Universiteit Leiden

EssCS - Topic 4

Introduction to Computer Networking

Lecture 13, 26.11.2024

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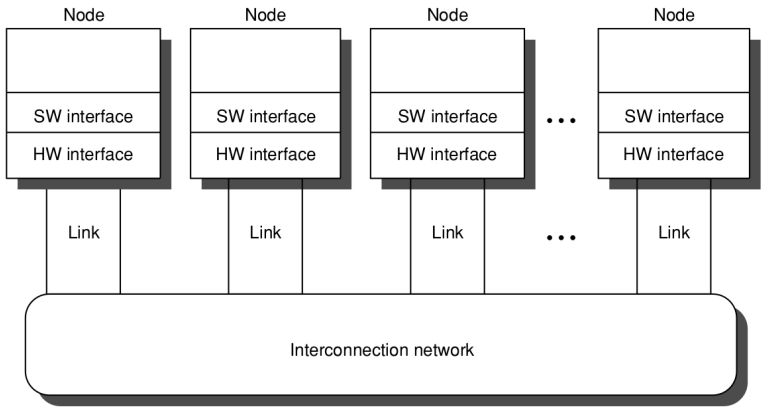
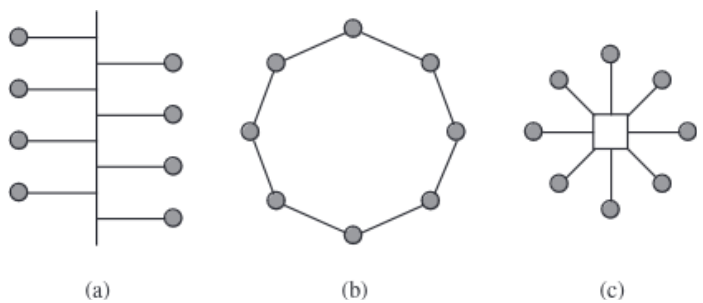
Basic terminology

- Node: sometimes also called a host, system or end-point, for us will be the entity that is communicating
- Link: simple communication channel, a wire or a simple bus



- Topology: organization of nodes and connections (i.e., also includes the direction)



(a) bus (b) ring (c) star

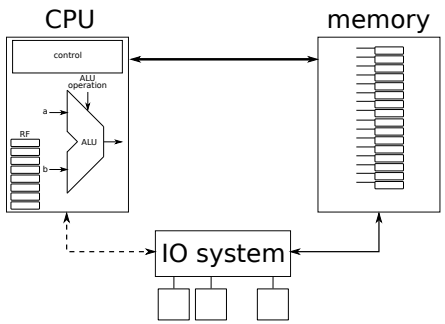
Basic Terminology

- Interface: point of contact between two entities

  HW perspective: IO ports
- Protocol: "code of conduct"

  sequence of steps specifying the behavior (how to react), includes message structure, meaning of certain bits/positions, prescribes the interface, ...
- Revisiting Topic 2 - known example: **memory bus**

  address, data, and control (direction: read or write)



- Revisiting Topic 2 - known example: multicore and shared memory

  cache controllers are snooping:

  they compare the address on the bus to the addresses they have cached
- Carrier sensing: listening to the medium before attempting to send

  collisions occur when nodes are trying to communicate simultaneously - they can cause data loss and decrease in performance

Generic types of networks

- based on number of nodes and their proximity

- Wide Area Network (WAN): thousands of nodes spanning a large area, with maximum distance being thousands of kilometers (e.g., internet, cable TV, military satellite network, . . .)
- Local Area Network (LAN): hundreds of nodes in a smaller area, with maximum distance up to a few kilometers (e.g., campus, large company building, home network)
- Storage or System Area Network (SAN): hundreds of nodes in a smaller area, with maximum distance up to a 100 meters (e.g., server rooms, clusters, HPC)

- Client-Server networks: two types of nodes, clients requesting services from the server(s) - usually there is a big difference in their capabilities (e.g., computational power, storage, . . .)
- Peer-To-Peer networks: only two nodes, but they assume both roles (behave as a client and a server to each-other)

Basic Terminology

- Message format: payload with a header and trailer

  typically header includes control information, such as destination, and trailer additional information, for example parity computer over the payload data

header	payload (data)	trailer

  metric: message size $[\#\text{bits}]$

  header and trailer are message overhead

- Timing parameters:
- Sender and receiver overhead: time for the node to inject the message into the network/to pull the node from the network

  includes both delay of hardware and software components
- time of flight: the time of the first bit of the message to arrive at the receiver
- transmission time: time for the message to pass through the network, excluding time of flight
- Bandwidth: maximum rate at which the network can propagate the data (data rate)

  $\text{Bandwidth} = \frac{\text{message size}}{\text{transmission time}}[bps]$ (includes headers and trailers !)

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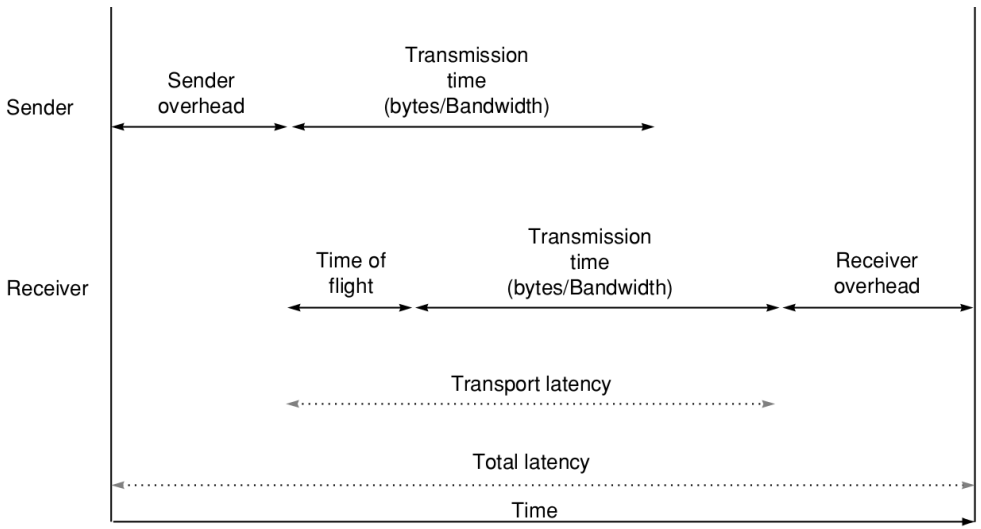


- transport latency: the time of the first bit of the message is injected till the last bit of message arrives at the receiver
- Total latency = Sender overhead + time of flight + transmission time + receiver overhead

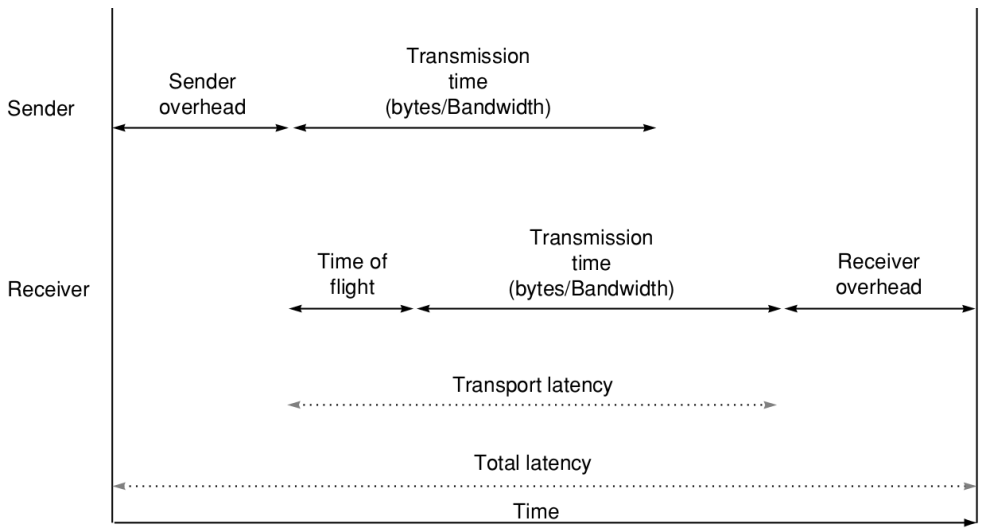
Example

Assume a network with a bandwidth of 1000 Mbits/second has a sending overhead of 80 microseconds and a receiving overhead of 100 microseconds. Assume two machines. One wants to send a 10000-byte message to the other (including the header), and the message format allows 10000 bytes in a single message. Compare SAN, LAN, and WAN by changing the distance.
Calculate the total latency in:

- SAN: 10 meters apart
- LAN: 500 meters apart
- WAN: 1000 kilometers apart

Use the assumption that the signals propagate at about 2/3 of speed of light ($\sim$300000km/s) in a conductor

$$\text{Bandwidth} = \frac{\text{message size}}{\text{transmission time}}[bps]$$ (includes headers and trailers !)



Total latency = Sender overhead + time of flight + transmission time + receiver overhead

Careful: in memory systems K, M, G are powers of 2! in networking K, M, G are powers of 10!

Transmission Modes

- simplex: unidirectional communication

  example: monitor
- half-duplex: both directions, but one at a time

  example: railroad with one track, walkie-talkie
- full-duplex: both directions simultaneously (two channels)

  example: two-lane road, telephone

Network Media

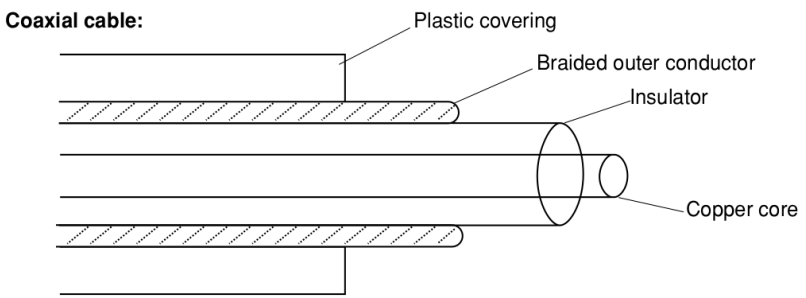
- twisted pair: twisted copper wires

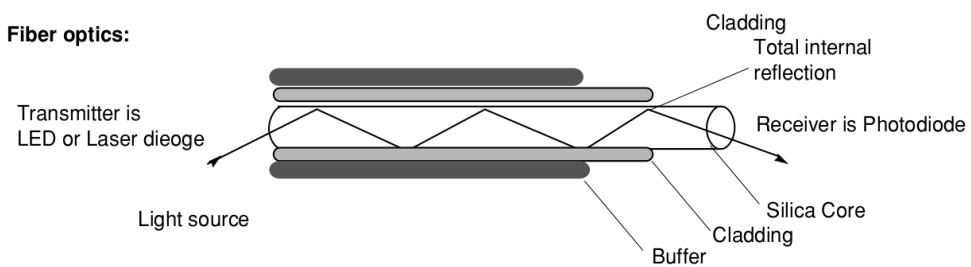
  Category 3: 10 Mbps, Category 5: 100 Mbps (up to 100 meters)
- coax cable: bandwidth depends on exact standard used and distance

  common cable up to 1 Gbps, thicker cable up to 2.5Gbps
- fiber optics: two main types of cables

  multimode: a few hundred meters (15, 300, 550m) at 10 Gbps

  singlemode: 10 or 40 km at 10 Gbps (depends on exact (sub)type!)

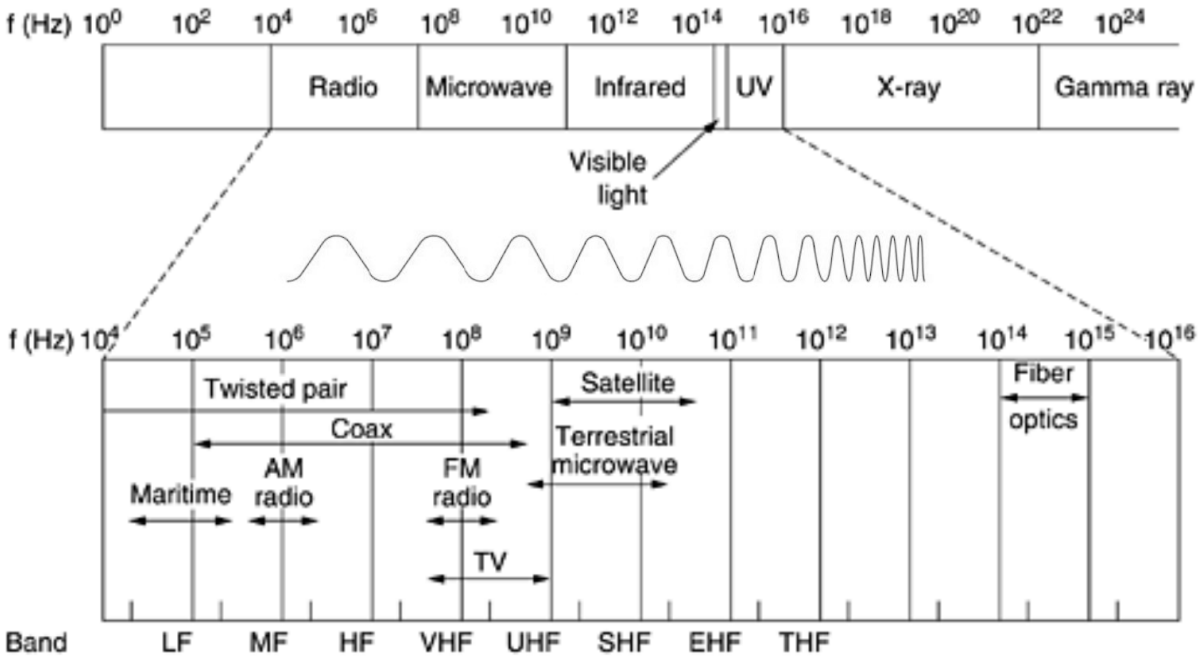




Network Media

- wireless communication

  frequency (f) = number of oscillations per second [Hz]



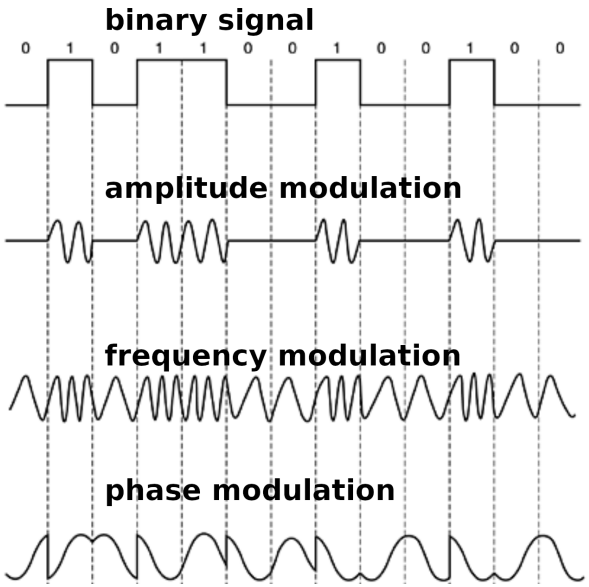
- all media suffer from attenuation and noise

  attenuation: loss of energy as signal propagates [dB/km]

  noise: unwated energy from other sources

Hardware perspective

- Modulation: assume a carrier signal - a sine wave



- Sampling: analog signal $\leftrightarrow$ time-discrete signal
- Sampling rate: number of samples per second [baud]

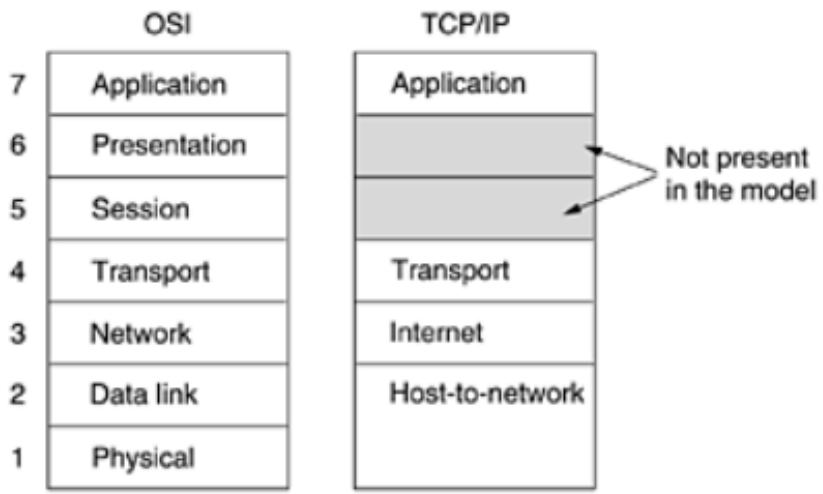
  during each baud we transmit/receive one symbol [$\frac{\#symbols}{second}$]
- What is the maximum possible detectable rate of change of the waveform?
- How many discrete symbol states can we resolve?
- Different encoding schemes and errors (during tutorial)

The Reference Models

- reference models: each layer has different functionality (with protocols and interfaces to layers above and below)
- what was just discussed is a small part of physical layer
- OSI = Open Systems Interconnection

7	Application	https, email, ...
6	Presentation	syntax and semantics of transmitted data
5	Session	establish/terminate communication sessions between host processes
4	Transport	ensures reliable transmission source $\rightarrow$ destination
3	Network	addressing, routing
2	Data Link	ensuring error-free transfer of data between the nodes
1	Physical	transmitting raw bits over a communication channel

- TCP/IP (Transmission Control Protocol/Internet Protocol)



- we will roughly follow a hybrid in a bottom-up fashion

`https://www.rfc-editor.org/`

- The RFC Series (ISSN 2070-1721) contains technical and organizational documents:
  - the Internet Engineering Task Force (IETF) `https://www.ietf.org/`
  - the Internet Research Task Force (IRTF) `https://www.irtf.org/`
  - and more ...
- article: A Concise Guide to the Major Internet Bodies

  `https://ubiquity.acm.org/article.cfm?id=1071915`

- for fun:

  `https://www.rfc-editor.org/rfc/rfc2549`