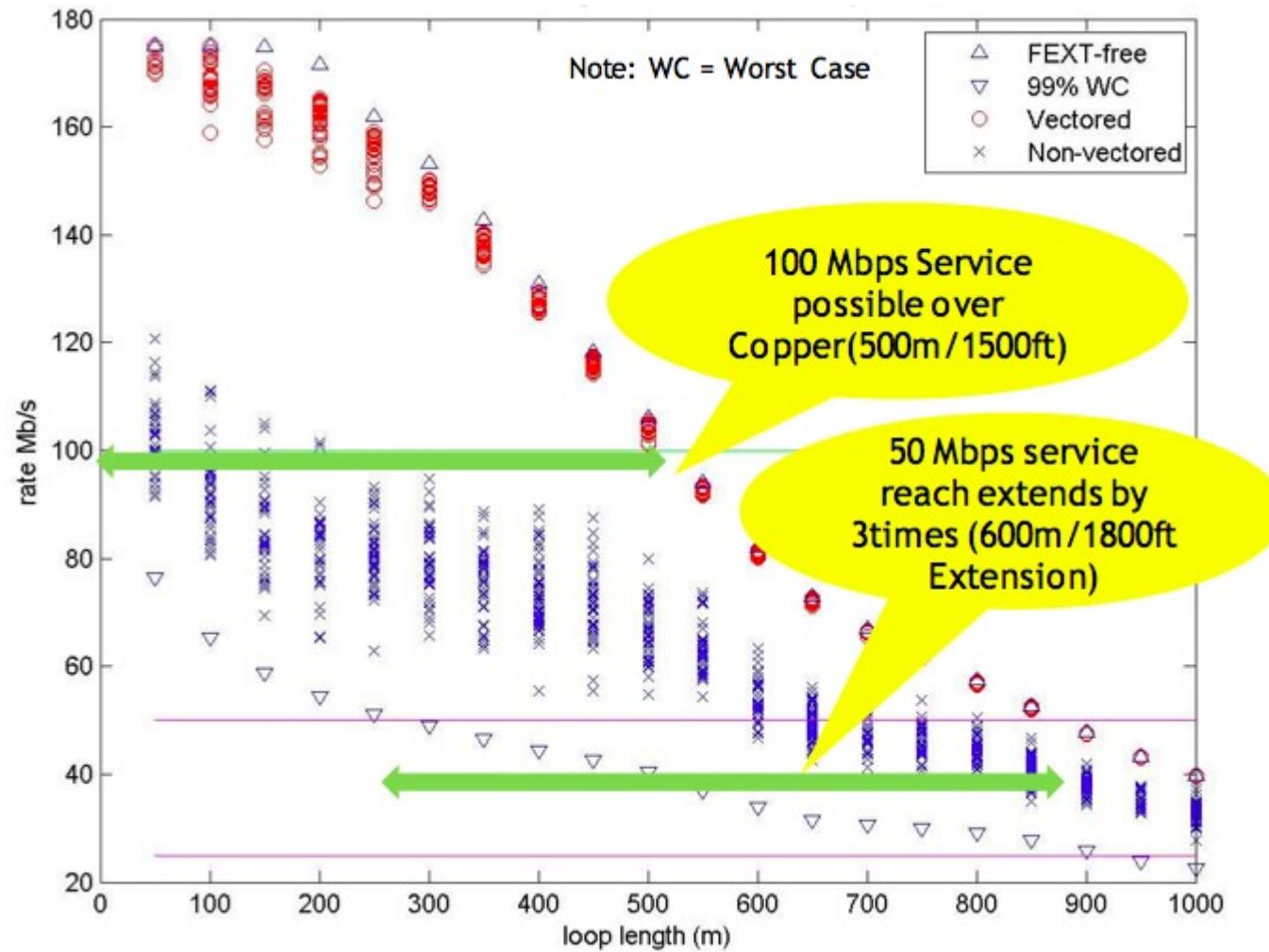
(b)



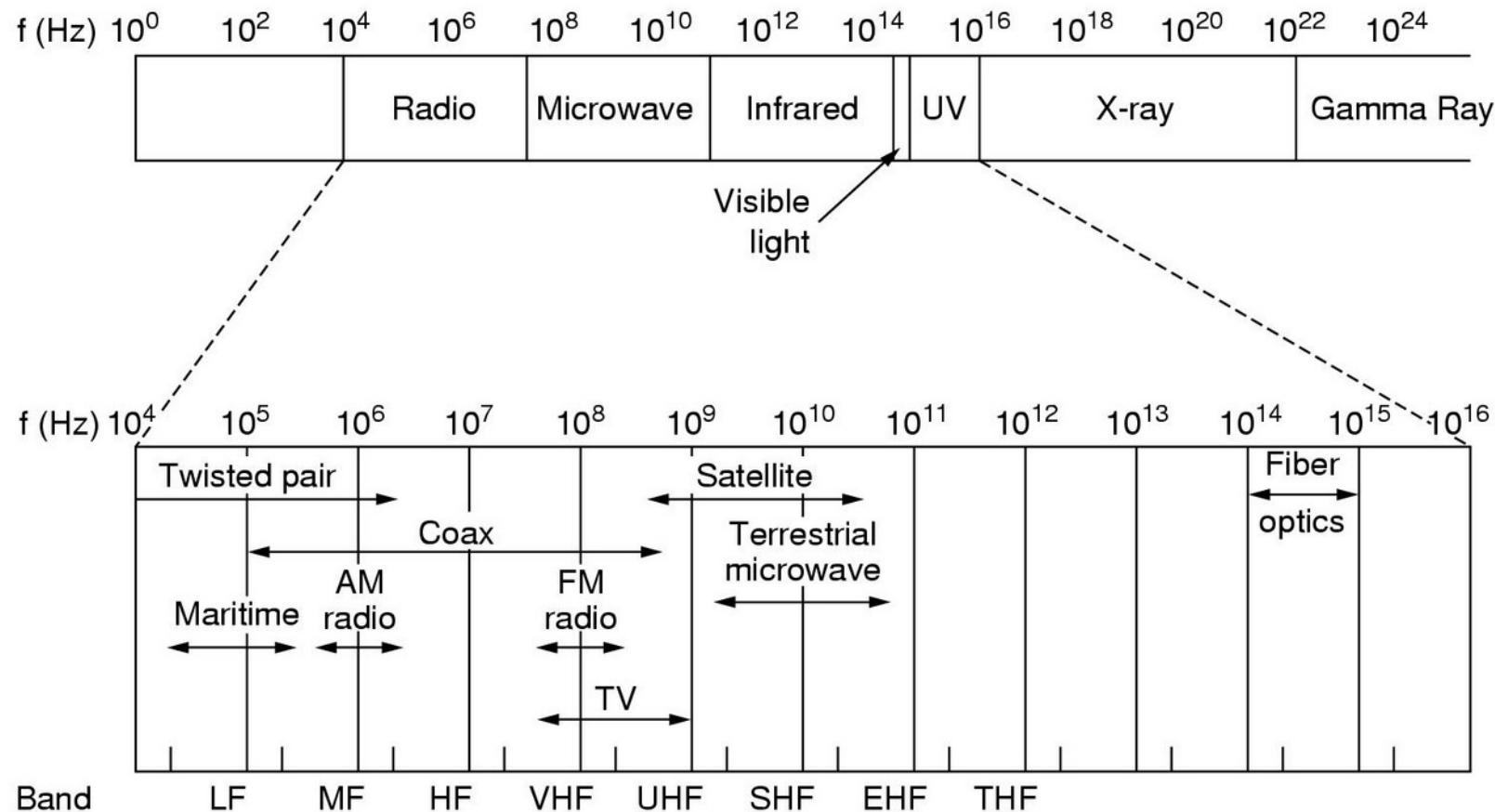
Glas vs Kupfer

- Bandbreite
- Dämpfung
- Störung
- Gewicht
- Abhören
- Photonen vs Elektronen
- Kosten

Vectoring

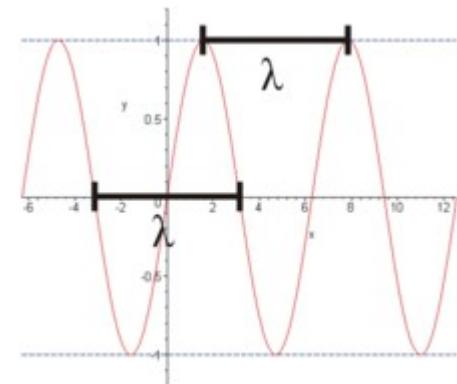


EM-Spektrum

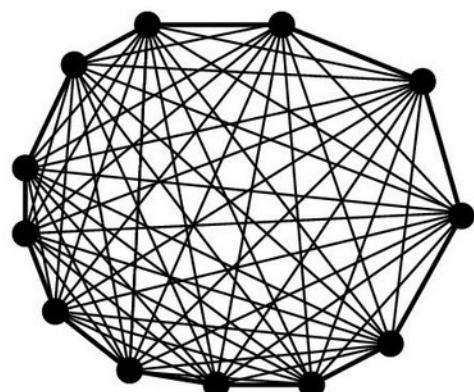


Drahtlose Übertragung

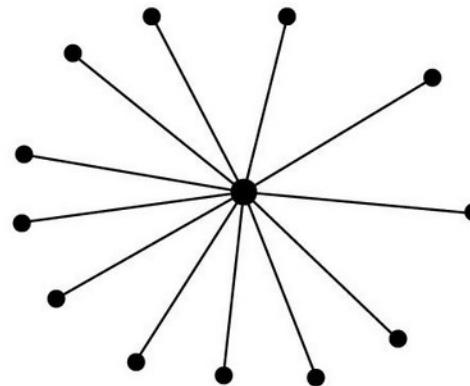
- Elektronen -> elektromagnetische Wellen
 - Maxwell 1865
 - Hertz 1887
 - Marconi
 - Radio
 - Mikrowellen
 - Infrarot
 - Lichtwellen, optischer Richtfunk (FSO)
- $$\lambda = c / f$$
- c = Ausbreitungsgeschwindigkeit
f = Frequenz



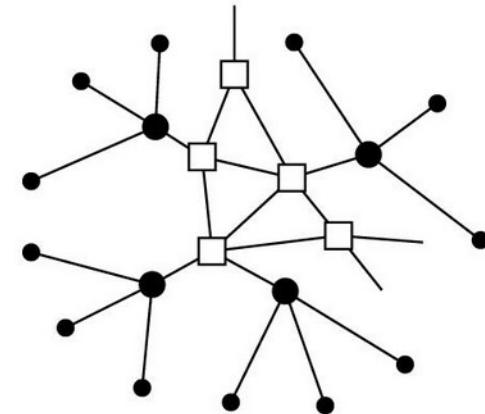
Telefonsystem



(a)

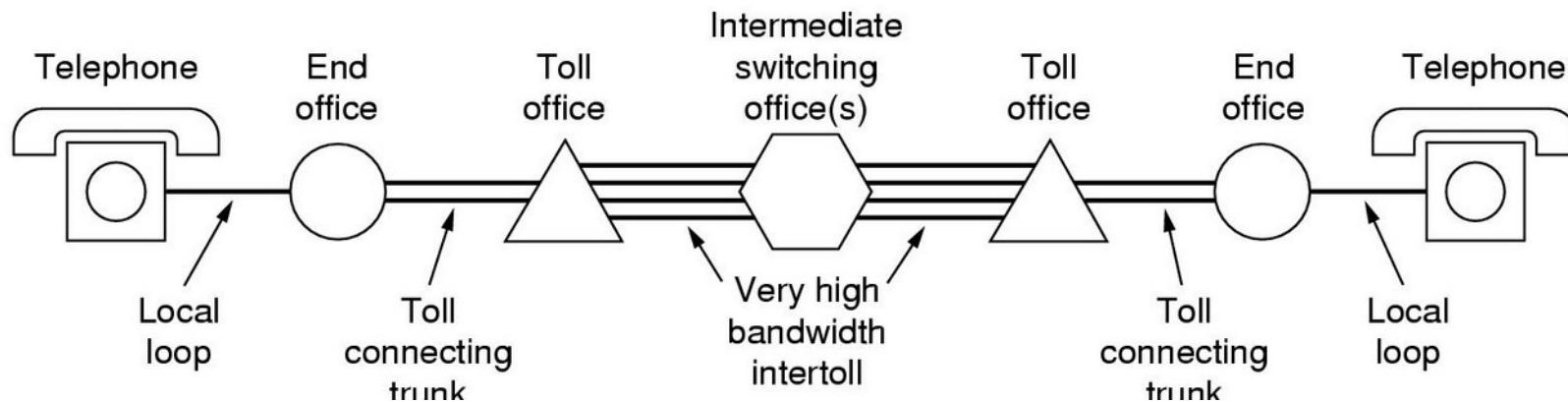


(b)



(c)

1876 – 1890, Monopol bis 1984



Telefonnetz – Komponenten

- Ortsvermittlungen
- Fernvermittlungen
- Vermittlungssämter



Montreal telephone exchange (ca. 1895)

Analog vs Digital

- Dämpfung/Verzerrung
- Informationsverlust
- Multimedia
- Datenraten
- Kosten für Verstärker
- Kosten für Wartung

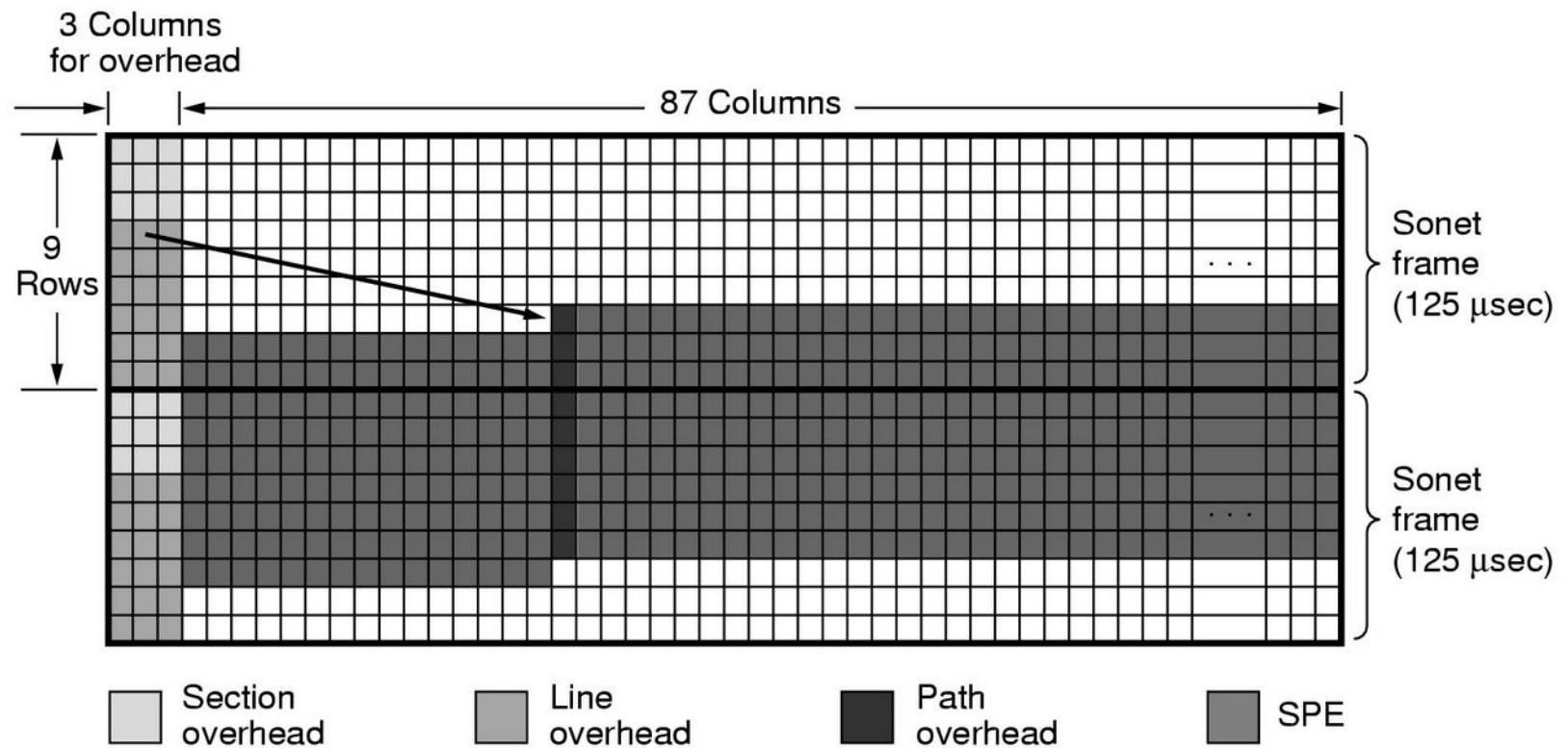
125µs

- Codec
- 8000 Abtastungen pro Sekunde
- 4 KHz
- Nyquist!
- PCM
- 7 bit = 56000, 8 bit = 64000
- = 1 Telefonkanal
- T1 = 24x, E1 = 32x

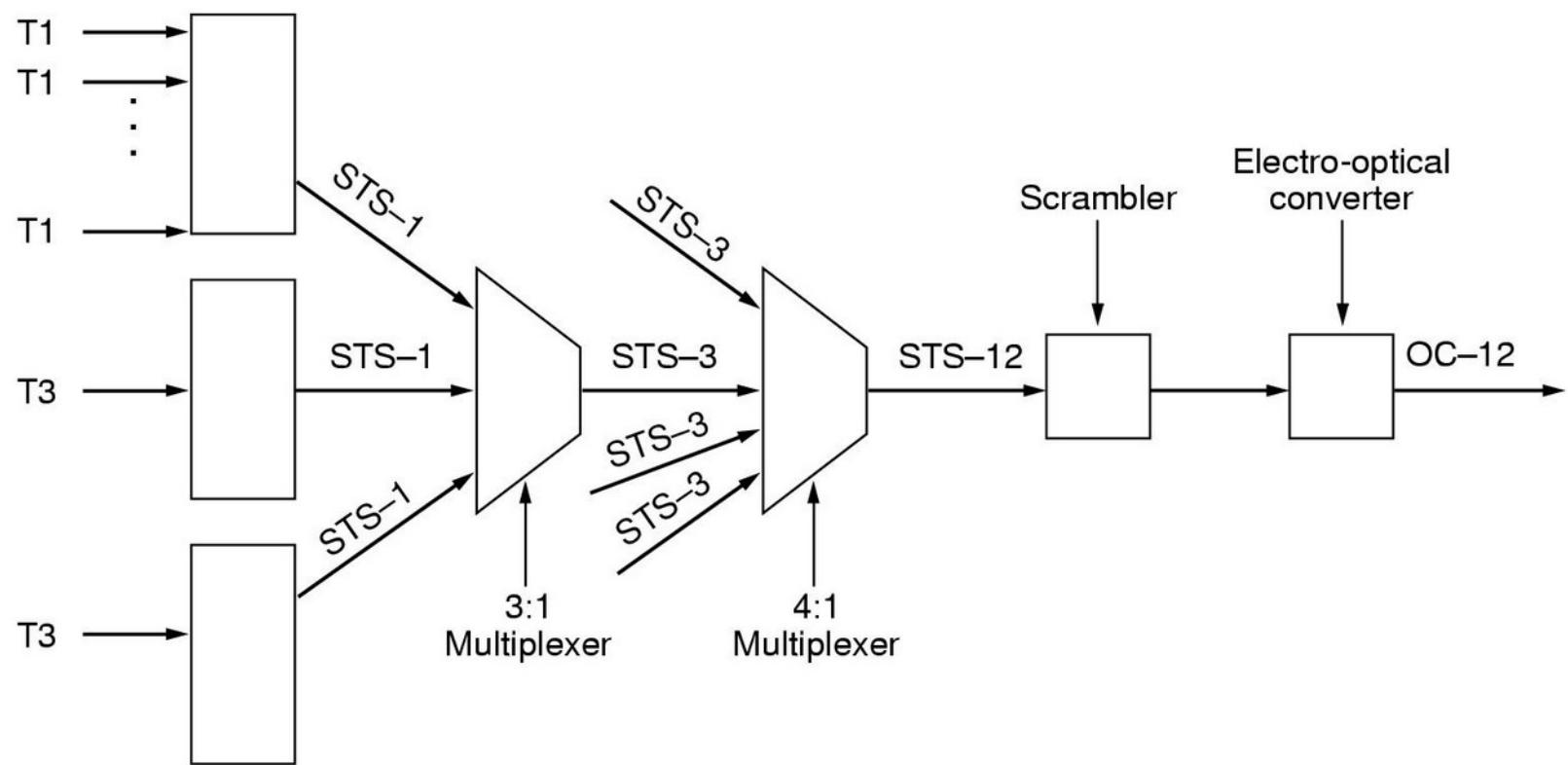
SONET/SDH

- Synchronous Optical NETwork
- CCITT (Comité Consultatif International Téléphonique et Télégraphique)
- (G.707, G.708.G.709) Synchronous Digital Hierarchy
- Interoperabilität
- OAM
- $810 \text{ byte} / 125 \mu\text{s} = 6480 \text{ bits} * 8000/\text{sec} =$
Synchronous Transport Signal-1 = 51.84Mbps
- - Synchronous Payload Envelope = 50.112 Mbps

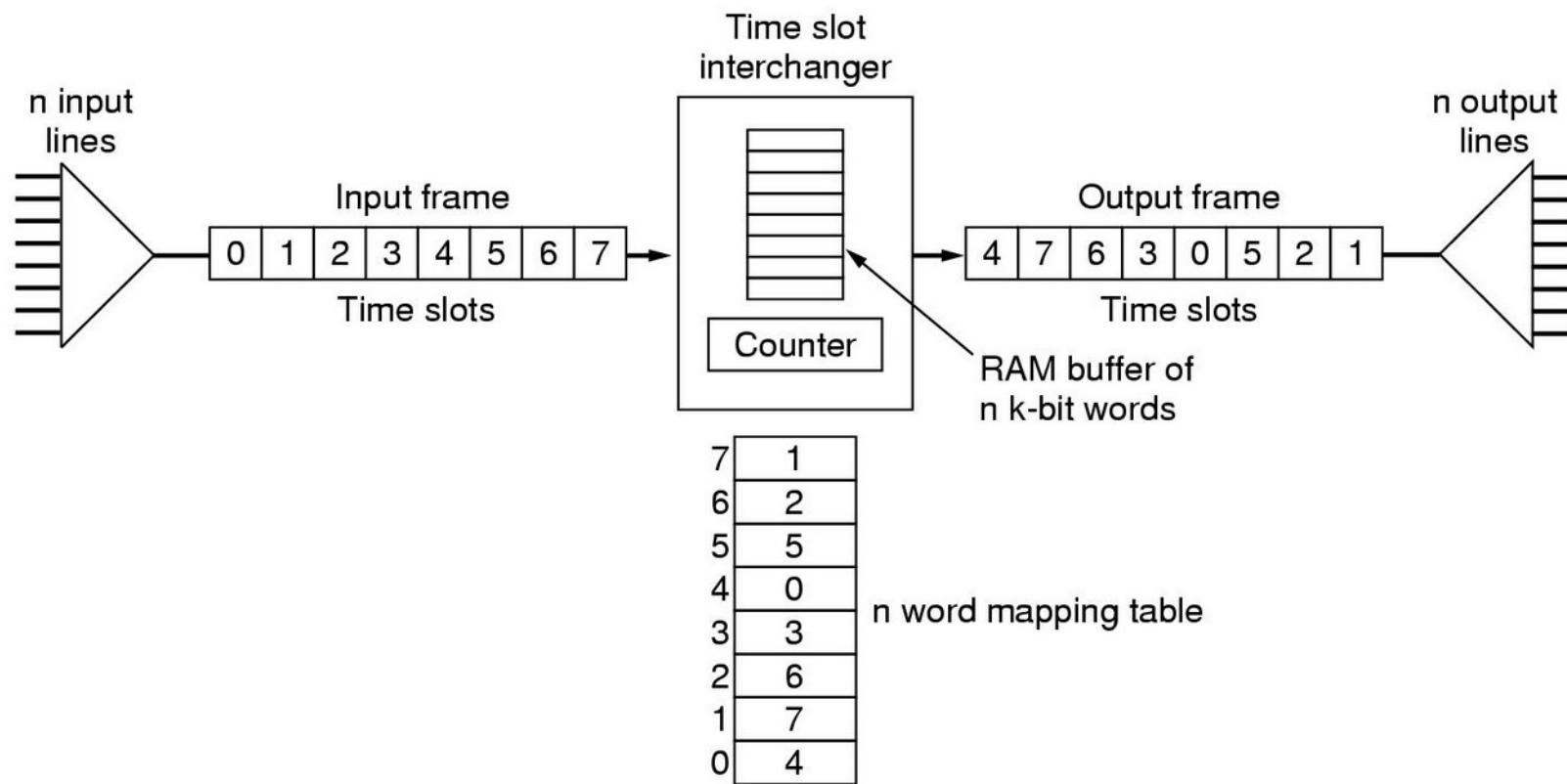
SONET Rahmen



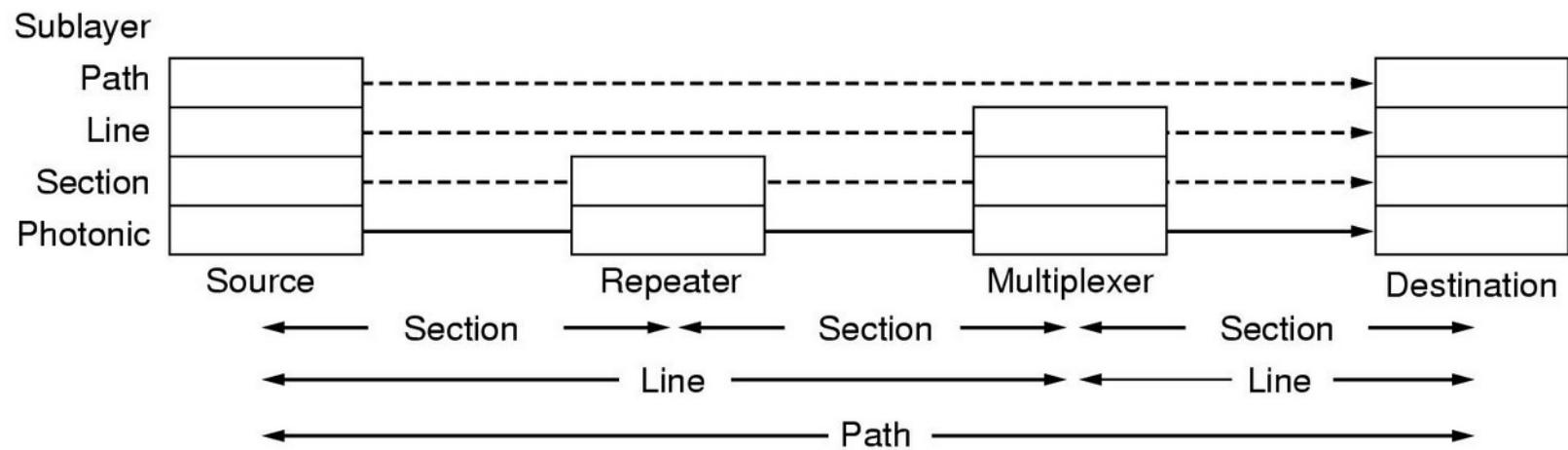
SONET Multiplex



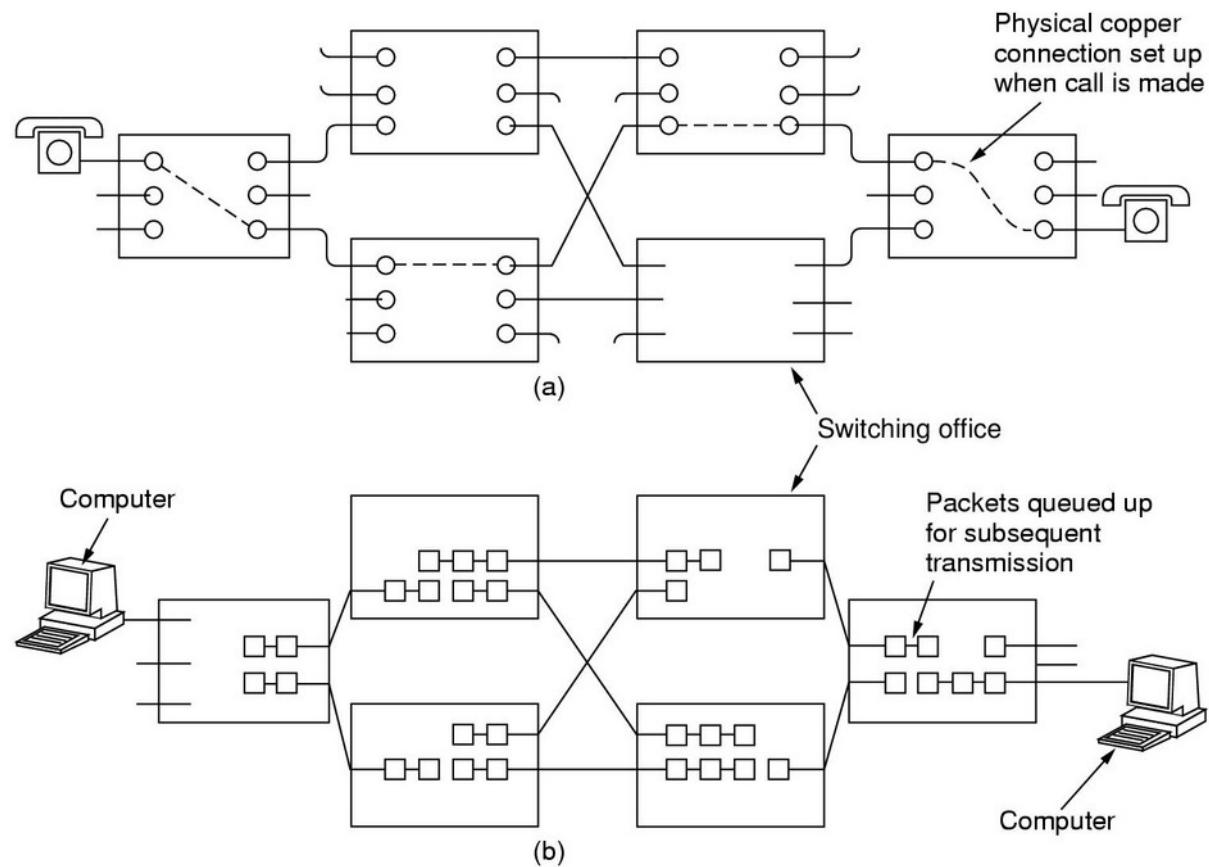
Zeitmultiplexvermittler



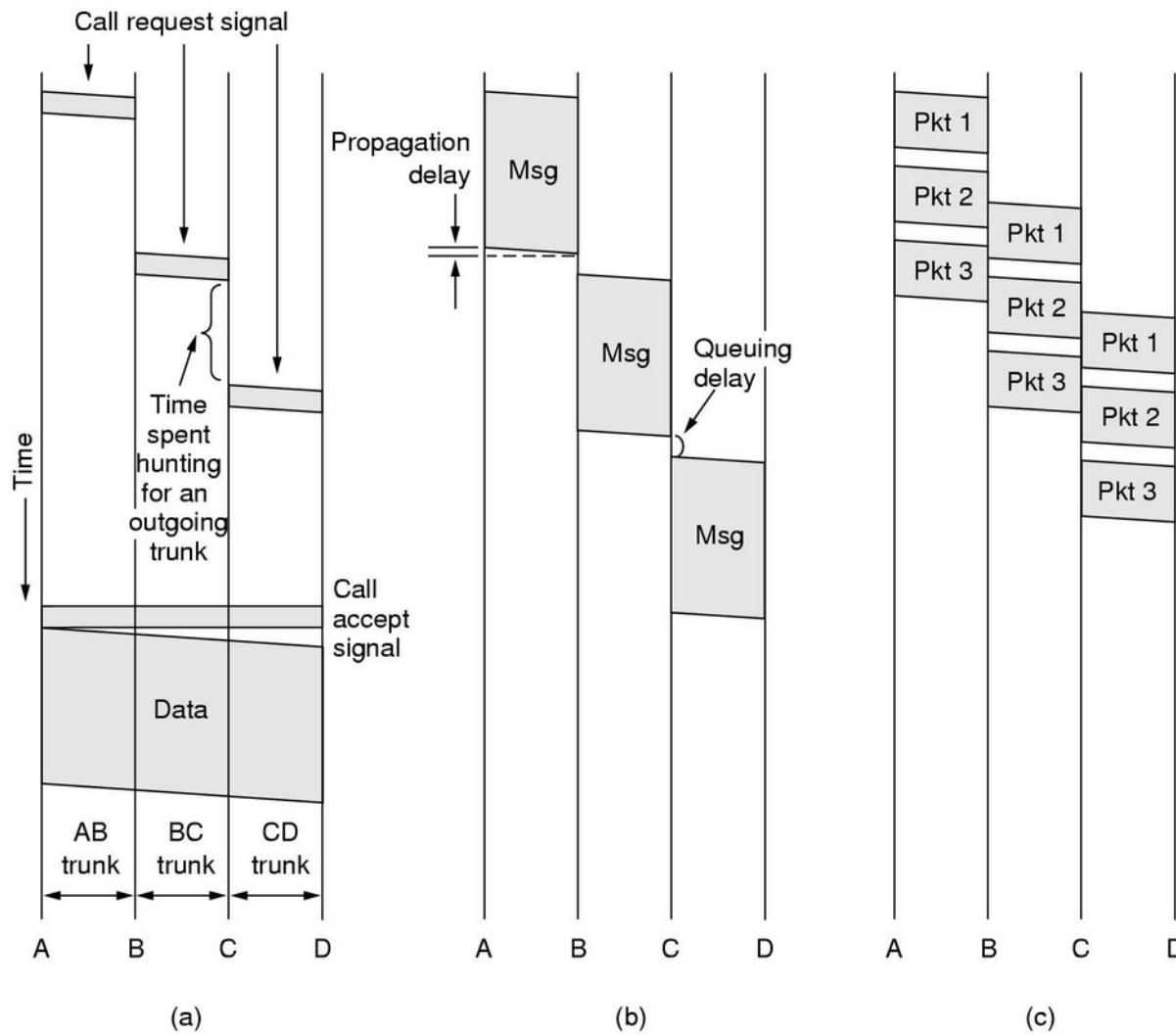
SONET Architektur



Vermittlung



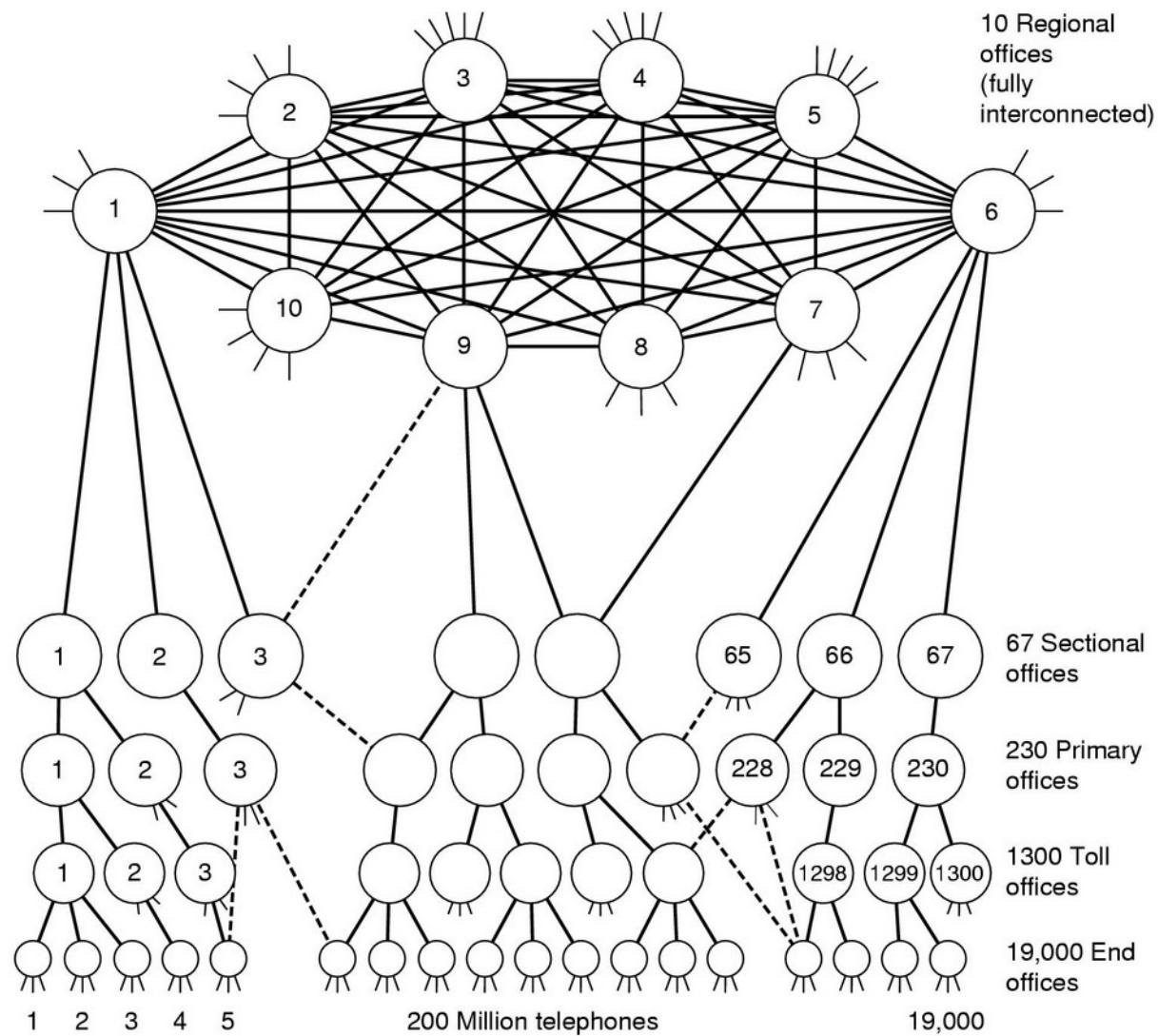
Vermittlungsarten



Vermittlung - Vergleich

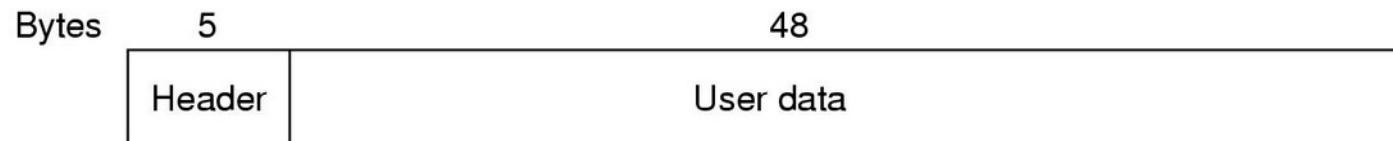
Merkmal	Leitung	Paket
Dedizierter Pfad	Ja	Nein
Bandbreite	Fest	Dynamisch
Belegung	Fix	Variabel
Pufferung	Nein	Ja
Route	Fest	Dynamisch
Verbindungsauflbau	Ja	Nein
Überlast	Anfang	Immer
Verrechnung	Zeit	Menge

Vermittlungshierarchie



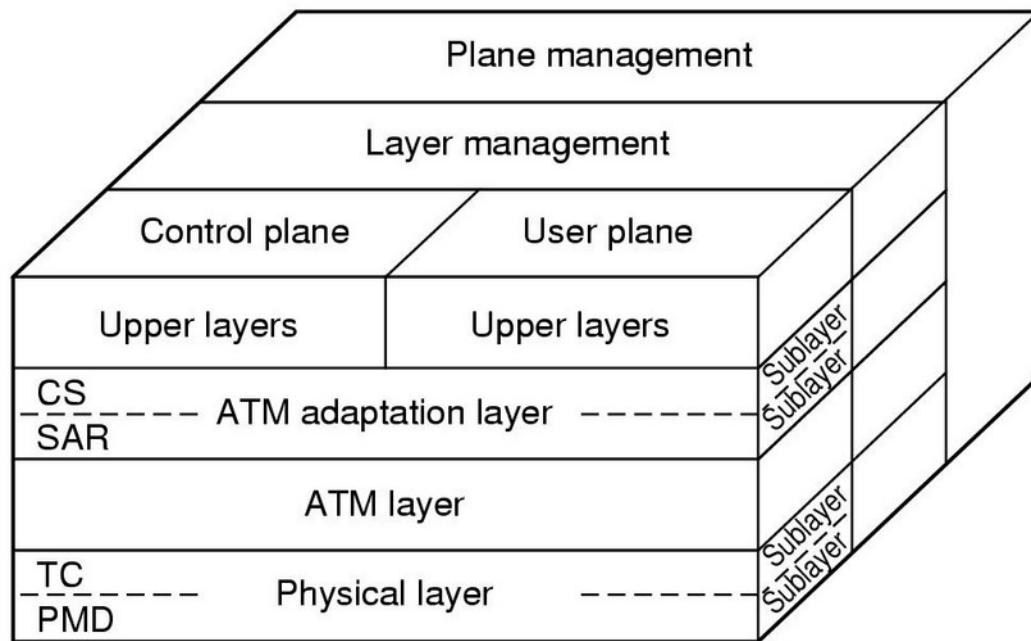
ATM

- Asynchronous Transfer Mode
- 155.52, 602.08 Mbps, ...
- $53 = 5 + 48$



- $360000 \text{ Zellen/sec} = 2.7 \mu\text{s}$

B-ISDN/ATM



CS: Convergence sublayer

SAR: Segmentation and
reassembly sublayer

TC: Transmission convergence
sublayer

PMD: Physical medium
dependent sublayer

ATM vs OSI

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2		TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1	Physical	PMD	Bit timing Physical network access

Modem



How To? SLIP? ULE?

- RFC1055
- RFC4326
 - BoF → Area, WG
 - Draft

“rough consensus and running code”

- RFC
- STD oder BCP

ISDN

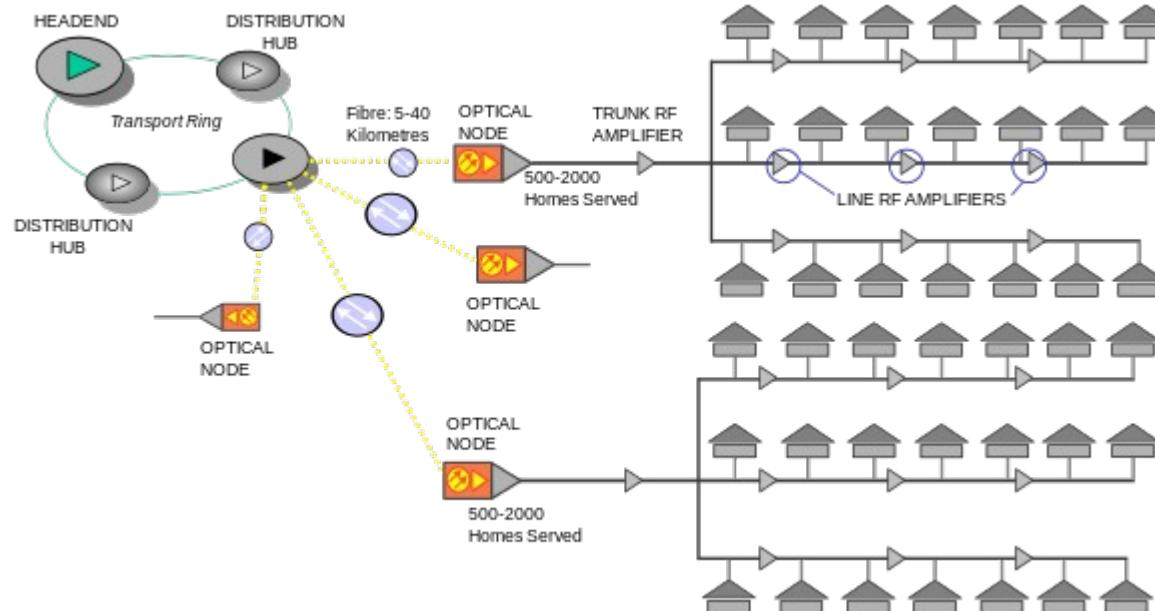
- B-Kanal 64 Kbps, D-Kanal 16 Kbps
- Basisanschluss 2B+1D
- Primär: 23B+1D, 30B +1D
- Leistungsmerkmale
 - Mehrfachrufnummer, Rufumleitung, Rufnummernanzeige, Konferenzschaltung, Anklopfen, Makeln, Parken, Subaddressierung, Tarifinfos, ...

xDSL/ADSL

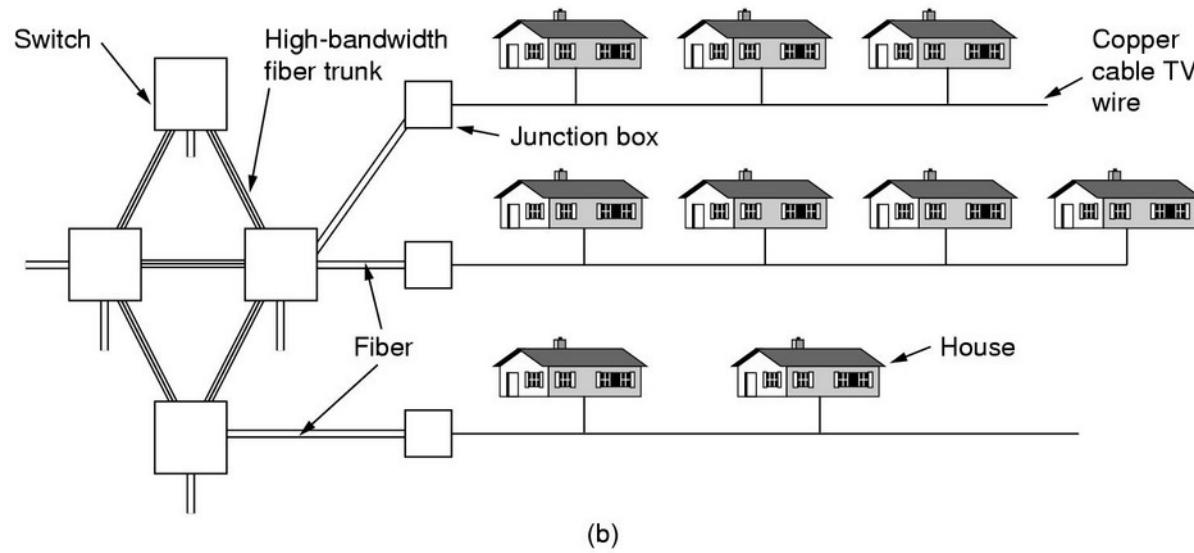
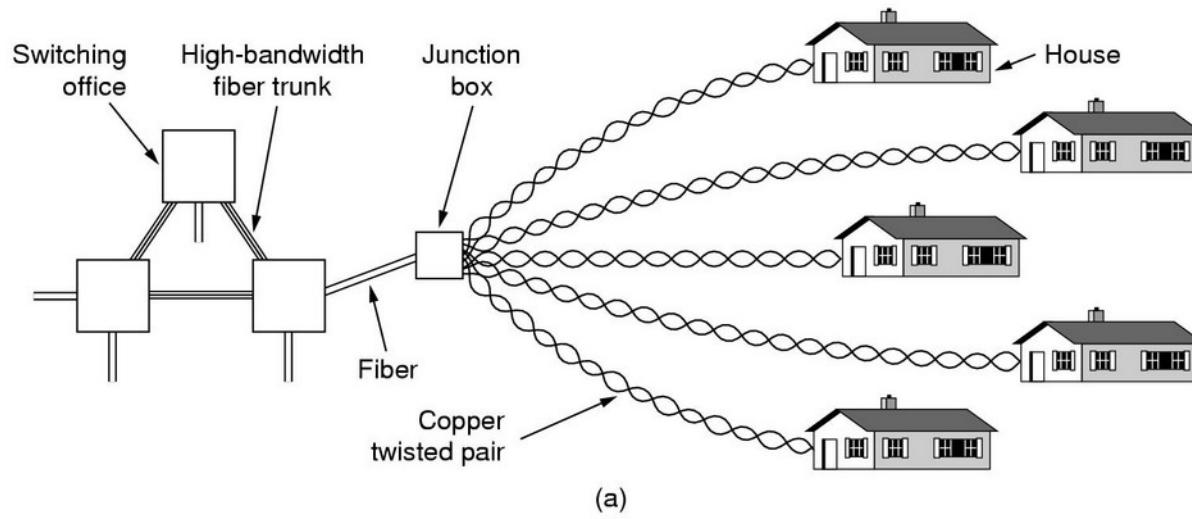
- (Asymmetric) Digital Subscriber Line
- Downstream/upstream
- 32Kbps-6Mbps/32Kbps-640Kbps
- Adaptive
- DMT Modulation
- HDSL 1,544 Mbps bi-directional
- VDSL bis 52Mbps

Kabelmodem

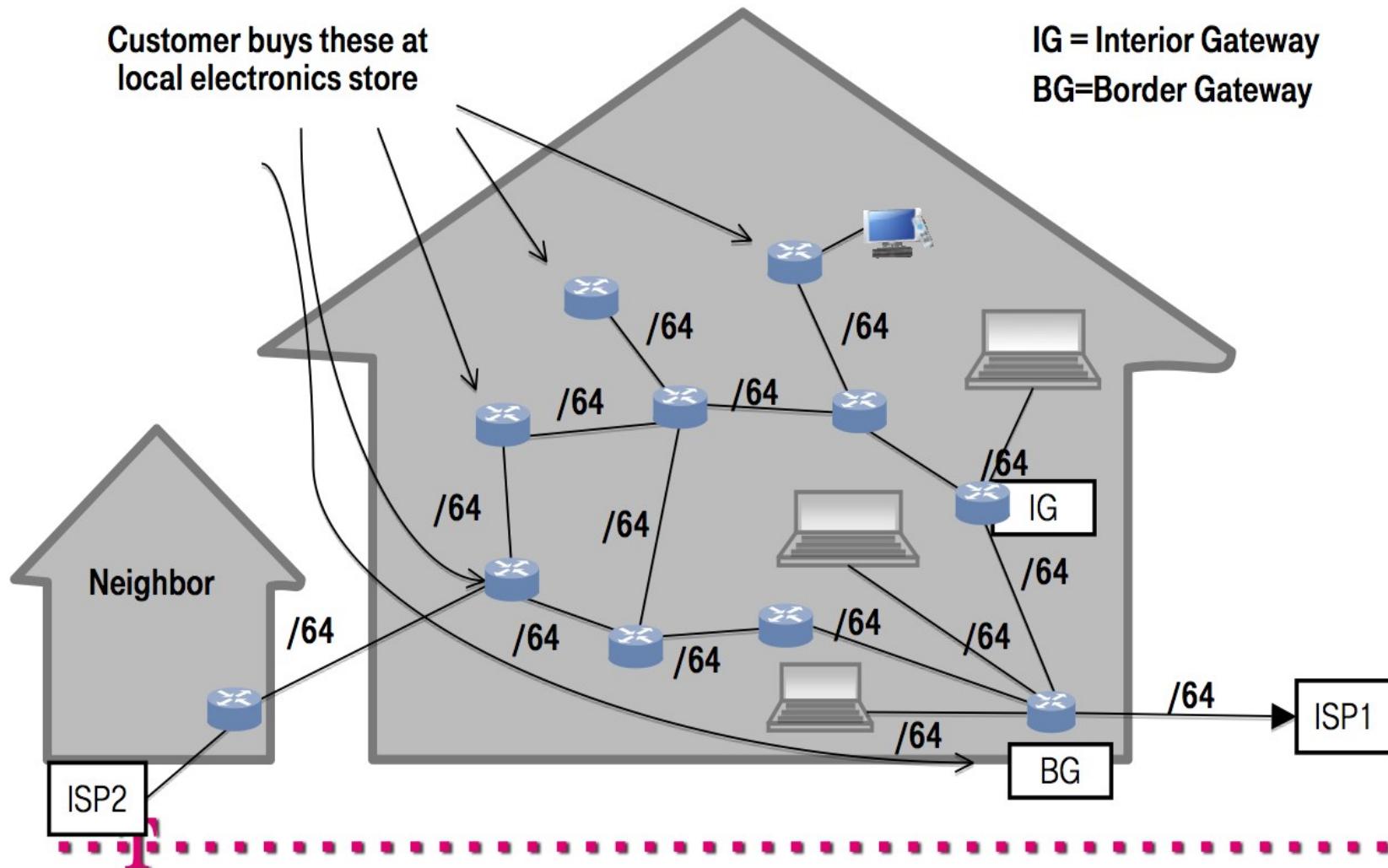
- Kabelfernsehen mit Rückkanal
- CATV Frequenzmultiplex
- Rückkanal Frequenz/Zeitmultiplex



FTTC



FTTH (zB Terastream)

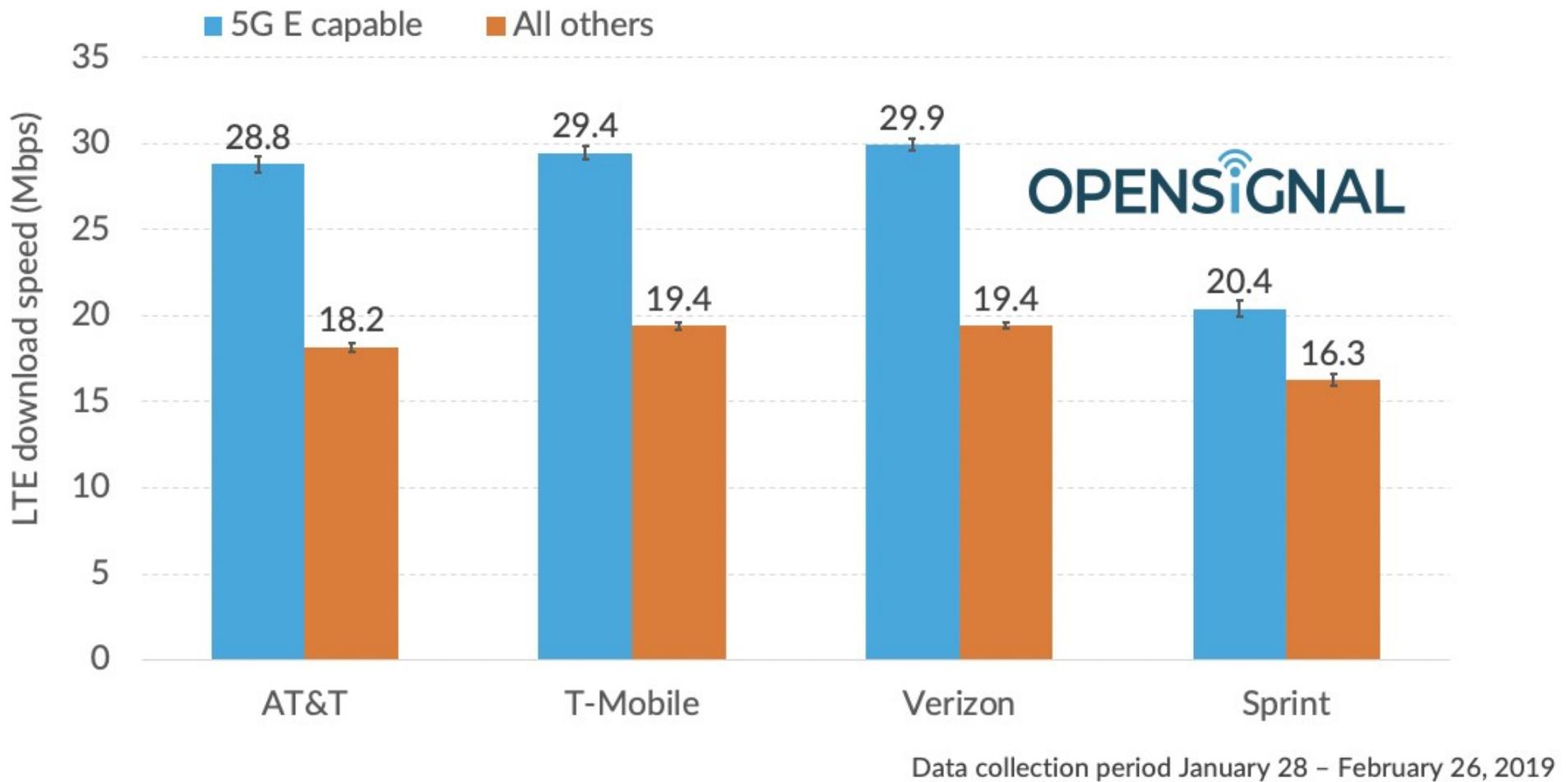


(Mobil)Funktelefone

- Analog
- DECT
- GSM
- GPRS
- UMTS/3G
- EDGE
- HSDPA
- LTE (3.9G)
- 4G/5G



4G Advanced > 5G E ?



<https://arstechnica.com/information-technology/2019/03/atts-5g-e-is-actually-slower-than-verizon-and-t-mobile-4g-study-finds/>

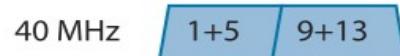
Cut

Ende 3. Termin (Online) 20.3.20

Beginn 4.Termin (Online) 27.3.20

WLAN IEEE 802.11 etc

2,4-GHz-Band



5-GHz-Band

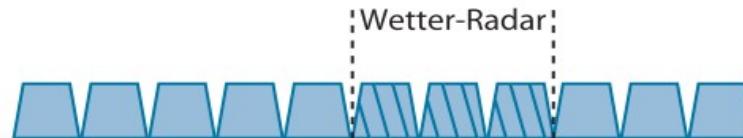
Kanalbreite



Kanal 36 40 44 48 52 56 60 64

Frequenz 5,2 5,3

Wetter-Radar



100 104 108 112 116 120 124 128 132 136 140
5,5 5,6 5,7 GHz

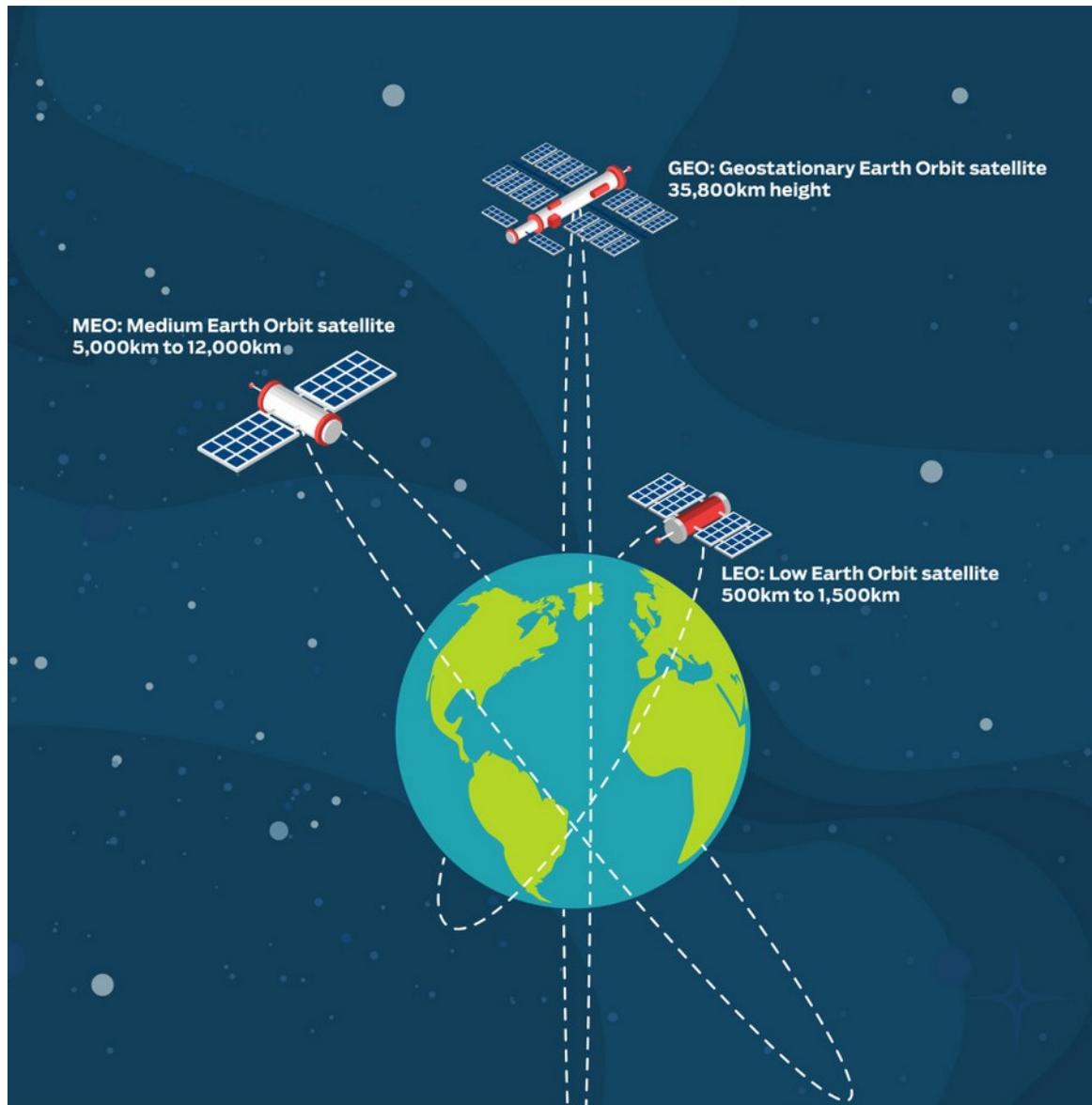
60-GHz-Band



Satelliten

- GEO, MEO, LEO
- VSAT
- Direct Broadcast
- C-, Ku-, Ka-Band, Q/V-Band
- 4, 12, 20, 50 GHz downlink
- 6, 14, 30, 70 GHz uplink

Umlaufbahnen - orbits



EO/TV/IP

- Meteosat.com/Planet.com
- Astra.com, Eutelsat.com
- Teledesic 288by03
- LeoSat 78by20
- SpaceX.com 11943by20
- OneWeb.world 600by21
- Kepler Communication CubeSats



<https://www.pcmag.com/article/362695/why-satellite-internet-is-the-new-space-race>

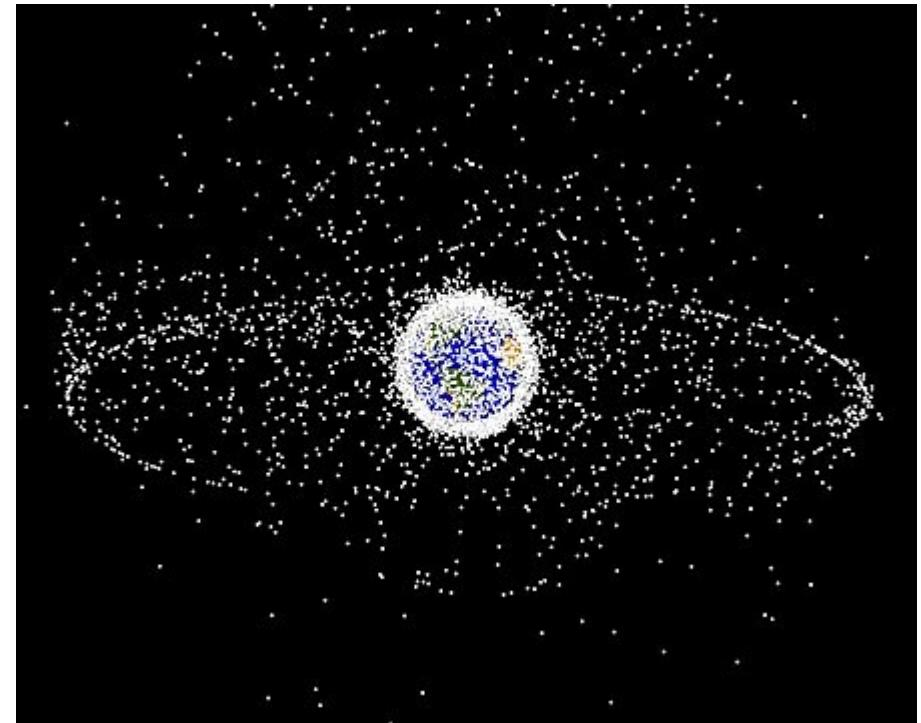
Free Space Optics

- 1880 Alexander Graham Bell meldet Photophone zur Übertragung von Sprache mittels Licht zum Patent an
- 1944 Lichtsprechgerät 80/80 gebaut von Carl Zeiss Jena

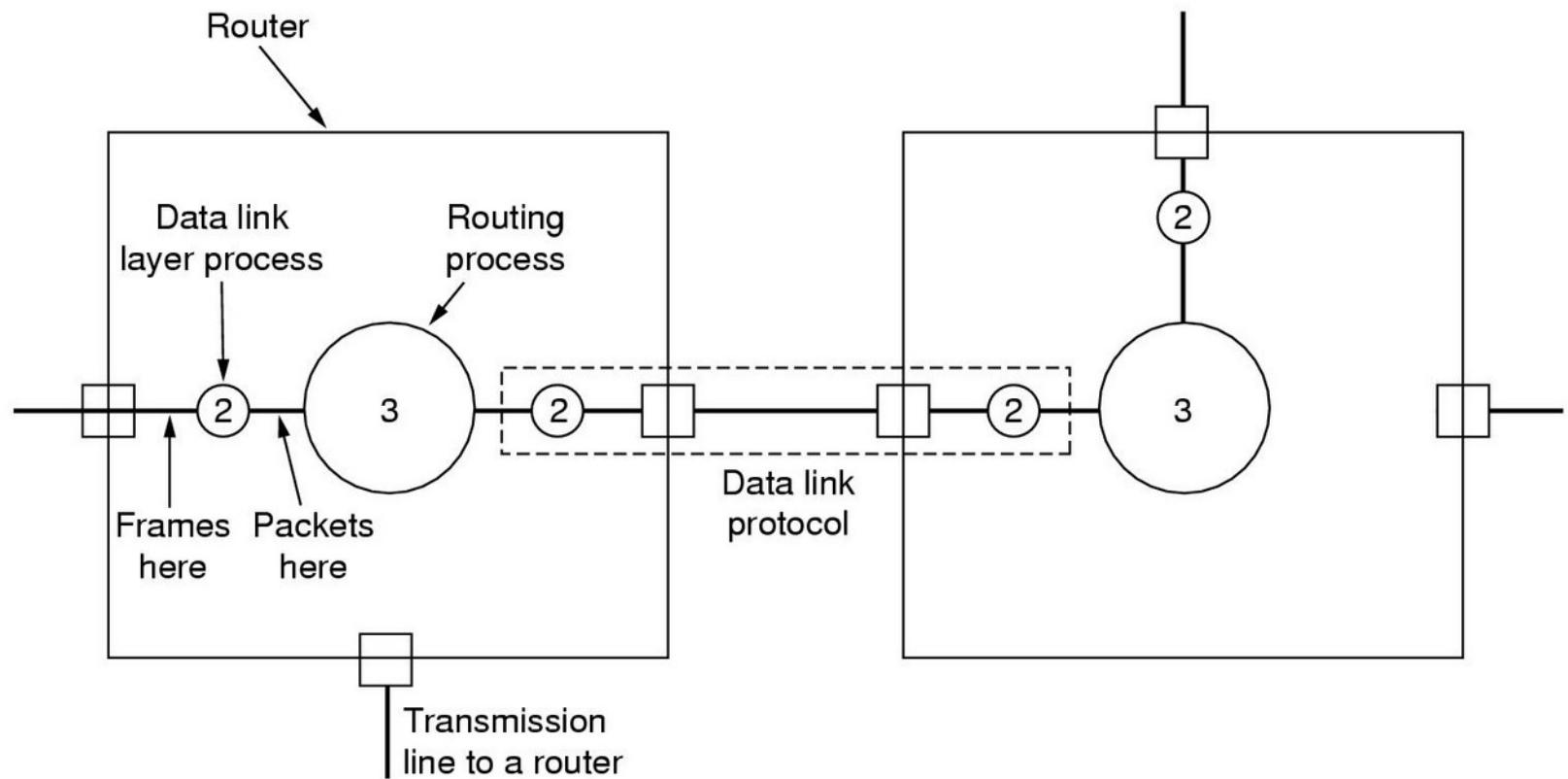


Satellit vs Glasfaser

- Zugang
- Mobilität
- Broadcast
- Verfügbarkeit
- Kosten
- Einsatzgeschwindigkeit
- Unabhängigkeit
- ABER: Weltraummüll (space debris)



Data Link - Sicherung



Pakete, Rahmen und Fehler

- Pakete - Ressourcen zu teilen
- Rahmen - Pakete abgrenzen
- Bit/Byte stuffing - Begrenzer erkennen
- Paritätsbits und CRC - Fehler erkennen
- Hamming Codes, FEC - Fehler korrigieren
- Interleaving - Burstfehler verteilen

Protokollvereinbarungen

- Const pktlen
- Integertype seq_nr
- Array pkt [1..pktlen]
- Frame_kind
(data,ack,nak)
- Struct Frame:
 - Kind: frame_kind
 - Seq: seq_nr
 - Ack: seq_nr
 - Info: pkt
- Wait_for_event(e)
- From_netw_layer(p)
- To_netw_layer(f)
- From_phys_layer(f)
- To_phys_layer(f)
- Start/Stop_timer(s)
- Start/Stop_acktimer(s)

Simplex Protokoll

- Sender
 - While(true)
 - From_netw_layer(b)
 - f.info = b
 - To_phys_layer(f)
 - End while
- Receiver
 - While (true)
 - Wait_for_event(e)
 - From_phys_layer(f)
 - To_netw_layer(f.info)
 - End while

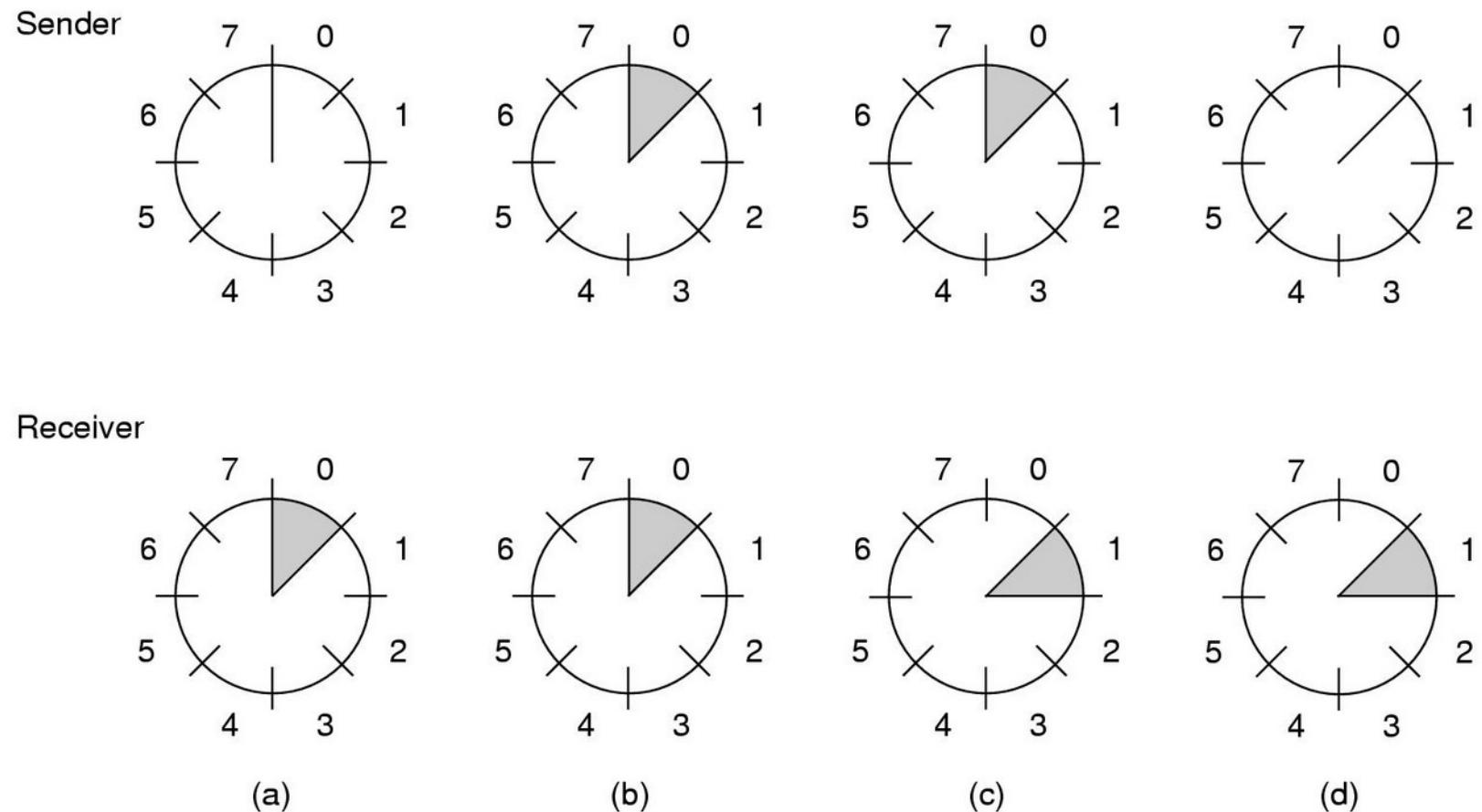
Stop/Wait Protokoll

- Sender
 - While(true)
 - From_netw_layer(b)
 - f.info = b
 - To_phys_layer(f)
 - Wait_for_event(e)
 - End while
- Receiver
 - While (true)
 - Wait_for_event(e)
 - From_phys_layer(f)
 - To_netw_layer(f.info)
 - To_phys_layer(x)
 - End while

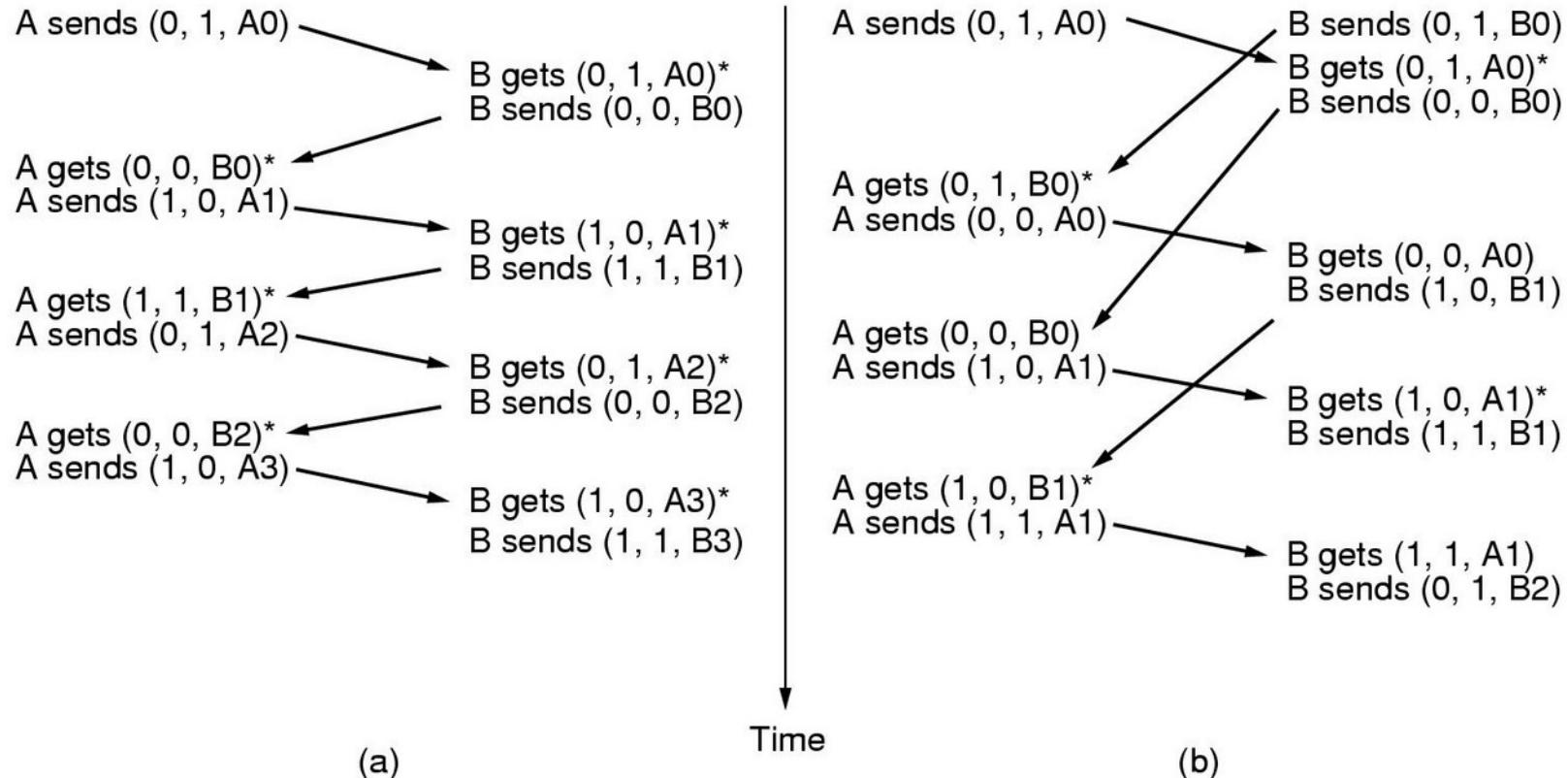
ARQ Protokoll

- Sender
 - From_netw_layer(b)
 - While(true)
 - F.seq = seq
 - f.info = b
 - To_phys_layer(f)
 - Wait_for_event(e)
 - If f.seq=seq then
 - seq++
 - From_netw_layer(b)
 - End if
 - End while
- Receiver
 - While (true)
 - Wait_for_event(e)
 - From_phys_layer(f)
 - If (f.seq = seq) then
 - To_netw_layer(f.info)
 - To_phys_layer(f.seq)
 - Seq++
 - End if
 - End while

Schiebefenster Größe 1, 3bit Snr



Schiebefenster



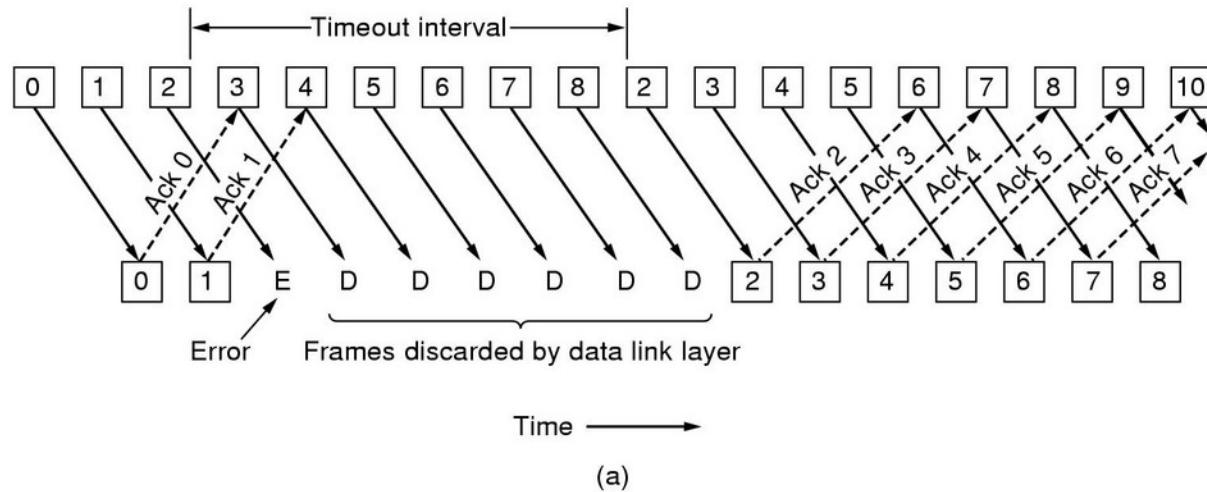
Schiebefenstergröße w

$BD = \text{Bandwidth [bps]} * \text{Delay [s]} / \text{bit pro Rahmen}$

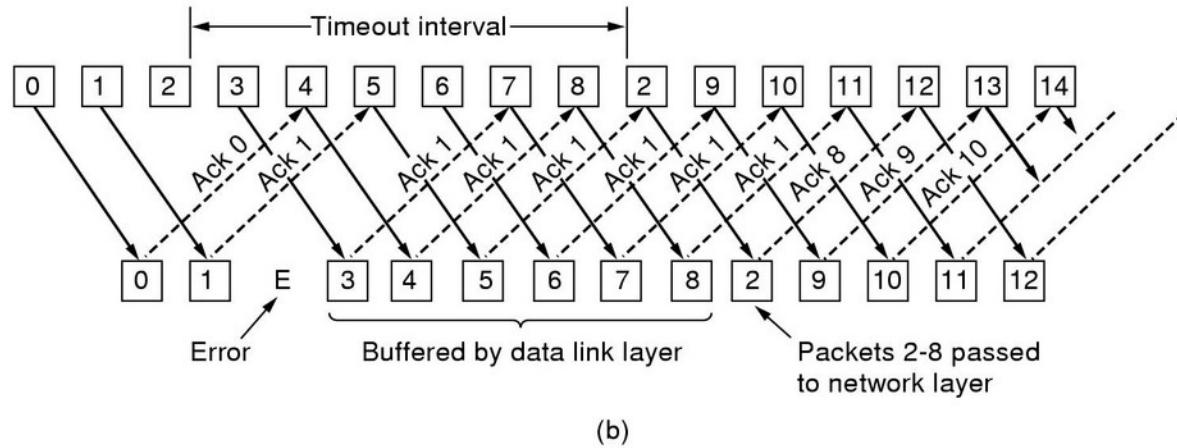
$$w = 2 * BD + 1$$

Schiebefenster und Fehler

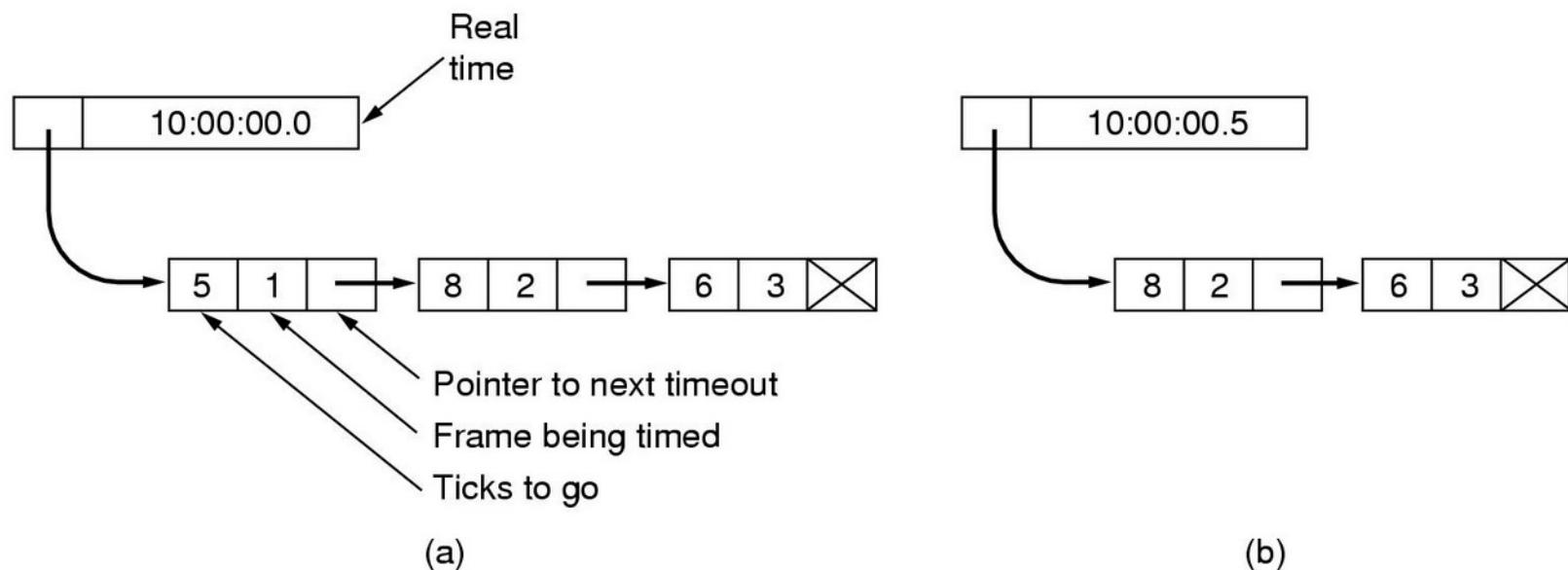
Go-back-N



Selective Repeat w/
cummulative Ack



Implementierung von Timern

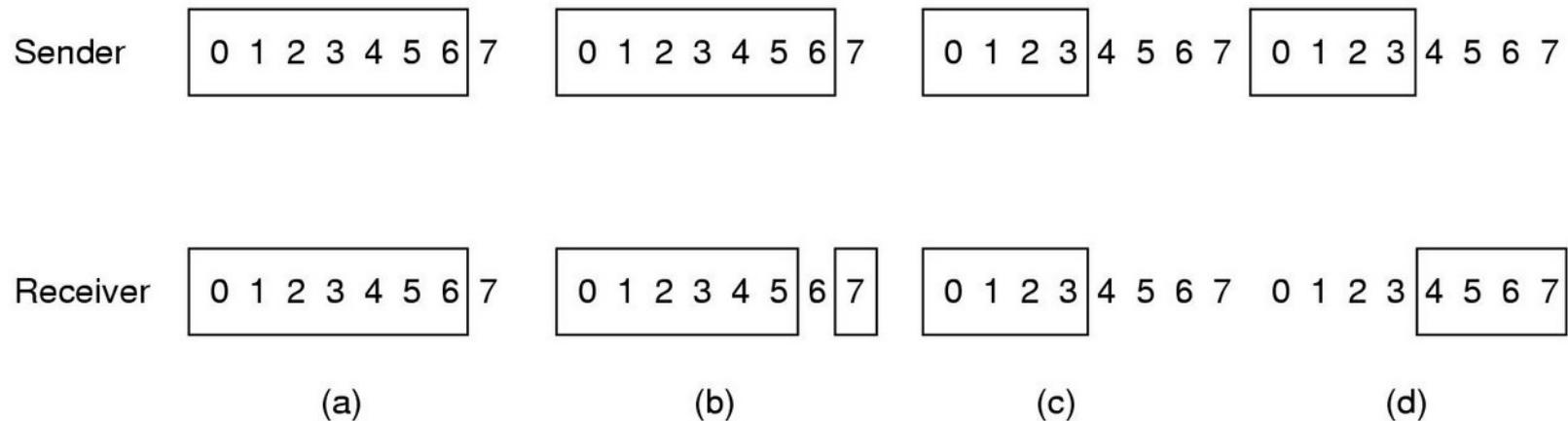


Uhren-Probleme aktuell ;)

“As part of its timekeeping function, GPS signals track the number of weeks lapsed since the satellite constellation began keeping time on Jan. 6, 1980. Because the onboard computers use a 10-bit system to track the number of weeks, the counter needs to reset to zero every 1,024 weeks or every 19 years—computers use a binary system to represent values, so a bit can be either a 1 or a 0, and with 10 bits, the maximum value is 2 to the 10th power, or 1,024. Since the GPS system went into use in 1980, the first reset of the week counters happened on Aug. 21, 1999, so the next one is set to take place on April 6.”

<https://techxplore.com/news/2019-04-gps-year-cicada-problem.html>

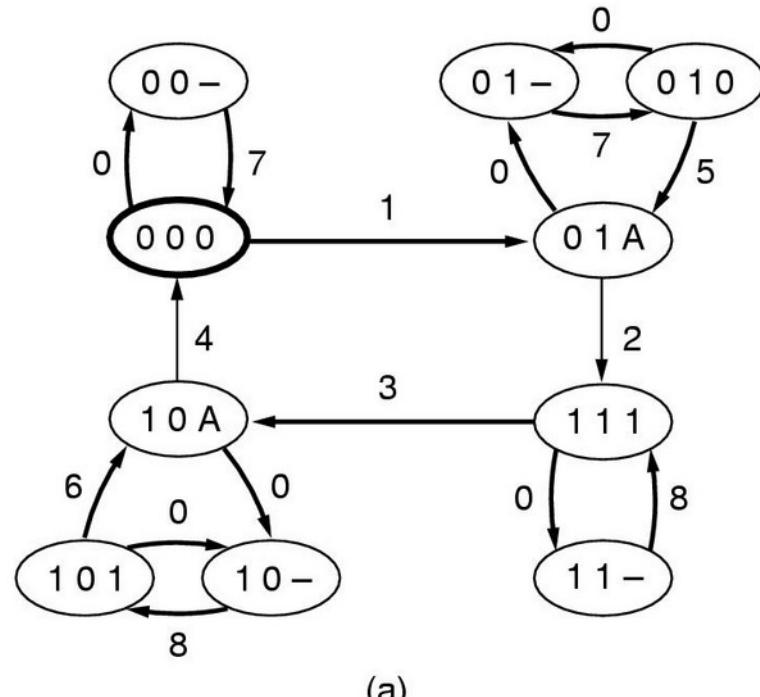
Selective-Repeat



Ack 0-6 lost
S: TO, repeat 0
R: Ack 6
Error!

Solution:
Use only half of window!

Protokollspezifikation FSM

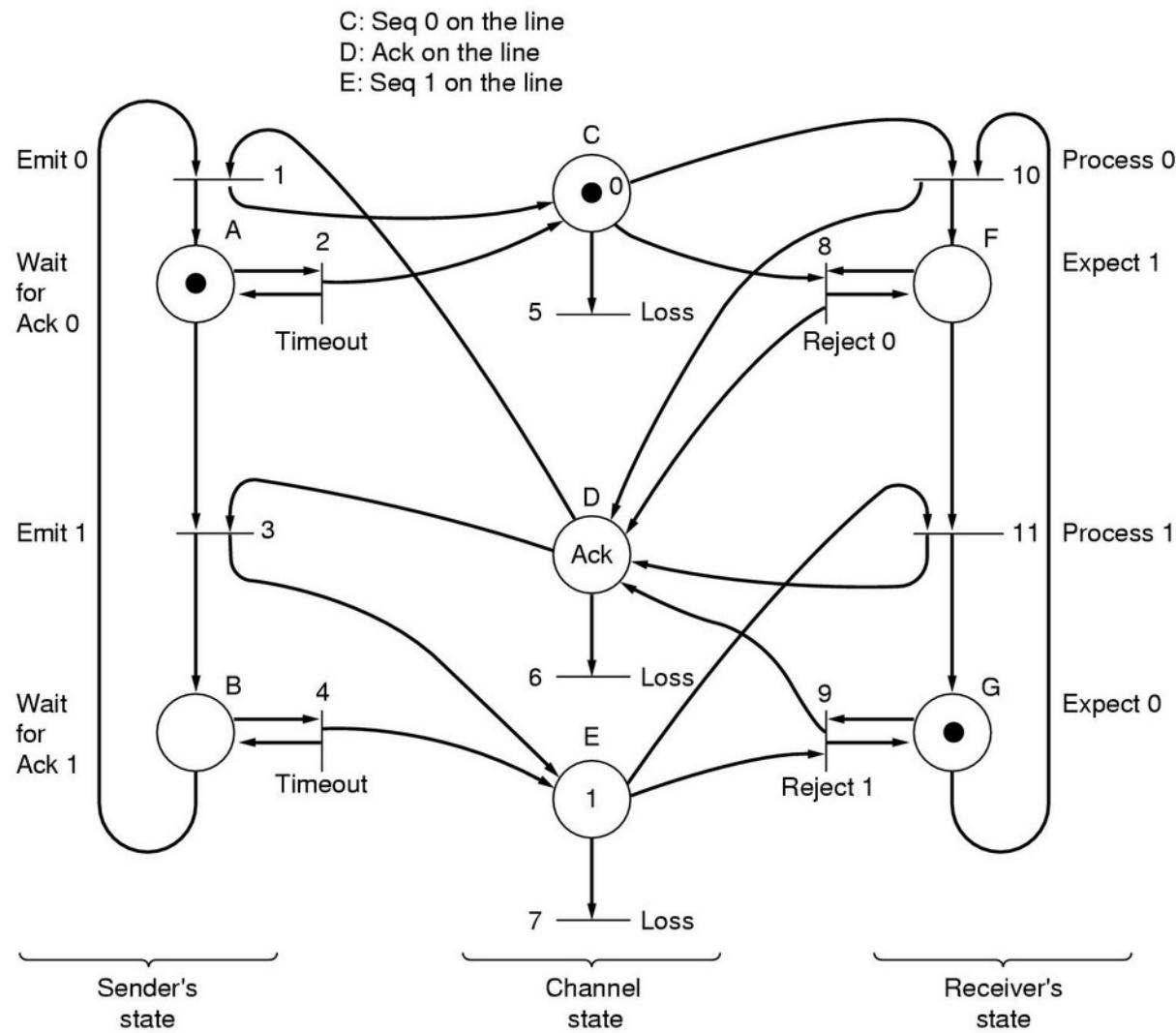


(a)

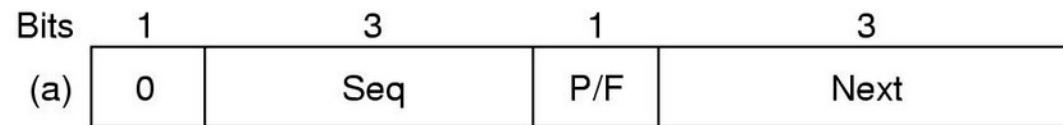
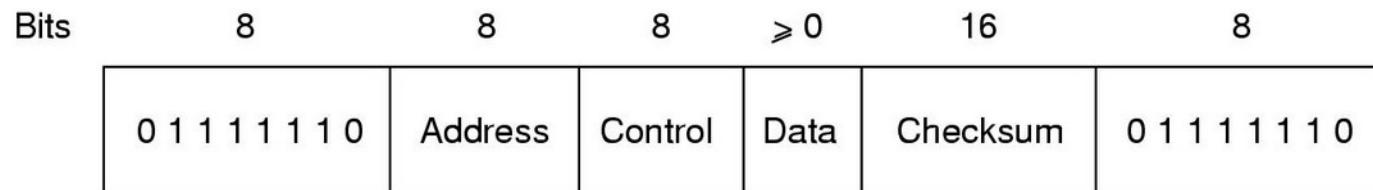
Transition	Who runs?	Frame accepted (frame lost)	Frame emitted	To network layer
0	-			-
1	R	0	A	Yes
2	S	A	1	-
3	R	1	A	Yes
4	S	A	0	-
5	R	0	A	No
6	R	1	A	No
7	S	(timeout)	0	-
8	S	(timeout)	1	-

(b)

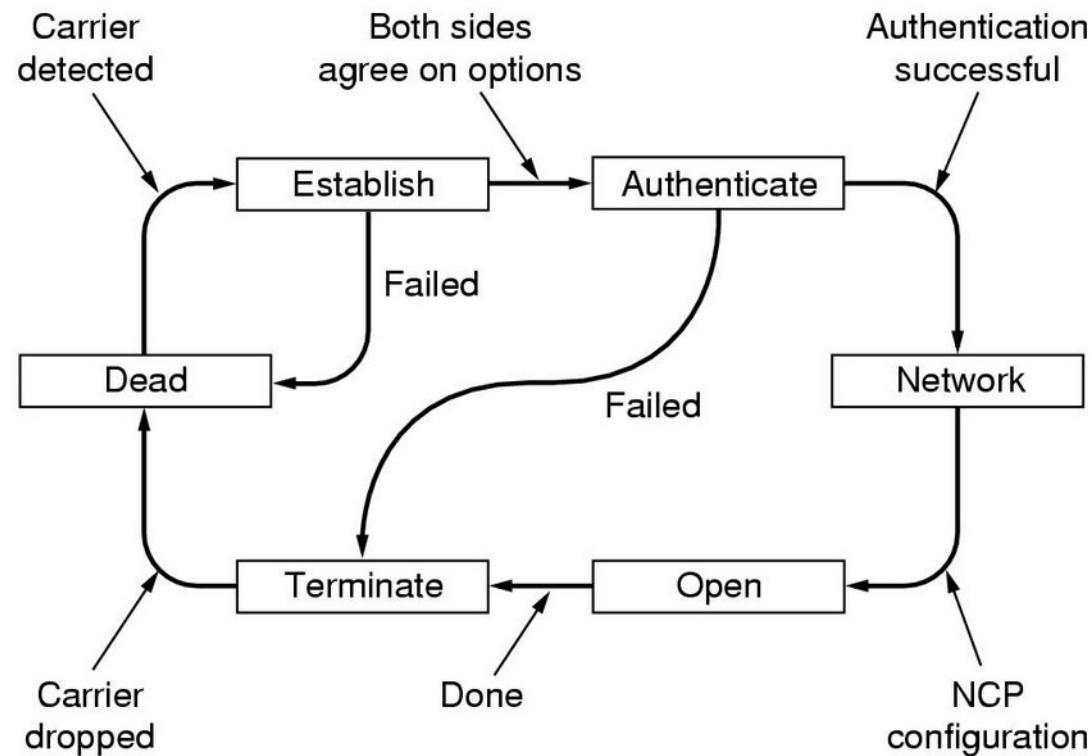
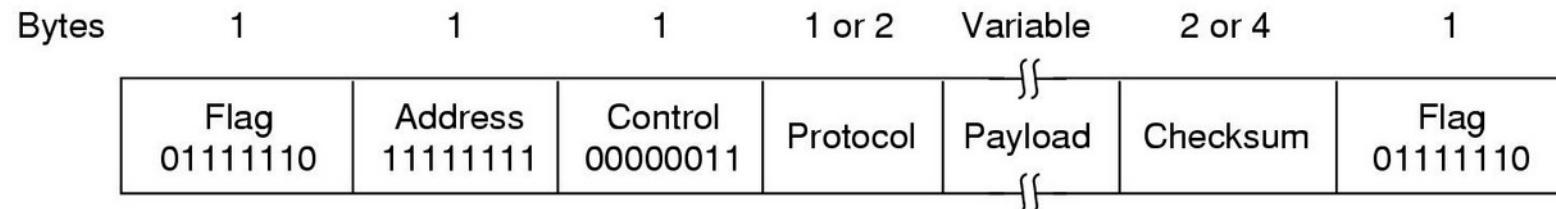
Protokollspezifikation PetriNetze



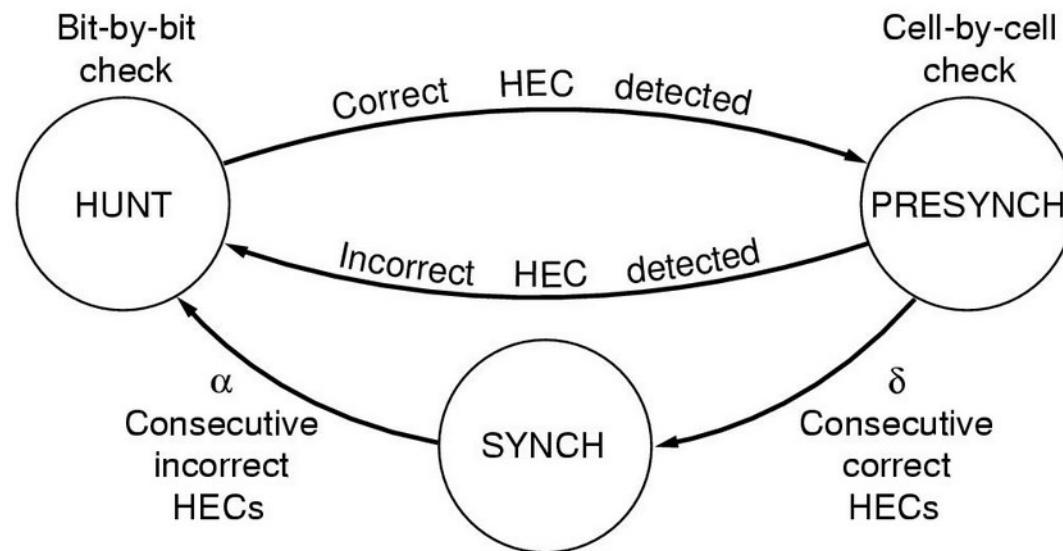
HDLC



PPP

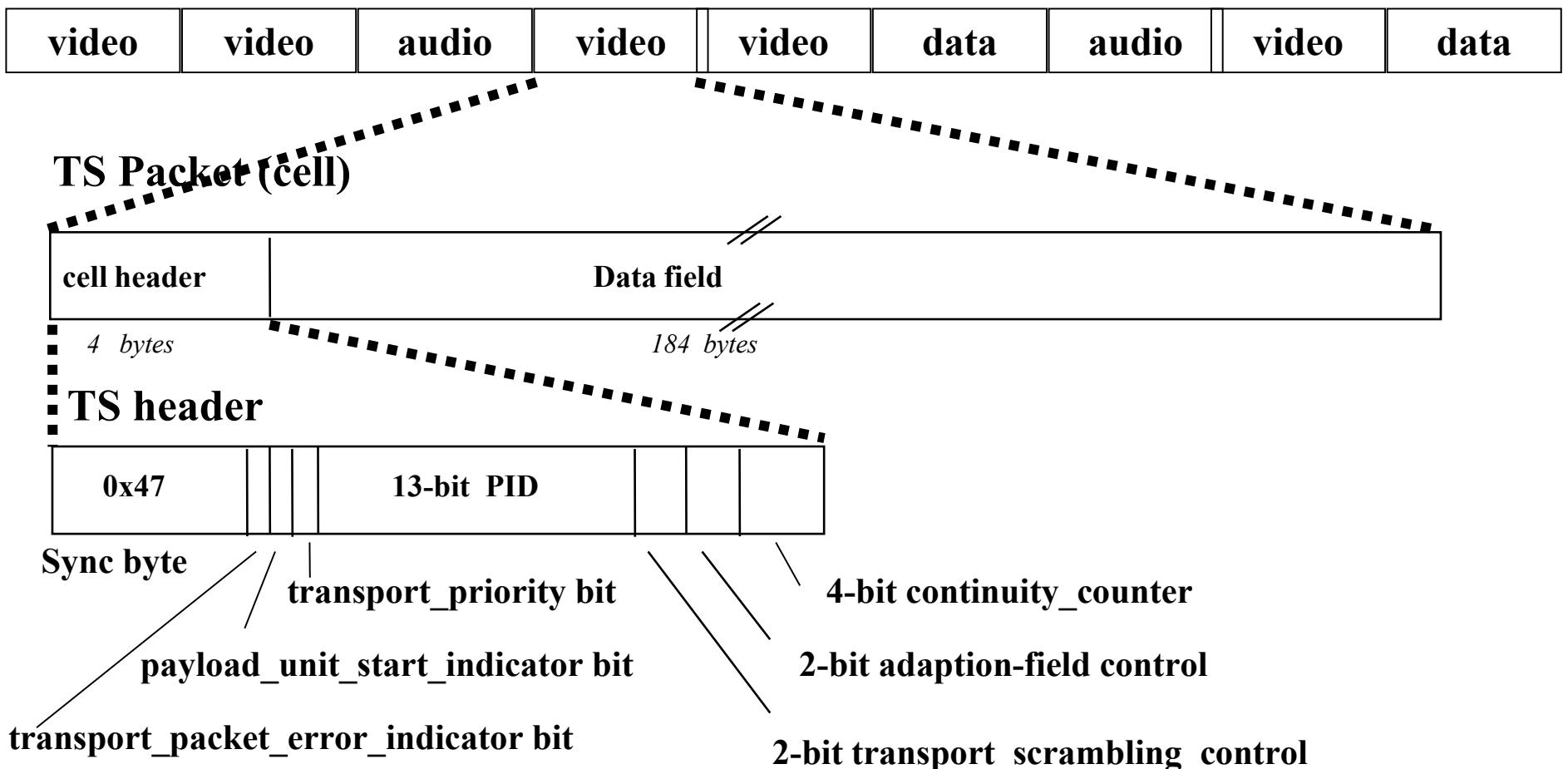


ATM



MPEG-2

asynchronous TDM



Medium Access Control

- Broadcast Netze
- Multiple Access/Random Access Channels
- LAN/Satellit/Wireless
- Statisch
 - FDM
 - Synchronous TDM
- Dynamisch

Dynamische Kanalzuordnung

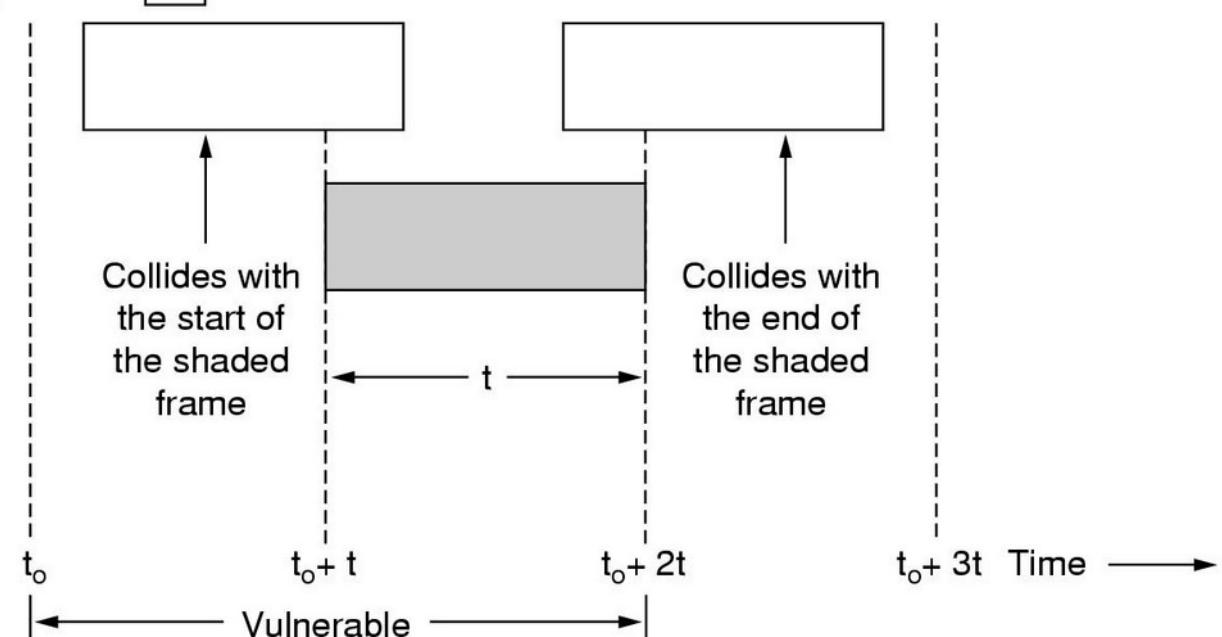
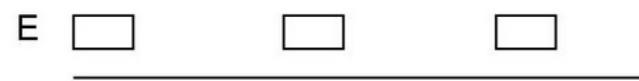
- Unabhängige Stationen erzeugen Datenverkehr
- Einzelkanal
- Beobachtbare Kollisionen
- Zeitunterteilung
 - Continuous
 - Slotted
- Trägerprüfung
 - Carrier Sense
 - No Carrier Sense

Warteschlangen - Queuing Theory

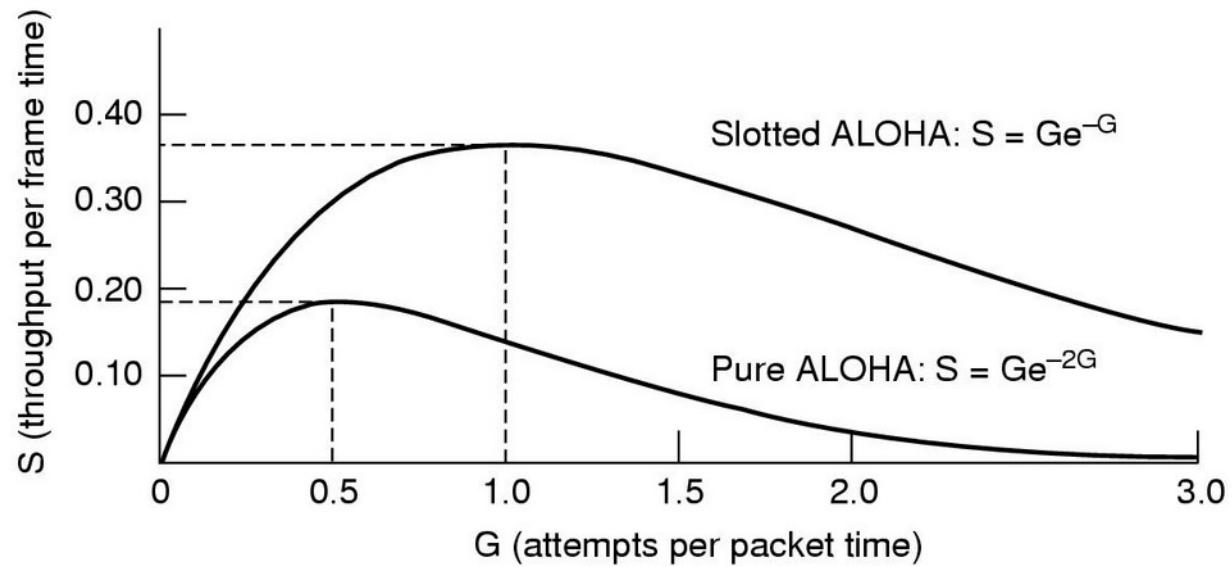
- Mittlere Wartezeit T [s]
- Kanalkapazität C [bps]
- Ankunftsrate λ [Rahmen/s]
- Exp-vert. Rahmenlänge μ [Bit/Rahmen]
- $T = 1 / (\mu C - \lambda)$
- $T_{FDM} = 1/(\mu(C/N) - (\lambda/N)) = N/(\mu C - \lambda) = NT$

ALOHA

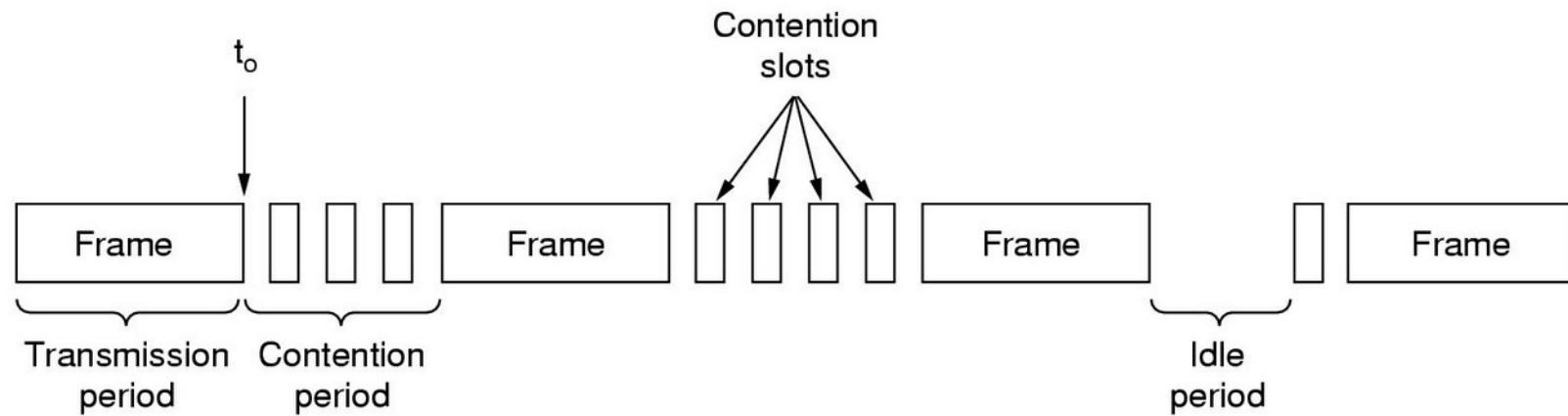
User



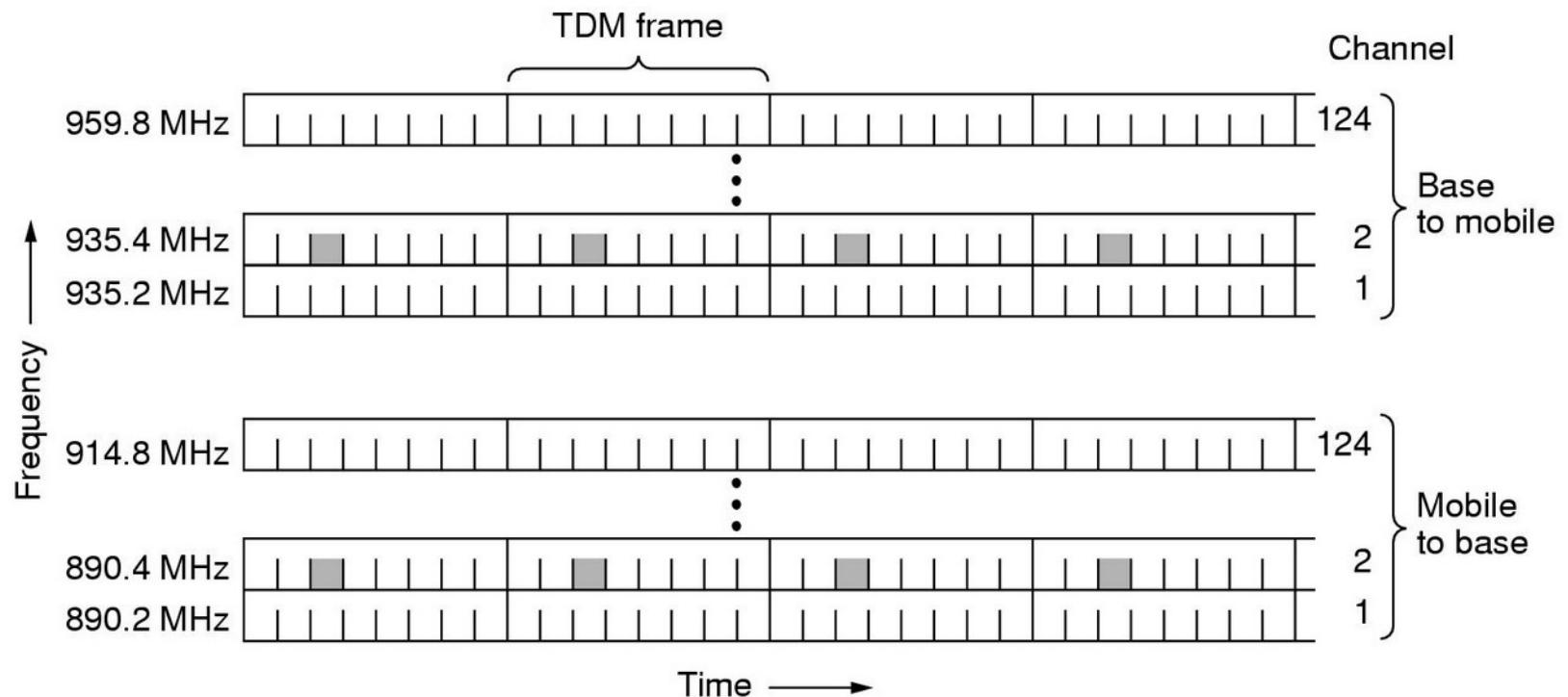
Slotted ALOHA



CSMA und CSMA/CD



GSM



CDMA

A: 0 0 0 1 1 0 1 1
 B: 0 0 1 0 1 1 1 0
 C: 0 1 0 1 1 1 0 0
 D: 0 1 0 0 0 0 1 0

(a)

A: (-1 -1 -1 +1 +1 -1 +1 +1)
 B: (-1 -1 +1 -1 +1 +1 +1 -1)
 C: (-1 +1 -1 +1 +1 +1 -1 -1)
 D: (-1 +1 -1 -1 -1 -1 +1 -1)

(b)

Six examples:

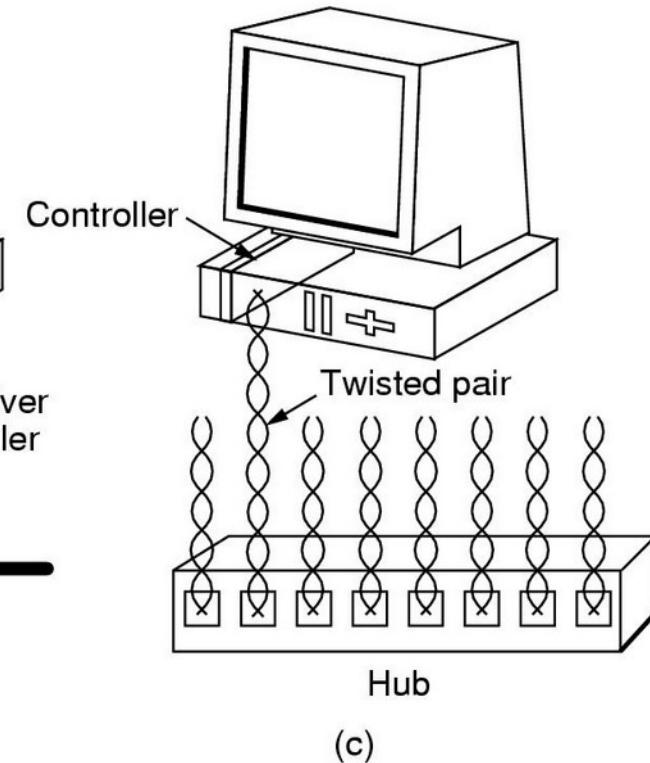
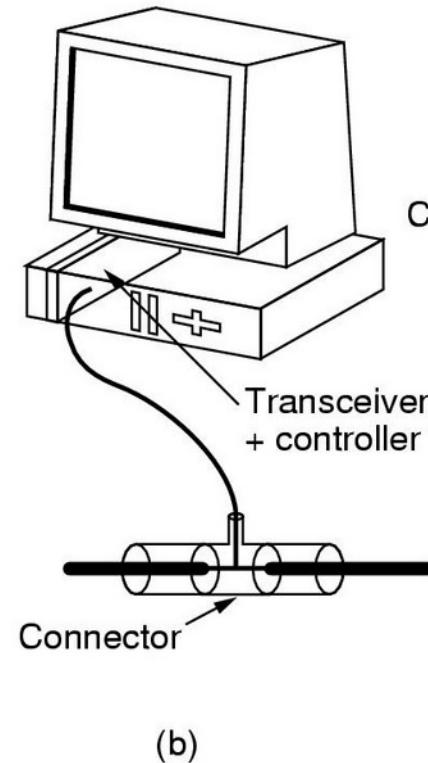
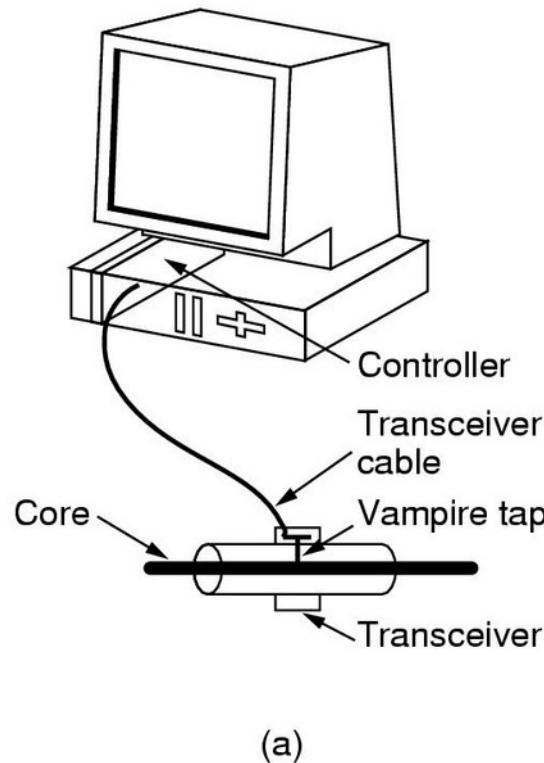
-- 1 -	C	$S_1 = (-1 +1 -1 +1 +1 +1 -1 -1)$
- 1 1 -	B + <u>C</u>	$S_2 = (-2 0 0 0 +2 +2 0 -2)$
1 0 --	A + <u>B</u>	$S_3 = (0 0 -2 +2 0 -2 0 +2)$
1 0 1 -	A + B + C	$S_4 = (-1 +1 -3 +3 -1 -1 -1 +1)$
1 1 1 1	A + B + C + D	$S_5 = (-4 0 -2 0 +2 0 +2 -2)$
1 1 0 1	A + B + <u>C</u> + D	$S_6 = (-2 -2 0 -2 0 -2 +4 0)$

(c)

$$\begin{aligned}
 S_1 \bullet C &= (1 +1 +1 +1 +1 +1 +1 +1)/8 = 1 \\
 S_2 \bullet C &= (2 +0 +0 +0 +2 +2 +0 +2)/8 = 1 \\
 S_3 \bullet C &= (0 +0 +2 +2 +0 -2 +0 -2)/8 = 0 \\
 S_4 \bullet C &= (1 +1 +3 +3 +1 -1 +1 -1)/8 = 1 \\
 S_5 \bullet C &= (4 +0 +2 +0 +2 +0 -2 +2)/8 = 1 \\
 S_6 \bullet C &= (2 -2 +0 -2 +0 -2 -4 +0)/8 = -1
 \end{aligned}$$

(d)

IEEE 802.3 und Ethernet

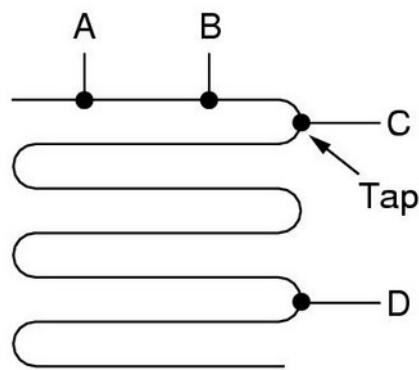


10Base5

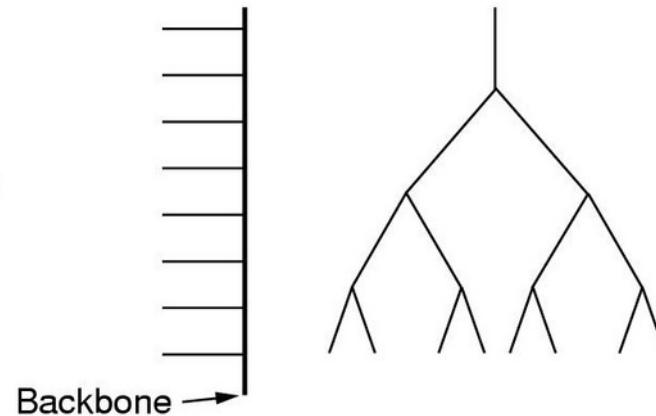
10Base2

10BaseT

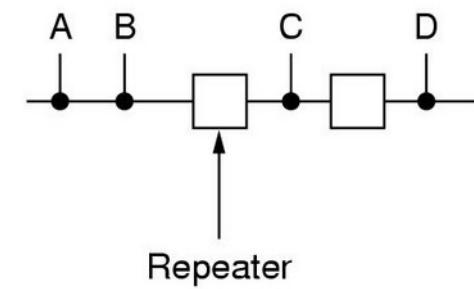
802.3 Topologien



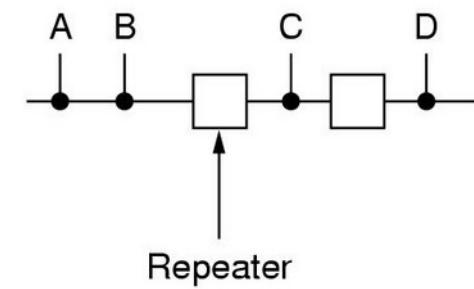
(a)



(b)

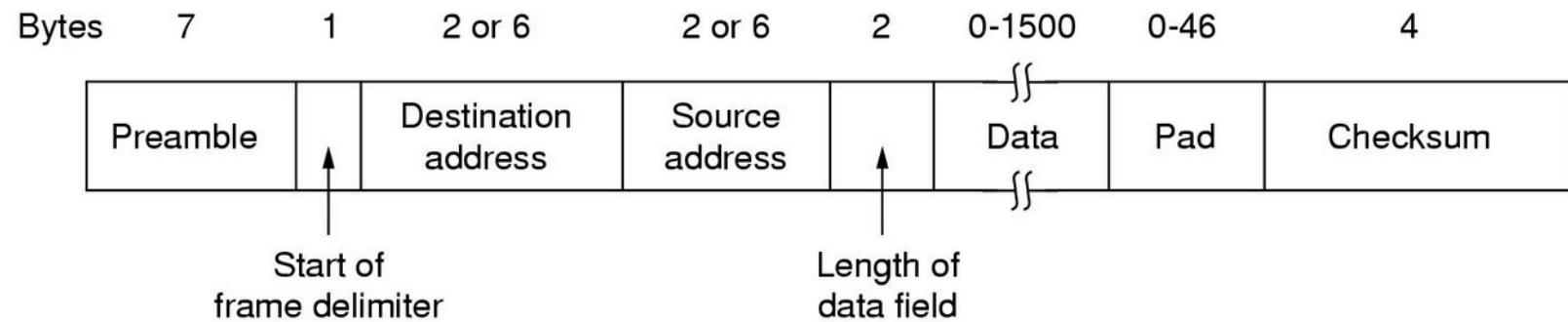


(c)



(d)

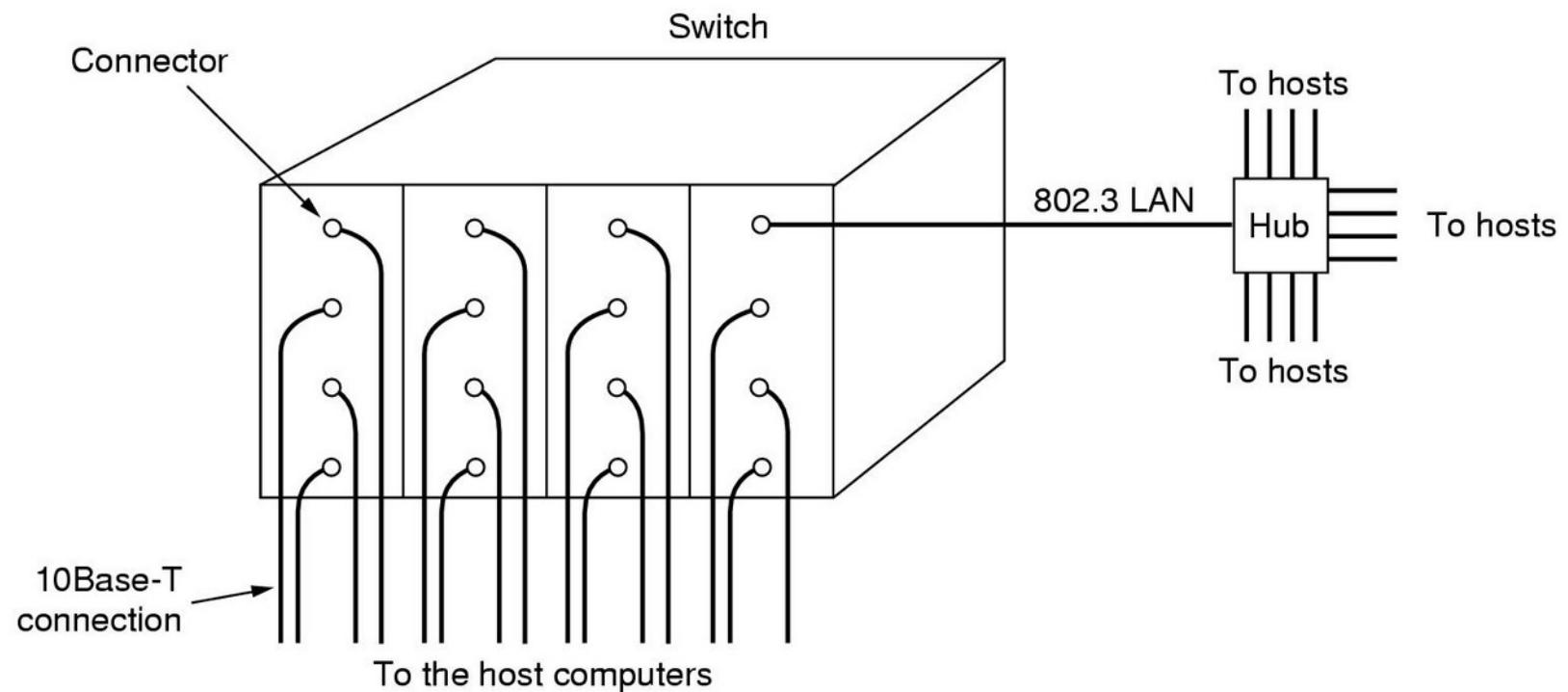
802.3 Rahmenformat



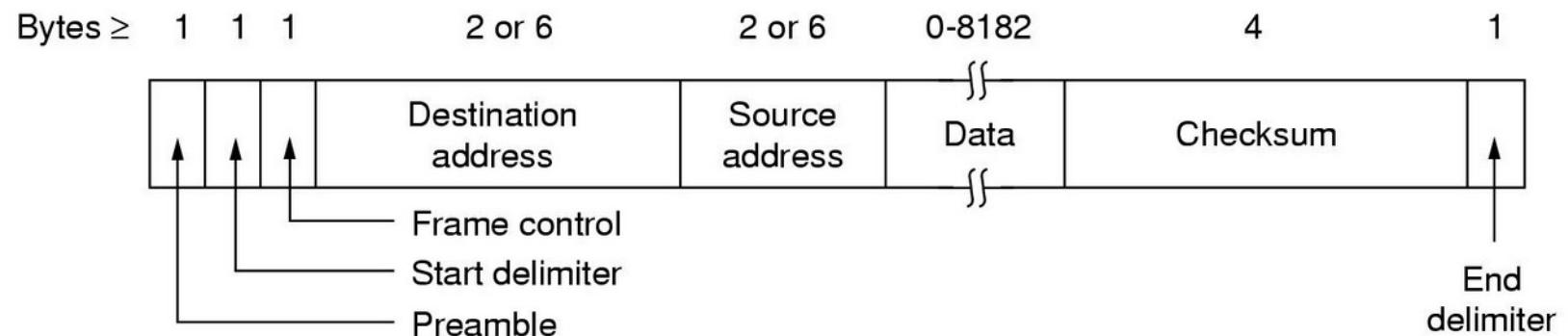
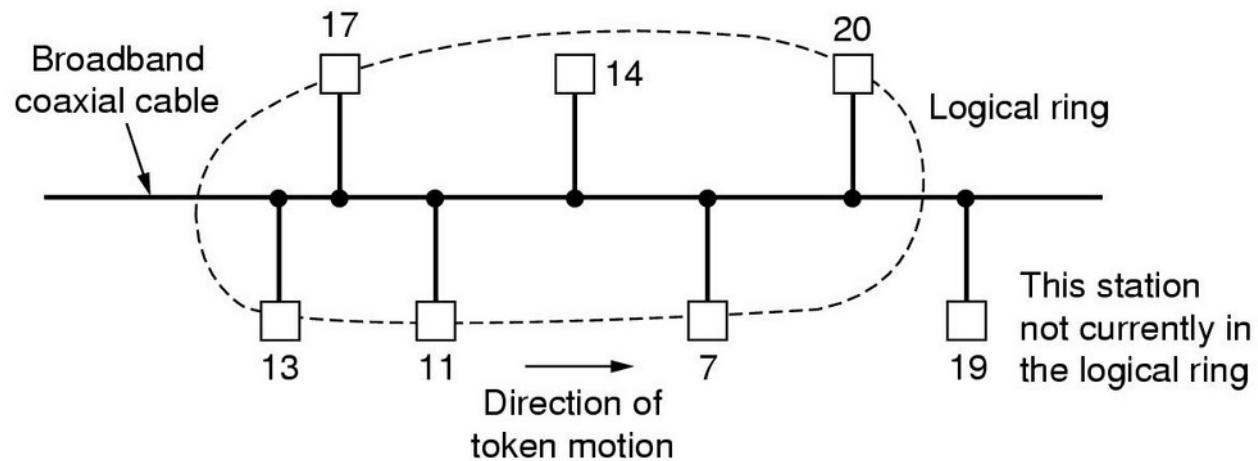
IEEE 802.3ab 1000BASE-T

- 100Base-T, F, TX (T4, T2)
- 1000Base-T, X
- 10GBase-T, LRM
- Autonegotiation

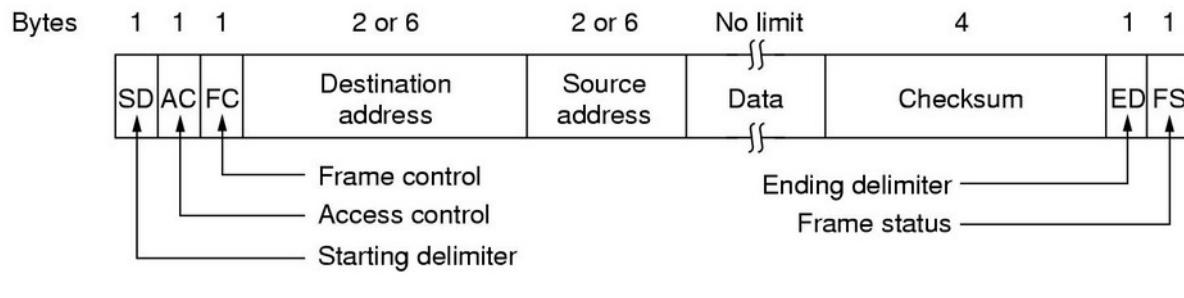
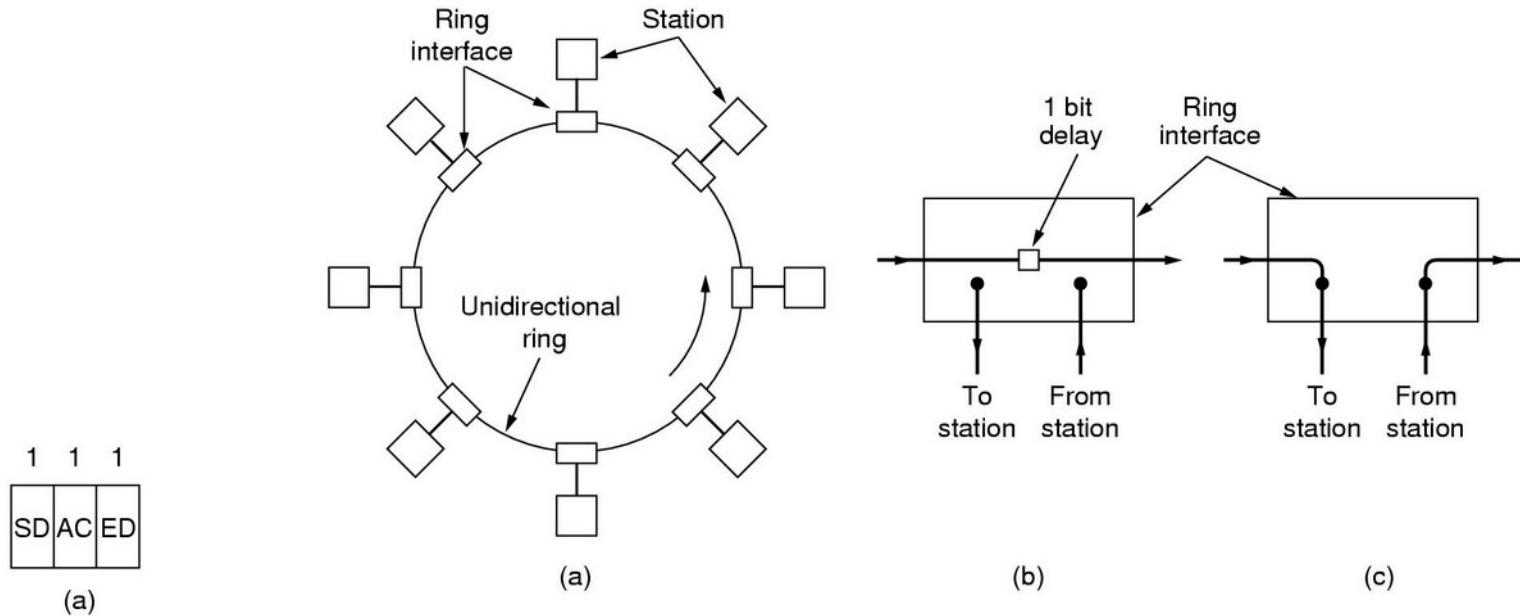
Switched 802.3



IEEE 802.4 Token Bus



IEEE 802.5 Token Ring



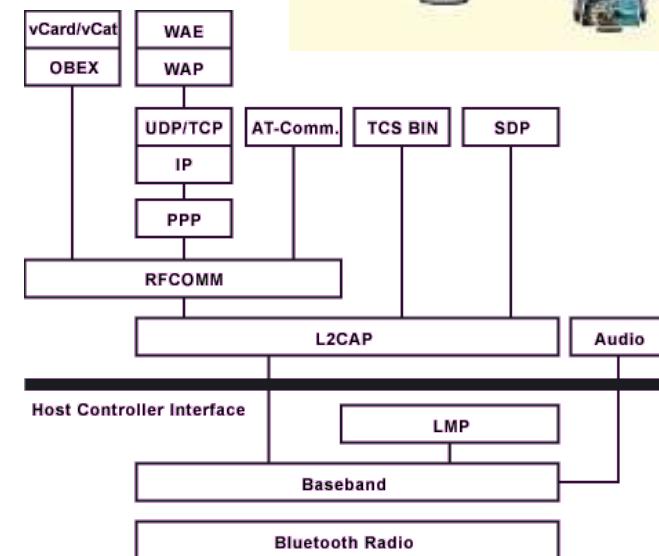
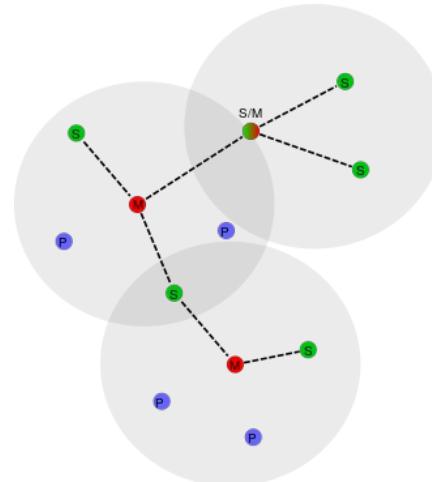
(b)

IEEE 802.11 (WLAN)

- Infrastructure/Ad-hoc
- 802.11a, 5GHz, 54Mbps
- 802.11b, 2.4GHz, 11Mbps
- 802.11g, 2.4GHz, 54Mbps
- 802.11n, MIMO/OFDM, 2.4GHz, 100Mbps

802.15(.1) (Bluetooth SIG)

- Architektur eines WPAN
 - Piconet
 - Scatternet
 - Only Master-slave communication
 - Centralized TDM system
- Protokollstapel
- Profile
- NFC



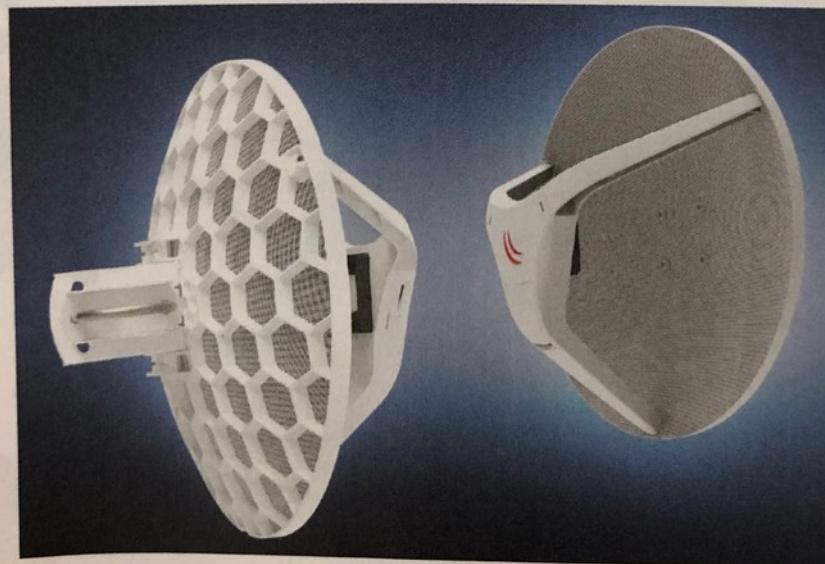
Cool?

Richtfunk-Kit für Gigabit-Ethernet

Mikrotik bringt eine mit 300 US-Dollar sehr günstige Richtfunkanlage heraus: Die „Wireless Wire Dish“ soll mit WLAN-Technik (IEEE 802.11ad) im allgemein lizenzfrei nutzbaren 60-GHz-Band bis zu 1500 Meter bei vollem Gigabit-Ethernet-Durchsatz überbrücken (950 MBit/s netto). An der für kürzere Strecken gedachten Version „Wireless Wire“ konnten wir das kürzlich bestätigen (c't 8/2018, S. 47).

Die knapp 40 Zentimeter großen und 22 Zentimeter tiefen Schüsseln werden übers LAN-Kabel mit Energie versorgt (Power over Ethernet nach IEEE 802.3af/at oder proprietär); sie ziehen laut Datenblatt maximal 5 Watt. Das Kit soll beispielsweise bei Meconet ab Ende Mai für knapp 250 Euro erhältlich sein.

(ea@ct.de)



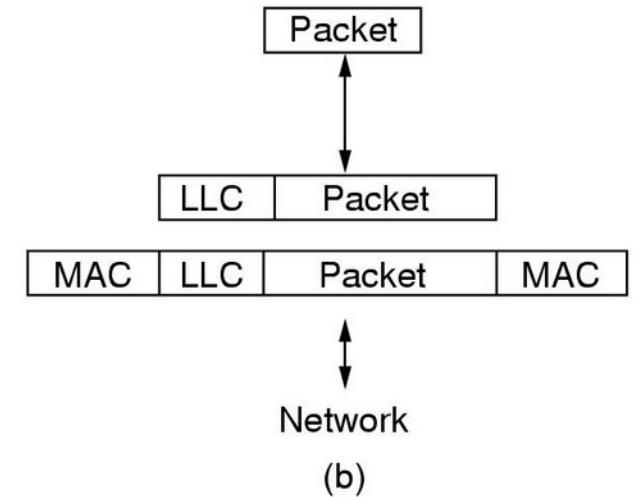
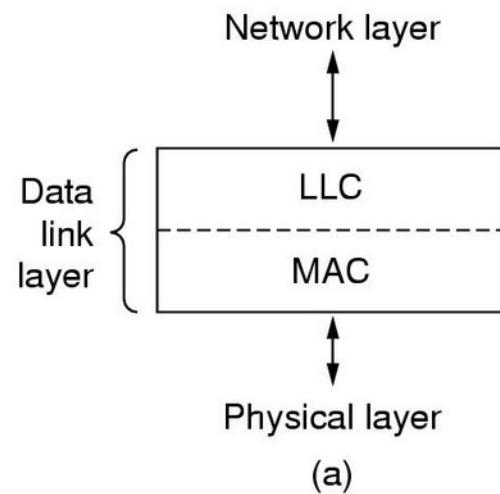
Die 60-GHz-Bridge Mikrotik Wireless Wire Dish soll 1,5 km drahtlos mit Gigabit-Geschwindigkeit überbrücken.

Uncool!



IEEE 802.X

- IEEE 802.2 LLC



- 802.1Q VLAN

<http://standards.ieee.org/getieee802>



GET 802® STANDARDS

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[IEEE 802.1™: Bridging & Management](#)

[IEEE 802.2™: Logical Link Control](#)

[IEEE 802.3™: Ethernet](#)

[IEEE 802.11™: Wireless LANs](#)

[IEEE 802.15™: Wireless PANs](#)

[IEEE 802.16™: Broadband Wireless MANs](#)

[IEEE 802.17™: Resilient Packet Rings](#)

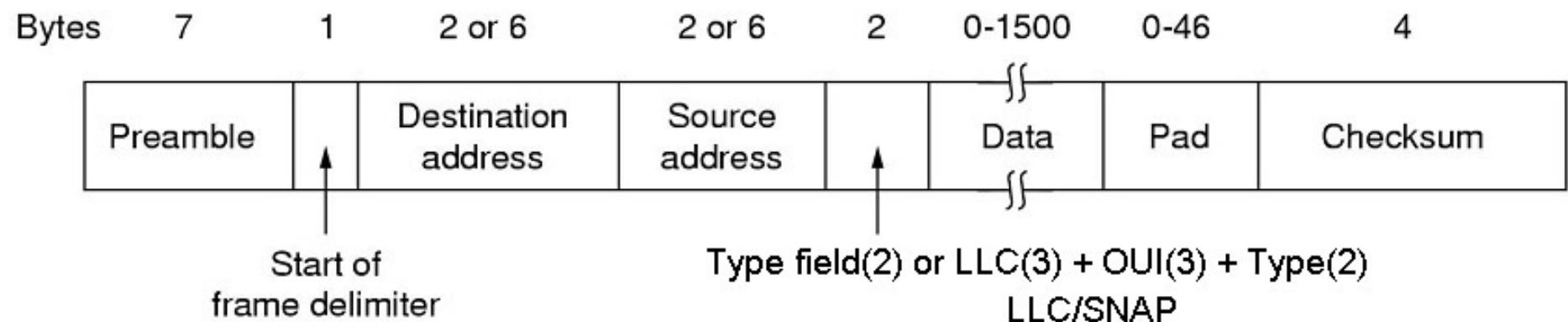
[IEEE 802.19™: TV White Space Coexistence Methods](#)

[IEEE 802.20™: Mobile Broadband Wireless Access](#)

[IEEE 802.21™: Media Independent Handover Services](#)

[IEEE 802.22™: Wireless Regional Area Networks](#)

802.2 LLC/SNAP



IEEE 802 MAC Adressen

- Müssen eindeutig (einzigartig) sein!
- IEEE Registration Authority
- IEEE Standards Department
- 445 Hoes Lane, P.O. Box 1331
- Piscataway, NJ 08855-1331

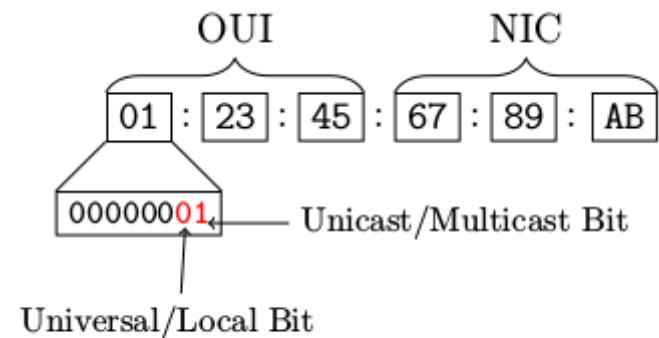


Figure 1: 48-bit MAC Address Structure

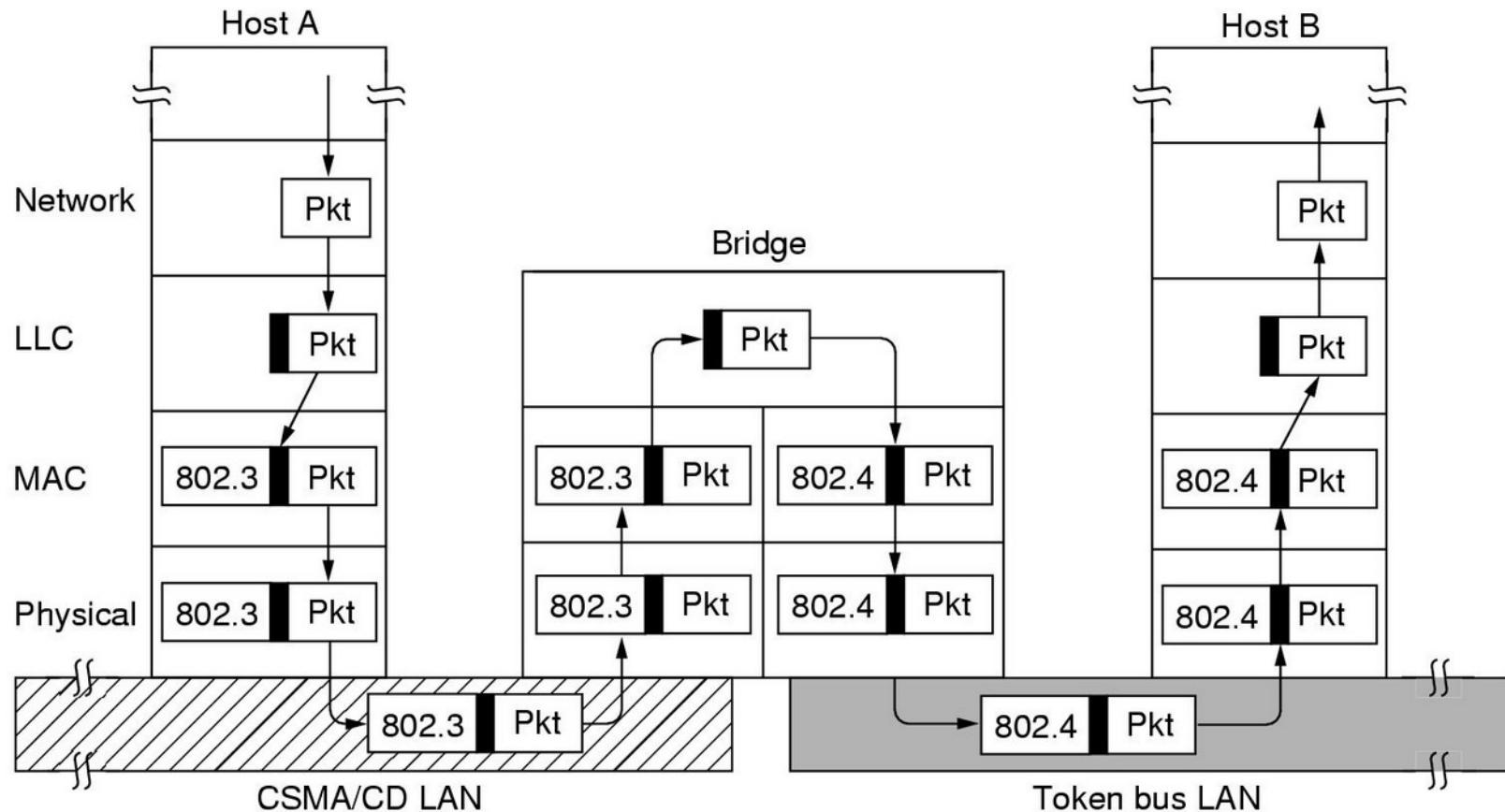
A Study of MAC Address Randomization in Mobile Devices When it Fails

<Https://www.wireshark.org/tools/oui-lookup.html>

Bridges

- Verbindung von LANs
- Strukturierung
- Lastverteilung
- Ausdehnung
- Fehlertoleranz
- Sicherheit

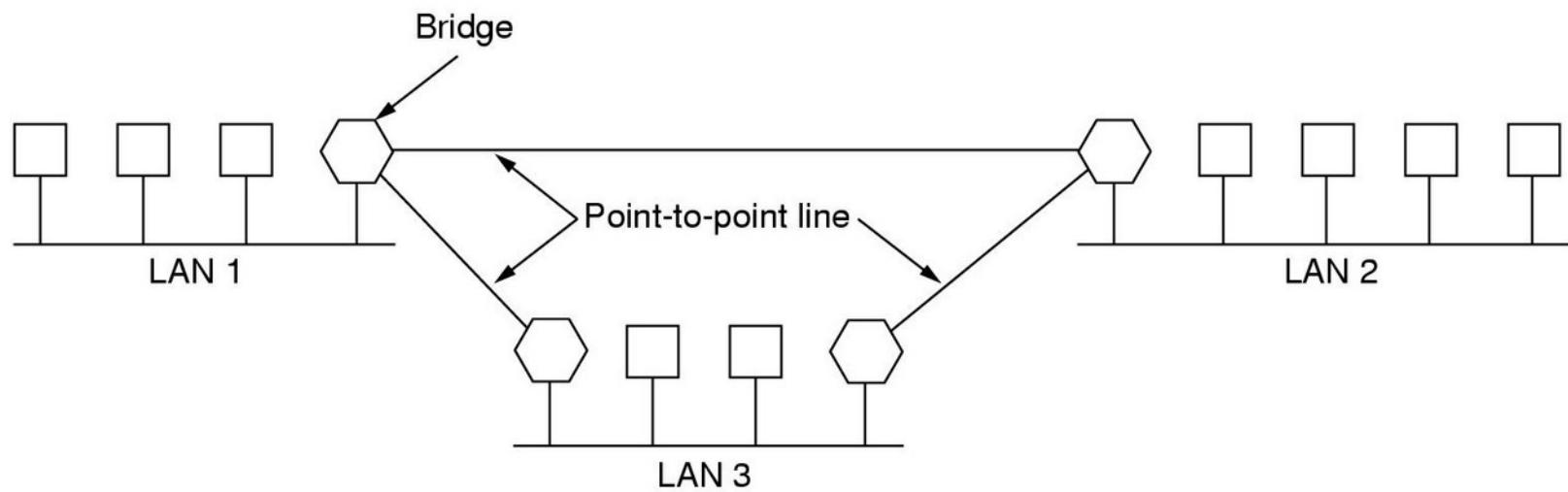
Bridging



Bridge-Typen

- Transparent
 - Dumm (flooding, backward learning)
- Spanning Tree
 - Einfach (Topologie, Wurzel)
- Source Routing
 - Aufwendig (Tabellen, Software, Hybrid, Hardware)
 - Suchrahmen von Hosts

Remote Bridges



Kanalzuordnung

FDM	Bitmuster	802.3/4/5
TDM	Bin Countdown	DQDB
Pure ALOHA	Tree-Walk	Wireless LAN
Slotted ALOHA	WDM	FDDI
1-persist CSMA	MACA	HIPPI
Nonpers CSMA	GSM	Fibre-Channel
N-pers CSMA	CDPD	MF-TDMA
CSMA/CD	CDMA	

Channel/Media Access

V • T • E	Channel access methods and media access control	
Channel-based	FDMA	OFDMA • WDMA • SC-FDMA
	TDMA	MF-TDMA • STDMA
	CDMA	W-CDMA • TD-CDMA • TD-SCDMA • DS-CDMA • FH-CDMA • MC-CDMA
	SDMA	HC-SDMA
	PDMA	
	PAMA	
Packet-based	Collision recovery	
	Collision avoidance	
	Collision-free	
	Delay and disruption tolerant	
Duplexing methods	TDD • FDD	

FEC vs ARQ

- Error rate
- Transmission delay/RTT
- Type of service
 - reliable/unreliable
 - streaming/bulk transfer
- Channel access type

Cut

Ende 4. Termin (Online) 27.3.20

Beginn 4.Termin (Online) 3.4.20

Die Vermittlung

- Unabhängig von Teilnetztechnologie
- Eineindeutige Adressen
- Abschirmung der Transportschicht vor Details der Teilnetze (Art, Topologie, Anzahl)
- Verbindungsorientiert vd verbindungslos
- Zuverlässig vs unzuverlässig
- ATM vs IP vs MPLS vs **VLAN**

Datagram vs VC

Kriterium	Datagram	Virtuelle Verbindung
Verb.aufbau	Nein	Ja
Adressierung	Voll	Nummer
Status	Nein	Tabelleneintrag
Routing	Unabhängig	Vorauswahl
Routingfehler	Rerouting	Abbruch
Überlastfehler	Paketverlust	Besetzt

Kombinationen

	Upper layer	Type of subnet
	Datagram	Virtual circuit
Connectionless	UDP over IP	UDP over IP over ATM
Connection-oriented	TCP over IP	ATM AAL1 over ATM

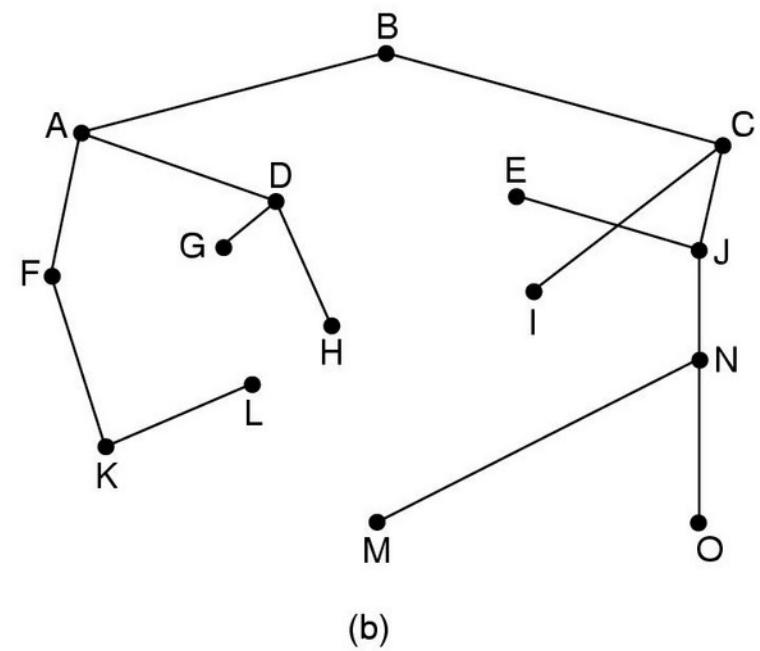
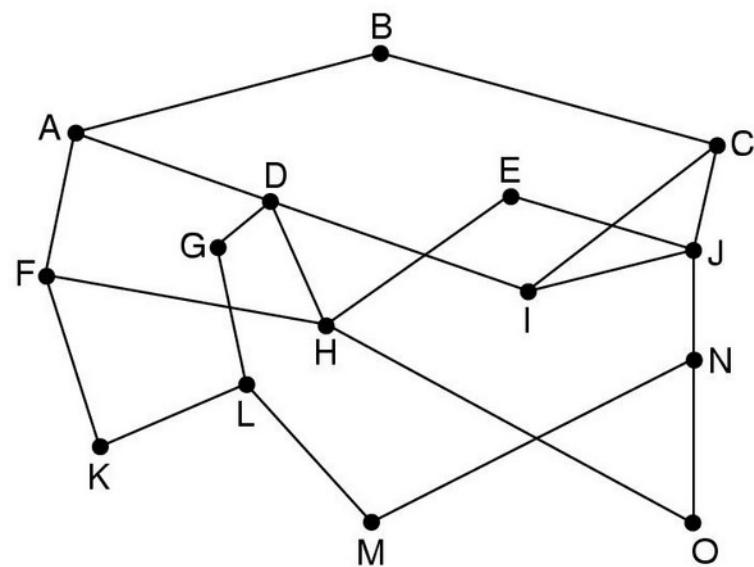
Routing

- Algorithmus
 - korrekt
 - einfach
 - robust
 - stabil
 - fair
 - effizient
- Warteschlagen
- Adaptiv vs nicht-adaptiv
- Dynamisch vs statisch

Routing/Addressing Schemes

- Unicast
- Broadcast
- Multicast
- Anycast
- Geocast

Spanning Tree



Flooding

- Weiterleitung auf allen anderen Leitungen
- Paketduplicata durch Zähler eingrenzen
 - Zähler: hop counter, src+seqnr, counter
- Robust
- Minimale Verzögerung
- Findet kürzesten/schnellsten Pfad

Shortest Path Routing

- Entfernung (Signallaufzeit)
- Bandbreite
- Auslastung
- Mittlere Warteschlangenlänge
- Verzögerung
- Kosten

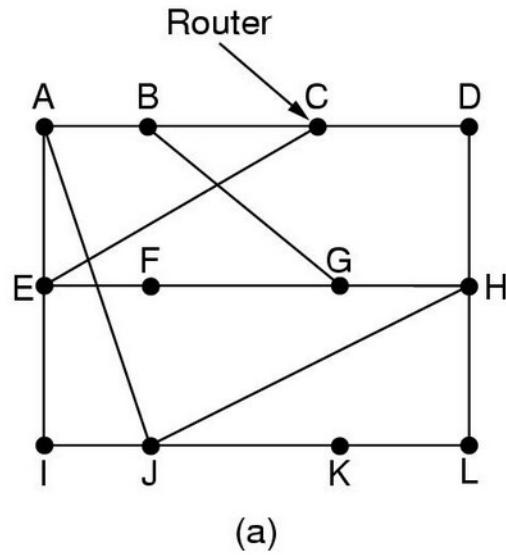
Flow-based Routing

- Statisch
- Verwendet
 - Topologieinformationen
 - Datenverkehrsmatrix
 - Leitungskapazitäten
- zur Berechnung des besten Flows

Distance Vector Routing

- Ford-Fulkerson, Bellman-Ford
- Tabelle
 - Ausgangsleitung für Ziel
 - Metrik (z.B. Länge oder Verzögerung)
- ECHO Pakete
- Tabellenaustausch

Distance-Vector Routing



New estimated delay from J

To	A	I	H	K	Line
A	0	24	20	21	8 A
B	12	36	31	28	20 A
C	25	18	19	36	28 I
D	40	27	8	24	20 H
E	14	7	30	22	17 I
F	23	20	19	40	30 I
G	18	31	6	31	18 H
H	17	20	0	19	12 H
I	21	0	14	22	10 I
J	9	11	7	10	0 -
K	24	22	22	0	6 K
L	29	33	9	9	15 K

JA delay is 8 JI delay is 10 JH delay is 12 JK delay is 6

Vectors received from J's four neighbors

New routing table for J

(b)

Count-to-Infinity Problem

- Problem der trägen Konvergenz (für schlechte Neuigkeiten)

A	B	C	D	E	
∞	∞	∞	∞	∞	Initially
1	∞	∞	∞	∞	After 1 exchange
1	2	∞	∞	∞	After 2 exchanges
1	2	3	∞	∞	After 3 exchanges
1	2	3	4	∞	After 4 exchanges

(a)

A	B	C	D	E	
1	2	3	4	∞	Initially
3	2	3	4	∞	After 1 exchange
3	4	3	4	∞	After 2 exchanges
5	4	5	4	∞	After 3 exchanges
5	6	5	6	∞	After 4 exchanges
7	6	7	6	∞	After 5 exchanges
7	8	7	8	∞	After 6 exchanges
\vdots					
∞	∞	∞	∞	∞	

(b)

A neu erreichbar

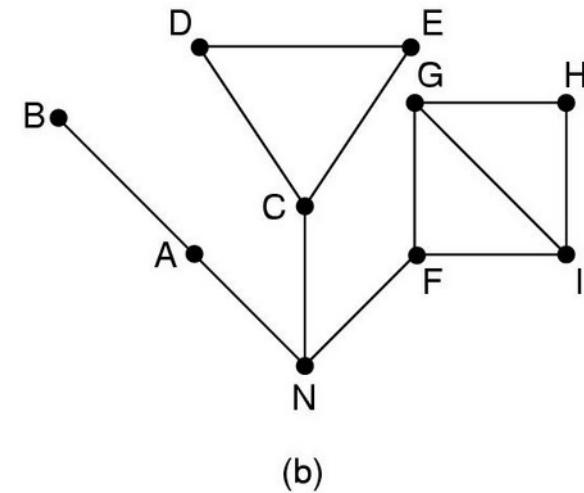
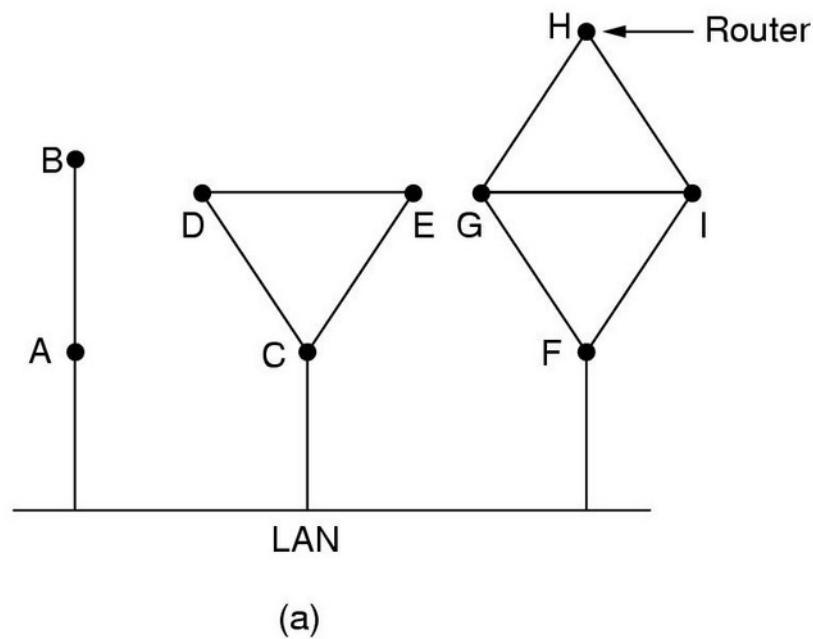
A unerreichbar

Link-State-Routing

- Ersetzt DVR wegen
 - Fehlende Kenntnis über Topologie
 - Trägheit und Fehlverhalten
- Vorgehen:
 - Ermittlung der Nachbar Router
 - Ermittlung der Verzögerung/Leitungskosten
 - Erstellung von Link-State-Pakete
 - Verteilung der Link-State-Pakete
 - Berechnung neuer Routen zu allen Routern

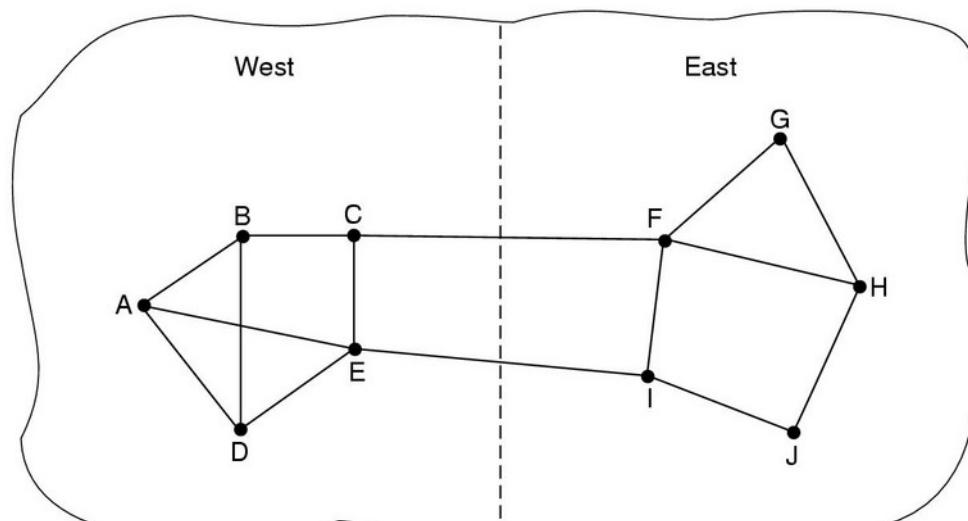
LSR: Ermittlung der Nachbar Router

- HELLO Pakete
- Eindeutige Namen!
- LAN Modellierung mit virtuellem Knoten



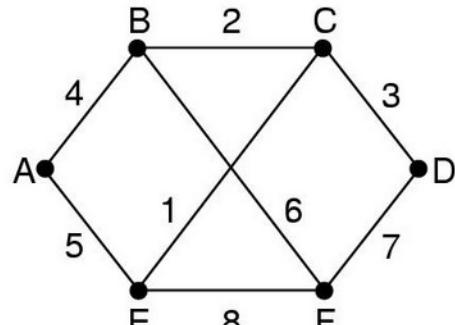
LSR: Ermittlung der Verzögerung

- ECHO Pakete
- Berücksichtigung von Auslastung?



LSR: Erstellung von Link-State-Pakete

- Identität, Folgenummer, Alter
- Wann? Periodisch oder bei Ereignis?



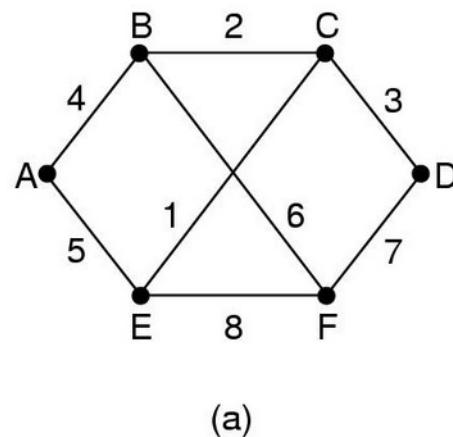
(a)

	Link	State	Packets
A	B	C	E
Seq.	Seq.	Seq.	Seq.
Age	Age	Age	Age
B 4	A 4	B 2	A 5
E 5	C 2	D 3	C 1
	F 6	F 7	F 8

(b)

LSR: Verteilung der Link-State-Pakete

- Kritisch! Flooding
- Nummernbereich, Ausfall, Fehler -> Altern
- Robuster: warten, bestätigen, flaggen, zB bei B:



Source	Seq.	Age	Send flags			ACK flags			Data
			A	C	F	A	C	F	
A	21	60	0	1	1	1	0	0	
F	21	60	1	1	0	0	0	1	
E	21	59	0	1	0	1	0	1	
C	20	60	1	0	1	0	1	0	
D	21	59	1	0	0	0	1	1	

(b)

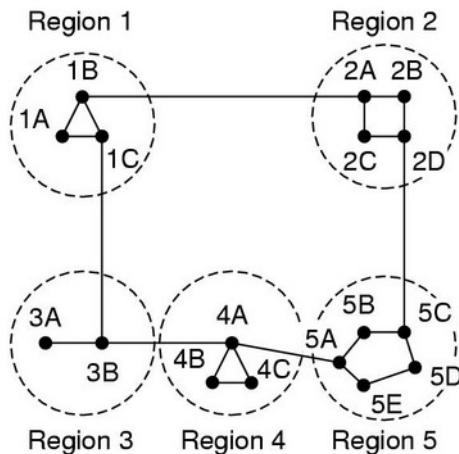
The table (b) shows the state of five routers (A, F, E, C, D) regarding a sequence number of 21. The columns represent Source, Seq., Age, and three Send flags (A, C, F) followed by three ACK flags (A, C, F). Router A has a seq of 21, age 60, and send flags (0, 1, 1) and ack flags (1, 0, 0). Router F has a seq of 21, age 60, and send flags (1, 1, 0) and ack flags (0, 0, 1). Router E has a seq of 21, age 59, and send flags (0, 1, 0) and ack flags (1, 0, 1). Router C has a seq of 20, age 60, and send flags (1, 0, 1) and ack flags (0, 1, 0). Router D has a seq of 21, age 59, and send flags (1, 0, 0) and ack flags (0, 1, 1).

LSR: Berechnung neuer Routen

- Algorithmus von Dijkstra
- Probleme
 - Speicher
 - Fehler
 - Multiprotokol
- IS-IS
- OSPF (RFC 2328)

Hierarchisches Routing

- Vermeidung von proportionalem Wachstum



(a)

Full table for 1A

Dest.	Line	Hops
1A	-	-
1B	1B	1
1C	1C	1
2A	1B	2
2B	1B	3
2C	1B	3
2D	1B	4
3A	1C	3
3B	1C	2
4A	1C	3
4B	1C	4
4C	1C	4
5A	1C	4
5B	1C	5
5C	1B	5
5D	1C	6
5E	1C	5

(b)

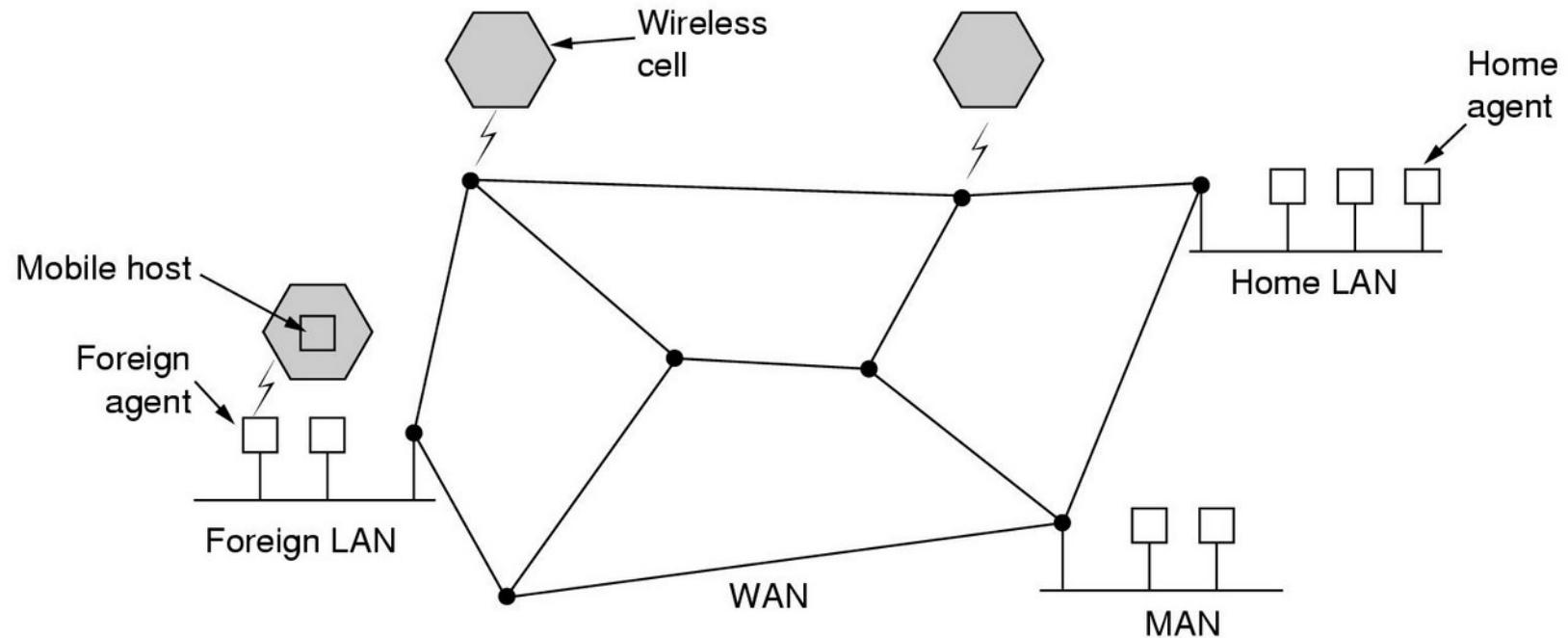
Hierarchical table for 1A

Dest.	Line	Hops
1A	-	-
1B	1B	1
1C	1C	1
2	1B	2
3	1C	2
4	1C	3
5	1C	4

(c)

Problem: Pfadlänge!

Routing für mobile Hosts 1



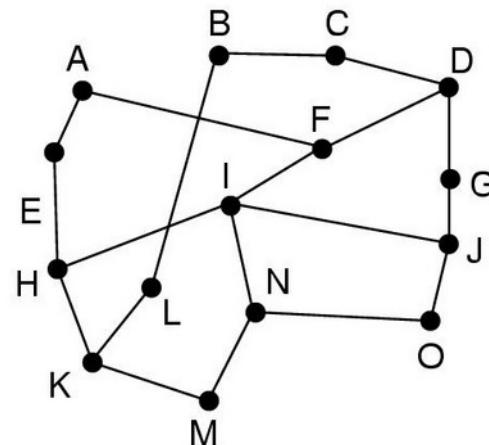
Routing für mobile Hosts 2

- Periodische Pakete (Fremdagent, Mobil)
- Anmeldung mit Heimatadresse
- Fremdagent kontaktiert Heimatagent
- Überprüfung der Sicherheitsinformationen
- Nach Bestätigung Eintrag in Tabelle
- Abmeldung

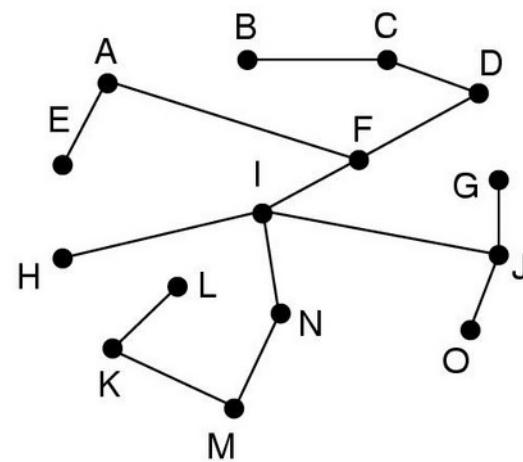
Broadcast Routing

- Multiple Point-to-point
- Flooding
- Multidestination Routing
- Spanning-Tree
- Reverse-Path-Forwarding

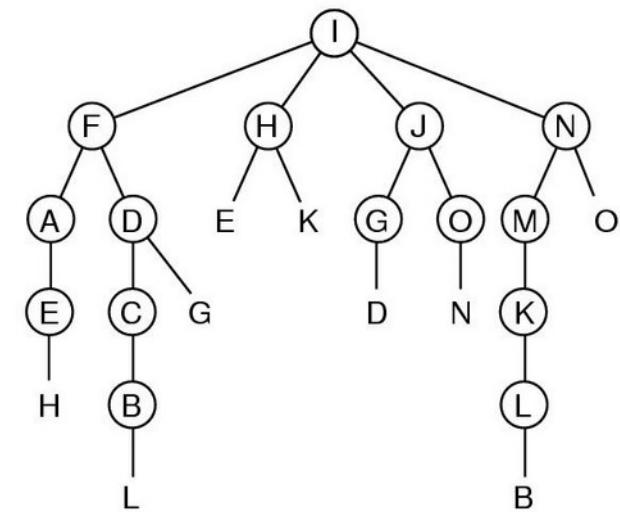
Reverse-Path-Forwarding



(a)



(b)



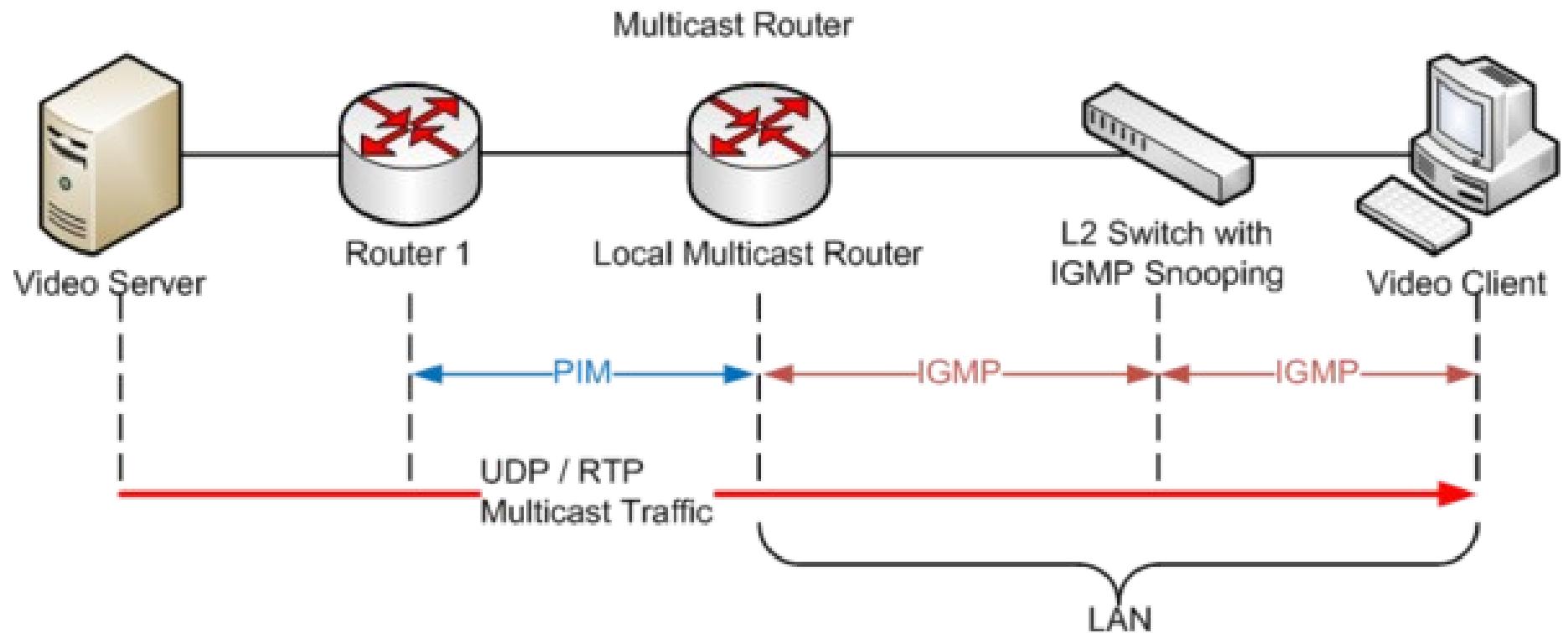
(c)

Netzwerk

Spanning Tree

Reverse Path Forwarding

Multicast Routing



https://en.wikipedia.org/wiki/Protocol_Independent_Multicast

Multicast Routing

- Lokal: Gruppenmanagement
 - Anlegen, löschen, beitreten, verlassen
- Global: Spanning Tree
 - Link-State-Routing
 - Distance-Vector-Routing+Reverse-Path-Forwarding
 - Core-base Trees
- Internet: **PIM**

(Mobile) Ad-hoc NETze und P2P

- Topologien
- Anwendungen
- Wireless ad hoc networks
- Ad-hoc Routing
- B.A.T.M.A.N