# Fieldbuses: Profibus

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# Agenda

A global introduction

Profibus

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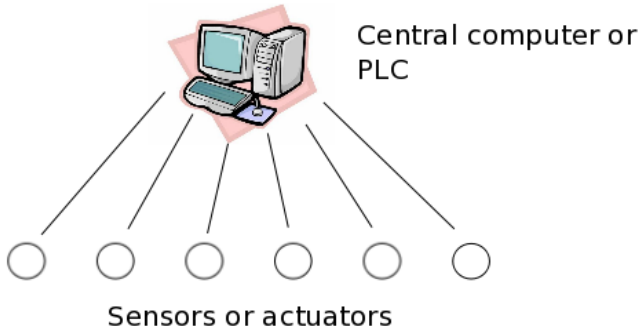
# A global introduction

- Before: a centralized topology




| Advantages | Disadventages |
|---|---|
| Only one link between sensors or actuators and PLC | Globally a lot of links |
| → no collision | → increasing the costs |
| → failures easily detected | → size of the system is reduced |
| → respect of real-time aspects | → scalability ? |

# Introduction

- To reduce costs and to allow scalability: a shared bus
- Problem:
  - How to share a medium taking into account the respect of real-time properties ?
- Different solutions exist in real-time networks domain
- Two specific solutions in the industrial domain:
  - PROFIBUS
  - FIP

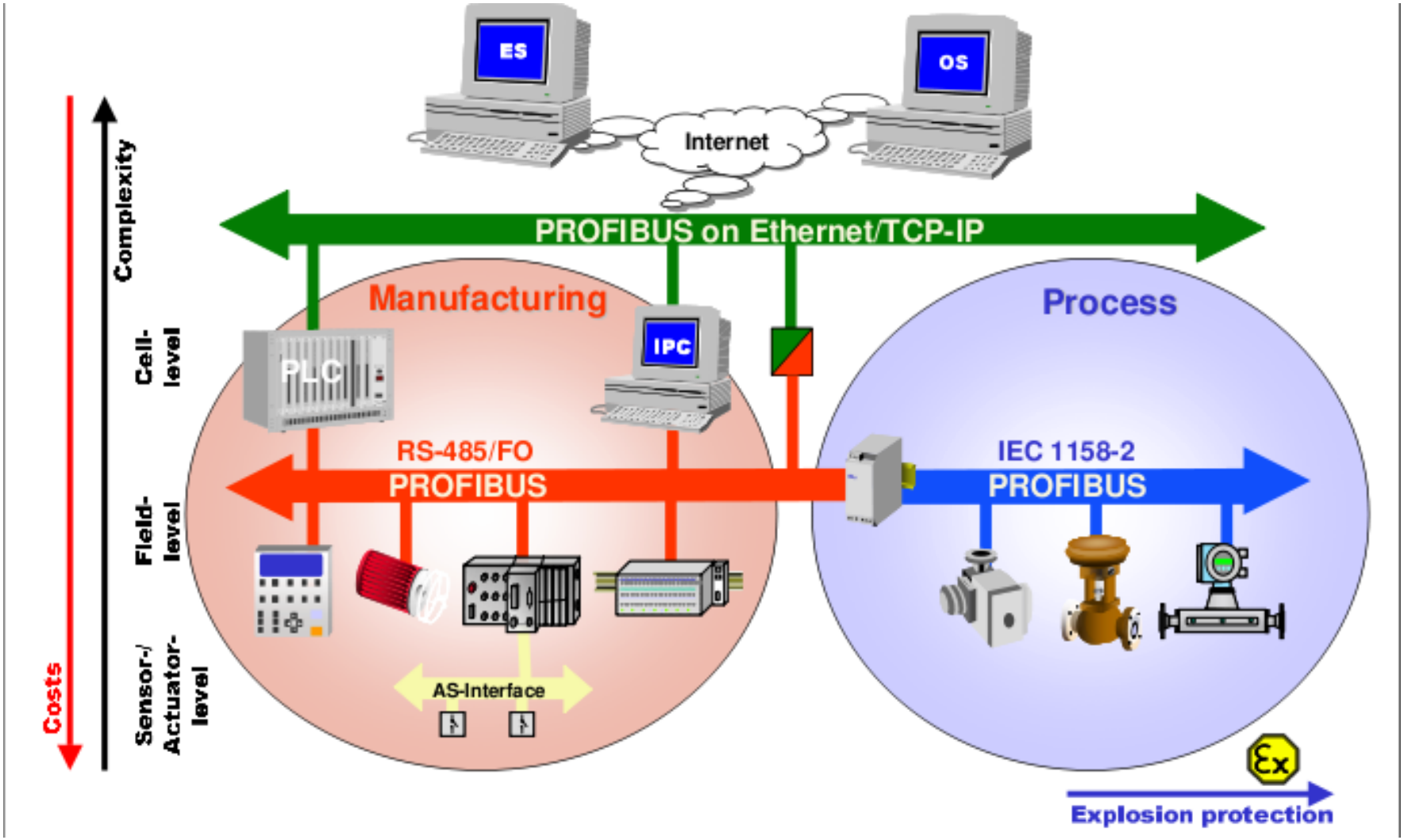
# Agenda

A global introduction

Profibus

- Briefly
- Communication profiles
- Medium access control
- Protocol architecture
- Data link layer (layer 2)
- Communication Profile DP
- Communication profile FMS
- Exercises

# Application Domain



# About Profibus

- Standard (EN 50170 and EN 50254) for the communications between industrial applications
  - Interconnection of equipments from different manufacturers
- Offers different protocols of communication (profiles):
  - DP: Decentralized Periphery
  - FMS: Fieldbus Message Specification
- Use different physical technologies:
  - RS-485, IEC 1158-2, Fiber Optic, ...

# Communication profiles

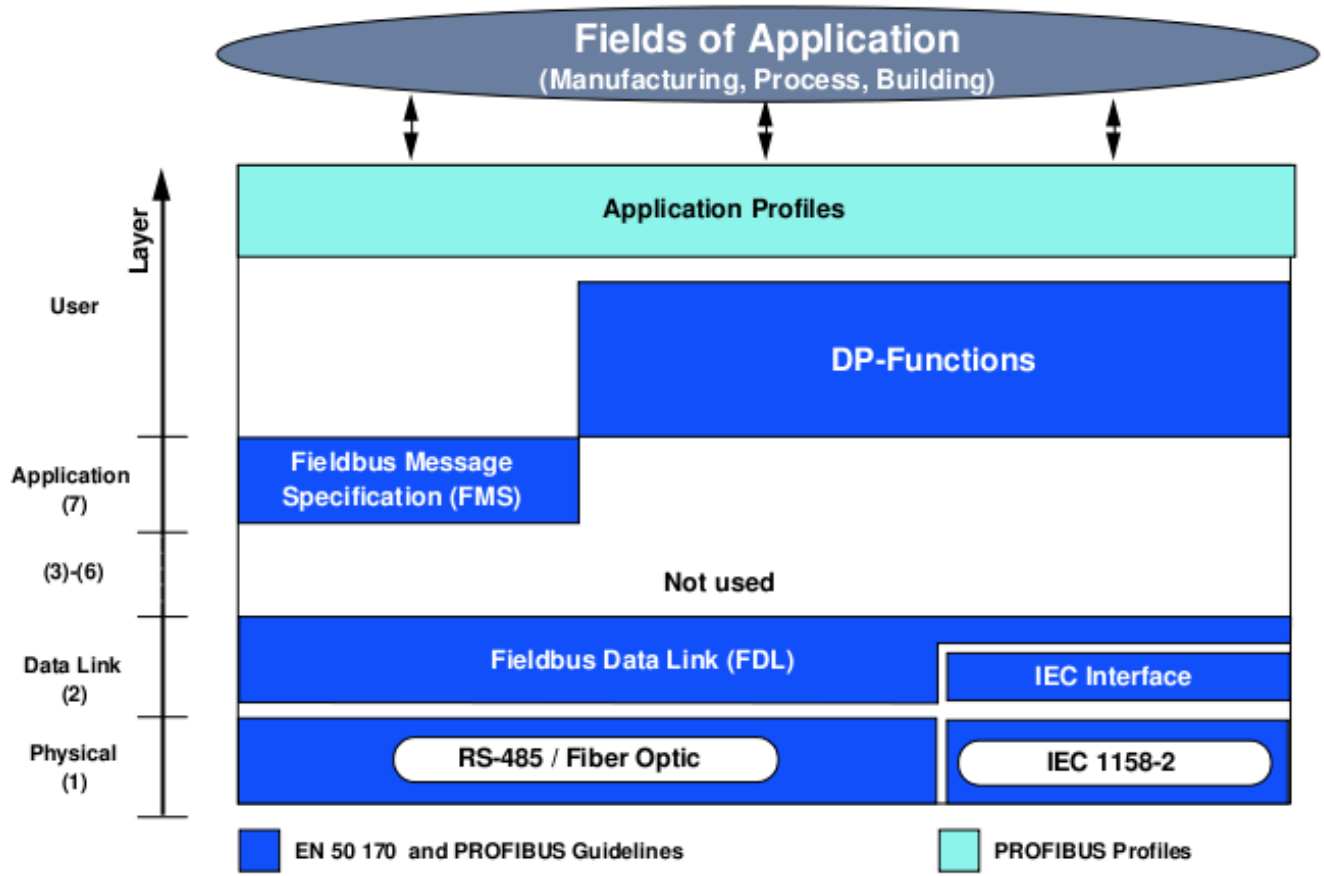
DP:
- most frequently used
- speed, efficiency, low connection costs
- communication between automation systems and distributed peripherals

FMS:
- communication between intelligent devices
- less used ($\rightarrow$ use of TCP/IP instead)

# Medium access control

- Multi-master system $\rightarrow$ interconnection of several automations systems with their associated peripherals using only one bus
- A master controls communications with its peripherals when it holds the bus access rights (a token)
- $\rightarrow$ Masters are called active stations
- The slaves $\rightarrow$ the peripherals:
  - I/O devices, transducers, sensors, ...
  - no direct access rights $\rightarrow$ receive and send message only when the master requested to do so (polling)
  - $\rightarrow$ Slaves are passive stations

# Protocol architecture

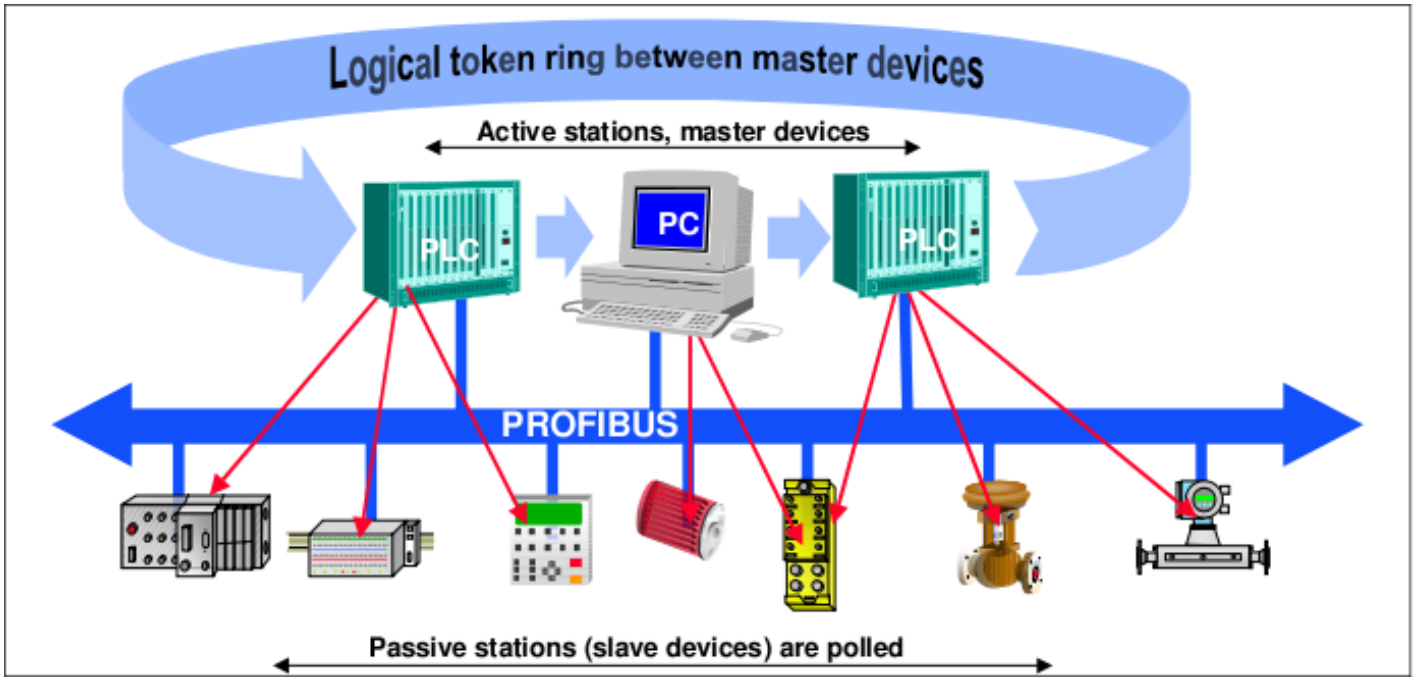



DP: *Direct Data Link Mapper* (DDLM), a user interface to directly access to layer 2

FMS : *Lower Layer Interface* (LLI) used for the FMS services to access to the layer 2 $\rightarrow$ Interconnection between applications (layer 7)

# Medium Access Protocol

- The FDL Layer (*Fieldbus Data Link*)

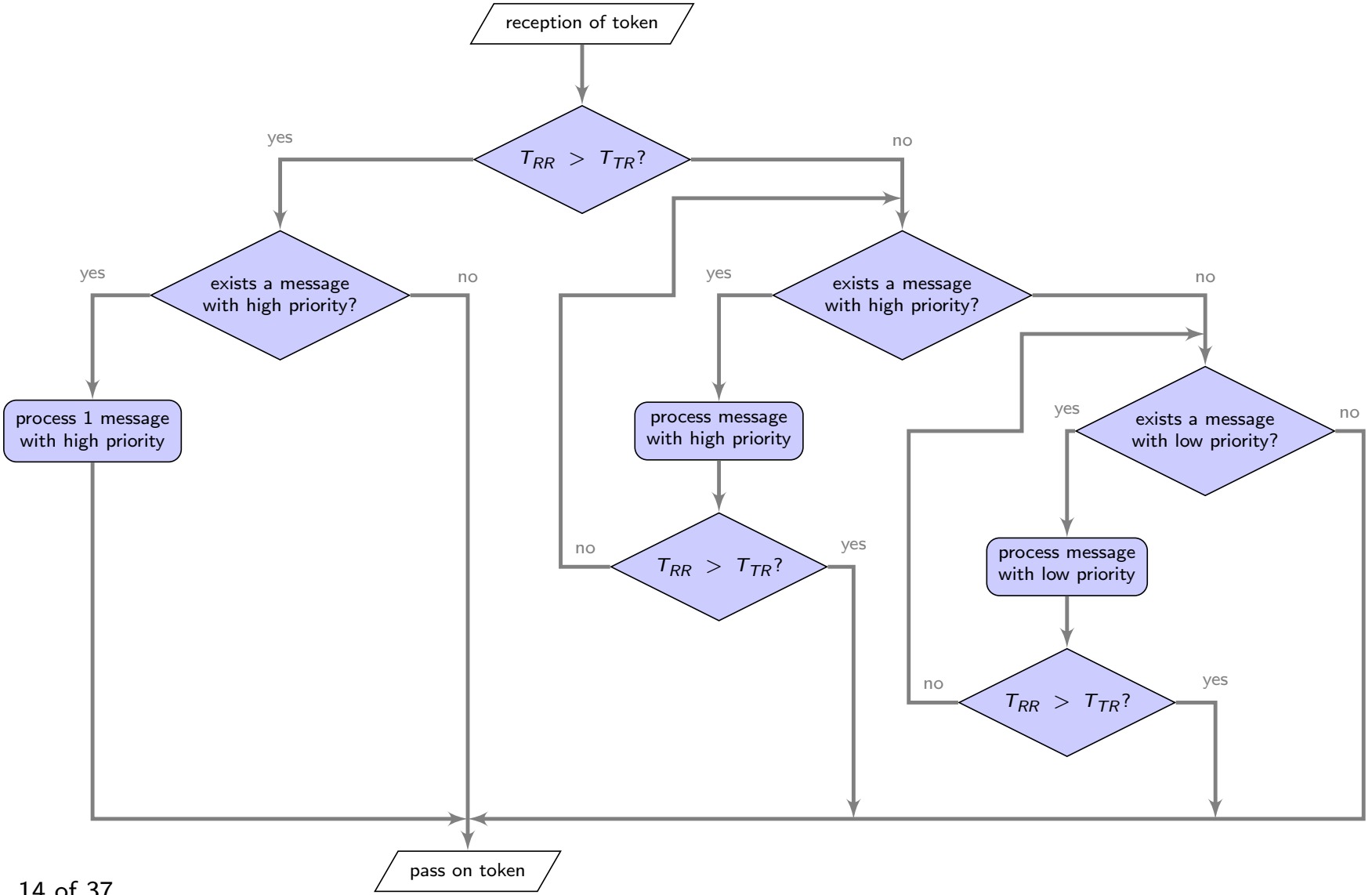



- A token passing between the masters
- *Polling* between masters and slaves

# Token Passing Procedure

- Ensure that the bus access right is assigned to a master during a defined timeframe
- During this timeframe, the master can access to its slaves
- Logical token ring $\rightarrow$ Sequence: increasing addresses of the masters
- At startup phase of a master station:
  - insertion in the logical token ring
  - deletion of defectives or switch-off master stations
- To respect that the token must have passed through the logical ring during a maximum period of time:
  - Target Rotation Time ($T_{TR}$): set during the configuration of the bus system
  - Real Rotation Time ($T_{RR}$)
  - Station can send a message if $T_{RR} < T_{TR}$

# Token Passing Procedure



# Functions of the link layer

- Token passing management and detection of transmission errors:
  - errors in station addressing (multiple addresses assigned)
  - errors in token passing (token loss, multiple tokens)
- Different possible communications:
  - pure master-slave system
  - pure master-master system (token passing)
  - a combination of the 2
- Layer 2 is connectionless, so:

Broadcast: A master station sends an unacknowledged message $\rightarrow$ all others stations (masters and slaves)

Multicast: A master station sends an unacknowledged message $\rightarrow$ a group of stations (masters and slaves)

# Services of the link layer

- For each type of profile $\rightarrow$ specific services

| Service | Function | DP | FMS |
|---|---|---|---|
| SDA | Send Data with Acknowledge | | ● |
| SRD | Send and Request Data with Reply | ● | ● |
| SDN | Send Data with No Acknowledge | ● | ● |
| CSRD | Cyclic Send and Request Data with Reply | | ● |

# Format of the frames

Data frame without data field

| SD1 | DA | SA | FC | FCS | ED |
|---|---|---|---|---|---|

Data frame with fixed data field length

| SD3 | DA | SA | FC | data field | FCS | ED |
|---|---|---|---|---|---|---|

(8 bytes)

Data frame with variable data field length

| SD2 | LE | LEr | SD2 | DA | SA | FC | data field | FCS | ED |
|---|---|---|---|---|---|---|---|---|---|

(max. 246 bytes)

Token frame

| SD4 | DA | SA |
|---|---|---|

| | |
|---|---|
| SD1...SD4: | Start Delimiter |
| LE: | Length |
| LEr: | Length (repetition) |
| DA: | Destination Address |
| SA: | Source Address |
| FC: | Frame Control |
| FCS: | Frame Check Sequence |
| ED: | End Delimiter |

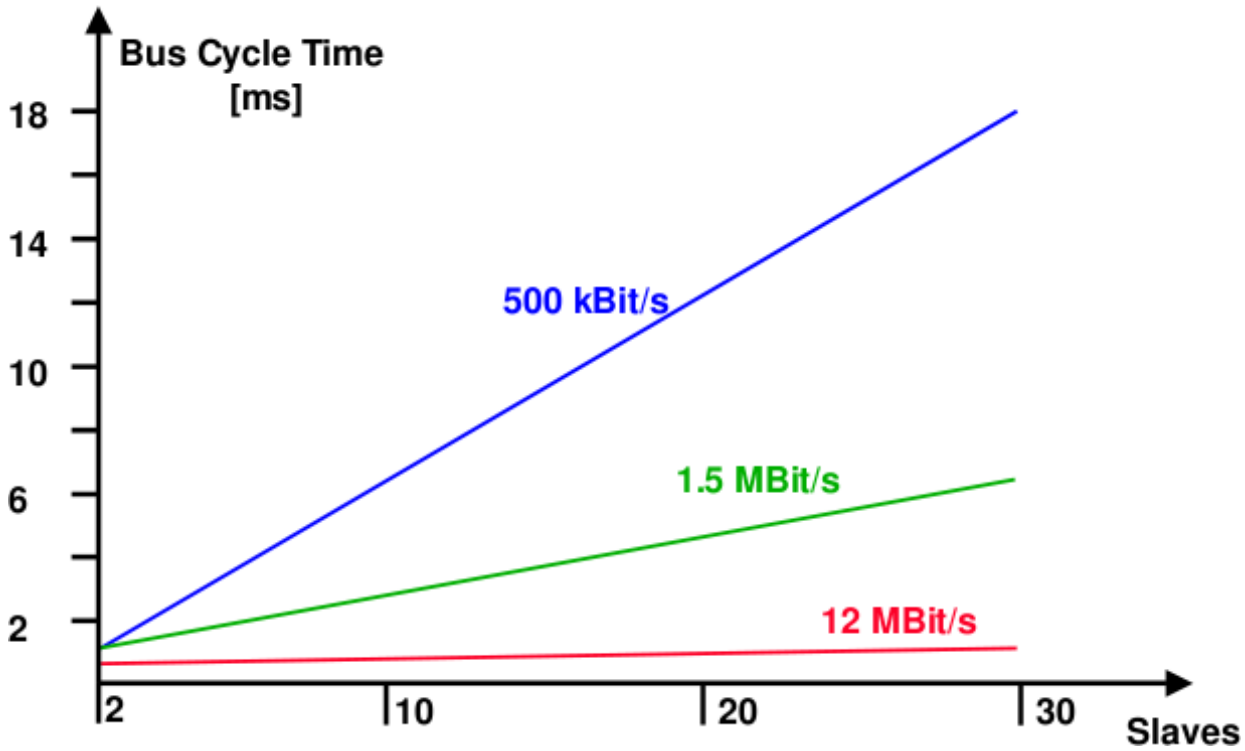
# Communication Profile DP

- DP = Decentralized Periphery
- Efficient data exchange at the field level
- Communication between PLC/PC or process control system and distributed field devices (I/O, drives, valves, ...) $\rightarrow$ fast serial link
- Data exchange with the peripherals $\rightarrow$ cyclic (mainly)
- Acyclic services:
  - Parameters initialization
  - Control operations
  - Alarms

# Basic functions

- The masters:
  - cyclic reading of input information from the slaves
  - cyclic writing of output information to the slaves
- Cycle time of I/O $<$ Cycle time of the automation system (generally 10ms)
- Diagnostic functions on both the masters and the slaves to control the communication

# Transmission speed




- $\approx$ 1msec at 12 Mb/s to emit 512 bits of input data and 512 bits of output data over 32 stations
- To increase speed, DP allows transmission of input and output data in a single message cycle (using SRD service)

# Diagnostic functions

- Messages transmitted over the bus collected by the master
- 3 different kinds:
  - stations-related diagnostics: status of the stations (overheat, low-voltage)
  - modules-related diagnostics: messages indicating that diagnostics are pending
  - Channel-related diagnostics: status of the medium (short circuit, for ex.)

# Different configurations

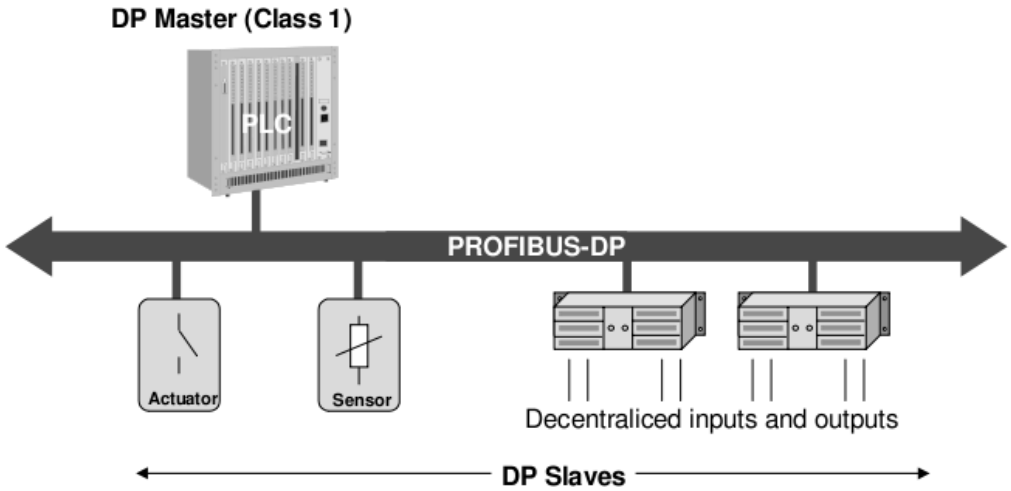
- Systems mono-master ou multi-master
- 126 equipments max. (masters or slaves) can be connected to the bus
- Systems configuration:
  - Number of stations
  - Assignment of stations adresses to I/O adresses
  - Data consistency of I/O
  - Format of the diagnostic messages
  - Bus parameters used

# Different configurations (cont'd)

- 3 types of devices:
  - DP Master Class 1 (DPM1): Central controller (PLC ou PC) which cyclicly exchanges information with distributed stations (slaves)
  - DP Master Class 2 (DPM2) : Equipments used for commissioning and for maintenance and diagnostics in order to configure the connected devices, evaluate de commande measured values and parameters and request the device status
  - Slaves: peripheral devices (I/O, Drives, Measure collector, actuators)
    - Transmission of data
    - Amount of data depends on the device type (246 bytes max.)

# Different configurations (cont'd)

- Mono-master systems:




- Multi-master systems:
  - independant subsystems composed of a master (DPM1) and its associated peripheral devices or configuration and diagnostic equipments
  - Data of the slaves can be read by all the masters
  - But only one master can write data to its slaves

# System behaviour

- DPM1 can be controlled either locally or by a configuration device through the bus
- 3 states of DPM1:

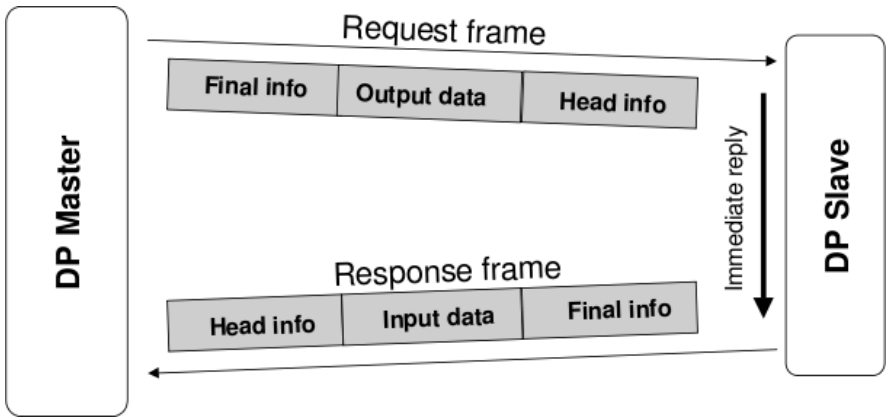
Stop: no data transmission
Clear: reading of slaves data and holding data in failsafe mode
Operate: DPM1 is in data transfer mode (reading data from the slaves and writing data to the slaves)

- Cyclic transmission of the status of DPM1 to the slaves (multicast)
- DPM1 reacts to a transmission failure (auto-clear parameter):
  - Saves the outputs of all slaves and changes to failsafe mode (Clear mode)
  - Stays in Operate mode, the system reaction is specified by the user

# Cyclic data transmission between DPM1 and the slaves

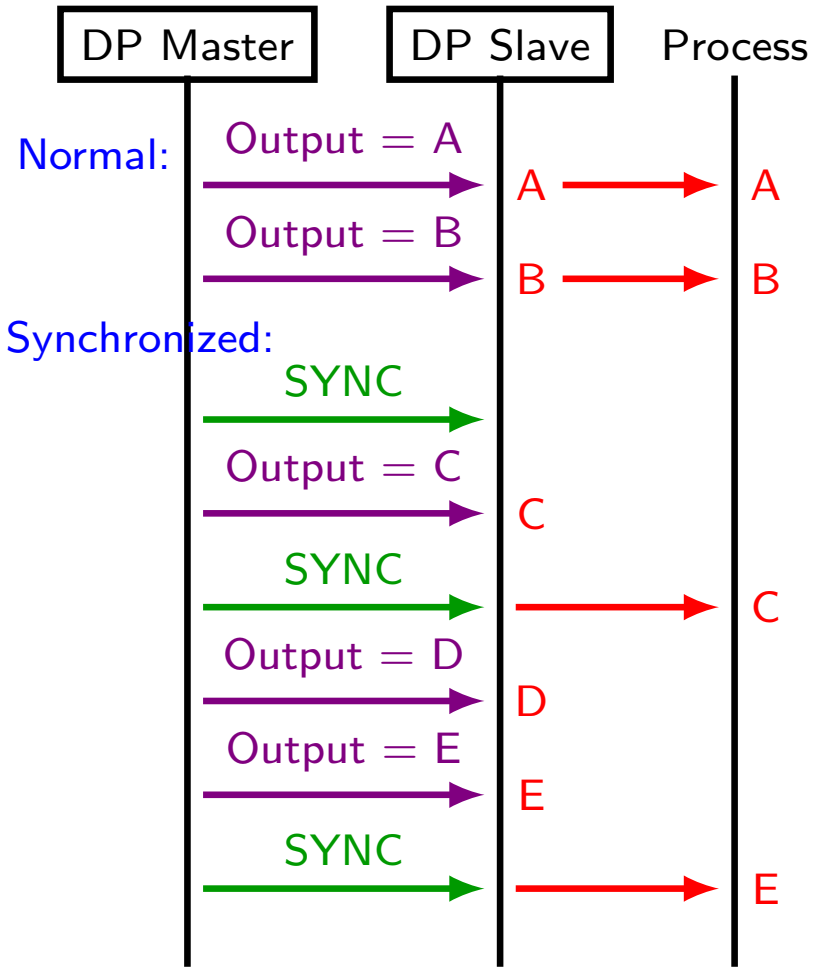
- Cyclic data transmission $\rightarrow$ user definition
  - Assignement of the slaves to the DPM1
- 3 transfert phases:
  - parametrization
  - configuration
  - data transfert
- In parametrization and configuration phases, checking of the master and slave configuration:
  - data type, format, length
  - number of data
  - $\rightarrow$ error protection

- Data transfert phase:



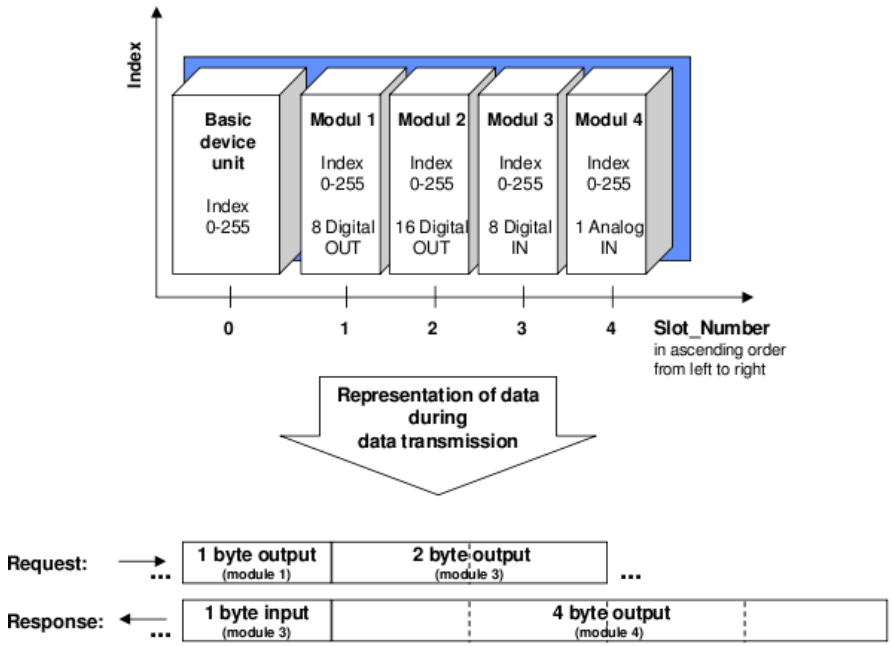
# Sync mode and freeze mode

- Commands sent by DPM1
  - Event-controlled synchronization of the slaves
- Sync Mode:
  - Output data are stored in the slaves between two Sync messages
  - When a Sync message is received, the stored output data are sent to the outputs
- Freeze Mode:
  - Inputs are frozen at the current value until next Freeze message
  - Input data are not updated



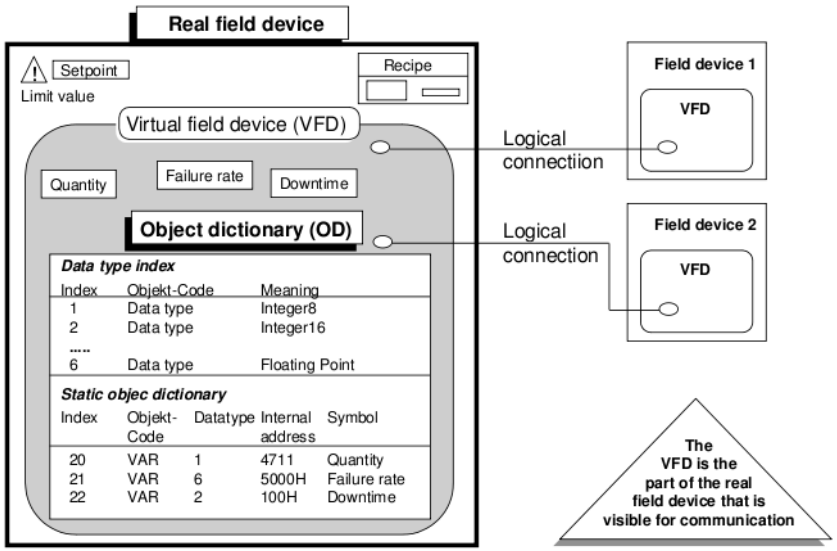
# Acyclic data transmission

- Control and configuration data, alarms
- Acyclic data transmission at the same time than cyclic data transmission
- Slaves are composed of modules $\rightarrow$ position in the frame identify the module
- Slot and index decomposition:



# Communication profile FMS

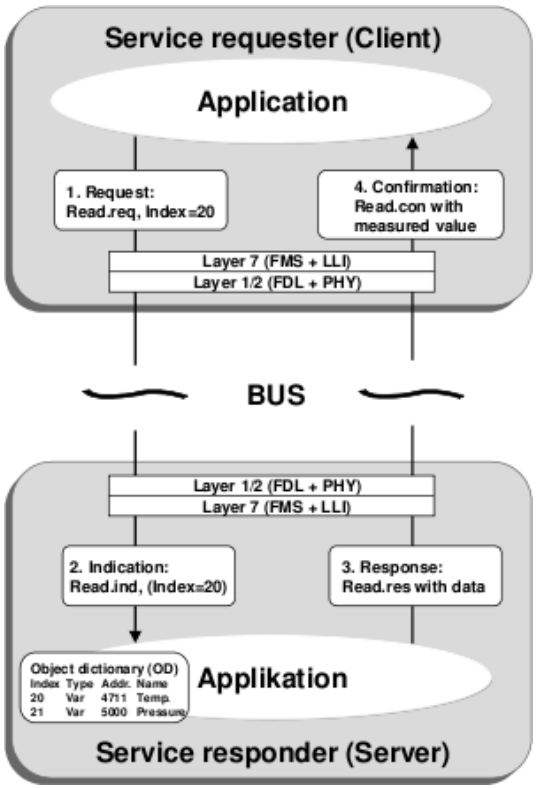
- Transmission at application layer between programmable controllers (PLC or PC):
  - Devices are composed of a set of virtual field devices (VFD)
  - These VFD share data (variables, tables, ...)




- FMS is an application layer composed of 2 parts:
  - Fieldbus Message Specification
  - Lower Layer Interface

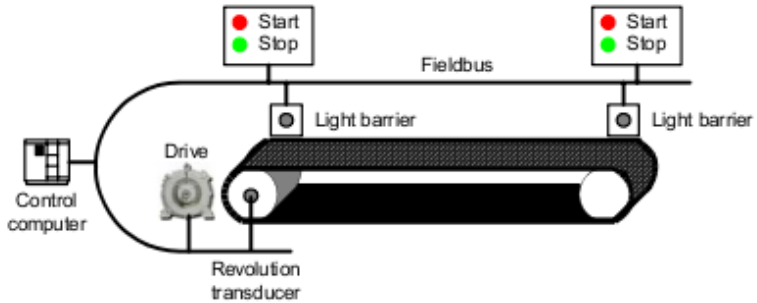
# LLI: Lower Layer Interface

- Mapping of layer 7 on layer 2
- Ensures transmission between the VFD in connected or non connected mode
- Sequence of a confirmed service:

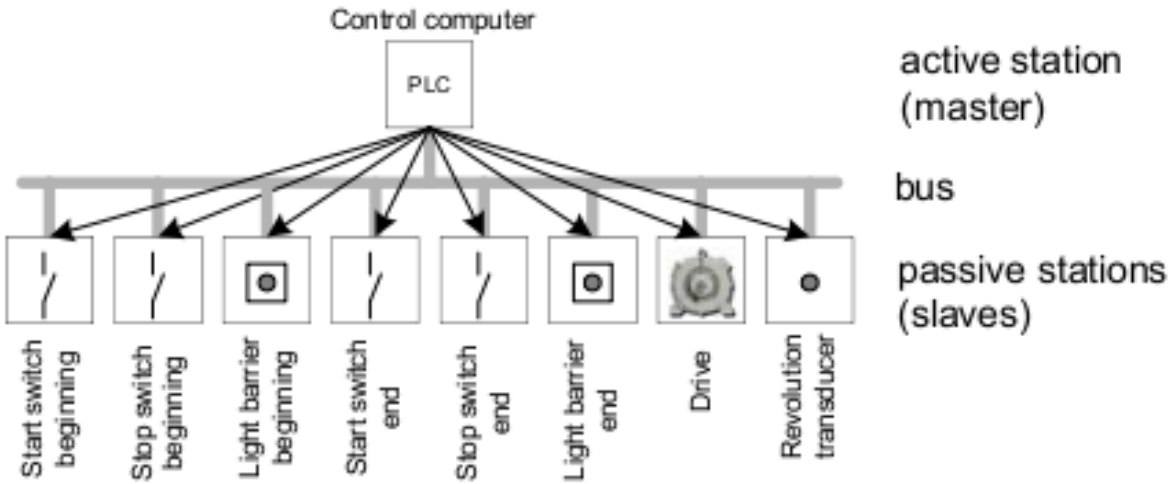


# Exercise I: Mono-master operation

- A conveyor belt system using a PROFIBUS system:




- Topology of the system:



# Exercise I: Mono-master operation

- Configuration:
  - 8 slaves polled cyclicly
  - SRD service
  - Fixed number of data: 8 bytes
  - Baud rate: 500 kBit/s
  - Overhead induced by monitoring the bus and processing by the slave is constant: $L_O$=500 bit-times.
- Requirement: the maximum reaction time of the system is $T_{max}$=50 ms

# Exercise I: Mono-master operation

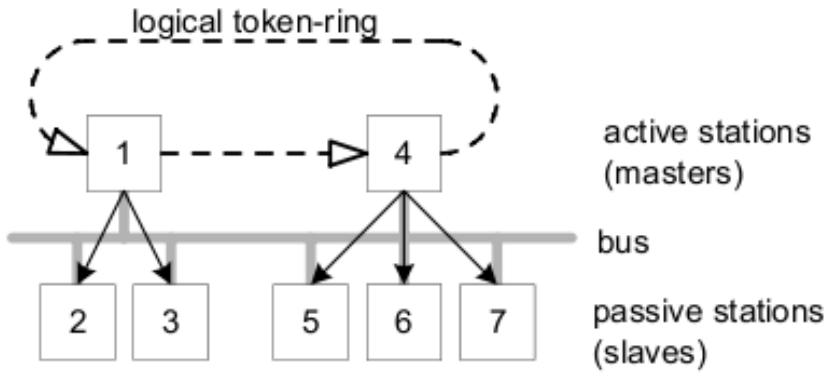
1. Calculate the length $L_F$ of a single data frame in number of bytes. As RS232 coding is used for frame, deduce this length in number of bits. How long does it take to completely process one SRD service operation ?
2. Calculate the minimal bus-cycle time that is required to poll all slave devices for one time. Is the limit for the maximal reaction time exceeded ?

# Exercise I: Mono-master operation

3. The master waits a period time $T_{SL}$ for the response of the slave. When this period expired, the transmission is considered to be failed and the message is sent again (at most twice). How must the period time $T_{SL}$ be chosen to guarantee the reaction time $T_{max}$ in the worst case ? Worst case: transmission failed twice and correct transmission at the third attempt.
4. The conveyor belt shall be enlarged to a total length of 1000m. Which problem arises concerning the bus system ? (At 1200m, the baud rate is 93,75 kBit/s)

# Exercise II: Multi-master operation

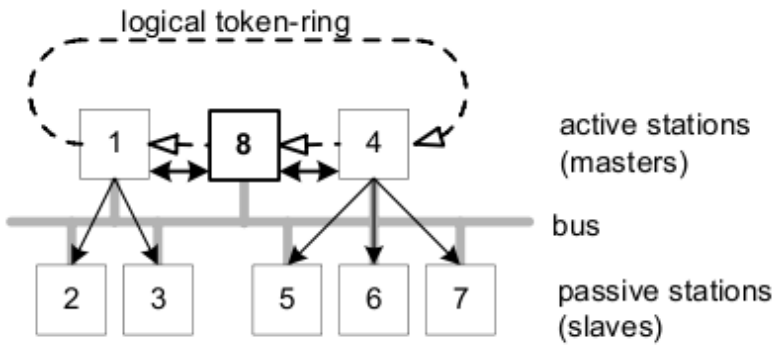
- Topology:




- Configuration:
  - 2 masters (1 and 4) control 2 or 3 slaves
  - SRD is used ($T_{SRD} = 1{,}6$ ms)
  - Time to check, manage and pass on the token is contant: $T_{Tok} = 1$ ms
- Construct the sequence of messages on the bus. Calculate the real rotation time of the token.

# Exercise III: Multi-master operation with a control station

- Topology:




- masters and slaves configuration is same as previously (SRD, durations)
- 8 is a control station and communicate with 1 and 4:
  - SDN-service ($T_{SDN}$=6,5 ms)
  - low priority messages
- Target-rotation-time is $T_{TR}$=10 ms

# Exercise III: Multi-master operation with a control station

- Configuration of the messages:

| Messages | Processing time | Priority |
|---|---|---|
| $M_{12}$, $M_{13}$, $M_{45}$, $M_{46}$, $M_{47}$ | $T_{SRD}$=1,6 ms | high |
| $M_{18}$, $M_{48}$, $M_{81}$, $M_{84}$ | $T_{SDN}$=6,5 ms | low |
| $M_{Tok}$ | $T_{Tok}$=1 ms | - |

- Messages stored in the FIFO queues of the active stations:
  - Master 1: $M_{12}$, $M_{13}$, $M_{18}$
  - Master 2: $M_{45}$, $M_{46}$, $M_{47}$, $M_{48}$
  - Master 8: $M_{81}$, $M_{84}$
- Construct the sequence of messages taking into account the different priorities of messages. Compute the resulting $T_{RR}$.