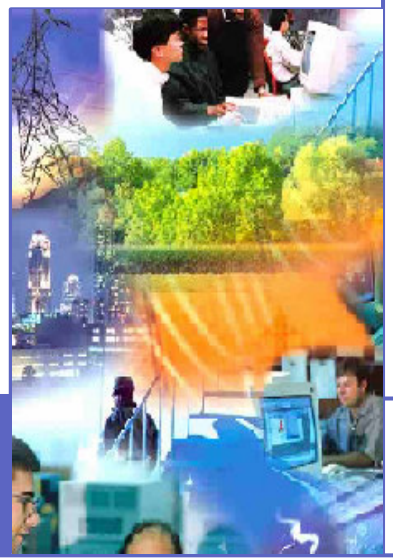


Klaus-Peter Brand

April 2006

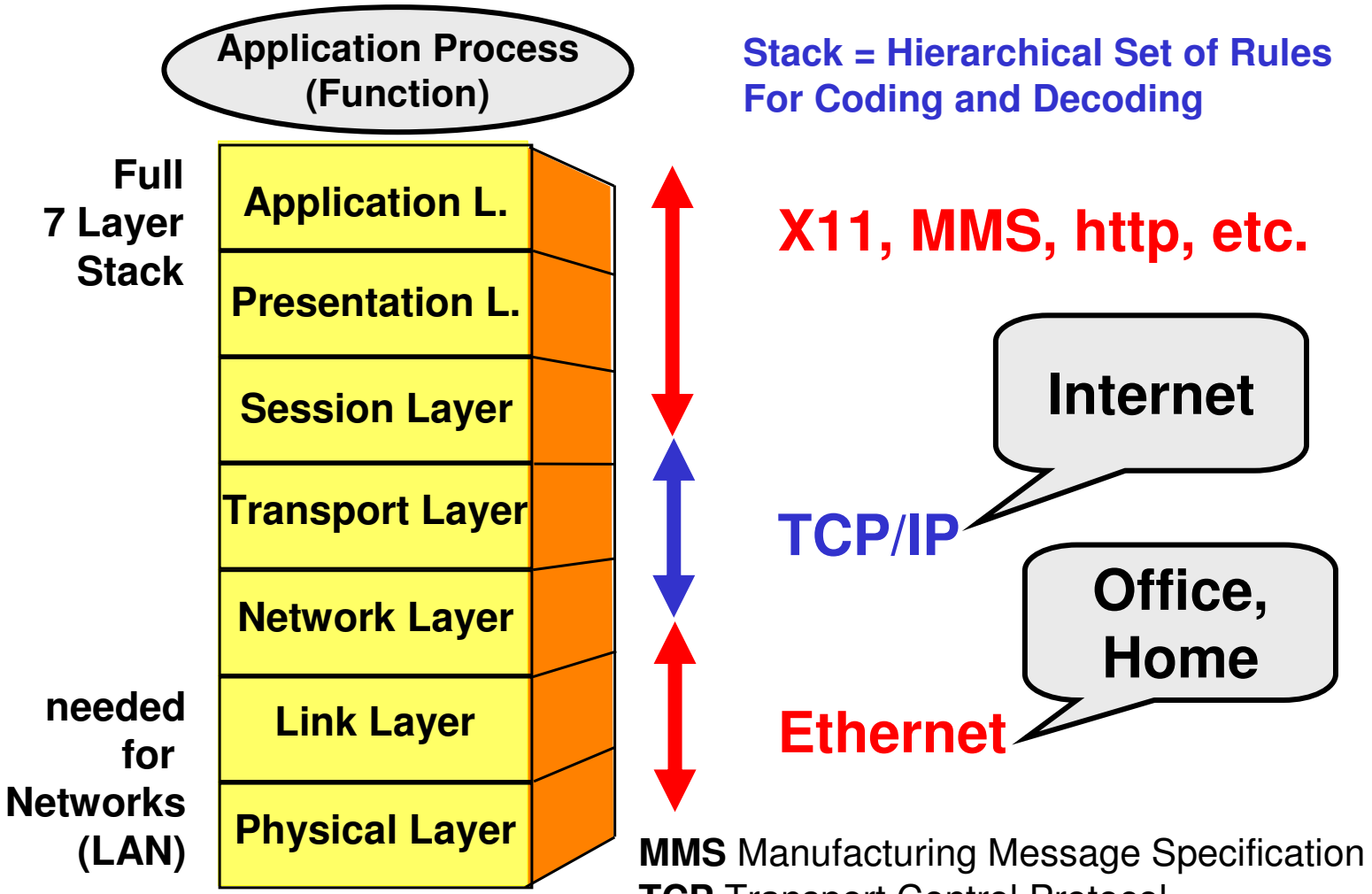
Communication Architectures with IEC 61850

Content

IEC 61850
The Communication Architectures
General Information about Ethernet and references to IEC 61850-8-1 and 9-2

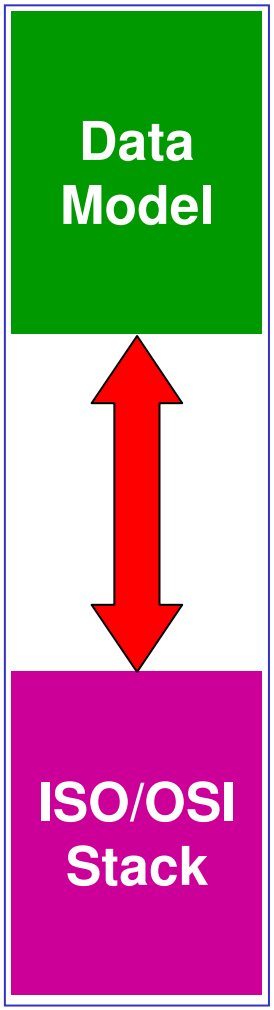
- Basics about Ethernet
- Switches
- Architectures
- Process bus

The 7 layers of the ISO/OSI Model



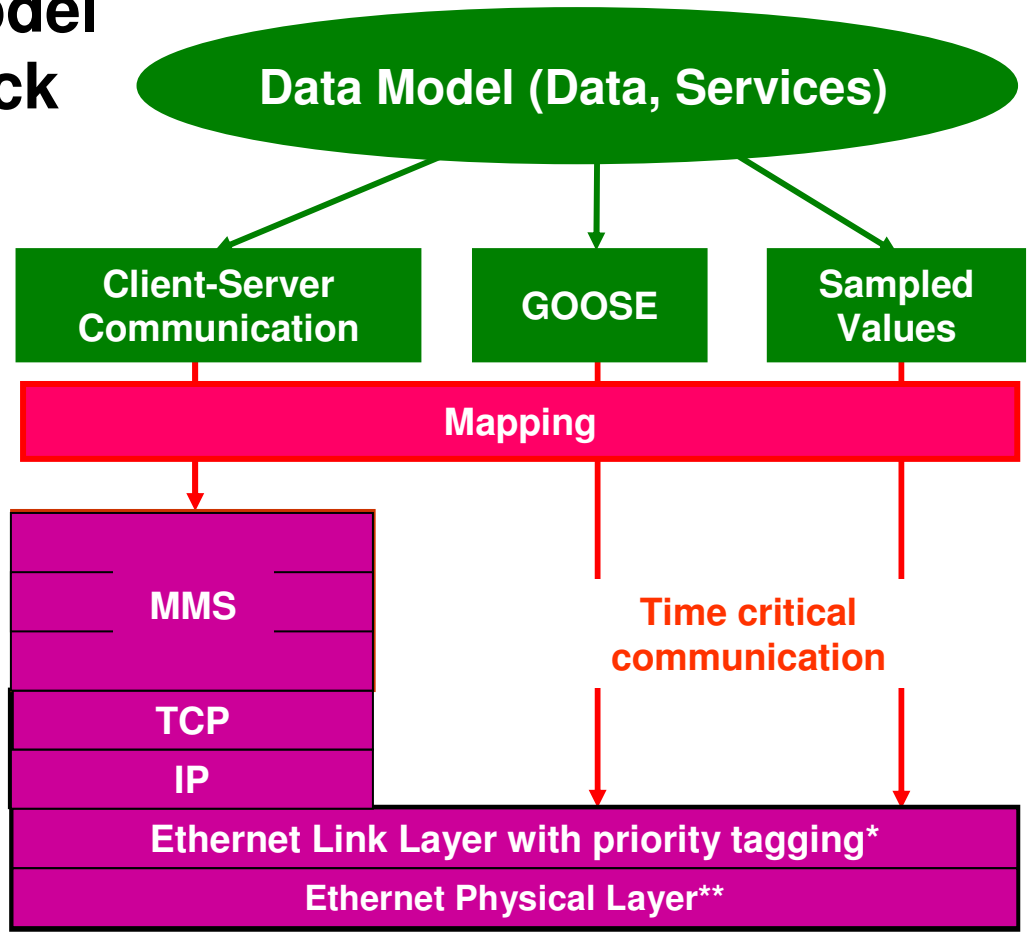
MMS Manufacturing Message Specification
TCP Transport Control Protocol
IP Internet Protocol

Communication Stack of IEC 61850



Data Model and Stack

=



*) **Priority tagging** of telegrams has to be supported
) **Speed 100 Mbit/s

Access methods

For serial communication, not only

- the Coding according to the ISO/OSI stack

but also

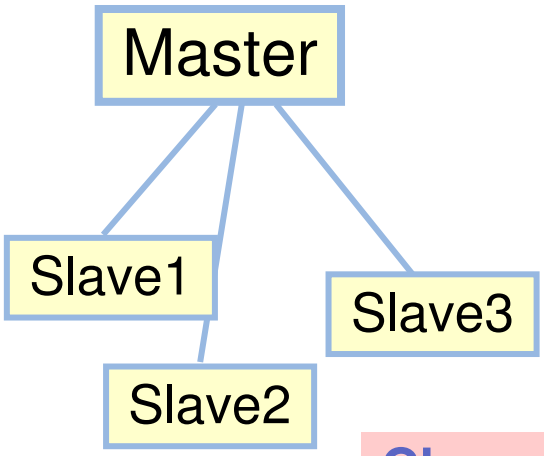
- the Access to and the use of the communication medium

has to be defined.

There exist basically 4 Access Methods, i.e.

- Master-slave
- Time division multiplex
- Token passing
- Carriers sense multiple access

Master-Slave Access



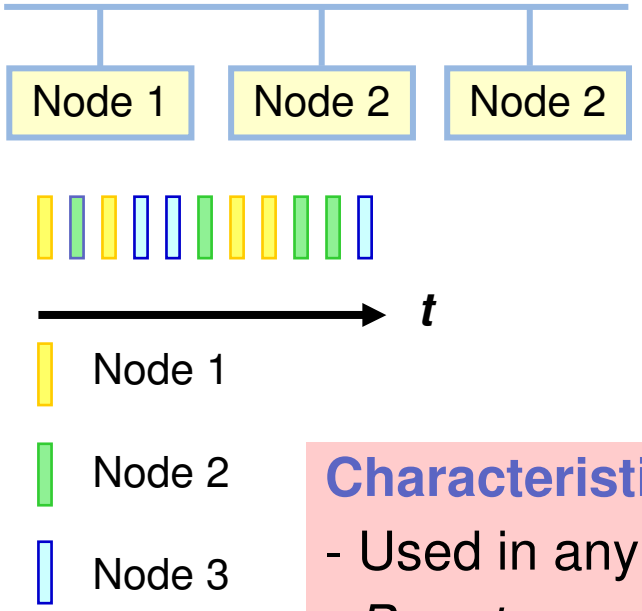
- The master has always access to the bus
- Slaves are polled in a fixed sequence by the master
- Slaves may respond by sending data

Examples: IEC 60870-5 (-101, 103), DNP3, etc. (Layers 1, 2, 7)

Characteristics

- Used in any topology
- No direct slave to slave communication
- Polling rate *depending on master*/transport media
- *Deterministic* response time
- Centralized transport media arbitration (bus administrator)

Time Divison Multiplex Media Access



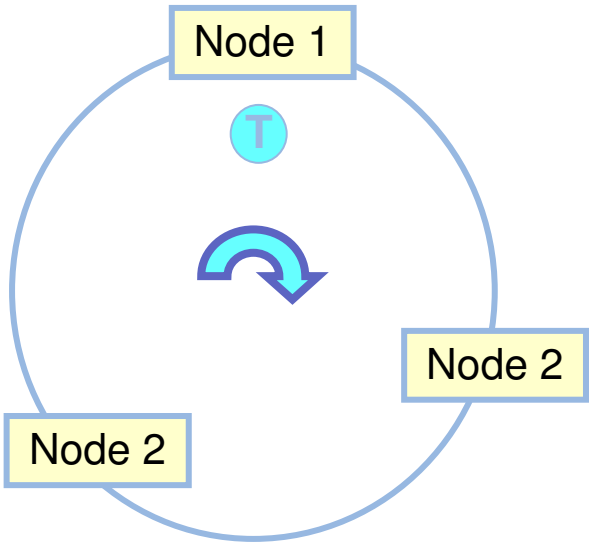
- Each node has its own time slot
- Node may send during this time

Examples: IEC 61375 (MVB) (Layers 1, 2, 7+)

Characteristics

- Used in any topology
- *Peer-to-peer* communication
- Fixed time slot *independent of the network load*
- *Deterministic* response time (no collisions)
- Centralized transport media arbitration (bus administrator)

Token Passing



- Token circulates around ring
- Any node may take the token as it passes by
- Take token, send data, pass token

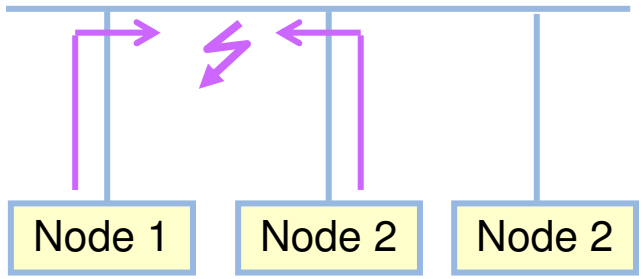
Examples: PROFIBUS (Layers 1, 2, 7)

Characteristics

- Used in any topology
- *Semi-deterministic* response time (no collisions, but token)
- Unnecessary *waiting times* with low network load
- Decentralized, token dependent transport media arbitration

CSMA/CD Media Access

Carrier Sense Multiple Access / Collision Detection



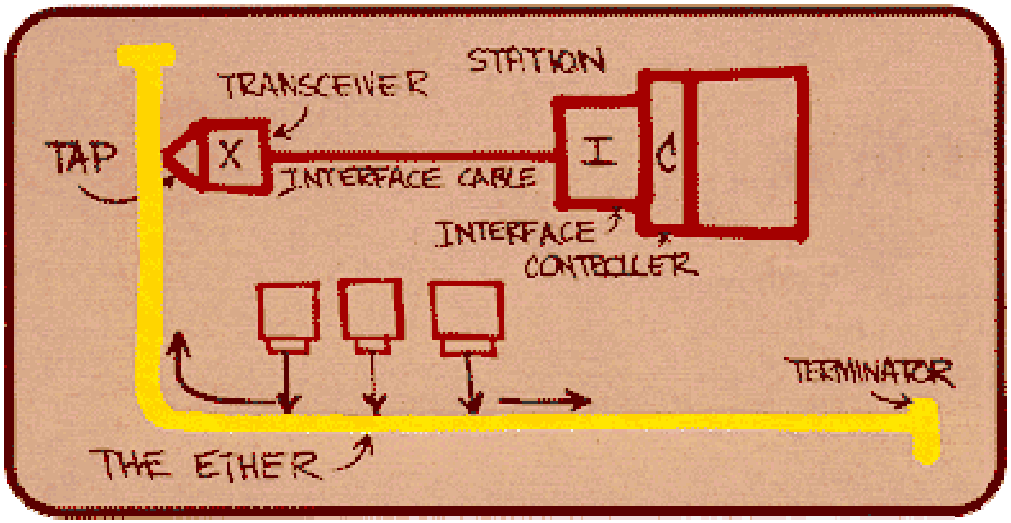
Ethernet Principle

- Each node listens to bus
- If bus is idle try to send
- If collision, try again :
  - stop transmission
  - send jamming signal
  - wait

Characteristics

- Used in bus topology
- Equal access rights for every node
- Response time *not determinable*
- No transport media arbitration (no bus administrator)

The First Ethernet



Bob Metcalfe, 1976

- 1976: Ethernet developped in Xerox Labs
- 1982: First Ethernet Specification from Digital, Intel, Xerox (DIX)
- 1985: First **IEEE 802.3** standard published

Features of Ethernet

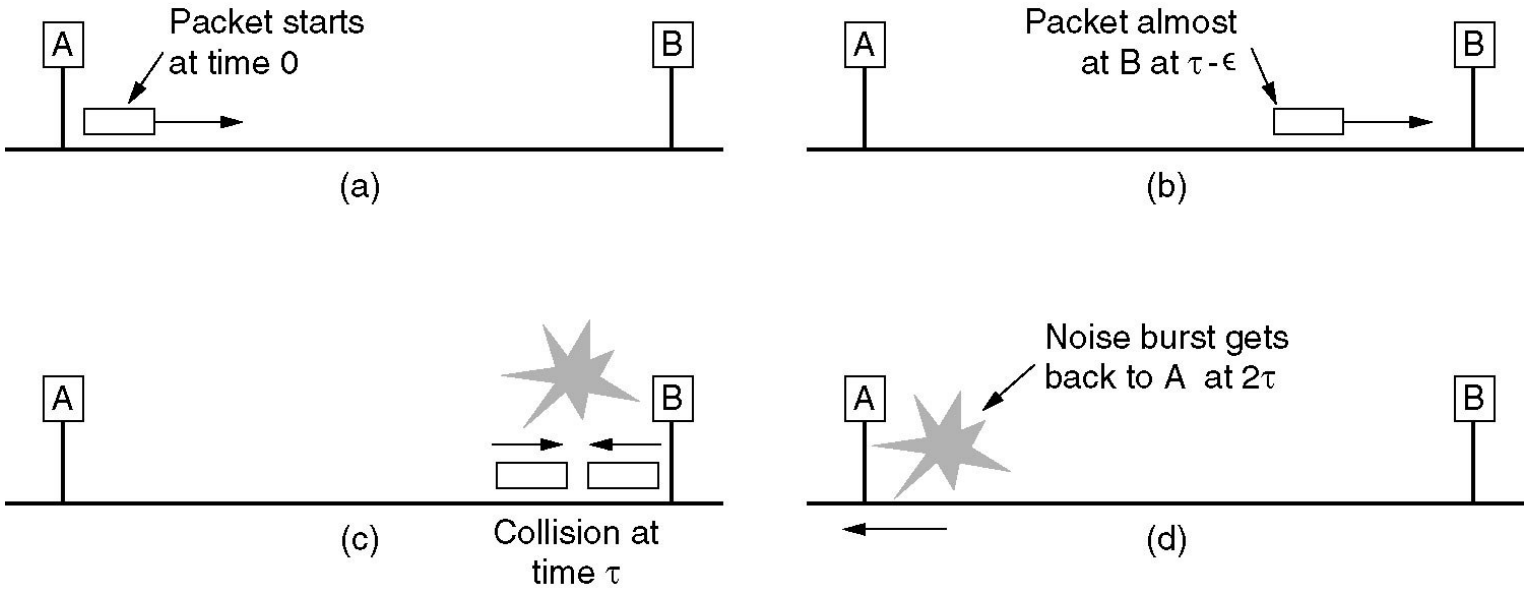
- Ethernet uses multiple access algorithm 1-persistent CSMA/CD
  - Easy decentralized algorithm
  - Very cheap implementations available
  - Ideal for transportation of best-effort traffic
- Ethernet communicates unacknowledged and connectionless
  - Ideal for transmission of IP-packets
- Ethernet is continuously improved regarding performance
  - ~3 MBit/s → 10 MBit/s → 100 MBit/s → 1.000 MBit/s → 10.000 MBit/s → ?
- Ethernet is standardized with IEEE 802.3
  - in IEEE 802 lots of Protocols for physical und data link layer are standardized
- Ethernet is the dominating LAN technology since years
- Ethernet is the communication technology where the most money is put in

Ethernet Problems by definition

- Ethernet's peak utilization is pretty low
  - Collisions limit the utilization of full bandwidth
- Peak throughput gets more worst with
  - more hosts
    - More collisions needed to identify single sender
  - smaller packet sizes
    - More frequent arbitration
  - longer links
    - Collisions take longer to observe, more wasted bandwidth
- Efficiency is improved by avoiding these problems

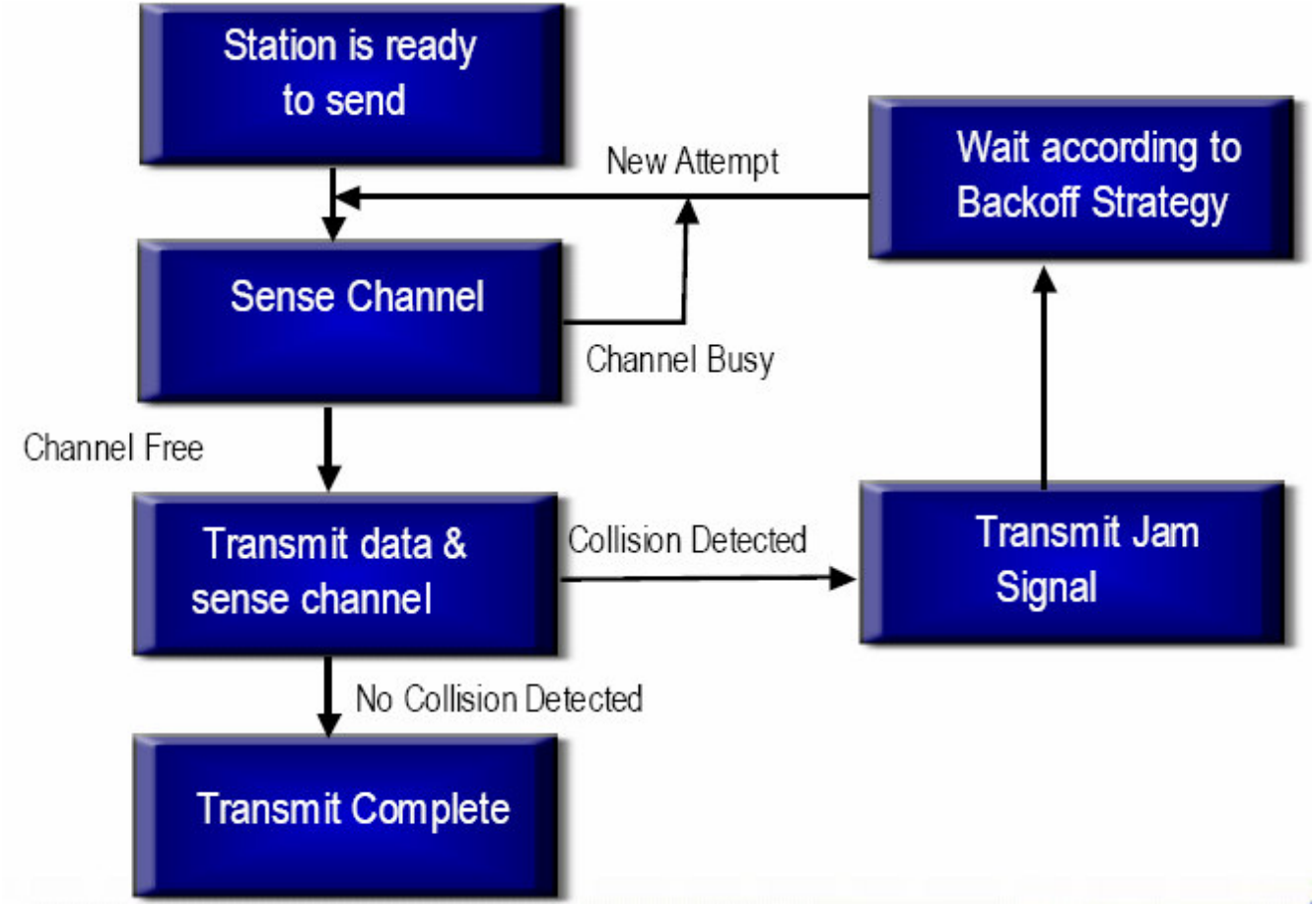
Collisions are causing the problems

- Collisions are caused when two nodes/adaptors try to transmit at the same time (adaptors sense collision based on voltage differences)
  - Both found line to be idle
  - Both had been waiting to for a busy line to become idle x



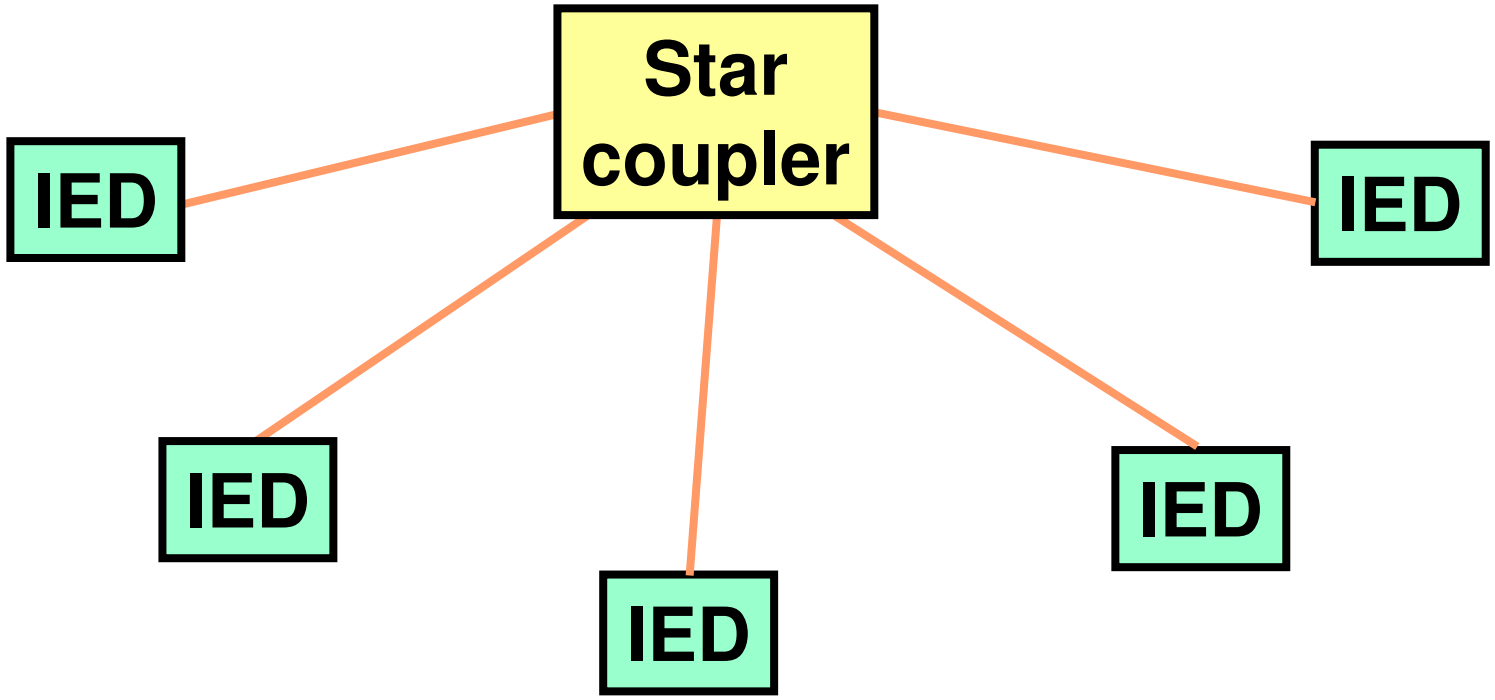
Collision detection can take as long as 2τ.

State Diagram for CSMA/CD according to IEEE 802.3



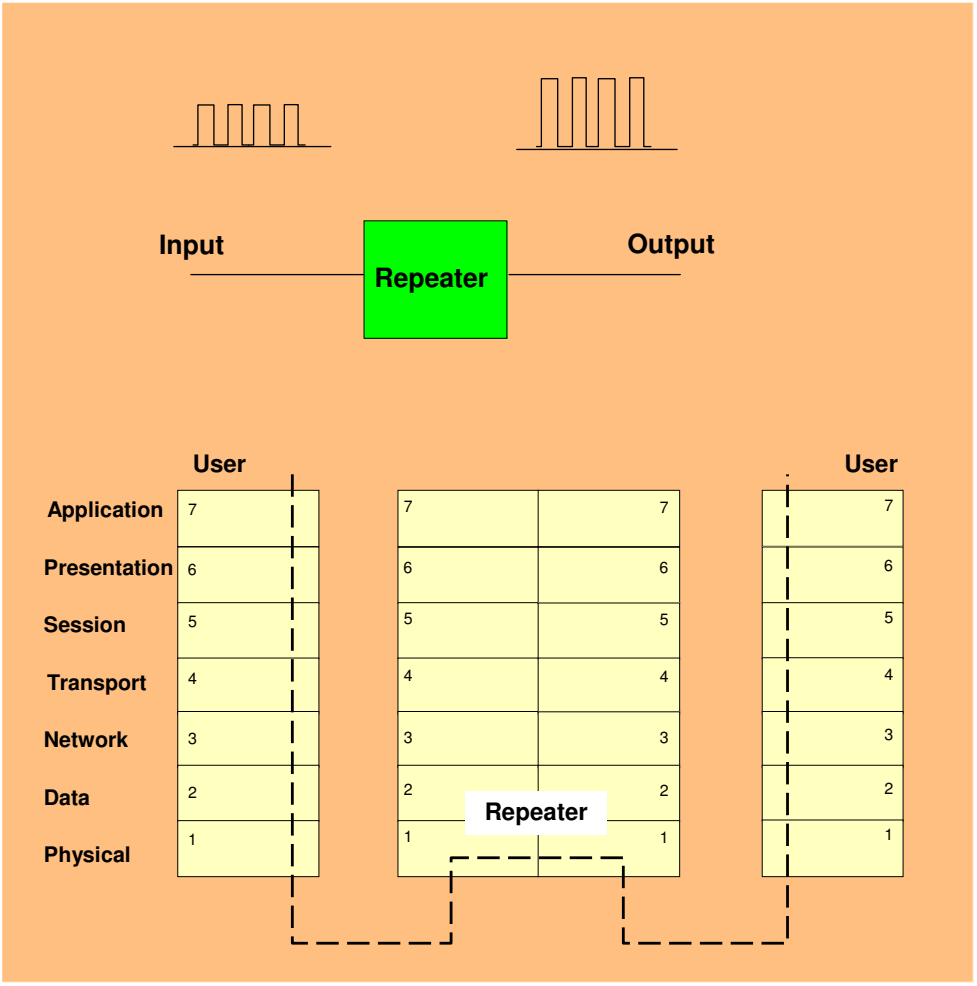
Communication by Star coupler

- **Star coupler is common, especially for optical links (example LON)**
- **Any IED is connected with any other IED**
- **All messages from any IED are distributed to all others**



- Star coupler is called **Hub** for Ethernet
- All messages may collide

Repeater and Hub



Repeater

-Works on level 1 only

- Connects two equal network segments
- Repeats all signals in both directions incl. refreshing, and reshaping if applicable
- No filtering, fully transparent

Hub (Star coupler)

- Multi-port repeater
- Broadcast of all messages to all ports
- Common Ethernet collision domain

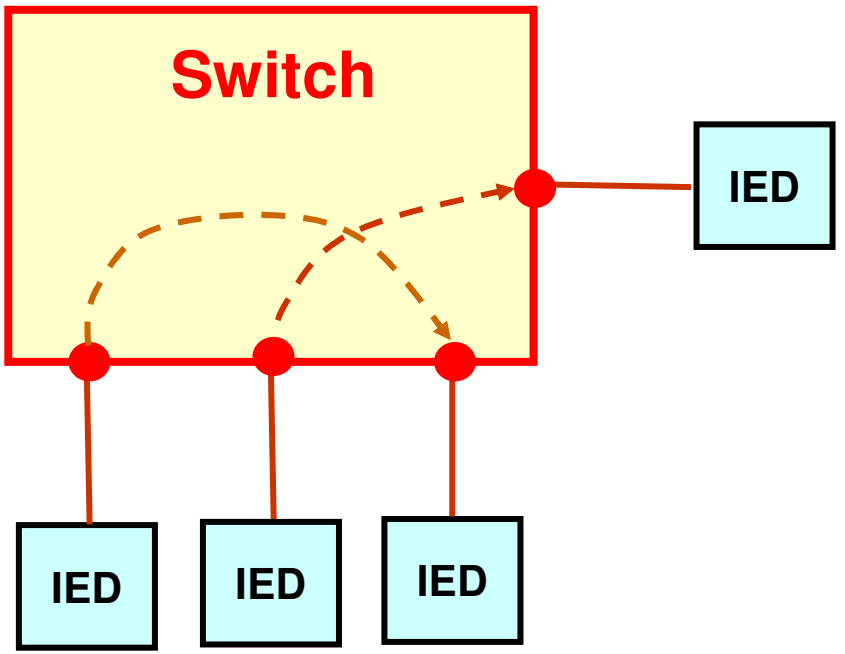
Impact of collisions

- Collisions reduce the **data flow**
- Result in unpredictable **transmission/response times**

- **Collisions have to be avoided in industrial systems !**

Star coupler designed as Switch

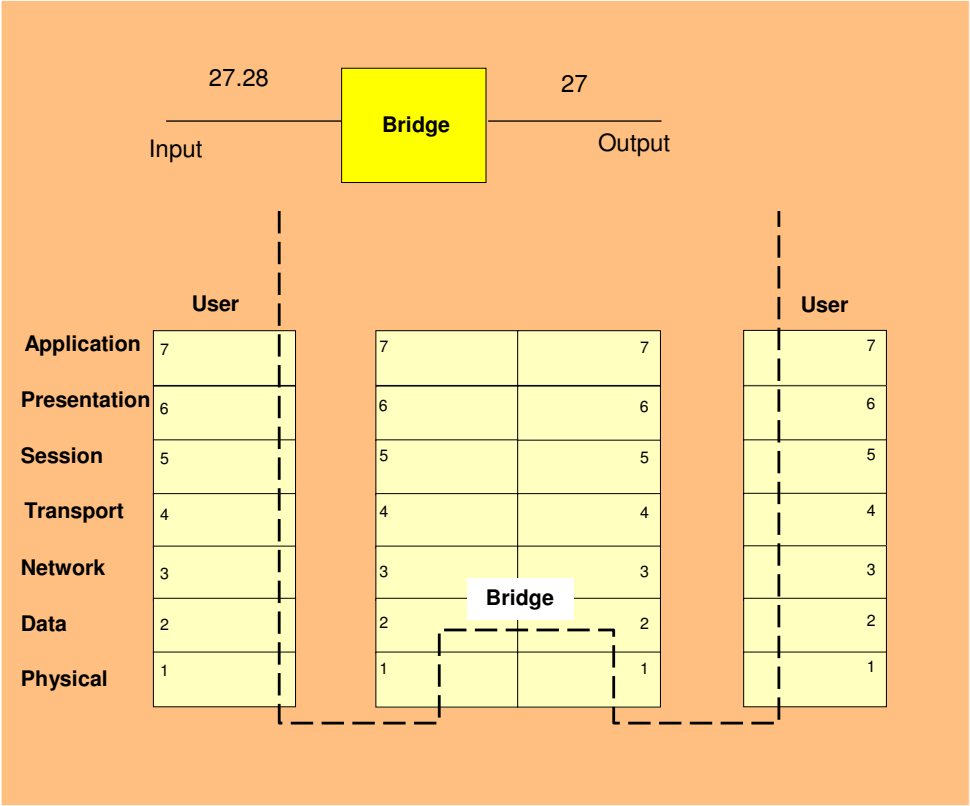
Important for the performance is
- the avoidance of collisions
- the support of priority tagging



1. The Switch connects all connected IEDs (star coupler)
2. The message of the sending IED is not distributed to all other IEDs but shortly stored for analysis of the receiver adress and forwarded only to the port connected with the receiving IED

1. A transient point-to-point connection is established
2. Collisions are avoided
3. Priorities may be supported by different storing queues

Bridge and Switch



Bridge

- Covers functionality of Layer 1 & 2
- Connects two equal network segments
- Packets are only passed if the source address is not within the same segment and the access is permitted (MAC address filtering, Level 2)

MAC address: Media Access Control address equal to Link layer address

Switch

- Multi-port bridge
- Connects two equal network segments
- Intermediate point-to-point connection of ports
- Store and forward allows queues for priority tagged messages
- Separated collision domains per port

General Requirements

- Switches are used in Substation environment. Therefore, switches have to fulfil the same **environmental requirements** as a.g. numerical protections devices
- Switches may be connected to rings and more complex networks. Therefore, switches have to support common **network reconfiguration algorithms** in case of network failures
- The Switches have to be **manageable**

Ethernet Switches

Features of Ethernet Switches

	A	B	C	D
Power Supply (110/220V DC)	**In preparation**	**Yes**	**No**	**No**
Red. Power Supply	No (Dual Source)	Yes (RS1600)	Yes (Mice)??	No (Dual Source)
Operating Temperature	-40 .. 65°C (8 fibre –40 .. 55°C)	-40 .. 85°C	0 .. 60°C	-40 .. 60°C
Connectors for Ring	MTRJ	MTRJ	ST, SC, MTRJ	ST, SC, MTRJ
Connectors for Devices	RJ45, MTRJ	RJ45, MTRJ RS1600: ST	RJ45, ST, SC, MTRJ	RJ45, ST, SC, MTRJ
Meshed Topology Support	Yes	Yes	Yes	**No**
Promoted Ring redundance concept	FRNT (Fast Re-config. of Network Topology)	Enhanced RSTP	HiPER Ring	S-Ring & LLL (Link Loss Learn)
Switchover Time	30 ms	5ms / switch	**~ 500ms**	**~ 300ms**
Other Ring Concepts	STP, RSTP	STP	RSTP	STP
Configuration	Ontime tool via Ethernet	Text file (via Ethernet), Console, web server	Hirschmann tool via Ethernet	Web server
Config. Via text file	No	Yes	No	No
Config. up-/ download (save config. on PC)	No	Yes	Yes (Memory Stick)	No
Ranking	**2**	**1**	**3**	**4**

Manageable switches

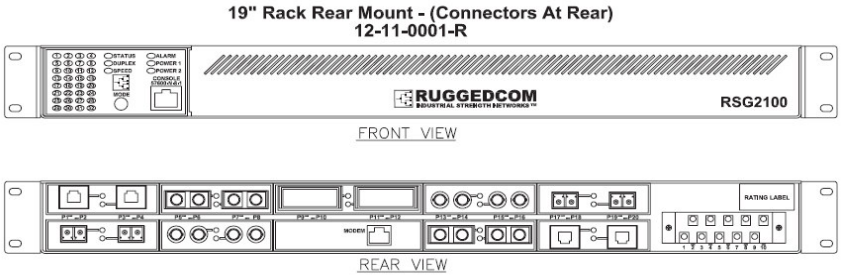
Features	Benefits
Virtual Local Area Network (**VLAN**)	■ Isolate traffic between groups of ports ■ Control access to the various VLAN groups ■ Allow devices that need to communicate to each other the maximum bandwidth
Bandwidth Rate Limiting	■ Set a maximum bandwidth for each port ■ Prevent unnecessary communication traffic from overwhelming devices
Quality of Service (**QoS**) *Priority tagging*	■ Allow "high priority" messages quick throughput ■ Define message importance
Simple Network Management Protocol (**SNMP**)	■ Monitor switch port parameters ■ Allows easy access to switch information for HMI, SCADA and other applications
Port Mirroring	■ Provides message troubleshooting access ■ Allows messages to be *monitored* for message content
Trunking redundancy	■ Relay contacts, flashing LEDs and SNMP traps help to quickly identify the broken links. ■ Trunking also provides more bandwidth between switches

Examples of Ethernet Components

- Ethernet Switches
  - RuggedCOM RSG2100
    - Big size switch, modular type
    - Up to 16x RJ45/ST/MTRJ
    - Gigabit Backbone
    - Opt. redundant PS
  - RuggedCOM RS900
    - Small size switch
    - 6x RJ45

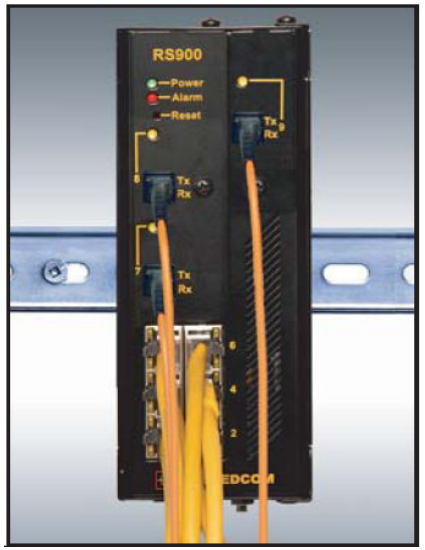
- Master Clock
  - Meinberg LANTIME/AHS
    - GPS Receiver
    - SNTP Time Server
    - 3x RJ45

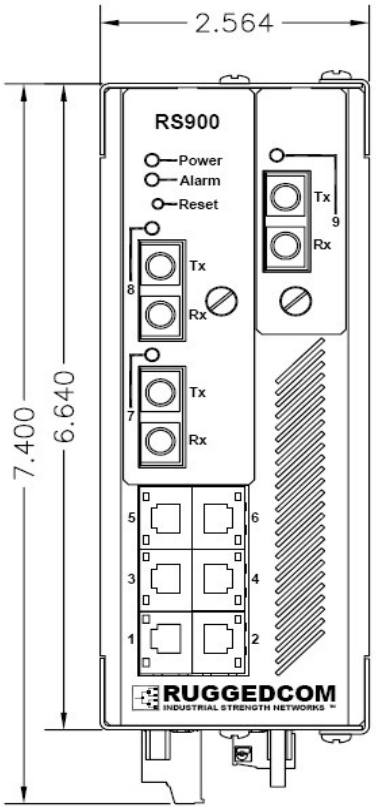
RuggedCom RSG2100



- 3-Gigabit Ethernet ports supporting copper and fiber media
- 16-Fast Ethernet ports supporting copper and fiber media
- 2 port modules for tremendous flexibility
- Multimode and single mode fiber support
- Industry standard fiber optical connectors: LC, SC, SFP
- Fully integrated, dual-redundant (optional) power supplies
- Universal high-voltage range: 88-300VDC or 85-264VAC
- CSA/UL 60950 safety approved to +85°C
- -40 to +85°C operating temperature (no fans)

RuggedCom RS900





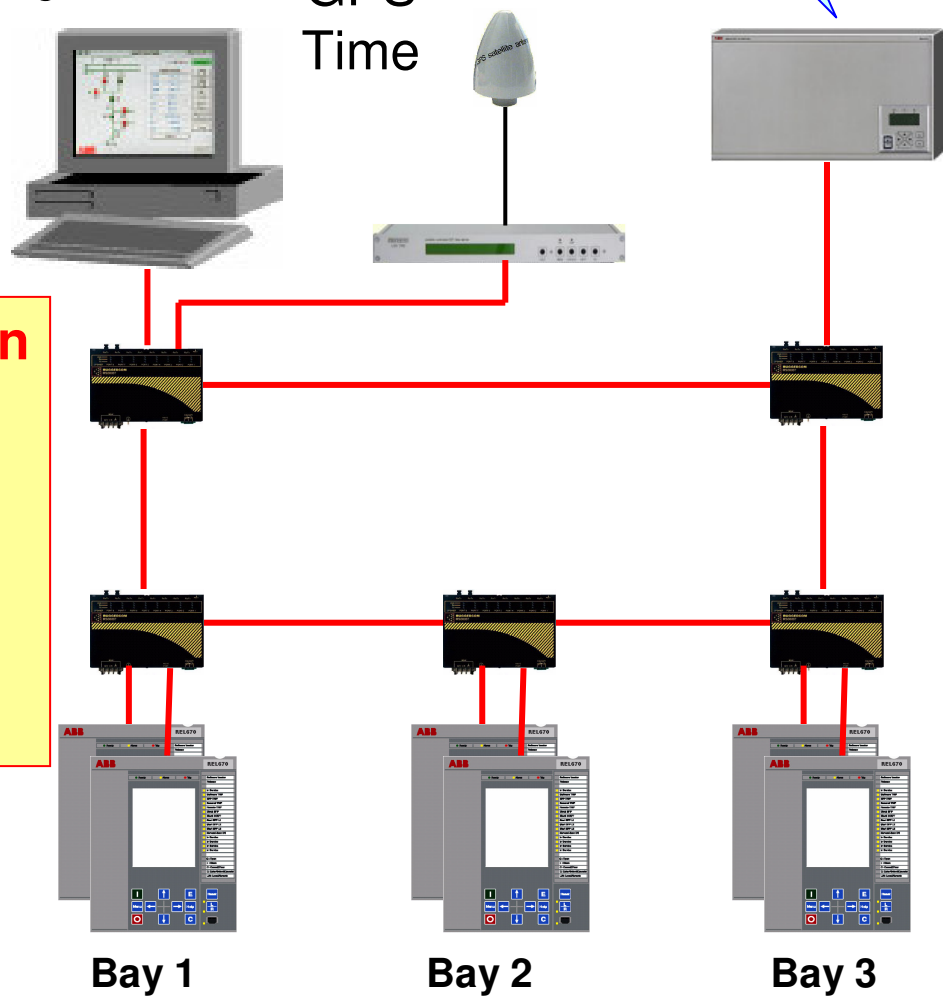
- Up to 9 Ports: 10/100BaseTX or 100BaseFX (Fiber Optical) combinations (Optional: 1-10/100BaseTX Port or 1-100BaseFX)
- Multimode and Singlemode optical transceivers
- Industry standard fiber optical connectors: LC, SC, ST, MTRJ
- Input voltages of 24VDC, 48VDC, and 88-300VDC or 85-264VAC
- CSA/UL 60950 safety approved to +85°C
- Operates over a temperature range of -40 to +85°C without the use of fans for improved reliability
- 20 AWG galvanized steel enclosure and DIN or panel mounting options provide secure mechanical reliability

Architecture Example: Ethernet Ring

Station Level Control

GPS Time

NCC Interface



Station Level

Most common architecture
IEC 61850 Station bus as Ethernet Ring with switches

Bay Level

Bay 1 Bay 2 Bay 3

Architecture depending on the requested availability and the requested performance of functions

Architecture influenced by cost constraints and available devices

Process bus: Independency from sensor technology

Samples
as values in
SI units
(SV)

TRIP
(GOOSE)

Protection Device

Logical Device
"Merging Unit"

LN TVTR

LN TCTR

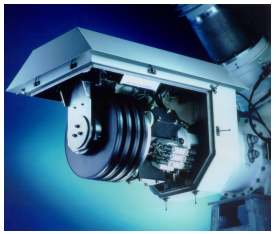
Logical Device
"Breaker IED"

LN XCBR

Logical Device
"Breaker IED"

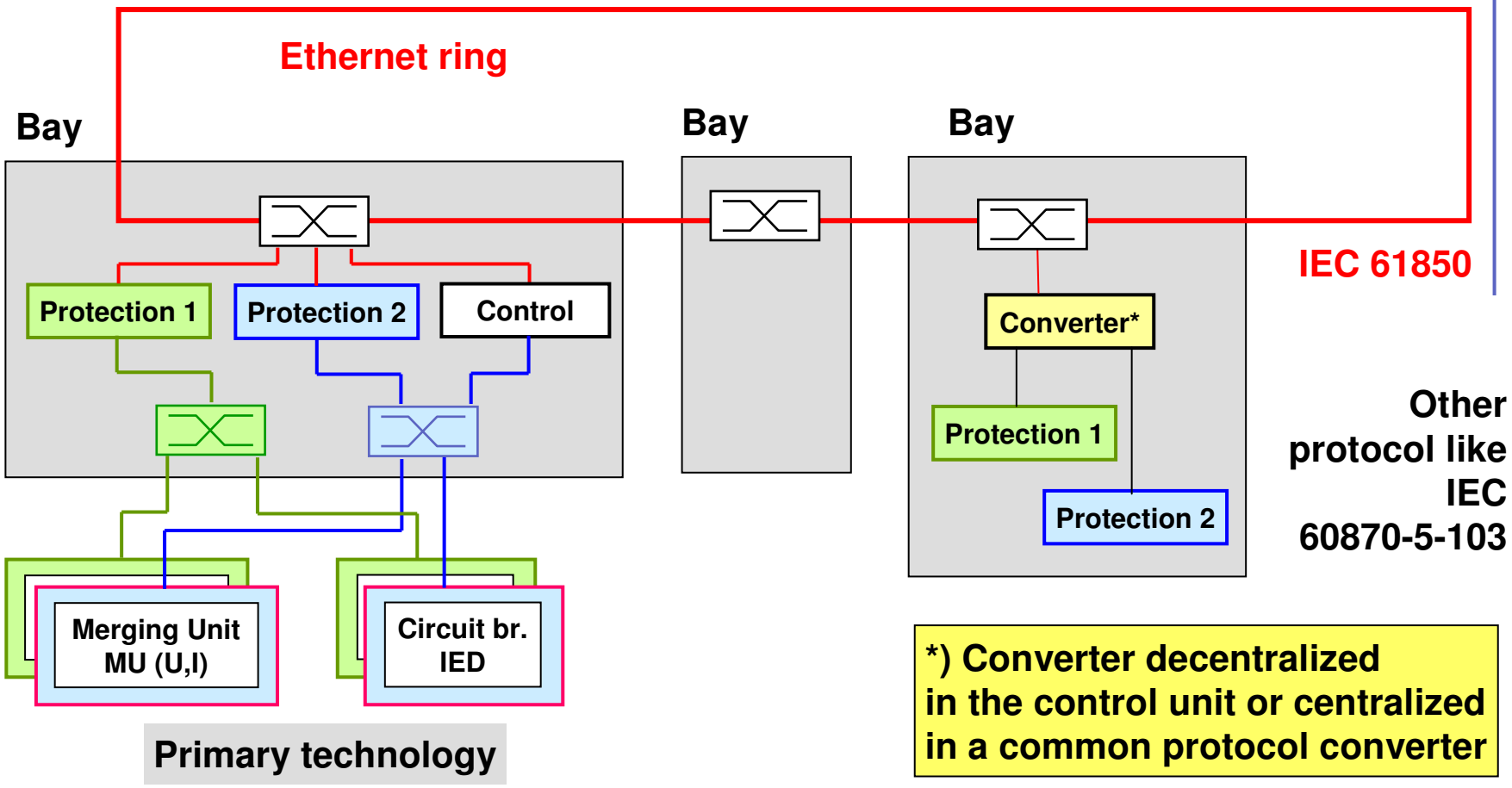
LN XCBR

Process bus



The Samples acc. to IEC 61850 Are independent from the instrument Transformer/Sensor Technology !!!

Ethernet ring, process bus, converter

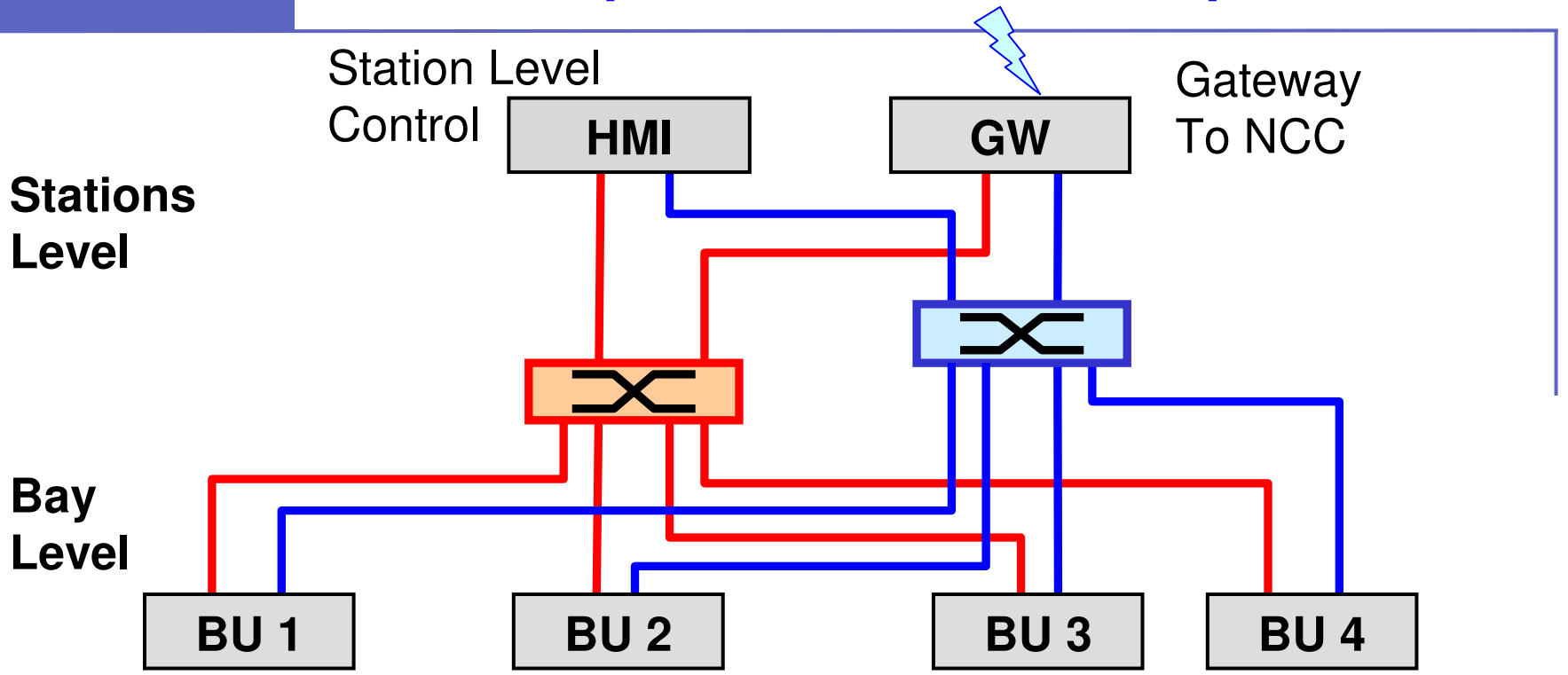


Other protocol like IEC 60870-5-103

*) Converter decentralized in the control unit or centralized in a common protocol converter

The process bus shall not jeopardize the requested independency of Main 1 and Main 2 !

The problem of redundant ports



Warning: **Redundant Stars or Rings** (devices with two parallel bus connections) are not interoperable, since the standard IEC 61850 has not yet defined this case. The problem are the private supervision of the redundant links and the switchover procedures. Solution in V2 of the standard?