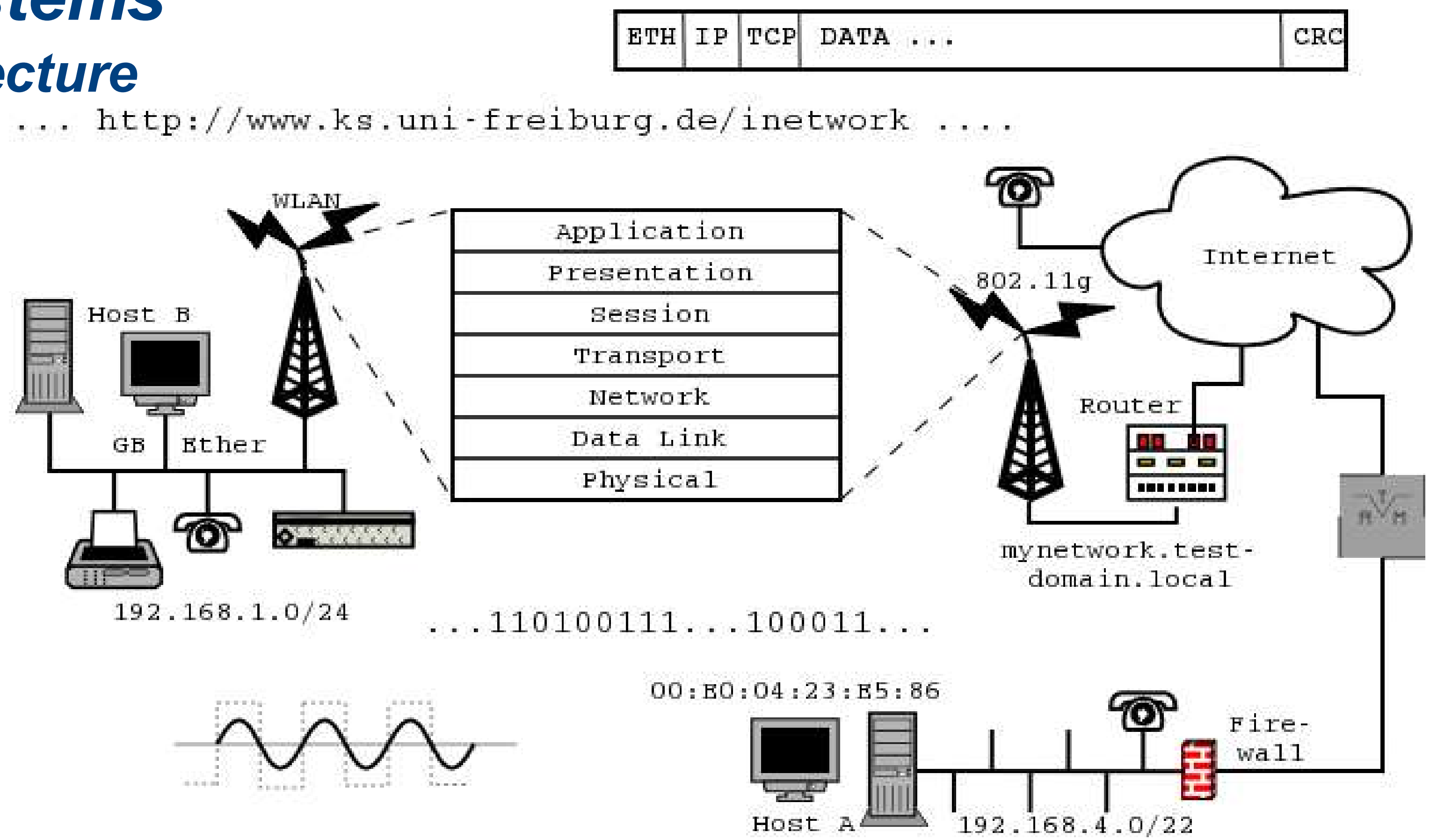
Communication Systems

2nd lecture



Chair of Communication Systems
Department of Applied Siences
University of Freiburg
2006

Communication Systems
Formalities

- We set up a mailing list for this course, please add your address to the list we pass around (if not done in last lecture)
- Use this list too, to indicate which of the three options for the written exam you prefer
  - Thursday, 27th of July, 6 - 8 pm
  - Friday, 28th of July, 10 - 12 am
  - Friday, 28th of July, 1 - 3 pm
- The lecture earns 6 ECTS points
- The lecture will start at 4:15pm as decided on Tuesday
- Next Tuesday is practical course – SR -113 in the basement of computing dept. (H.-Herder-Str.10)

Communication Systems
Last lecture

- Introduction into this course, for more information please check the slide set of last lecture!
- Definitions of
  - Internets
  - Hosts and end systems
  - Intermediate systems, packet switches, routers
- Examples of IP networks (BelWue, B- and G-Win, GEANT, ... tier 1 & 2 providers)
- Service descriptions
- Definition of a protocol

Communication Systems
Last lecture

- Layers of protocols
- Communication in networks
- Introduction to client-server-model
- Circuit switched networks (e.g. telephone system)
- Packet switched networks (e.g. IP based networks)
- Comparison of circuit and packet switching

Communication Systems
Plan for this lecture

- Packet and message segmentation
- Network taxonomy (overview on types of networks)
- Network access (connect of end systems to an internet)
- Data communication and physical bit representation and transportation
- Meaning for layering
- Layer models
- OSI / IP

Communication
Network Core (taxonomy of networks)

- Network core inside of the network not visible to the end user (application)
- Sample pictures of (IP based) network cores given some slides before
- Main distinction of network types
- Important concepts of network taxonomy
- Two fundamental approaches in network cores:
  - **Circuit switching**
  - **Packet switching**

Network Core
Circuit Switching (CS)

- Resources needed along a path, like bandwidth, buffers reserved for the duration of communication
- Telephone systems operate that way – a connection is called a circuit
- Reservation procedure may require a lot of complexity (and therefore delays) and may produce costs
- Connection quality in terms of bandwidth, delay, error rate, ... will remain the same during communication
- Quality of Service (QoS) is a big issue in telephony networks: Voice connections are heavily influenced through delays, packet loss and changing bandwidth)

Network Core
Circuit Switching (CS)

- Concept known from the traditional world of analogous telephony systems
- Guaranteed reserved constant bandwidth may use a given connection much below real capacity
- Hardware protocols designed mostly for telephony, like ISDN and ATM use circuit switching
  - ATM still forms the backbone (core network) of UMTS mobile phone network
- Costs usually calculated in terms of time usage and possible maximum bandwidth of a link not in term of transferred volumes
- Problems can be seen with designing and establishment of Voice-over-IP services (in contrast to traditional Telco services)

Network Core
Packet Switching (PS)

- Completely different concept
- Source breaks long messages (e.g. FTP file) into smaller data chunks called packets
- Each packet travels through communication links and most inevitably crosses packet switches called routers
- Packet switches use store-and-forward mechanism
  - Packet must be received completely before it could sent out an outgoing line
  - It is queued into outbound packet queue to handle busy links

Network Core
Packet Switching

- Packets therefore suffer from
  - Transmission delays – if packet consists of L bits and the outgoing link handles R bps delay is L/R seconds
  - Switching delays (routing decisions are to be made)
  - Queuing delays (wait in outgoing buffer)
- If queue is full – packets are discarded and packet loss occurs
- Share of bandwidth in packet switching networks via statistical multiplexing

Network Core
Packet Switching

- Circuit switching uses frequency division multiplexing (FDM) or time division m. (TDM) instead
- Statistical multiplexing is much more flexible than FDM or TDM (with fixed frequencies and time slots) and can utilize a given bandwidth much better
- Packet switching networks
  - Cheaper, easier to implement (less complex)
  - More efficient, no waste of bandwidth

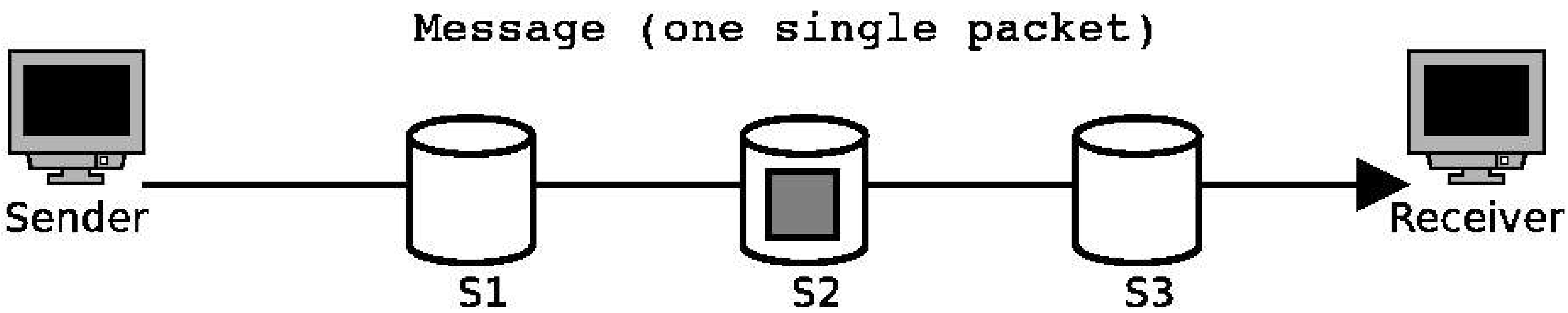
Communication
Comparison

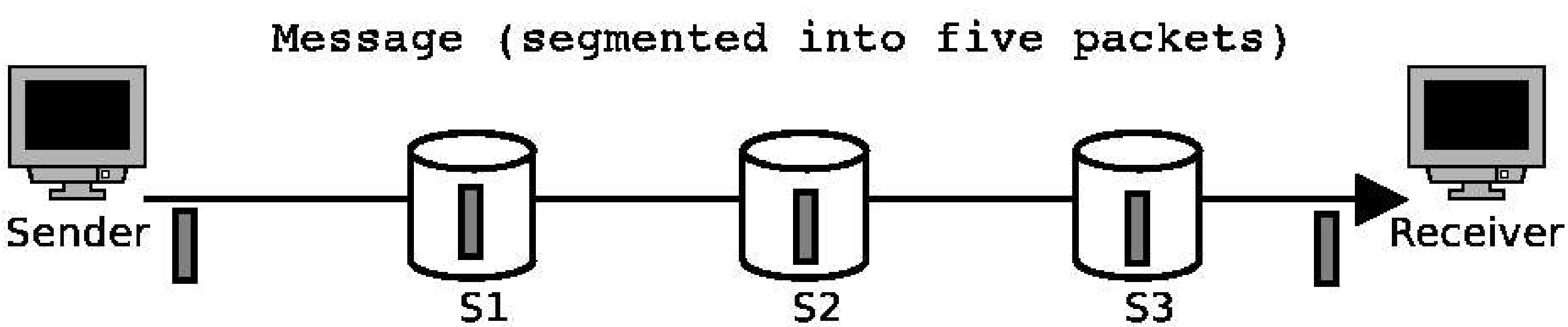
- Efficiency of the use of a 10 Mbps link shared by some users
  - Suppose users generate data at 1 Mbps in 10 percent of there online time (idle reading webpages, analyzing data, ...)
  - Circuit switching would reserve 1 Mbit per user, so at max 10 Users may share the link
  - For packet switching the probability of user activity is 10%, if there are 35 users probability of 11 active users (less bandwidth for every user than required) is 0.0004
  - Thus probability that less than 10 users share the link is 0.9996 (no delay or packet discarding occurs)
  - Packet switching allows much more users sharing one link!

Communication Systems
Packet switching networks

- How to determine the size of packets? How about message switching?
- Remember: “Proposal” of protocol to obtain a webpage:
  - **H**: TCP connection request to **W**
  - **W**: TCP connection reply
  - **H**: GET http://www.ks.uni-freiburg.de/index.php
  - **W**: deliver <file>
- Every step could be one message (= one single packet) sent over the network

- Or: larger messages could be **segmented** (split into packets of a defined maximum size)





Communication Systems
Message switching

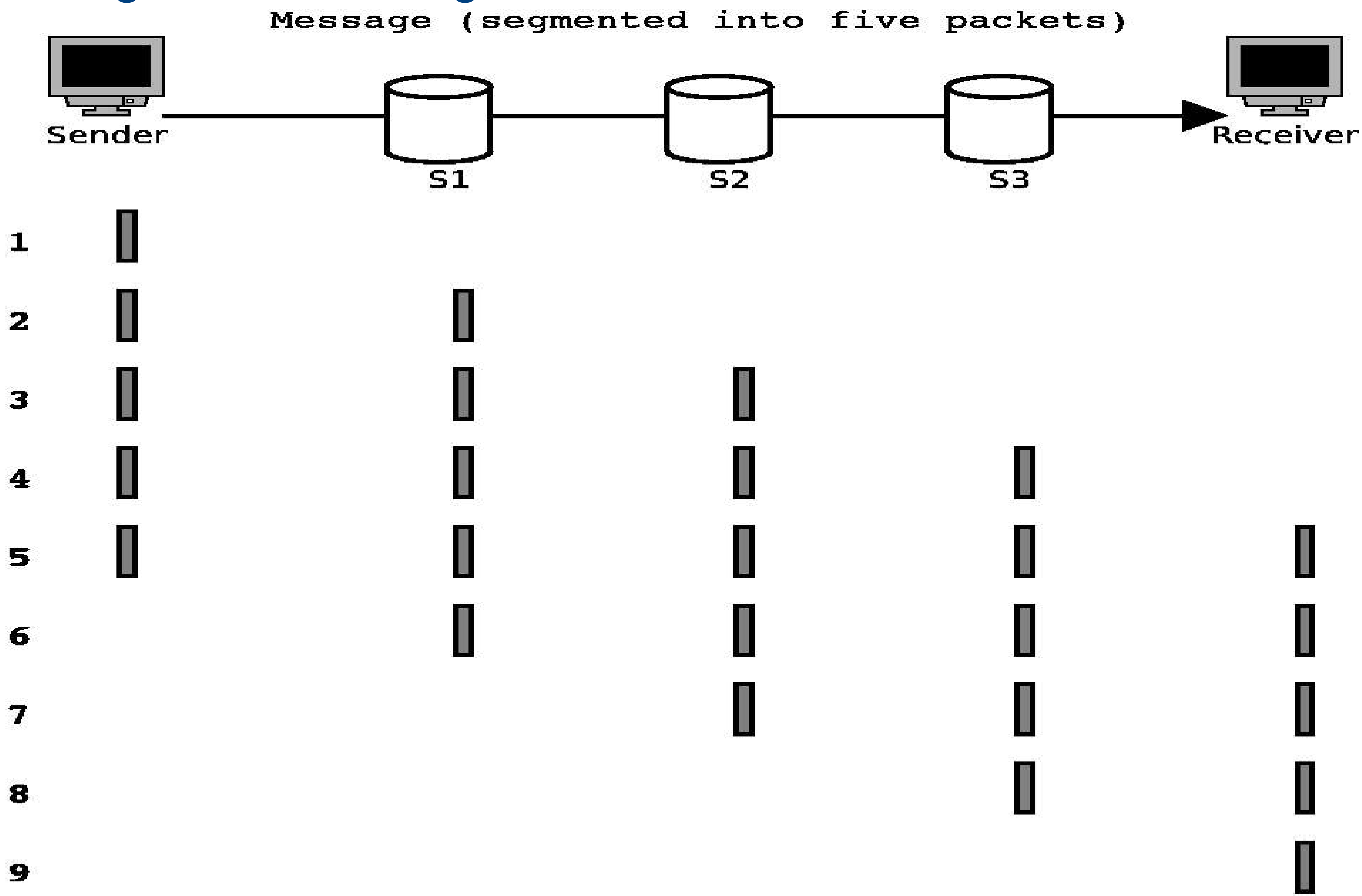
- Depicts network of four links and two end systems (sender and receiver)
- Store and forward sending
- In upper part of picture message is kept intact
  - Complete message has to be received before sent out again
  - Four subsequent steps (sender to switch S1, S1 to S2, ...)
  - 1.25 Mbyte of message in 10 Mbits network – message needs 1 second to travel over one link (1.25 Mbyte = 10 Mbit)
  - Result: 4 seconds from sender to receiver

Communication Systems
Segmented message switching

- In lower part of picture message is segmented
  - Segmented message could **pipelined –** packets could travel in parallel
  - If first packet is sent out on second link, second packet can use the first link same time etc.
  - Same four subsequent steps
  - 0.25 Mbyte of message in 10 Mbits network – segmented message needs 0.2 seconds to travel over one link
  - 9 steps needed – see next picture

Communication Systems

Segmented message



Communication Systems
Segmented message switching

- Message has to be disassembled and reassembled after all packets received
- We get: 9 * 0.2 seconds = 1.8 seconds
  - Better than half the time of unsegmented message
  - Time for
    - Disassembling and reassembling
    - Header overhead (five headers instead of one)
    - Switching delay
  - ... assumed zero in this example (higher in reality but mostly much smaller then transfer delays!!)

Communication Systems
Packet forwarding

- Not explained how the packet switches S1 – S3 in example knew how to route
- Different concepts for types of network with segmented message switching:
  - Routing using fixed destination address – **datagram network (DN)**
  - Routing using virtual circuit numbers
- Internet is datagram network
- ATM or X.25 example for **virtual circuit network (VC)**

Communication Systems
Packet forwarding

- Routing setup very different
- DN switches packets - no dedicated communication path and capacity, each packet may use some other path to travel from one partner to the other, implementation for path detection and error handling needed
- Analogue for DN postal service- sending letter by me to a specific enterprise in Hamburg
  - Put destination address on that letter and my reply address on the back
  - Find a postal box somewhere (was easier a year ago :-))
  - Put the letter in the box (and forget it)

Communication Systems
Packet forwarding

  - Somebody takes it to the central post office (needs only whose and forget it)
  - It is routed to Hamburg then
  - In Hamburg upon receipt rerouted to the street
  - In the enterprise routed to the destination person
  - And the person might answer my request and ...
- No connection state is kept in any router
- If something fails – need for special signaling of errors

Communication Systems
Packet forwarding

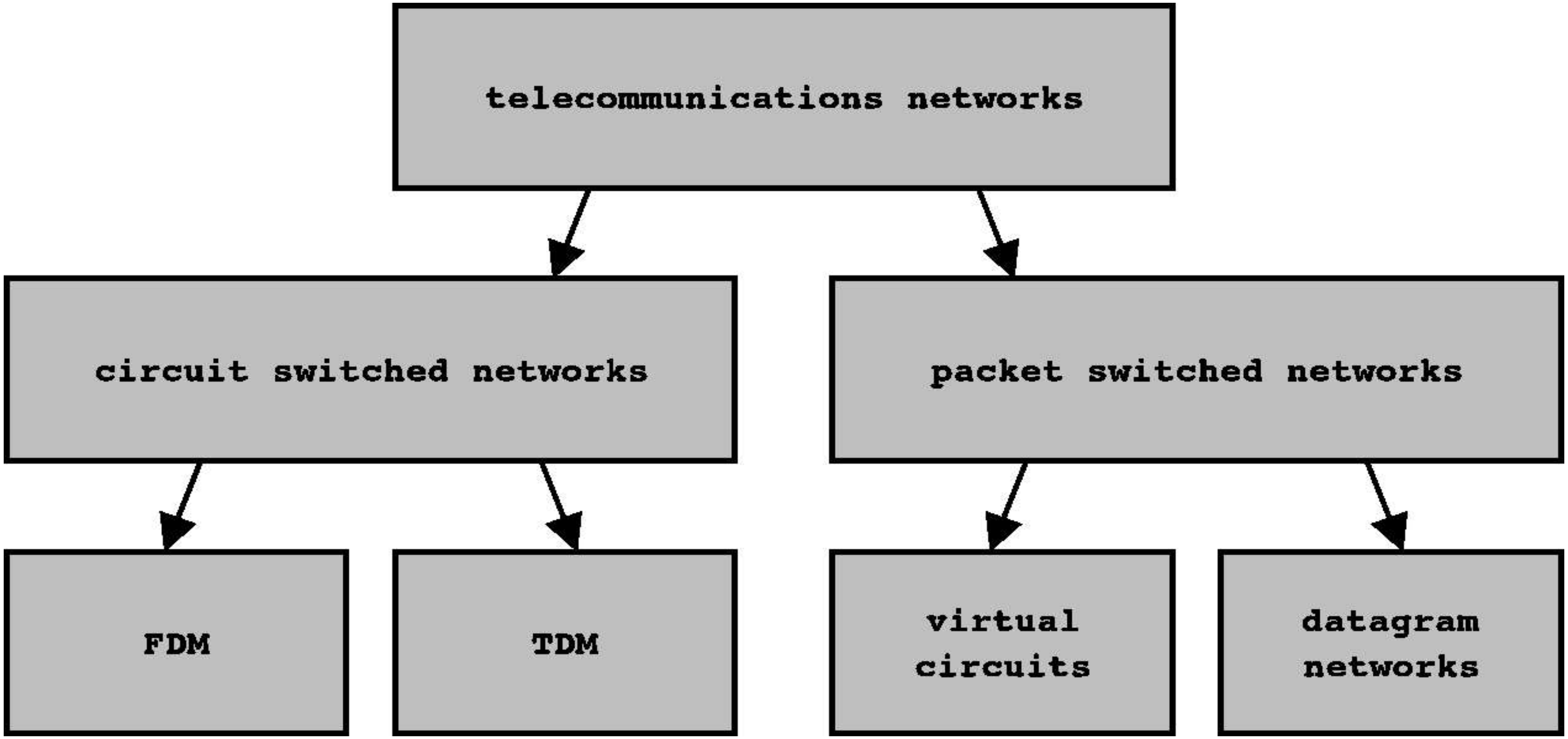
- Circuit Switching - dedicated communication path between two partners is set up in advance before packets could be sent
- used for telecommunication, found with ISDN (integrated services digital network) and ATM (asynchronous transfer mode) networks
- VC consists of **path** – series of links and packet switches and virtual circuit numbers for each link between all intermediate systems
- Numbers must not equal path number – flexible setup, but tanslation tables has to been kept
- Network must maintain **state information** until connection is terminated

Communication Systems
Packet forwarding

- Circuit switching
  - suffers setup delays (route must be established before the first packet could be sent out)
  - simpler routing mechanism after path is set up
  - May offer broader variety of services (bandwidth, delay, cost, ... optimized -> could be criterion during route setup)
- Packet switching
  - Route decision in every switch along the path needed
  - Route decision for every single packet required because no state is kept

Communication Systems
categorization

- Different kind of networks could be distinguished, “taxonomy”:



Introduction

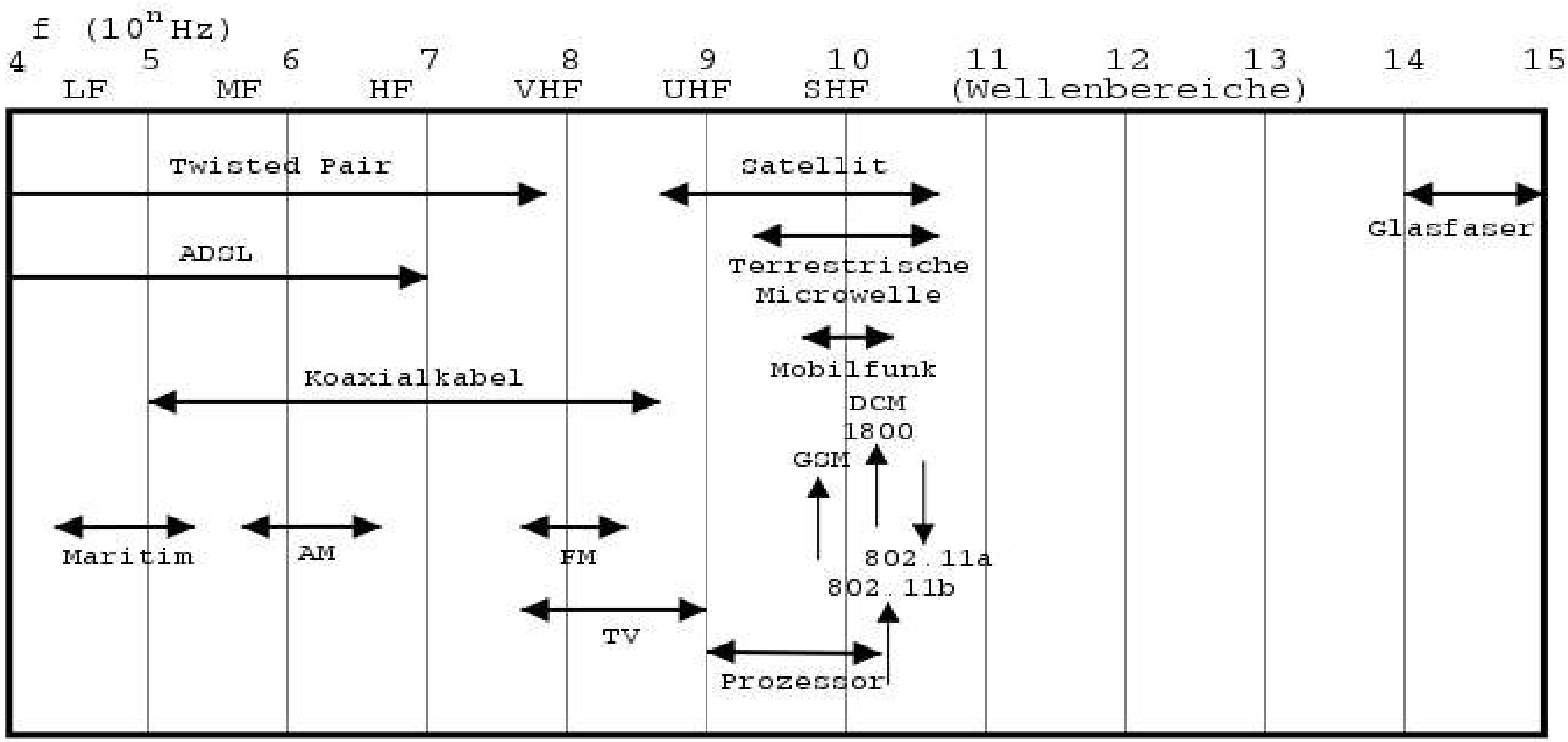
transportation of bits - physical media

- Independent of the type of network – bits have to be transported somehow over various distances
- Presented some important network access technologies by now, which use very different media they operate upon
- Moving electrons generate electromagnetic waves which dissipate through transmission media
- **Transmission media –** the medium over which electromagnetic waves travel
- **Guided media** – the waves are guided along a physical path (copper wire, cables at 2/3 of the speed of light ~ 2x10^8 m/s)
- **Unguided media** – no physical guide (air, vacuum, water at the speed of light ~ 3x10^8 m/s)

Introduction

physical media – use of frequency spectrum

- Efficient use of frequency spectrum plays a major role on physical level (we will see for 2G, 3G mobile phone networks)



Nutzung des Frequenzspektrums zur Kommunikation

Introduction

physical media - frequency, spectrum and bandwidth

- Wavelength λ (Lambda) is the distance between two maxima of magnitude
- Time domain (examination of the signal over amount of time)
  - Periodic signal – repeating after a period *T*
  - Frequency – *f*, inverse of the period (*1/T*), measured in cycles per second Hz (Hertz)
  - Amplitude – *A*, the instantaneous value of a signal at any time *s(t)* – measured in V (Volts)
  - Phase – Φ, measure of relative pos. in time within a single period
- Fundamental equation: $\lambda f=c$ (c speed of light nearly constant :-))

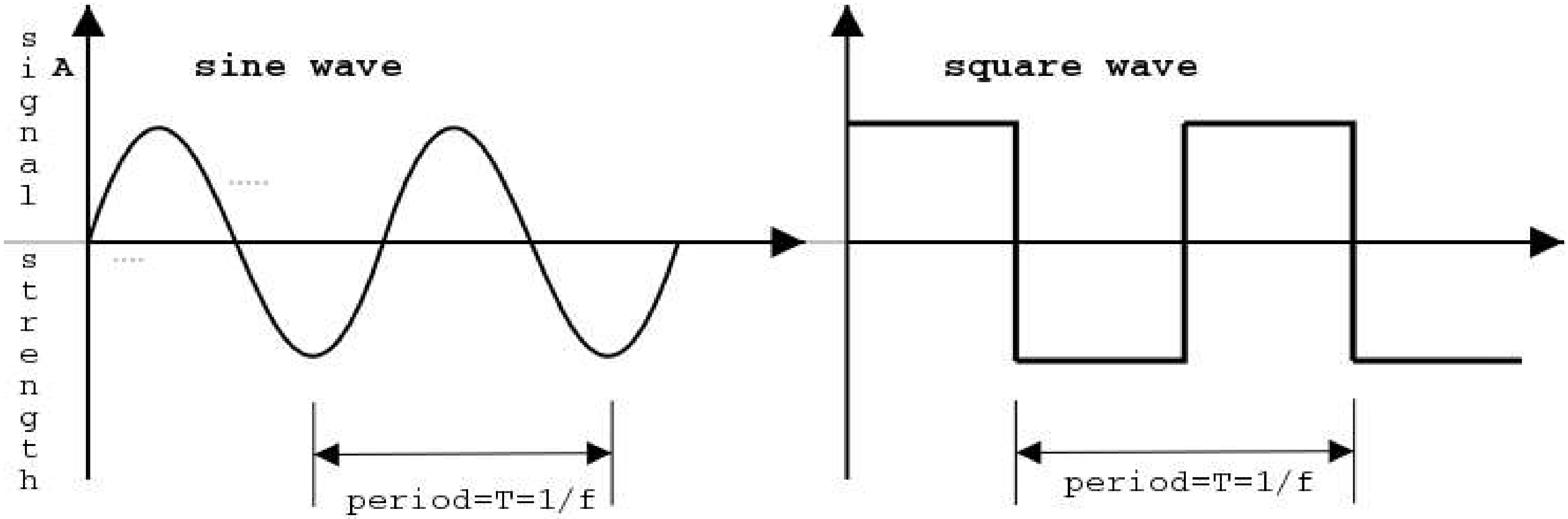
Introduction

physical media - frequency, spectrum and bandwidth

- Spectrum – Range of frequencies in a given signal
- Absolute bandwidth **–** width of the spectrum ($f_n - f_1$), where f_1 is the smallest and f_n is the highest frequency in a signal
- Effective **bandwidth** – width of the spectrum carrying most of the energy of the signal

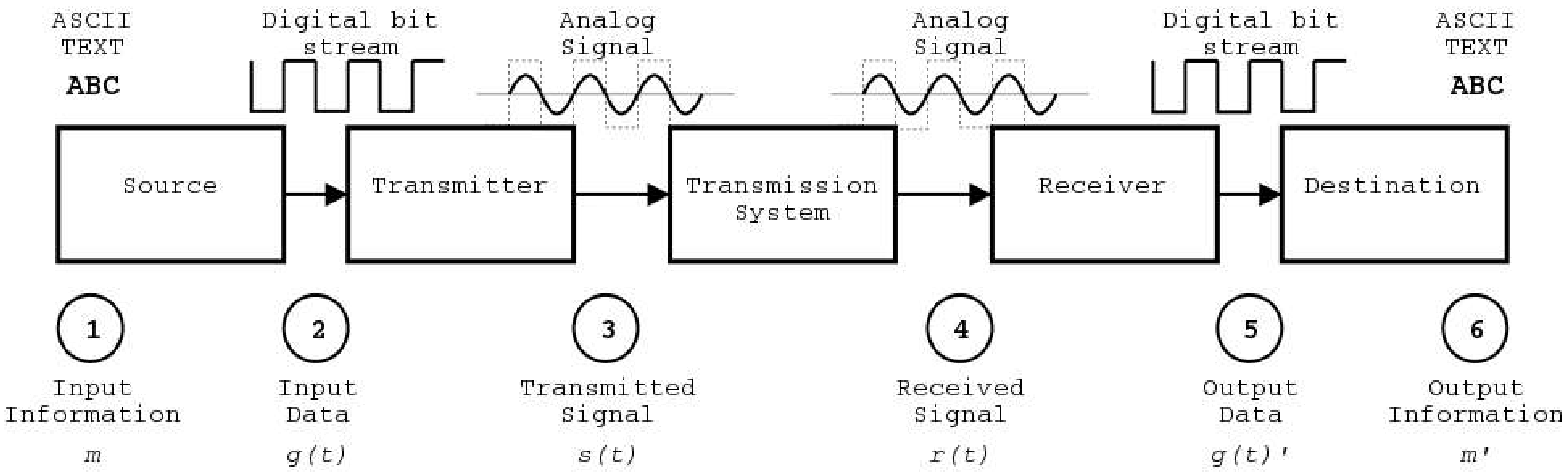
Introduction
representation of waves

- Periodic signal $s(t+T)=s(t)$
- General wave $s(t)= A \sin(2*\pi f t+\Phi)$
- Parameters: amplitude, frequency and phase



Communication Systems
communication between computers

- For transportation information has to be encoded and the digital bit stream of data has to prepared for transportation via analogous signaling – networks imply aspects of **data en/decoding**



Introduction

encoding

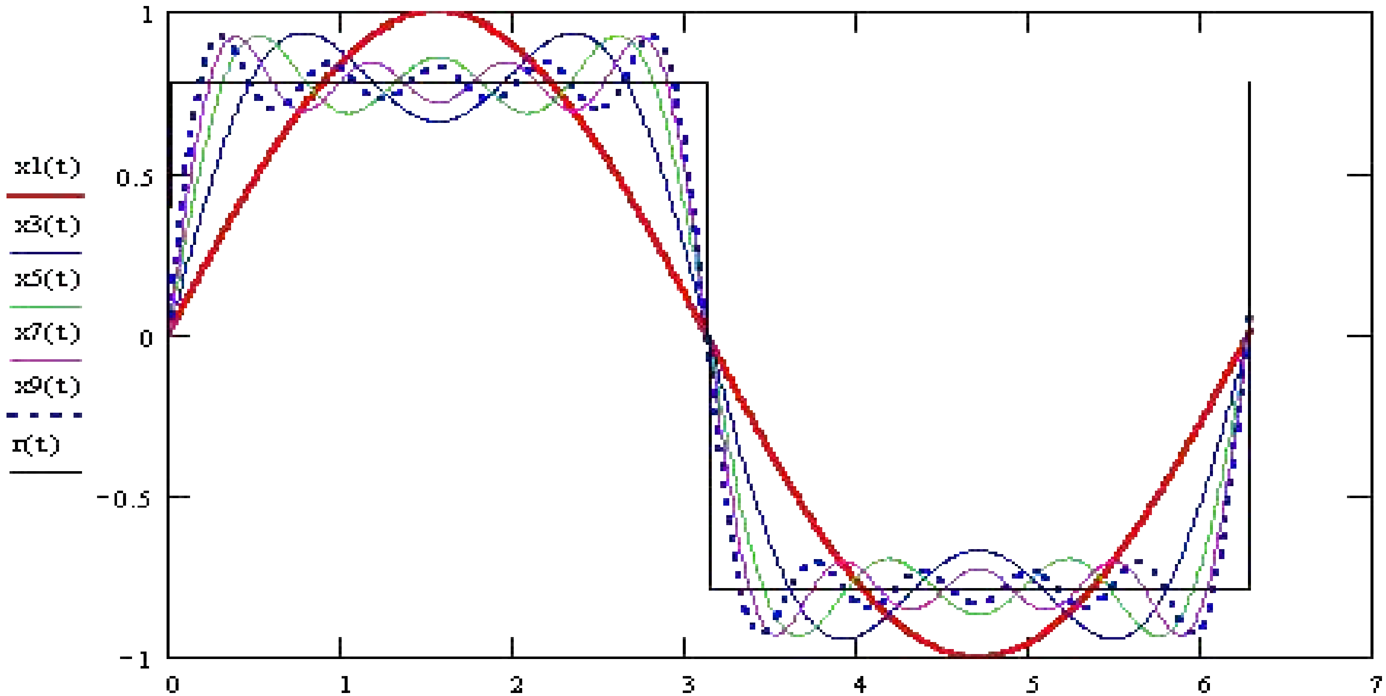
- Information can be encoded through modulation of these three parameters: amplitude, frequency and phase
- Frequency of signals is directly proportional to the transfer rates
- We have to be concerned with the form of signals; **analog** or **digital**
- Digital signals can not transferred directly, its frequency depends on the step speed and may vary heavily
- Digital signals (square waves) have to be encoded before transmission to analog signals
- We will see reversed process for the digitization of voice for digital telephony networks and VoIP

Introduction
encoding

- Streams of digital data are represented as square waves
- Square waves has to be encoded before transmission
- But: What is a square wave?
  - What frequency components digital waves are composed of?
  - How many components do I need to compose and later recreate a given wave?
  - What is a realistic spectrum of this signal, where is the main energy of the signal?

Introduction
encoding

- Fourier Analysis of a signal (square wave) shows that it can be composed of overlapping sine and cosine functions
- Amplitudes of the signal parts are amplitudes of the n^{th} harmonic of the sine and cosine function with a frequency of n/T (T is the period of signal)



Introduction
encoding

- Not all harmonics carry the same amount of energy
- With 5 harmonics a recreation of the signal is possible
- With up to 15 harmonics the signal quality still improves, but the difference with more then 15 harmonics becomes marginal

Introduction
bits and baud

- Amount of time *T* for transferring of 01100110 depends on the **step speed**
  - tells the number of changes of the signal within a second
  - measured in **baud**
  - **baud rate must not be identical to the bit rate**: If a coding with currents of 8 steps is used, three bits may be transferred with one signal level, so the bit rate is higher than baud rate)
- The number of signal levels seem to imply there is much room for higher bitrates at a given bandwidth, but there are restrictions ...

Introduction
Data Rate and Bandwidth

- Used the terms of data rate and bandwidth with some implicit meaning, so explaining now:
  - There is a relationship between **Data Rate** and **Bandwidth**
  - Assume we have a square wave of repeating 0101… If a positive pulse is a "1" and a negative a "0" then each pulse lasts ½ T ($T=1/f$) and the data rate is $2f$ bits per second (bps)
  - To generate such a signal many frequency components (harmonics) need to be composed
  - If the components are limited to a maximum frequency (restrictions of bandwidth) we need to make sure the signal is accurately represented.
  - Depending on the accuracy a given bandwidth can carry a particular data rate.

Introduction
Data Rate and Bandwidth

- The theoretical maximum communication limit is given by the **Nyquest** Formula: $C=2\,B\,log_2\,M$
  - C = capacity or data transfer rate in bps
  - B = bandwidth in Hz
  - M=number of possible signal levels

Introduction

restrictions to signalling

- Signal strength, noise and crosstalk
  - Important parameter in communication is the received **signal strength**
  - As a signal propagates it will be attenuated (decreased)
  - Attenuation of a signal increases with frequency, so highest frequencies may not be usable within a given bandwidth
  - Different frequencies travel at different speeds through guided media, so we may get delay distortion
  - The transportation medium may experience interference (**noise**)
  - **Crosstalk** of strong output signals to weak receive signals

Communication Systems
conclusion

- Combined Effects
- The named effects add up and decrease the effective data rate transferable over a given medium
- Circuits for regeneration of signals are needed
  - Examples are amplifiers for analog signals (antennas for wireless LAN) or repeater for digital signals (ethernet, ...)
- The communication types and needs define the part of the electromagnetic spectrum which might be used

Communication Systems
conclusion

- Different media types
  - Single twisted pair – modem, ISDN, DSL
  - 2 twisted pairs – 10,100 Mbits Ethernet, TokenRing
  - 4 twisted pairs (good insolating electromagnetically wise) – 1Gbps Ethernet
  - Coaxial cable – TV cable networks, cable modem, 10 Mbits Ethernet
  - Fiber optics – several Ethernet standards, FDDI, ATM, ...
  - Air – divided into several frequency blocks for GSM, UMTS, 802.11b, a/h, satellite links, ...

Communication Systems
data communication - conclusion

- As we have seen by now for transportation of information with computer systems several steps involved (not all introduced in depth)
  - Encoding of information (type and representation of texts, encoding of pictures, video streams etc.)
  - Transformation of data for transportation
  - Splitting data into packets
  - Encoding of bit streams into physical representation
  - Signaling over wire, fiber optics, wireless, ...
  - And vice versa

Communication Systems
next lecture and practical course, literature

- Next Tuesday is practical course – check for a working computing dept. ID (the account should be enabled, otherwise visit the user service at ground floor)
- Next lecture is on Thursday the 4th of May
- Literature
  - Peterson, Davie "Computer Networks - A Systems Approach" 2nd edit. pages 2-58
  - Tanenbaum, "Computer Networks" 3rd edit. pages 3-71