Netze und verteilte Systeme I

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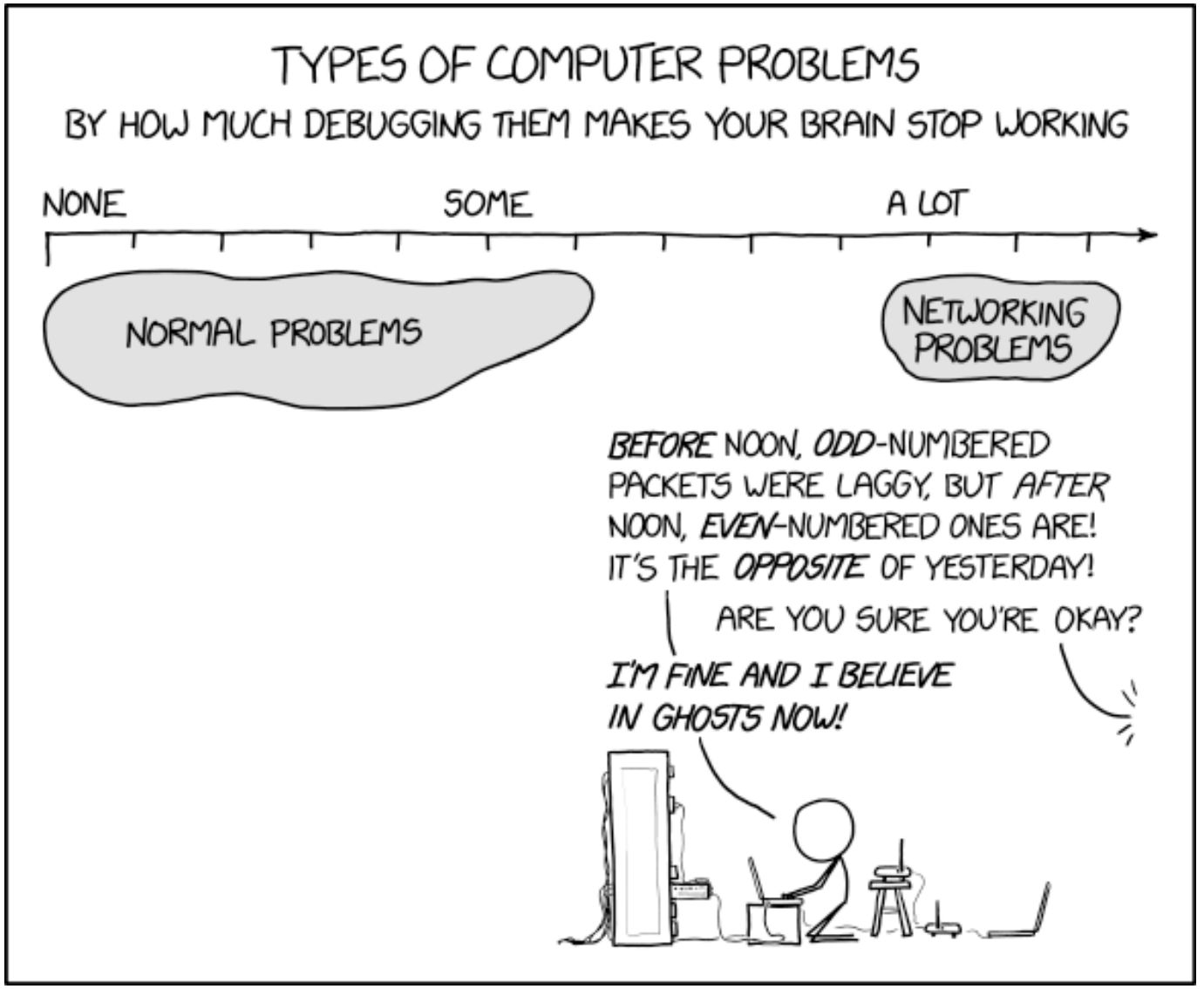
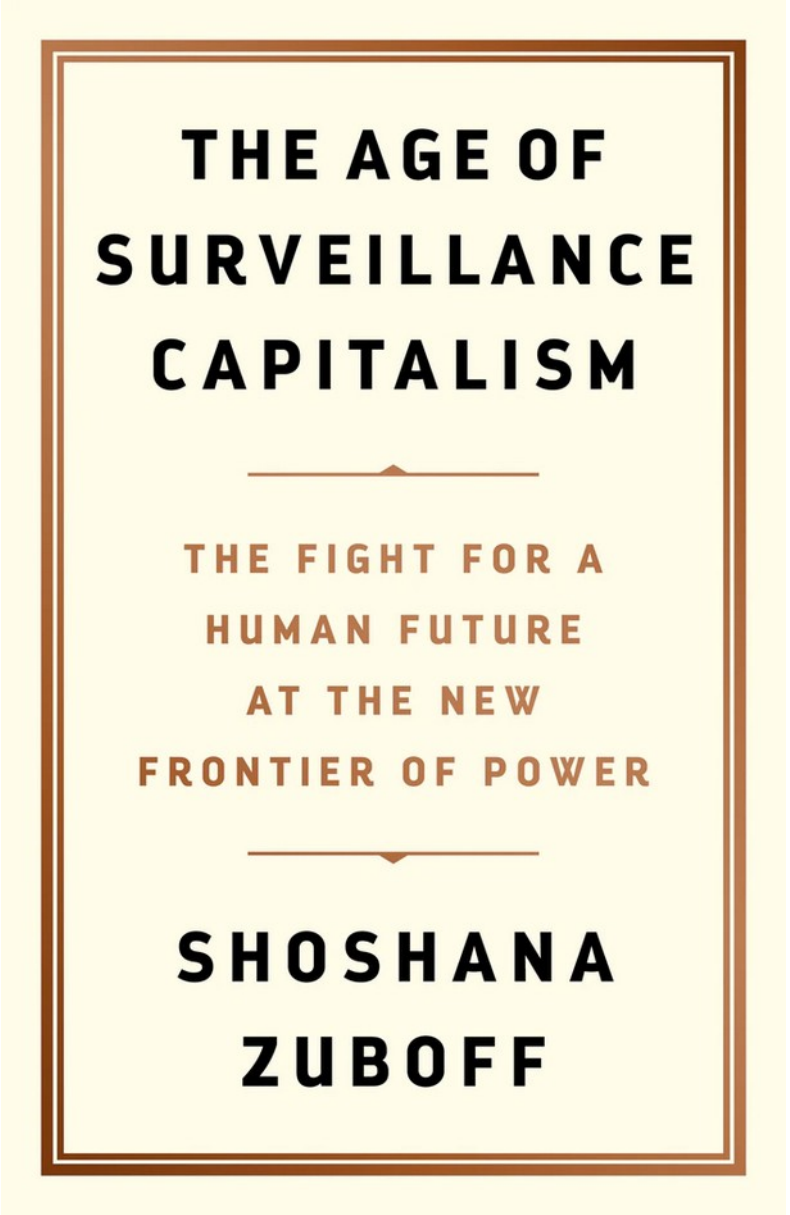
Überblick

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


TYPES OF COMPUTER PROBLEMS
BY HOW MUCH DEBUGGING THEM MAKES YOUR BRAIN STOP WORKING
NONE
SOME
A LOT
NORMAL PROBLEMS
NETWORKING PROBLEMS
BEFORE NOON, ODD-NUMBERED PACKETS WERE LAGGY, BUT AFTER NOON, EVEN-NUMBERED ONES ARE! IT'S THE OPPOSITE OF YESTERDAY!
ARE YOU SURE YOU'RE OKAY?
I'M FINE AND I BELIEVE IN GHOSTS NOW!

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


HELLO. MY NAME IS ACHIM KLEINER.
IS THIS THE NSA? I HAVE
A FESTPLATTENABSTURZ AND
I WOULD LIKE TO HAVE A BACK
UP FROM MÄRZ BIS JULI.

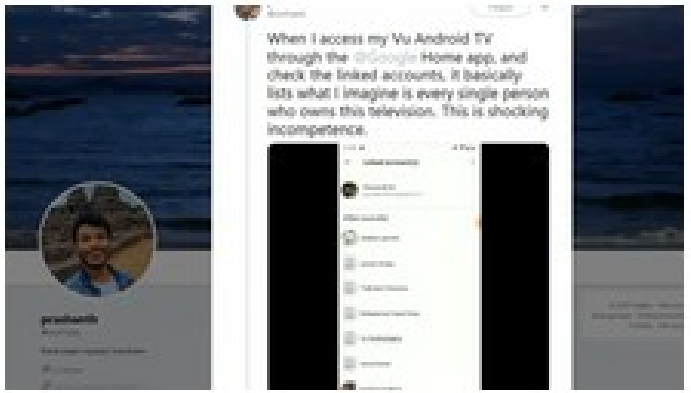
DNS 1.1.1.1-9.9.9.9

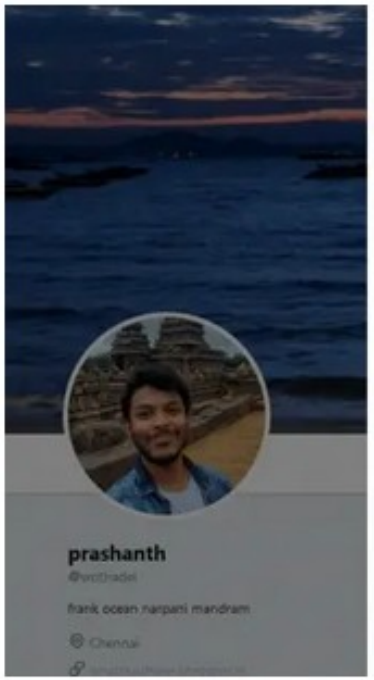
Networked = Hacked

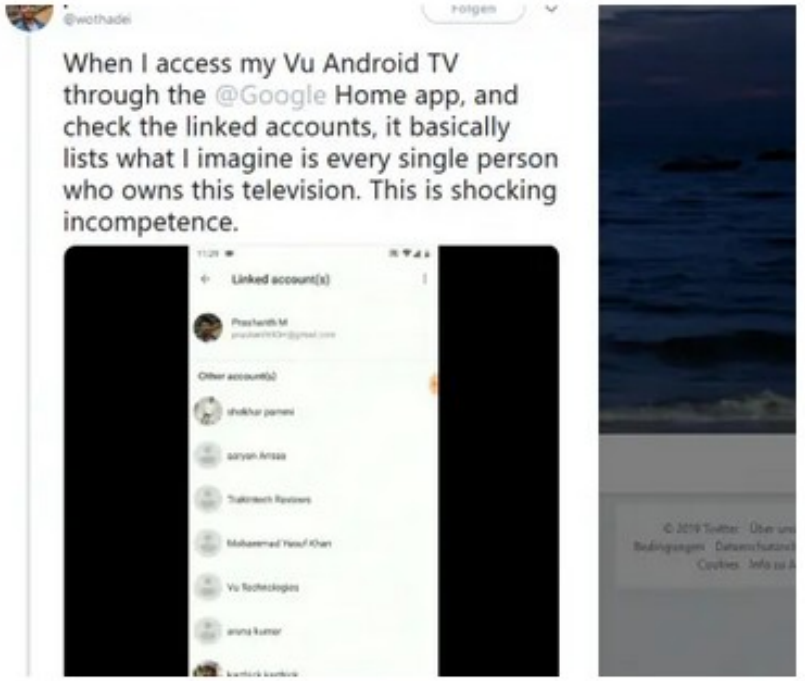
Android TV zeigte fremde Nutzerkonten an

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

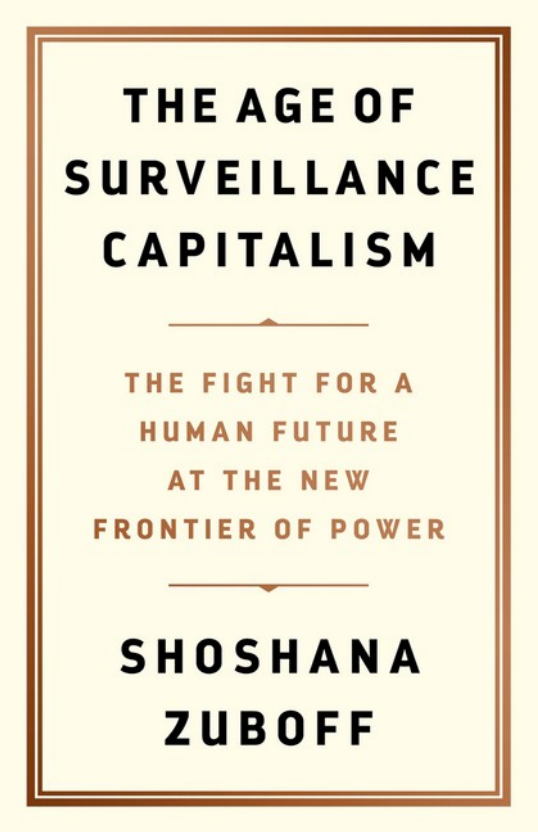
EFF.org 28.2.19

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 („**Rechenschaftspflich**t“).

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

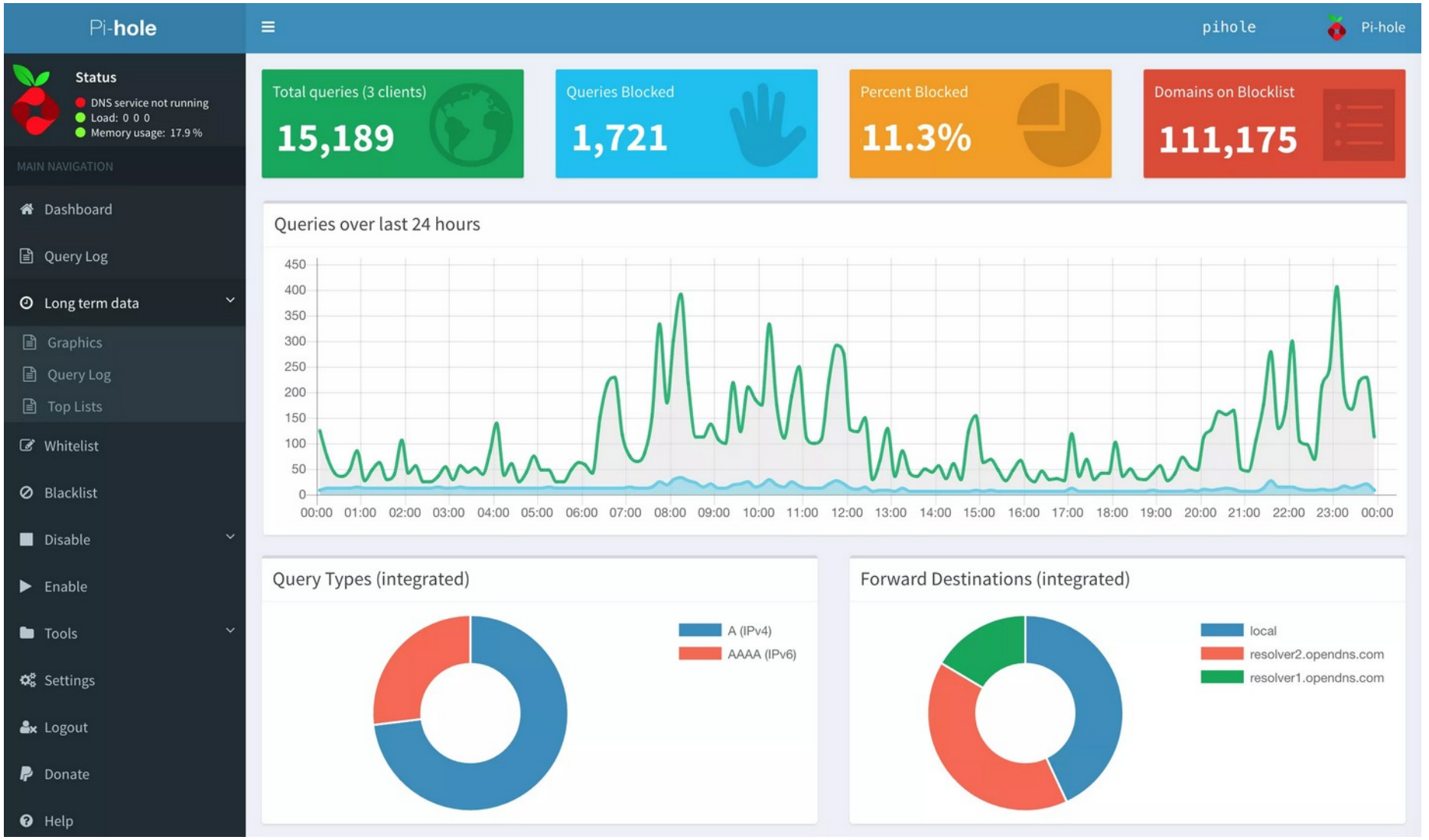
Entwicklungen

- 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?

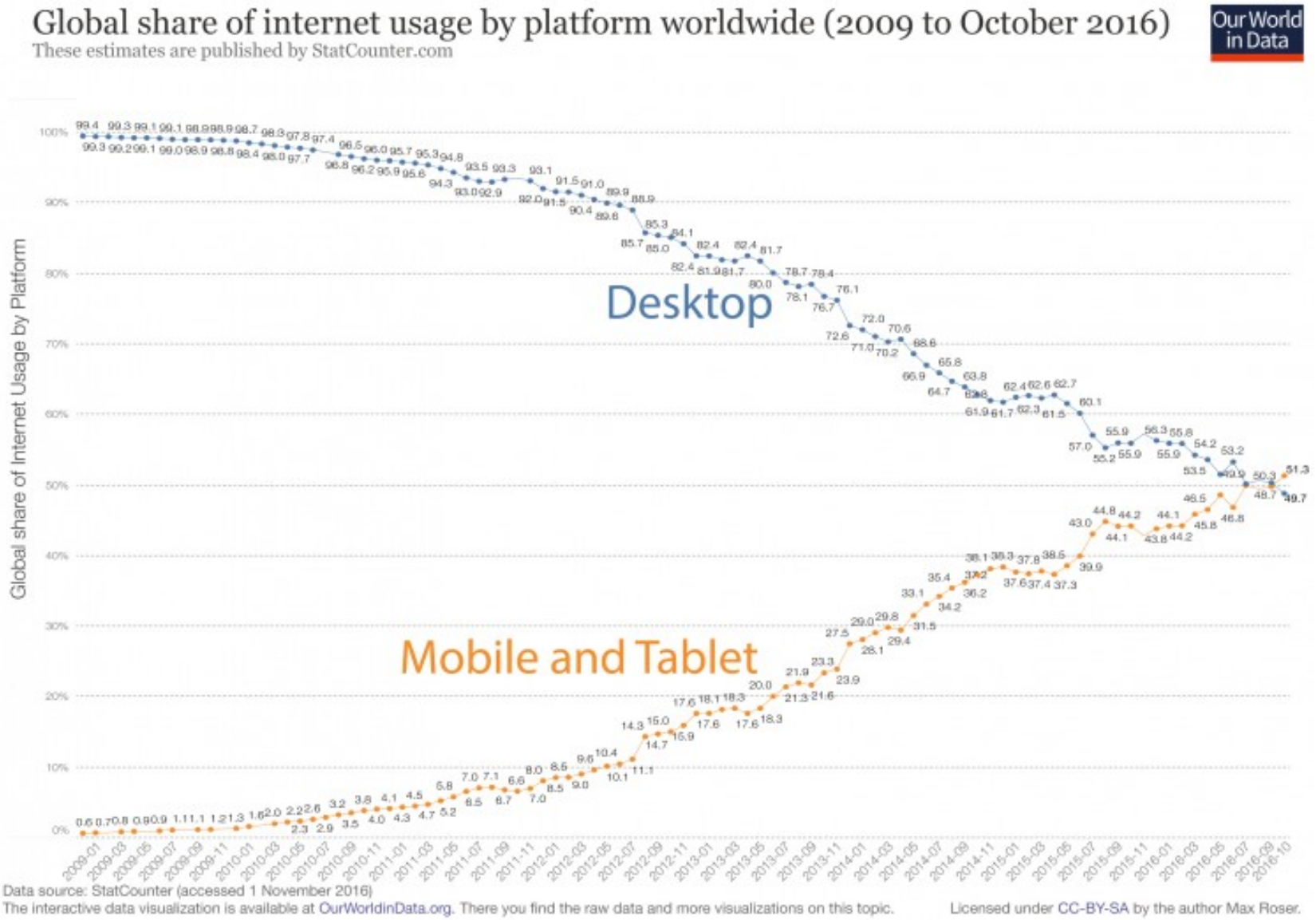
Altertum

- 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)
- **Verbindungsaufbau**:
  - 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 ;)

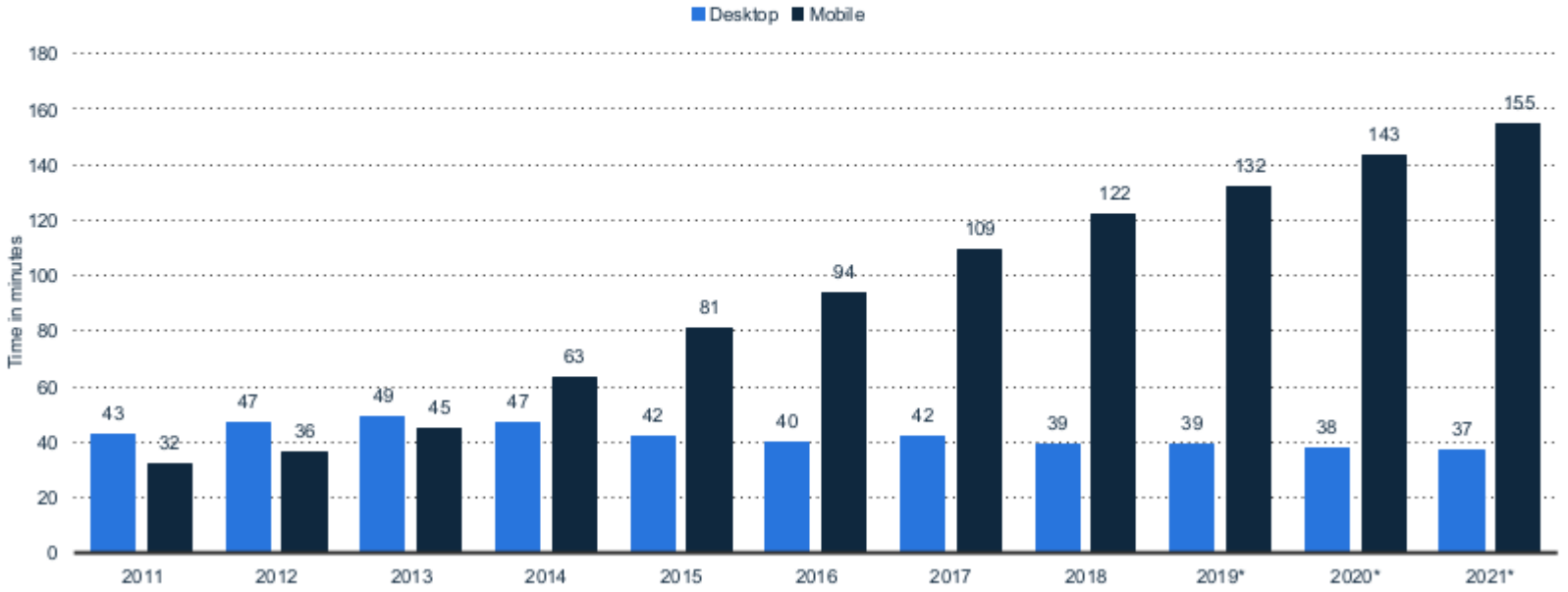
Desktop vs Mobile devices



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; ID 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

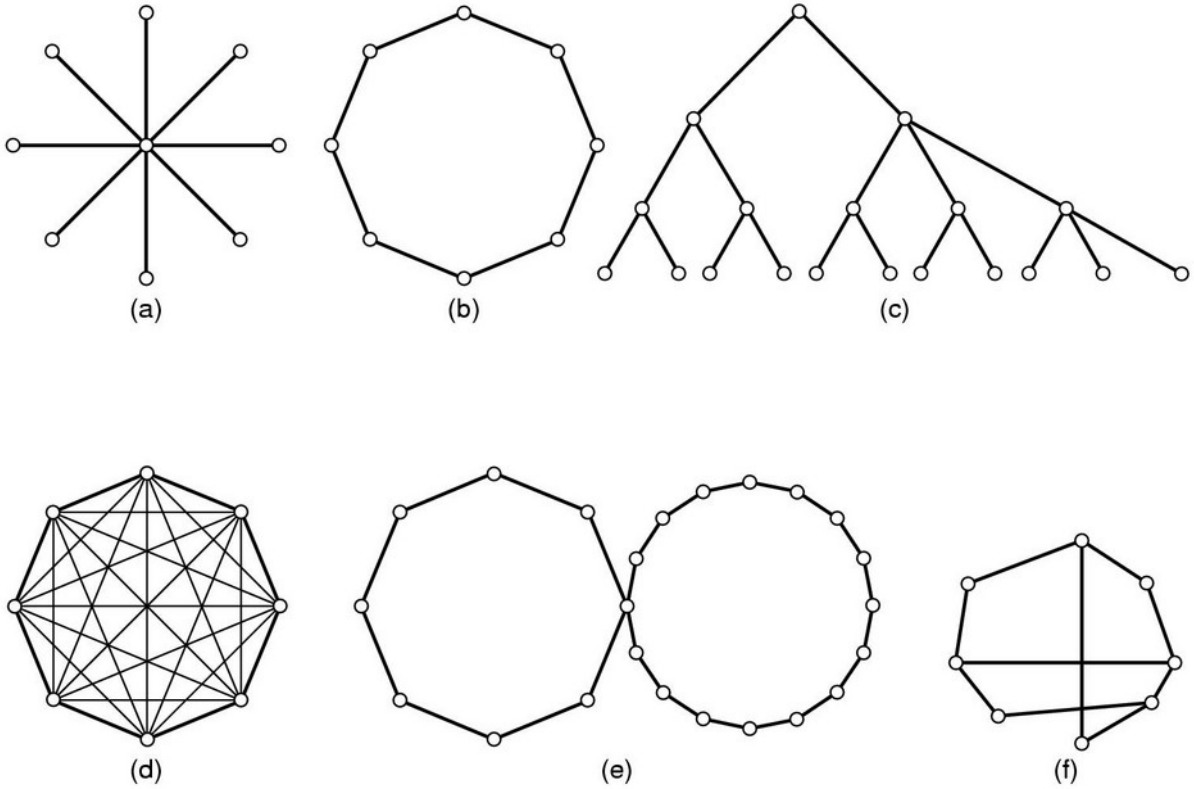
Netze: Übertragungsart

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

Netze: Reichweite

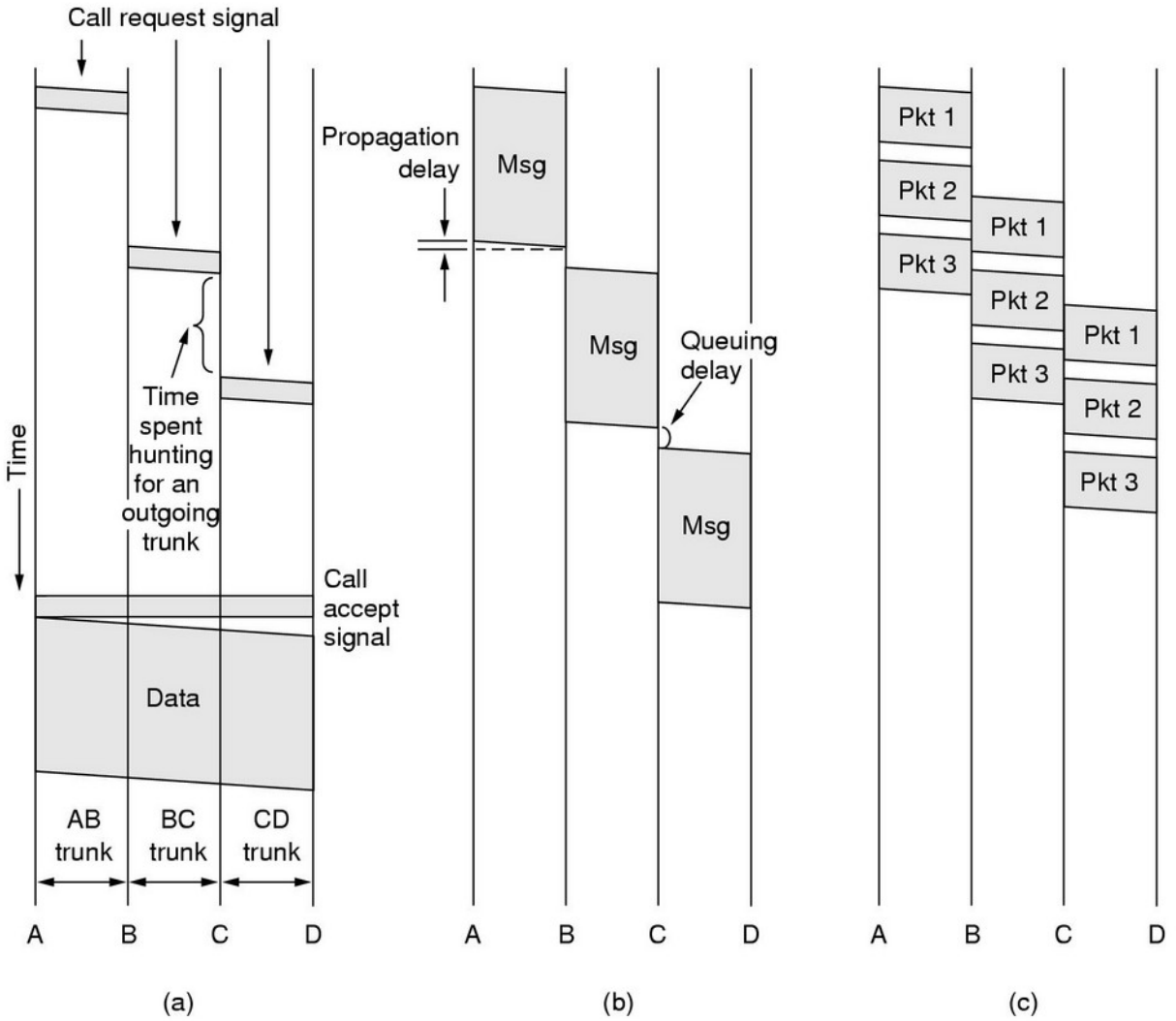
Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1,000 km	Continent	
10,000 km	Planet	The Internet

Netze: Topologien



Netze: Vermittlung

- Leitung
- Paket
- Nachrichten



Netze: Zugang

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

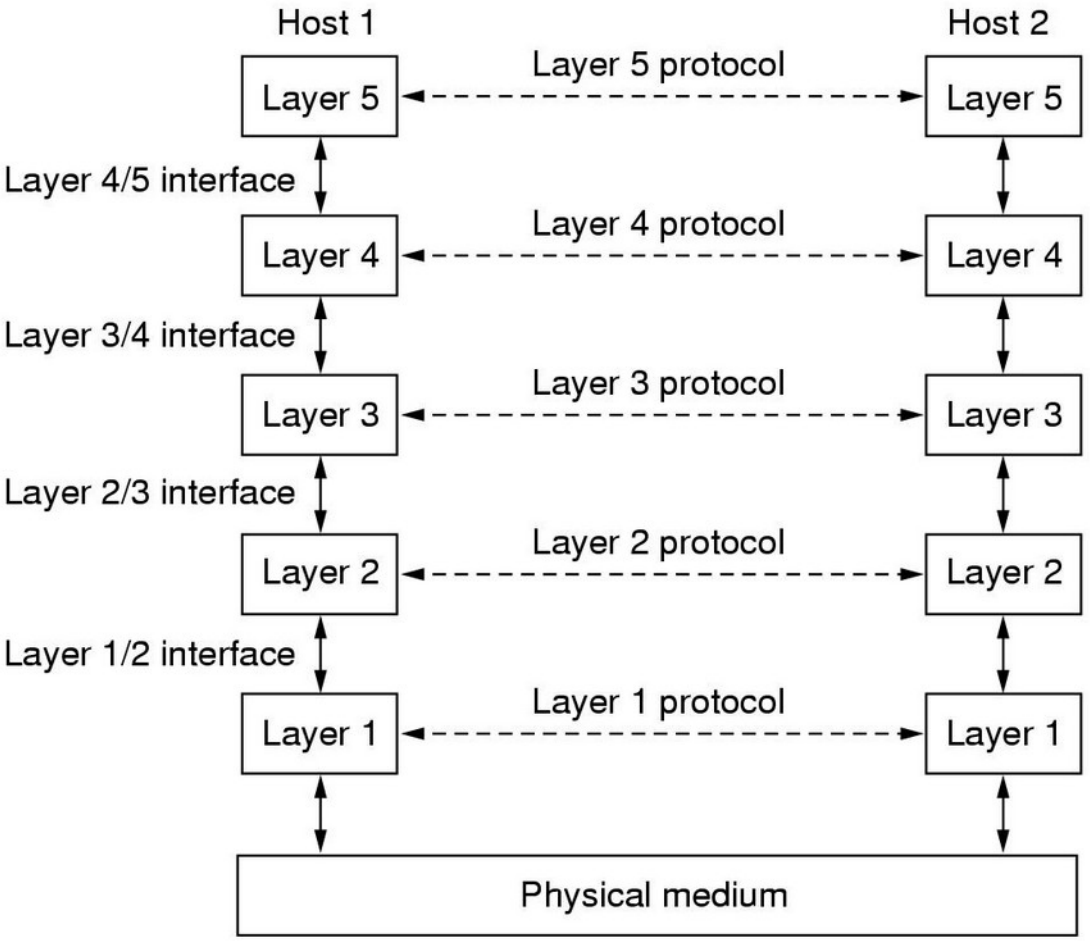
Netze: Übertragungsart

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

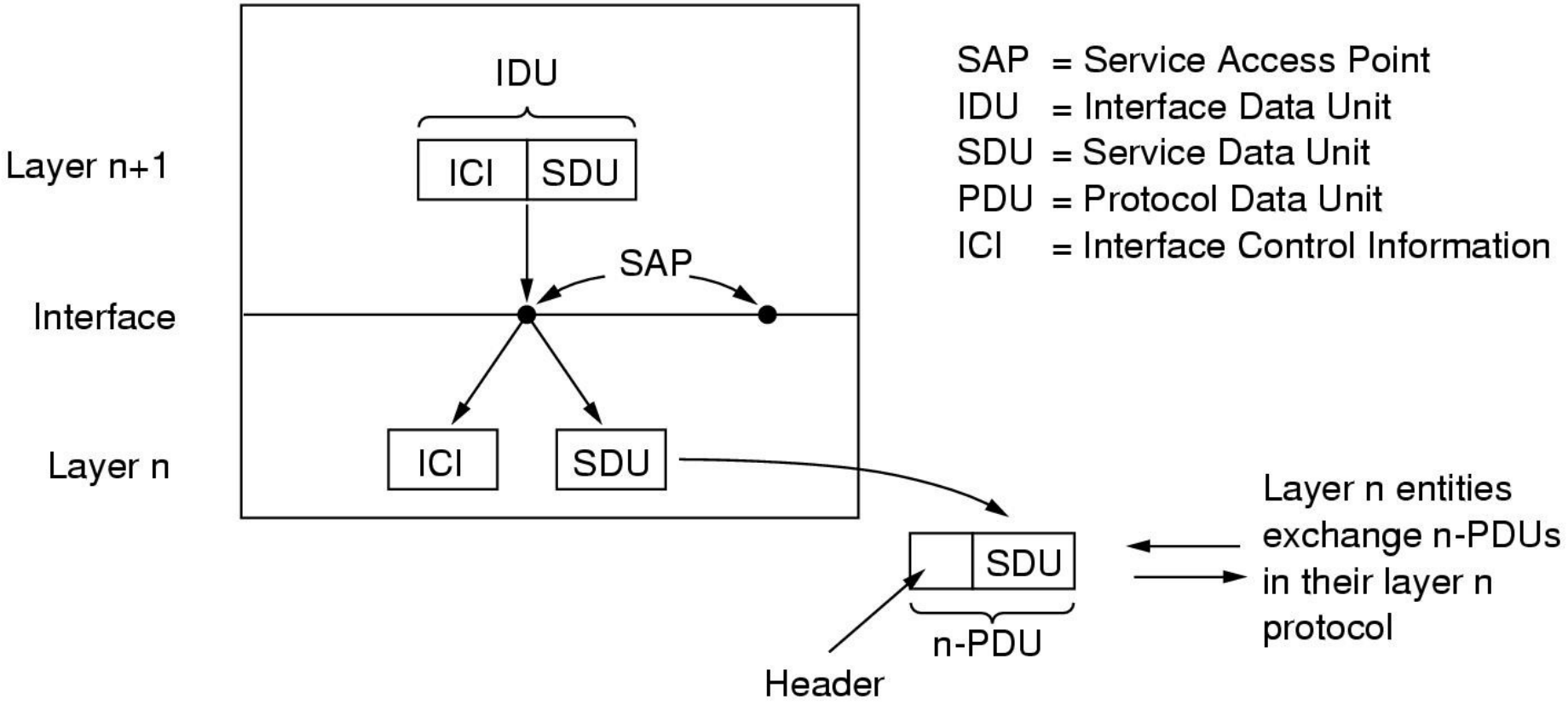
Netze: Entwurfsaspekte

- 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
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

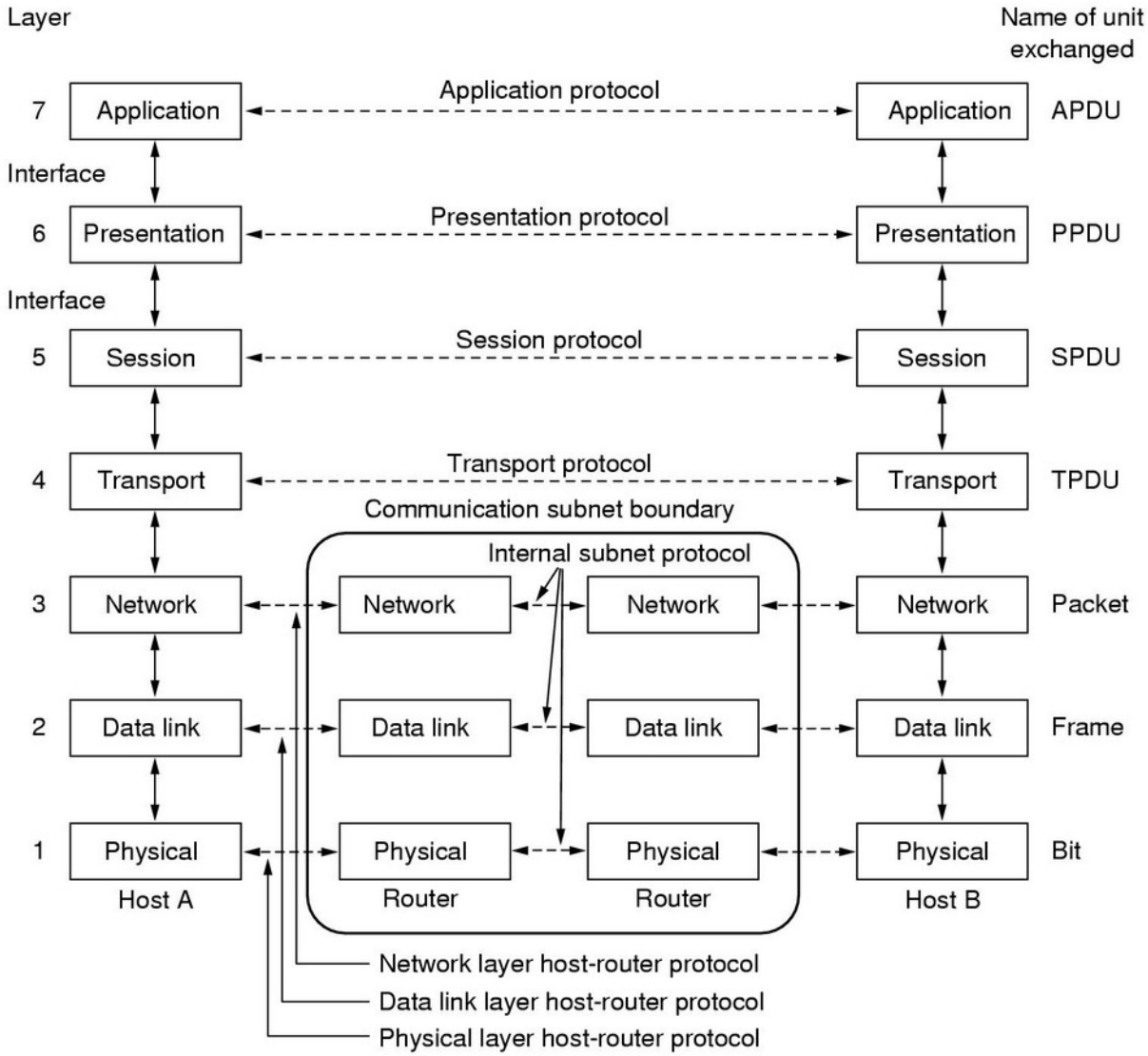
Dienstprimitiven

- 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

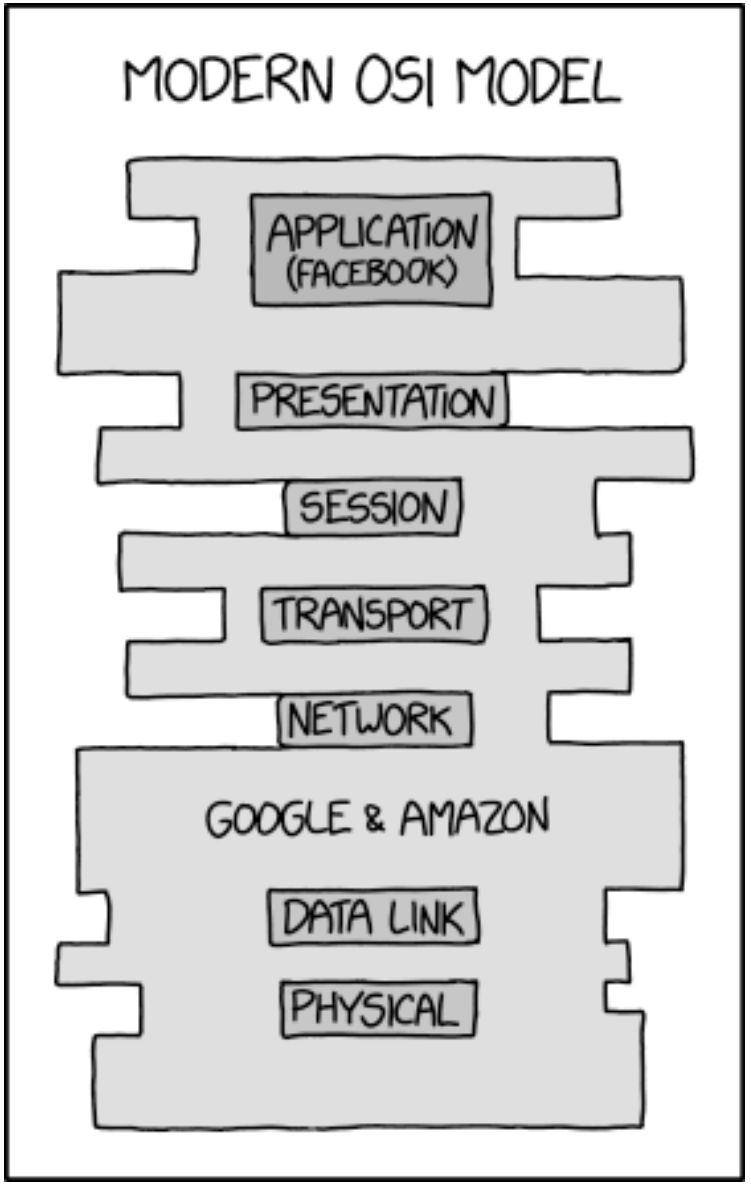


Protocol Stacks

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
Four layers	*Four layers*	*Five layers*	*Four+one layers*	*Five layers*	*Five layers*	*Three layers*	*Seven layers*
"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 ;)


MODERN OSI MODEL
APPLICATION (FACEBOOK)
PRESENTATION
SESSION
TRANSPORT
NETWORK
GOOGLE & AMAZON
DATA LINK
PHYSICAL

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

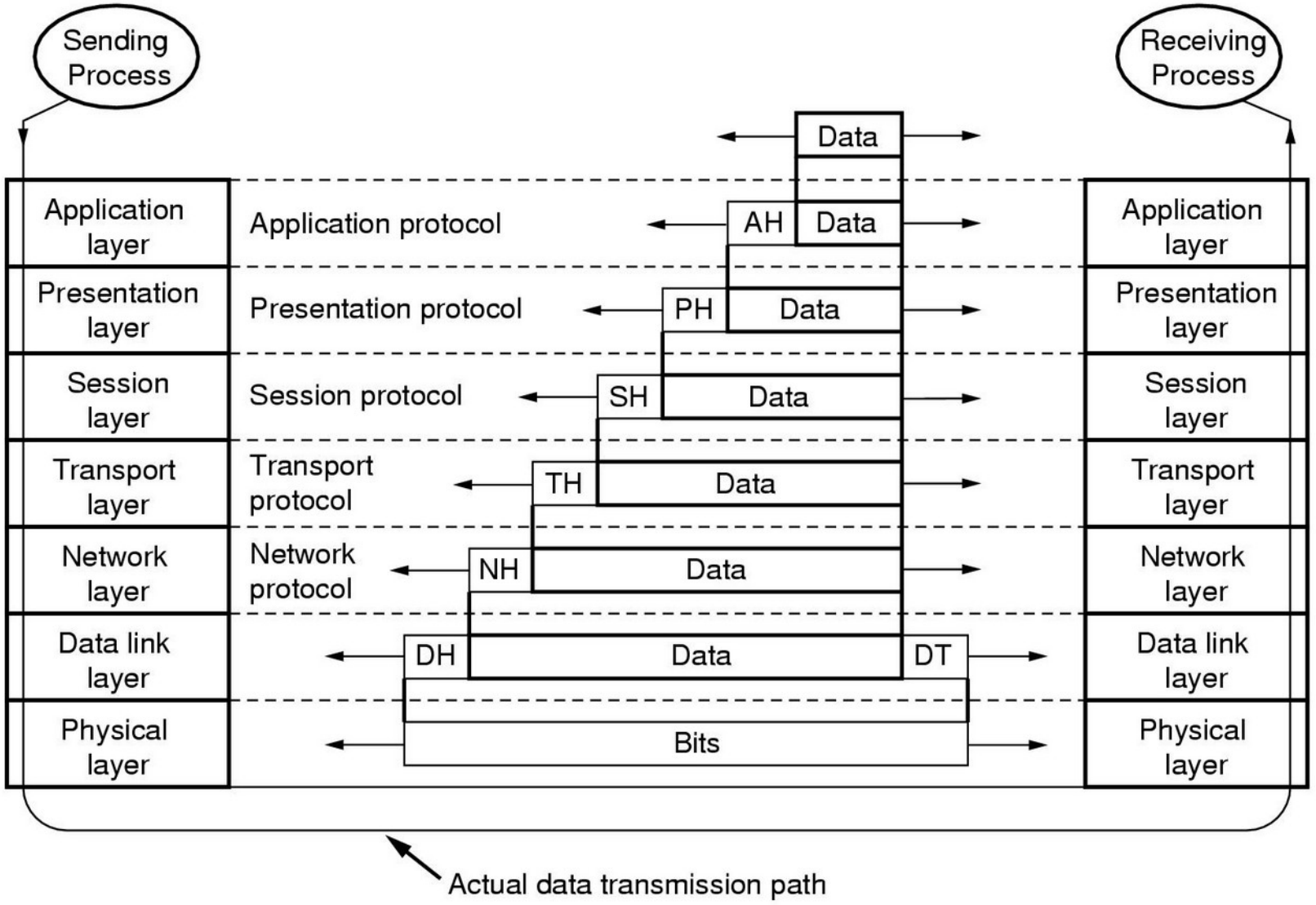
Presentation - Darstellung

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

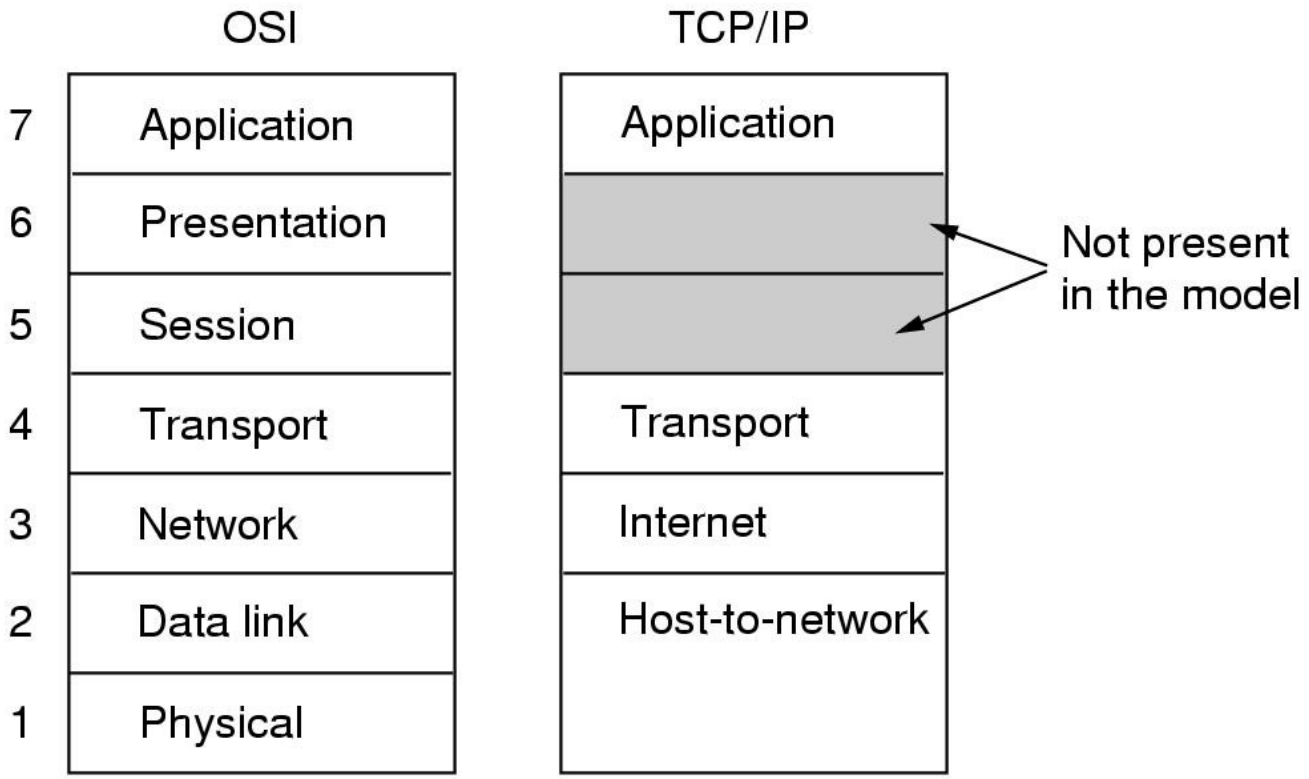
Application - Anwendung

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

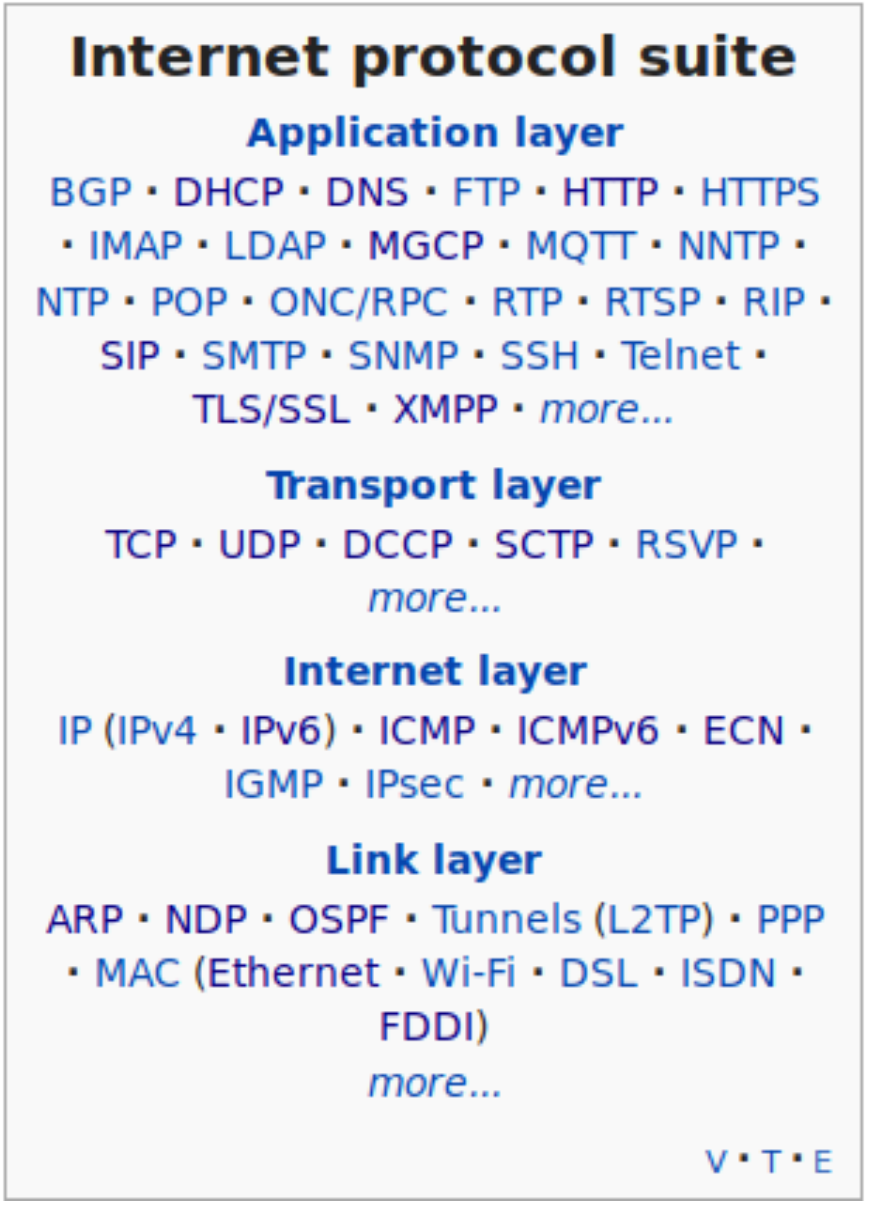
ISO/OSI-RM Beispiel



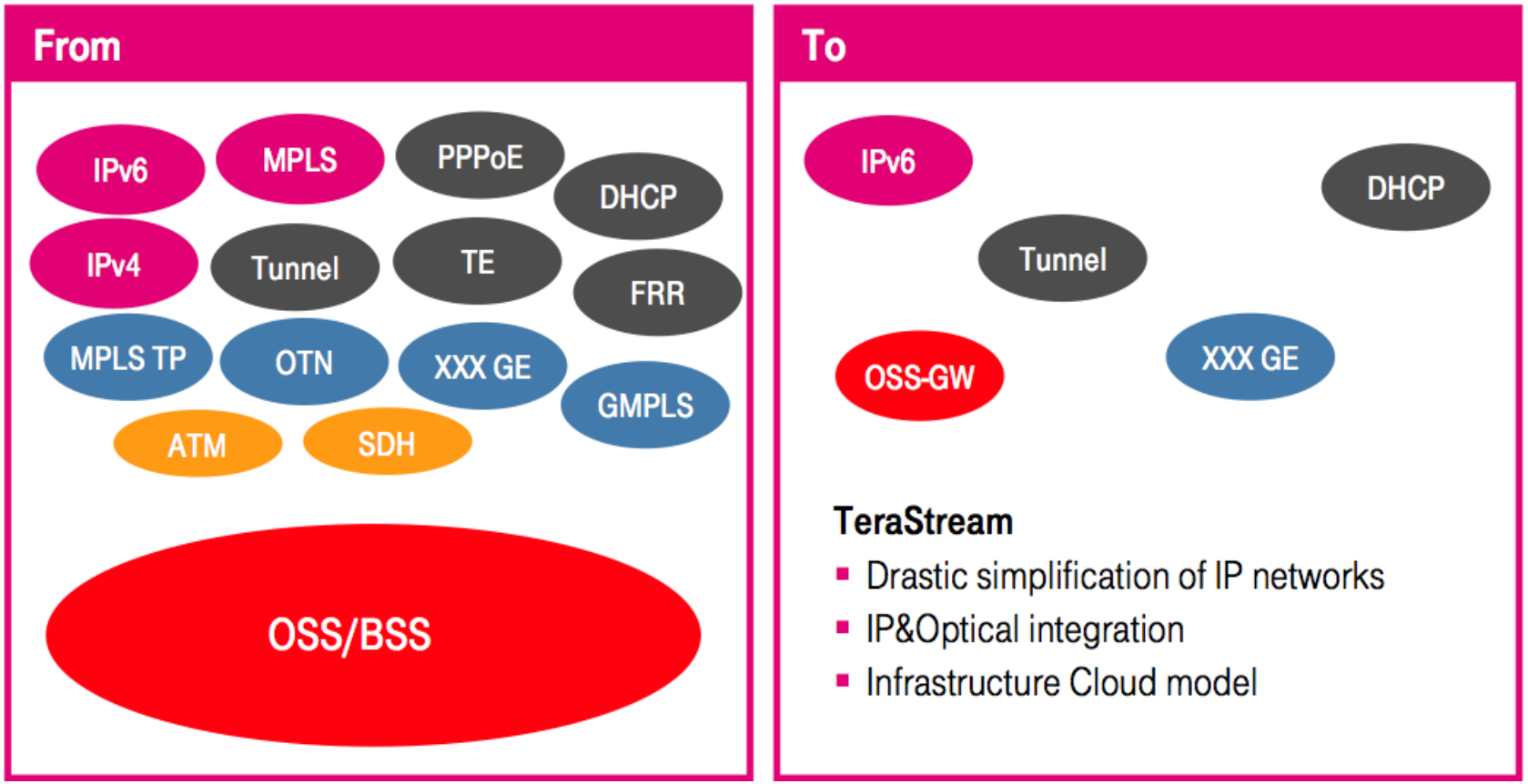
OSI vs TCP/IP


OSI
TCP/IP
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data link
1
Physical
Application
Transport
Internet
Host-to-network
Not present
in the model

Protokolle der TCP/IP Suite

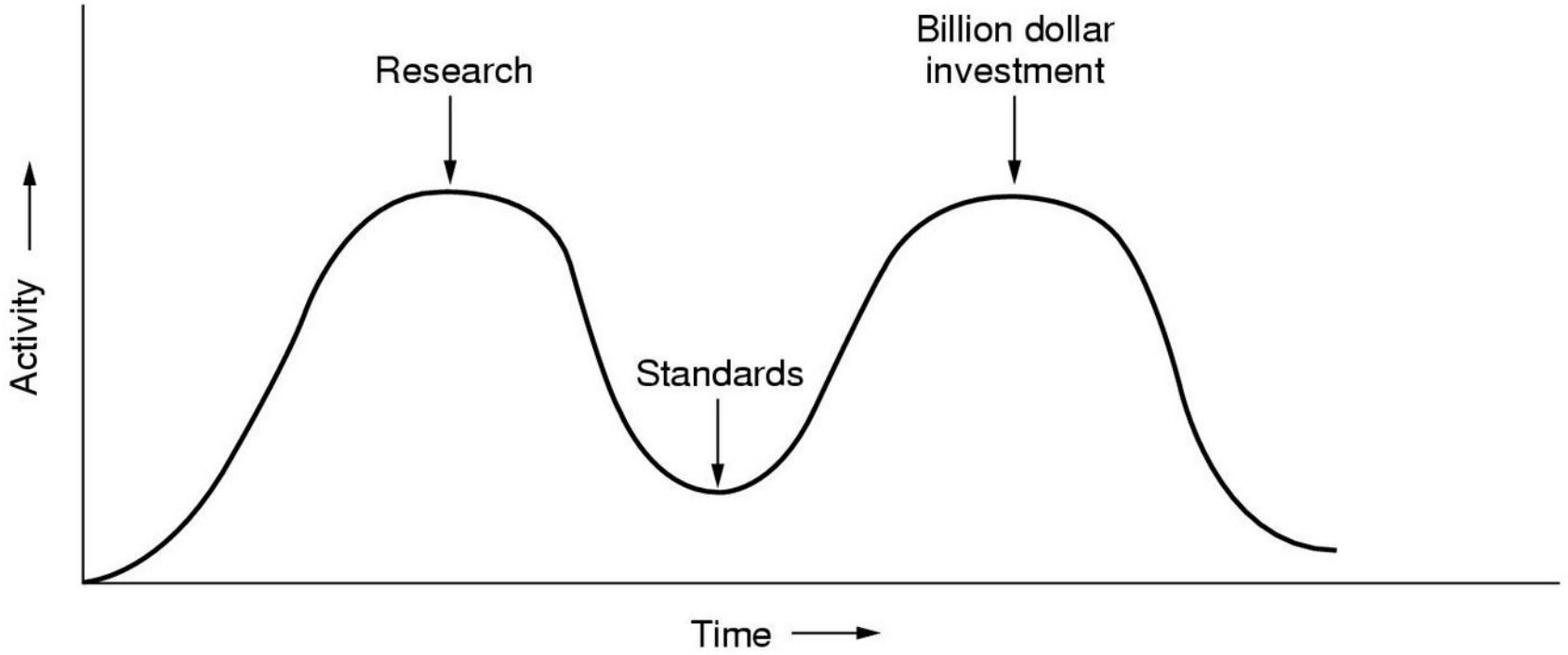


Einfach(er)?!



OSS OSS OSS/BSS

Dilemma


Research
Billion dollar investment
Standards
Activity
Time

“Gremien”

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

  IEEE

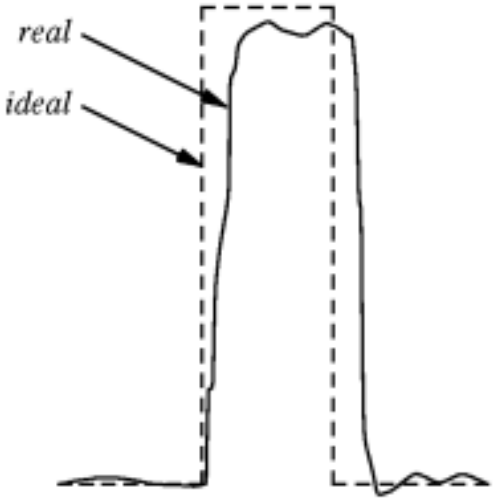
- IAB, Internet Society
- IETF, IRTF
- IANA, ICANN, RIPE, ...

Physische Medien

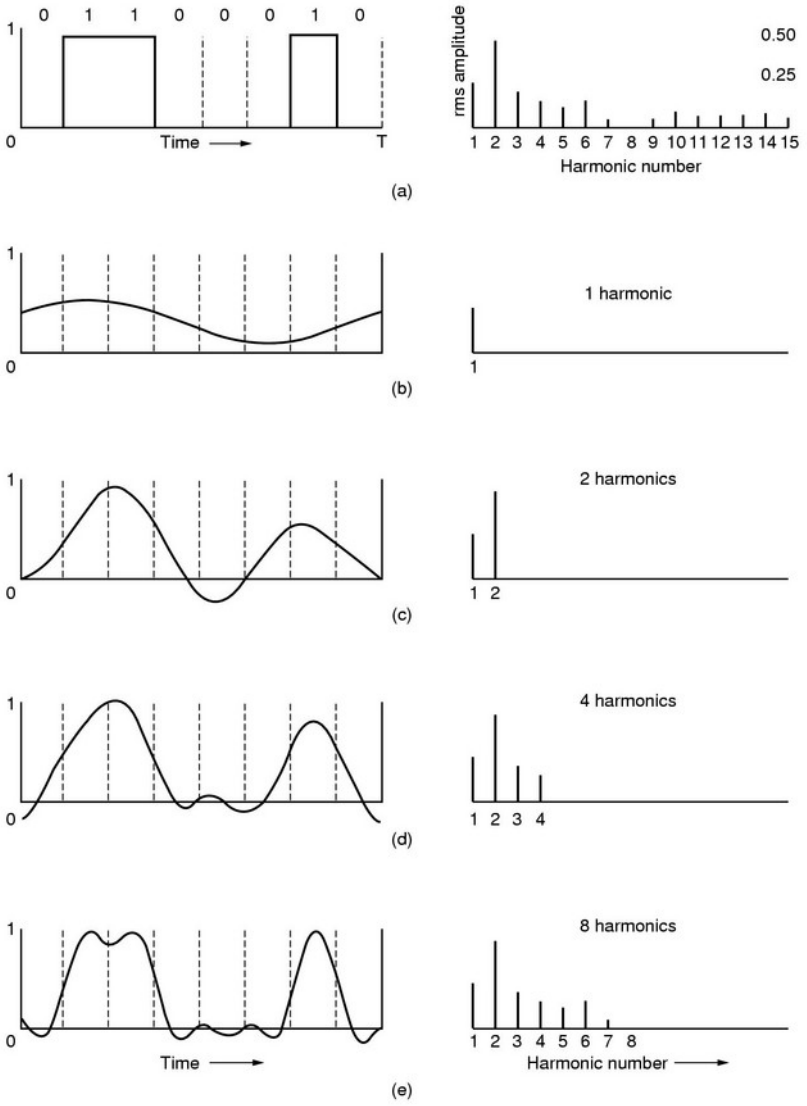
- Twisted Pair
- Coax
- Glass Fiber

- Radio
- Satellites
- Microwave
- Infrared
- Laser

Signalbeschränkung



Fourier-Analyse



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 einem 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 log2*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.

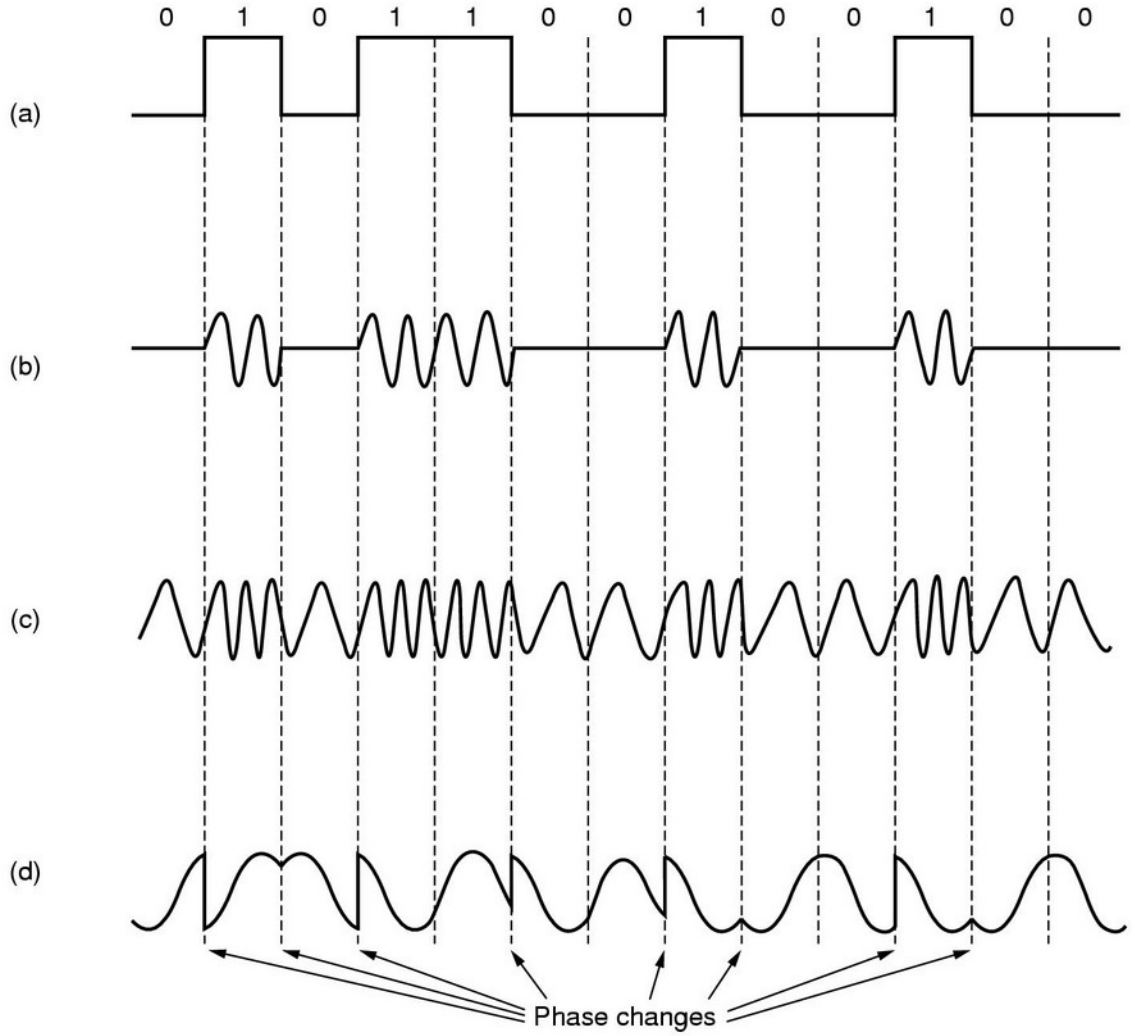
Language

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

Einfache Modulationsarten

- Amplitudenmodulation
- Frequenzmodulation
- Phasen-/Winkelmodulation

Modulation Types



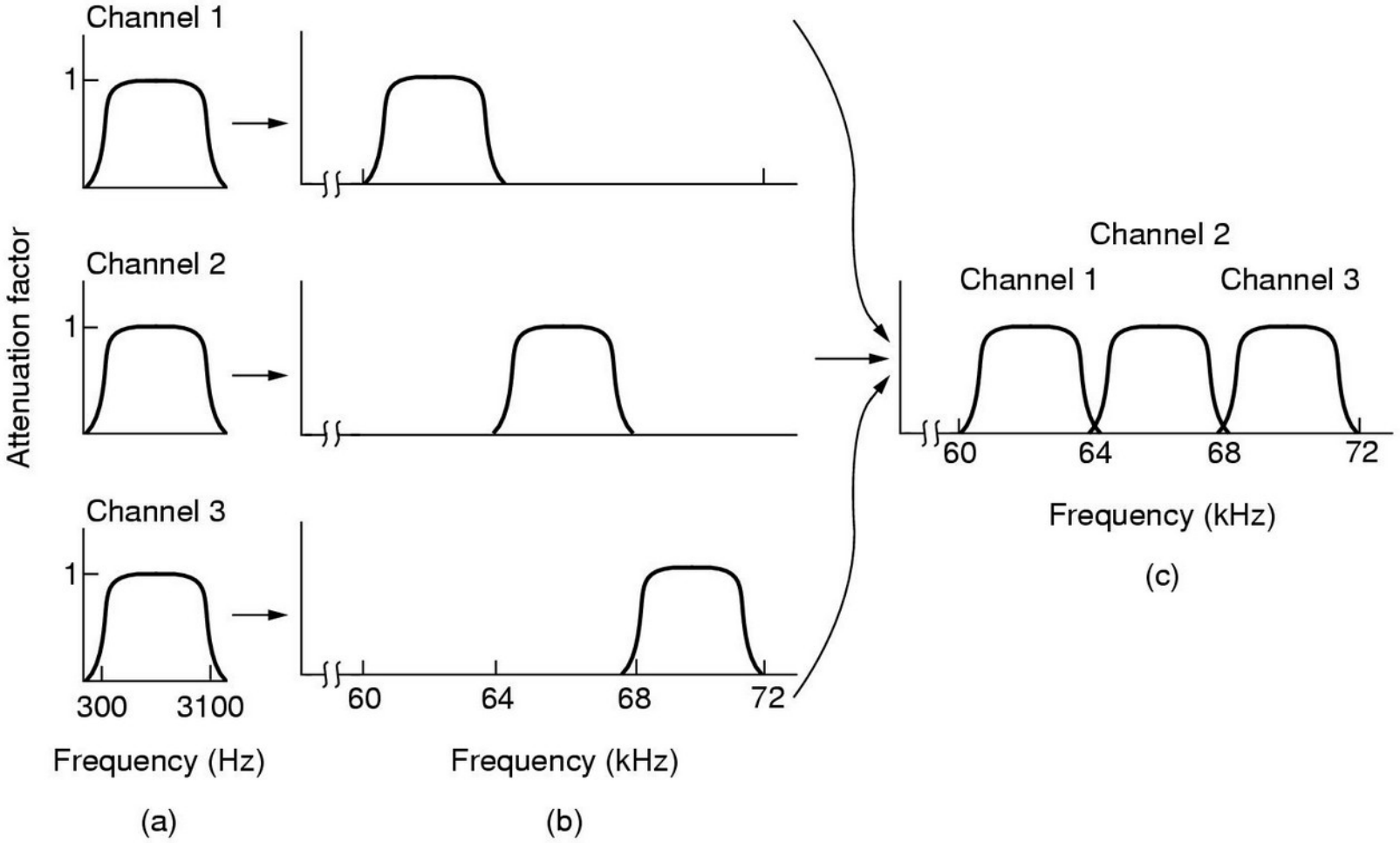
Multiplexing

- **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.

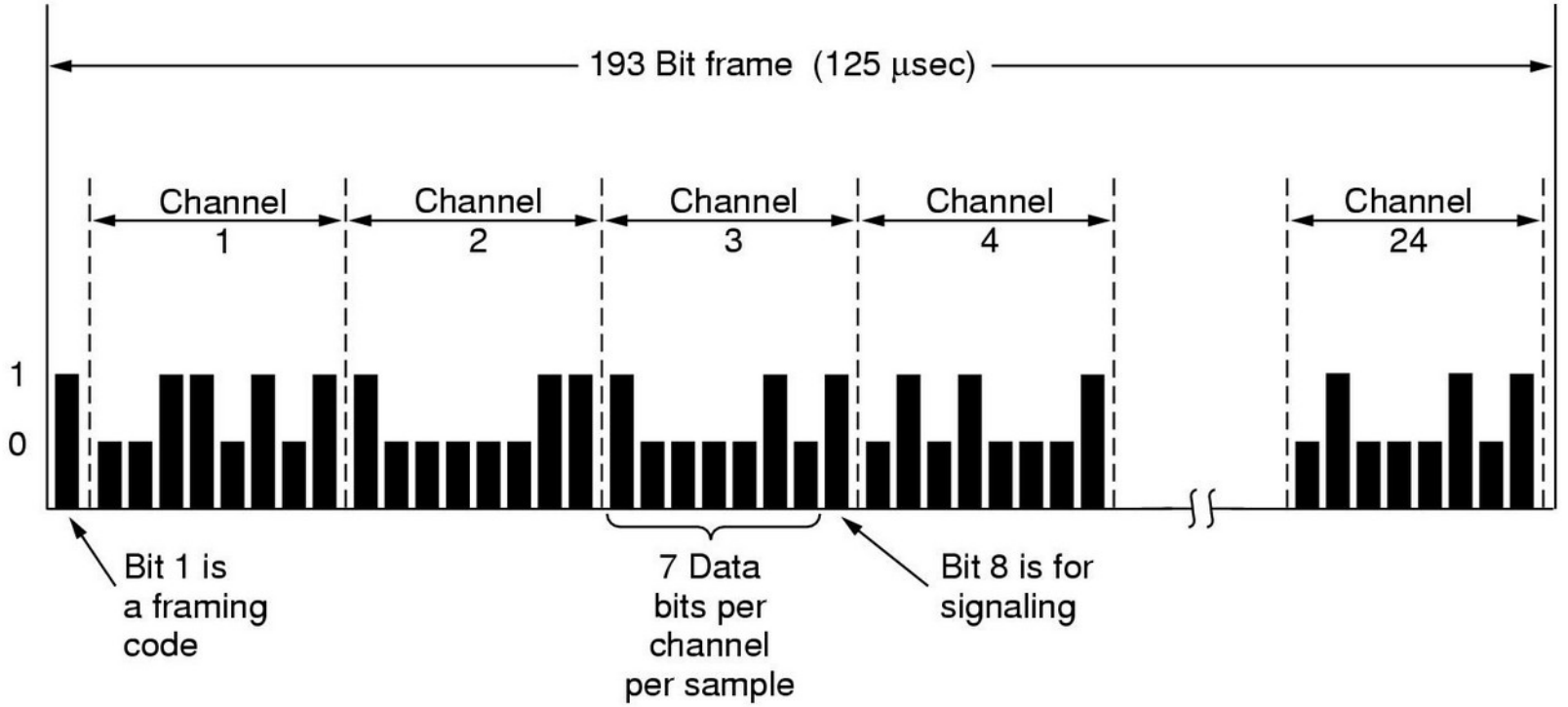
Frequency-division Muxing



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.

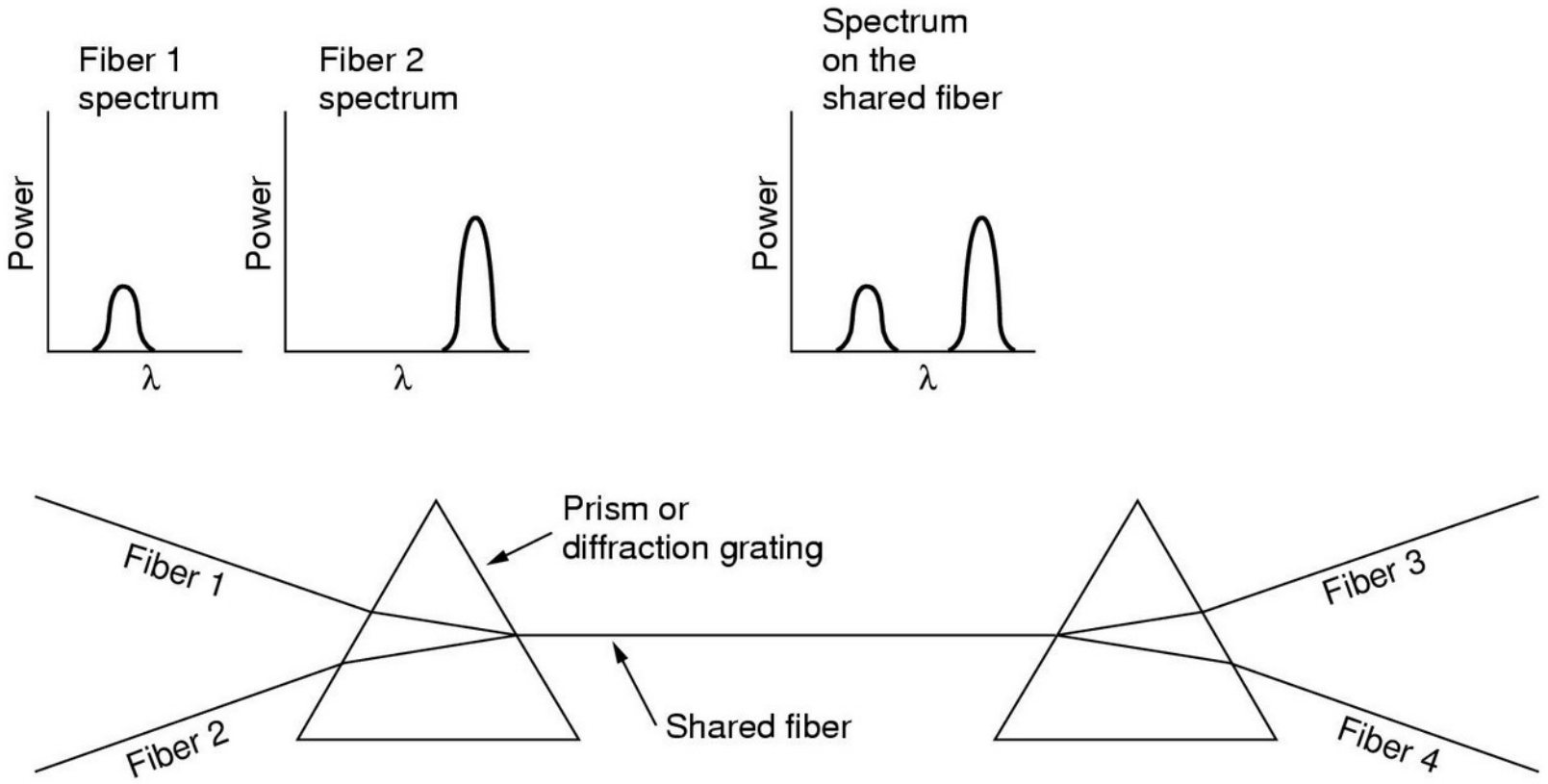
Time-division Muxing



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

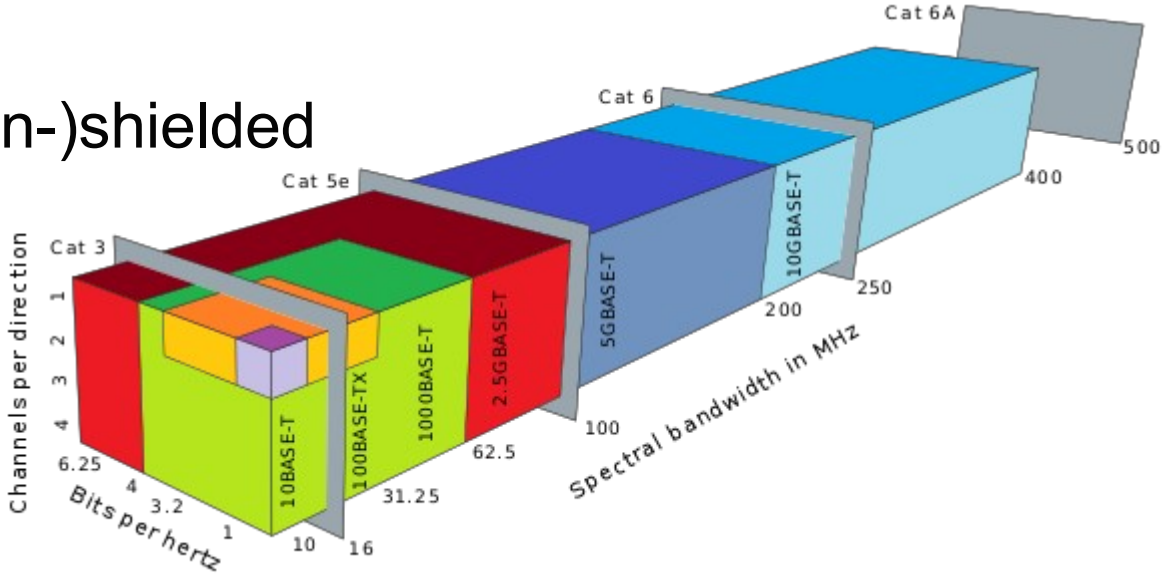
- **signaling: 1.** The use of signals for controlling communications. **2.** In a telecommunications network, the information exchange concerning the establishment and control of a connection and the management of the network, in contrast to user information transfer. **3.** The sending of a signal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

Transmission Medium

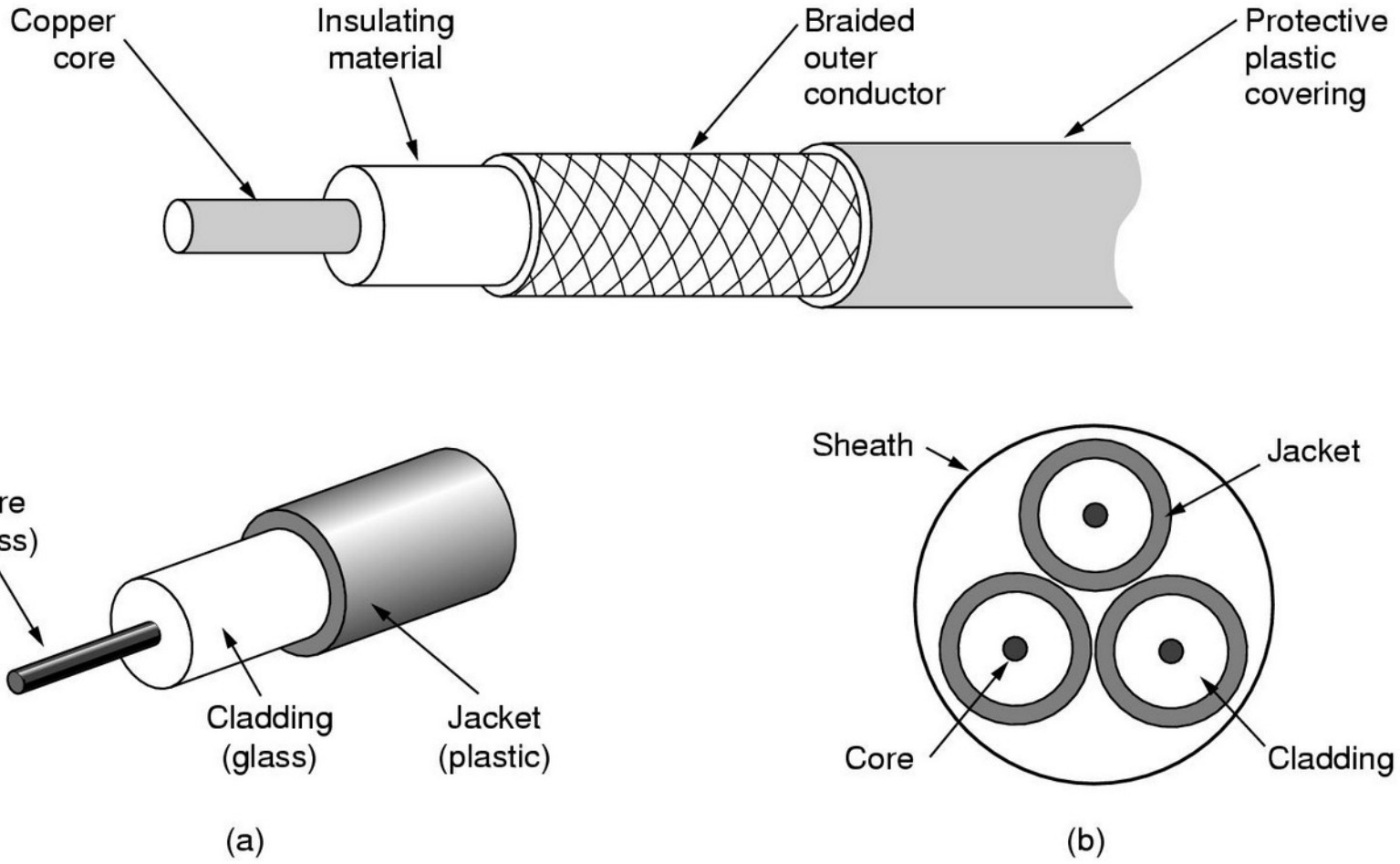
- **transmission medium:** Any material substance, such as fiber-optic cable, twisted-wire pair, coaxial cable, dielectric-slab waveguide, water, and air, that can be used for the propagation of signals, usually in the form of modulated radio, light, or acoustic waves, from one point to another. *Note:*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

Kabel

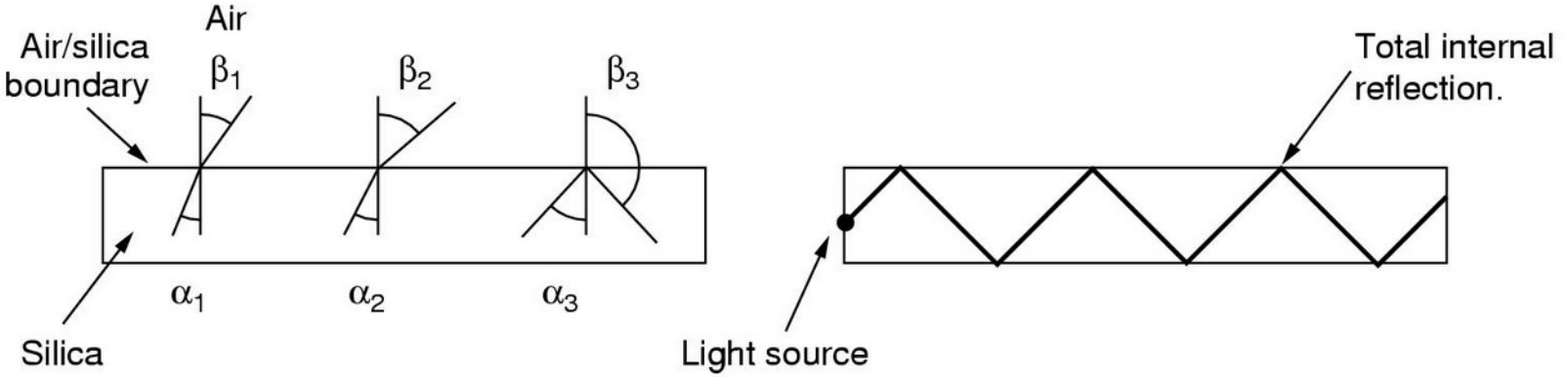
- Kupfer
  - Twisted pair, (un-)shielded
  - Kat3
  - Kat5
  - ...
  - Kat8
  - Koaxialkabel
- Glas
  - LED
  - Laser, single-/multi-mode

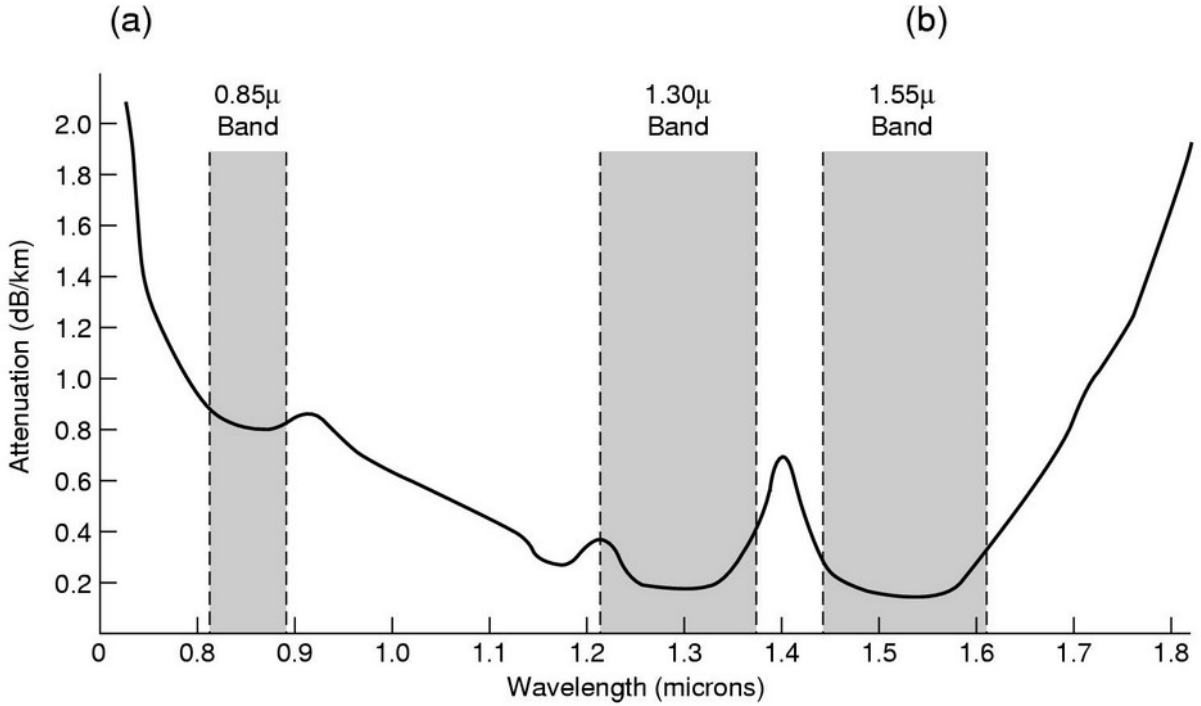


Kabelaufbau



Glasfaser

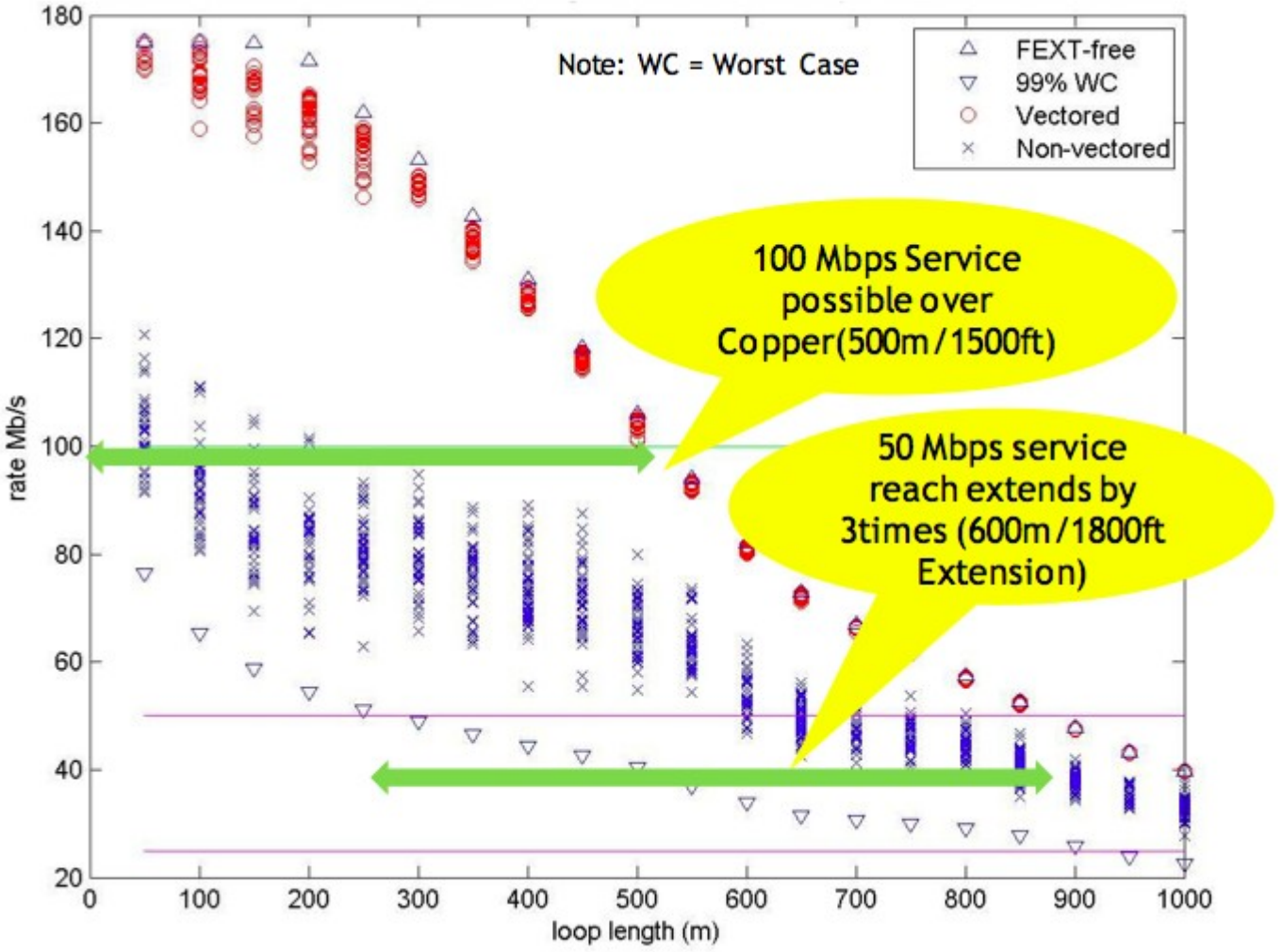

Air
Air/silica boundary
β_1
β_2
β_3
α_1
α_2
α_3
Silica
Total internal reflection.
Light source


(a)
(b)
0.85μ Band
1.30μ Band
1.55μ Band
Attenuation (dB/km)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Wavelength (microns)

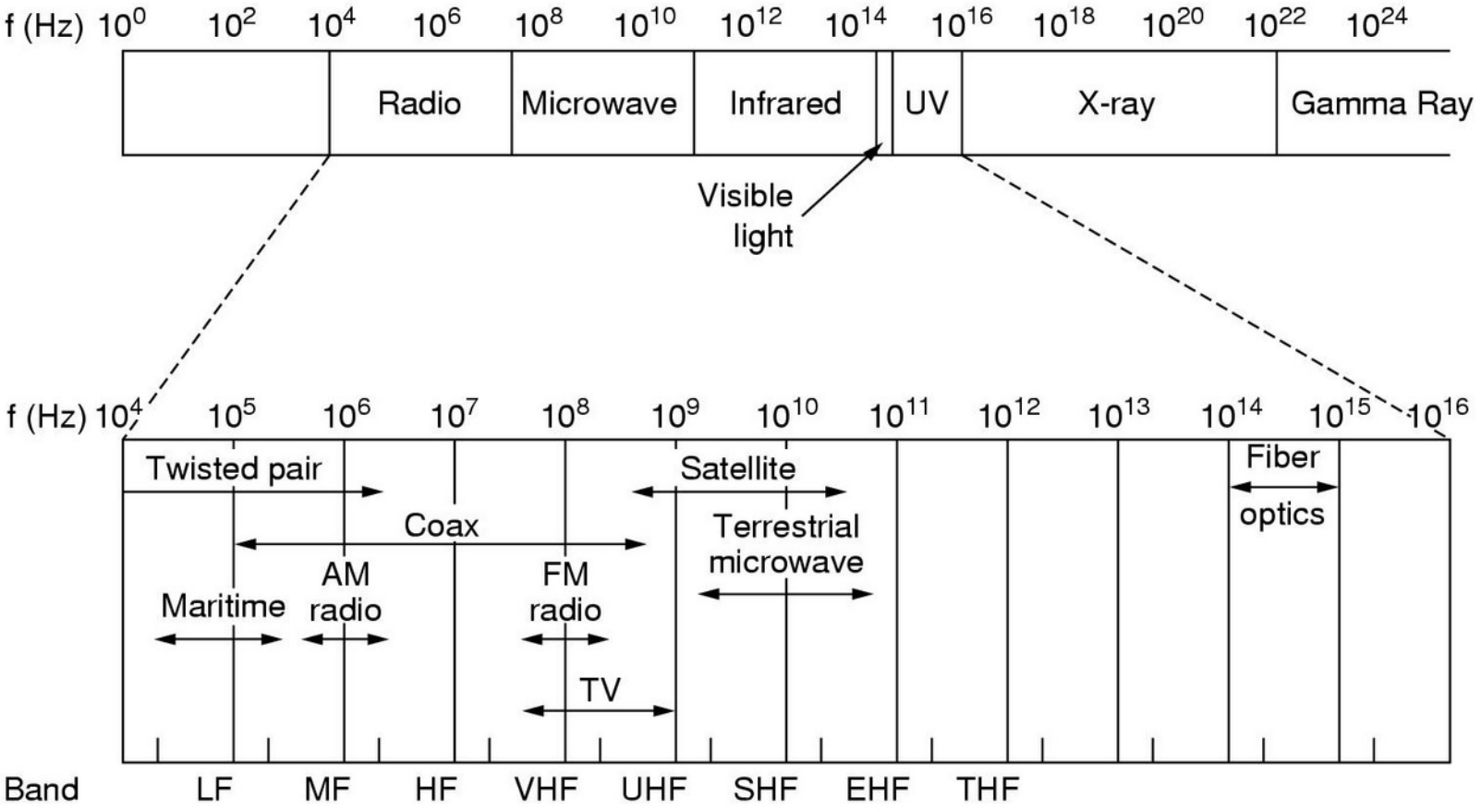
Glas vs Kupfer

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

Vectoring


Note: WC = Worst Case
FEXT-free
99% WC
Vectored
Non-vectored
100 Mbps Service possible over Copper(500m/1500ft)
50 Mbps service reach extends by 3times (600m/1800ft Extension)
rate Mb/s
loop length (m)
180
160
140
120
100
80
60
40
20
0
100
200
300
400
500
600
700
800
900
1000

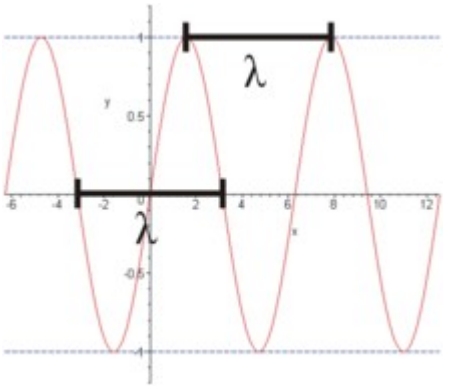
EM-Spektrum


f (Hz) 10^0 10^2 10^4 10^6 10^8 10^10 10^12 10^14 10^16 10^18 10^20 10^22 10^24
Radio
Microwave
Infrared
UV
X-ray
Gamma Ray
Visible light
f (Hz) 10^4 10^5 10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16
Twisted pair
Coax
Satellite
Terrestrial microwave
Fiber optics
Maritime
AM radio
FM radio
TV
Band
LF
MF
HF
VHF
UHF
SHF
EHF
THF

Drahtlose Übertragung

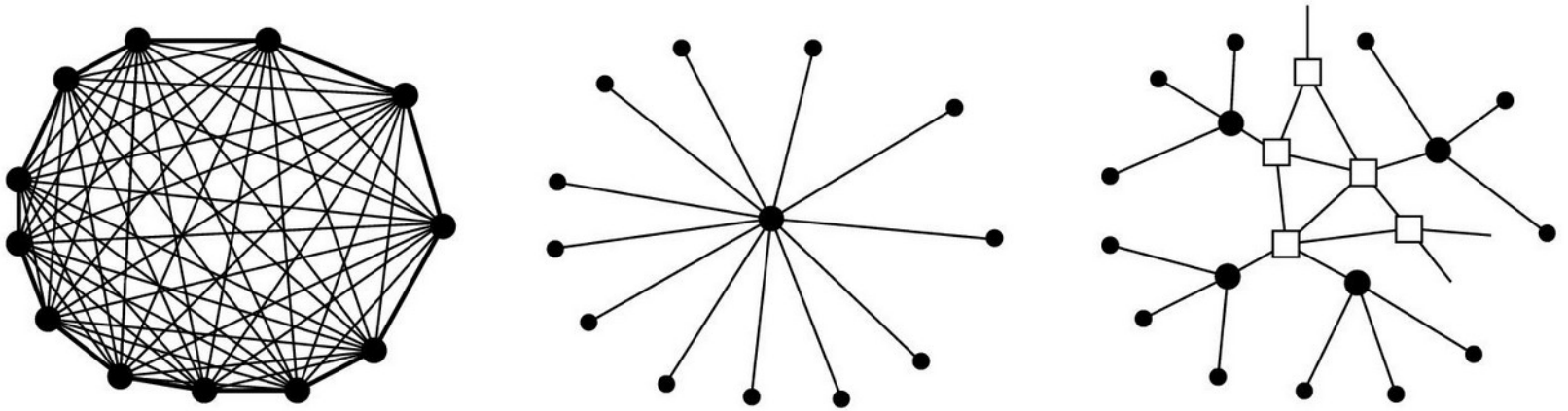
- Elektronen -> elektromagnetische Wellen
- Maxwell 1865
- Hertz 1887
- Marconi
- Radio
- Mikrowellen
- Infrarot
- Lichtwellen, optischer Richtfunk (FSO)

$$\lambda = c / f$$



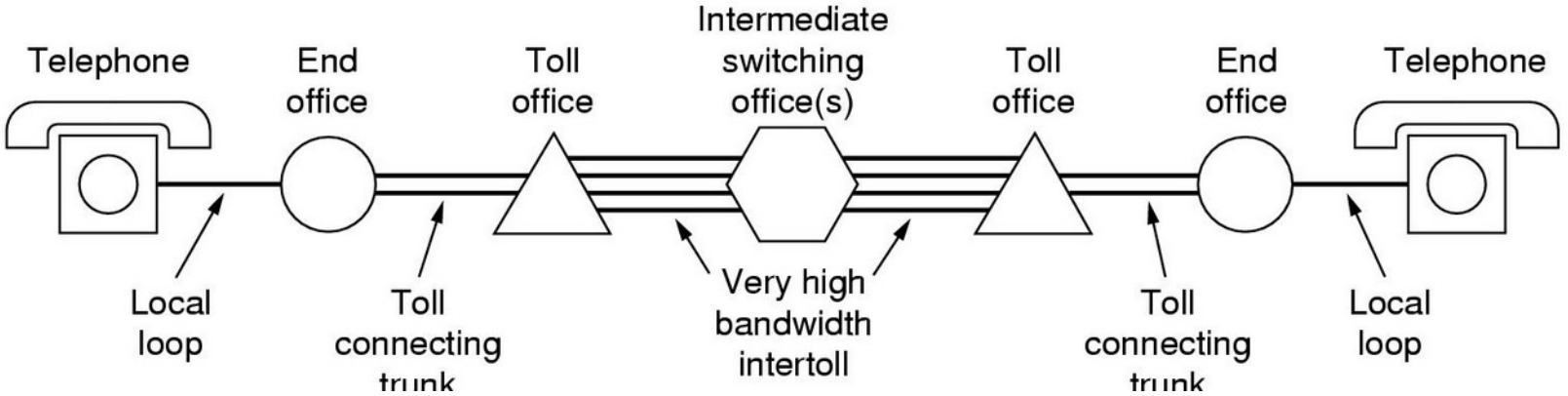
c = Ausbreitungsgeschwindigkeit
f = Frequzenz

Telefonsystem



(a) (b) (c)

1876 – 1890, Monopol bis 1984



Telefonnetz – Komponenten

- Ortsvermittlungen
- Fernvermittlungen
- Vermittlungsämter

Montreal telephone exchange (ca. 1895)

Analog vs Digital

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

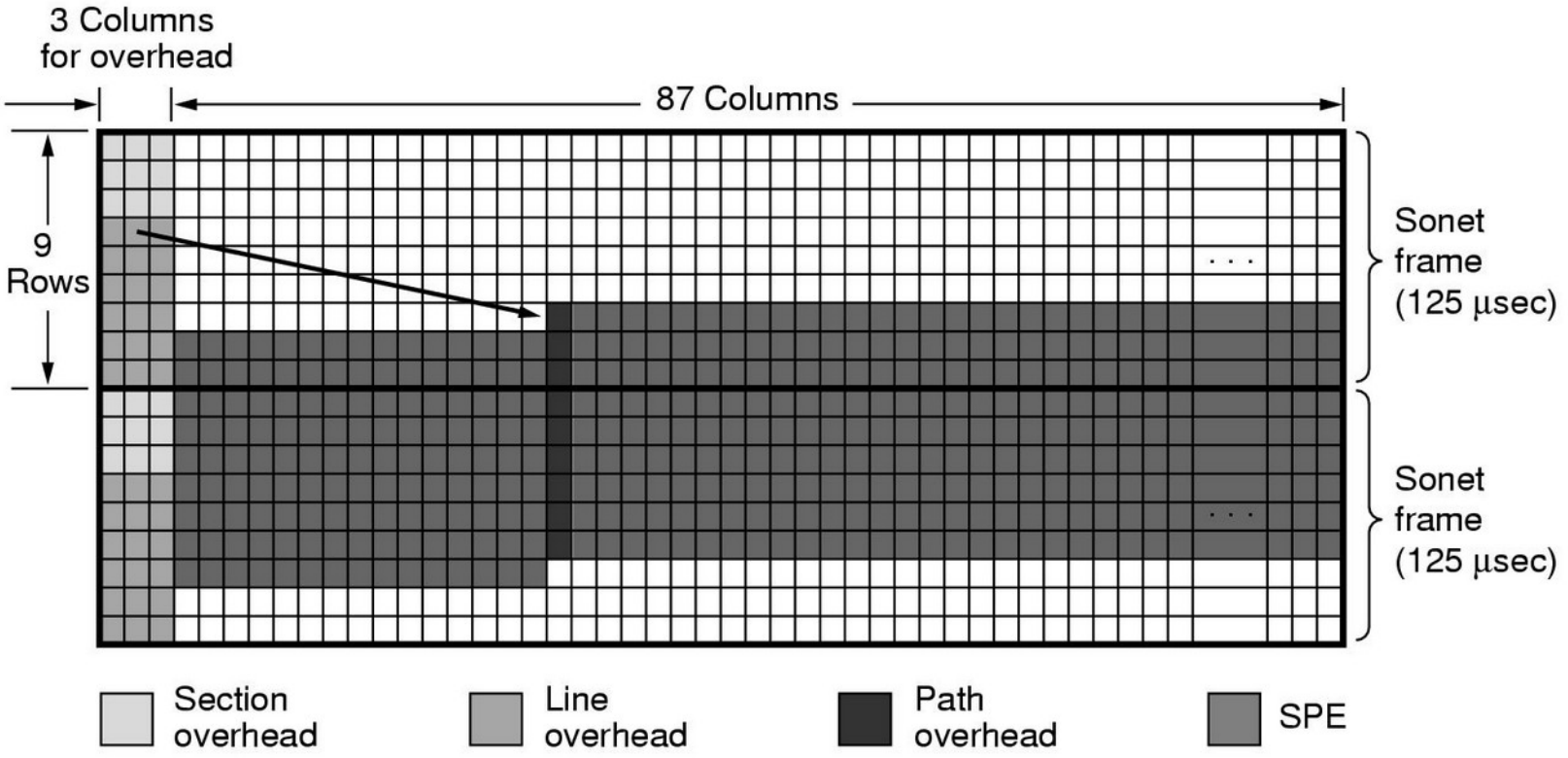
125µs

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

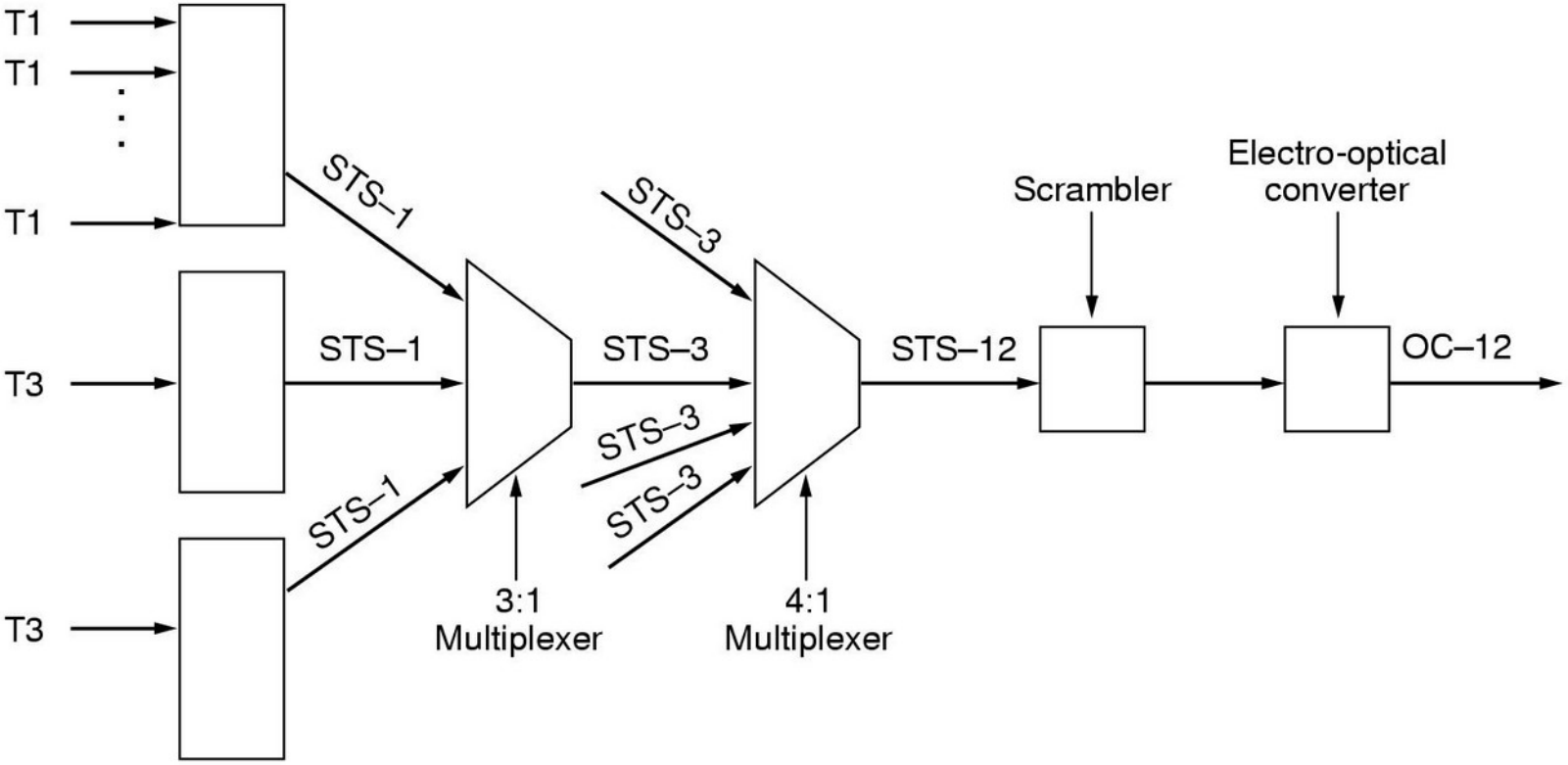
SONET/SDH

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

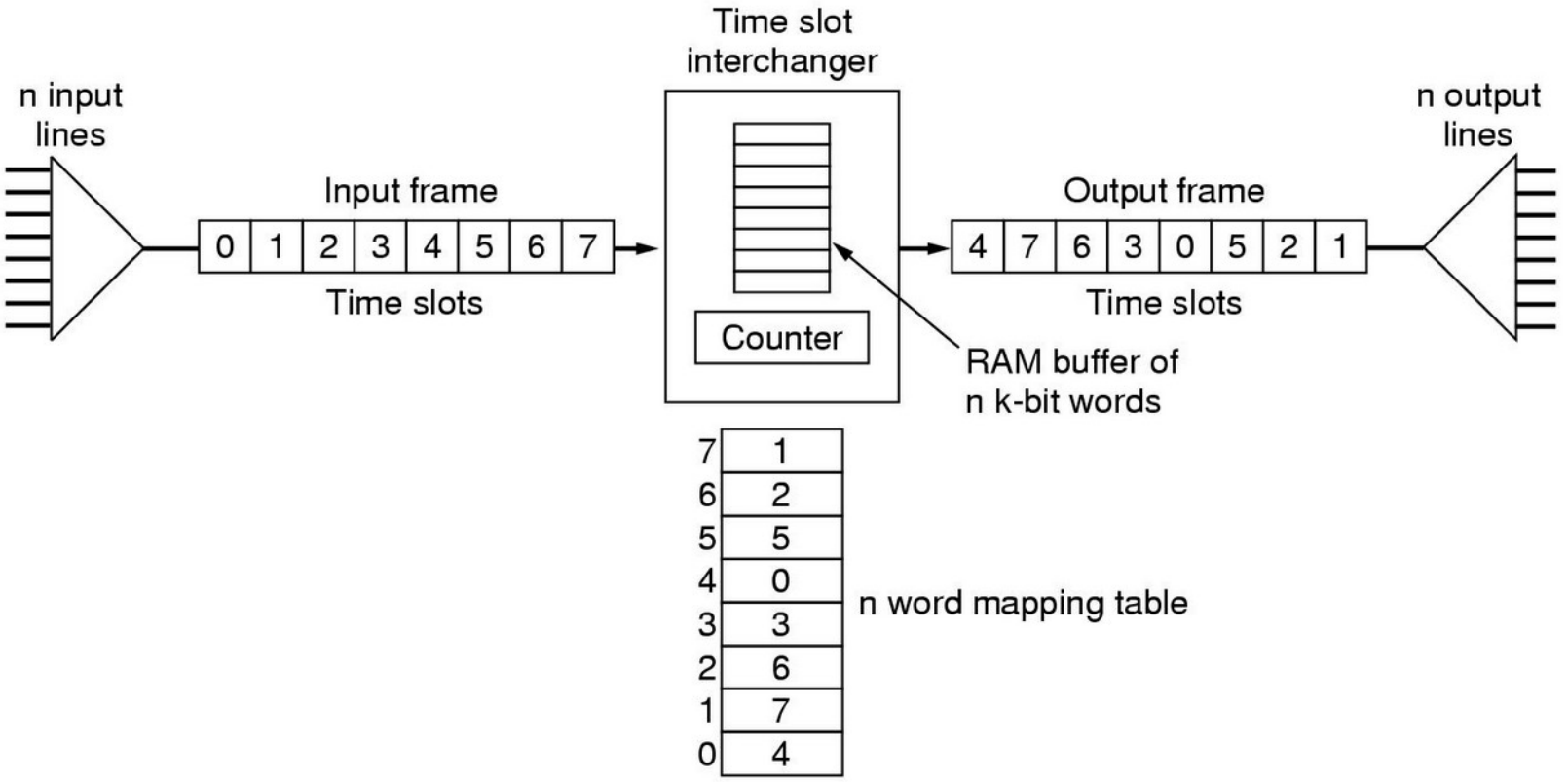
SONET Rahmen



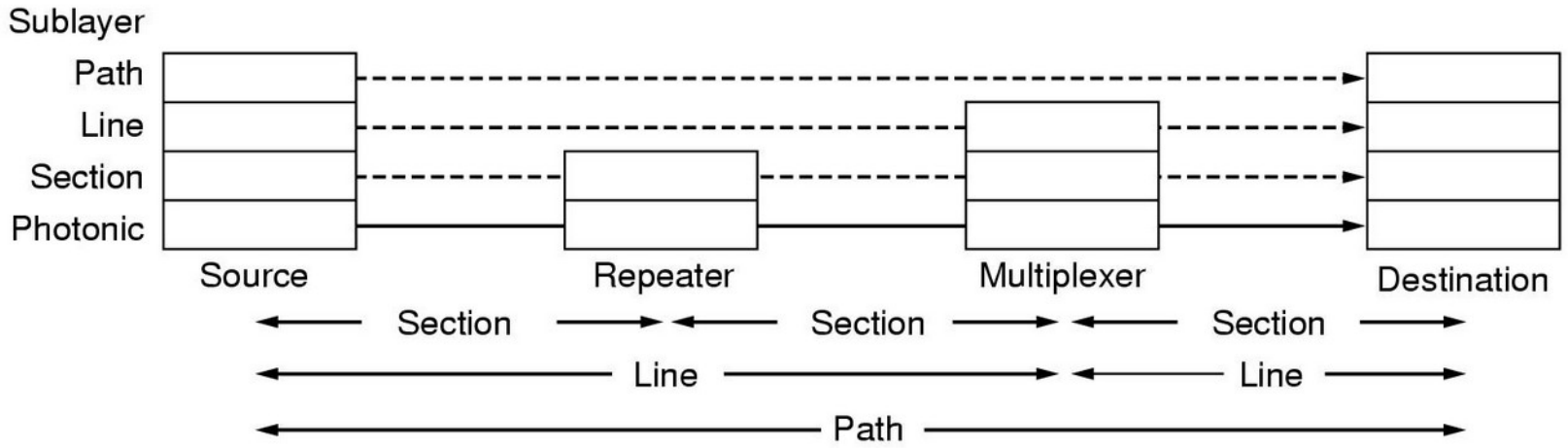
SONET Multiplex



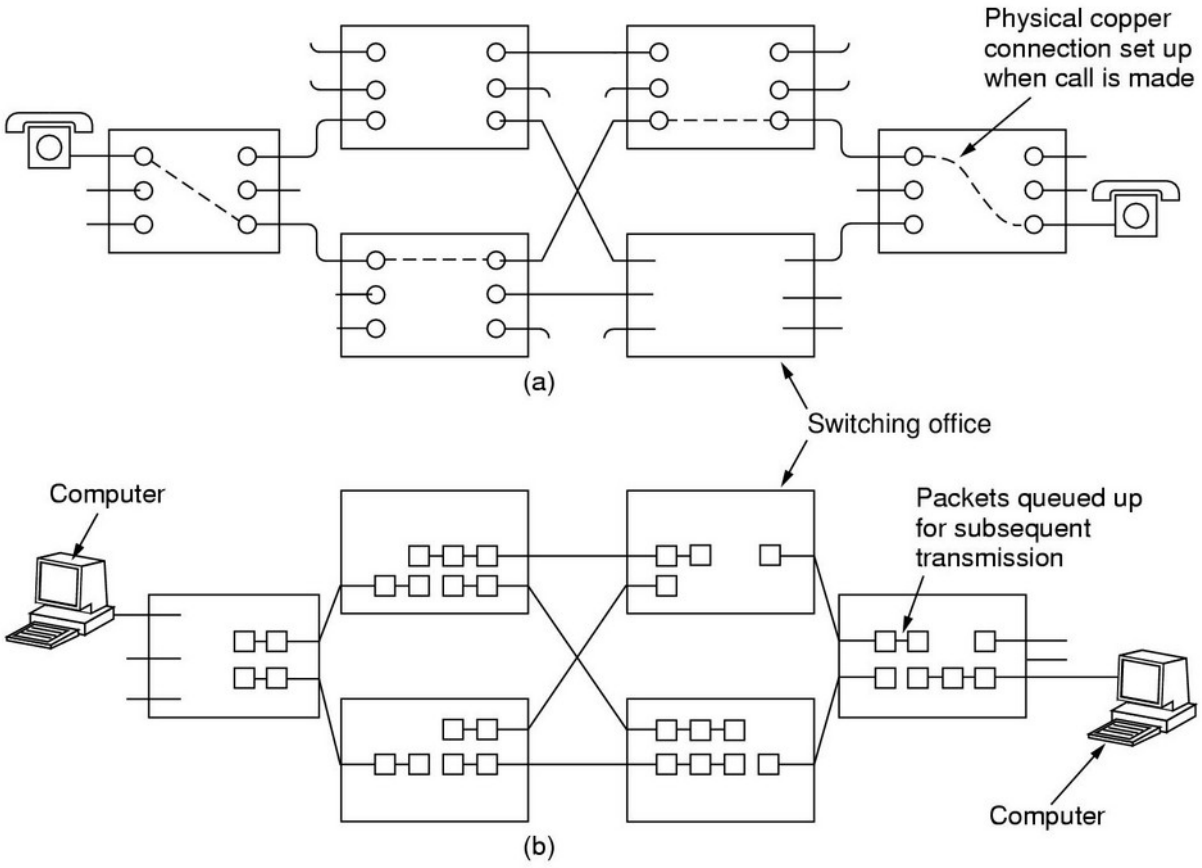
Zeitmultiplexvermittler



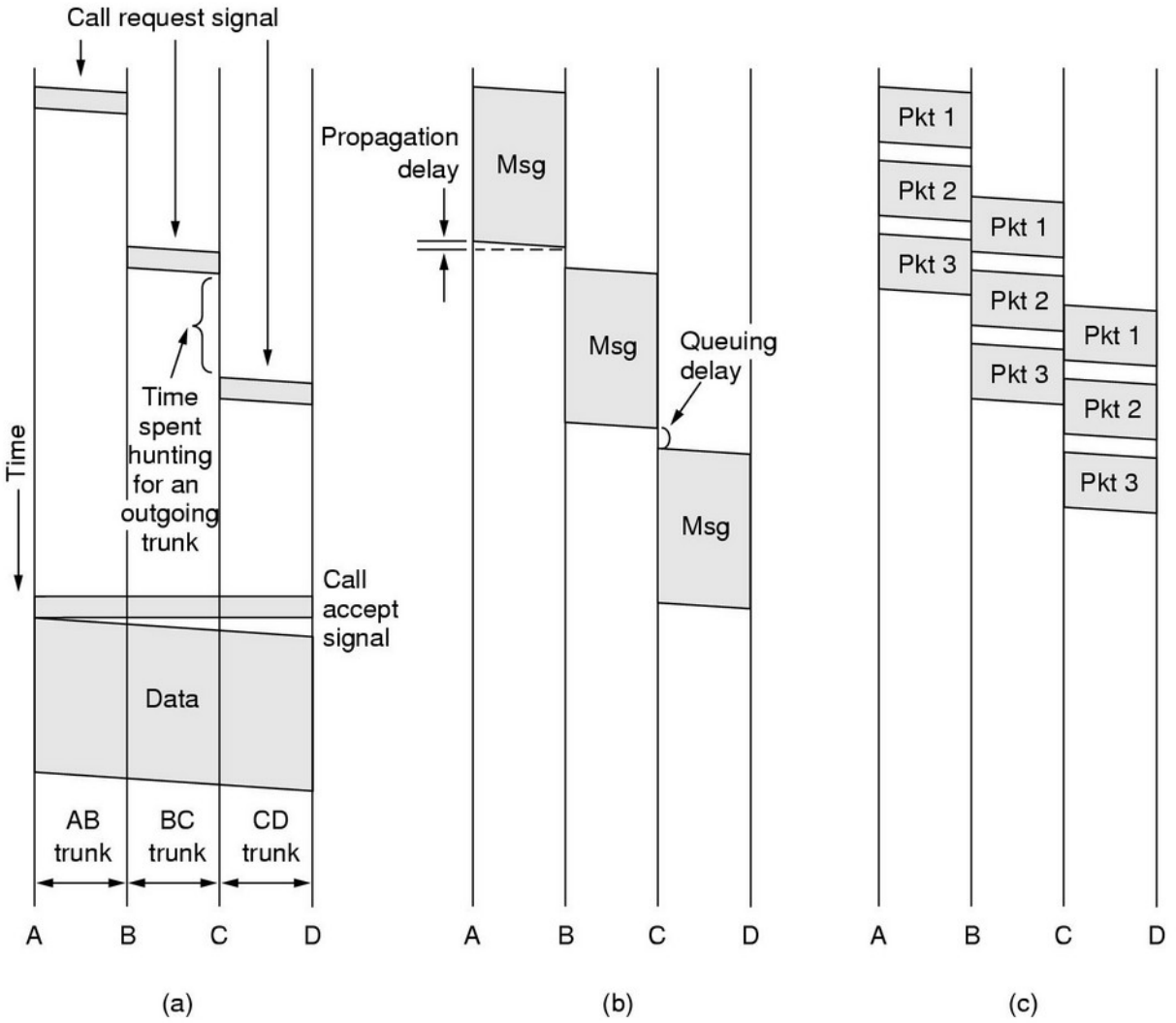
SONET Architektur



Vermittlung



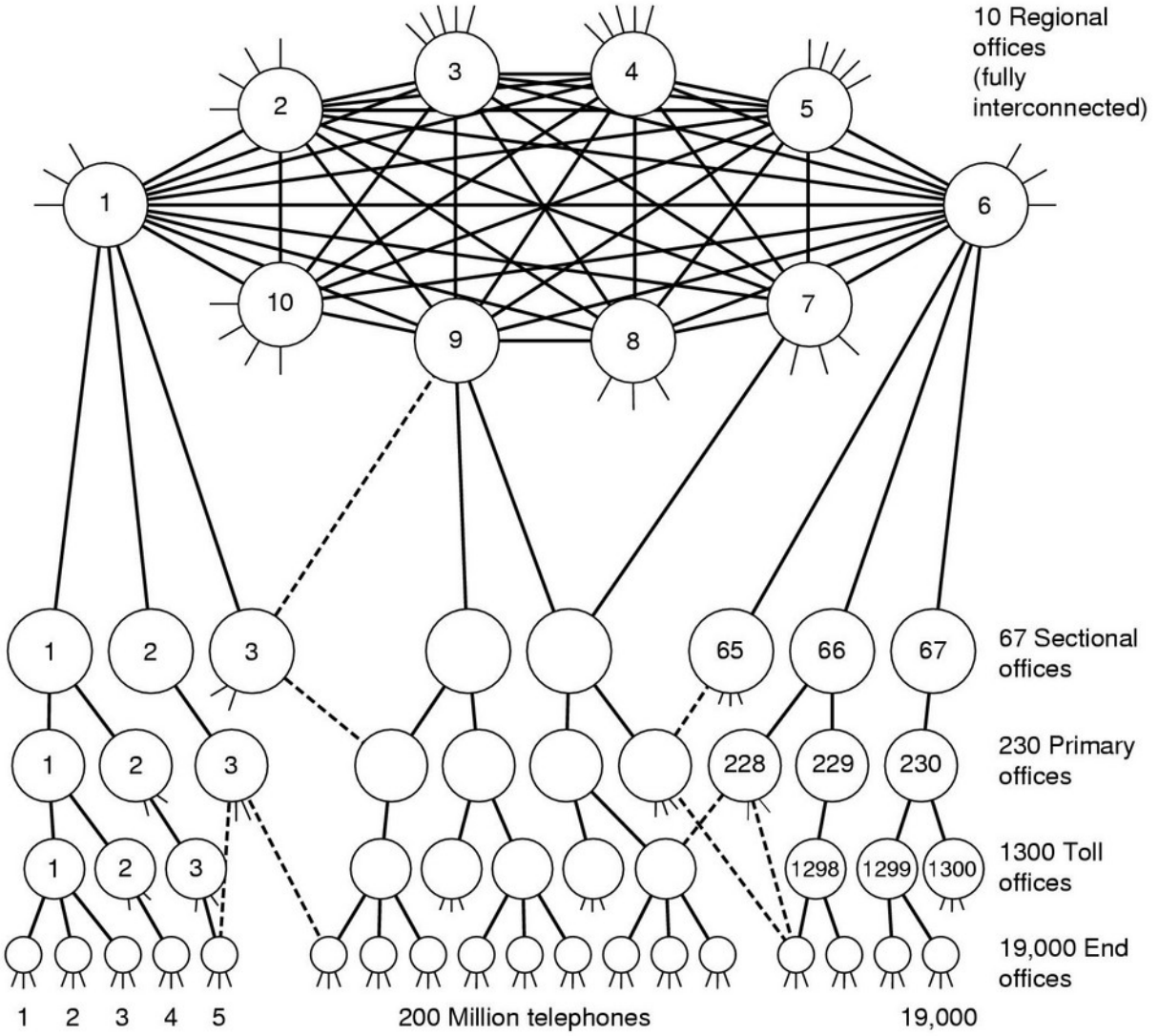
Vermittlungsarten



Vermittlung - Vergleich

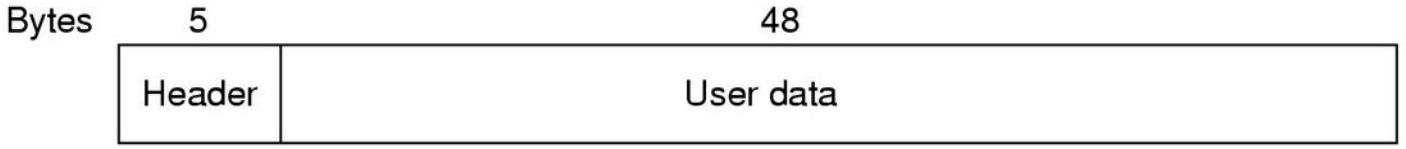
Merkmal	**Leitung**	**Paket**
Dedizierter Pfad	Ja	Nein
Bandbreite	Fest	Dynamisch
Belegung	Fix	Variabel
Pufferung	Nein	Ja
Route	Fest	Dynamisch
Verbindungsaufbau	Ja	Nein
Überlast	Anfang	Immer
Verrechnung	Zeit	Menge

Vermittlungshierarchie



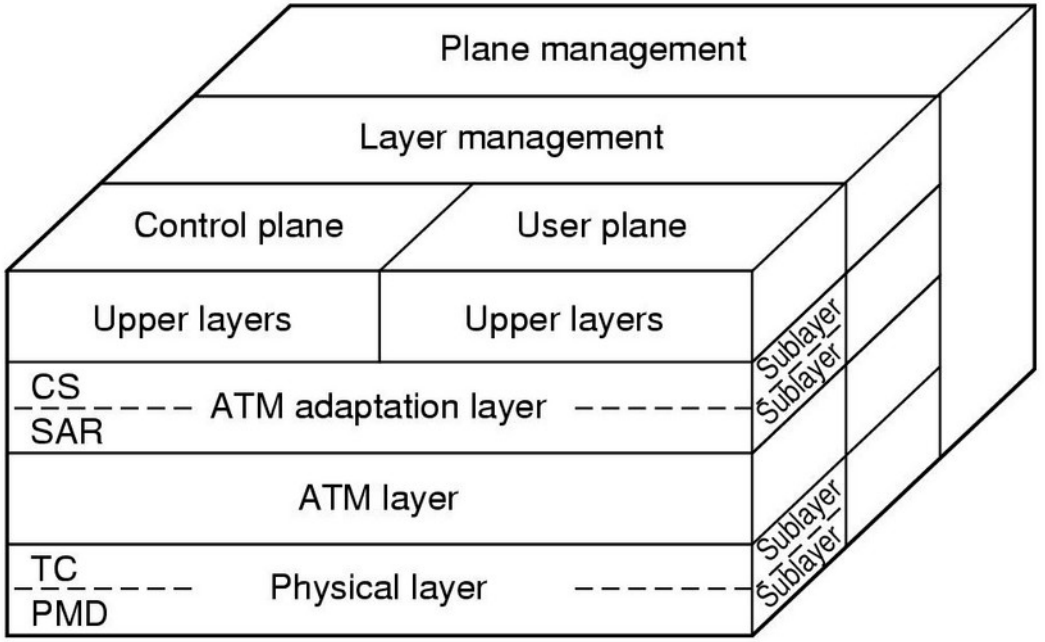
ATM

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



- 360000 Zellen/sec = 2.7 μs

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	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		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

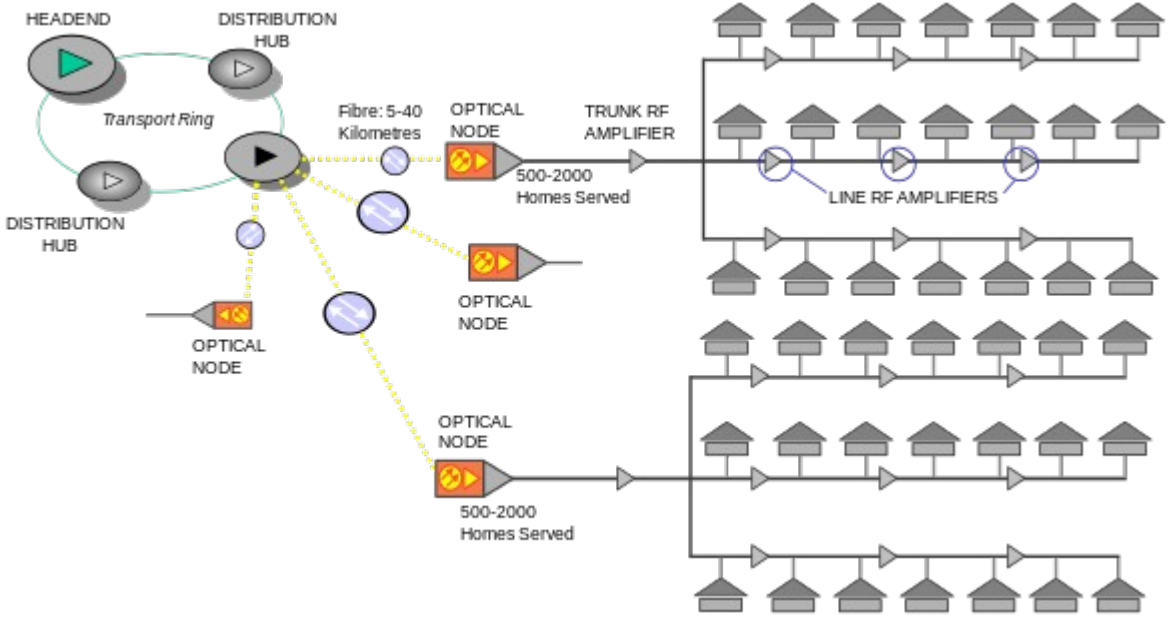
- B-Kanal 64 Kbps, D-Kanal 16 Kbps
- Basisanschluss 2B+1D
- Primär: 23B+1D, 30B +1D
- Leistungsmerkmale
  - Mehrfachrufnummer, Rufumleitung, Rufnummernanzeige, Konferenzschaltung, Anklopfen, Makeln, Parken, Subaddressierung, Tarifinfos, ...

xDSL/ADSL

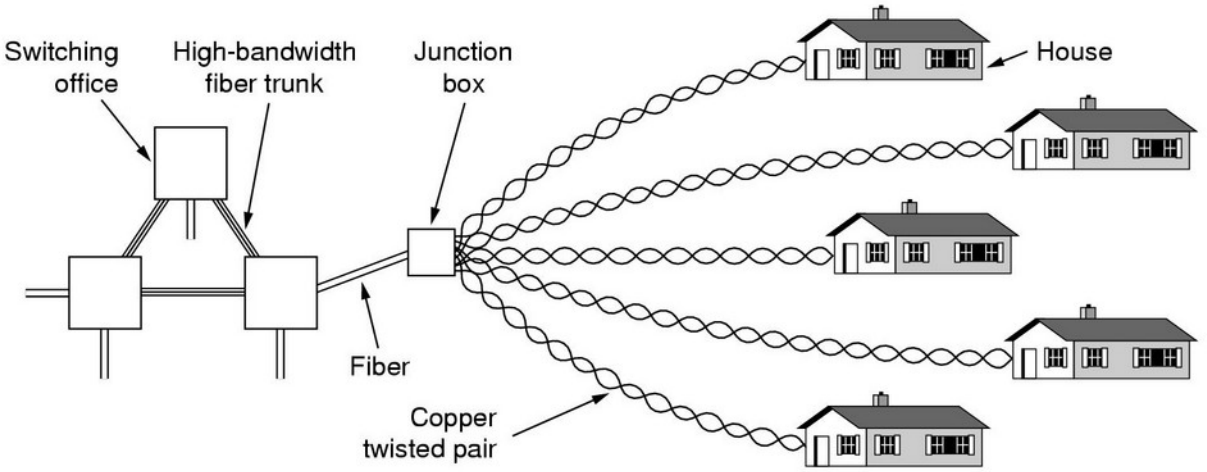
- (Asymmetric) Digital Subscriber Line
- Downstream/upstream
- 32Kbps-6Mbps/32Kbps-640Kbps
- Adaptiv
- DMT Modulation
- HDSL 1,544 Mbps bi-directional
- VDSL bis 52Mbps

Kabelmodem

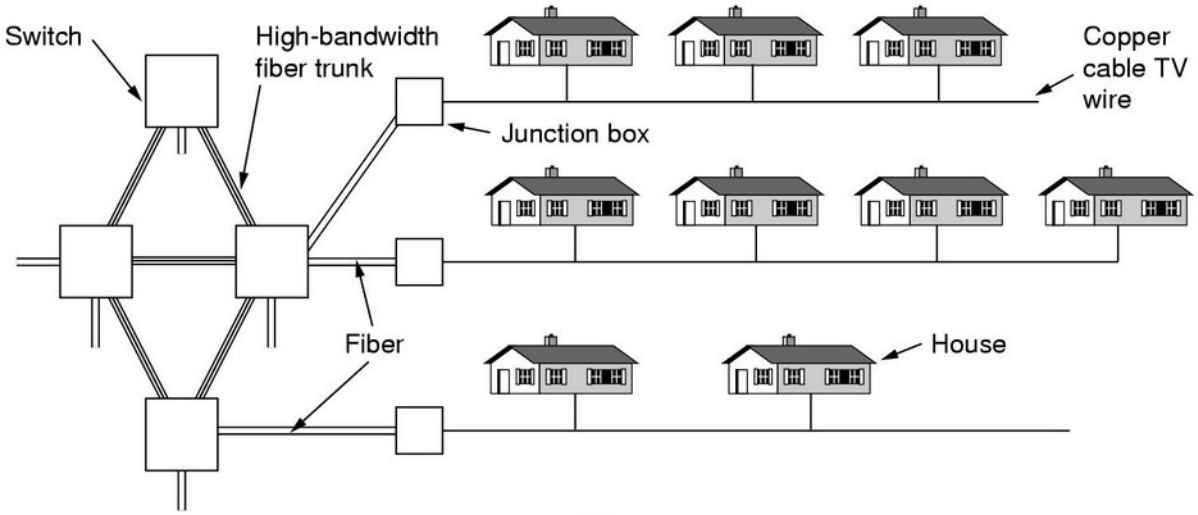
- Kabelfernsehen mit Rückkanal
- CATV Frequenzmultiplex
- Rückkanal Frequenz/Zeitmultiplex



FTTC

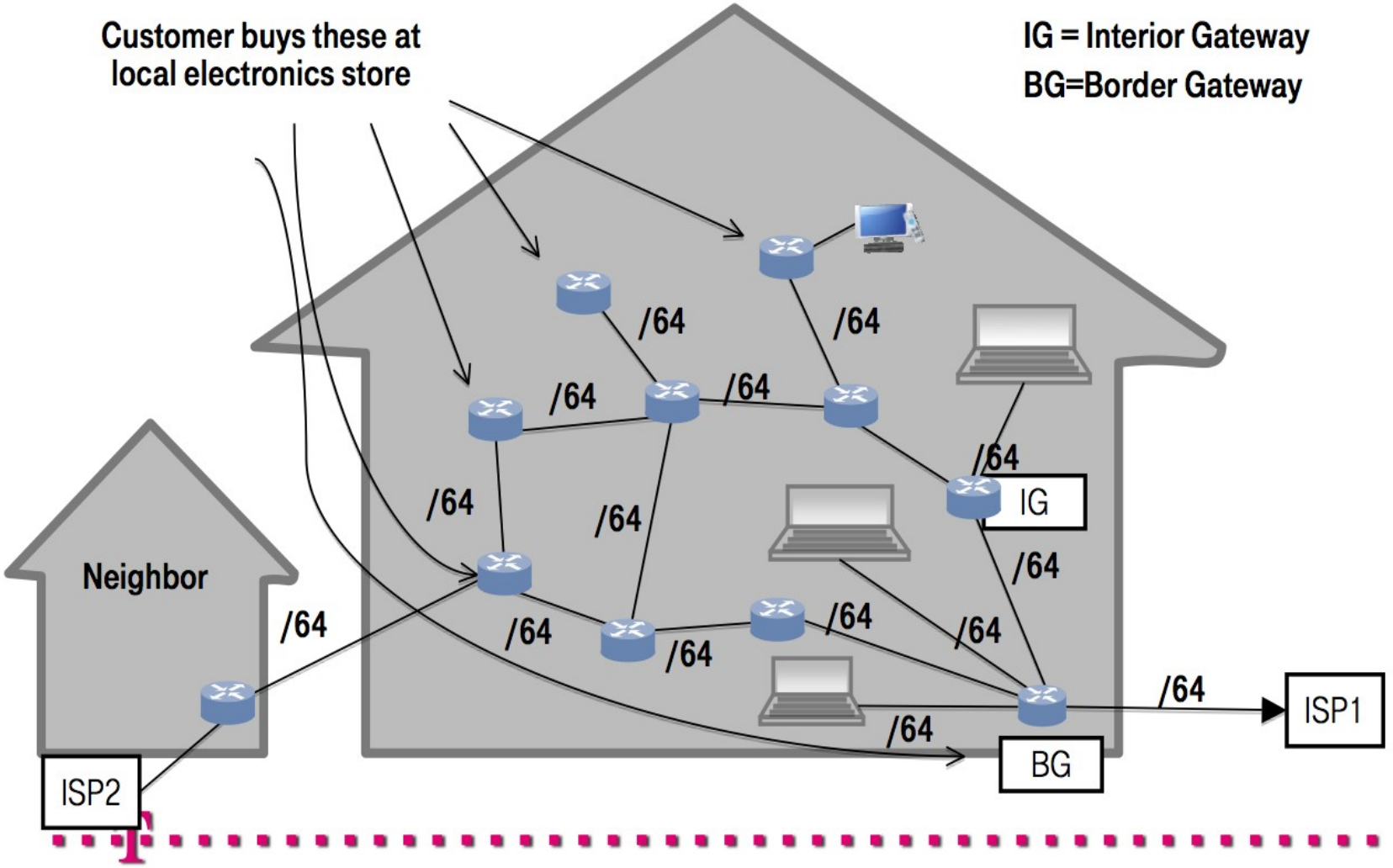

Switching office
High-bandwidth fiber trunk
Junction box
House
Fiber
Copper twisted pair

(a)


Switch
High-bandwidth fiber trunk
Copper cable TV wire
Junction box
Fiber
House

(b)

FTTH (zB Terastream)

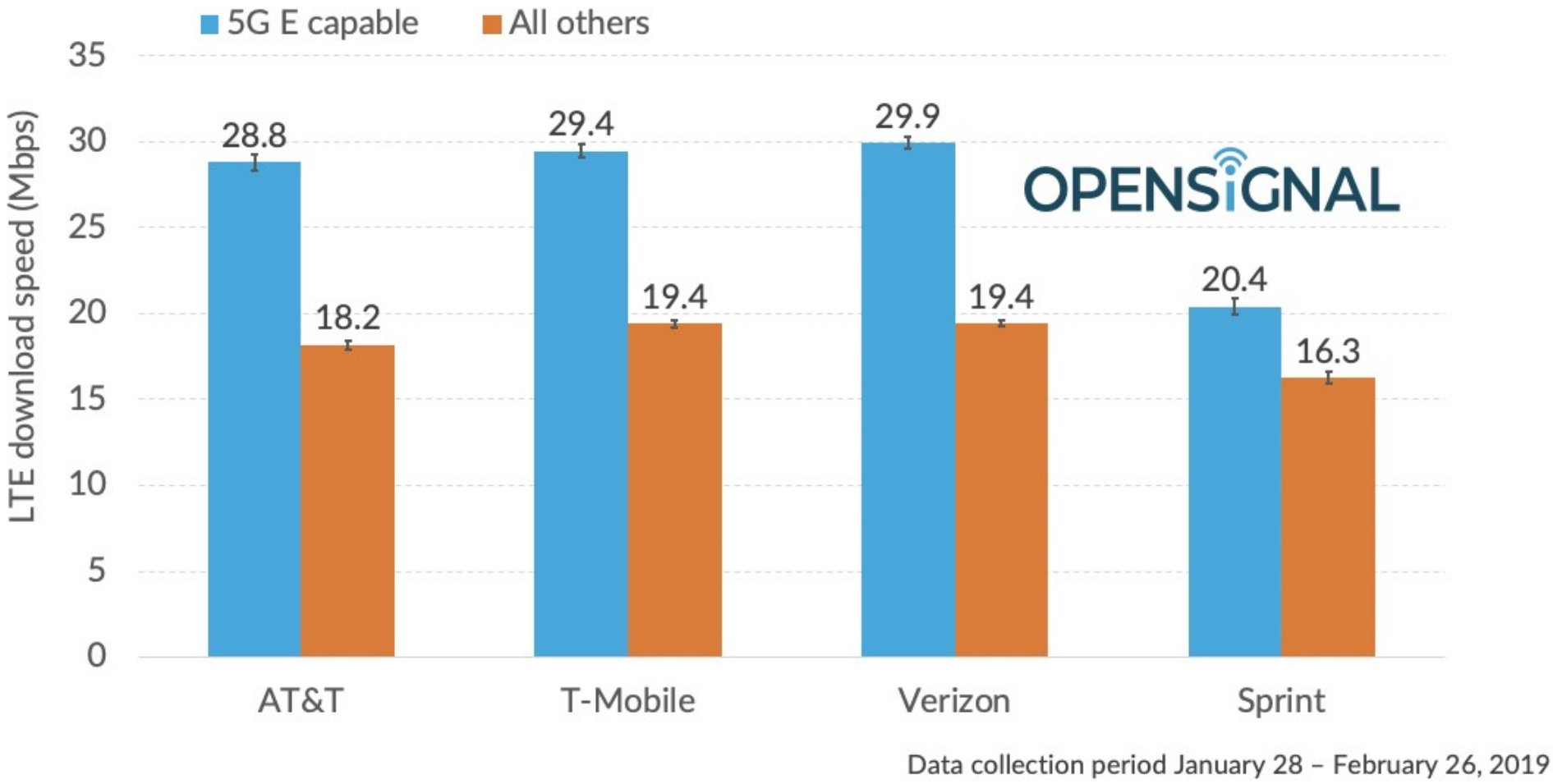


(Mobil)Funktelefone

- Analog
- DECT

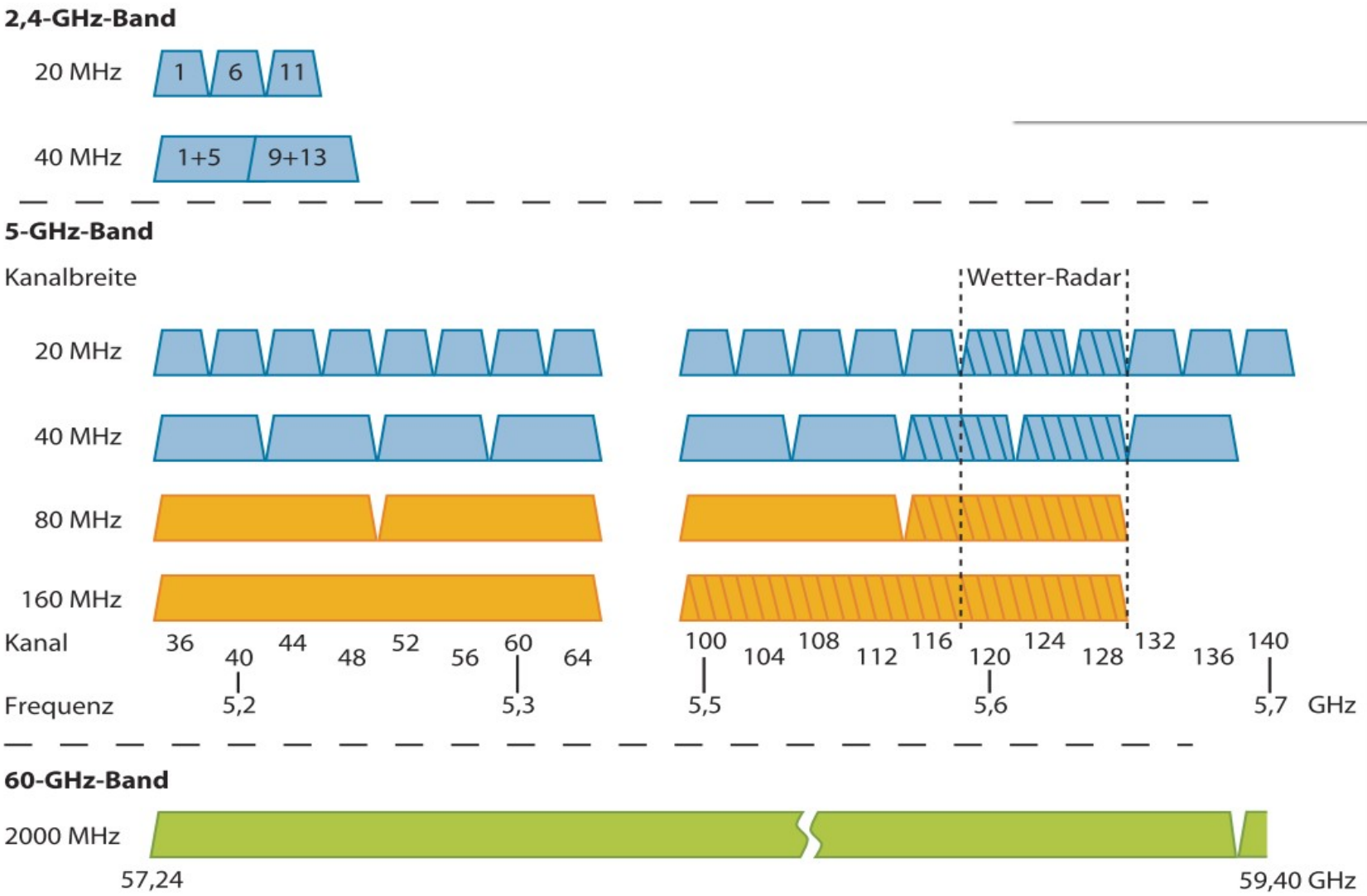
- GSM
- GPRS
- UMTS/3G
- EDGE
- HSDPA
- LTE (3.9G)
- 4G/5G

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/

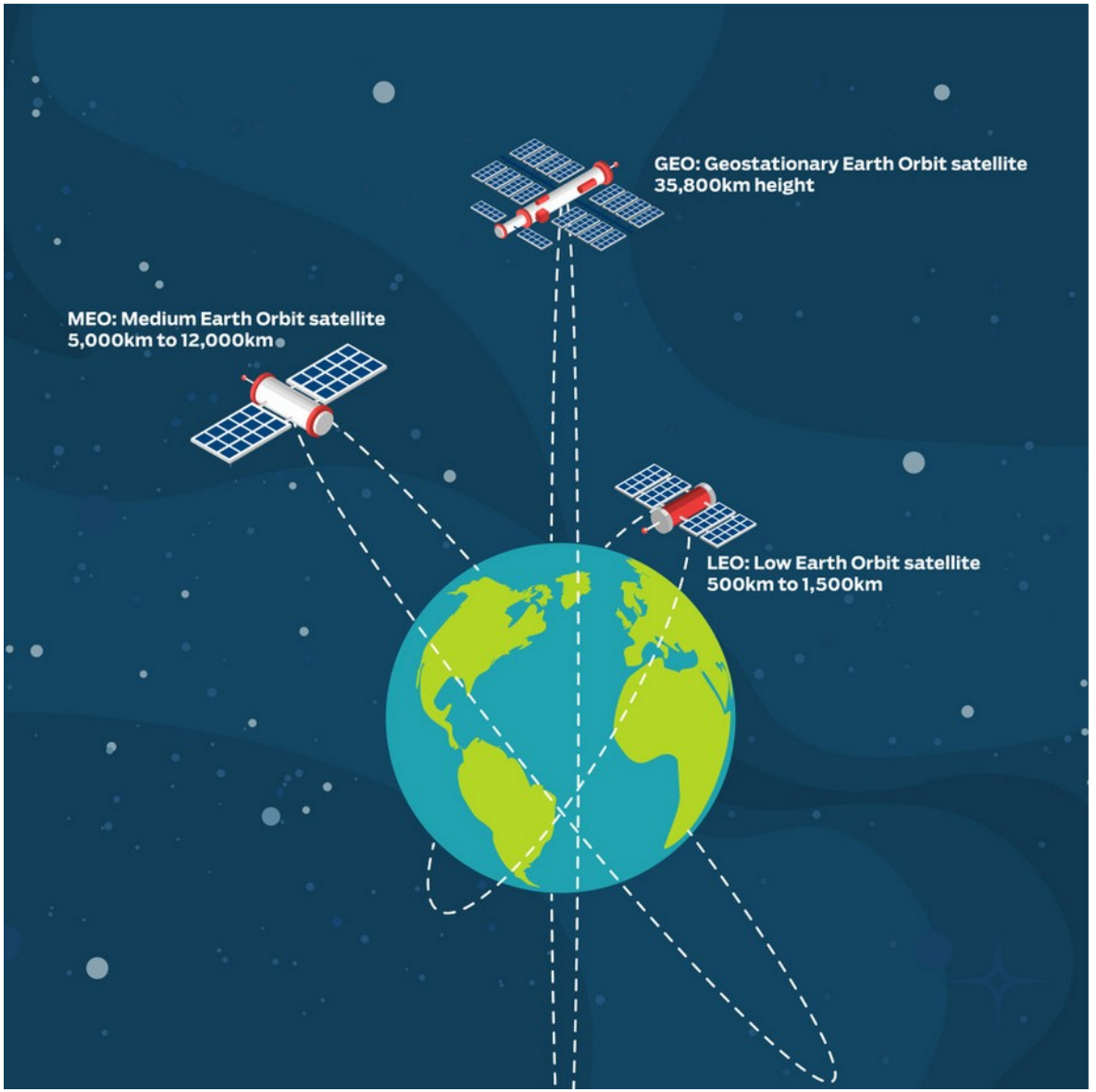
WLAN IEEE 802.11etc



Satelliten

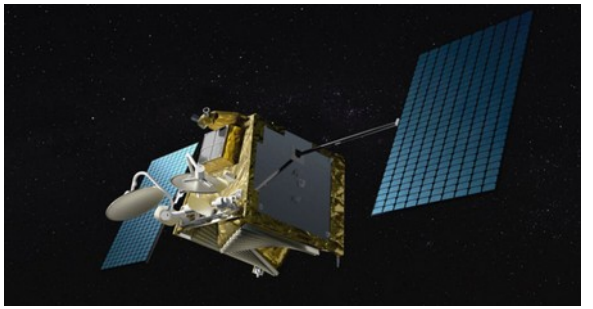
- GEO, MEO, LEO
- VSAT
- Direct Broadcast
- C-, Ku-, Ka-Band, Q/V-Band
- 4, 12, 20, 50 GHz downlink
- 6, 14, 30, 70 GHz uplink

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



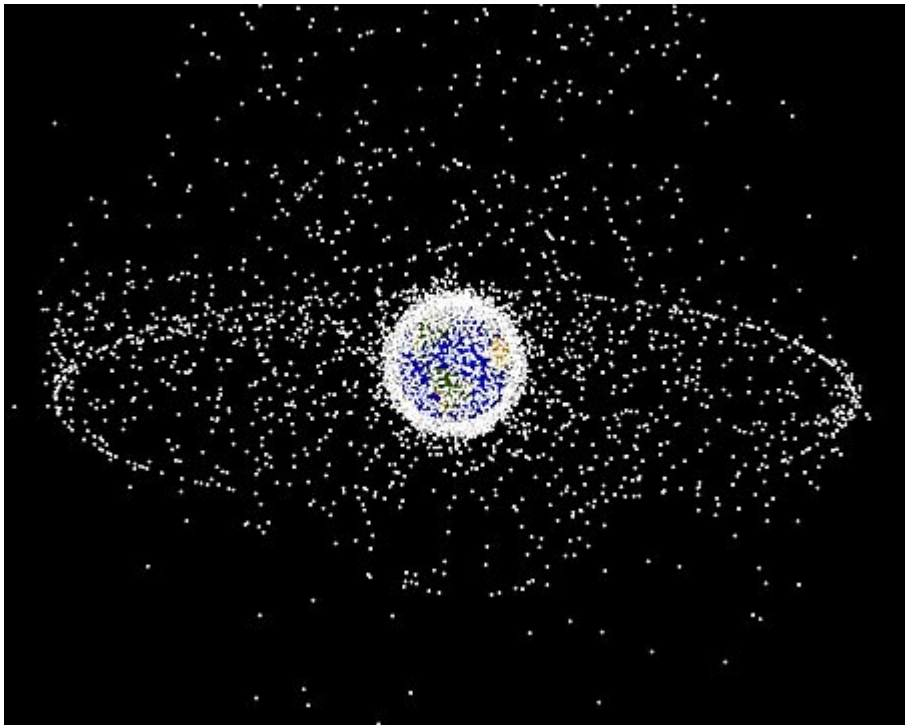
https://www.pcmag.com/article/362695/why-satellite-internet-is-the-new-space-race

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)

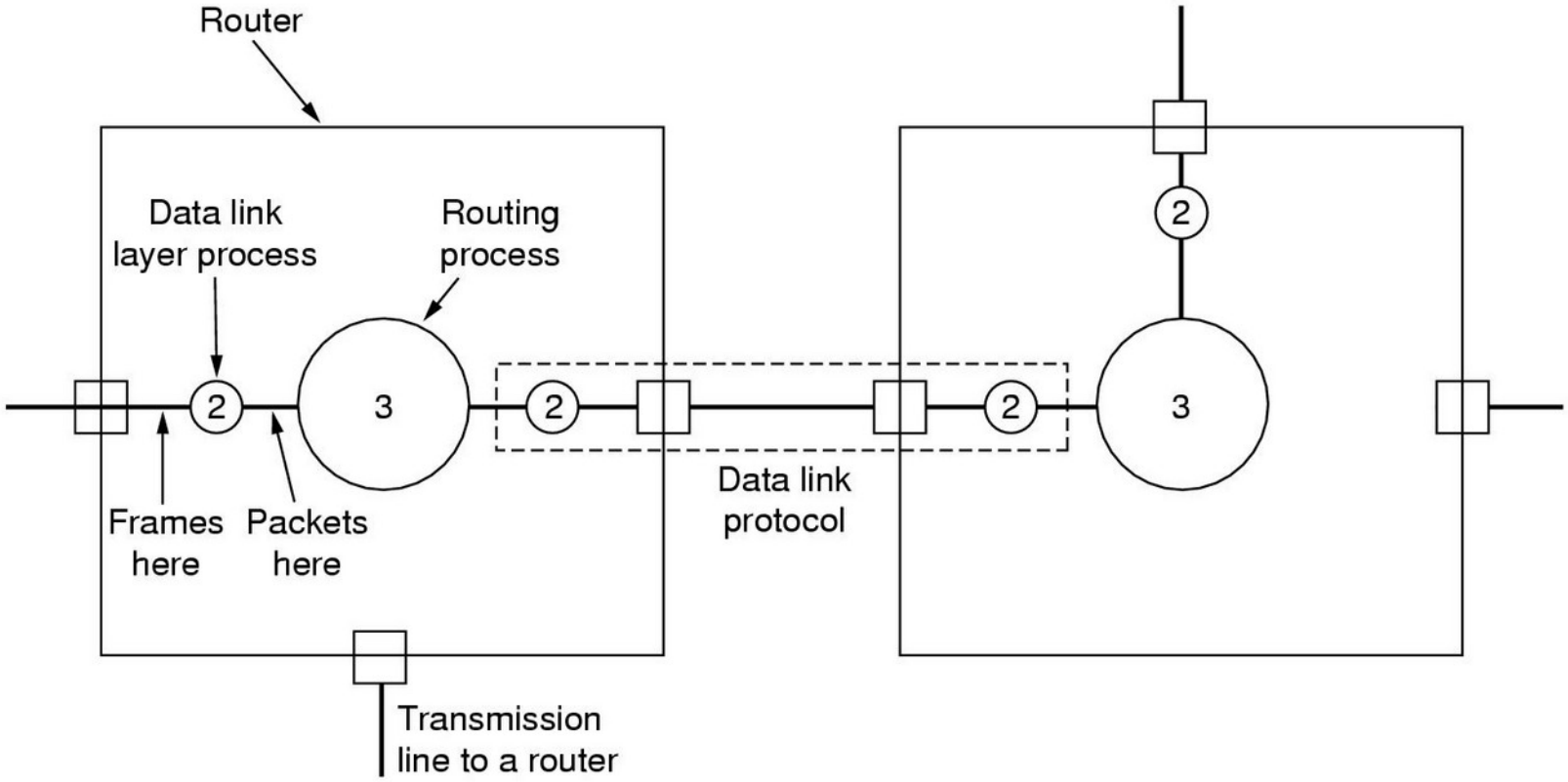


Cut

Ende 2. Termin (Online) 12.3.20

Beginn 3.Termin (Online) 19.3.20

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

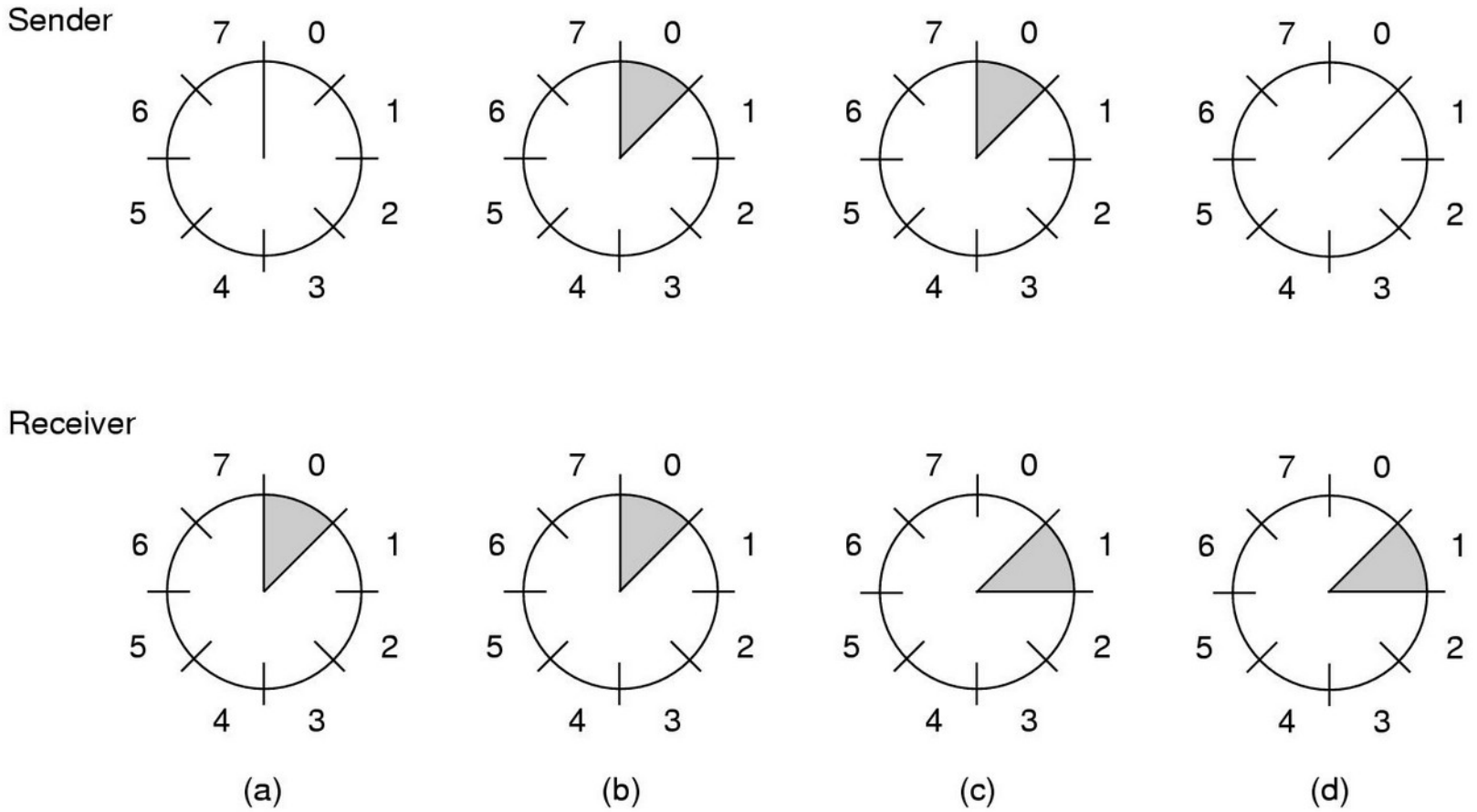
- Receiver
- While (true)
  - Wait_for_event(e)
  - From_phys_layer(f)
  - To_netw_layer(f.info)
  - To_phys_layer(x)
- End while

ARQ Protokoll

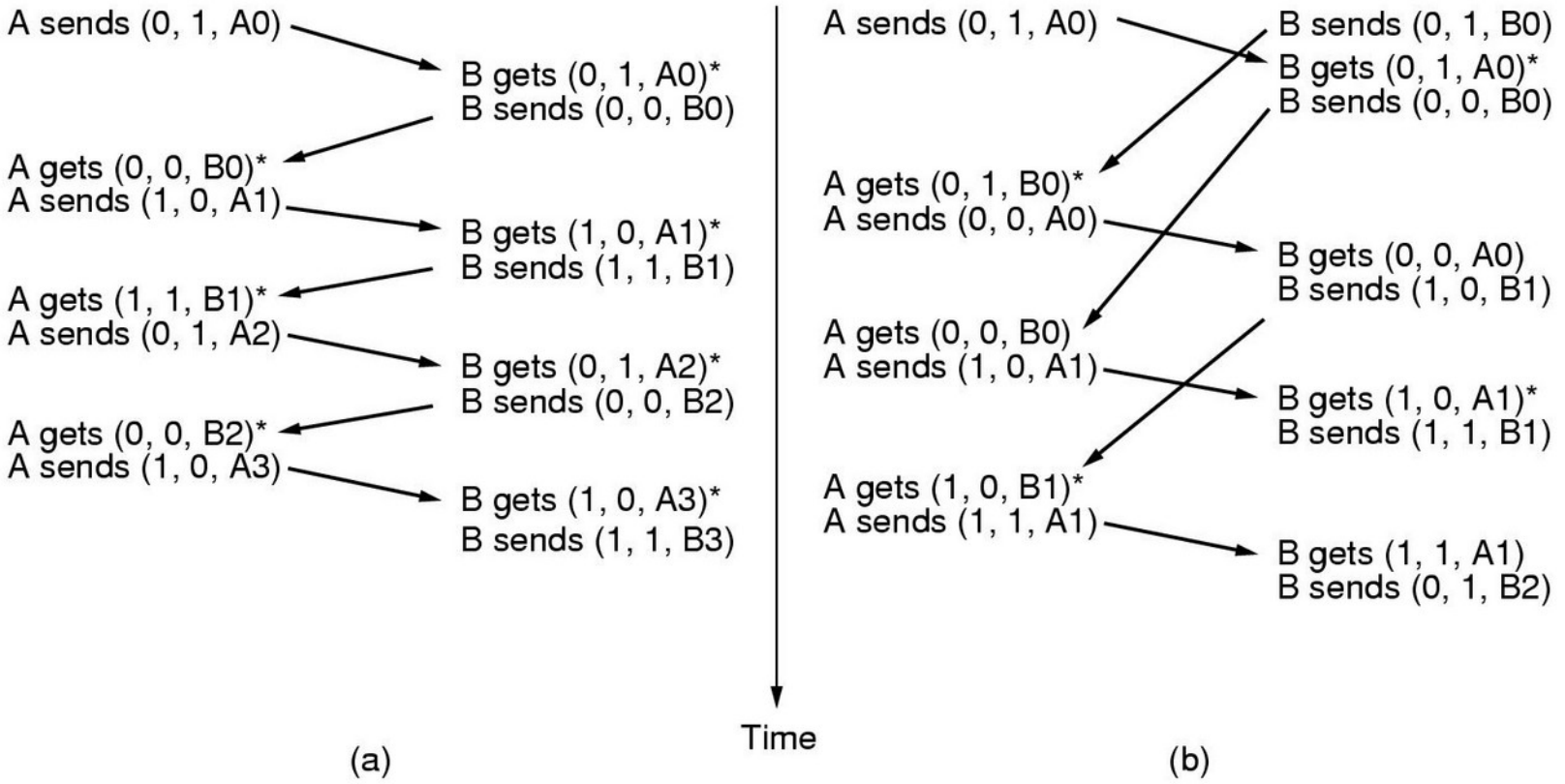
- Sender
- From_netw_layer(b)
- While(true)
  - F.seq = seq
  - f.info = b
  - To phys_layer(f)
  - Wait_for_event(e)
  - If f.seq=seq then
    - seq++
    - From_netw_layer(b)
  - End if
- End while

- 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



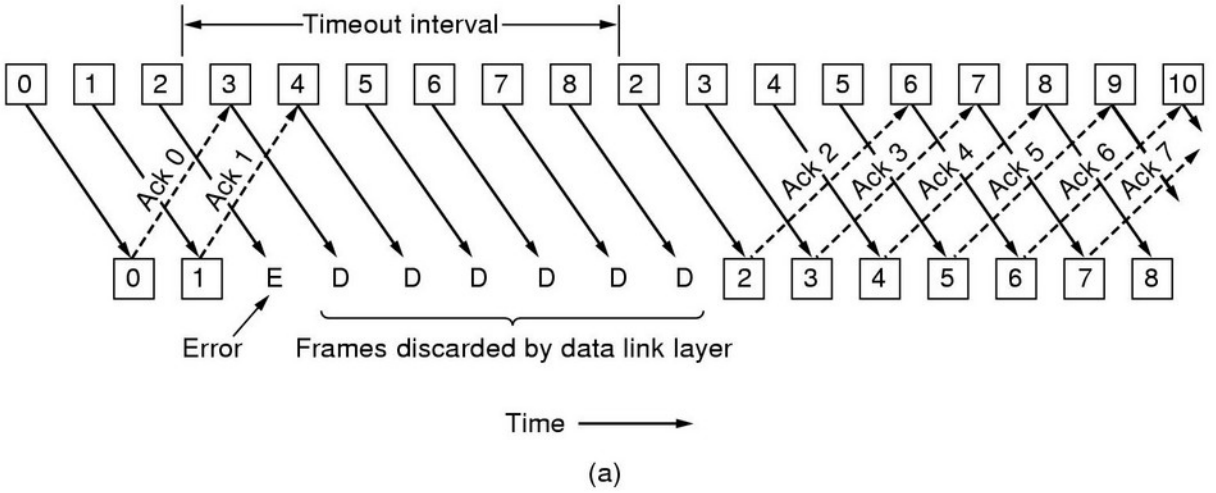
Schiebefenstergröße w

BD = Bandwidth [bps] * Delay [s] / bit pro Rahmen

$$w = 2 * BD + 1$$

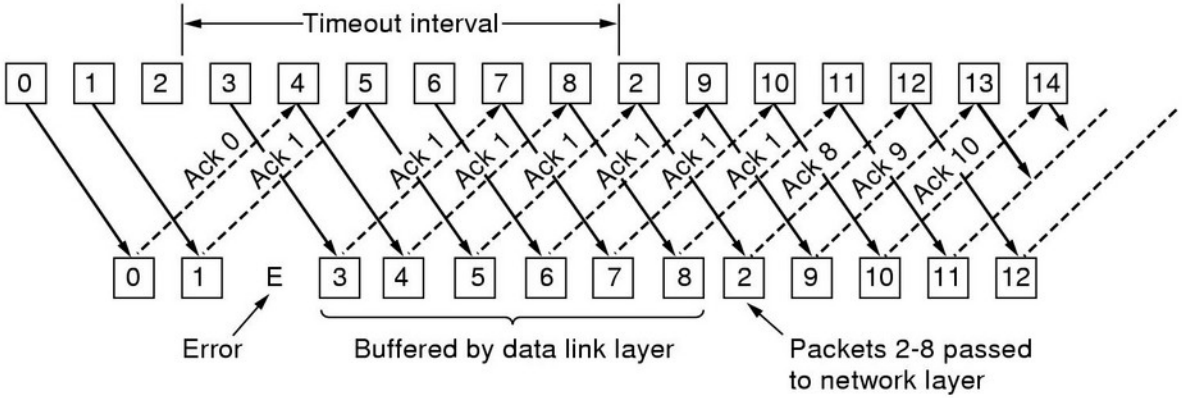
Schiebefenster und Fehler

Go-back-N



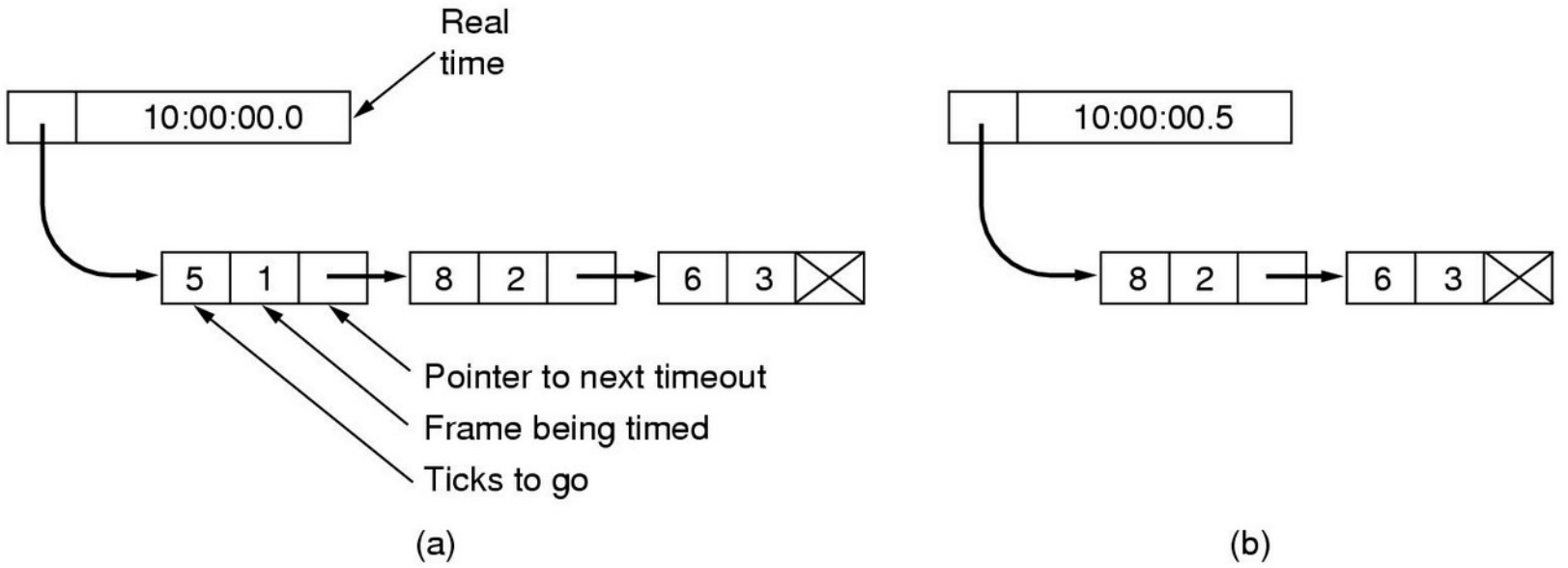
(a)

Selective Repeat w/ cummulative Ack



(b)

Implementierung von Timern

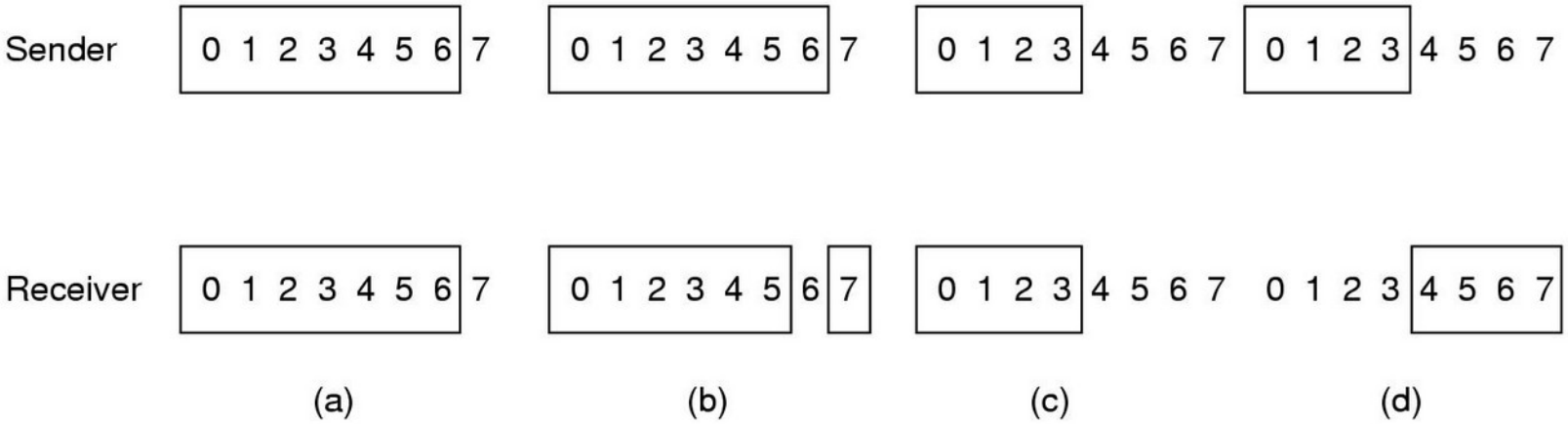


Uhren-Probleme aktuell ;)

“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

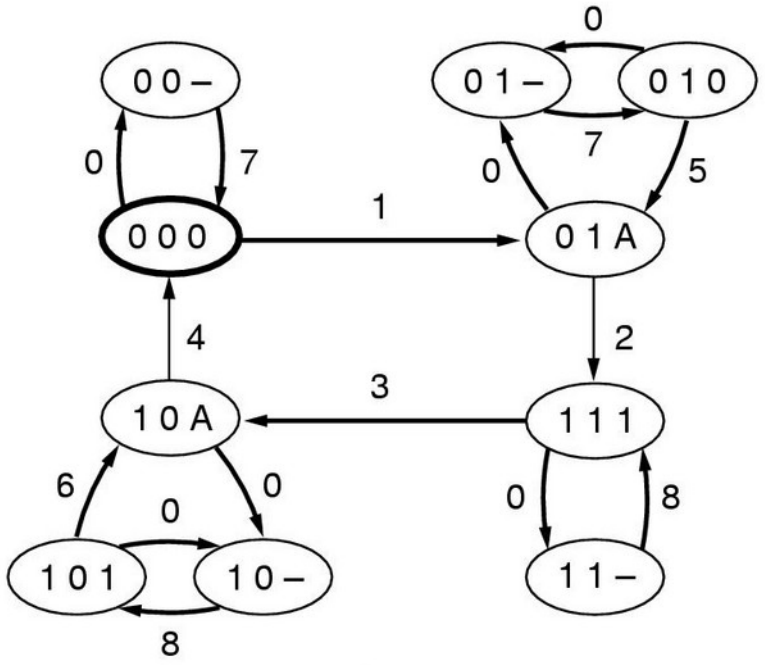
Selective-Repeat



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

Solution:
Use only half of window!

Protokollspezifikation FSM

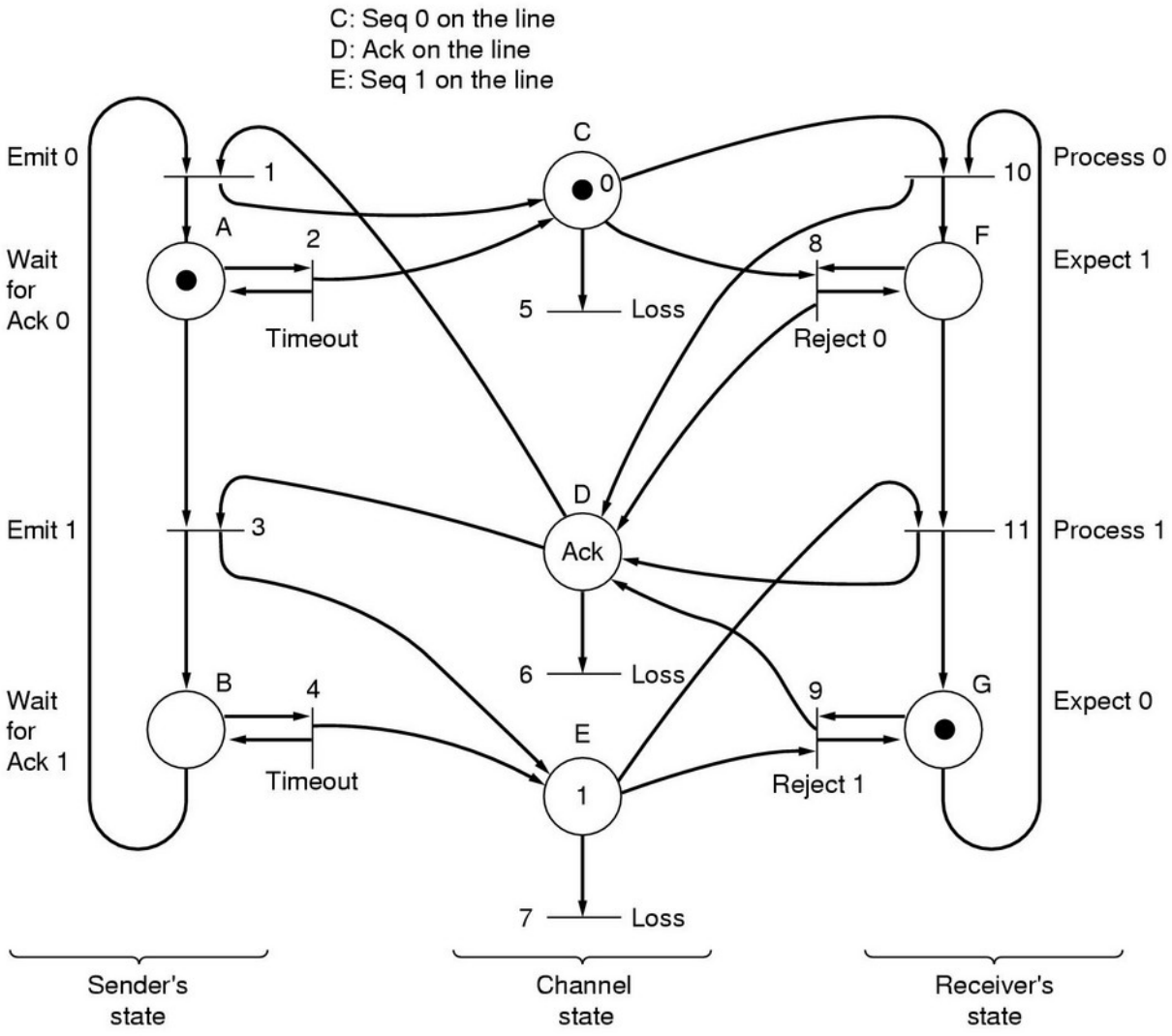


(a)

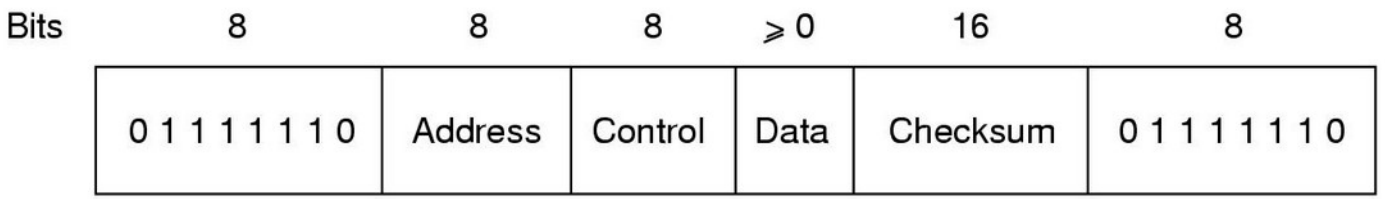
Transition	Who runs?	Frame accepted	Frame emitted	To network layer
0	–	(frame lost)		–
1	R	0	A	Yes
2	S	A	1	–
3	R	1	A	Yes
4	S	A	0	–
5	R	0	A	No
6	R	1	A	No
7	S	(timeout)	0	–
8	S	(timeout)	1	–

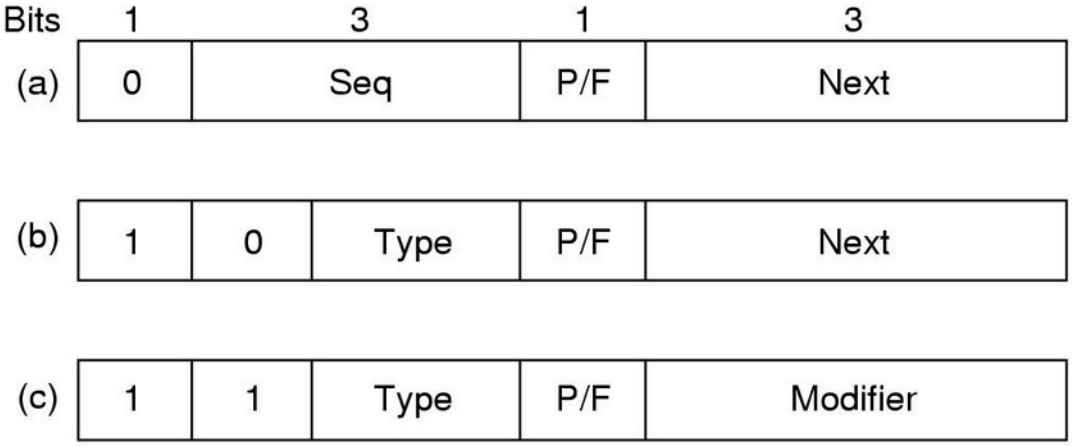
(b)

Protokollspezifikation PetriNetze

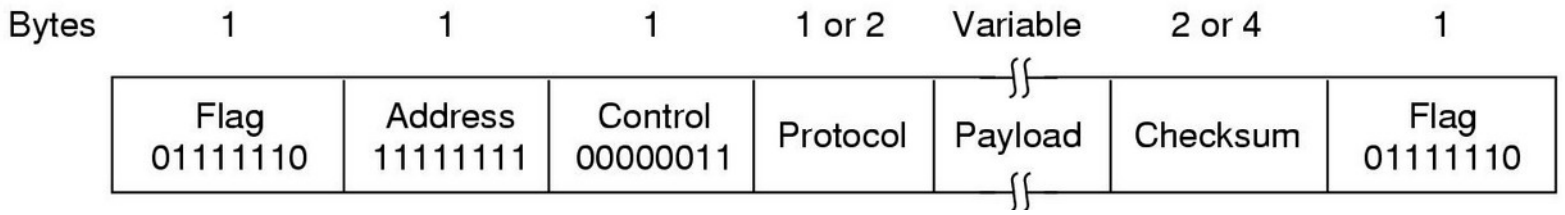


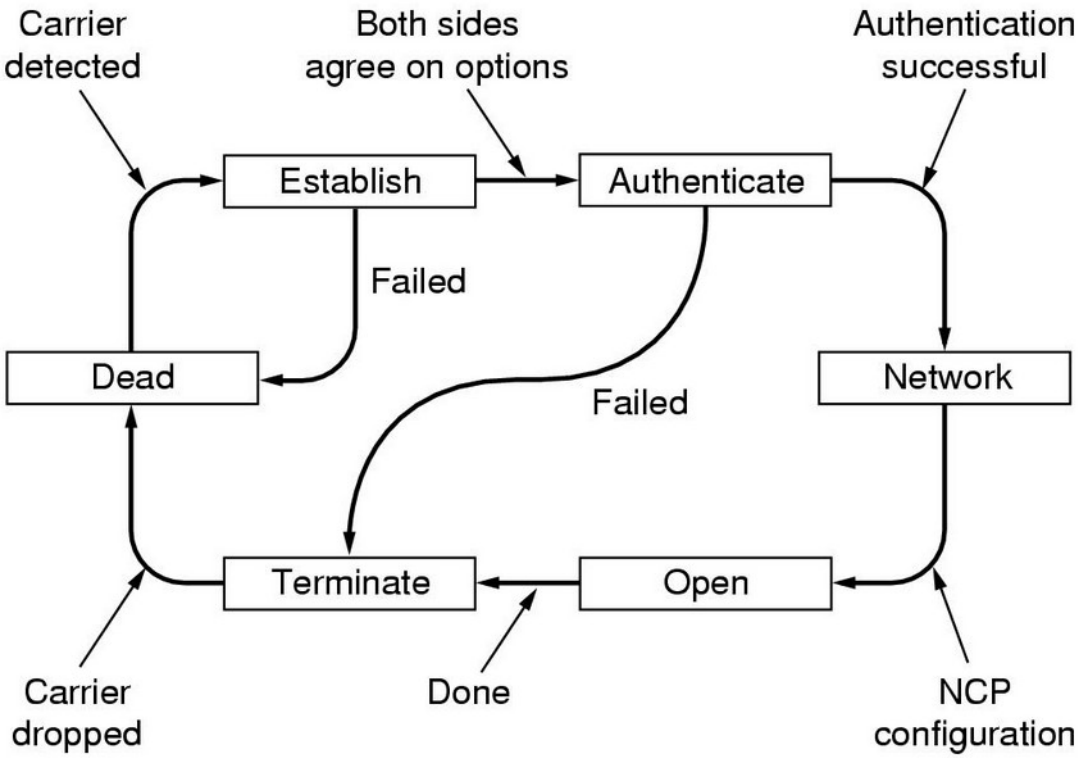
HDLC


Bits
8
8
8
≥ 0
16
8
0 1 1 1 1 1 1 0
Address
Control
Data
Checksum
0 1 1 1 1 1 1 0

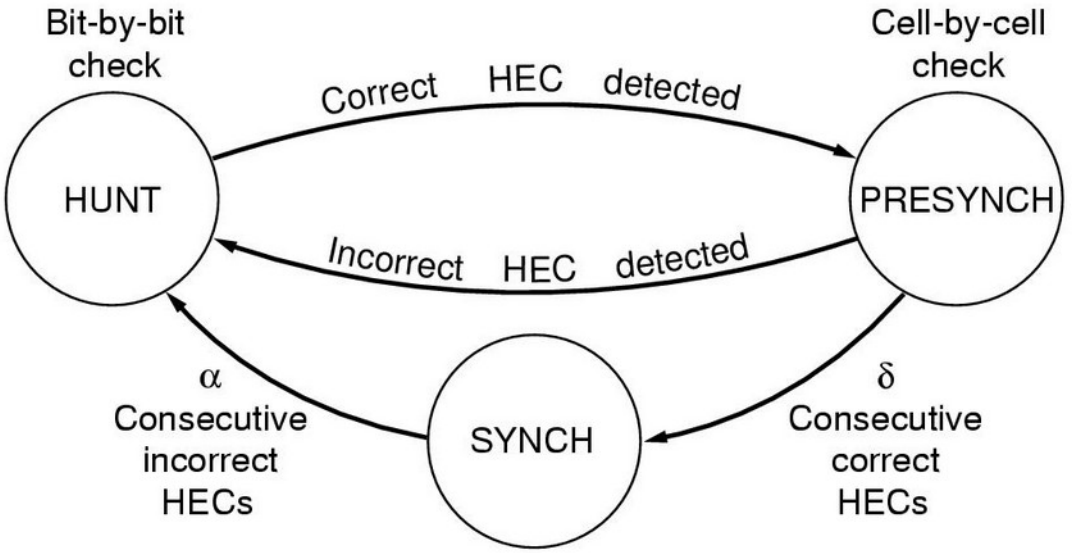

Bits
1
3
1
3
(a)
0
Seq
P/F
Next
(b)
1
0
Type
P/F
Next
(c)
1
1
Type
P/F
Modifier

PPP

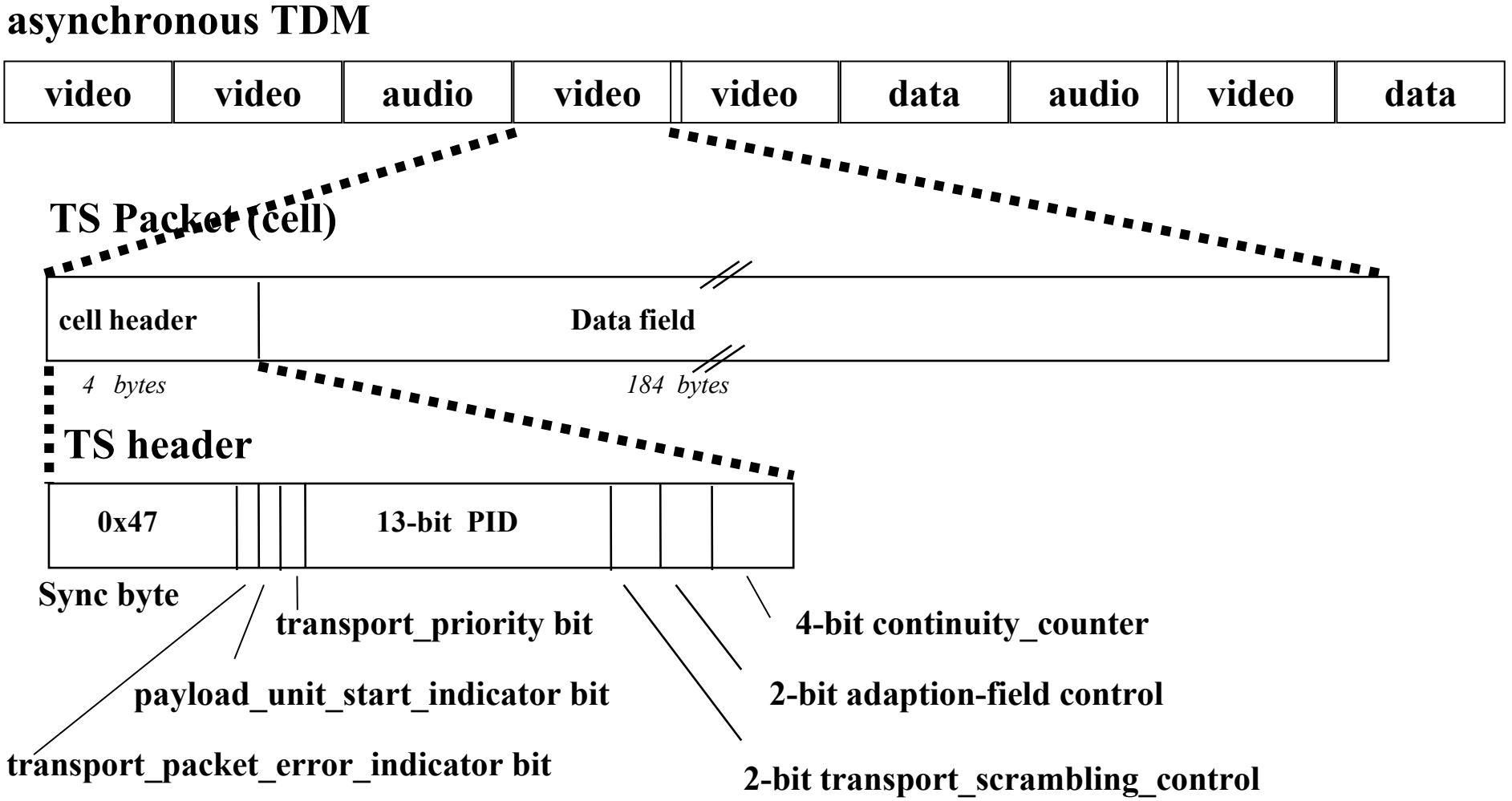

Bytes
1
1
1
1 or 2
Variable
2 or 4
1
Flag
01111110
Address
11111111
Control
00000011
Protocol
Payload
Checksum
Flag
01111110


Carrier
detected
Both sides
agree on options
Authentication
successful
Establish
Authenticate
Failed
Dead
Failed
Network
Terminate
Open
Carrier
dropped
Done
NCP
configuration

ATM


Bit-by-bit check
Cell-by-cell check
Correct HEC detected
HUNT
PRESYNCH
Incorrect HEC detected
α
Consecutive incorrect HECs
SYNCH
δ
Consecutive correct HECs

MPEG-2


asynchronous TDM
video
video
audio
video
video
data
audio
video
data
TS Packet (cell)
cell header
Data field
4 bytes
184 bytes
TS header
0x47
13-bit PID
Sync byte
transport_priority bit
payload_unit_start_indicator bit
transport_packet_error_indicator bit
4-bit continuity_counter
2-bit adaption-field control
2-bit transport_scrambling_control

Medium Access Control

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

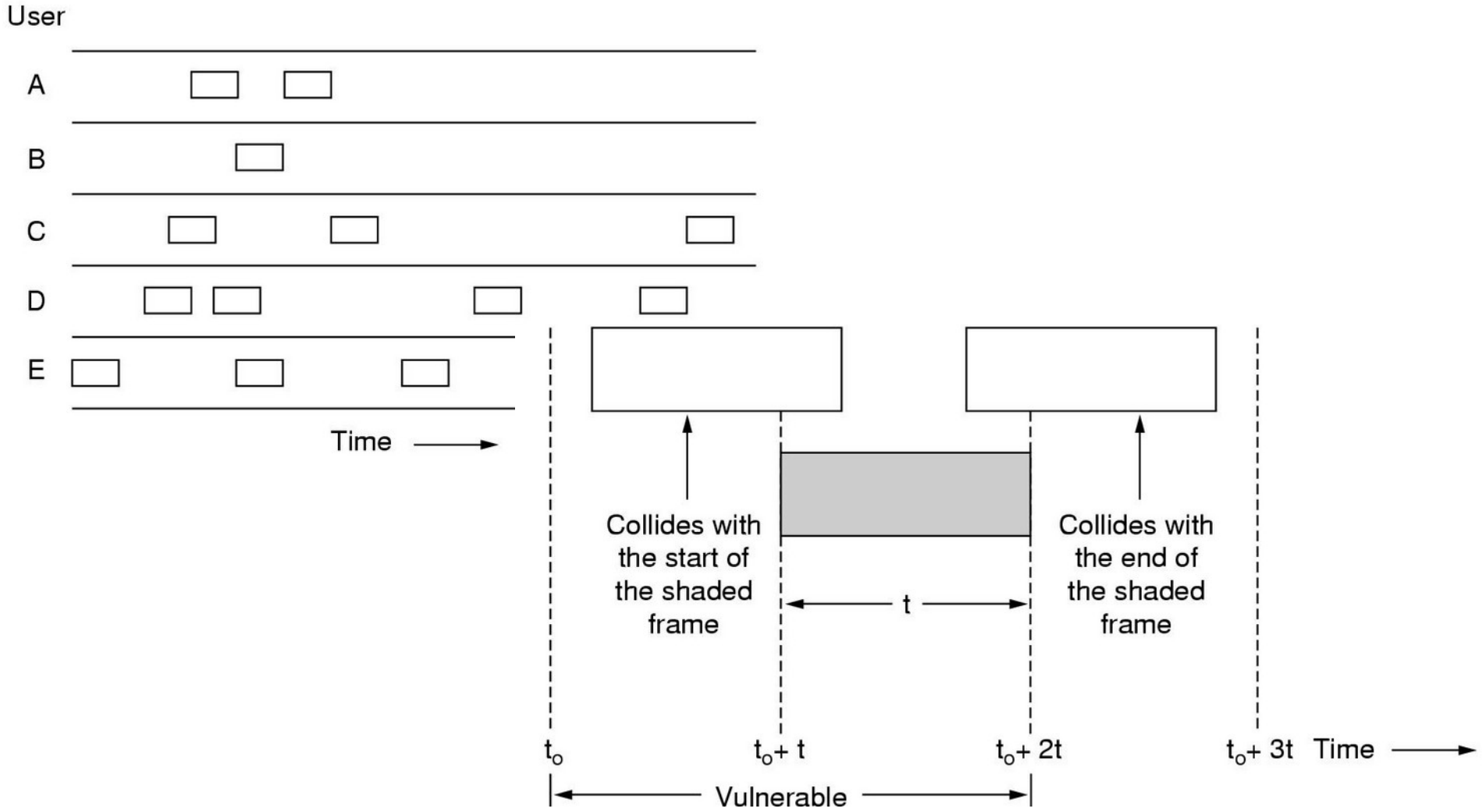
Dynamische Kanalzuordnung

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

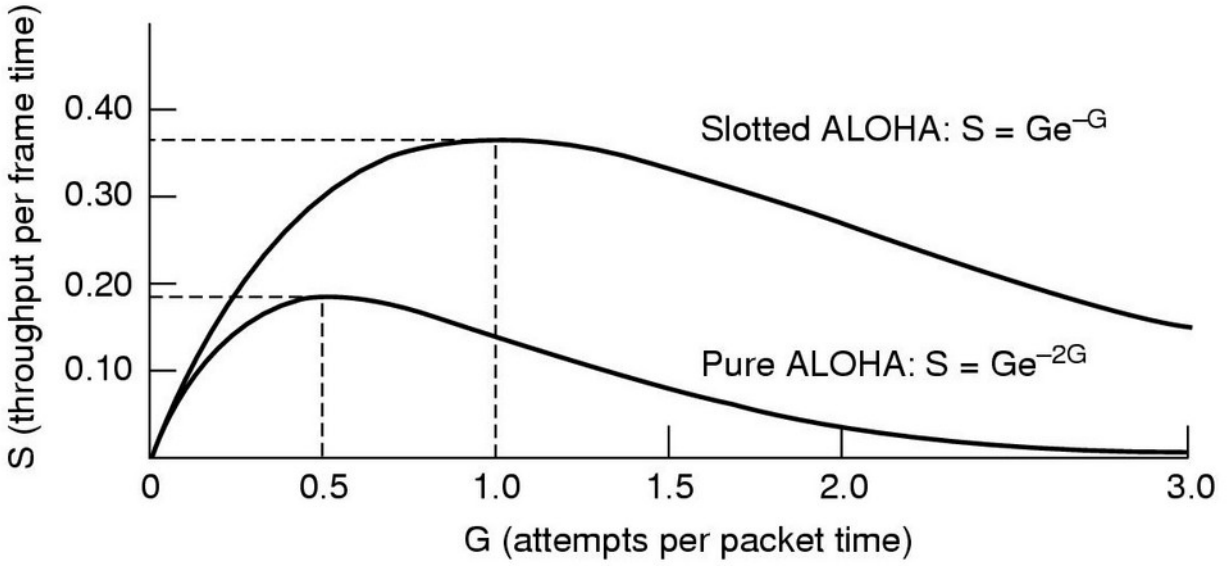
Warteschlangen - Queuing Theory

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

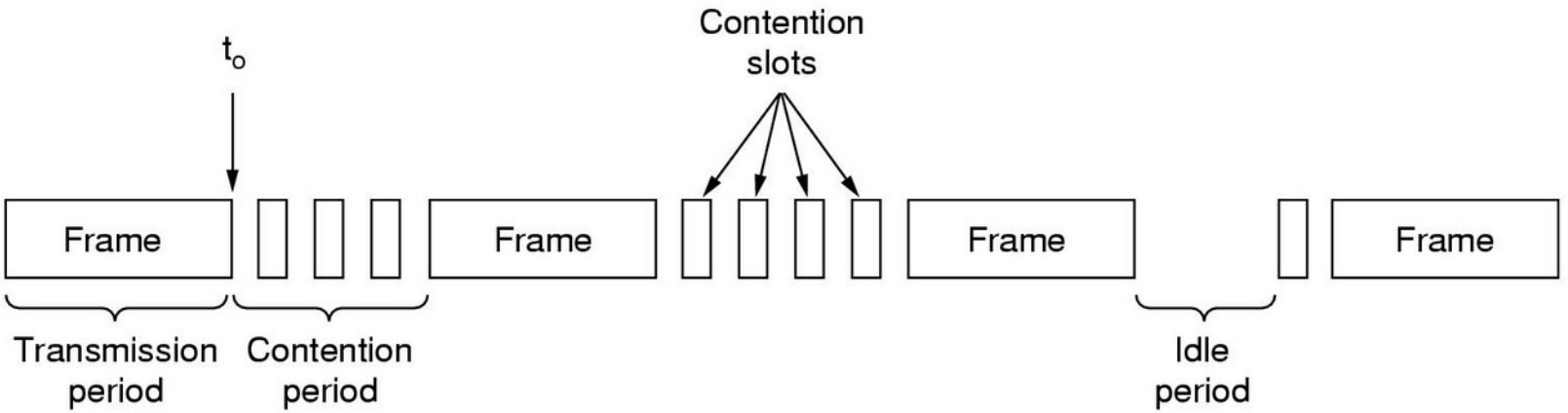
ALOHA


User
A
B
C
D
E
Time
Collides with the start of the shaded frame
t
Collides with the end of the shaded frame
t_o
t_o+ t
t_o+ 2t
t_o+ 3t
Time
Vulnerable

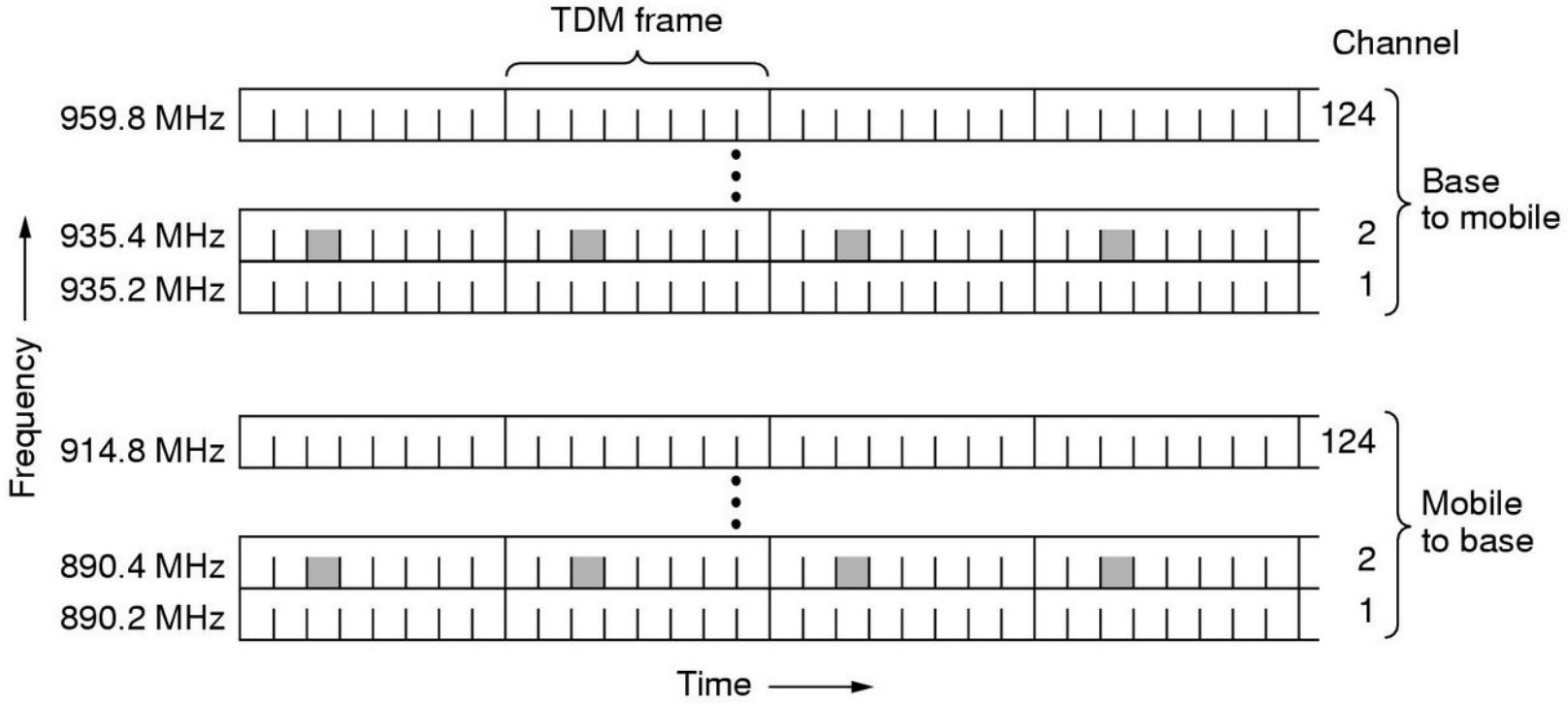
Slotted ALOHA



CSMA und CSMA/CD



GSM


TDM frame
Channel
959.8 MHz
124
935.4 MHz
2
935.2 MHz
1
Base to mobile
Frequency
914.8 MHz
124
890.4 MHz
2
890.2 MHz
1
Mobile to base
Time

CDMA

A: 0 0 0 1 1 0 1 1	A: (–1 –1 –1 +1 +1 –1 +1 +1)
B: 0 0 1 0 1 1 1 0	B: (–1 –1 +1 –1 +1 +1 +1 –1)
C: 0 1 0 1 1 1 0 0	C: (–1 +1 –1 +1 +1 +1 –1 –1)
D: 0 1 0 0 0 0 1 0	D: (–1 +1 –1 –1 –1 –1 +1 –1)
(a)	(b)

Six examples:

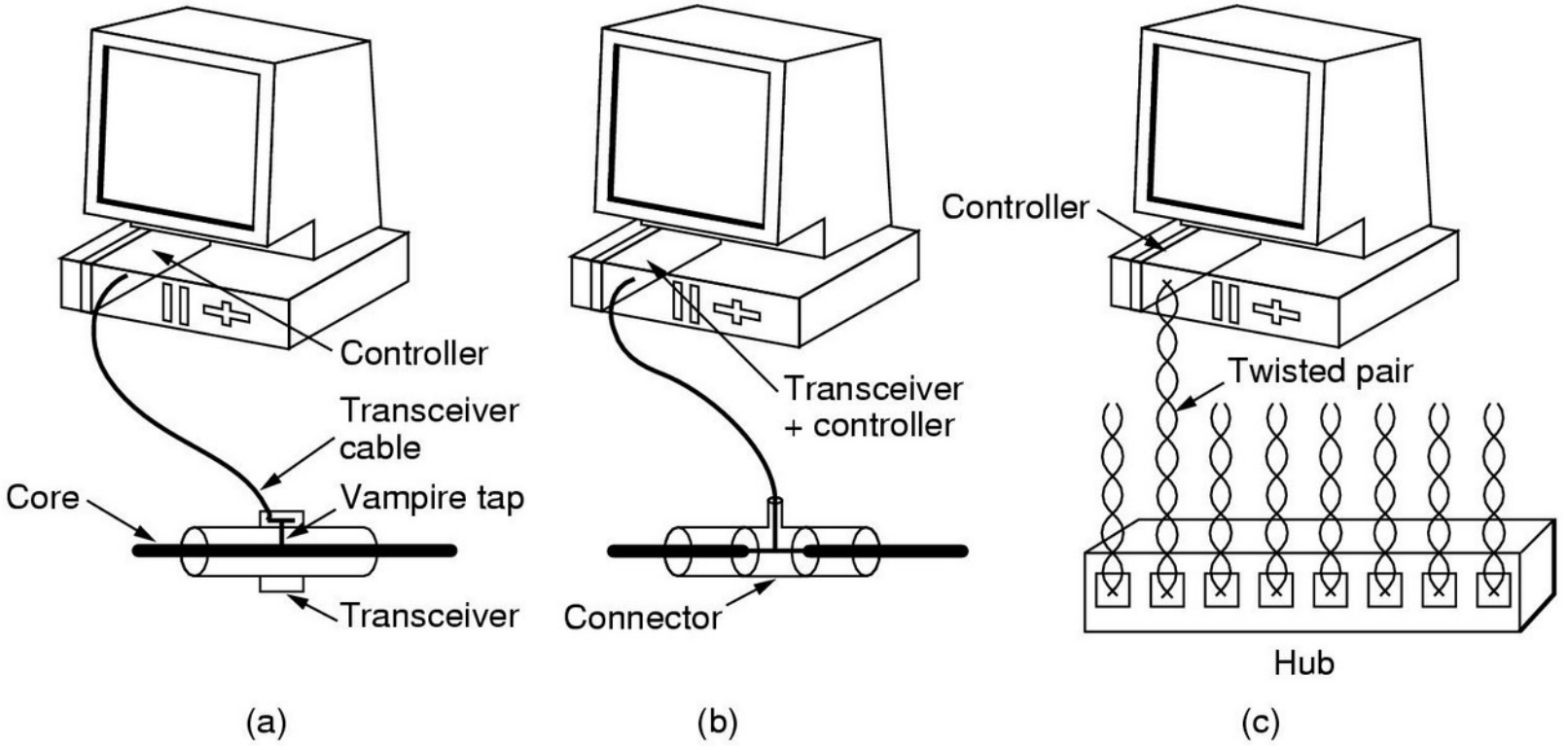
– – 1 –	**C**	S_1 = (–1 +1 –1 +1 +1 +1 –1 –1)
– 1 1 –	**B** + $\overline{\mathbf{C}}$	S_2 = (–2 0 0 0 +2 +2 0 –2)
1 0 – –	**A** + $\overline{\mathbf{B}}$	S_3 = (0 0 –2 +2 0 –2 0 +2)
1 0 1 –	**A** + **B** + **C**	S_4 = (–1 +1 –3 +3 –1 –1 –1 +1)
1 1 1 1	**A** + **B** + **C** + **D**	S_5 = (–4 0 –2 0 +2 0 +2 –2)
1 1 0 1	**A** + **B** + $\overline{\mathbf{C}}$ + **D**	S_6 = (–2 –2 0 –2 0 –2 +4 0)

(c)

$S_1 \bullet C = (1 +1 +1 +1 +1 +1 +1 +1)/8 = 1$
$S_2 \bullet C = (2 +0 +0 +0 +2 +2 +0 +2)/8 = 1$
$S_3 \bullet C = (0 +0 +2 +2 +0 –2 +0 –2)/8 = 0$
$S_4 \bullet C = (1 +1 +3 +3 +1 –1 +1 –1)/8 = 1$
$S_5 \bullet C = (4 +0 +2 +0 +2 +0 –2 +2)/8 = 1$
$S_6 \bullet C = (2 –2 +0 –2 +0 –2 –4 +0)/8 = –1$

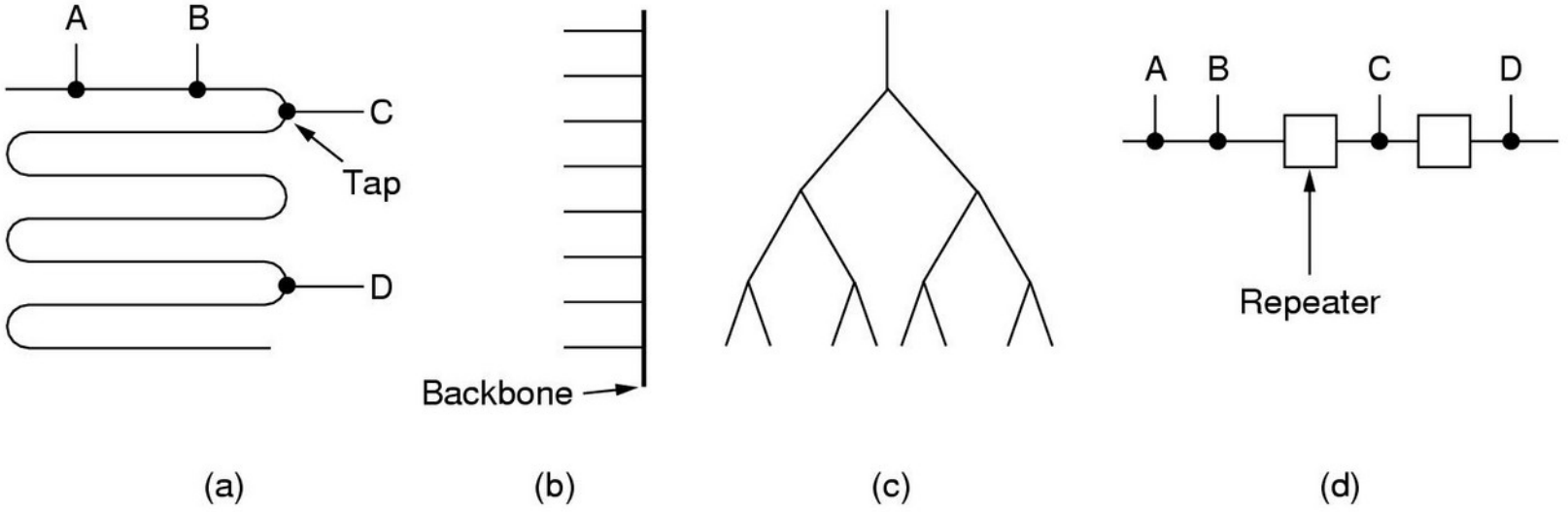
(d)

IEEE 802.3 und Ethernet

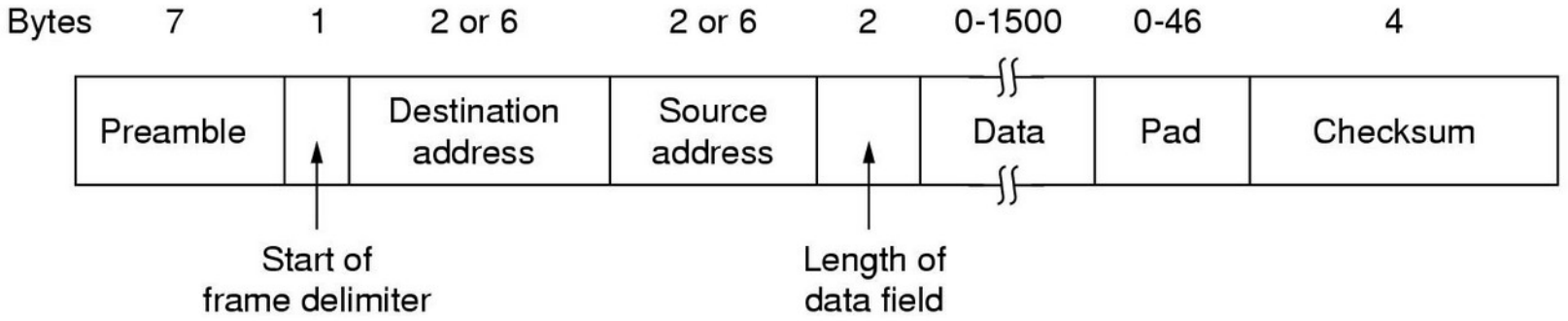


10Base5 10Base2 10BaseT

802.3 Topologien



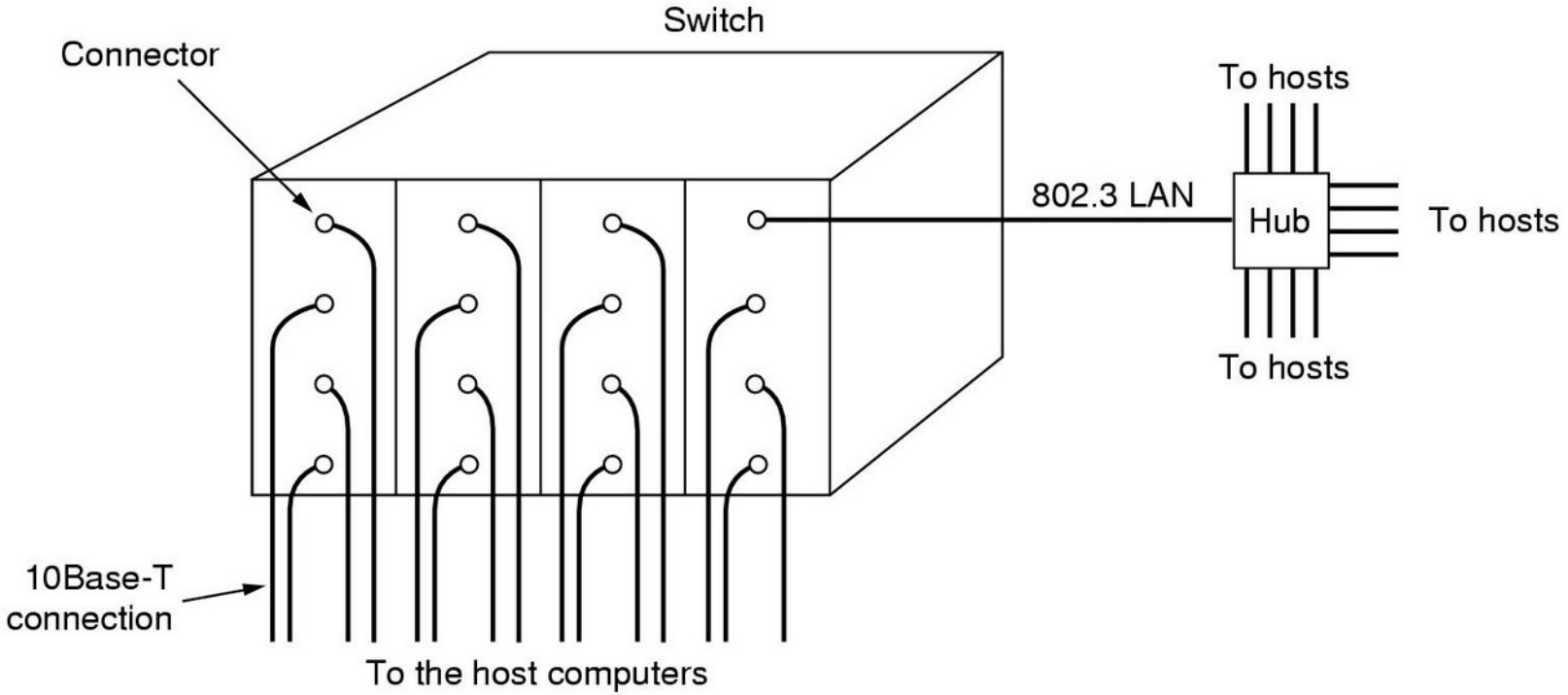
802.3 Rahmenformat



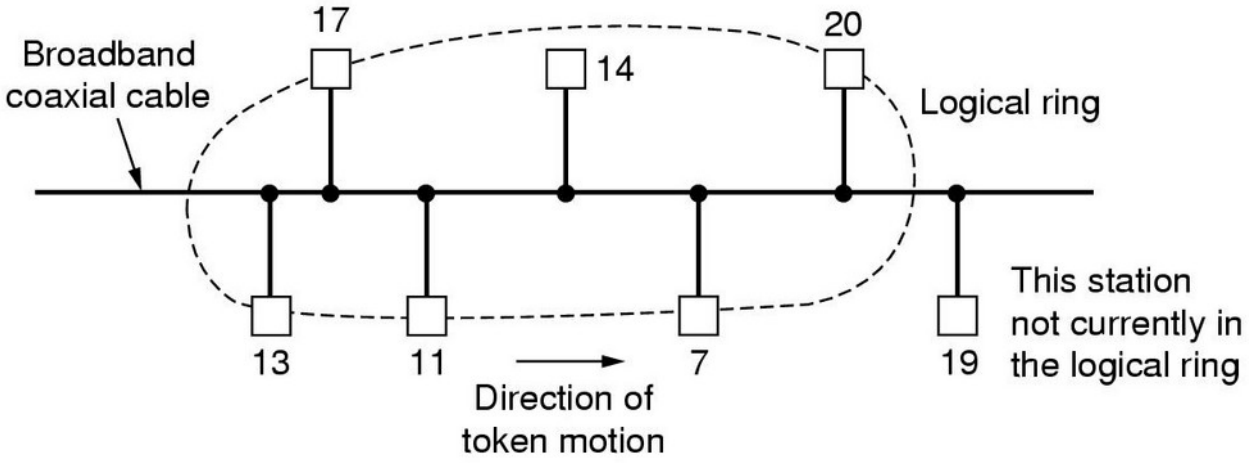
IEEE 802.3ab 1000BASE-T

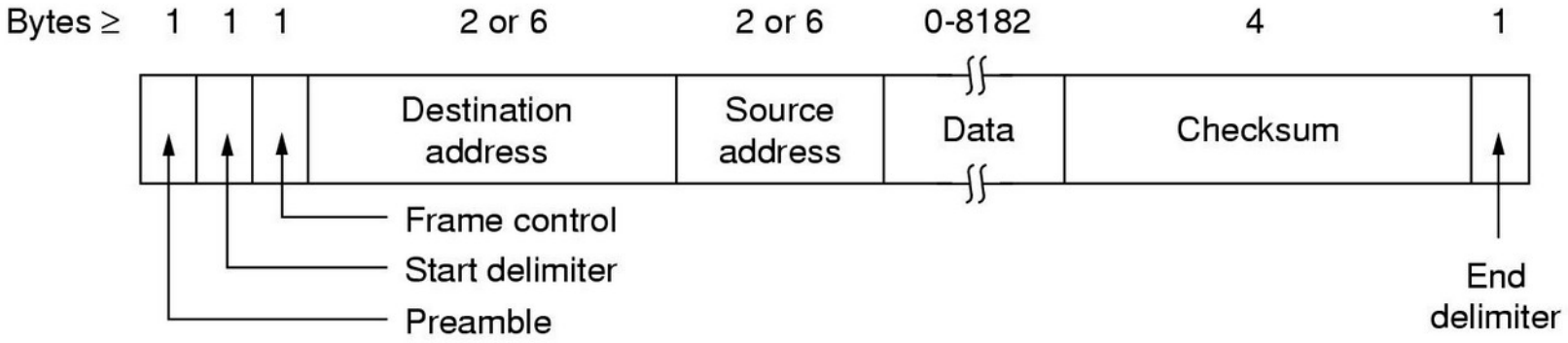
- 100Base-T, F, TX (T4, T2)
- 1000Base-T, X
- 10GBase-T, LRM
- Autonegotiation

Switched 802.3

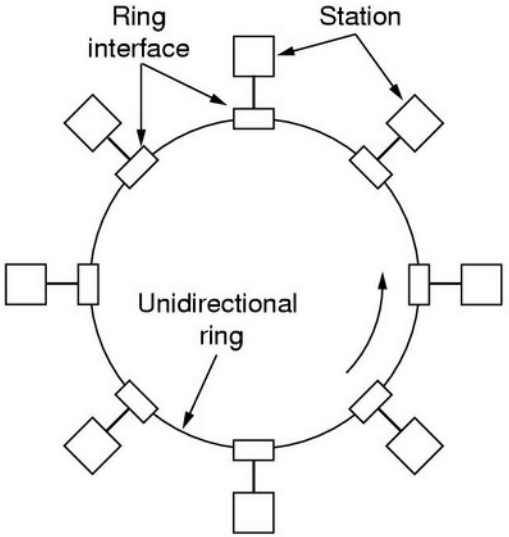


IEEE 802.4 Token Bus

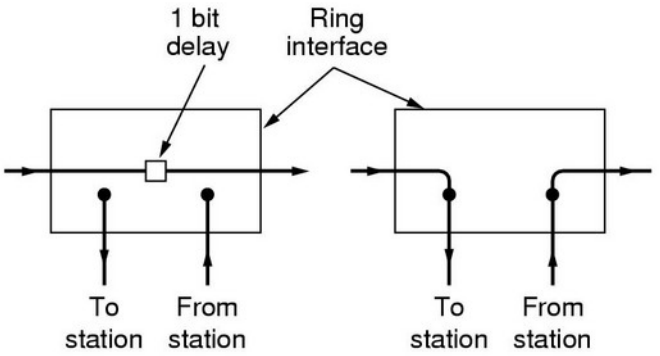




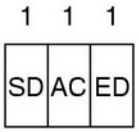
IEEE 802.5 Token Ring



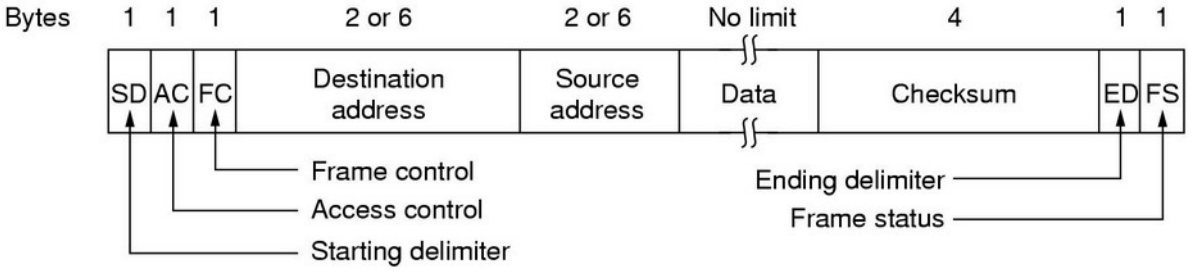
(a)



(b) (c)



(a)



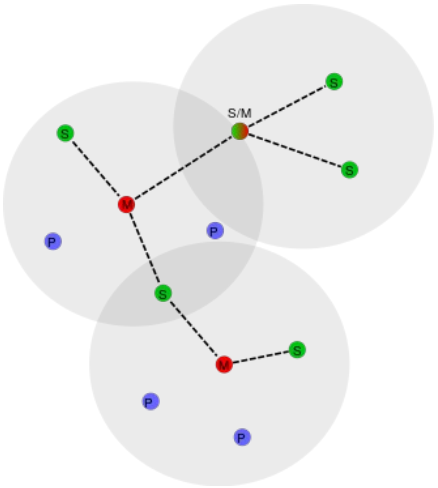
(b)

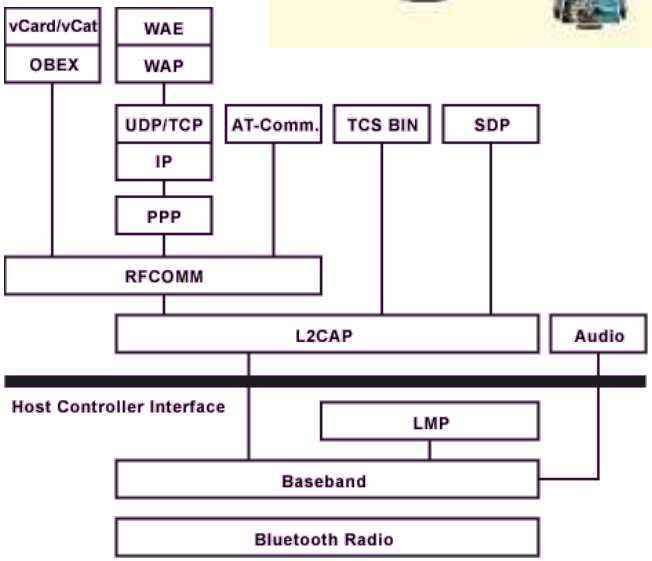
IEEE 802.11 (WLAN)

- 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



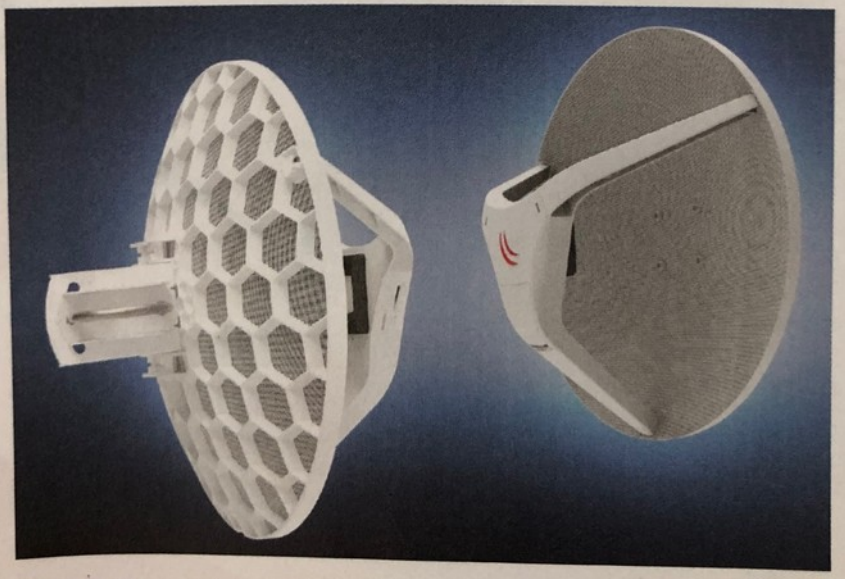


Cool?

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!

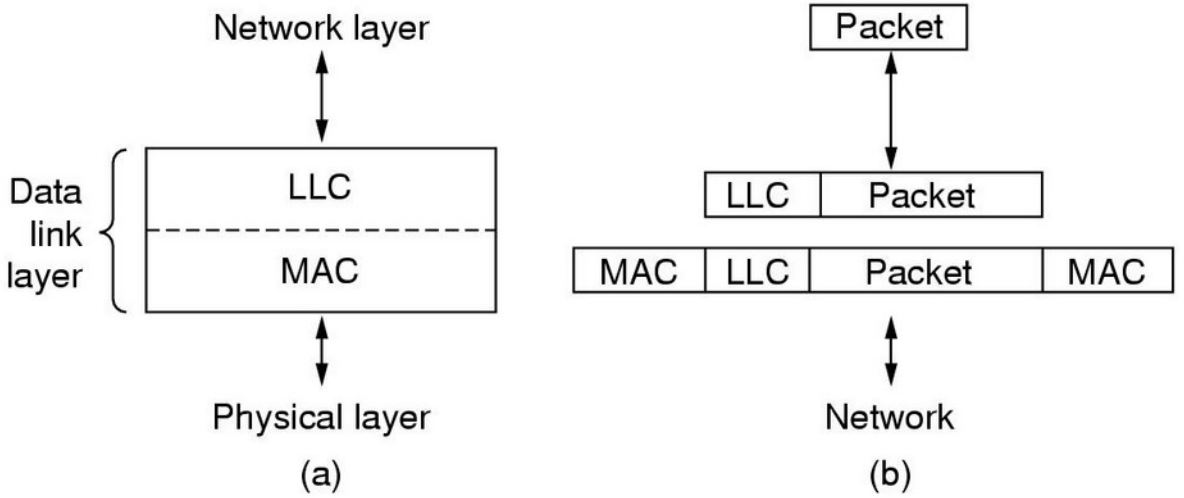
Cut

Ende 3. Termin (Online) 22.3.20

Beginn 4.Termin (Online) 27.3.20

IEEE 802.X

- IEEE 802.2 LLC



- 802.1Q VLAN

http://standards.ieee.org/getieee802

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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

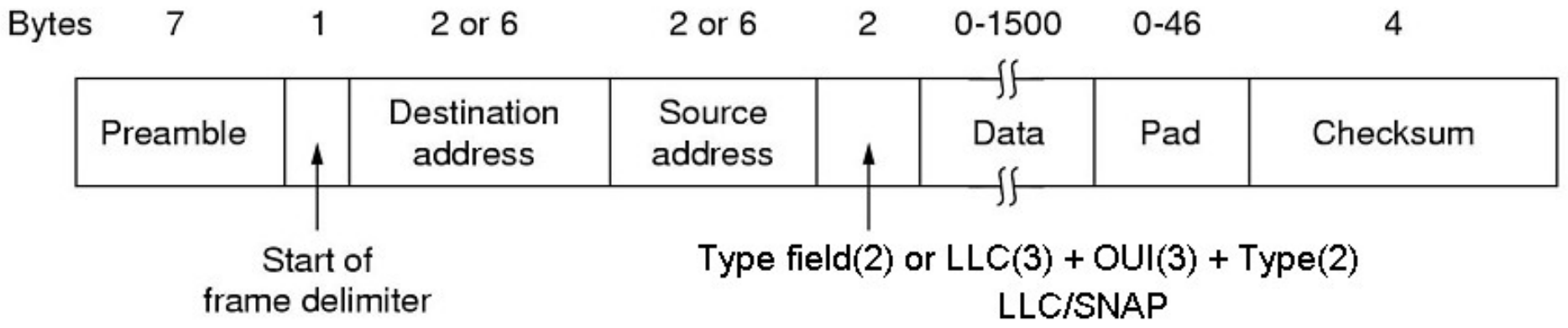
IEEE 802.19™: TV White Space Coexistence Methods

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

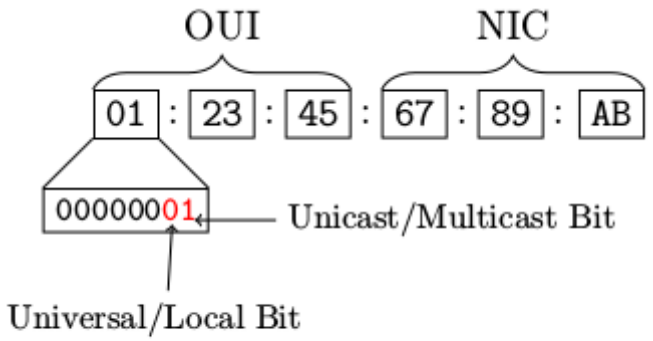


Figure 1: 48-bit MAC Address Structure

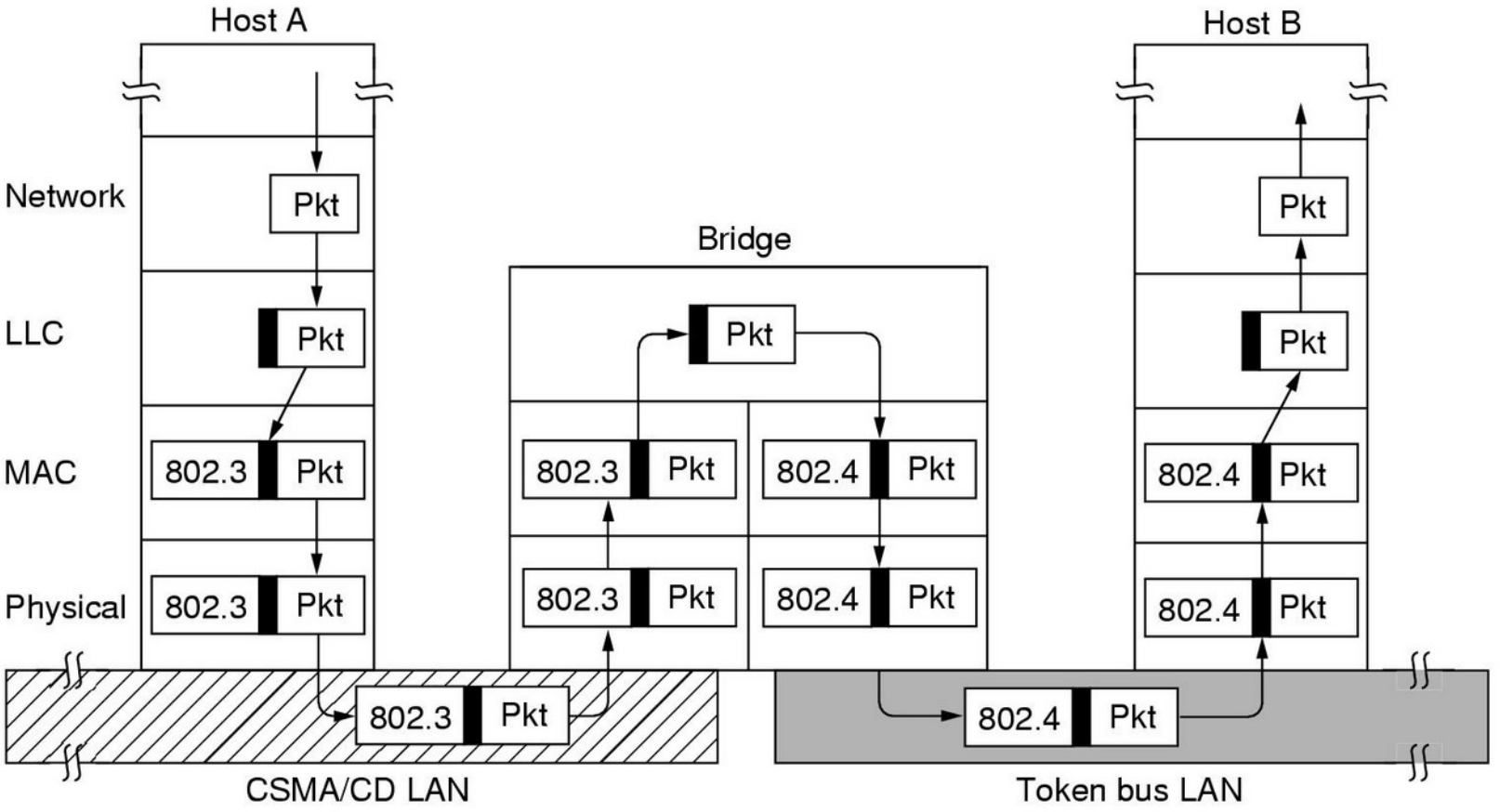
A Study of MAC Address Randomization in Mobile Devices When it Fail
s

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

Bridges

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

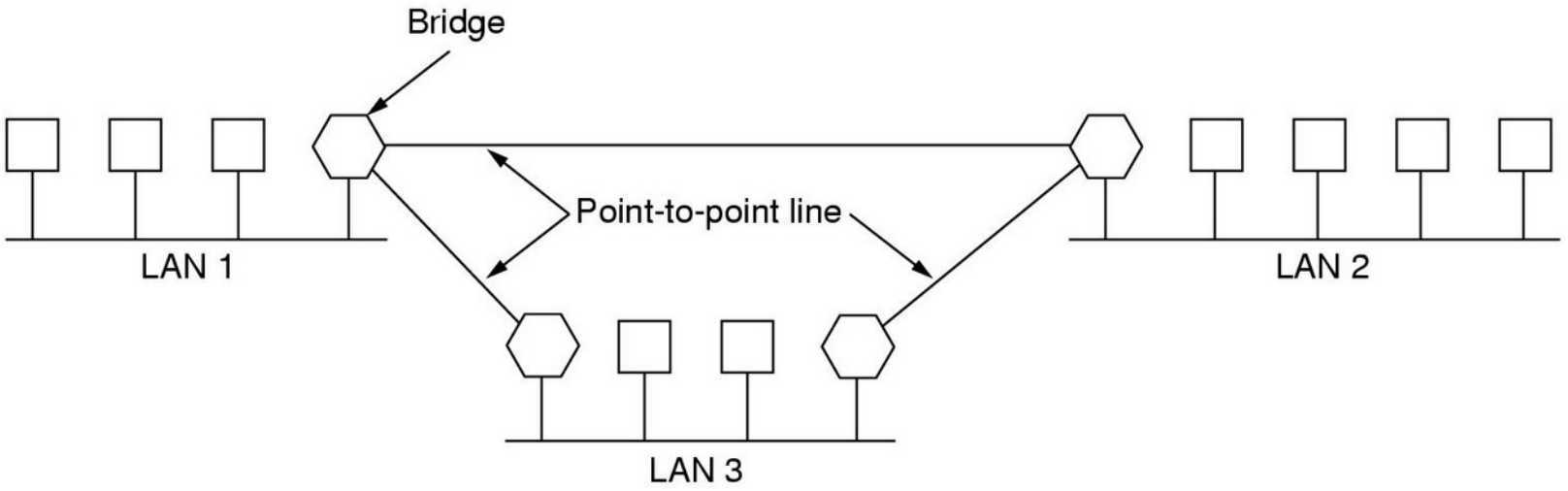
Bridging


Host A
Host B
Network
LLC
MAC
Physical
Bridge
Pkt
802.3
802.4
CSMA/CD LAN
Token bus LAN

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**	ALOHA • Slotted ALOHA • R-ALOHA • AX.25 • CSMA/CD
	Collision avoidance	MACA • MACAW • CSMA • CSMA/CA • DCF • PCF • HCF • CSMA/CARP
	Collision-free	Token ring • Token bus • MS-ALOHA
	Delay and disruption tolerant	MANET • VANET • DTN • Dynamic Source Routing
Duplexing methods	TDD • FDD	

FEC vs ARQ

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

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	Type of subnet: Virtual circuit
Connectionless	UDP over IP	UDP over IP over ATM
Connection-oriented	TCP over IP	ATM AAL1 over ATM

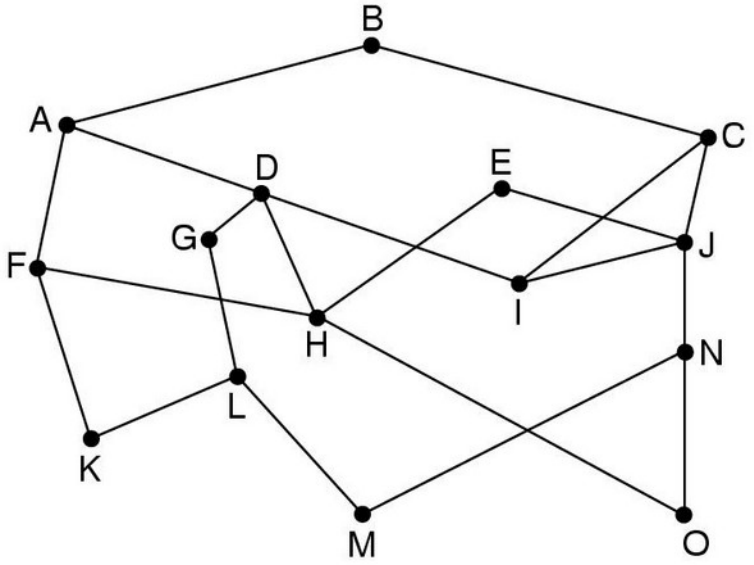
Routing

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

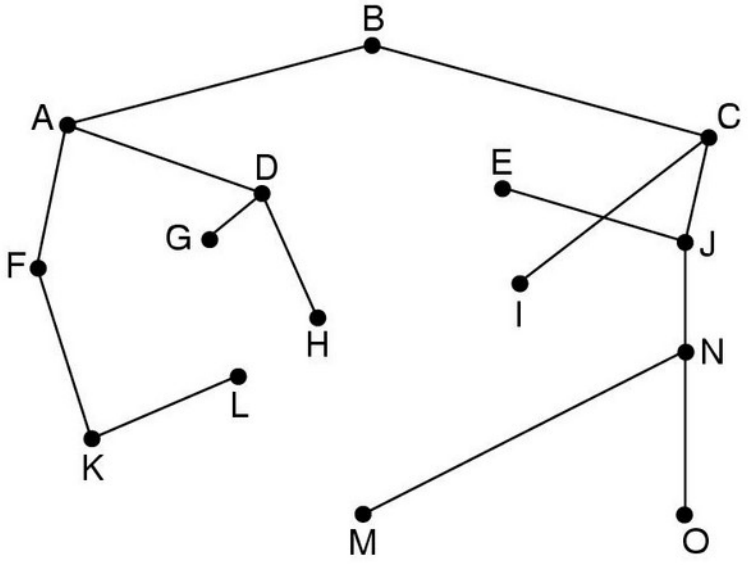
Routing/Addressing Schemes

- Unicast
- Broadcast
- Multicast
- Anycast
- Geocast

Spanning Tree



(a)



(b)

Flooding

- Weiterleitung auf allen anderen Leitungen
- Paketduplikate 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

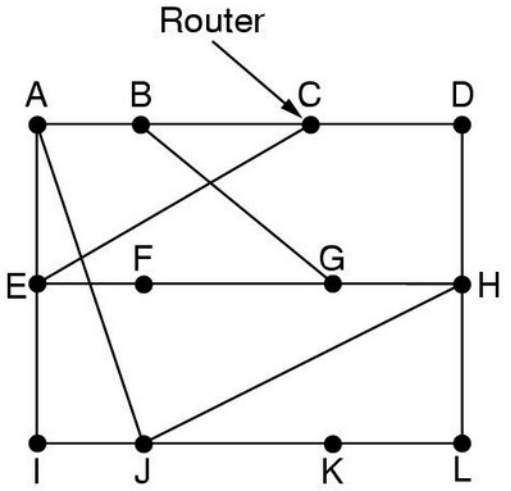
Flow-based Routing

- Statisch
- Verwendet
  - Topologieinformationen
  - Datenverkehrmatrix
  - Leitungskapazitäten
- zur Berechung 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



(a)

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

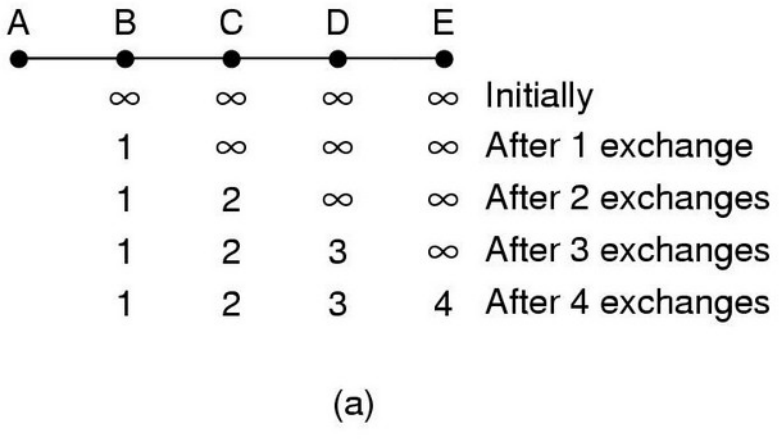
Vectors received from J's four neighbors

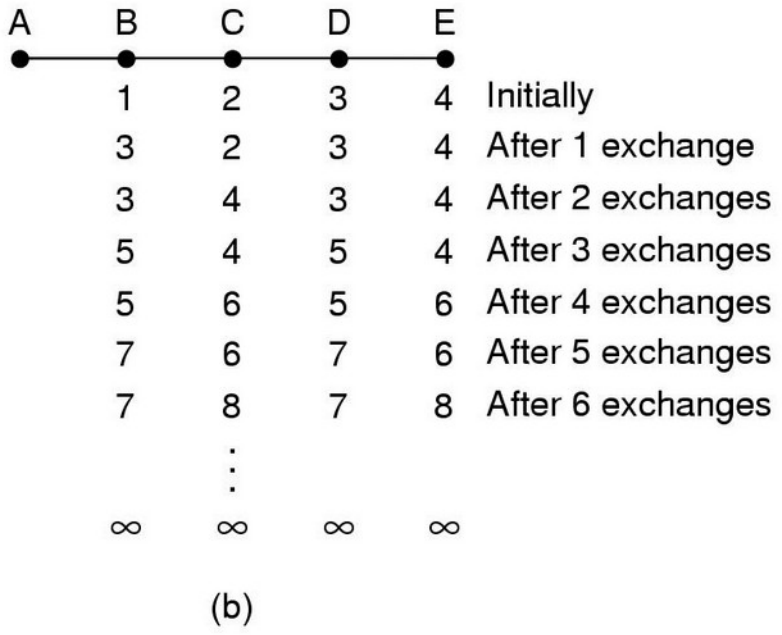
New routing table for J

(b)

Count-to-Infinity Problem

- Problem der trägen Konvergenz (für schlechte Neuigkeiten)





A neu erreichbar

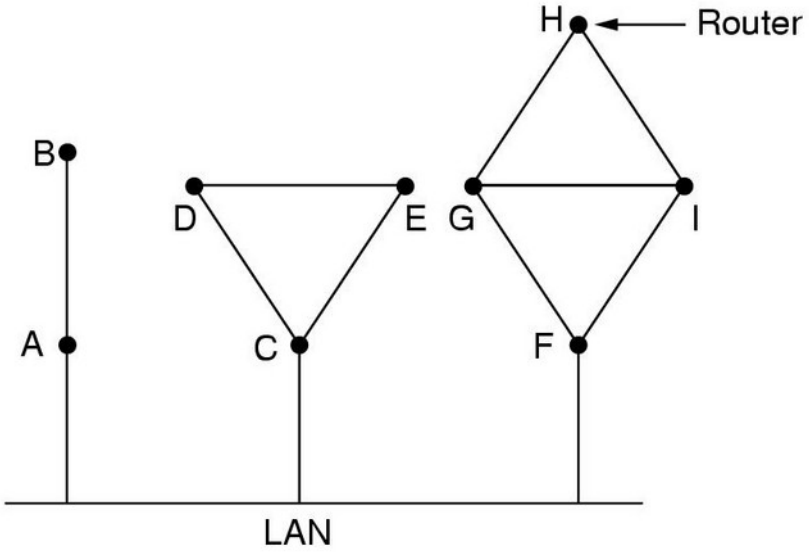
A unerreichbar

Link-State-Routing

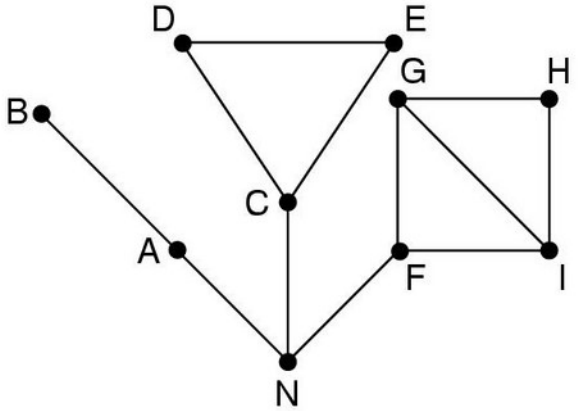
- Ersetzt DVR wegen
  - Fehlende Kenntnis über Topologie
  - Trägheit und Fehlverhalten
- Vorgehen:
  - Ermittlung der Nachbar Router
  - Ermittlung der Verzögerung/Leitungskosten
  - Erstellung von Link-State-Pakete
  - Verteilung der Link-State-Pakete
  - Berechnung neuer Routen zu allen Routern

LSR: Ermittlung der Nachbar Router

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



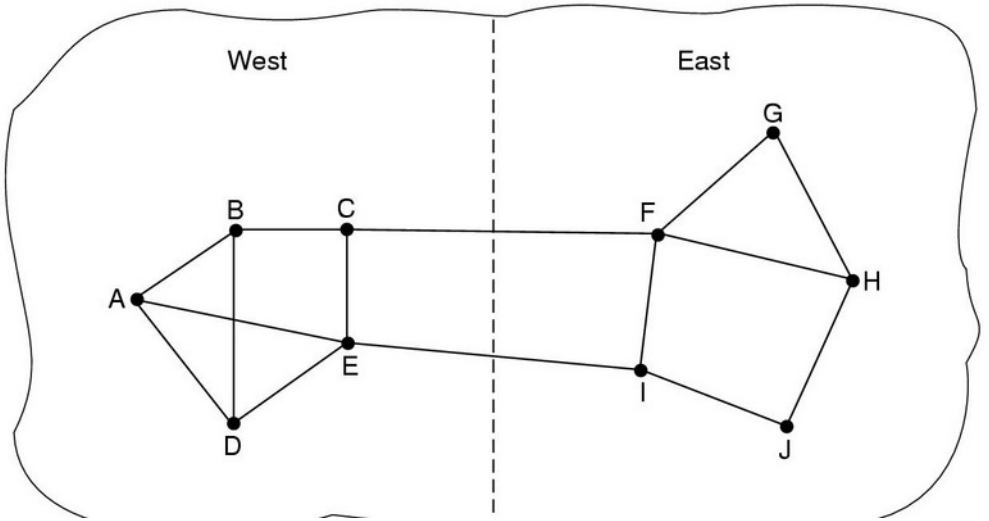
(a)



(b)

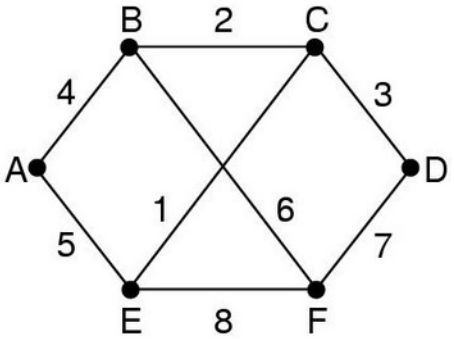
LSR: Ermittlung der Verzögerung

- ECHO Pakete
- Berücksichtung von Auslastung?



LSR: Erstellung von Link-State-Pakete

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



(a)

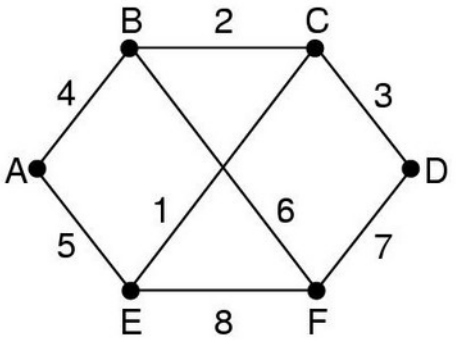
Link State Packets

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

(b)

LSR: Verteilung der Link-State-Pakete

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



(a)

Source	Seq.	Age	Send flags A	Send flags C	Send flags F	ACK flags A	ACK flags C	ACK flags F	Data
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	

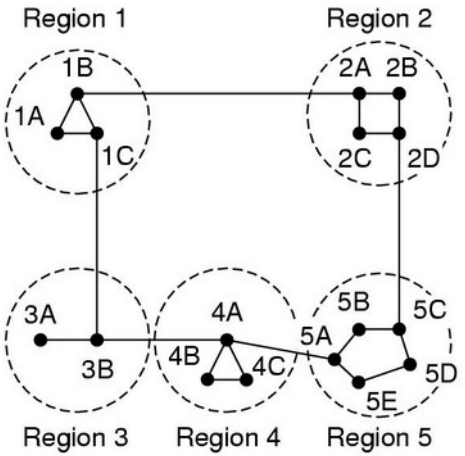
(b)

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)

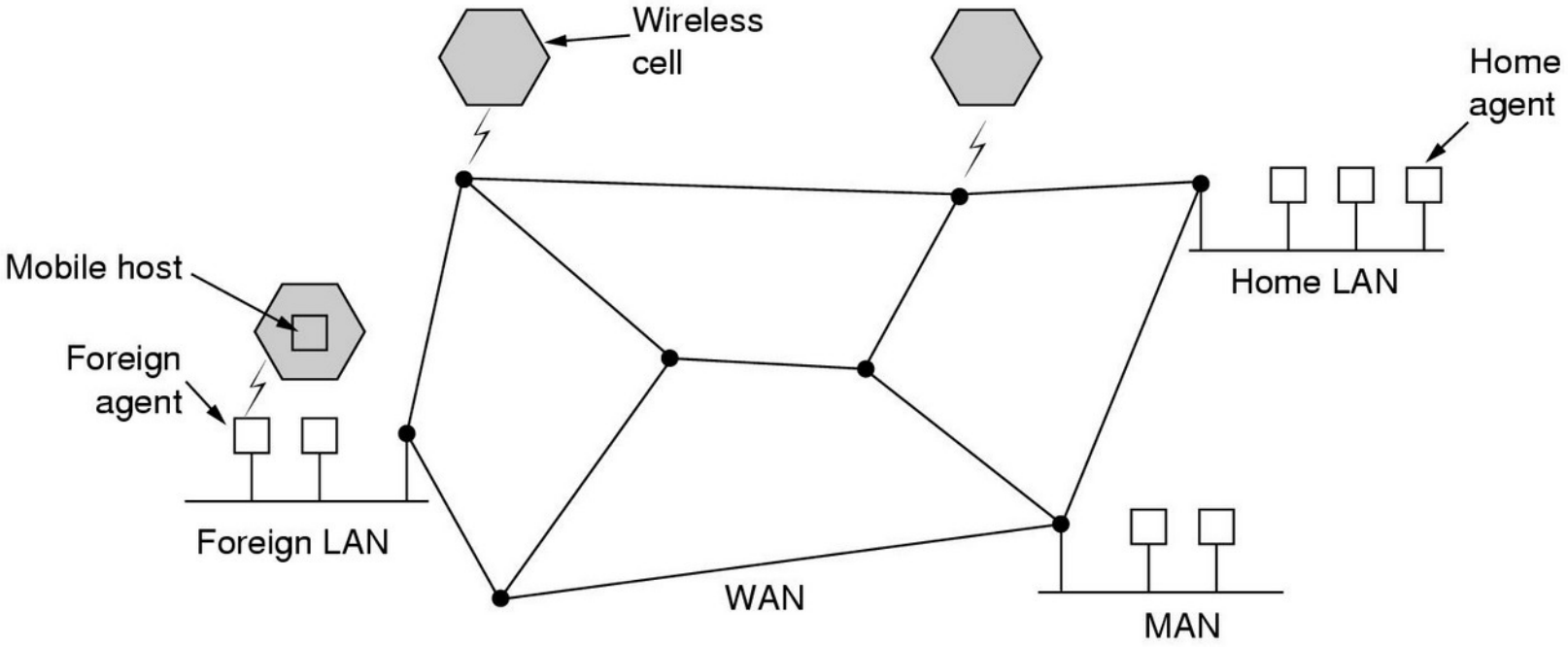
Hierarchical table for 1A

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



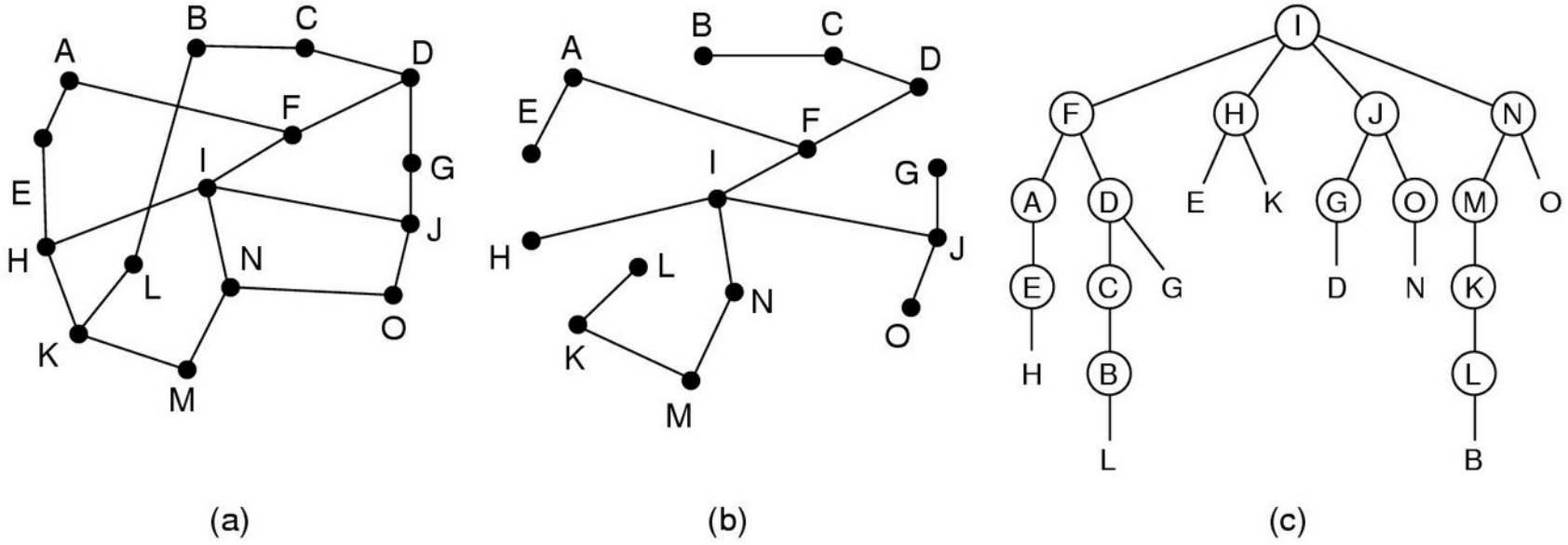
Routing für mobile Hosts 2

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

Broadcast Routing

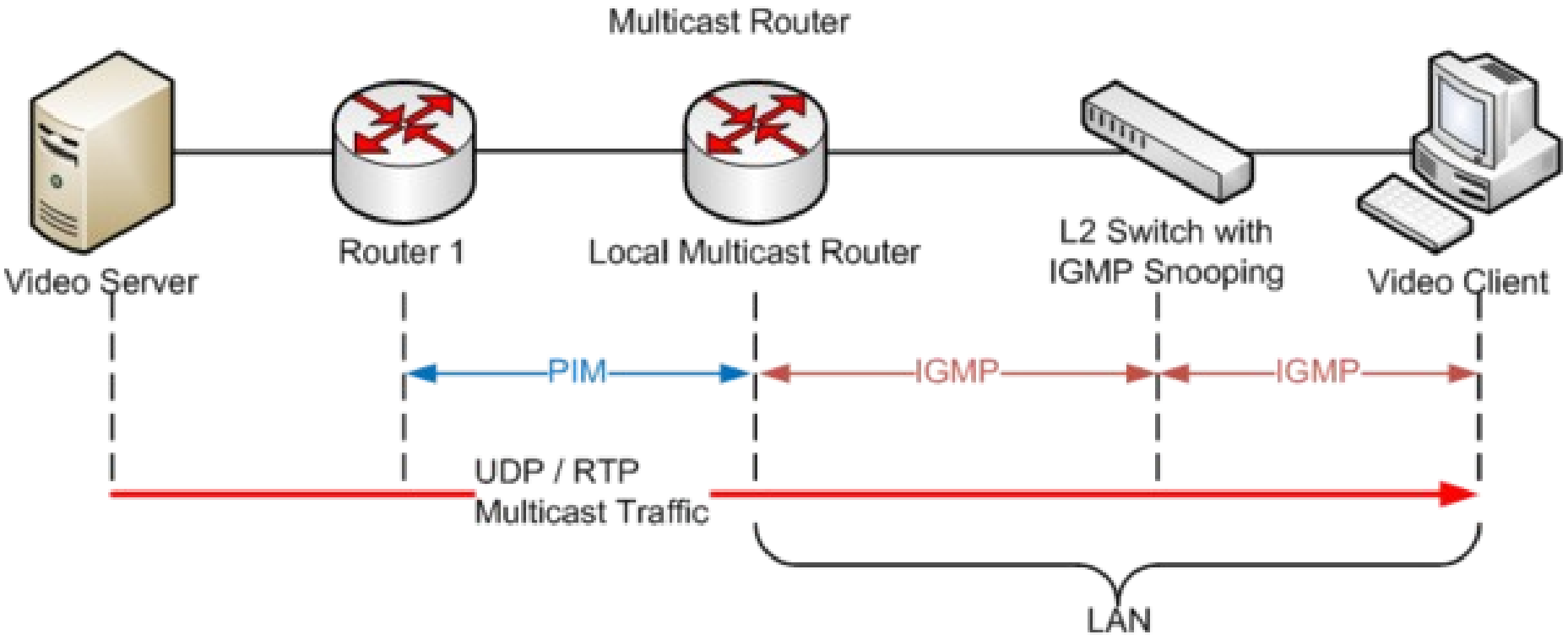
- Multiple Point-to-point
- Flooding
- Multidestination Routing
- Spanning-Tree
- Reverse-Path-Forwarding

Reverse-Path-Forwarding



Netzwerk Spanning Tree Reverse Path Forwarding

Multicast Routing



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

Multicast Routing

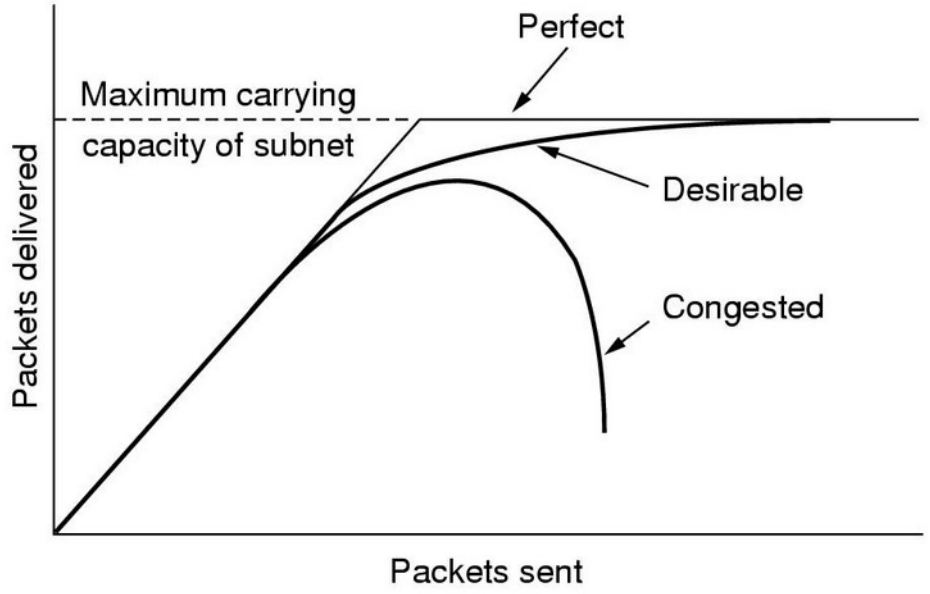
- Lokal: Gruppenmanagement
  - Anlegen, löschen, beitreten, verlassen
- Global: Spanning Tree
  - Link-State-Routing
  - Distance-Vector-Routing+Reverse-Path-Forwarding
  - Core-base Trees
- Internet: PIM

(**M**obile) **A**d-hoc **NET**ze und P2P

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

Congestion: Paket-Staus

- Überlast vs Resourcenmangel



- Staukontrolle vs Flusskontrolle

Ansätze zur Überlastkontrolle

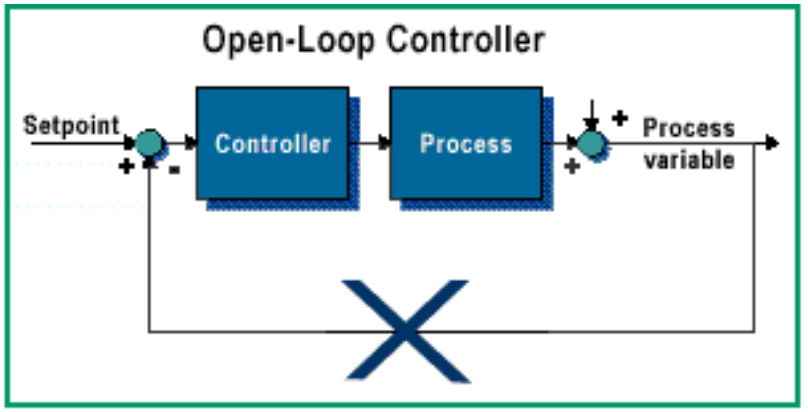
langsamer

- *Netzausbau (provisioning)*
- *Umleitung (traffic-aware routing)*
- Zugangskontrolle (admission control)
- Drosselung (choke packets, ...)
- Lastabwurf (load shedding, RED, ...)

schneller

Staukontrolle generell

- Open Loop
  - Per Design, ohne Umgebungskenntnisse



- Closed Loop
  - Überwachung, wann und wo Überlast
  - Übertragung an Stelle wo Korrektur nötig
  - Berichtigung, um Problem zu beheben

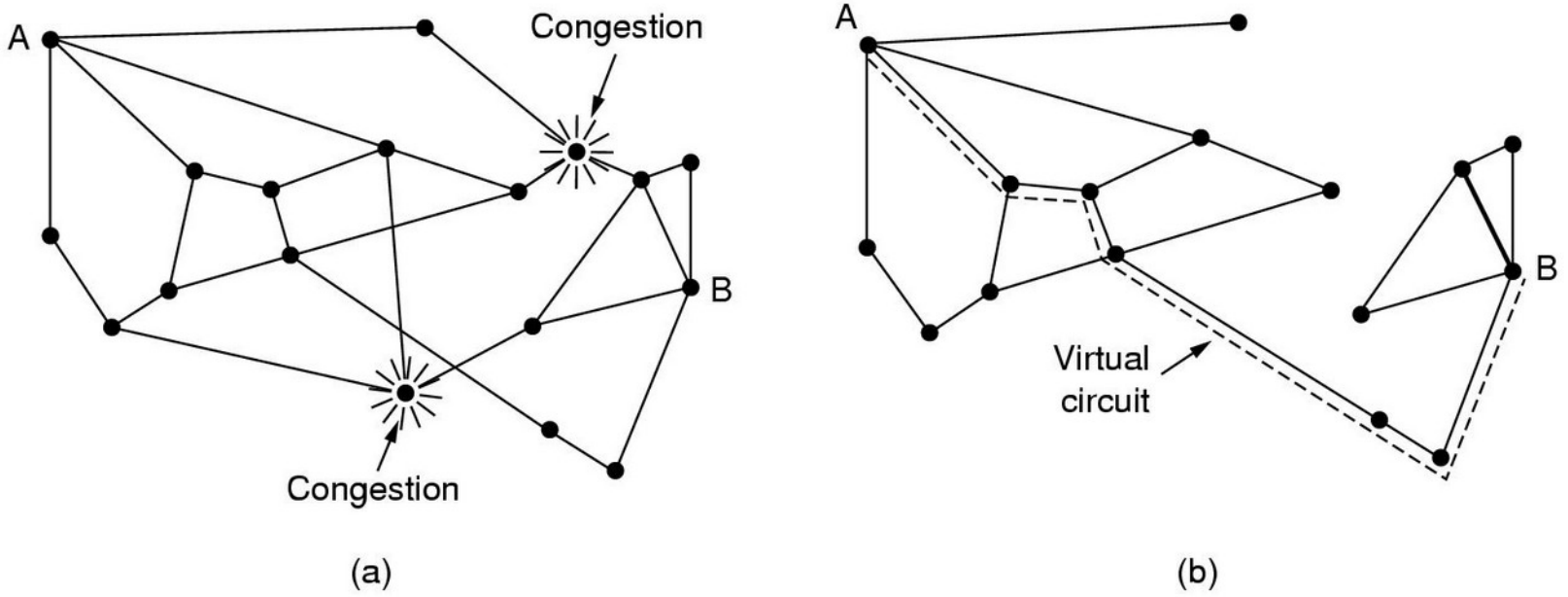
Staukontrolle im Kontext

- Transportschicht
  - Wiederholung, Reordering, ACKs, Flusskontrolle (Ratenkontrolle/Schiebefenster), Timeouts, ...
- **Vermittlungsschicht**
  - **VC vs DG, Queues, Dropping, Routing, Shaping, ...**
- Sicherungsschicht
  - Wiederholung, Queuing, ACKs, Flusssteuerung, Fehlererkennung/-korrektur, ...

Stauvermeidung bei VC

(congestion avoidance)

- Zugangsbeschränkung (admission control)
- Dienstgüteaushandlung (QoS negotiation)
- Umleitung (rerouting)

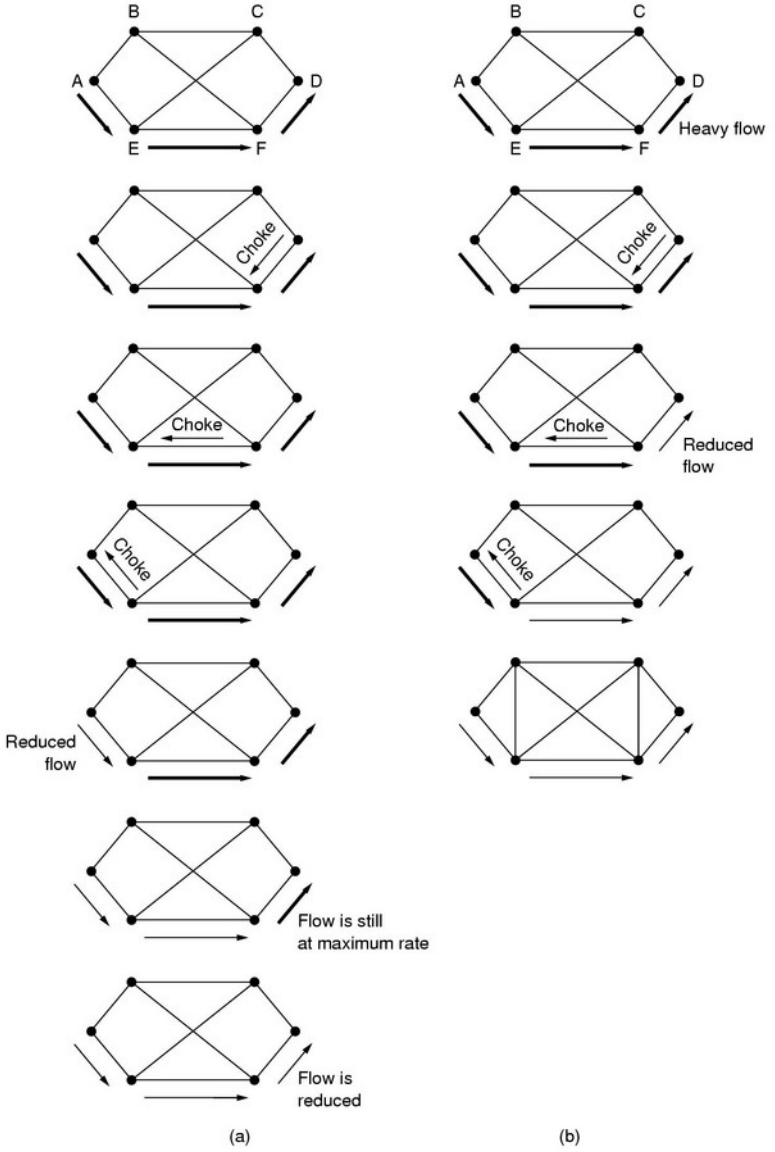


Choke-Pakete/-Bits

- Berechung der Warteschlangenverzögerung
  - $d_{neu} = \alpha * d_{alt} + (1 – \alpha) * s$
  - d Verzögerung, α Gewichtung, s Ws-Länge
- Statt Warteschlangenlänge
  - Leitungsauslastung
  - Pufferauslastung
- Verfahren
  - Bei Krise die Quelle mit Chokepaket informieren
  - Quelle drosselt Verkehr
  - wenn keine Chokepakete Verkehr beschleunigen
- oder Explicit Congestion Notification (ECN) mittels Bits in jedwedem Paket Richtung Senke...

Hop-by-Hop Choke-Pakete

- langsam bei LFN
- Teilstrecken bremsen
- Entlastung Stromabwärts
- Stromaufwärts mehr Puffer nötig



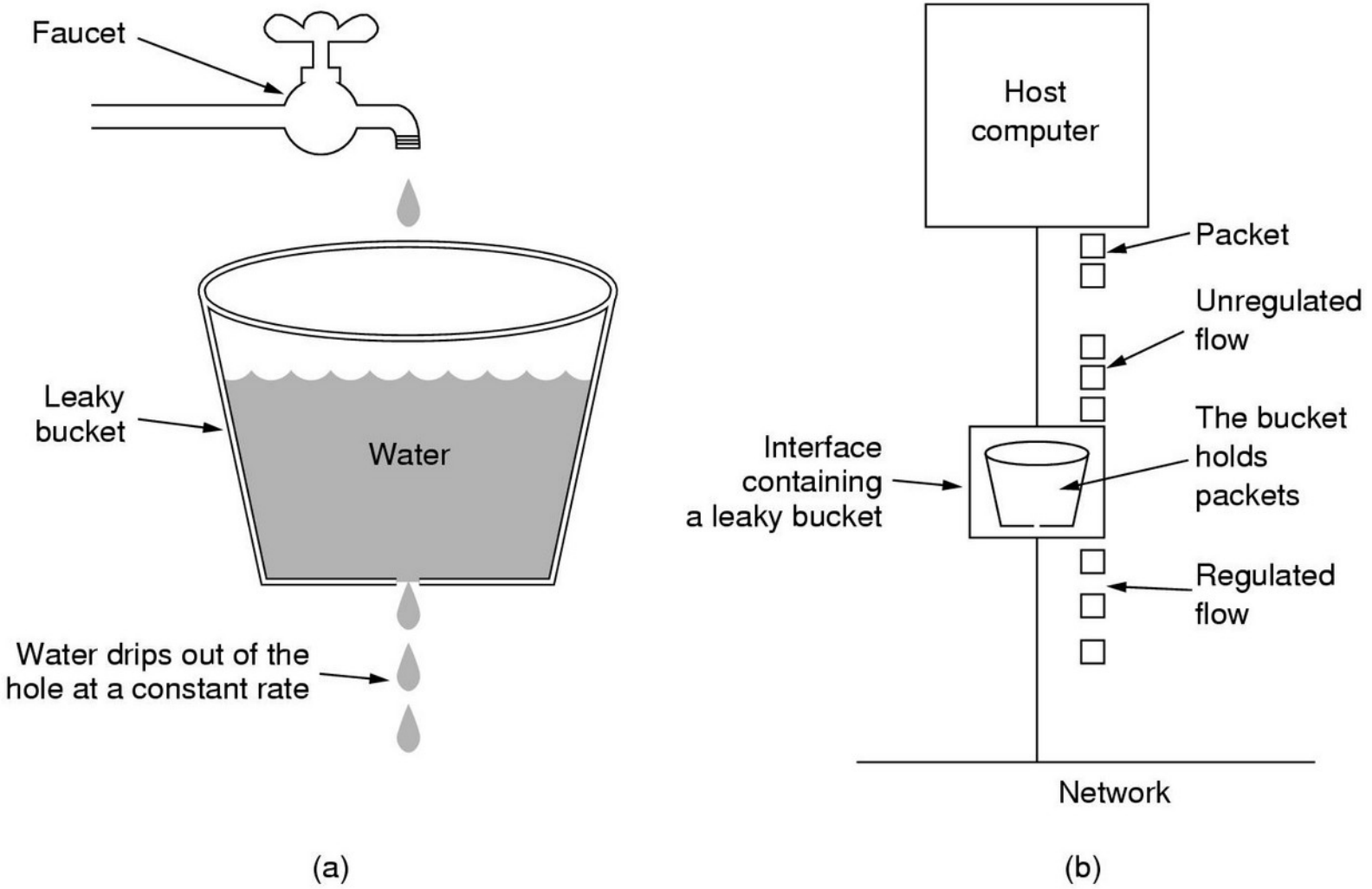
Load-Shedding / RED

- Wegwerfen von Paketen
- Zufällig oder nach bestimmten Kriterien
    - Alt vor Neu vs Neu vor Alt
    - Berücksichtigung des Typs/Inhalts
- Einteilung in Prioritätsklassen/Prioritätsbits
- Anreiz auf Kennzeichnung
- Wegwerfen von Zellen/Paketen

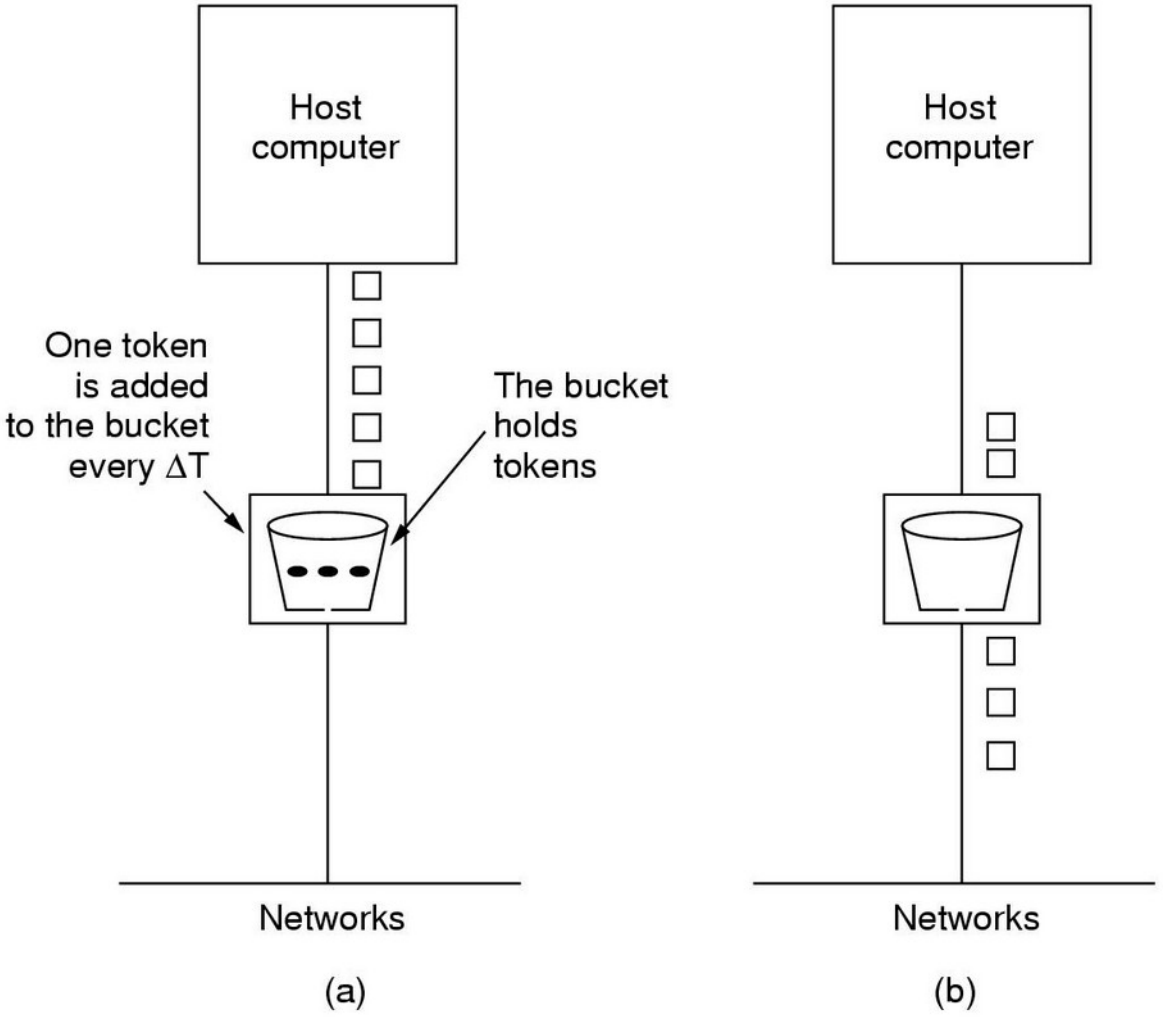
Traffic-Shaping

- Ausbügeln von Verkehrsspitzen
- Regeln der Übertragungsrate
- Vereinbarung von Kennzahlen (min,max,avg,qd) = Traffic Policing
- CBR, VBR, UBR (ABR)
- Queuing Disciplines
- SLA
- QoS Anforderungen und Techniken

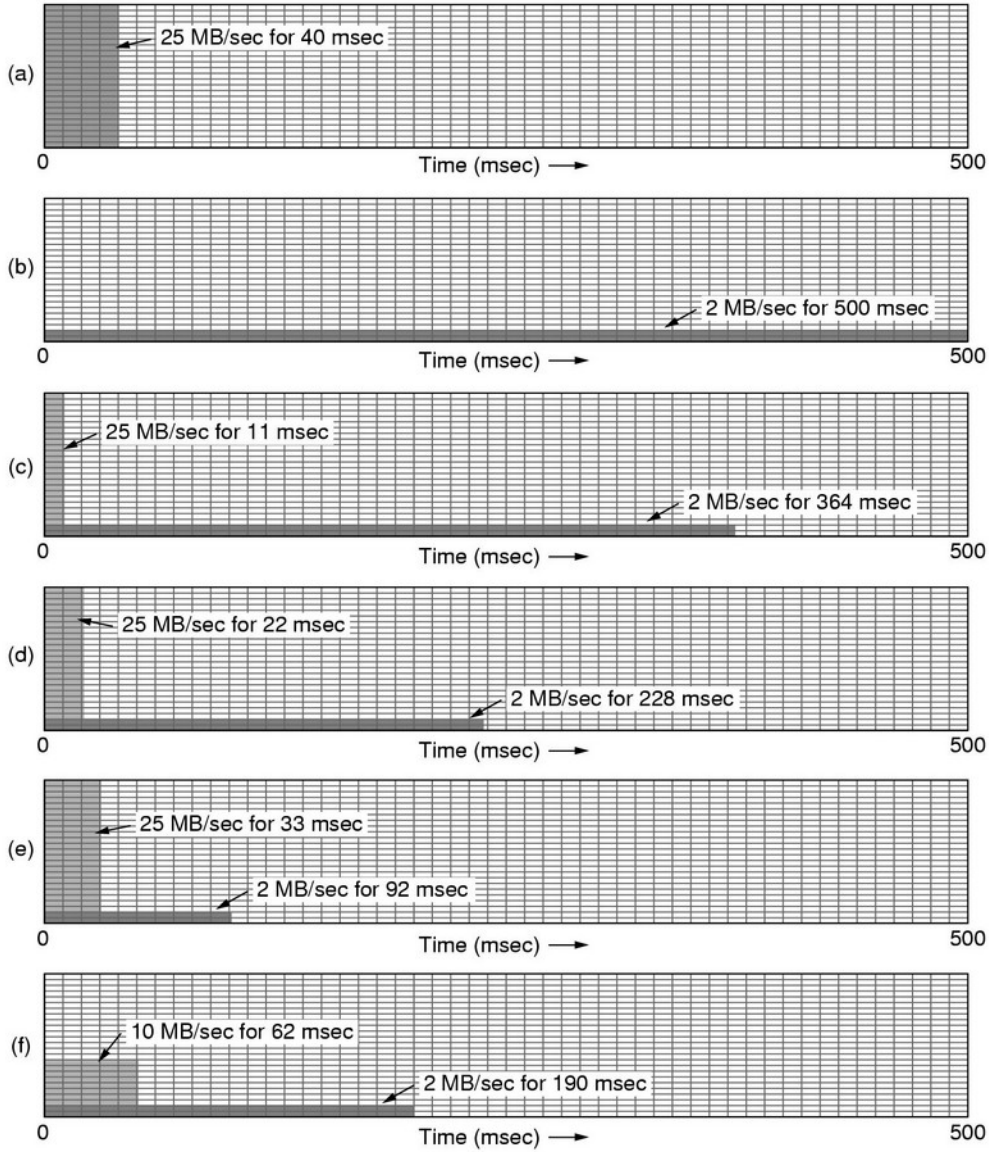
Leaky-Bucket-Algorithmus



Token-Bucket-Algorithmus



Beispiel LB und TB

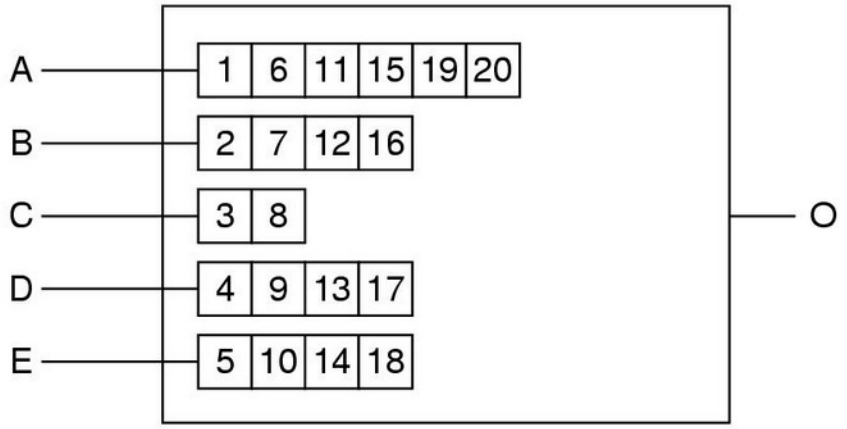


Flow Specification

Merkmal	**Gewünschte Dienstgüte**
Maximale Paketgöße (B)	Sensitivitätsverlust (B)
Token-Bucket-Rate (Bps)	Intervallverlust (ms)
Token-Bucket-Größe (B)	Packet-loss (P)
Max. Ü-rate (Bps)	Min. Delay (ms)
	Max. Jitter (ms)
	Qualitätsgarantie

Weighted Fair Queuing

- Fair Queuing, damit Brave überleben
- Bytes statt Pakete, damit Kleine überleben
- Plus Prioritäten = Weighted Fair Queuing



(a)

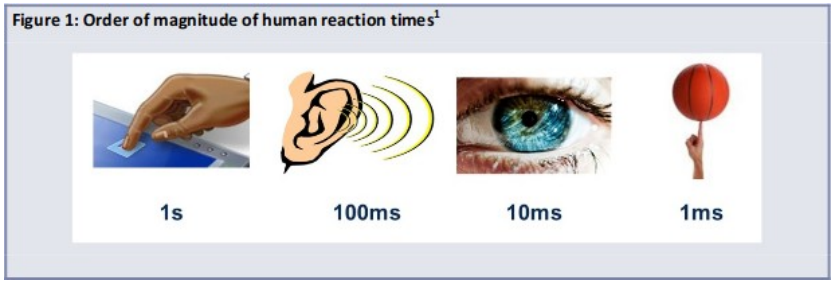
Packet	Finishing time
C	8
B	16
D	17
E	18
A	20

(b)

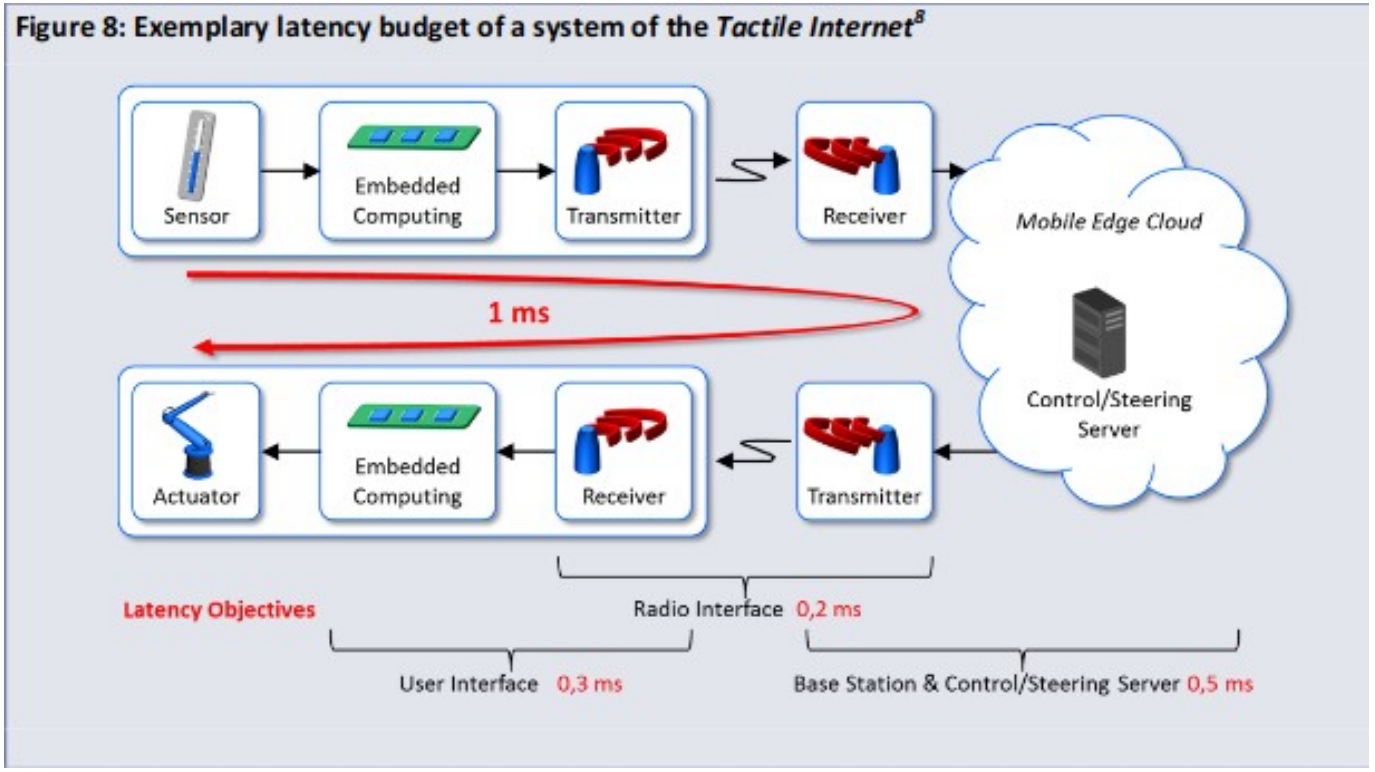
Jitter-Kontrolle

- Differenz zwischen Ankunftszeiten
- Wichtig bei Audio/Video
- Berechnung der erwarteten Ü-zeit
- Umsortieren in Wartenschlangen
- Früher oder später schicken

IEEE Tactile Internet (5G ;-)



Extremely low latency in combination with high availability, reliability and security



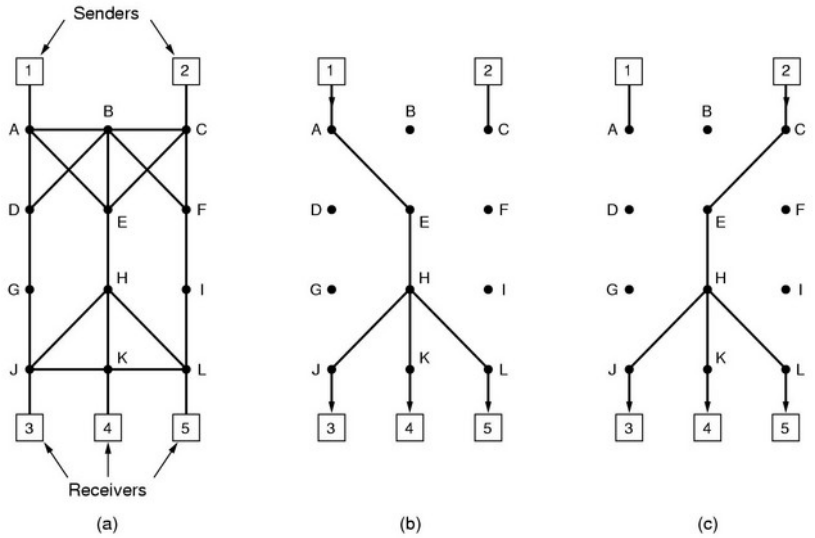
https://www.itu.int/dms_pub/itu-t/oth/23/01/T23010000230001PDFE.pdf

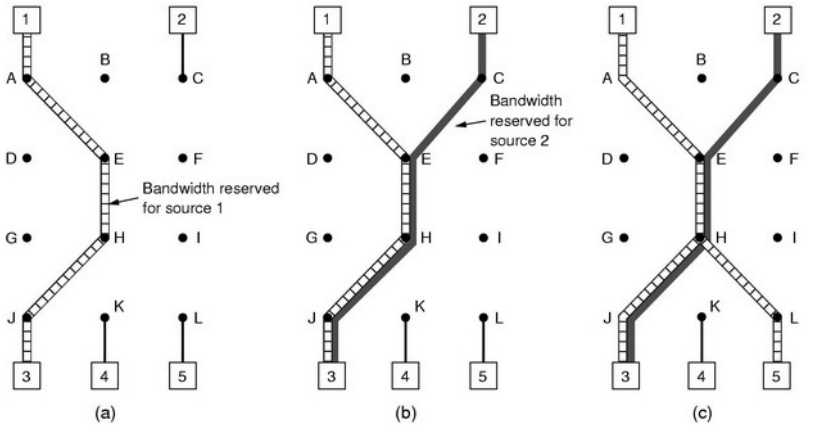
Internet-QoS

- Integrated Services – IntServ
  - Flusseinteilung, siehe RSVP
- Differentiated Services – DiffServ
  - (Verkehrs-)Klasseneinteilung
- Label switching – MPLS
  - Strom(-Leitungs)einteilung

Multicast Staukontrolle

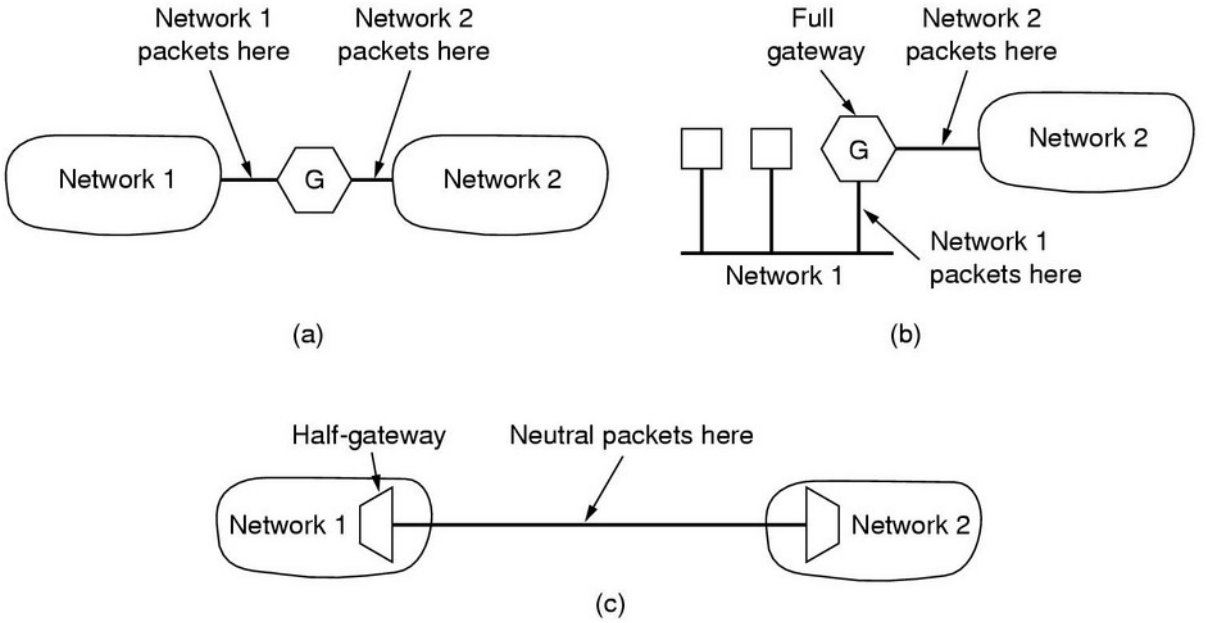
- RSVP
- Spanning Tree vom Multicast routing
- Reservierungsnachrichten zum Sender
  - Reserviert oder abgelehnt





Netzverbund/Internetworking

- Bridges
- Switches
- Router



- Mulitprotokollrouter
- Transport-Gateways
- Applikations-/Verarbeitungs-Gateways

Merkmale von Netzen

Merkmal	**Varianten**
Dienst	Verbindungslos, verbindungsorientiert
Protokolle	IPv4, IPv6 (IPX, *AppleTalk, DecNet, SNA*)
Adressierung	Adresslänge, Flach (802) oder hierarchisch (IP)
Multicasting/Broadcasting	Ja oder nein
Paketgröße	Minimum/Maximum Transmission Unit
Dienstgüte	Ja oder nein, versch. Klassen und Arten
Fehlerbehandlung	Zuverlässig, geordnet oder ungeordnet
Flußkontrolle	Schiebefenster, Rate, andere, keine
Überlastbehandlung	Leaky-/token-bucket, Choke, RED, ECN…
Sicherheit	Datenschutzregeln, Verschlüsselung,...
Parameter	Timeouts, Flußspezifikationen, QoS
Abrechnung, Kostenerfassung	Zeit, Volumen, QoS, keine

Internet-Netzverbund

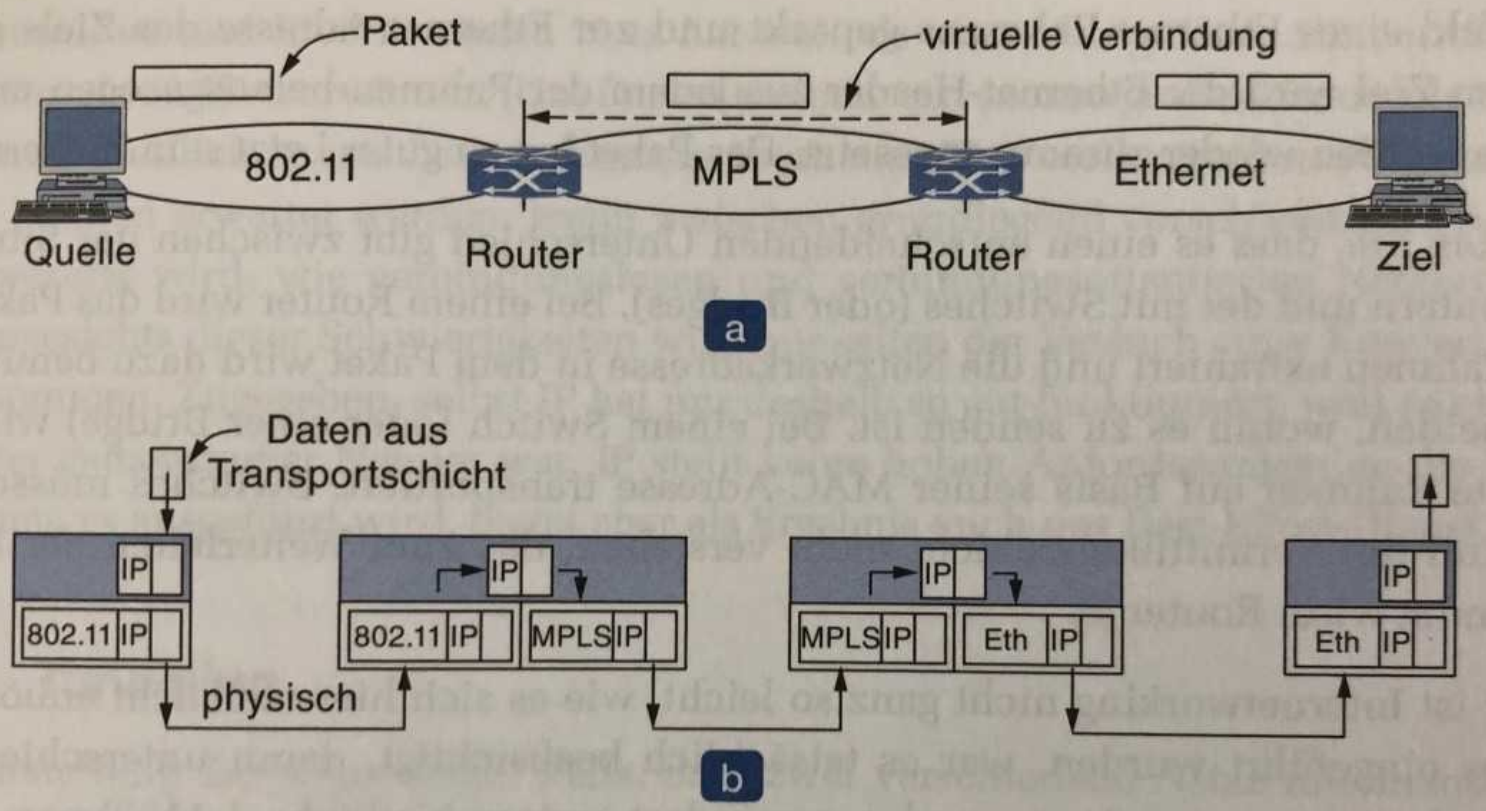
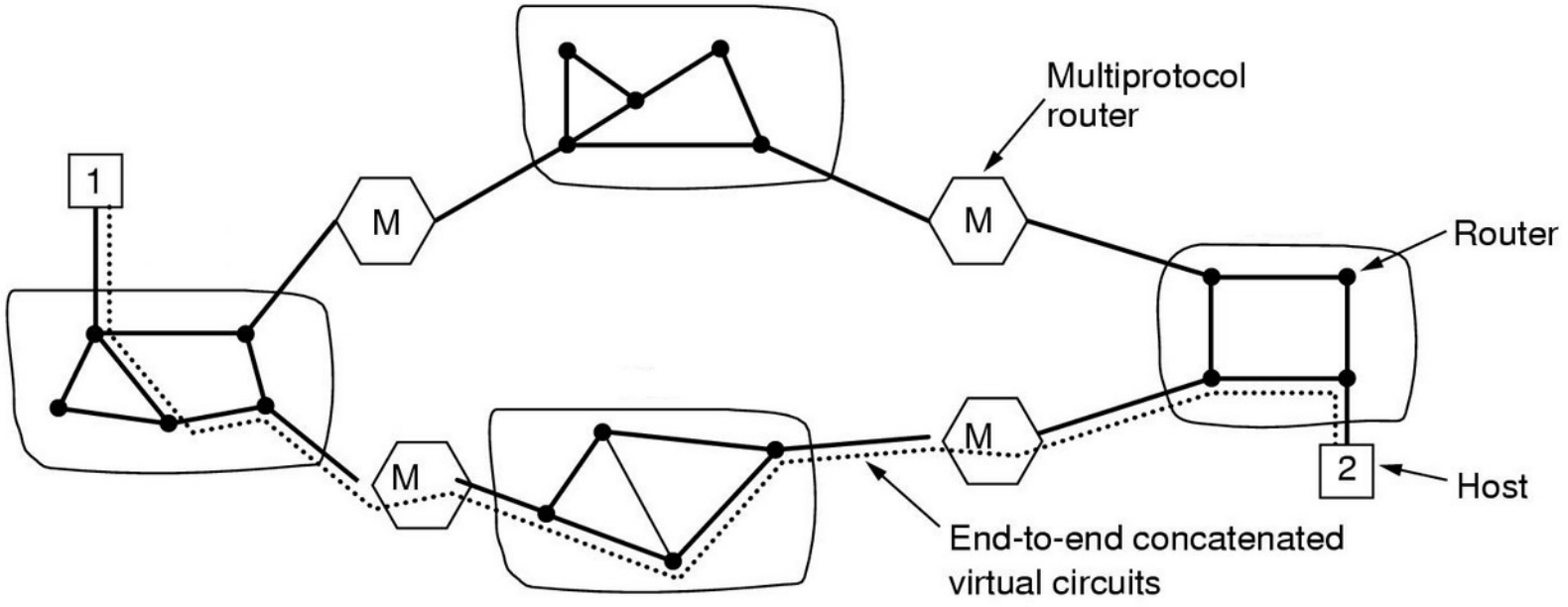


Abbildung 5.39: (a) Ein Paket, das unterschiedliche Netze durchquert. (b) Abarbeitung der Vermittlungsschicht- und Sicherheitsschichtprotokolle.

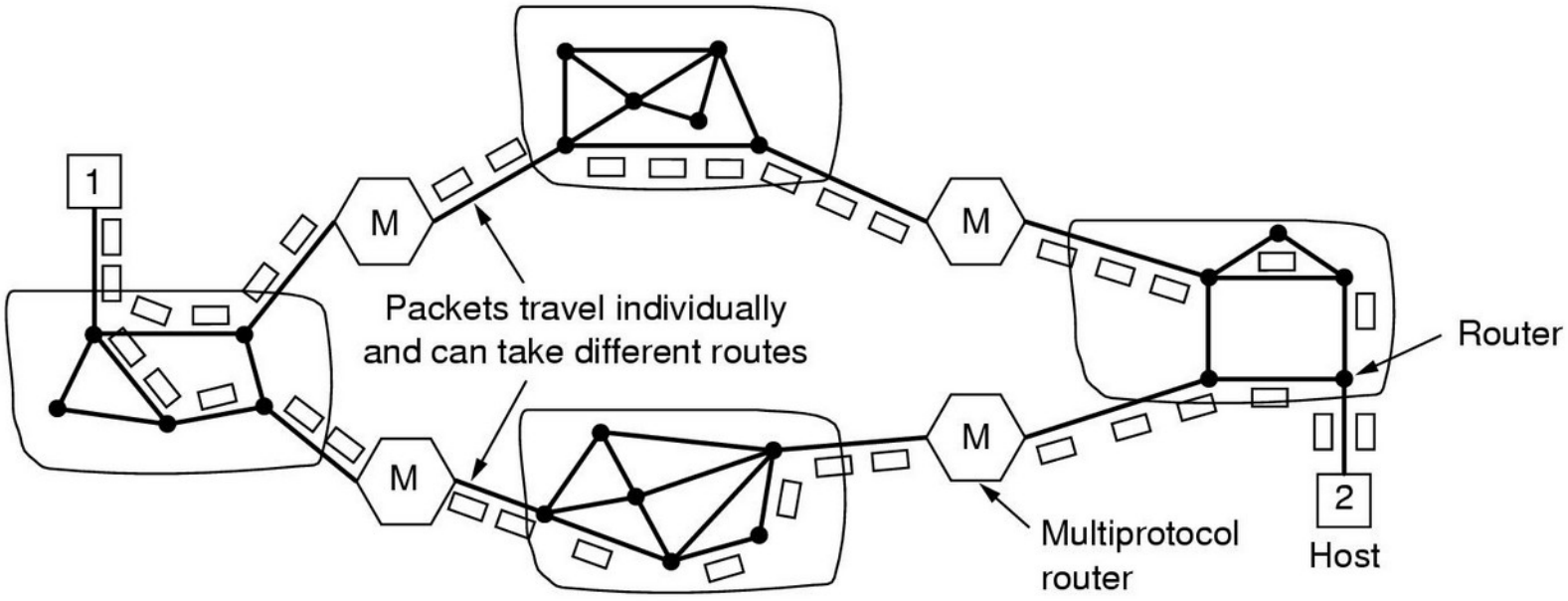
Verbund virtueller Leitungen

- Multiple Verbindungen -> Tabellen



Verbund von Datagram-Netzen

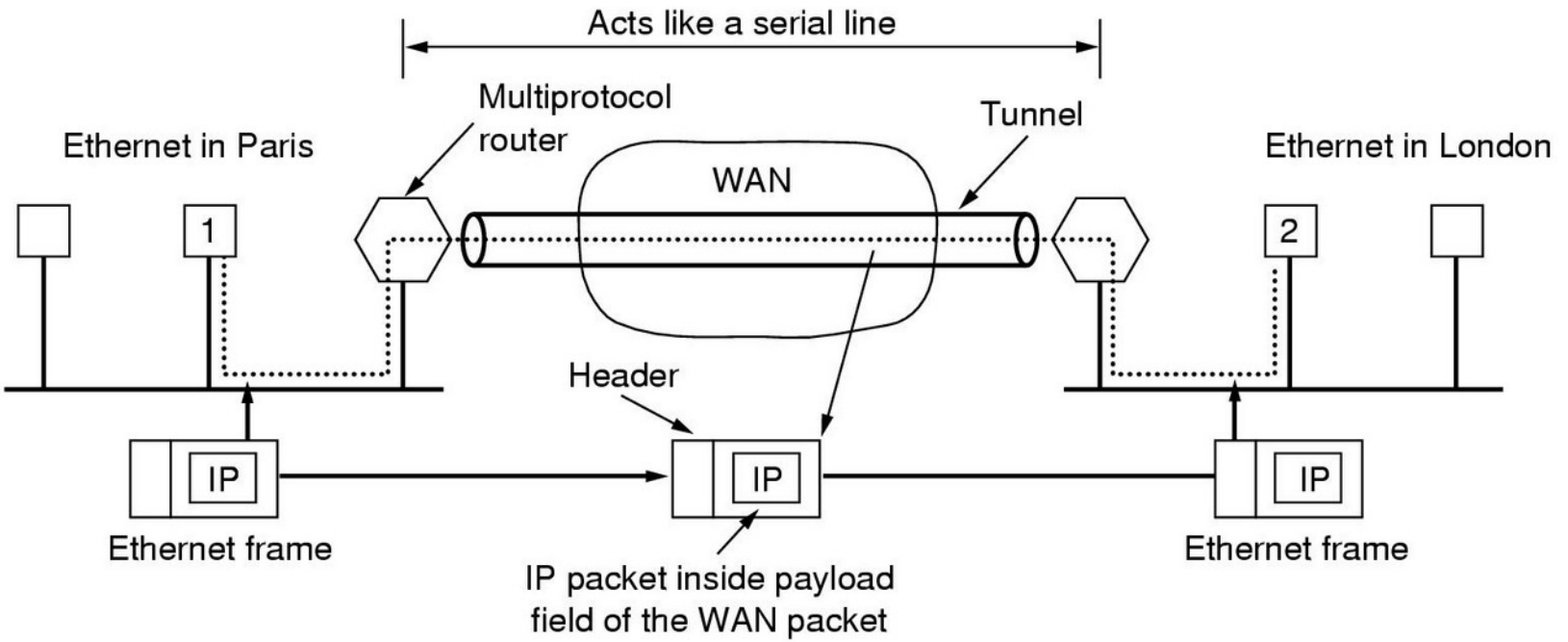
- Universelles Paketformat – IP(v4)

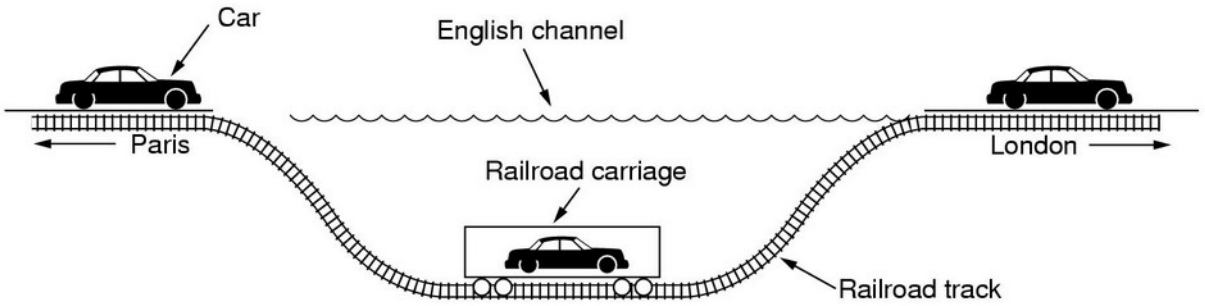


Verbundnetze: VC vs DG

VC	**DG**
Kurze Header	Lange Header
Reihenfolge gleich	Reihenfolge beliebig
Keine Duplikate	Duplikate/Verluste
Fixe Route	Jede (Ausweich-) Route
Puffer pro Verbindung	Überlast
VC über DG schwierig(er)	DG über VC einfach(er)

Tunneln/Kapseln/GRE





Tunneling →Virtualisation

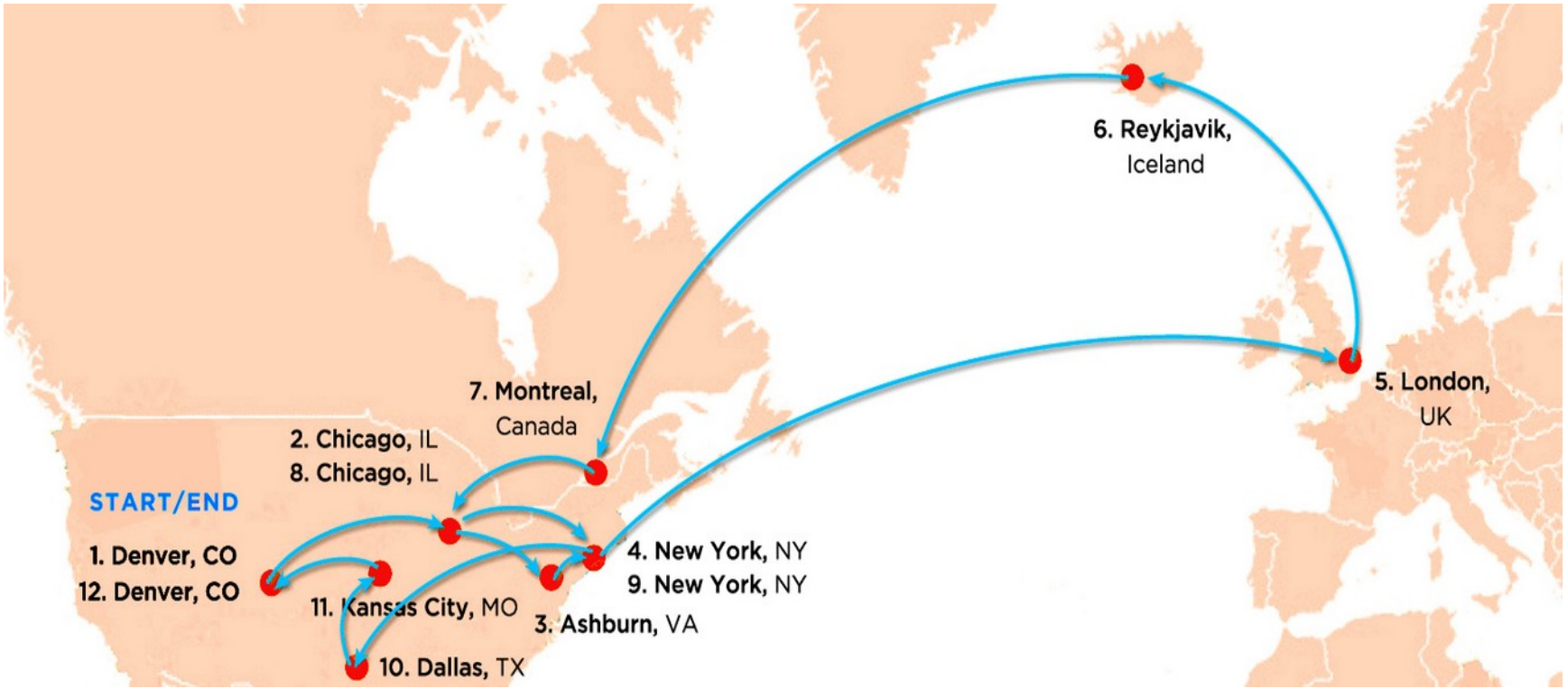
- Virtual Extensible LAN (Ethernet over UDP)
- Tunneling Protocols ("X" in/over "Y")
- Network Function Virtualisation (e.g. IDS)
- Software Defined Networking (e.g. OpenFlow)
- Network Virtualisation e.g. OpenStack, Kubernetes
- RFC8560 (May 2019)

Internetwork-Routing

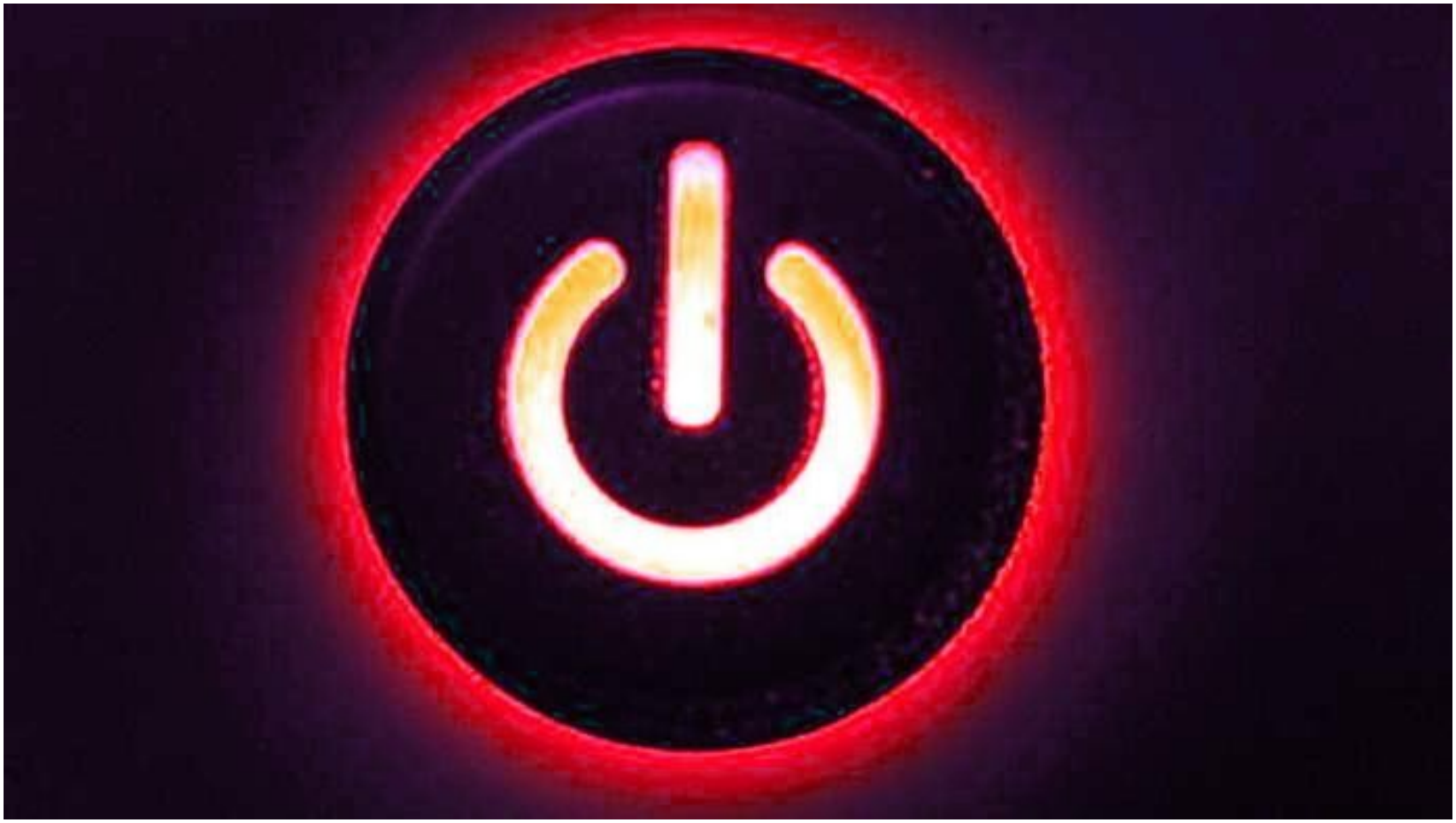
- Internes (OSPF) vs externes Routing (BGP) -> (nummerierte) Autonome Systeme
- Direkte vs getunnelte Beförderung
- Gesetze und Regelungen, Datenschutzrecht
- Peering, Kosten und Abrechnung
- Routen-/Pfadauswahl

“Rätselhafte Entführungen im Internet”

http://www.heise.de/netze/meldung/Raetselhafte-Entfuehrungen-im-Internet-2053503.html



Internet “Kill-Switch”



https://www.accessnow.org/tag/internet-shutdown/

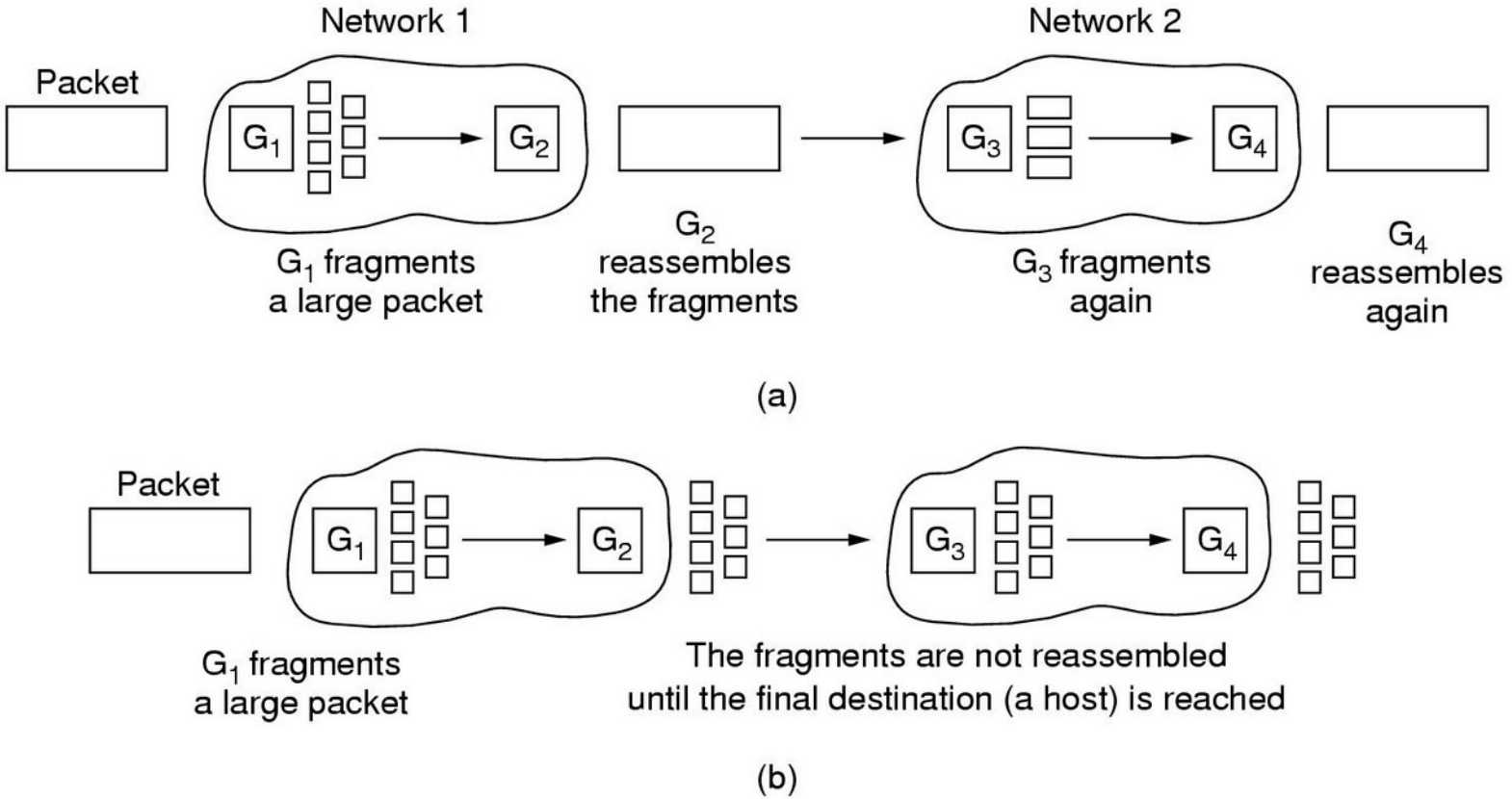
https://www.heise.de/newsticker/meldung/RIPE-74-IP-Adress-Entzug-als-Strafe-gegen-Regierungen-3711380.html

Warum Fragmentierung?

- Hardware (Rahmenlänge/Zeitschlitze)
- Betriebssystem (Puffer)
- Protokolle (Längenfeld)
- Standards
- Fehler-/Wiederholungsminimierung
- Kanalbelegung
- = Segmentierung

Wie Fragmentierung?

- Transparent vs nicht-transparent



Fragmentierungsprobleme

- Nicht erlaubt: Path MTU Discovery mit Don’t Fragment Bit

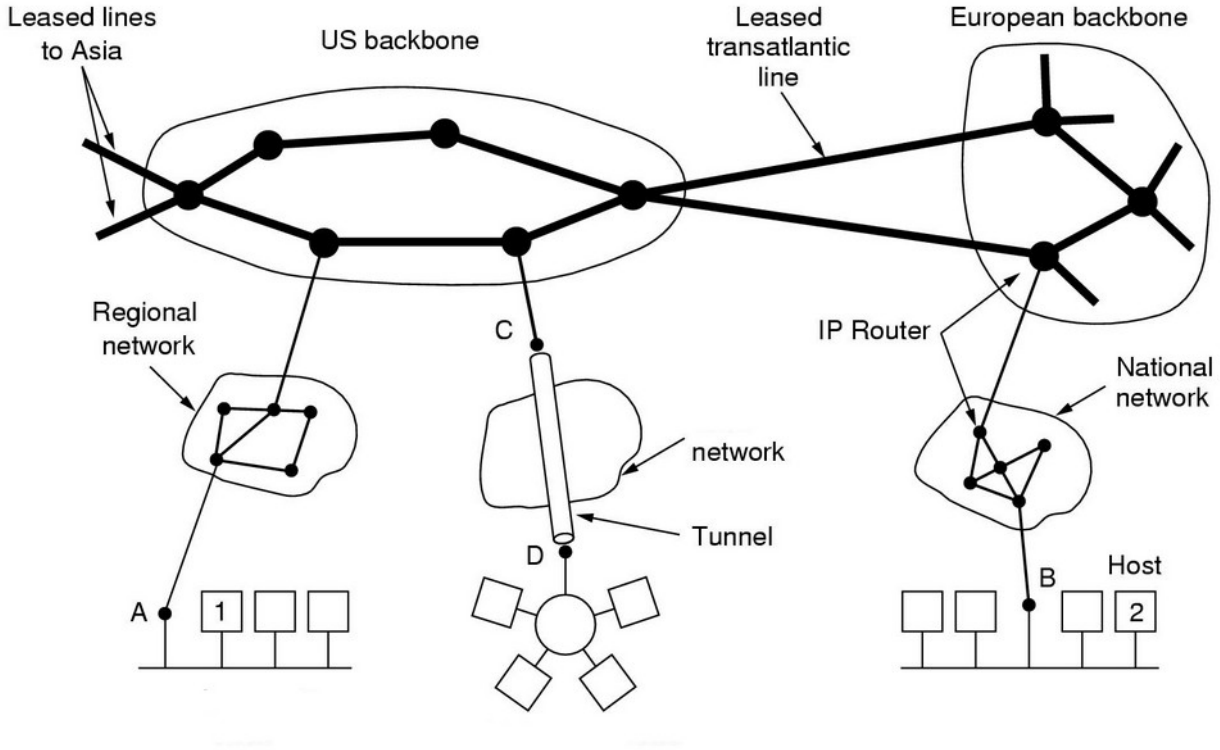
- Transparent
    - gleicher Router
    - Overhead durch mehrmaliges Frag/Defrag
- Nicht-transparent
    - Host
    - Nummerierung, wenn Frag-zahl sich ändert
    - Hilfe durch elementare Fragmentgröße -> IP

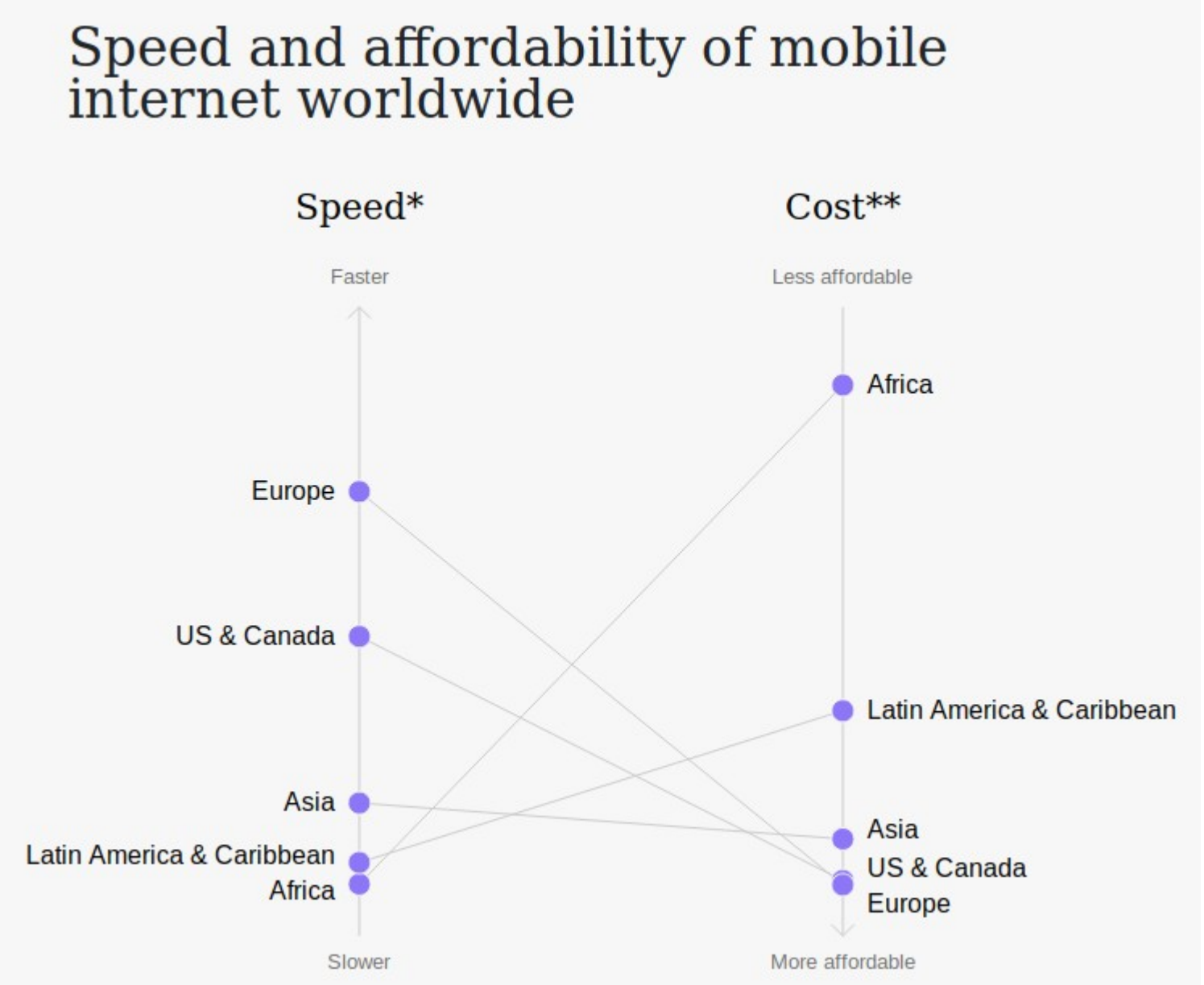
„Ships in the Night“

- Gemeinsame oder getrennte Routing-Entscheidungen
- Common vs Separate
- Independent vs Integrated
- IPv4 -> IPv6

“Das Internet”

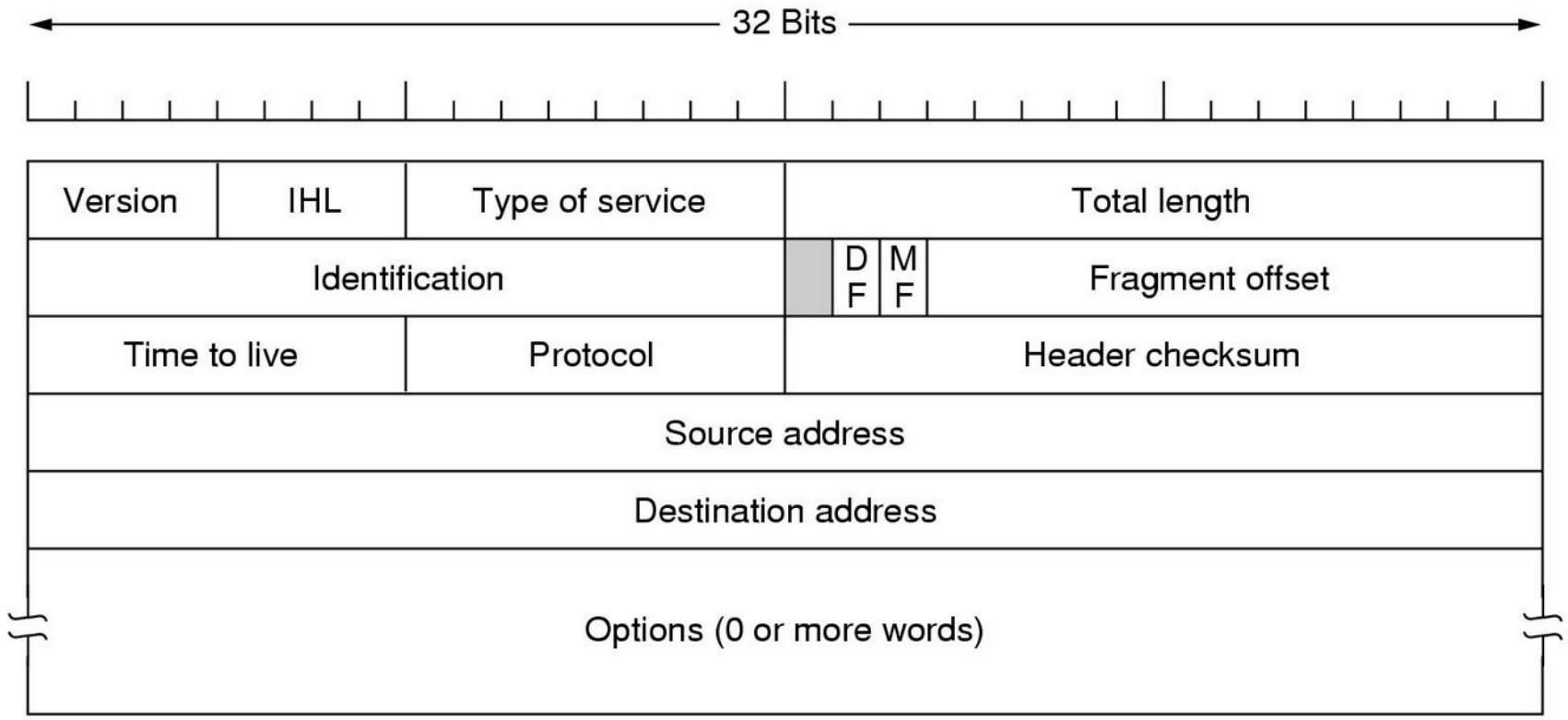
- Kopplung von Autonomen Systemen mit IP





https://internethealthreport.org/2019/the-worlds-slowest-internet-is-the-least-affordable/

Der Internet Protokoll Header



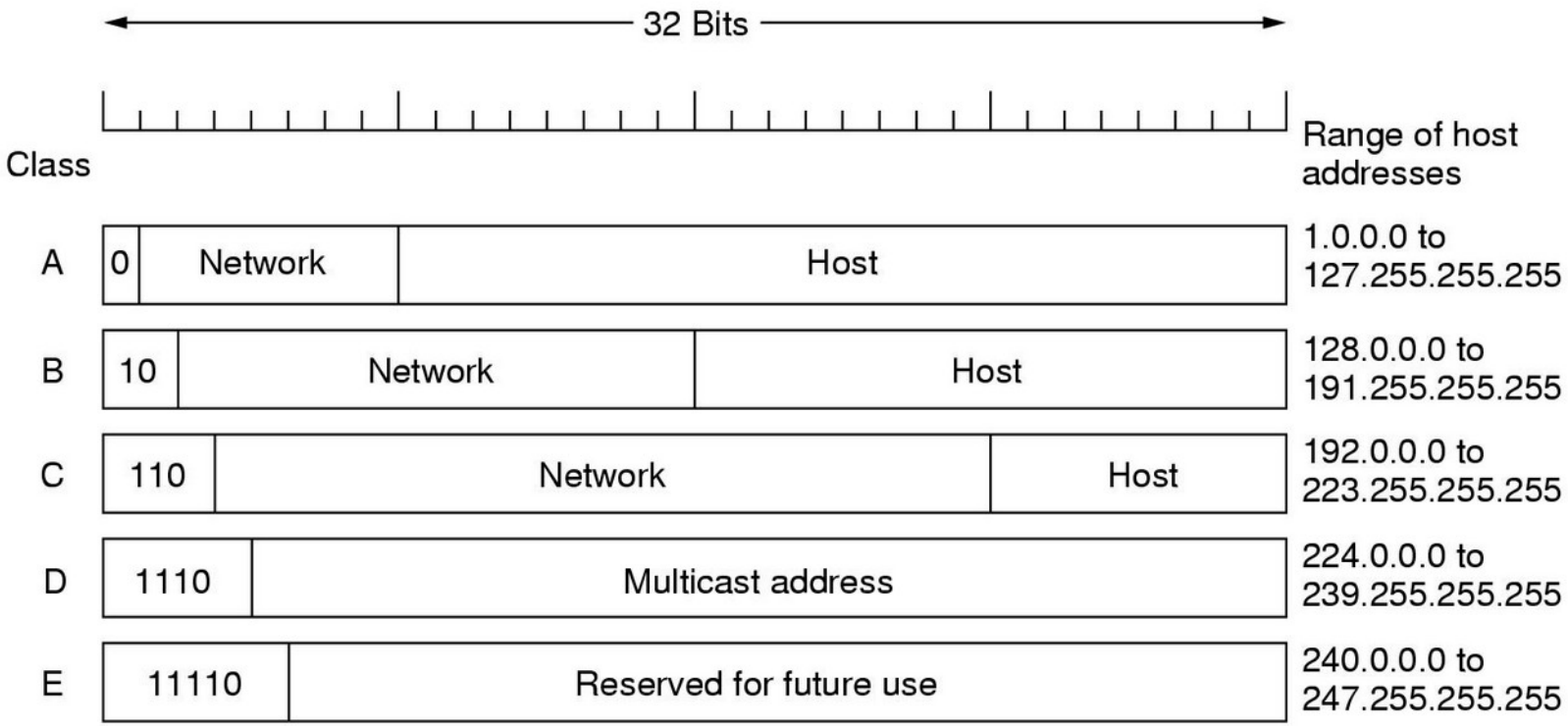
Orig. TOS=3bit Precedence+DTR+2bit reserved

Akt. TOS=6bit DSCP (Differentiated Services Code Point)+2bit ECN

…und seine Optionen

Sicherheit	z.B. Routenvermeidung
Striktes Source-Routing	Kompletter Pfad
Loses Source-Routing	Liste von Routern
Routenaufzeichnung	IP-Adresse von Routern
Zeitstempel	Adresse und Zeitmarke

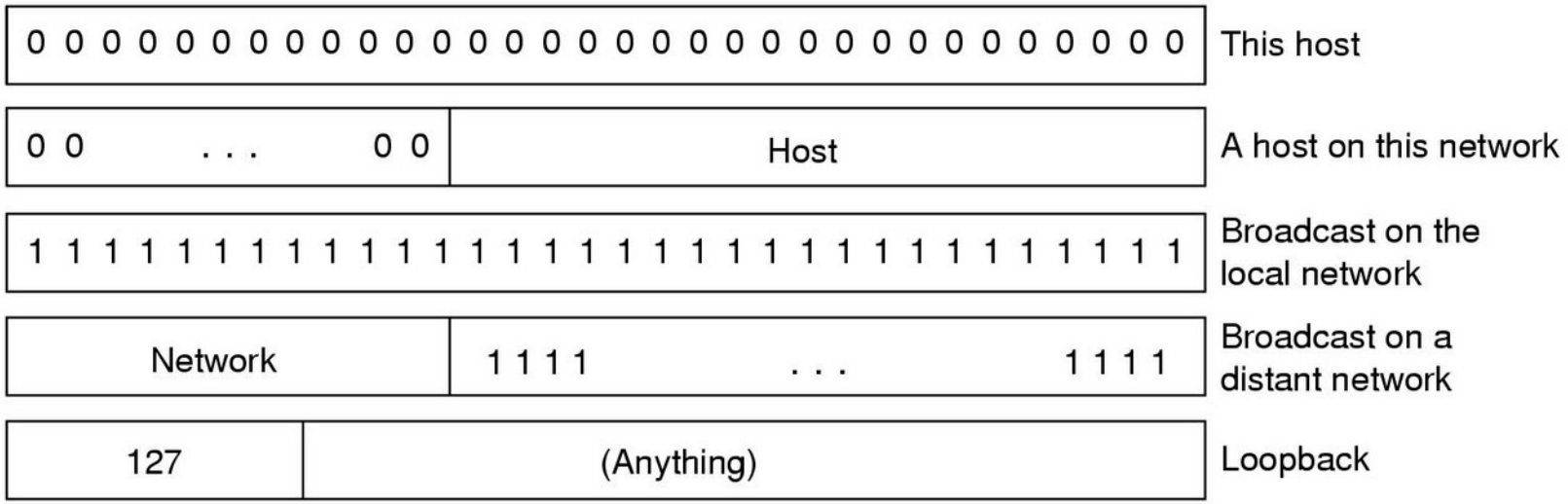
IPv4-Adressen



Address Class	Bits In Prefix	Maximum Number of Networks	Bits In Suffix	Maximum Number Of Hosts Per Network
A	7	128	24	16777216
B	14	16384	16	65536
C	21	2097152	8	256

Spezielle IPv4-Adressen

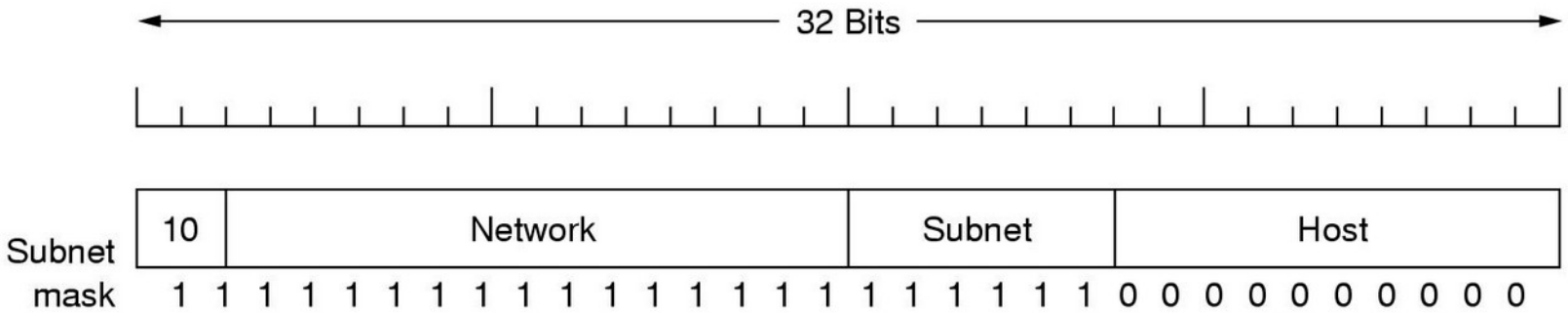
- Netzwerk, Broadcast



- RFC1918-Private Adressen: 10/8, 172.16/12, 192.168/16
- Link-local Adressen: RFC3927: 169.254/16

Teilnetze / subnets

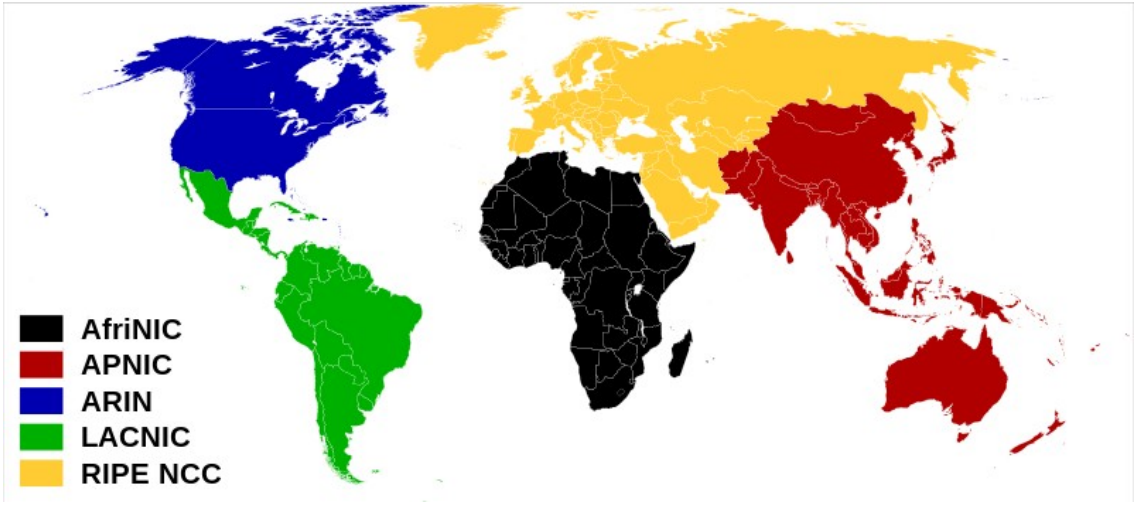
- Wenige zu große B, viele zu kleine C



- Angabe
  - 10.1.1.1/23
  - net 10.1.0.0 netmask 255.255.254.0 broadcast 10.1.1.255
  - 10.5.0.1/17
  - net 10.5.0.0 netmask 255.255.128.0 broadcast 10.5.127.255
  - https://www.heise.de/netze/tools/netzwerkrechner/

CIDR

- Classless Inter-Domain Routing (RFC 1519)
- Knappe Adressen durch Klasseneinteilung ABC
- Vermeidung von riesigen Routing-Tabellen durch Aggregation und Einteilung in Zonen (zB 194 RIPE, 196 AFRINIC, 198 ARIN, 200 LACNIC, 133 APNIC)
- http://www.iana.org/assignments/ipv4-address-space



NAT und so

- Network Address Translation aka IP masquerading
  - Interne IP-Adressen (meist private) IPs “umschreiben” in 1 oder mehrere (meist public) IPs
  - Mapping über 16 bit Transportprotokoll-Ports
  - “Verbindungsaufbau” von innerhalb (meist) nötig
- Port Forwarding aka Destination NAT
  - Damit interne Ports (=Rechner/Dienste) über public-IP erreichbar sind
  - Problem bei dynamischen public-IPs → dynDNS
- Session Traversal Utilities for NAT (STUN), October 2008
  hieß mal Simple Traversal of UDP through NATs
- Traversal Using Relays around NAT (TURN), April 2010
- Interactive Connection Establishment (ICE), July 2018

SNAT vs DNAT

SOURCE NETWORK ADDRESS TRANSLATION EXAMPLE				
Source	Destination		Source	Destination
10.0.0.2:1234	8.8.8.8:53/udp		178.190.120.3:4096	8.8.8.8:53
10.0.0.3:1234	8.8.8.8:53/udp		178.190.120.3:4097	8.8.8.8:53
10.0.0.4:3032	141.201.80.2:80/tcp		178.190.120.3:4096	141.201.80.2

SNAT vs DNAT

DESTINATION NETWORK ADDRESS TRANSLATION EXAMPLE				
Source	Destination		Source	Destination
2.0.0.2:10203	178.190.120.3:80/tcp		2.0.0.2:10203	10.0.0.2:80
6.6.6.9:30321	178.190.120.3:22/tcp		6.6.6.9:30321	10.0.0.3:22
9.9.9.9:44444	178.190.120.3:443/tcp		9.9.9.9:44444	10.0.0.3:443

Warum nur NAT?

- Vorteile?
  - IP Masquerading → Privatsphäre
  - IP Adressraum Vergrößerung
- Nachteile
  - Intermediäre vertrauenswürdig? Mitm!
  - Erreichbarkeit “interner” Geräte
  - Abbruch von Verbindungen bei NAT-Crash
  - Benutzt “Wissen” über Transportschicht (Port)
  - STUN/TURN leaken interne/private Addressen

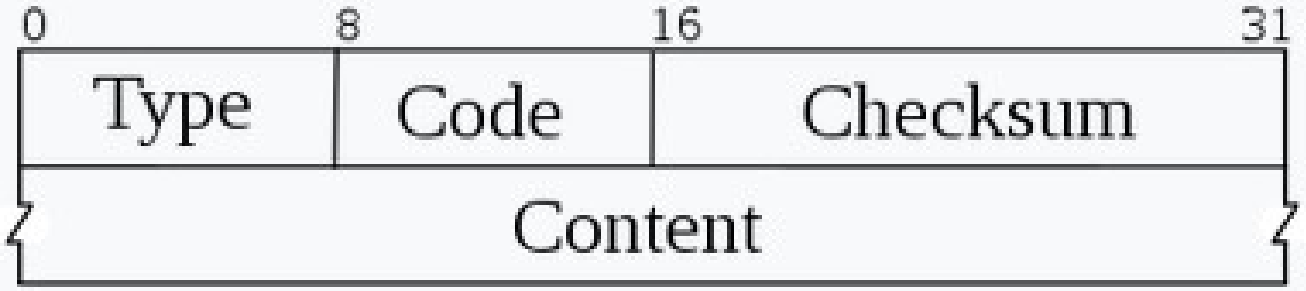
Internet Steuerprotokoll: ICMP

- Internet Control Message Protocol, inside IP, Protocol 1
  RFC 792, RFC 1812, cleanup: RFC 6918
  - Destination Unreachable (Type: 3, Code: 0-15)
  - Time Exceeded
  - Parameter Problem
  - Source Quench (deprecated, May 2012)
  - Redirect
  - Echo-Request und Echo-Reply
  - Timestamp-Request und Timestamp-Reply
  - Router Advertisement und Router Solicitation

ICMP packet format

Internet Control Message Protocol

Communication protocol



A general header for ICMPv4.

Purpose	Auxiliary protocol for IPv4 [1]
Developer(s)	DARPA
Introduced	1981
OSI layer	Network layer
RFC(s)	RFC 792

Internet Steuerprotokoll: ARP

- Address Resolution Protocol RFC 826
  - EtherType 0x806
  - IP-Adresse → MAC-Adresse? who-is → is-at
  - Caching, Proxy-ARP, Gratuitous ARP

ARP-Nachrichtenformat am Beispiel Ethernet-MAC-Adressen und IPv4-Adressen

Bit 0–7	Bit 8–15	Bit 16–23	Bit 24–31
Hardwareadresstyp (1)		Protokolladresstyp (0x0800)	
Hardwareadressgröße (6)	Protokolladressgröße (4)	Operation	
Quell-MAC-Adresse			
Quell-MAC-Adresse		Quell-IP-Adresse	
Quell-IP-Adresse		Ziel-MAC-Adresse	
Ziel-MAC-Adresse			
Ziel-IP-Adresse			

ARP packet format

Internet Protocol (IPv4) over Ethernet ARP packet

Octet offset	0	1
0	Hardware type (HTYPE)	
2	Protocol type (PTYPE)	
4	Hardware address length (HLEN)	Protocol address length (PLEN)
6	Operation (OPER)	
8	Sender hardware address (SHA) (first 2 bytes)	
10	(next 2 bytes)	
12	(last 2 bytes)	
14	Sender protocol address (SPA) (first 2 bytes)	
16	(last 2 bytes)	
18	Target hardware address (THA) (first 2 bytes)	
20	(next 2 bytes)	
22	(last 2 bytes)	
24	Target protocol address (TPA) (first 2 bytes)	
26	(last 2 bytes)	

Internet Steuerprotokoll: RARP

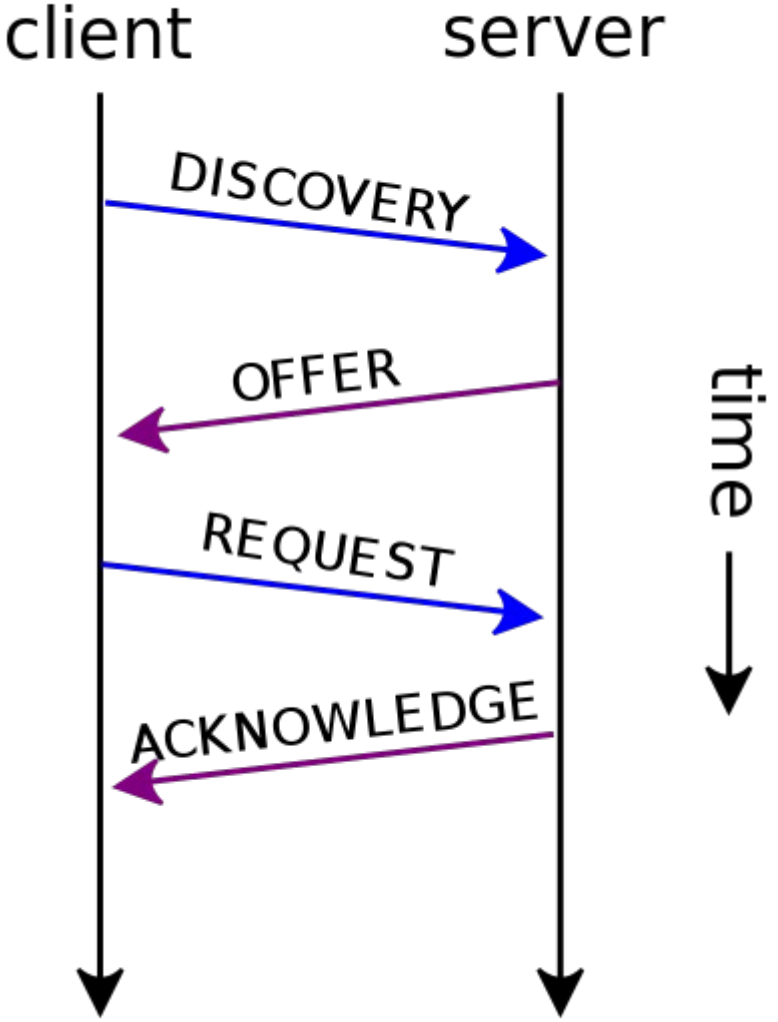
- Reverse Address Resolution Protocol
  RFC 903
  - MAC-Adresse -> IP-Adresse?
  - Begrenztes Broadcasting mit 32x1
  - Ethertype 0x8035
  - Keine (Sub-)Netzmaske
- BOOTP RFCs 951, 1048, 2131
  - Verwendet UDP
  - Einstellen von IP Adresse, Netzmaske, Router, Bootserver

DHCPv4

- Dynamic Host Configuration Protocol
- RFC 2131
- Erweiterung von BOOTP
- Zuteilung von IP Adresse, Netzmaske, Router, Zeit, ...
- Client-server model
- 3 modes
    - Automatic allocation
    - Dynamic allocation
    - Manual allocation

DHCPv4 Nachrichten

- DISCOVER(client)
- OFFER(server)
- REQUEST(c)
- ACK(s)
- RELEASE(c)
- INFORM(c)
- NAK(s)
- DECLINE(c)



DHCPv4 Client Verhalten

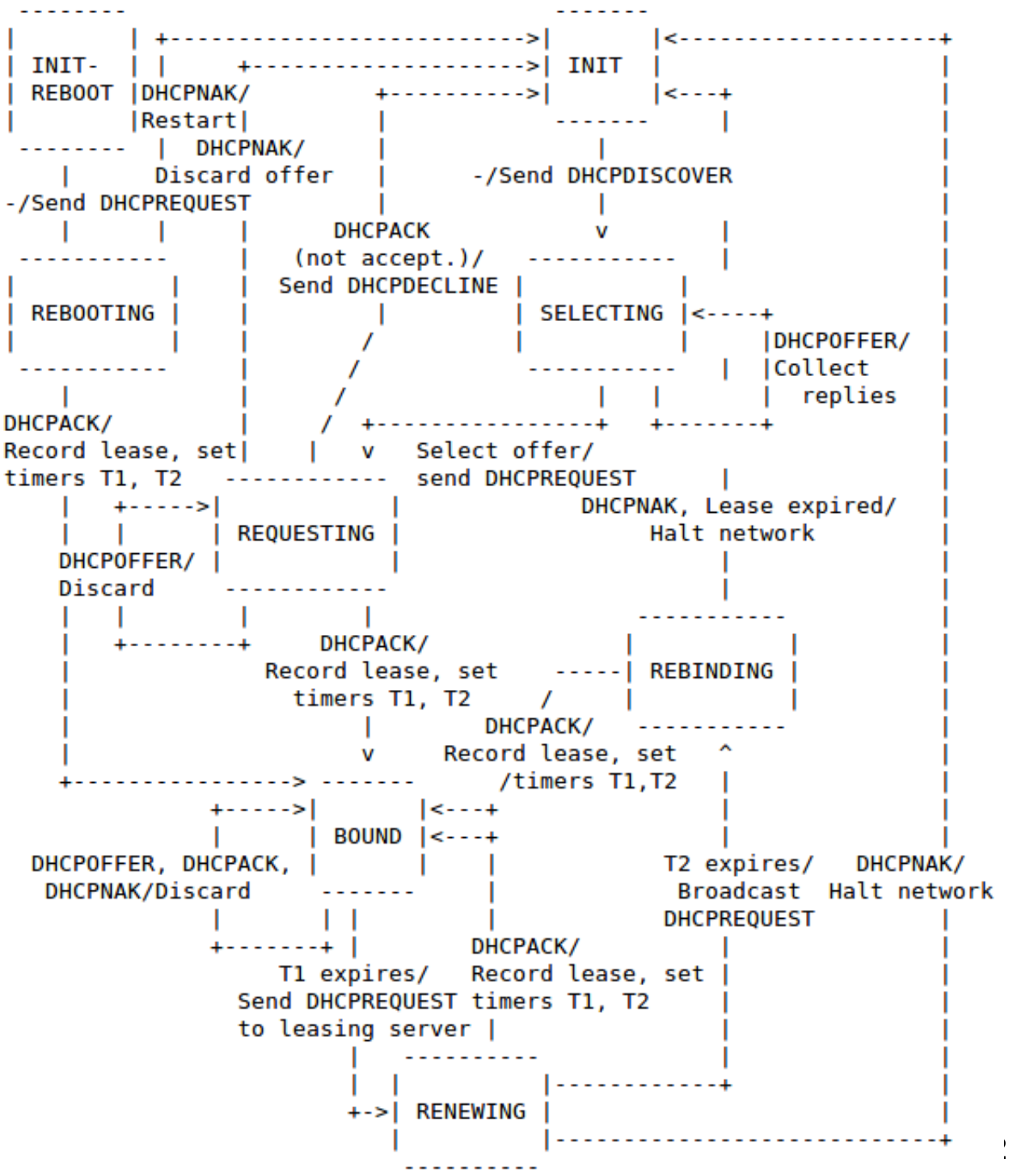
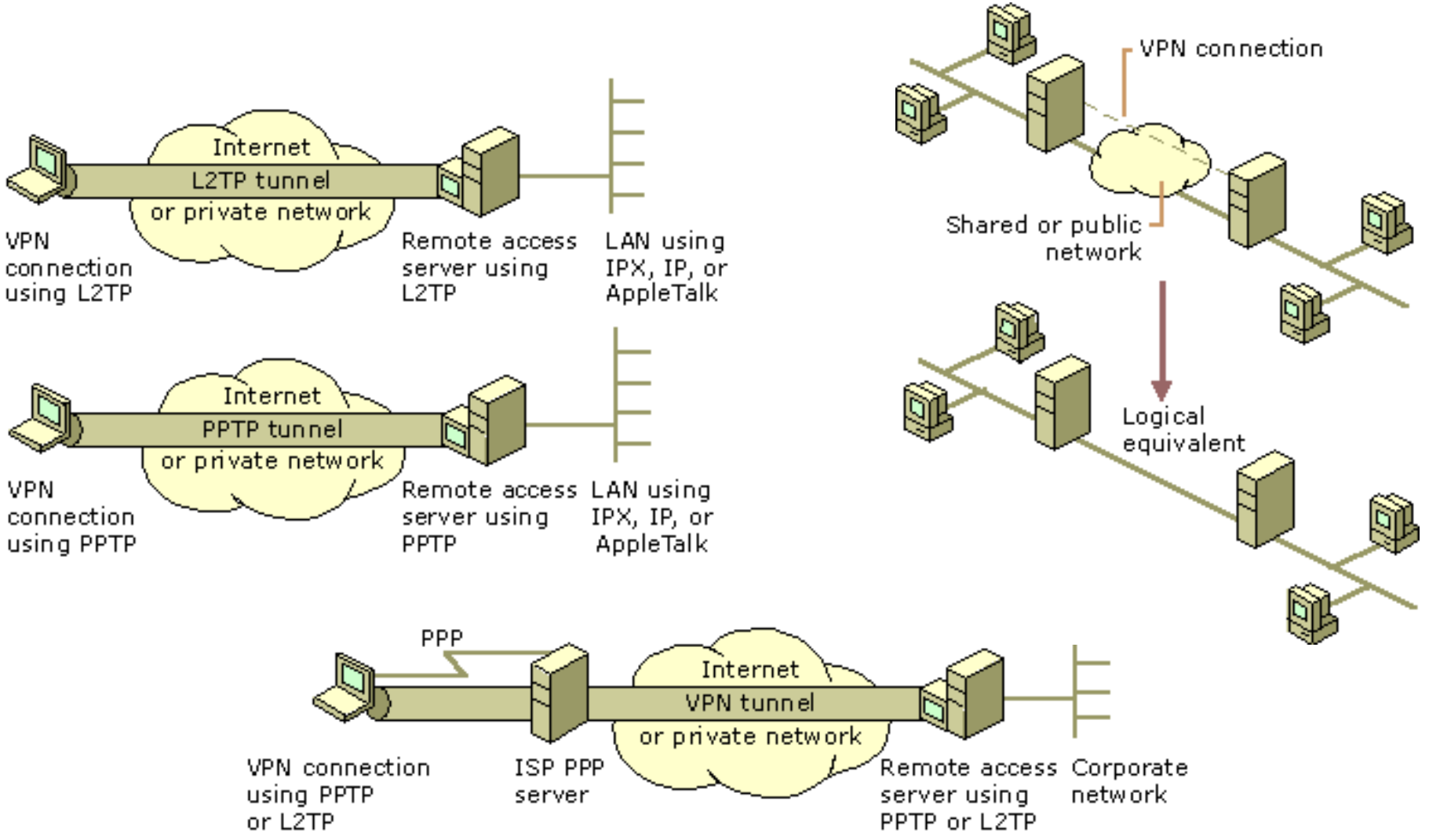
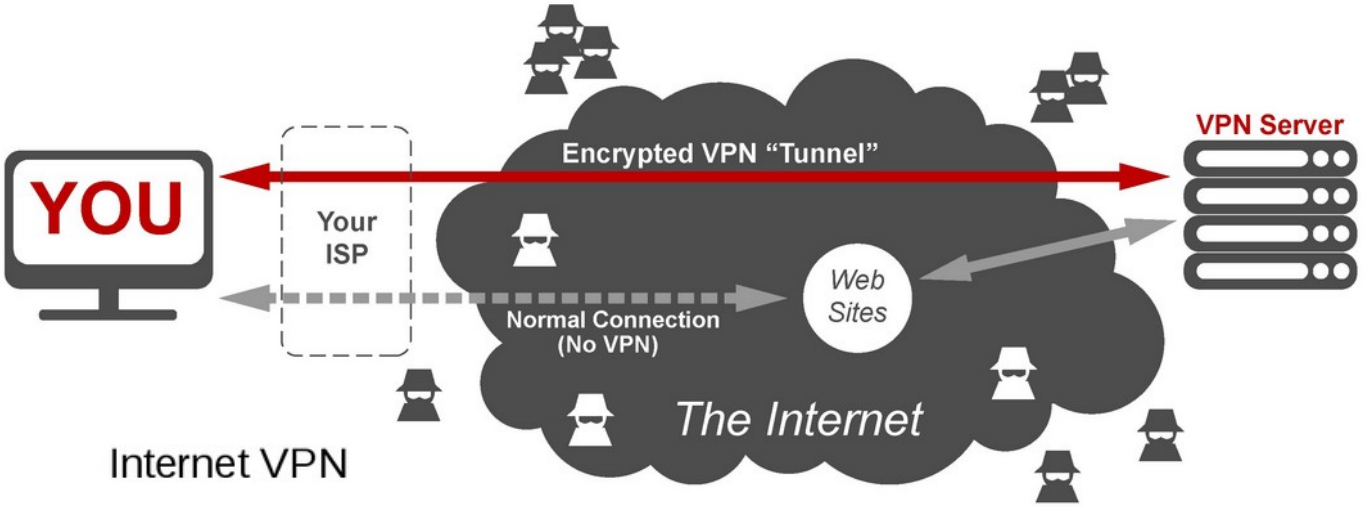


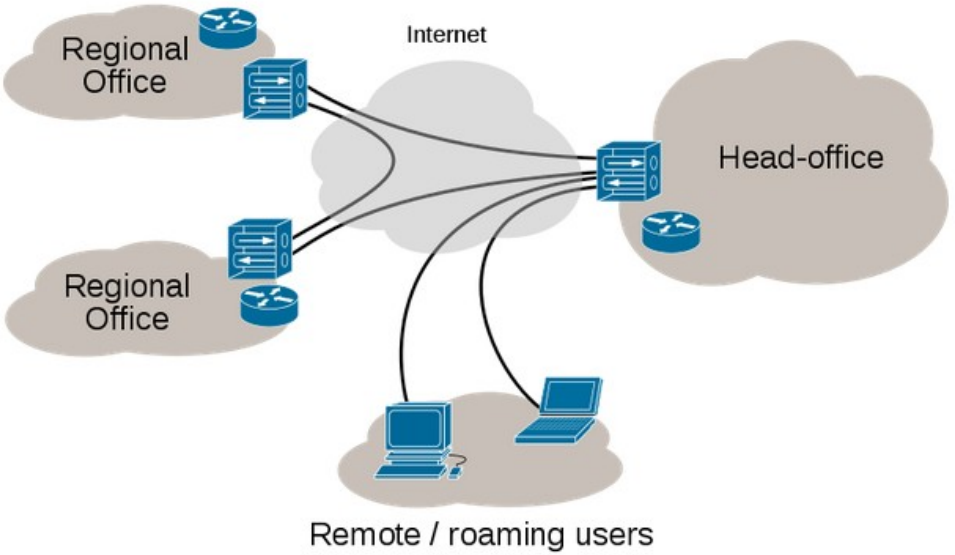
Figure 5: State-transition diagram for DHCP clients

Virtual Private Networks



Virtual Private Networks



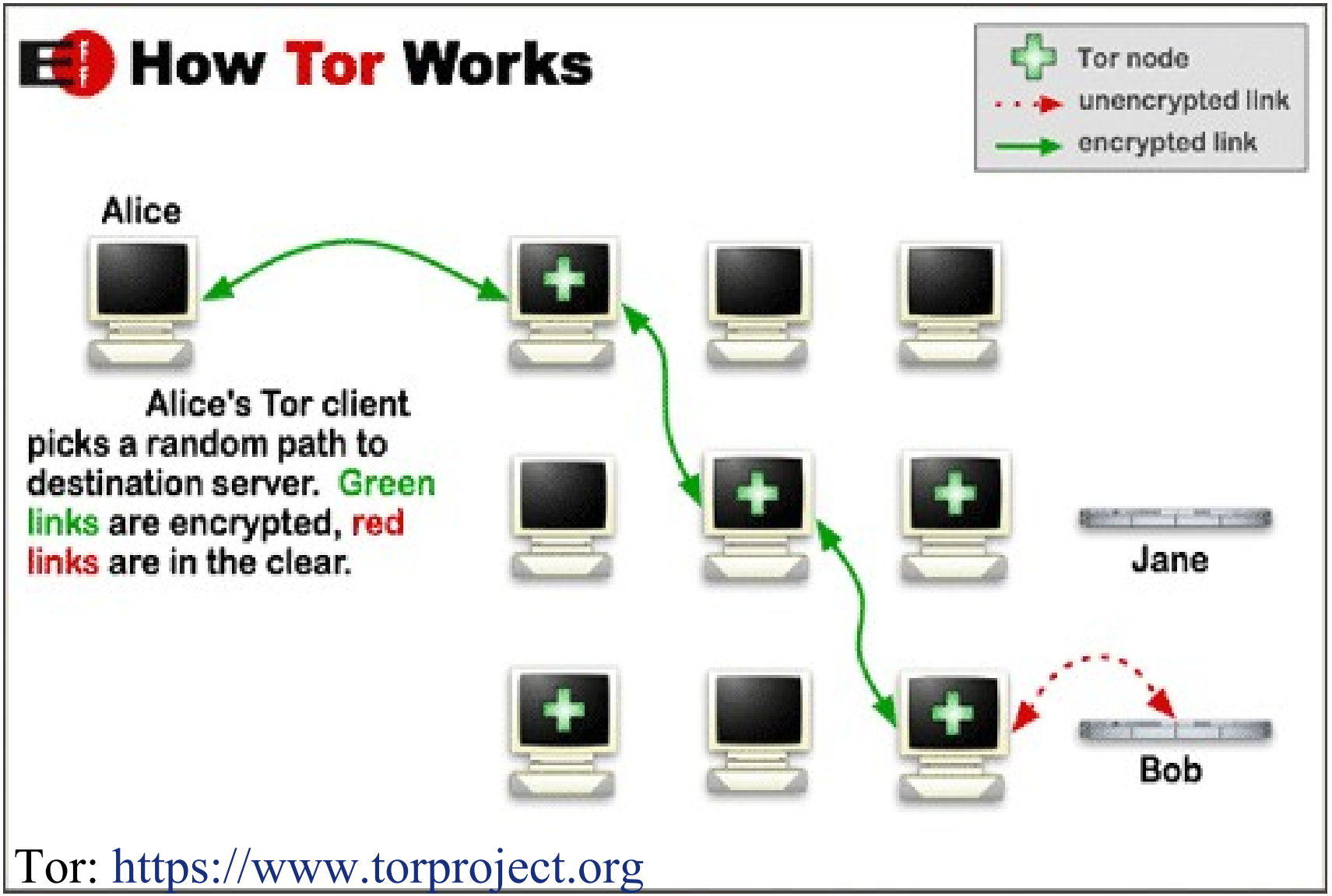


PPTP, L2TP, ...

- Point-to-Point Tunneling Protocol (PPTP) PPTP uses user-level Point-to-Point Protocol (PPP) authentication methods and Microsoft Point-to-Point Encryption (MPPE) for data encryption.
- Layer Two Tunneling Protocol (L2TP) with Internet Protocol security (IPSec) L2TP uses user-level PPP authentication methods and machine-level certificates with IPSec for data encryption.
- Openssl
- Openvpn
- WireGuard

Vergleich von VPN-Lösungen

The Onion Routing network



Tor: https://www.torproject.org

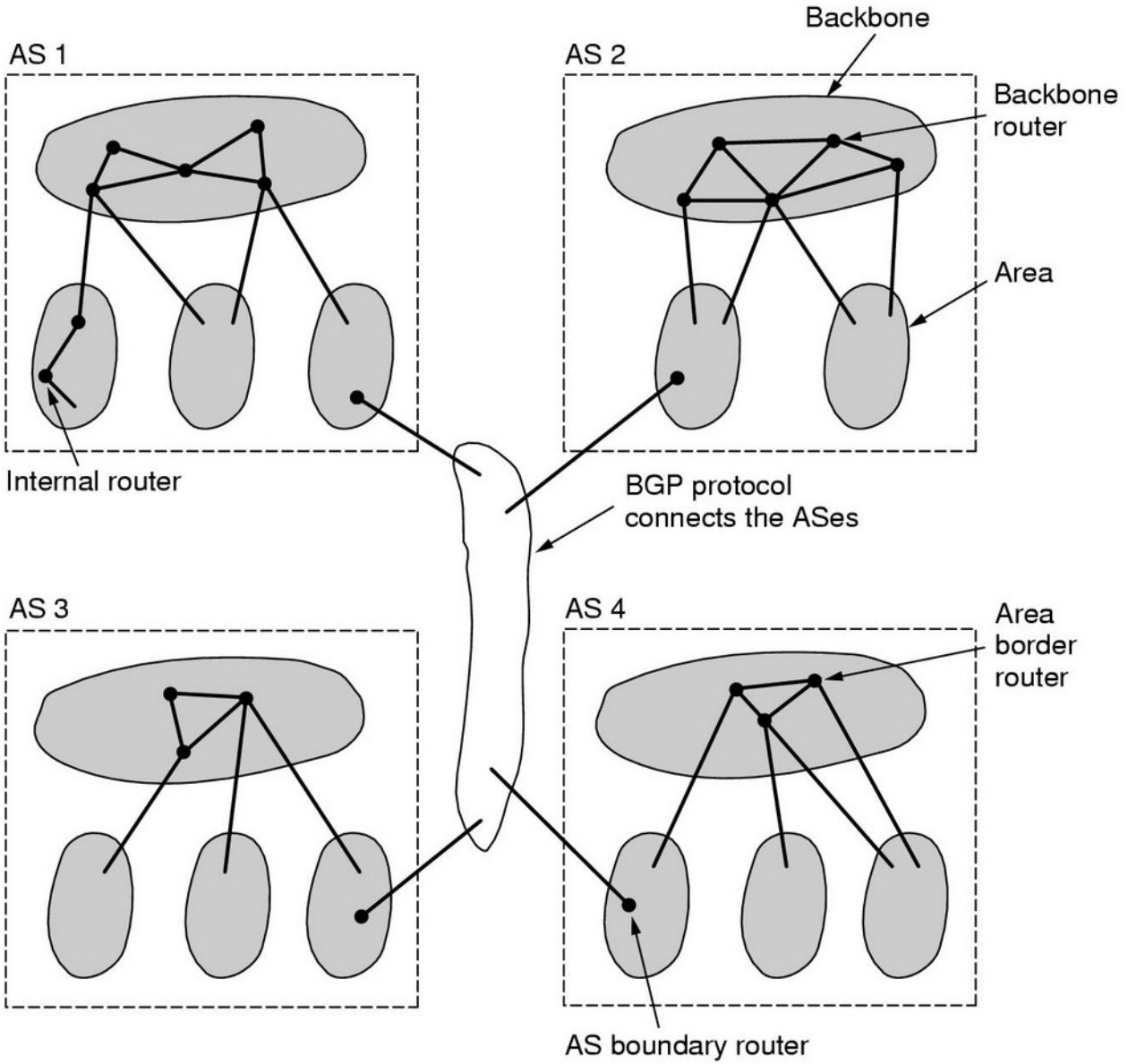
OSPF (1)

- Open Shortest Path First (RFC 2328 v2, 5340 v3 4IP6)
  - **Intradomain**, internal gateway protocol, within AS
  - Open, Multimetrik, dynamisch, Lastausgleich, hierarchisch, ...
  - Für PTP, Multi-Access Networks mit Broadcast (LAN) oder ohne (WAN)
  - Areas, Backbone-Area -> Graphen
  - Router: Interne, Grenz, Backbone, AS
  - Kommunikation mit IP (Protocol 89)
  - Flooding

OSPF (2)

Nachrichtentyp	**Beschreibung**
Hello	Periodisch auf alle Interfaces
Database Description	SeqNr neuester LSAs holen
Link State Request	Neuere Einträge anfordern
Link State Update	Einträge feststellen
Link State Ack	Bestätigung für Update

OSPF (3)


Backbone
AS 1
AS 2
Backbone router
Area
Internal router
BGP protocol connects the ASes
AS 3
AS 4
Area border router
AS boundary router

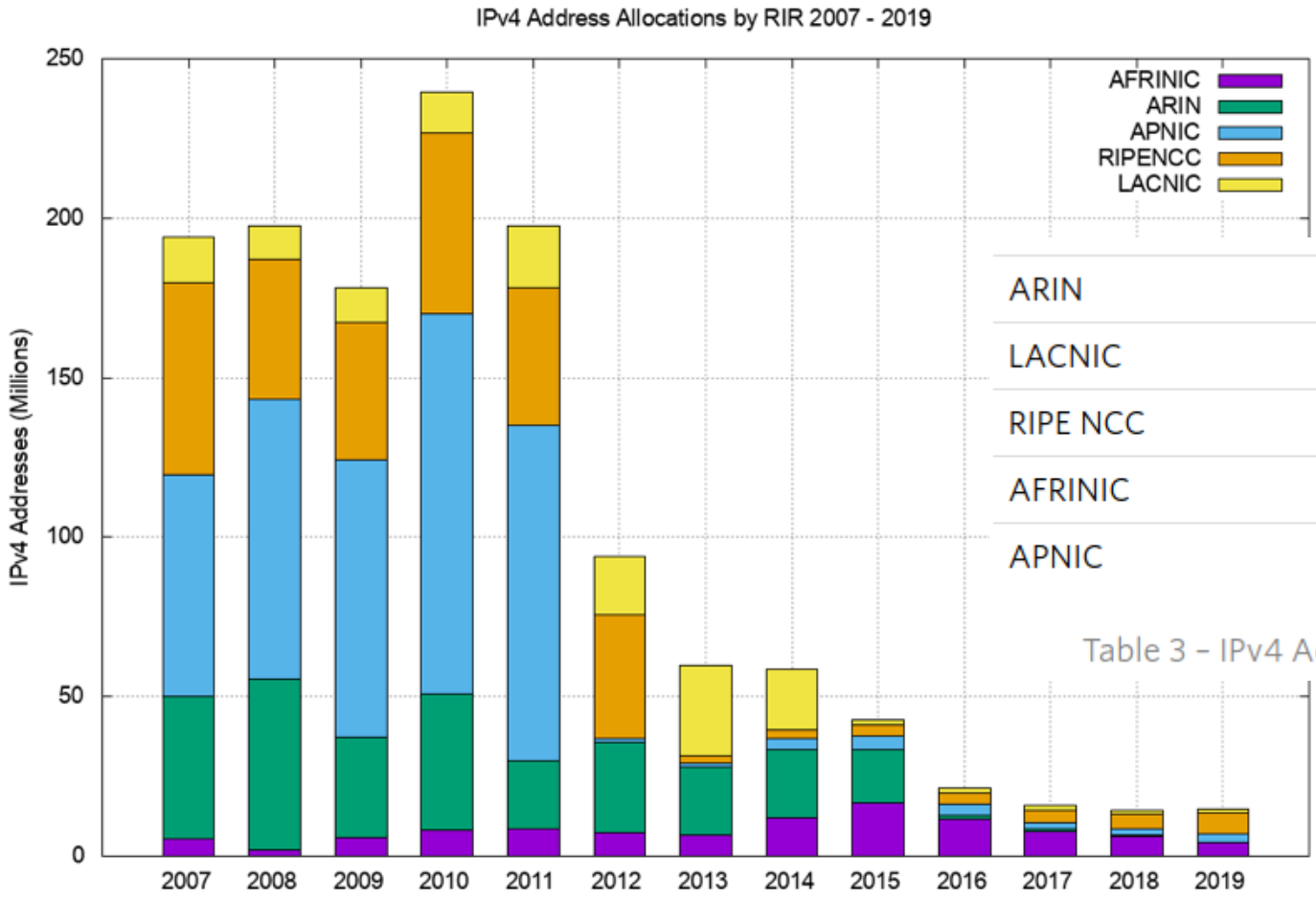
BGP

- Border Gateway Protocol (RFC 1654, 1268)
- **Interdomain**, external gateway protocol
- Policy-Routing, Peering-Vereinbarungen
- Netzarten: Stub, Multiconnected/-homing, Transit
- Kommunikation mittels TCP
- Distance-Vector mit Komplettpfad -> Path-Vector zur Erkennung von Fehlern und Vermeidung von Count-to-Infinity
- Pfadlänge als Optimierungswert gut?
- BGPsec (RFC 8205), September 2017 Test your ISP ;)

IP-Multicast

- Class D: 224.0.0.0-239.255.255.255, 224.0.0.0/4
- Permanente oder temporäre Gruppen
  - 224.0.0.1 alle Hosts in einem LAN
  - 224.0.0.2 alle Router in einem LAN
  - 224.0.0.5 alle OSPF-Router in einem LAN
  - ...
  - IANA Guidelines for IPv4 Multicast Address Assignments
- LAN
  - Internet Group Management Protocol (RFC 1112, 2236, 3376, 4604)
  - mDNS
- WAN
  - Distance Vector Multicast RP (RFC 1075)
  - Multicast OSPF (RFC 2328)
  - Protocol Independent Multicast (RFC 2362)

IPv4 am Ende?



ARIN	exhausted
LACNIC	exhausted
RIPE NCC	exhausted
AFRINIC	mid-2020
APNIC	late-2021

Table 3 – IPv4 Address Pool Depletion Projections b

https://blog.apnic.net/2020/01/21/addressing-2019/