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HW/SW Codesign II

Interfaces

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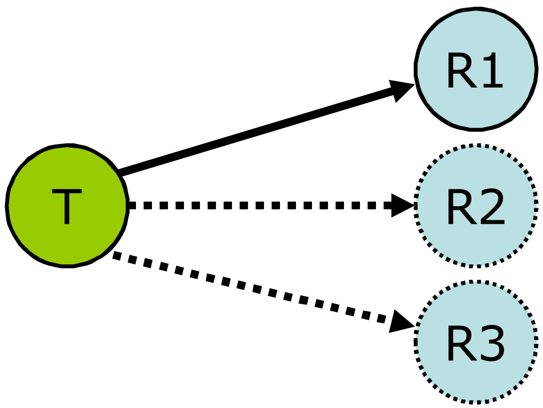
Contents

- $\boxed{\text{Basics}}$
- Classification
- Some Wired Interface Standards
- Some Wireless Interface Standards

Communication

- (abstract) **declaration**

  Communication is the transmission of information from one transmitter to at least one receiver.



- transmitted kind of information depends on ___________________
  (e.g. transmit “a website” → ASCII signs → bits)

Interface

- **definition**[1]

  An interface is a (dis)connection point of two (sub)systems. The systems can be separated at this point. The interface is defined as ______________________, even if it is a border of this system.

- **definition**[1]

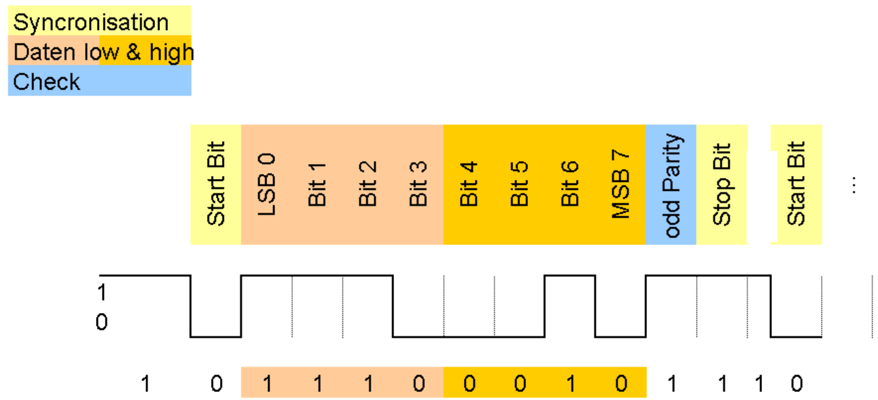
  Hardware interfaces of communicating systems are standardised specifications about the concurrence of signals. So the information exchange is possible without taking care about the specifics of the system. Three classes of properties can be defined by the hardware interface:
  - ____________ properties
  - ____________ properties
  - ____________ properties

[1] *Bernd Schürmann: Grundlagen der Rechnerkommunikation. Friedr. Vieweg & Sohn Verlag, Wiesbaden 2004*

Functional Properties (I)

- specification of
  - coding (semantic)
  - bit- and byte ordering
  - protocol
  - timing

- e.g. asynchronous serial communication (like RS-232)



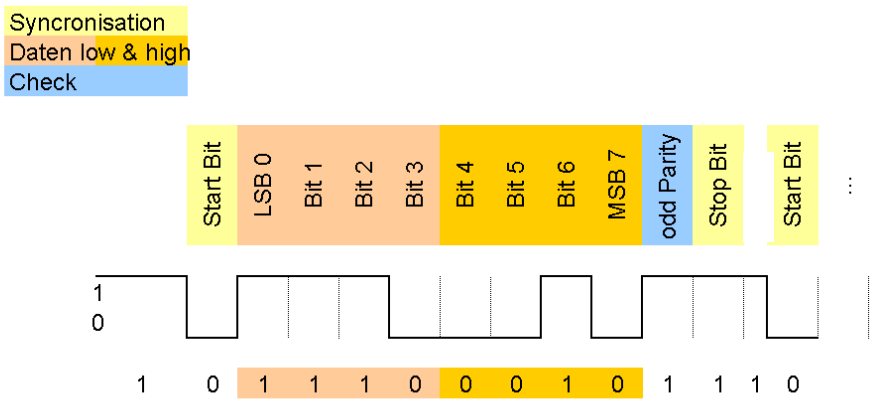
Functional Properties (II)

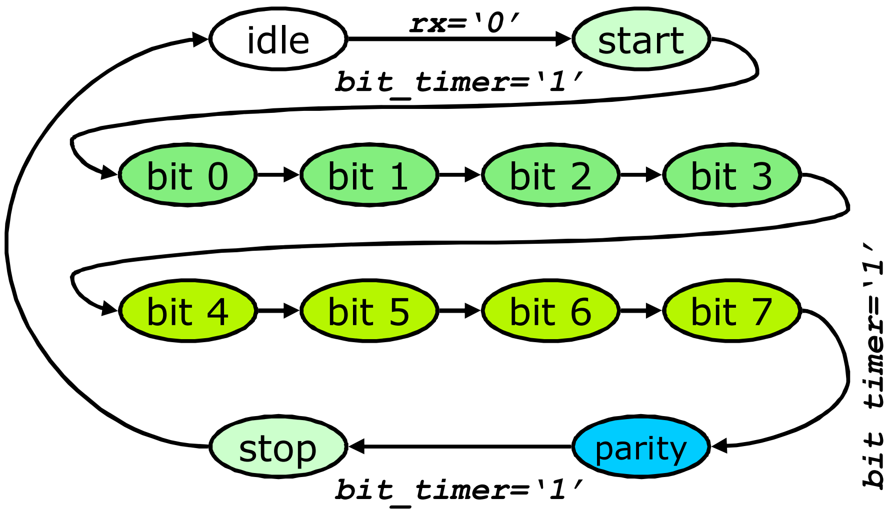
- how to model the communication protocol in detail?

→ ______________________________

  – model a protocol as set of states and (conditioned) transitions

- e.g. asynchronous serial communication (like RS-232)



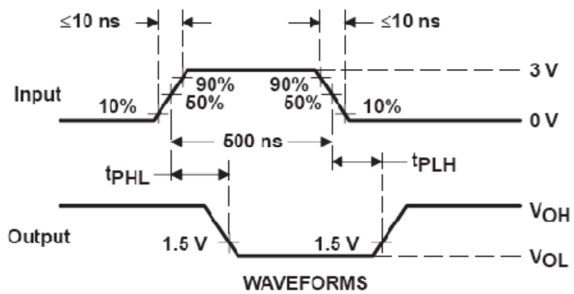


Electrical Properties

- specification of ____________________
- specification of static electrical conditions/behaviour
  - necessary/produced voltages for logical levels ‘1’ and ‘0’
  - currents for in- and outputs
  - input and output resistance
- specification of dynamic electrical conditions/behaviour
  - latency for level switching (high to low, low to high)
- e.g. MAX232 – RS-232 Driver/Receiver

PARAMETER			TEST CONDITIONS	MIN	TYP†	MAX	UNIT
V_{OH}	High-level output voltage	T1OUT, T2OUT	R_L = 3 kΩ to GND	5	7		V
V_{OL}	Low-level output voltage‡	T1OUT, T2OUT	R_L = 3 kΩ to GND		7	5	V
r_o	Output resistance	T1OUT, T2OUT	$V_{S+} = V_{S-} = 0$, $V_O = \pm 2$ V	300			Ω
I_{OS}§	Short-circuit output current	T1OUT, T2OUT	V_{CC} = 5.5 V, V_O = 0		±10		mA
I_{IS}	Short-circuit input current	T1IN, T2IN	V_I = 0			200	µA

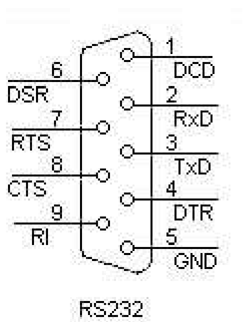
PARAMETER		TYP	UNIT
$t_{PLH(R)}$	Receiver propagation delay time, low- to high-level output	500	ns
$t_{PHL(R)}$	Receiver propagation delay time, high- to low-level output	500	ns

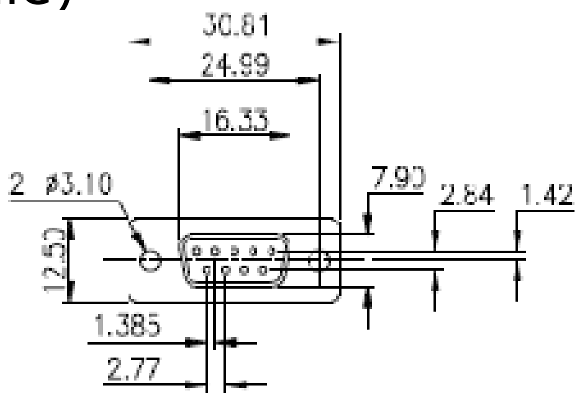


Mechanical Properties

- specification of
  - dimensioning of connectors
  - pin assignment of connectors
  - maximal cable length (depending on electrical properties)
  - antenna length
  - …

- e.g. RS-232 D-SUB9 connector (female)



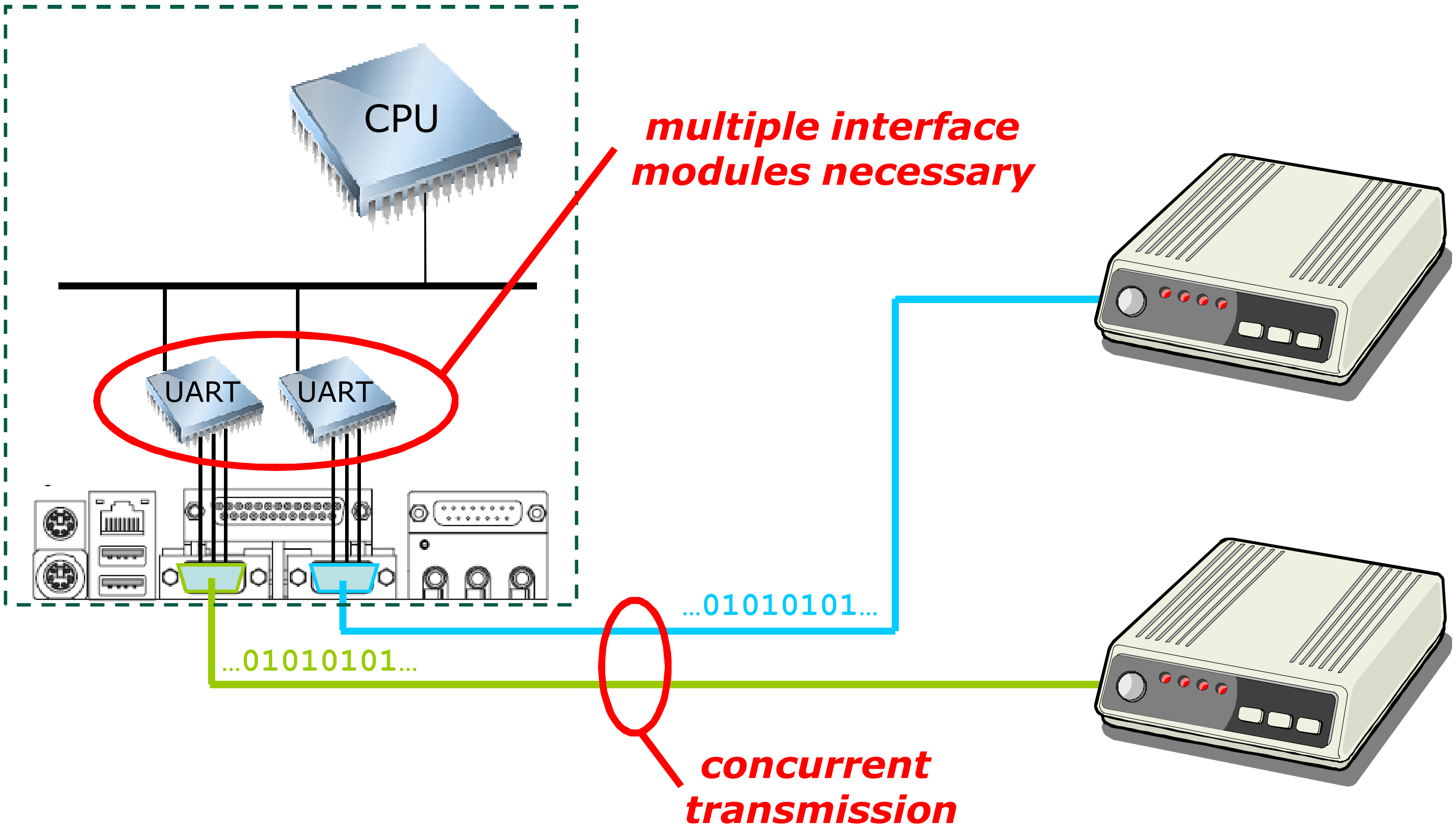


Point-To-Point Communication

- an interface module converts internal signals of the system in standardised signals of the interface
- a communication is called point-to-point (P2P), if it is limited to ______________________________________ by (electrical, mechanical and/or functional) properties of interface module
  - intermediate stations (router, hubs, …) are not allowed
- advantages:
  - no device addressing and arbitration techniques necessary
  - realtime properties can easily be fulfilled
  - in many cases no data or packet formatting necessary
- disadvantages:
  - many dedicated interface modules and wires are necessary to communicate with several devices

Example

modems connected via RS232



Bus Systems

- **definition**[1]

  A bus is a multi-conductor line, which allows data- and information-interchange between different system components [...]. It connects all according components of a system [...]. The information-interchange between the components is realised by ________________.

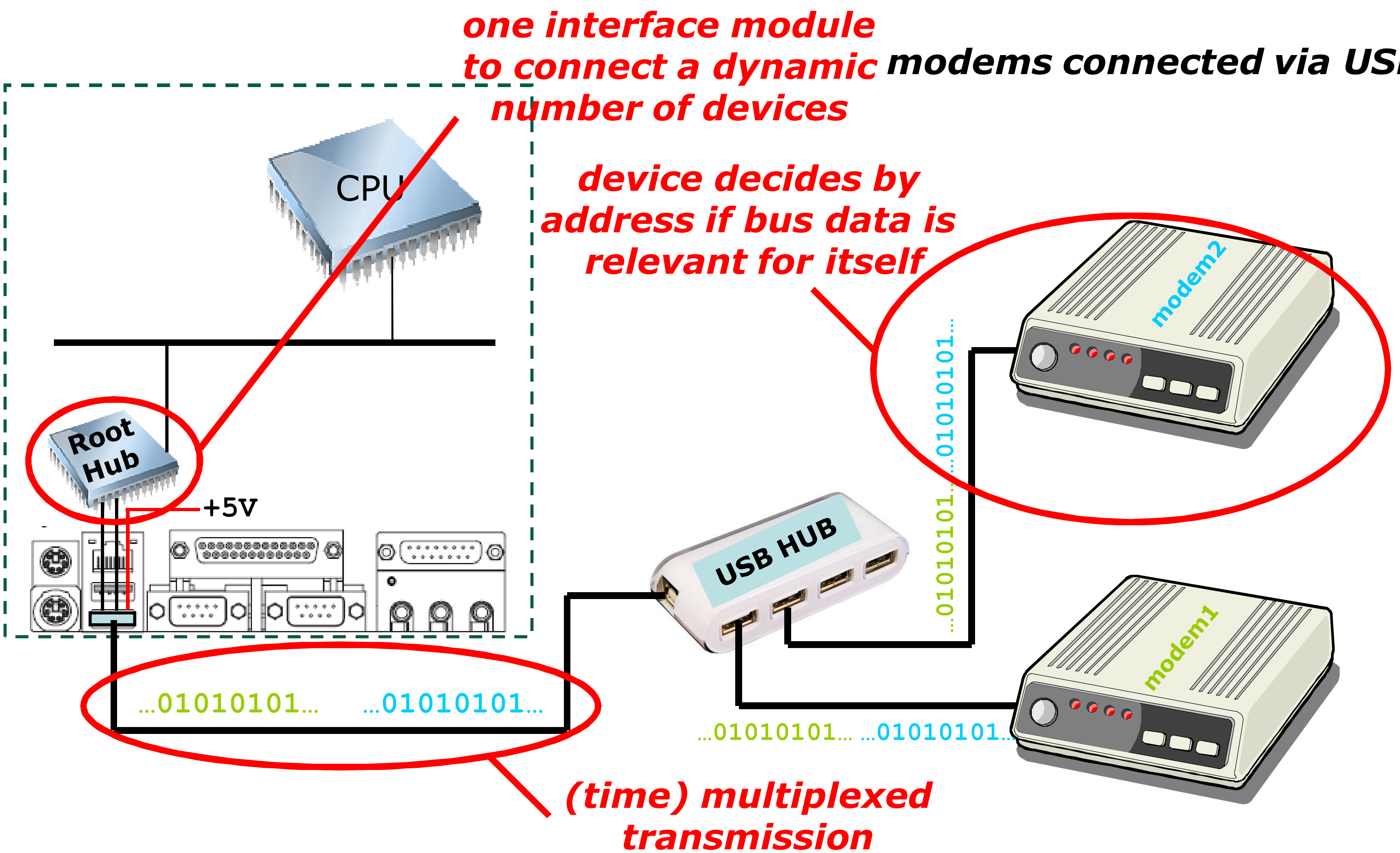
  → one transmitter (at one time), many (possible) receivers

- advantages
  - one interface module per device to communicate with all other devices
  - multi-/broadcasting possible
- disadvantages
  - slower communication speed (due to multiplexing)
  - solve fairness problems in arbitrating

[1]*Bernd Schürmann: Grundlagen der Rechnerkommunikation. Friedr. Vieweg & Sohn Verlag, Wiesbaden 2004*

Example

modems connected via USB



Multiplexing Methods

- _______________ multiplexing
  - different communications are modulated to different frequencies and are transmitted via a broadband medium
  - e.g. analogue TV via coax cable
- _______________ multiplexing
  - time is divided in slots
  - transmitter gets a specific slot in every cycle (static) or can acquire slot(s) (dynamic)
  - e.g. ISDN, Bluetooth
- _______________ multiplexing
  - different communications are mapped to different (orthogonal) codes
  - e.g. UMTS, GPS
- _______________ multiplexing
  - different communications are transmitted on different connections (e.g. physical wires)

Contents

- Basics
- Classification
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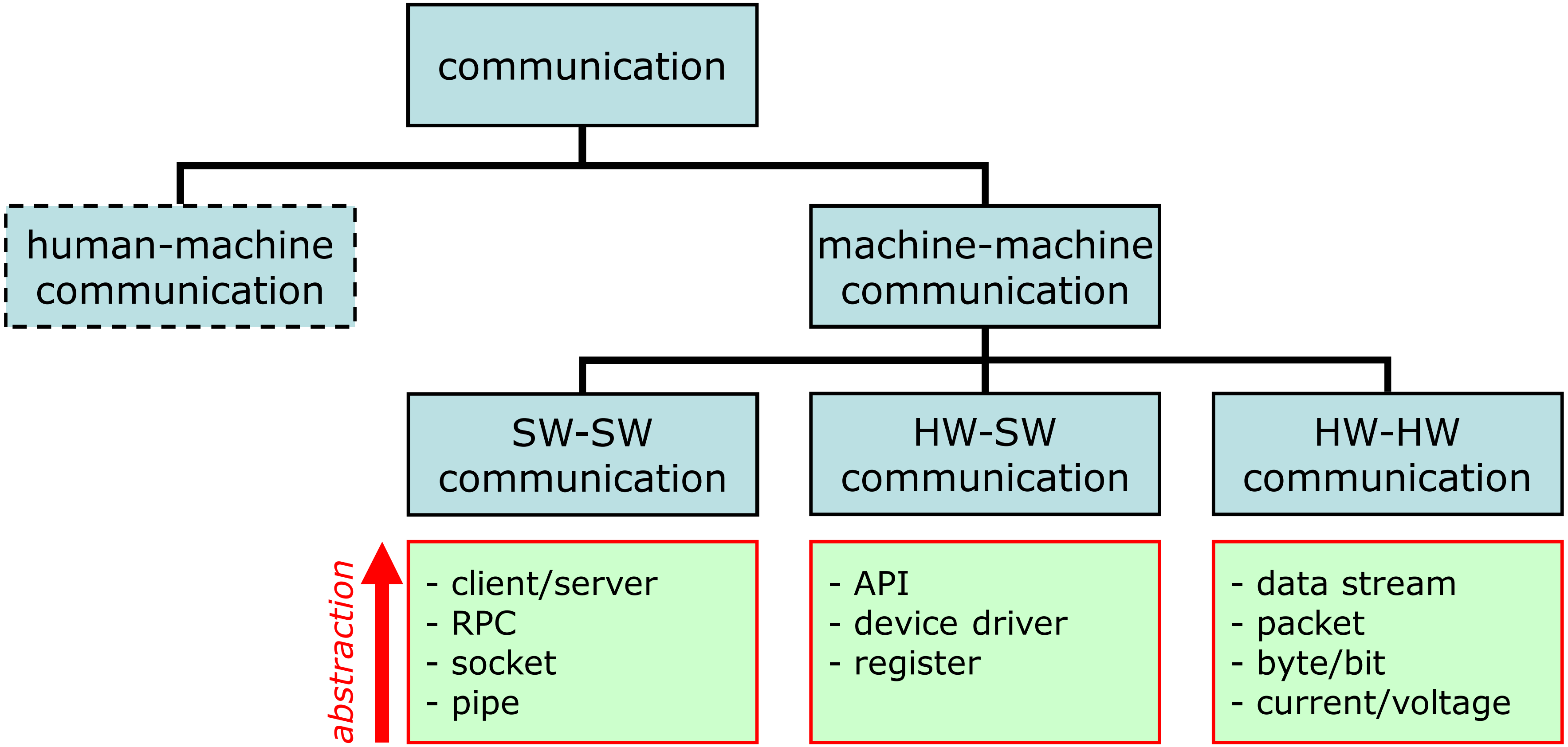
- Some Wireless Interface Standards

Classification (I)

- communication and interfaces can be defined on different

  ____



ISO/OSI Model

- define different layers of abstraction in communication

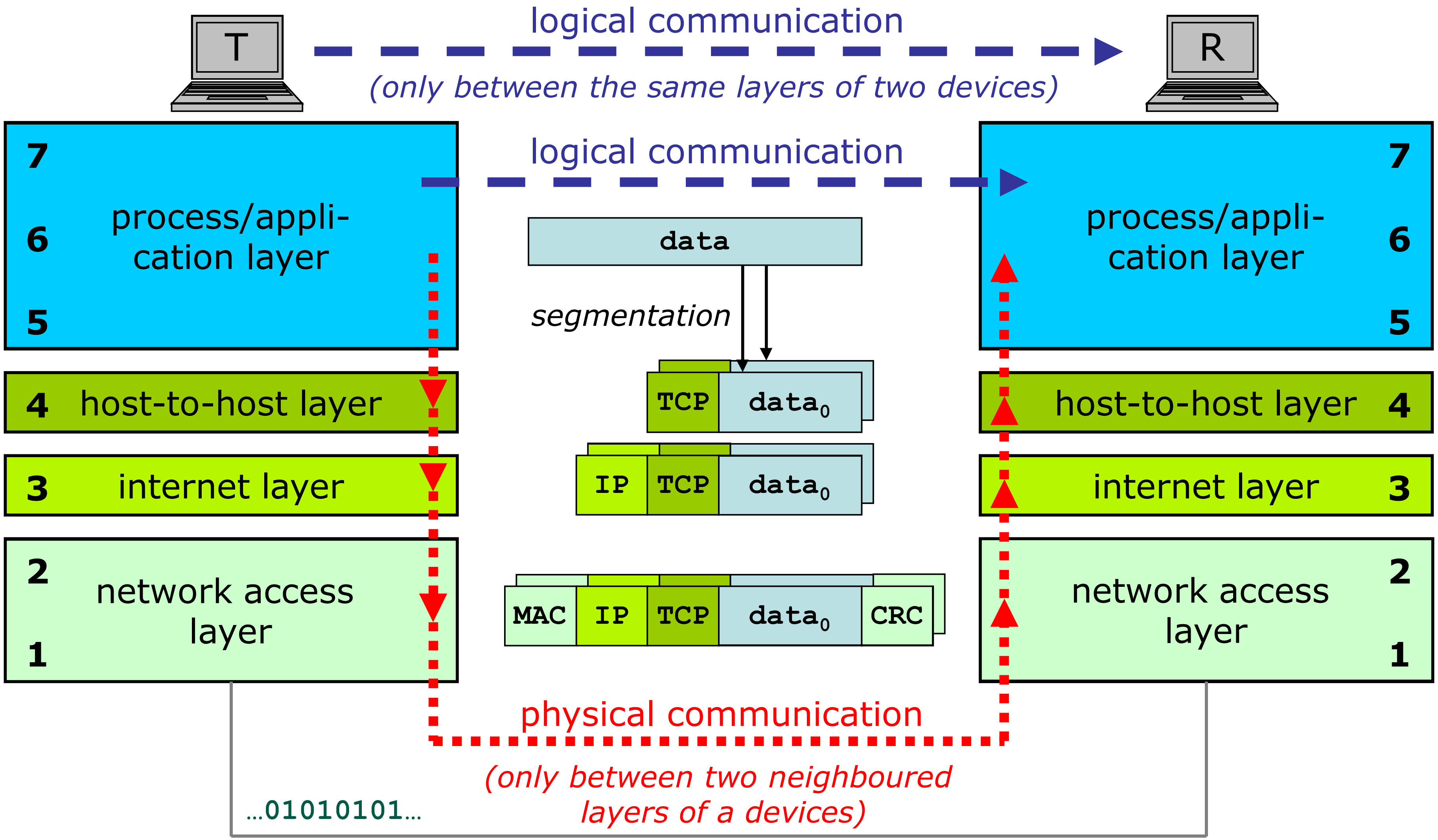
7	application layer	*mail client*
6	presentation layer	*de/encryption, compression*
5	session layer	*session control (start, stop, …)*
4	transport layer	*segmentation, packet ordering*
3	network layer	*data routing*
2	________________ layer	*point-to-point transmission*
1	________________ layer	*electrical modulation, cabling*

…01010101…

application

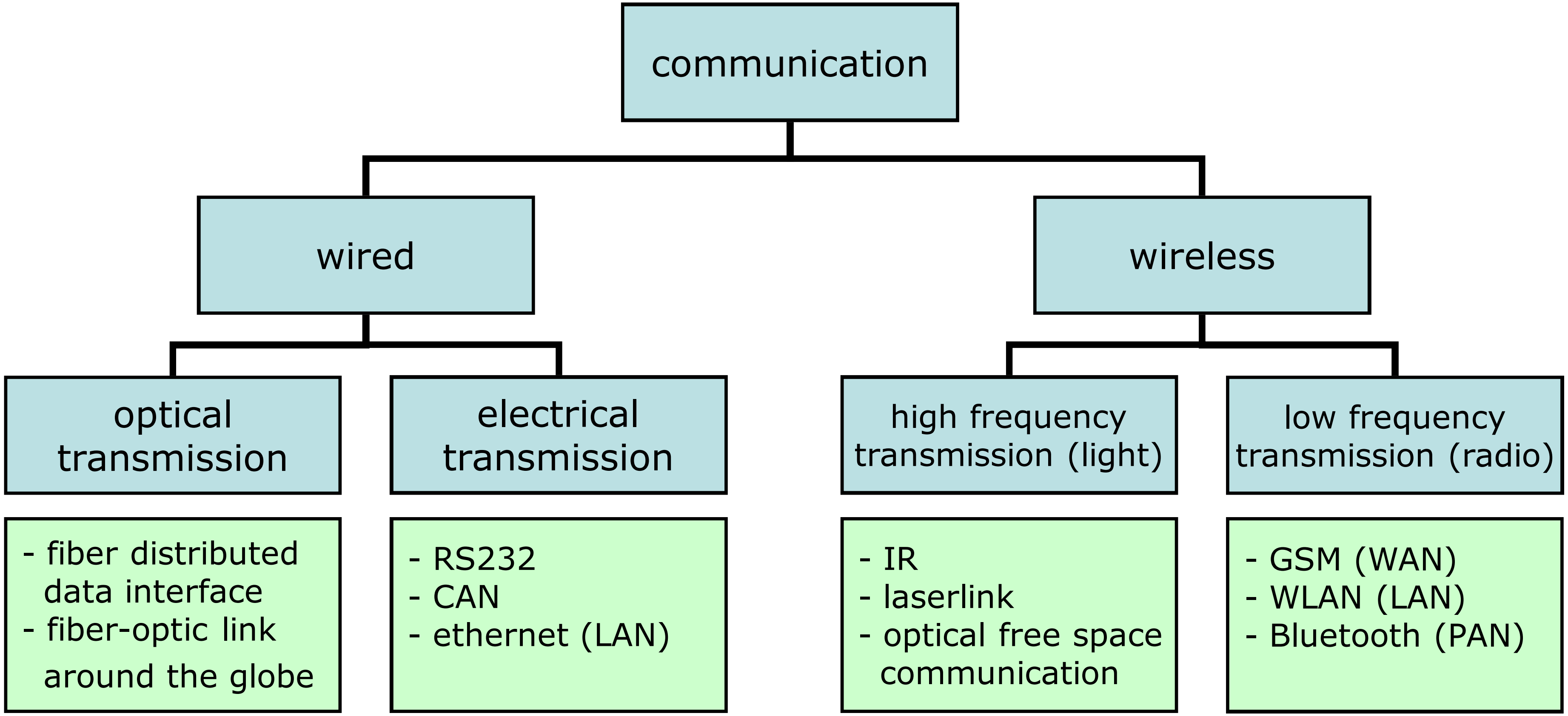
transportation

Example: TCP/IP Communication



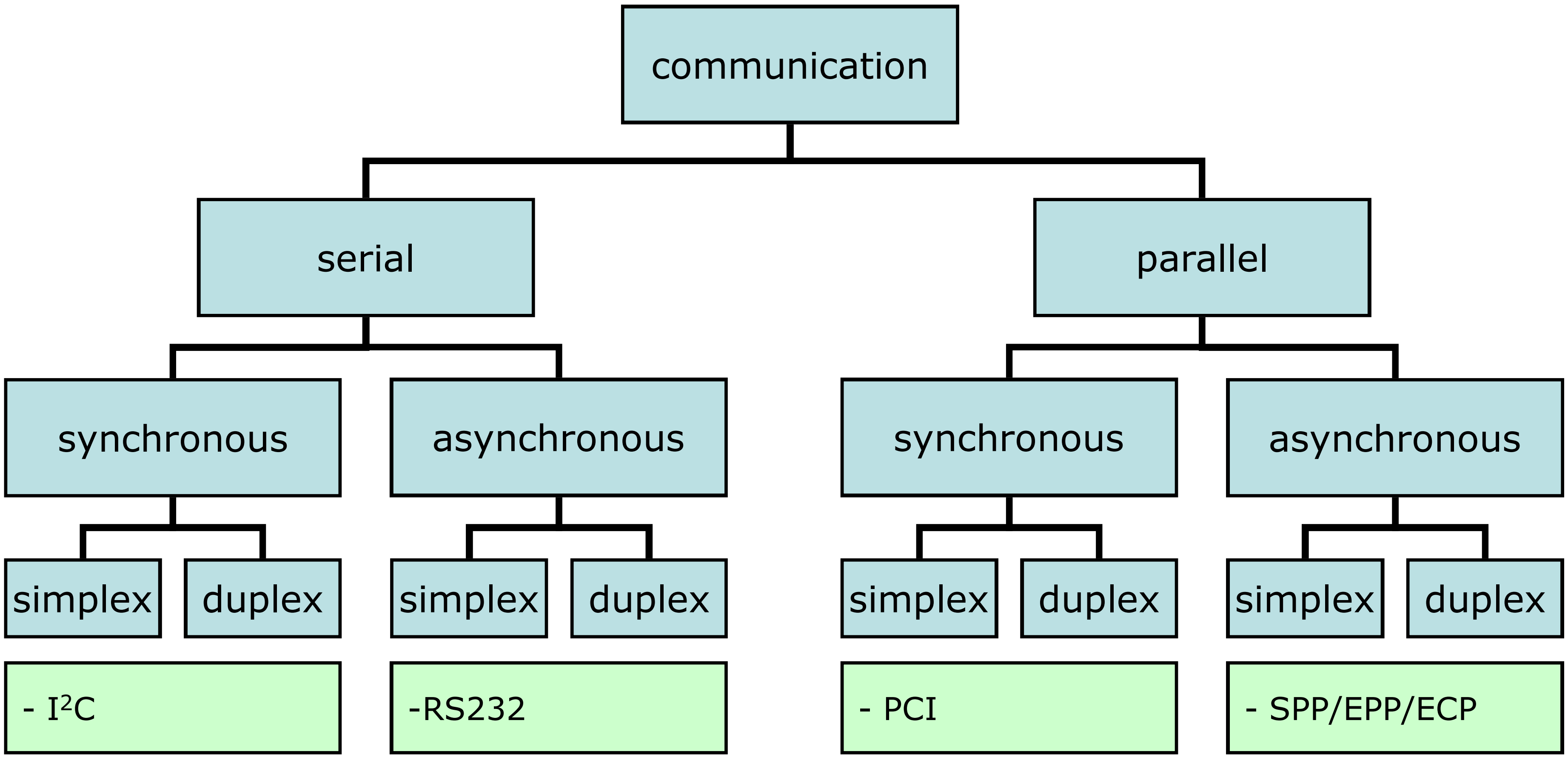
Classification (II)

- communication can be classified by the used transmission medium



Classification (III)

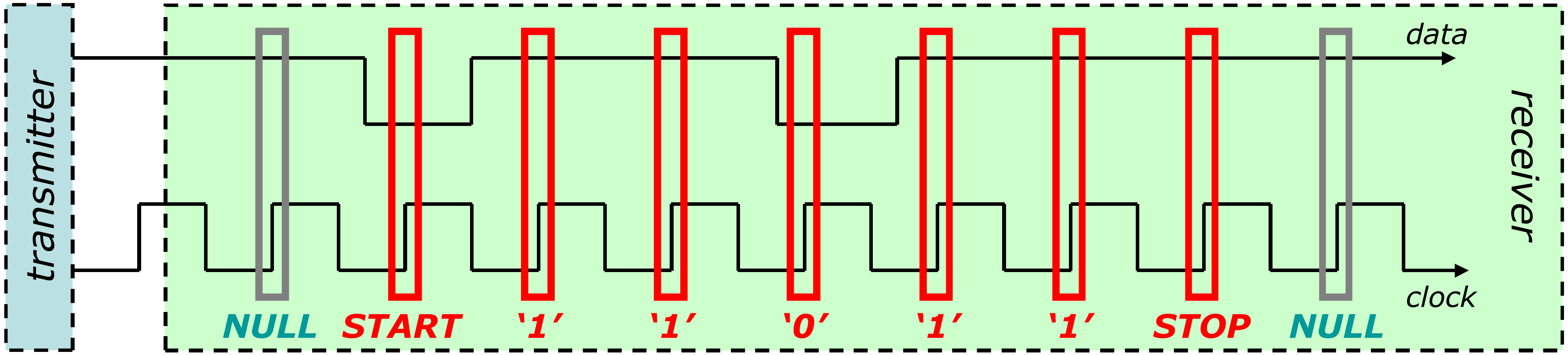
- interface an be classified by parameters of bit transmission



Synchronous Communication

- sampling time synchronisation between transmitter and receiver during communication, time between two transmissions is defined

- usually a ___________________________________ code is used for synchronisation (→ master/slave relation necessary)

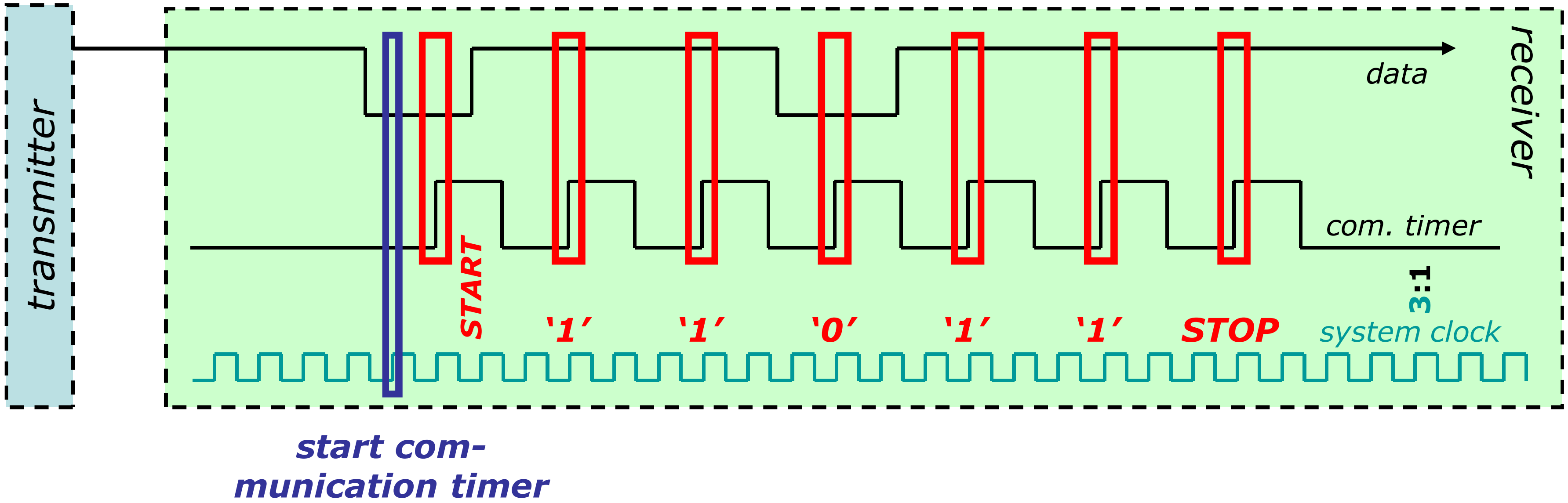


- advantage: no resynchronisation necessary → higher data rate

Asynchronous Communication

- no common time base → information about sampling times and necessary for receiver (e.g. baud rate, ratio between communication and system clock, …), any time between two transmissions

- synchronisation necessary to detect beginning of a transmission (e.g. ____, …)



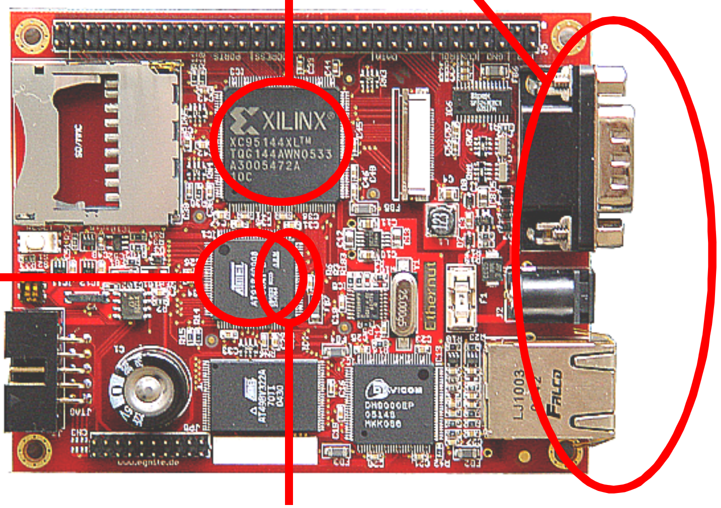
- advantage: no master/slave differentiation necessary

Interfaces in HW/SW Codesign

- in embedded systems a lot of interfaces are necessary
  → **important for developer**

HW-HW interfaces

- *on-chip busses*
- *debugging (JTAG)*
- *data transfer (USB, RS232, …)*



SW-SW interfaces

- *between processes (pipe, …)*
- *between programs (sockets, RPC, …)*

HW-SW interfaces

- *registers (e.g. for usage of UART)*
- *shared memory*

Contents

EIA-232 (formerly RS-232)

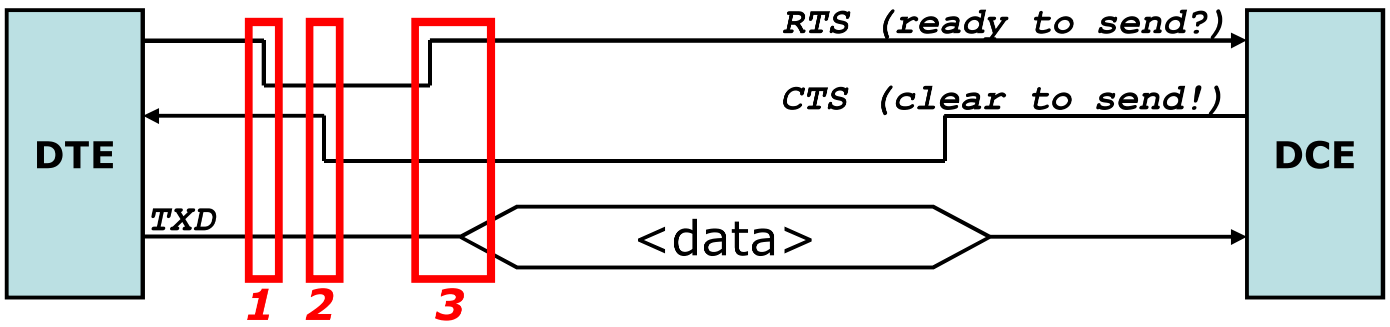
- defines ________________________________-communication between a terminal (DTE – data terminal equipment) and a modem device (DCE – data communication equipment)
- specified in 1962 by Electronics Industries Association (EIA)
  (since 1997: Electronics Industries Alliance)
- used for communication between non modem devices too (PC-PC, PC-printer, ES-ES, …)
- actual version (1997): ANSI/EIA/TIA-232-F-1997
- simplex, half-duplex and full-duplex possible
- software and hardware handshake defined for flow control

EIA-232 – Functional Definition (I)

- protocol: see [slide 03-6]
- transmission of words, word length of 5 to 8 bits (mostly 7 or 8)
- usually ASCII is used for coding signs
- least significant bit (LSB) transmitted first
- dedicated baud rates from 50…9600…115200…460800 bits/s defined
- parity bit with different semantic (“ODD”, “EVEN”, …) for detection of transmission error possible

EIA-232 – Functional Definition (II)

- flow control: if DTE faster than DCE, dataflow must be stopped
  – hardware flow control (additional handshake wires)



  – software flow control XON/XOFF (special control signs)
    - characters XON (ASCII 17, start dataflow) and XOFF (ASCII 19, stop dataflow)
    - ____

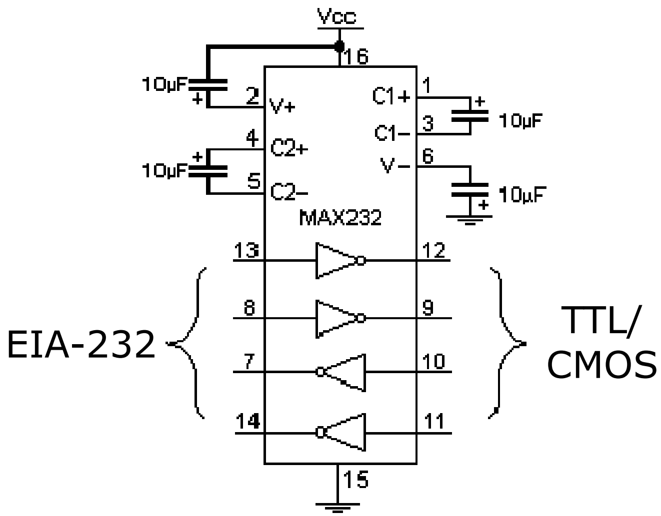
- in principal, dataflow can be stopped only in direction DTE→DCE (but meantime the DTR and DSR lines are used to control flow DCE→DTE)

EIA-232 – Electrical Definition

- static voltages used for bit transmission

- ______________________________
  - logical ‘1’: -3 … -25V
  - logical ‘0’: +3 … +25V
  - undefined: -3 … +3V

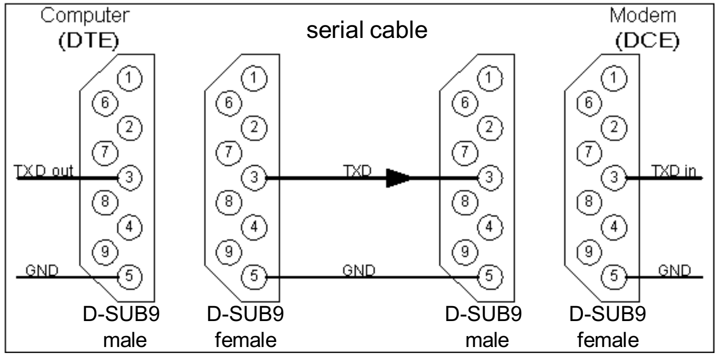
- usually level converters used for switching between system voltage (TTL/CMOS) and EIA-232 voltage



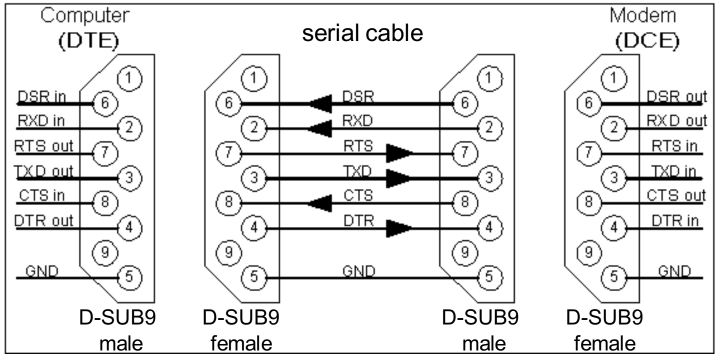
e.g. MAX232

EIA-232 – Mechanical Definition

- different connectors and cables defined



simplex communication using D-SUB9 connectors



duplex communication with hardware flow control using D-SUB9 connectors

- ___________________________: one wire per signal, voltage levels in respect to system common (e.g. GND)

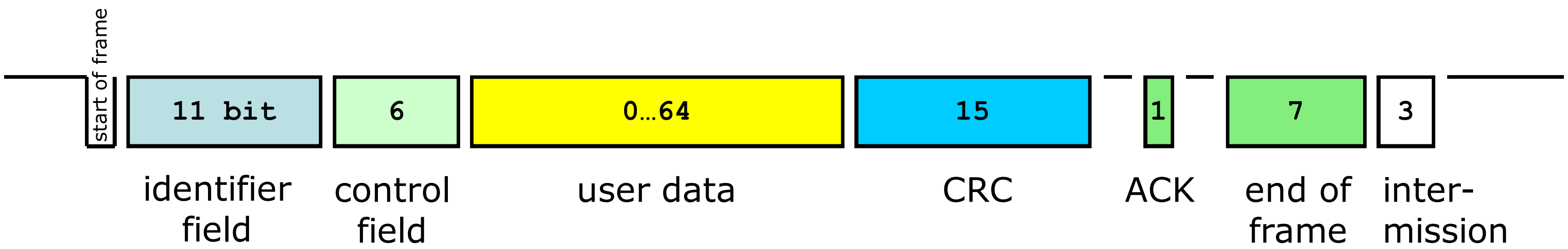
- applicable cable length depends on baud rate and used materials (max. total capacitance of cable and connector = 2500pF → cable length usually < 15m)

Controller Area Network (CAN)

- ISO 11898 standardised fieldbus (interconnection of sensors, actors and controller units) for ________________________ communication, realtime conditions feasible
- released by Bosch and Intel in 1987, aim: reduce number of wiring harnesses in automotive domain
- high speed (1 MBit/s) and low speed/ fault tolerant (125 kBit/s) modes available
- theoretically unlimited number of bus nodes possible, up to 100 with common interface units
- message oriented broadcast bus → no receiver address in messages, all nodes can "hear" all transmissions

CAN – Functional Definition (I)

- CAN specification covers ______________________________
- typically realised as a line topology, star and ring topologies possible (with restrictions)
- four types of message frames defined
  - data frame: containing up to 8 byte of user data
  - remote frame: requesting the transmission of specific user data
  - error frame: transmitted by any node detecting an error
  - overload frame: inject a delay between data and/or remote frames
- e.g. data frame



CAN – Functional Definition (II)

- identifier field marks the _______________ of a message (not the address of transmitter or receiver)
  - e.g. temperature, voltage, commands for actors, …
  - sensor marking possible (e.g. by marking the content with the ID: "temperature of sensor 1", …)

- every bus node reads the message and "decides" if the content of the message is relevant for itself

- two identifier field formats defined
  - base frame format: 11 bit (CAN 2.0A)
  - extended base frame format: 29 bit (CAN 2.0B)
  - base frame format has to be accepted, extended base frame format can be accepted but has to be tolerated by every bus node

CAN – Functional Definition (III)

- problem
  - one serial wire, many nodes
  - → how to prevent conflicts in accessing the bus?

- solution
  - CAN uses bitwise arbitration based on the identifier fields
  - requires a transmission medium which allows a hard (dominant) and a soft (recessive) bus state

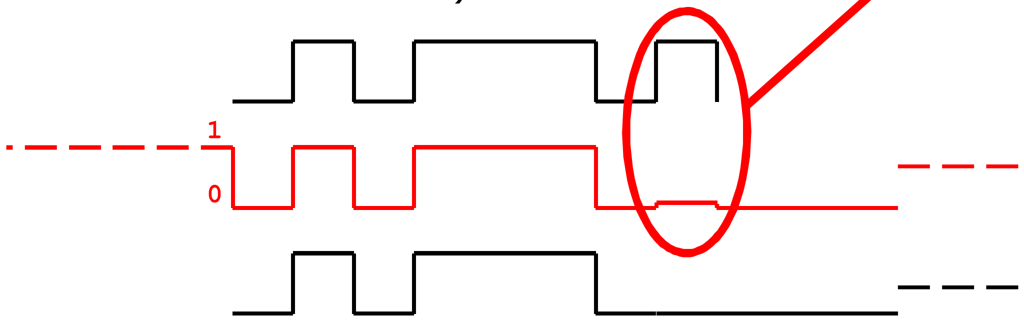
- example (2 messages at same time)
  (bus with recessive state '1' and dominant state '0')

bus state != message state
→ sender of message1 stops arbitration, message2 wins

$ID_{message1}$: 01011101000

resulting bus state

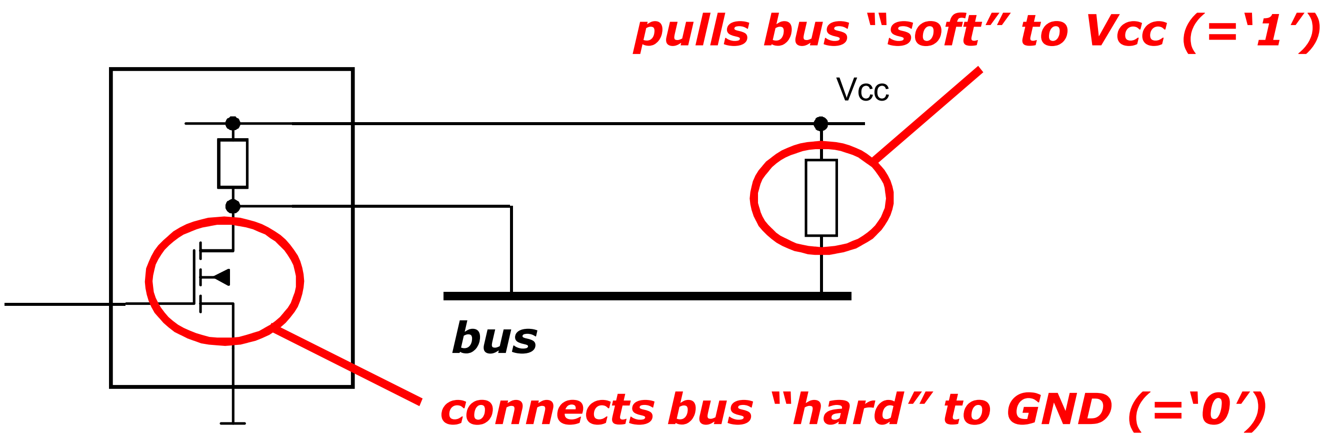
$ID_{message2}$: 01011100000



→ ____

CAN – Electrical Definition

- CAN is not limited to a single physical layer → many different specifications based on electrical and optical mediums specified
- important is the support of a ____________________ and a ____________________ bus state, e.g. by pull-up/down nets



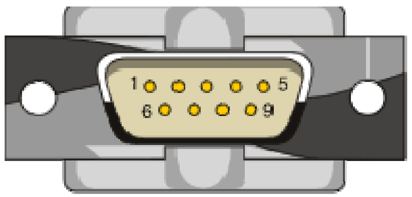
- widespread physical layers are
  - RS-485
  - ISO 11898-2:2003 – High-Speed medium access unit

CAN – Mechanical Definition

baudrate	bit time	cable length	baudrate	bit time	cable length
1000 kBit/s	1 µs	40 m	100 kBit/s	10 µs	400 m
500 kBit/s	2 µs	80 m	50 kBit/s	20 µs	800 m
250 kBit/s	4 µs	160 m	20 kBit/s	50 µs	2000 m
125 kBit/s	8 µs	320 m	10 kBit/s	100 µs	4000 m

- several mechanical definitions exist - depending on the used physical layer and mediums

- e.g. ISO 11898/ CAN in Automation (CiA) DS102-1
  - usage of a D-SUB9 connector

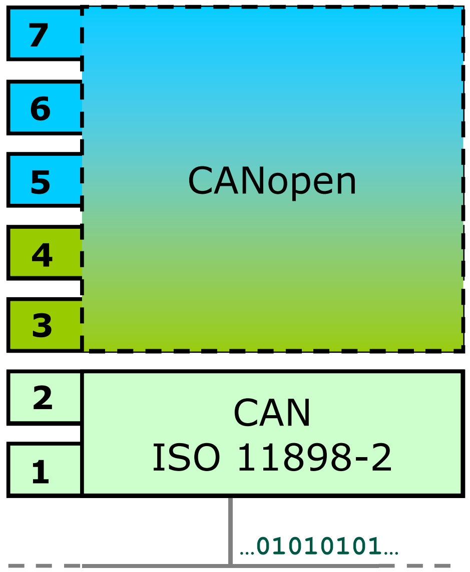


1… not connected
2… CAN_L
3… CAN_GND
4… not connected
5… not connected
6… CAN_GND
7… CAN_H
8… not connected
9… not connected

  - cable length recommendation

CANopen

- CANopen uses CAN data link and physical layer and realises the ___
  ____
  (but not all typical tasks of the layers are specified and implemented!)



- developed by Bosch, maintained by CAN in Automation (CiA), standardised as EN 50325-4 an, used especially in automation technology

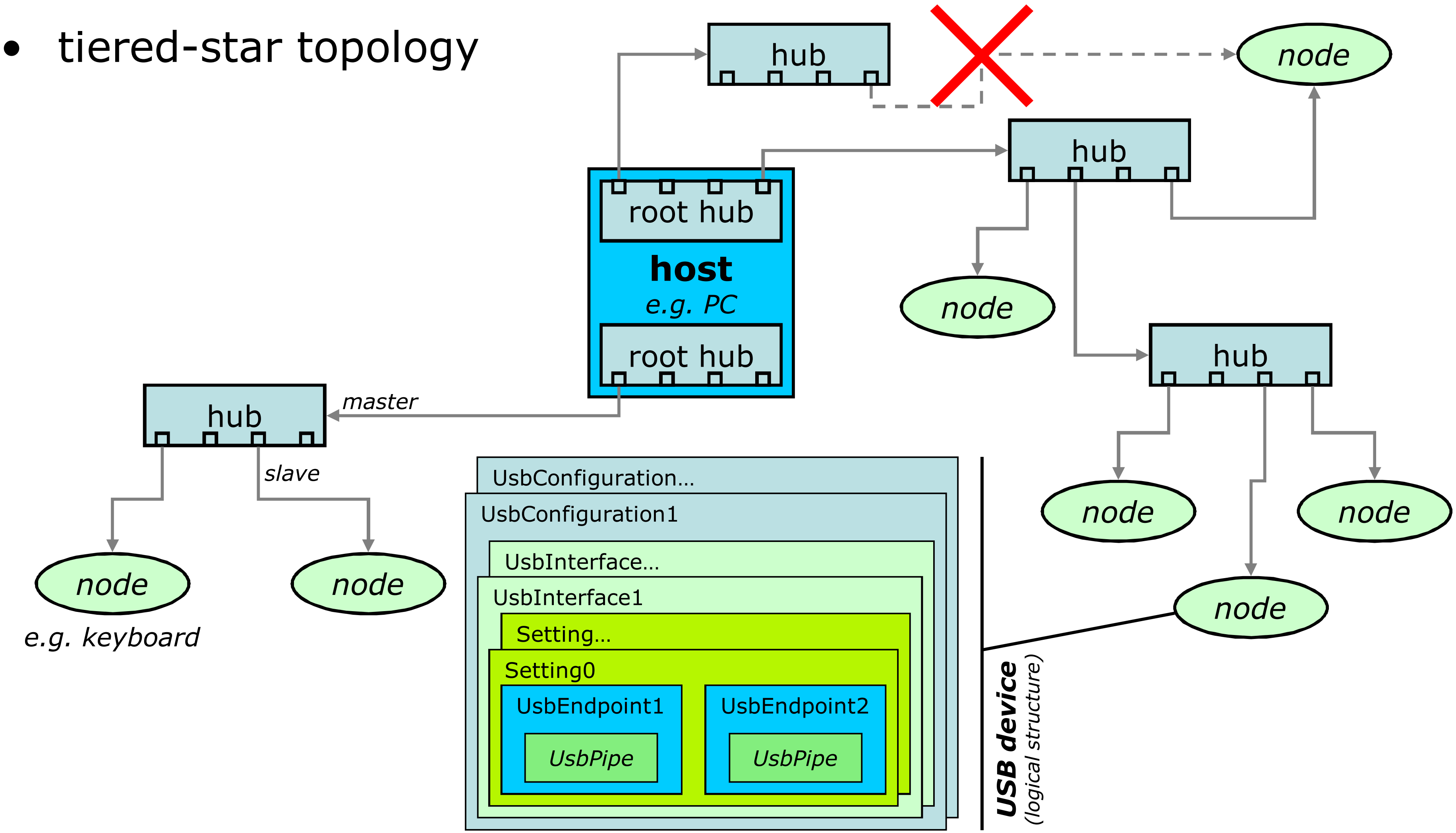
- provides standardised communication objects for
  - realtime data (Process Data Objects, PDO)
  - configuration data (Service Data Objects, SDO)
  - network management data (boot–up message, error messages, …)
  - special functions (time stamp, sync message, …)

Universal Serial Bus (USB)

- introduced by Intel in 1995, maintained by USB Implementers Forum (USB-IF)
- aim: replace all PC interfaces with low and medium speed (PS/2, RS-232, parallel, …) by a uniform standard
- meantime three datarates (can be used concurrently)
  - low-speed (USB 1.0, 1995): 1,5 MBit/s
  - full-speed (USB 1.1, 1998): 12 MBit/s
  - high-speed (USB 2.0, 2000): 480 MBit/s
- hot plug-and-play support
- up to 127 devices can be connected to one host in a tiered-star/tree topology
- **attention: USB is only a ______________ bus, physical transmission is realised as ____________________________**

USB – Functional Definition (I)

- tiered-star topology

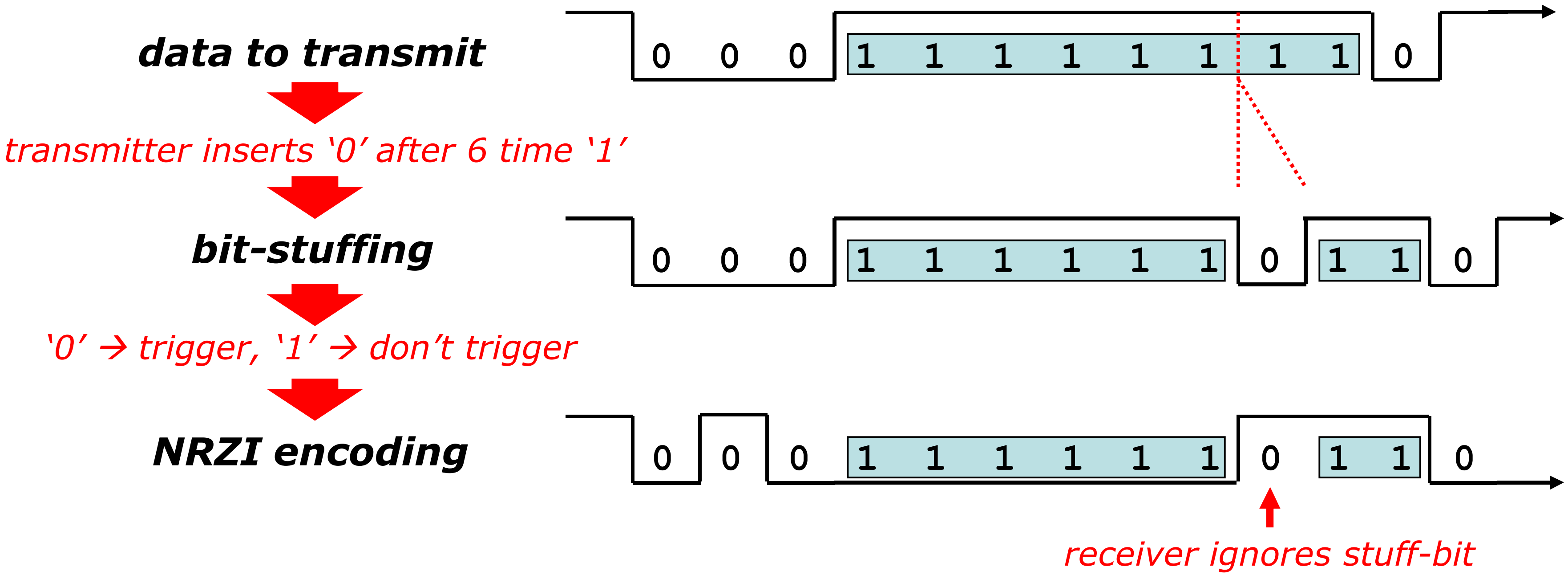


USB – Functional Definition (II)

- every node gets a dynamic ID (7 bit) by host (necessary for hot plug-and-play)
- logical, directed channels (USB-Pipes) used for communication between host and endpoints (4 bit sub-address) of devices
- communication itself is ________________________
  - scheduling by host
  - host polls every node for data – a node cannot initialise transmission
  - communication always between host and node, node-to-node communication not possible
- 4 transfer modes defined
  - control data transfer: configure the devices dynamically
  - bulk data transfer: transmission of huge amounts of data
  - isochronous data transfer: stream of defined bandwidth and latency
  - interrupt data transfer: single signs

USB – Electrical Definition

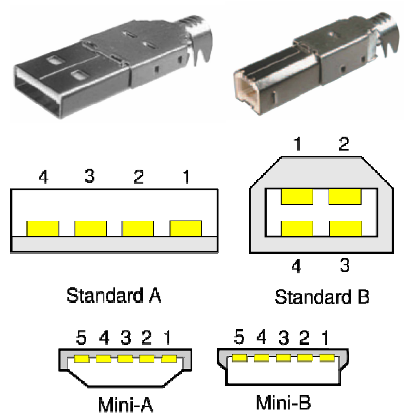
- bit-stuffing and NRZI (non return to zero inverted) encoding for ______________________________



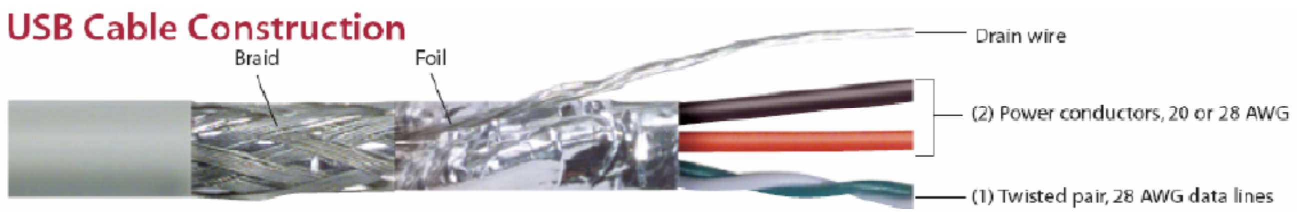
- USB allows bus powering (power for devices provided by USB cable) and self powering (external power supply)

USB – Mechanical Definition

- connectors prevent user from plugging a cycle in topology
  - plug ‘A’ is plugged to host or hub
  - plug ‘B’ is plugged to devices (hub)
  - → only star topology possible



- 4 wires necessary
  - 2 twisted cables (D+, D-) for bus signals
  - 2 cables for power supply (+5V/500mA, GND)



- max. cable length ~ 5m, no passive extension allowed by standard

More Wired Interface Standards

- Inter-Integrated Circuit (I^2C) / Two-Wire Interface (TWI)
  - _______________________ bus with 7 bit address space
  - developed by Philips to connect different devices on a board
  - master/slave bus with a baudrate of up to 100 kBit/s (standard) and 400 kBit/s (fast)
  - very simple to use → widely-used in embedded systems

- IEEE 1394 / Firewire
  - serial bus, developed by Apple, standardised in 1995
  - synchronous and asynchronous transfer modes defined
  - up to 400 MBit/s baudrate (using a copper cable)
  - up to 64 devices on one bus, no defined host necessary, every device can communicate directly with any other device
  - hot plug-and-play support, realtime conditions can be fulfilled

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- Classification
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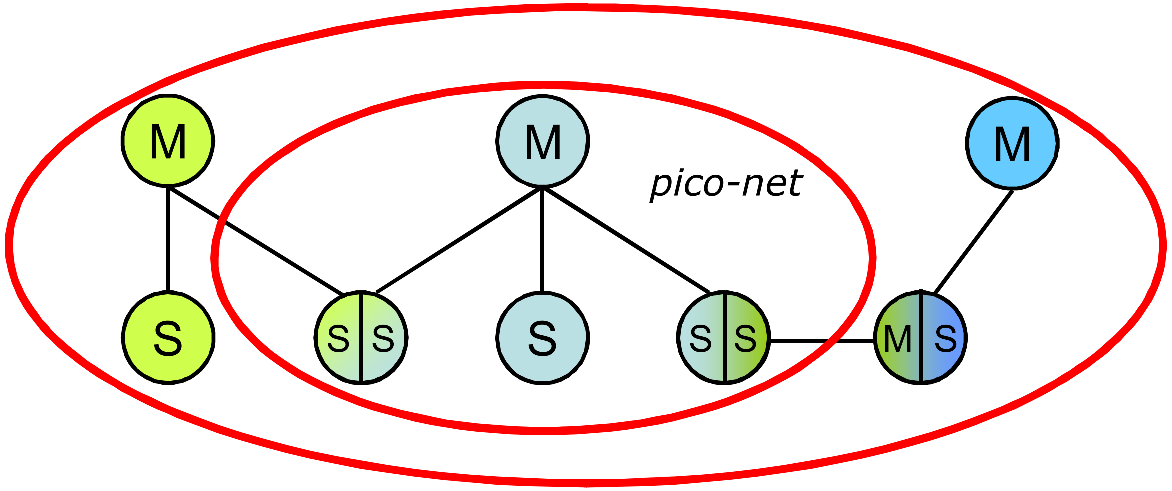
- Some Wireless Interface Standards

Bluetooth (I)

- introduced as Bluetooth 1.0 in 1998 by Bluetooth Special Interest Group (SIG, Ericsson, Nokia, IBM, Intel, Toshiba, …)
- aim: replace all cables between PC and peripheral devices → star topology with master (PC) – slave (peripherals) relation
- datarates up to 1 MB/s, since Bluetooth 2.0 (2004): 2.1 MB/s
- a devices provides different (but standardised) services (called profiles), which can be used by communication partner
- ____ are possible concurrently

Bluetooth (II)

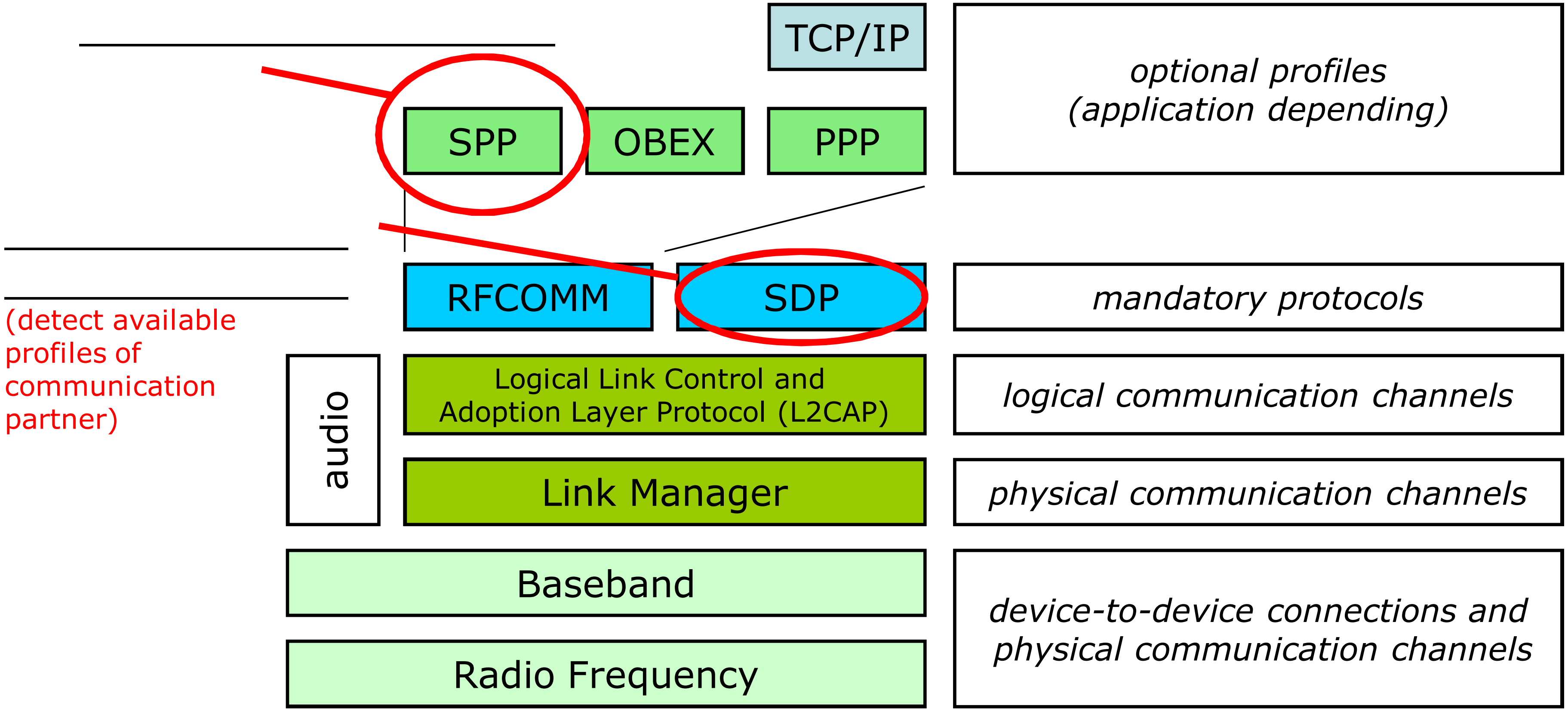
- topology



- master controls communication (time multiplexing, frequency hopping scheme, …) of pico-net
- role-switch (toggle master/slave relation) possible
- ____________________ to build-up networks

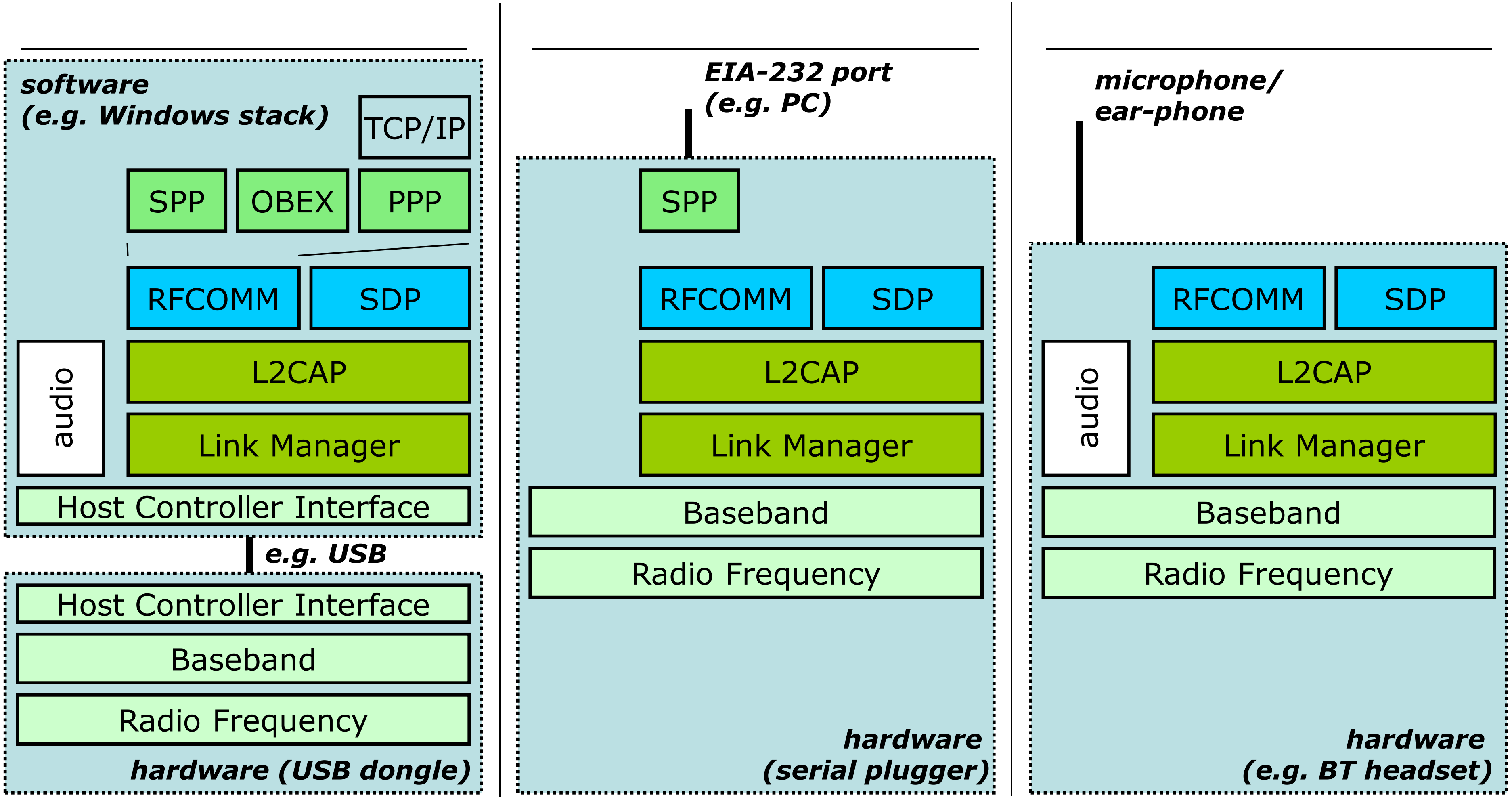
Bluetooth – Functional Definition (I)

- definition of a whole stack of protocols



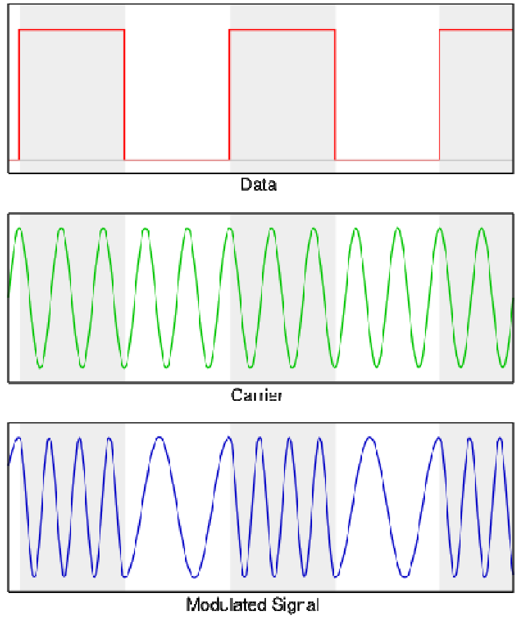
Stack Implementation Alternatives

- stack is implemented differently – depending on application



Bluetooth – Electrical Definition

- 2.4 GHz ISM-band, 79 channels between 2400 … 2483 MHz
- ______________________________ for ‘1’ and ‘0’ modulation



- ______________________ to prevent from collisions
  - change channel every 625µs
  - selected channel (hopping scheme) depends on masters device address and randomised values
- 3 different transmitting power classes
  - class 3: 1mW → up to 10m
  - class 2: 25mW → up to 20m
  - class 1: 100mW → up to 100m, integrated power control
- communication with host via UART and USB possible

Bluetooth – Mechanical Definition

$\emptyset$

nothing

WLAN / IEEE 802.11

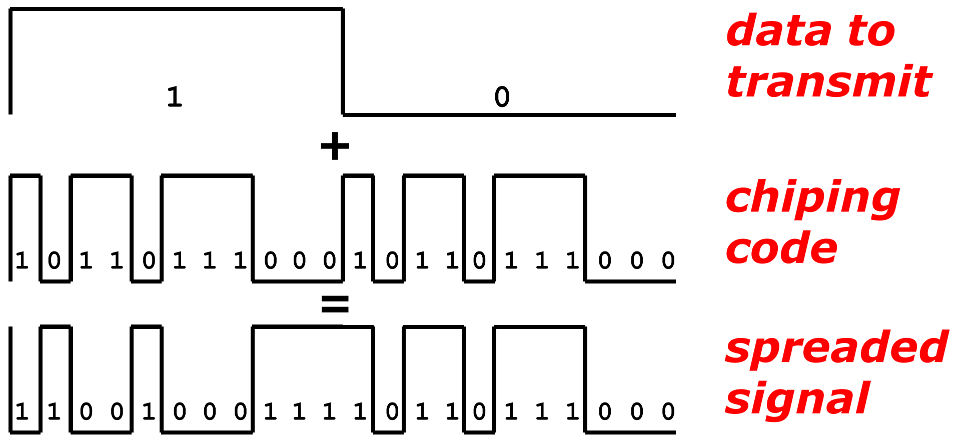
- covers the ISO/OSI layer 1 + 2 (physical + data link layer) → wireless medium for higher network protocols like TCP/IP
- aim: replace/extend the wired ethernet → same addressing as ethernet (MAC) used
- meanwhile a lot of standards
  - 802.11 (1997): 2 MBit/s at 2.4 GHz
  - 802.11a/h (1999): 54 MBit/s at 5 GHz
  - 802.11b (1999): 11 MBit/s at 2.4 GHz
  - 802.11g (2003): 54 MBit/s at 2.4 GHz, widely spread
  - 802.11n (planned 2009): up to 250 MBit/s at 2.4 and 5 GHz
  - 802.11y (planned): 53 MBit/s at 3.7 GHz, long range (5km)
- typically communication range of 30-50m indoor and 100-300m outdoor

WLAN – Functional Definition

- 3 modes defined
  - ___________________ mode
    - defined access points (AP) and clients
    - several APs interconnected by dedicated network (not by the provided WLAN!), mostly with uplink to inter-/intranet
    - client connects to an available AP, handover only client initialised (no management between APs)
  - __________ mode
    - clients interconnect spontaneously among each other → no defined AP, all clients equal
    - if no routing protocol used, communication only between devices in each others communication range possible
  - ______________________________________
    - increase network coverage by interconnection of APs via the provided WLAN

WLAN – Electrical Definition

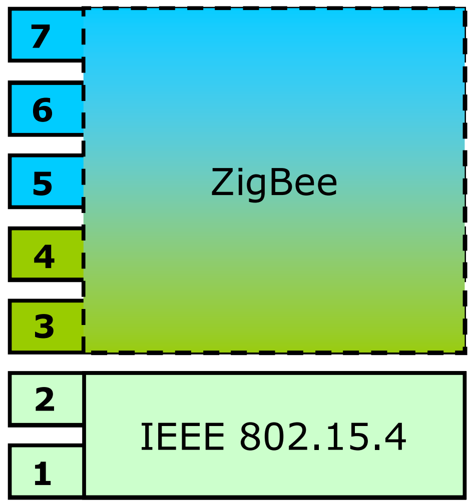
- Direct Sequence Spread Spectrum (DSSS) to prevent from interfering radiation
  - define a chiping code and add it to the data
  - ____________________________ ____________________________ (by factor of chiping code size)



- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA, probabilistic media access control) to prevent from two devices using the same channel at the same time
  - listen to channel before transmission
  - if channel is free → start transmission
  - if channel is used → wait a random time

IEEE 802.15.4 / Zigbee

- released in 2004 by IEEE and ZigBee Alliance
- aim: near field interconnection (10 – 100m) of home user devices and sensor nodes at ______________________________
- IEEE 802.15.4 defines ISO/OSI layer 1 + 2 used by upper layers of ZigBee
- usage of 2.46 GHz and 868 MHz ISM-band (in Europe)
- bandwidth of 20 (868 MHz) and 250 kBit/s (2.46 GHz)



ZigBee – Functional Definition

- automatically built-up topology with 3 device classes
  - ZigBee End Device: application, no message relay functionality
  - ZigBee Router: application + relay
  - ZigBee Coordinator: root of network, gateway to other networks

- different topologies possible (star, tree, graph)

- 2 addressing modes
  - ________________________: 64 bit node address (allocated by IEEE ≈ MAC) and endpoint (≈ port of TCP/IP)
  - _____________: 16 bit network address, every node registers to coordinator and gets an ID, coordinator builds a lookup table of active devices and their IDs

- very small packets (max. 128 bytes)

ZigBee – Electrical Definition

- usage of 1 channel at 868 MHz and 16 channels at 2.46 GHz
  - the coordinator selects a suitable (e.g. low activity) channel for whole network
  - all devices on same channel belong to network
- DSSS and CSMA/CA (see [slide 03-51])
- special attention to reduction of power consumption
  - 3 states: send, receive, sleep
  - ______________________________

More Wireless Interface Standards

- WirelessUSB
  - USB cable replacement, up to 480 MBit/s, 3.1 – 10.6 GHz
- High Performance Radio Local Area Network (HiperLAN)
  - similar to WLAN, 25 MBit/s, 5 GHz
- Global System for Mobile Communications (GSM)
  - digital mobile phone standard, 270 kbit/s per channel, 900/1800 MHz, widely spread (around 2 billion users)
- Universal Mobile Telecommunications System (UMTS)
  - 3G digital mobile phone standard, up to 2 MBit/s, 1.9/2.1 GHz
- Wireless Interoperability for Microwave Access (WiMax)
  - DSL alternative, up to 70 MBit/s, up to 50km range, 3.4-3.6 GHz (Germany)