STR9 Ethernet SpeedWay

Networking and Ethernet

2007

STM EMMA Prague
enrico.marinoni@silica.com

Content

- Networking
  - ISO OSI model – described layer by layer
- Ethernet
  - History
  - Standards Around Ethernet
  - Media Access Control (MAC) IEEE 802.3

Networking

ISO OSI Model

	Layer	Function
7	**Application**	Network process to application
6	**Presentation**	Data representation and encryption
5	**Session**	Inter-host communication
4	**Transport**	End-to-end connections and reliability
3	**Network**	Path determination and logical addressing
2	**Data link**	(Physical) addressing
1	**Physical**	Media; signal and binary transmission

Physical Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

- Media – connectors, cables
  - Metal: Coaxial cable, Twisted-Pair
  - Optical: Optical fiber
  - Radio: Wi-Fi, GSM, Bluetooth
  - Infra Red (IR)
- Signal
  - Modulation
  - Line coding
- Standards: RS-232, V.35, ISDN, 10BASE-T, 100BASE-FX, SONET, xDSL, 802.11b

Data Link Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

- Framing:

Frame:

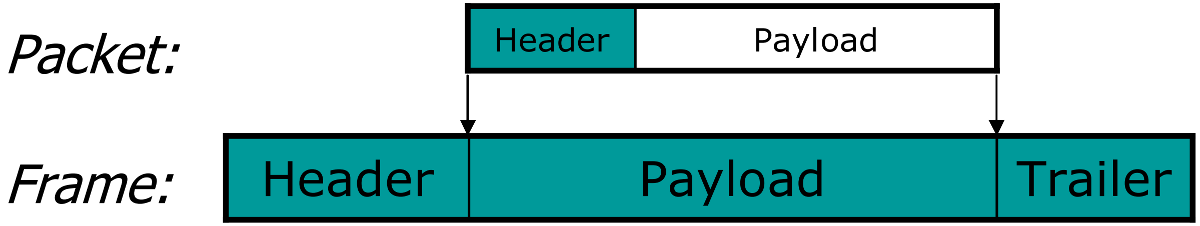
Header	Payload	Trailer

- Header: Destination and Source (Link) **addresses**, Control information
- Trailer: Checksum
- Standards: **Ethernet**, 802.11 (WiFi), token ring, FDDI, PPP, HDLC, Frame Relay, ATM, Fibre Channel

Network Layer

- Application
- Presentation
- Session
- Transport
- **Network**
- Data link
- Physical

- "Packetization":

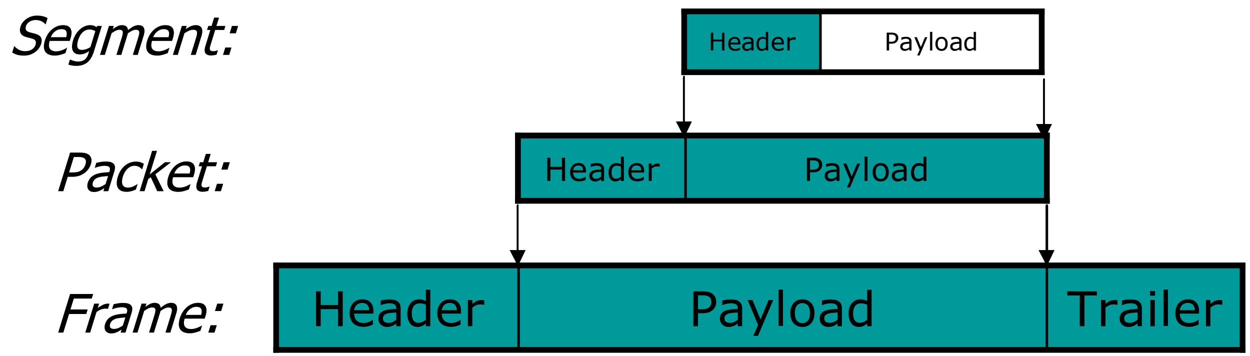


- Path determination
  - network routing, flow control, network segmentation (e.g. by bridge) and error control functions
- Logical addressing
- Standards: **IP**, IPv6, IPSec, IPX, X.25

Transport Layer

- Application
- Presentation
- Session
- **Transport**
- Network
- Data link
- Physical

- "Segmentation":



- Virtual Connections, Same Order Delivery, Reliable Data, Congestion Avoidance
- Standards: **TCP**, **UDP**, SPX, ATP

Session Layer

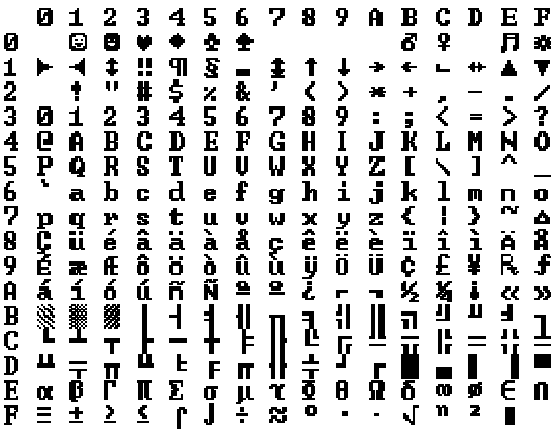
Application
Presentation
Session
Transport
Network
Data link
Physical

- Managing the dialogue between end-user application processes.
- Often unused, but there are exceptions e.g. web conferencing – to ensure audio and video match up
- Standards: Named Pipes (RPC), NetBIOS

Presentation Layer

- Application
- **Presentation**
- Session
- Transport
- Network
- Data link
- Physical

- Data formatting and encryption



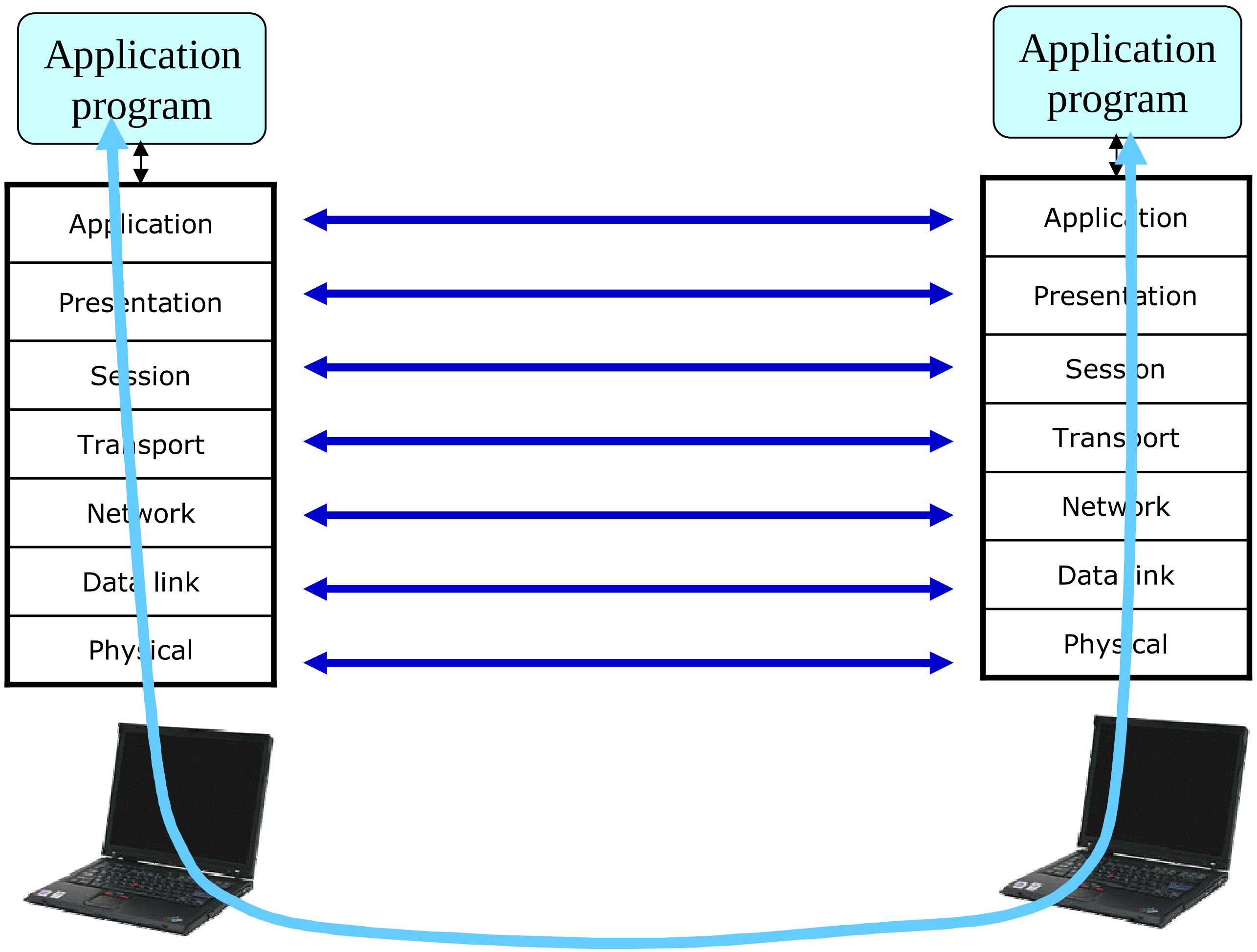
- Standards: ASCII, Unicode, RSA, DES, GIF, MPEG

Application Layer

Application
Presentation
Session
Transport
Network
Data link
Physical

- Network process to application: e.g. virtual file, virtual terminal and job transfer and manipulation protocols
- Standards: **HTTP**, SMTP, SNMP, FTP, Telnet, SSH

OSI Layers



Application program
Application
Presentation
Session
Transport
Network
Data link
Physical
Application program
Application
Presentation
Session
Transport
Network
Data link
Physical

Ethernet

History of Ethernet

- Ethenet was invented in the period of 1973-1975 by **Robert Metcalfe** and David Boggs at **Xerox** PARC. Patented in 1975 the experimental Ethernet ran at 3 Mbit/s and had 3-bit addressing.
- Metcalfe left Xerox in 1979 and founded **3Com**. He convinced DEC, Intel and Xerox to promote Ethernet as **standard**, the so-called "DIX" standard with 10 Mbit/s speed and 48-bit address.
- Thanks to J.H.Saltzer's paper suggesting that token-ring architectures were theoretically superior to Ethernet-style technologies, computer manufactures decided not to include Ethernet in their products, which allowed 3Com to build business around selling add-in Ethernet network cards.
- Ethernet originally worked on coaxial cable. It required a method to deal with collisions on the media – the **CSMA/CD** method was introduced in Ethernet.
- The word *"Ethernet"*: Searching a word to describe a medium that would be everywhere and serve for the propagation of electromagnetic waves into data packet, the word **"ether"**, fallen in disuse in 1900s, was chosen.

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Industrial Ethernet

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STM EMMA Prague
enrico.marinoni@silica.com

ISO OSI vs. TCP/IP

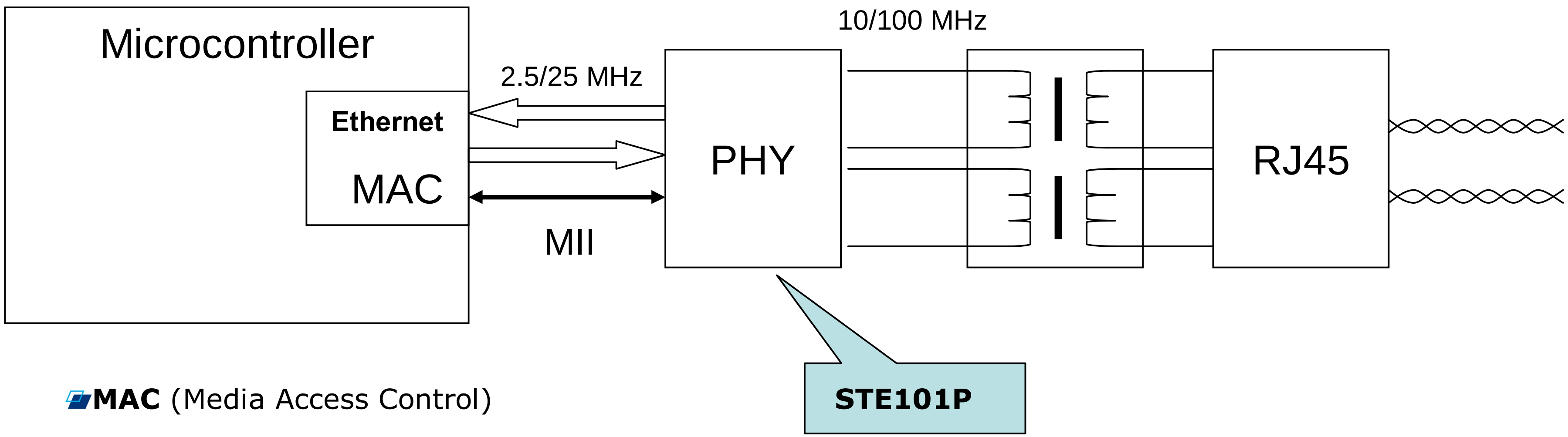
Ethernet

TCP/IP
Application
TCP/UDP
Internet (IP)
Physical and Link

ISO7498/ OSI model
Application
Presentation
Session
Transport
Network
Data links
Physical

Ethernet

Ethernet



MAC (Media Access Control)

Ethernet TCP/IP Example

Ethernet

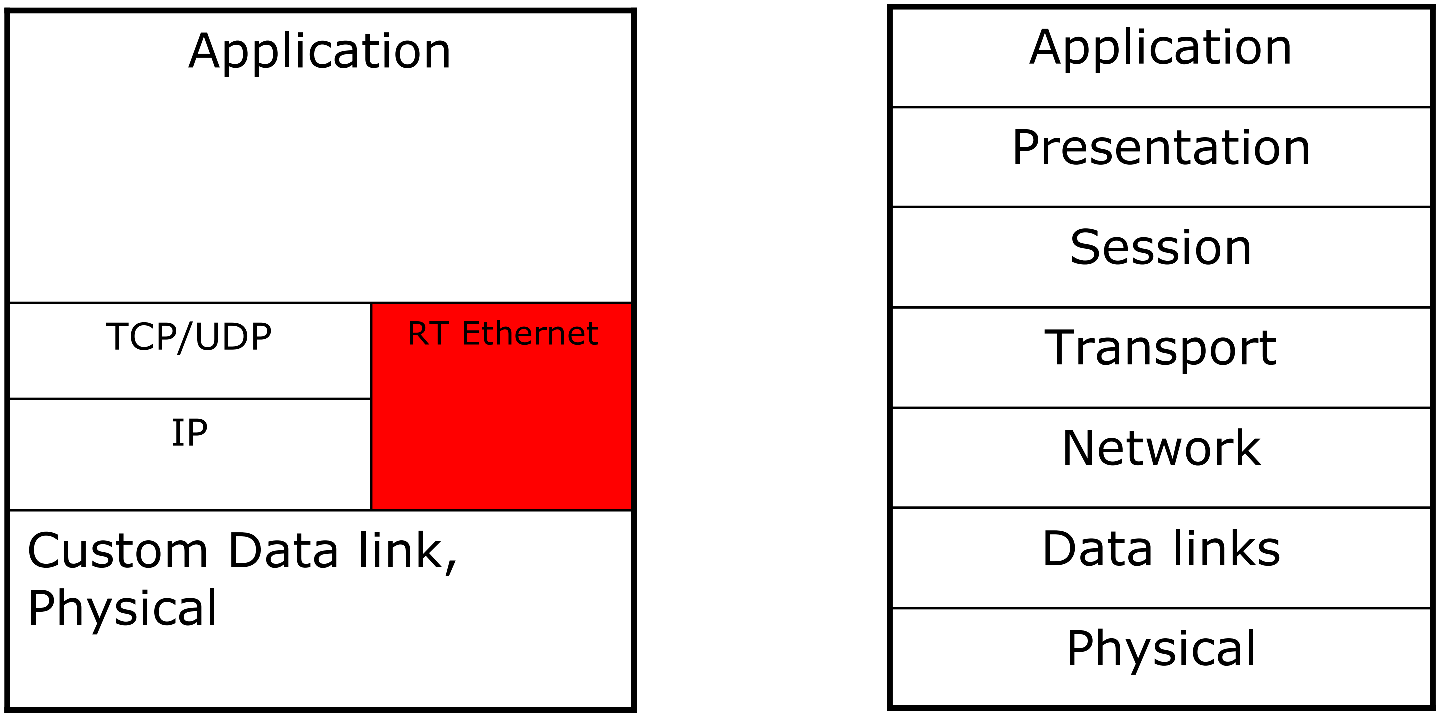
Click for manual

ISO OSI vs. Real Time Ethernet

RT Ethernet

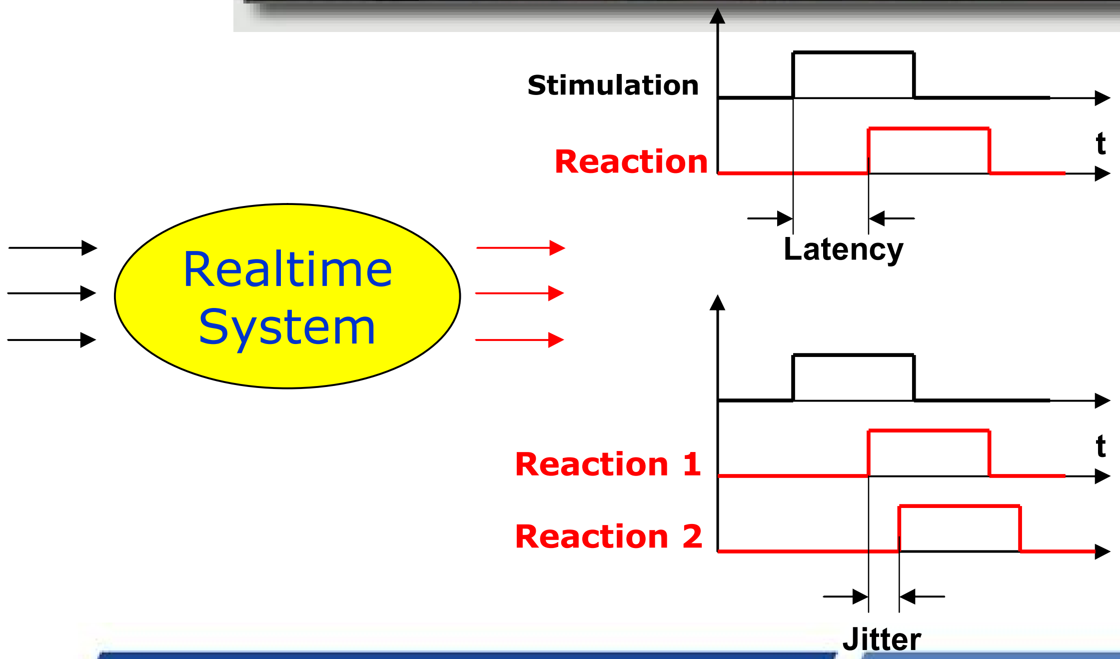
RT protocol

ISO7498/ OSI model



What means „Realtime" ?

RT Ethernet



- 3 Parameters of Realtime:

1.) minimize Latency

2.) maximize Data Throughput

3.) Simultaneity: to minimize Jitter

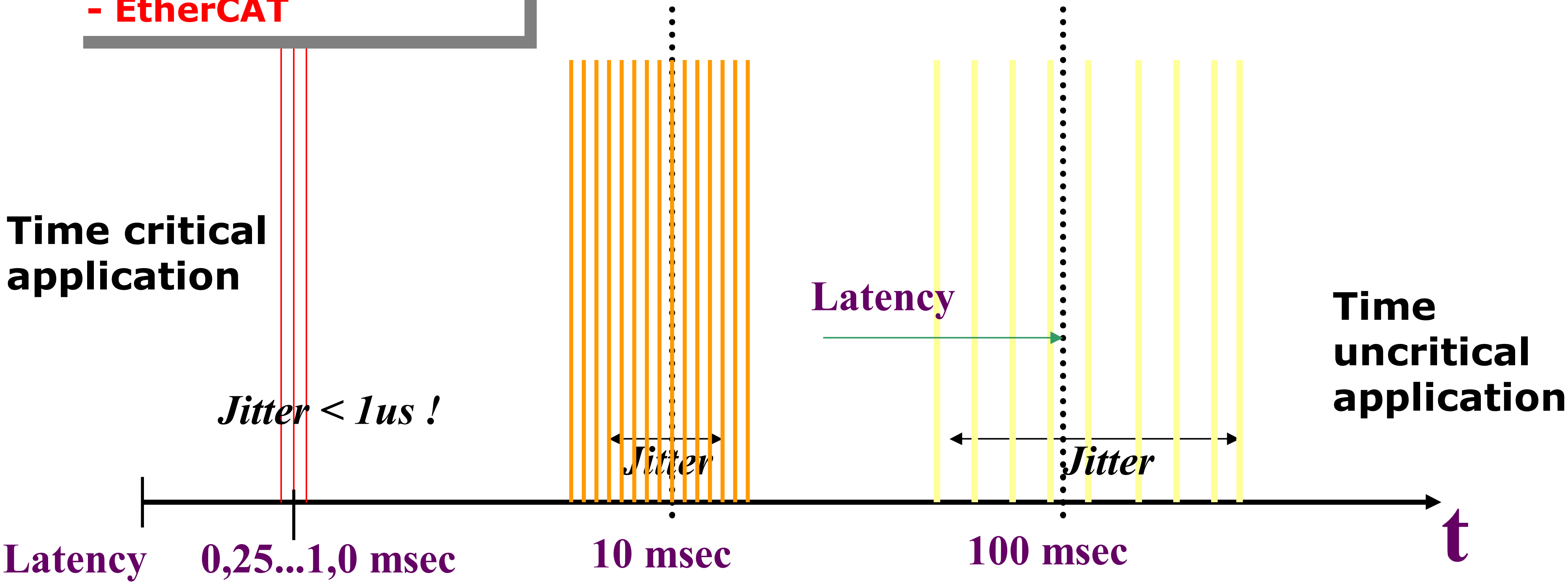
What means „Ethernet Realtime“ ?

RT Ethernet

Hard Real Time
- Powerlink
- Sercos III
- Ethernet/IP with CIPsyn
- Profinet IRT
- EtherCAT

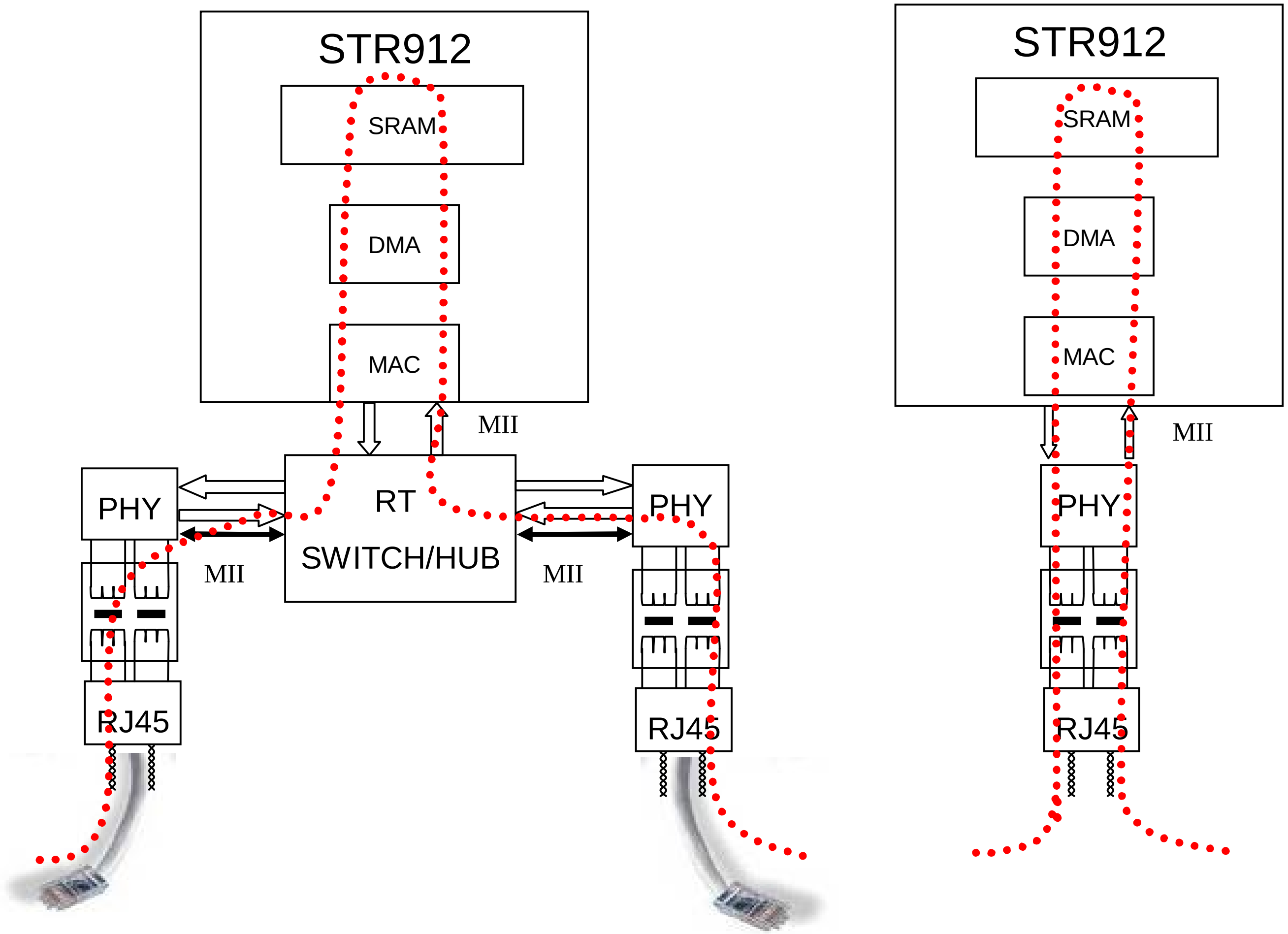
Soft Realtime
- Ethernet/IP
- Modbus/TCP
- Profinet SRT

Non Real Time
- all TCP/IP



RT Ethernet node

RT Ethernet

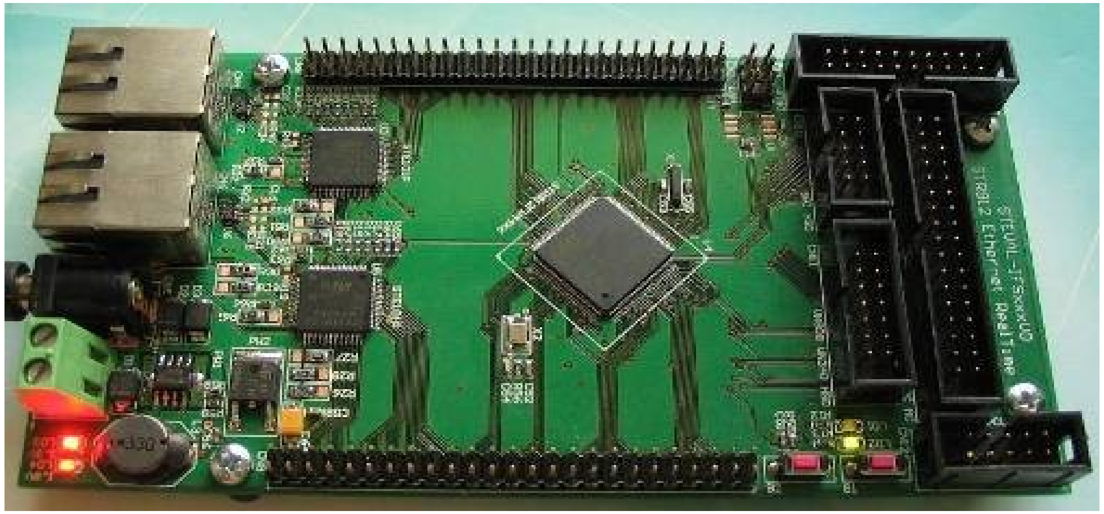


Typical requirements:

- Fast response time (data read/write)
- Minimized throughput delay of the data frame
- Minimized Jitter
- Daisy chain connectivity – no collisions on the medium

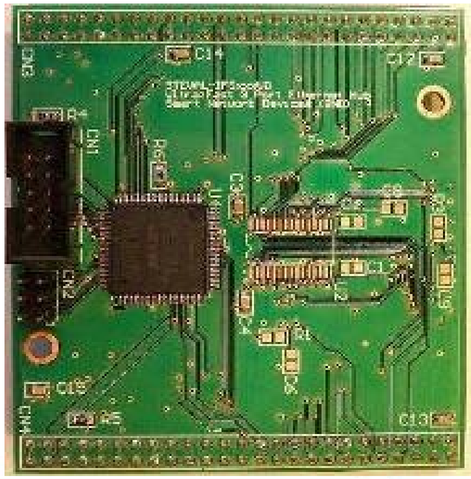
RT Ethernet node example

RT Ethernet



Dual PHY

Carry board



RT IP
extension

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TCP/IP

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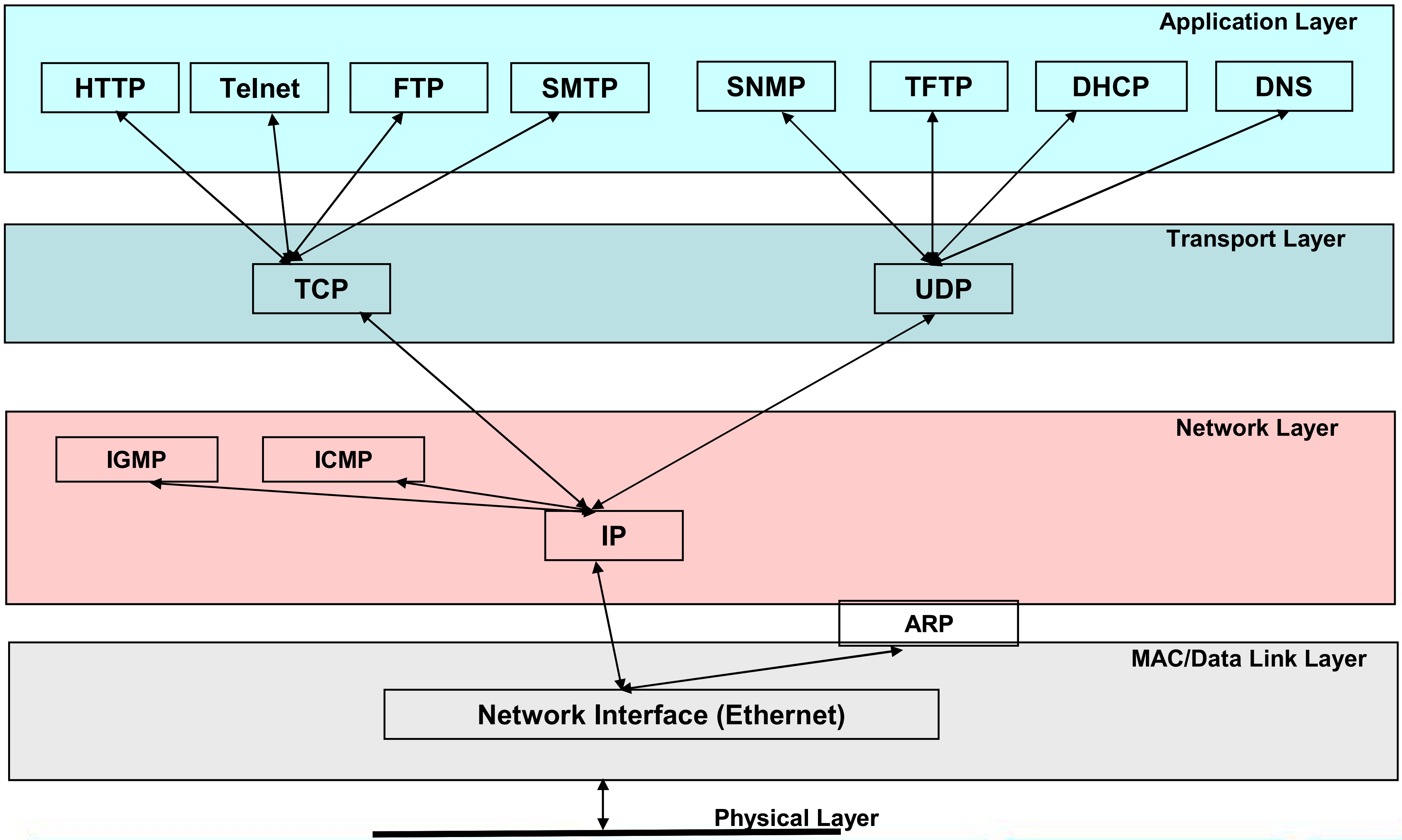
TCP / IP

TCP/IP vs. OSI

TCP/IP		ISO OSI model
Application	**Application System**	Application
		Presentation
		Session
TCP/UDP	**Transport System**	Transport
IP		Network
Data link and Physical (Ethernet)		Data link
		Physical

TCP/IP Stack



Application Layer
HTTP
Telnet
FTP
SMTP
SNMP
TFTP
DHCP
DNS
Transport Layer
TCP
UDP
Network Layer
IGMP
ICMP
IP
ARP
MAC/Data Link Layer
Network Interface (Ethernet)
Physical Layer

IP
Internet Protocol

IP Protocol

- The **Internet Protocol** (**IP**) is a data-oriented protocol used for communicating data across a packet-switched internetwork.
  - "Packetization" – encapsulation of data
  - Fragmentation – breaking packets into fragments small enough to pass over a link with smaller frame size
  - Routing – Addressing and Path determination
  - Reliability – IP is **not reliable**, protocols of upper layers have to be used
- **IPv4 Internet Protocol version 4** is the fourth iteration of the Internet Protocol (IP) and it is the first version of the protocol to be widely deployed.
  IPv4 is the dominant network layer protocol on the Internet and apart from IPv6 it is the only protocol used on the Internet.

IP Packet Structure

<table>
<tr><th>+</th><th>Bits 0–3</th><th>4–7</th><th>8–15</th><th>16–18</th><th>19–31</th></tr>
<tr><td>0</td><td>Version
specifies if it's an IPv4 or IPv6 packet</td><td>Header length
the length of the header</td><td>Type of Service
also referred to as Quality of Service (QoS) - describes what priority the packet should have (used in streaming multimedia applications such as voice over IP)</td><td colspan="2">Total Length</td></tr>
<tr><td>32</td><td colspan="3">Identification
helps reconstruct the packet from several fragments</td><td>Flags
e.g. a flag that says if the packet is allowed to be fragmented or not</td><td>Fragment Offset
a field to identify which fragment this packet is attached to</td></tr>
<tr><td>64</td><td colspan="2">Time to Live
the number of hops (router, computer or device along a network) the packet is allowed to pass before it dies (for example, a packet with a TTL of 16 will be allowed to go across 16 routers to get to its destination before it is discarded)</td><td>Protocol
TCP, UDP, ICMP, etc...</td><td colspan="2">Header Checksum</td></tr>
<tr><td>96</td><td colspan="5">Source IP Address</td></tr>
<tr><td>128</td><td colspan="5">Destination IP Address</td></tr>
<tr><td>160</td><td colspan="5">Options (optional)</td></tr>
<tr><td>160 or 192+</td><td colspan="5">Data</td></tr>
</table>

Maximal data size = Max. Ethernet Payload – IP Header = 1500 – 20 = 1480 bytes

TCP
Transmission Control Protocol

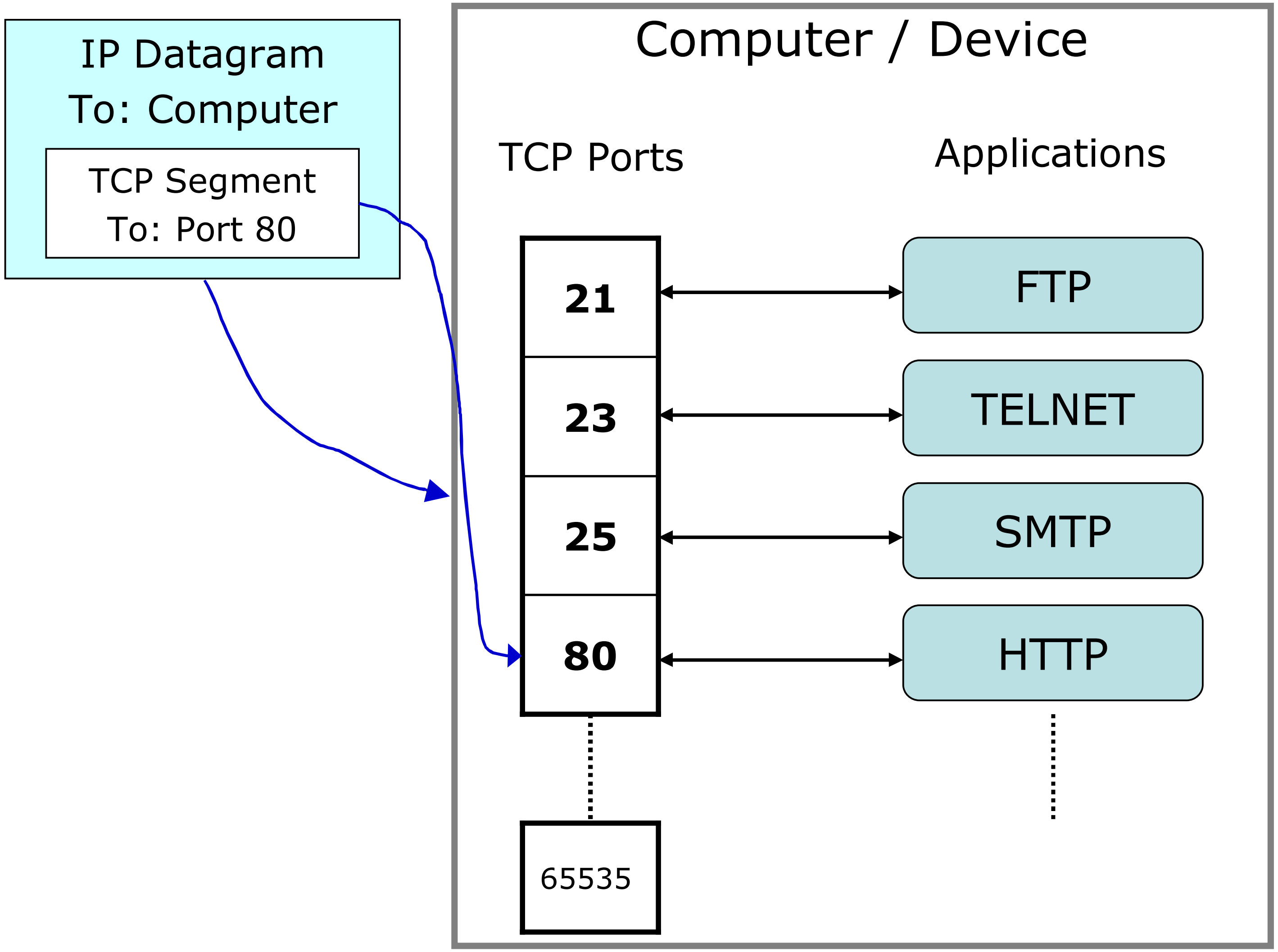
TCP Protocol

- The **T**ransmission **C**ontrol **P**rotocol is one of the core protocols of the Internet protocol suite, often simply referred to as TCP/IP. Using TCP, applications on networked hosts can create *connections* to one another, over which they can exchange streams of data using Stream Sockets.
- The protocol guarantees reliable and in-order delivery of data from sender to receiver.
- TCP protocol avoids **congestion** using **window** mechanisms

TCP Segment Structure

+	Bits 0–3	4–7	8–15	16–31
0	**Source Port** the sending port			**Destination Port** the receiving port
32	**Sequence Number** the sequence number of the first data byte in TCP segment			
64	**Acknowledgment Number** the sequence number the sender expects next, it says to the other side how many data bytes were already received			
96	**Data Offset** specifies the size of the TCP header in 32-bit words. The minimum size header is 20 bytes and maximum 60 bytes	**Reserved**	**Flags** ACK (Acknowledgement), PSH (Push function – application data), RST (Reset/refuse the connection), SYN (Synchronize sequence numbers), FIN (No more data from sender), URG (Urgent pointer field – see below – is significant)	**Window** the number of bytes the sender is willing to receive starting from the acknowledgement field value – used for Congestion avoidance
128	**Header Checksum**			**Urgent Pointer** if the URG flag is set, then this 16-bit field is an offset from the sequence number indicating the last urgent data byte – used by routers
160	**Options** (optional)			
160/ 192 +	**Data**			

TCP Ports


IP Datagram
To: Computer
TCP Segment
To: Port 80
Computer / Device
TCP Ports
Applications
21
23
25
80
65535
FTP
TELNET
SMTP
HTTP

UDP
User Datagram Protocol

UDP

- The **User Datagram Protocol** (**UDP**) is one of the core protocols of the Internet protocol suite. Using UDP, programs on networked computers can send short messages sometimes known as *datagrams* to one another. UDP is sometimes called the **Universal Datagram Protocol** or Unreliable Datagram Protocol.

- **UDP does not provide the reliability and ordering that TCP does. Datagrams may arrive out of order, appear duplicated, or go missing without notice.**
  Without the overhead of checking whether every packet actually arrived, **UDP is faster and** more **efficient** for many lightweight or time-sensitive purposes. Also, its stateless nature is useful for servers that answer small queries from huge numbers of clients.

UDP vs. TCP

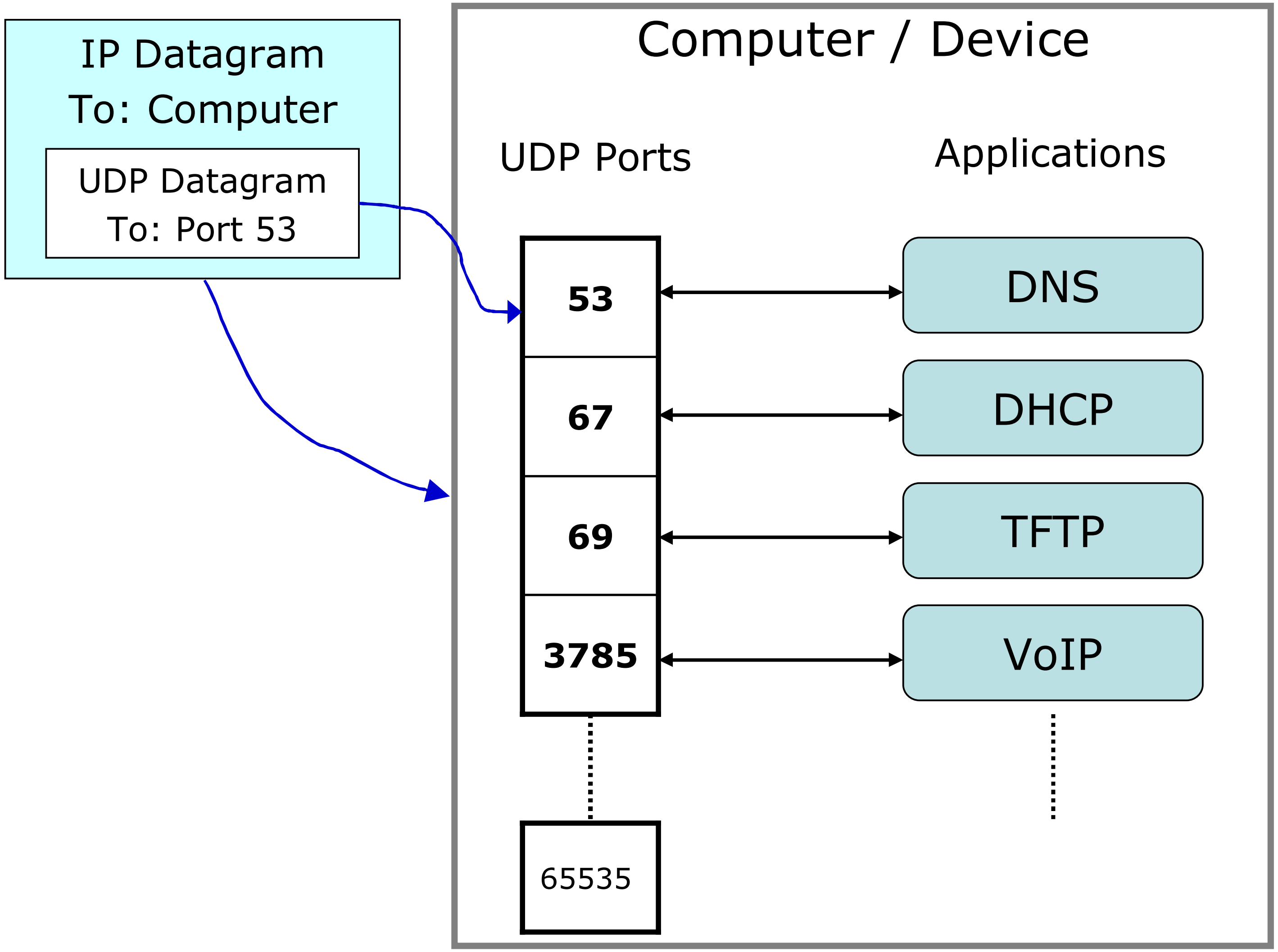
UDP	TCP
Unreliable – sender does not know if packet was received, when he sends a packet it can be lost on the way	**Reliable** – if sender sends a packet, he knows it arrived, unless the connection has failed, if the packet is lost server will re-request it
Not ordered – when sender sends two packets he does not know if they will be received in the same order	**Ordered** – packets are always received in the right order
Lightweight – there is no overhead caused by connection tracking no ordering, it is **faster**	**Heavyweight** – realiability, congestion avoidance etc. take time to process
Datagrams – packets are sent individually	**Streaming** – packets are sent as a continuous ”stream”

UDP Datagram

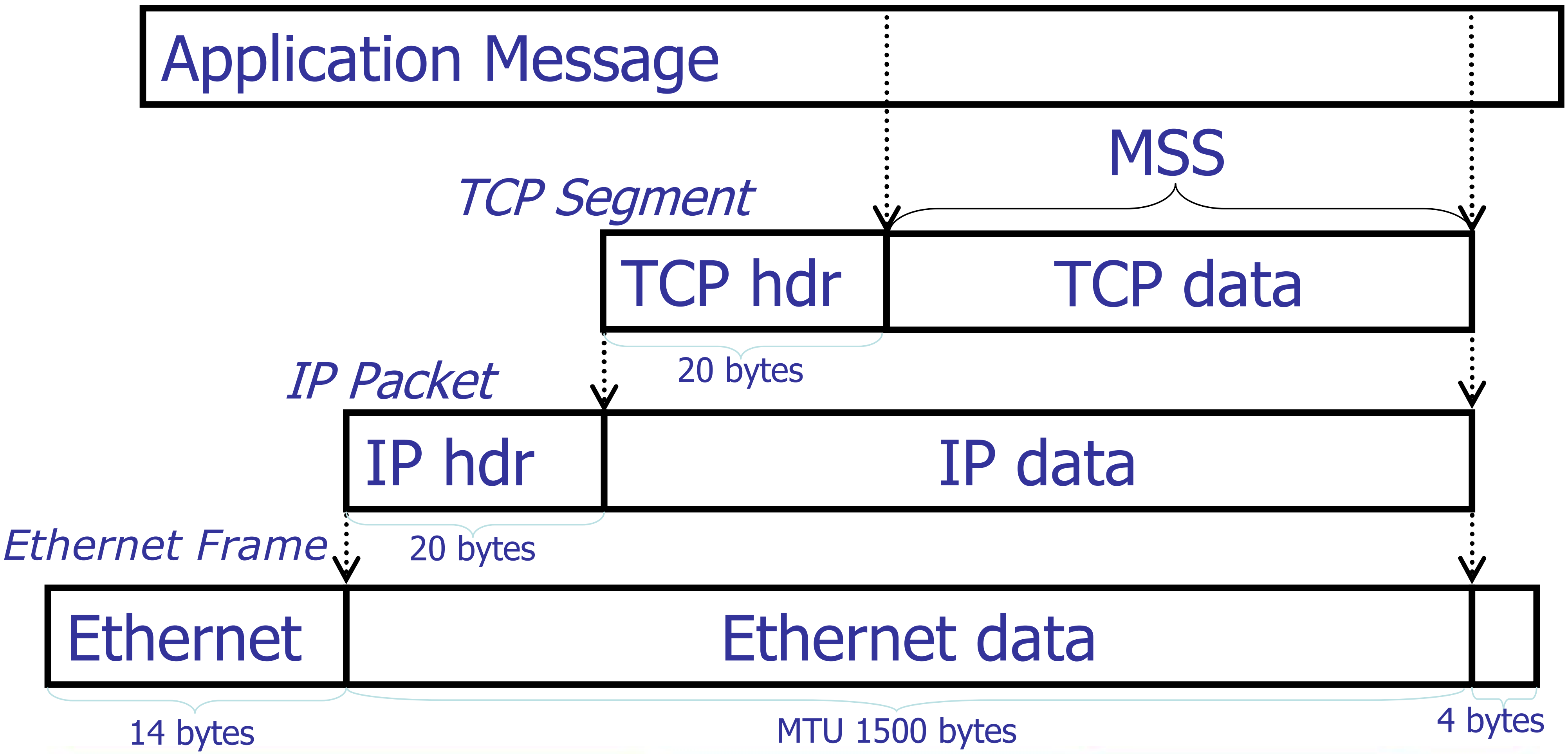
+	Bits 0 - 15	16 - 31
0	Source Port	Destination Port
32	Length	Checksum
64	Data	

- **Source port** – identifies the sending port when meaningful and should be assumed to be the port to reply to if needed. If not used then it should be zero.
- **Destination port** – field identifies the destination port and is required.
- **Length** – the length in bytes of the entire datagram: header and data. The minimum length is 8 bytes since that's the length of the header.
- **Checksum** –the checksum field is used for error-checking of the header and data.

UDP Ports


IP Datagram
To: Computer
UDP Datagram
To: Port 53
Computer / Device
UDP Ports
Applications
53
67
69
3785
65535
DNS
DHCP
TFTP
VoIP

Packet Terminology Overview



TCP/IP Stacks

	uCOS	uIP	LWIP	TCPnet	easyWEB (it is just a demo)
Flash memory footprint	20076	5664	13830	26464	8019
RAM memory footprint	13954	988	9825	21800	2584
Pros	• Well defined interface • Well structured code • Good support	• The best in code size • Very good for 8/16 bit microcontrollers • Doesn't cost a penny	• Well defined interface • Doesn't cost a penny • Fast enough	• Well defined interface • Suitable to run standalone or with RTOS • Good support	• Well defined interface • Well structured code • Small footprint
Cons	• Licensing costs • Code size more • Needs the support of a RTOS	• No support • If we want to develop few apps we have to have a better understanding of the code since it doesn't have a good interface	• No support • If we want to develop few apps we have to have a better understanding of the code since it doesn't have a good interface • Needs the support of a RTOS	• Requires Keil's RT library => Licensing costs	• Only one webpage • Only one connection at a time • No pictures

STR91x Firmware and Libraries

Reference	Description
	www.stmcu.com
STR910-EVAL	STR91x demonstration firmware
STR91M	STR91x MAC/DMA controller (ENET) firmware Library
STR91S	STR91x standard firmware Library
STR91U	STR91x USB firmware library