



Concept of Industry 4.0: PLC network extensions and real time Networks

Asean-Factori 4.0 project

Grenoble-Valence , Spring 2021

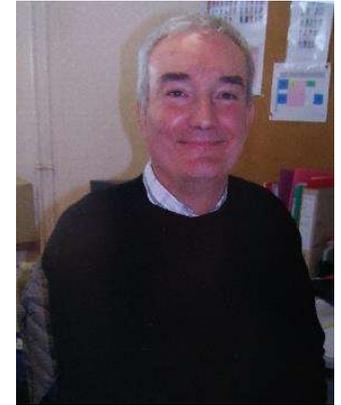
denis.genon-catalot@univ-grenoble-alpes.fr





Condensed CV

- 1993- Docteur (Ph.D.) Applied Physics from Joseph Fourier University
former name of Grenoble University Alpes
- 1995 Teams for ESISAR engineer school foundation in Valence - Grenoble INP.
Head of the Electronics Department new curricula include 6 month Industrial project
- 1998 New challenge Telecoms chair for the creation of the Telecoms and Networks Dpt.
IUT – Valence : Technological Institute in the University Grenoble Alpes.
- 2002- Founder and Head of the Administration and Security Networks Bachelor.
- 2010 to 2013 President of all French Networking and Telecommunication Departments
Design the new curricula for 29 Departments (still applied in 2021).



Research

- 1996, one of three founders of the LCIS Laboratory first research labs in Valence.
ID: EA 3747 Research laboratory with 30 permanents researchers (ERC , MIT-35 Etienne Perret)
and up to 40 PhD Post Doctorate, internships students,..
- Contributions research : Embedded systems and designing new architecture and protocols for some patents
(Fieldbus, low power RF and PLC communication system).
- IEEE, SPIE, ..member and since 2006 EAEEIE European association treasurer
- LCIS leader for several European projects : ITEA2-Osami, Artemis-Arrowhead,
and Frenchs industrials partnerships : ANR-POUCET, ANR-C3 μ , BGLE- ADN4SE,..
Supervising many industrials PhD : Critical Fieldbus Networks, Smart Buildings, DC autonomous Buildings,..

Contact : Denis.genon-catalot@univ-grenoble-alpes.fr



University Grenoble Alpes location and International position



- ▶ **56,000** students
- ▶ **3,400** PhD students
(45% international)
- ▶ **7,500** employees, of which
 - **5,500** academic
 - **2,000** staff



Ranking 2020 : 99^e position over 1000 Universities



<http://www.shanghairanking.com/Shanghairanking-Subject-Rankings/index.html>





UGA - Valence site

Historical Rhone valley path

...since romans time



Valence

2h to join Paris (TGV)
1h to join Marseille (TGV)

Dynamic environment

Population: 250,000
6000 students



Asean-Factori 4.0



4 - DGC



2021 Lightspeed :
Thales will product
LEO network satellites
fleet of 298 satellites
for Telesat operator.

...
1921: CROUZET
precision mechanics



Summary :

UGA-1 Field test :

**Description of small hydro power plant
Requirements for automation architecture**

UGA-2. Field bus network

RS232c / RS-485/ Modbus RTU/ Profibus...

UGA-3. Ethernet network

Modbus TCP/ Profibus IP/...

UGA-4. Real time Ethernet

Ethercat/Powerlink/ ...

UGA-5. Wireless sensors/actuators

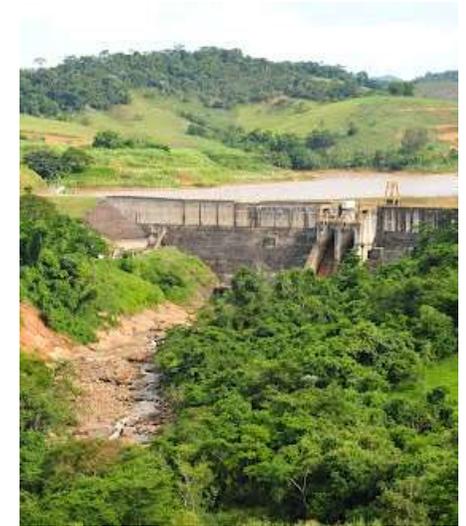
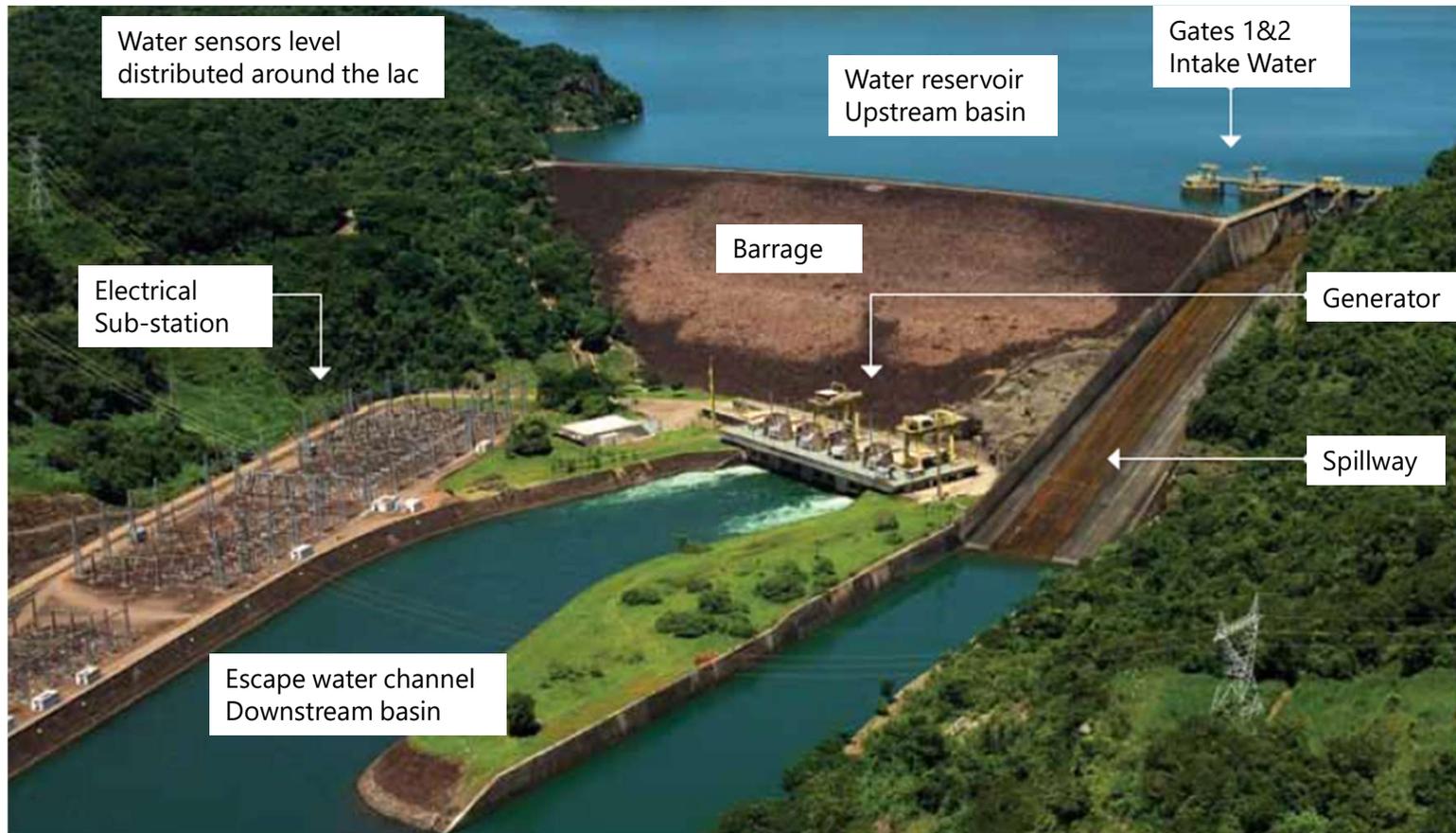
Mbus/LoRa

UGA-6. Unified communications

Informations over the cloud



Small Hydro Power Plant – Top View

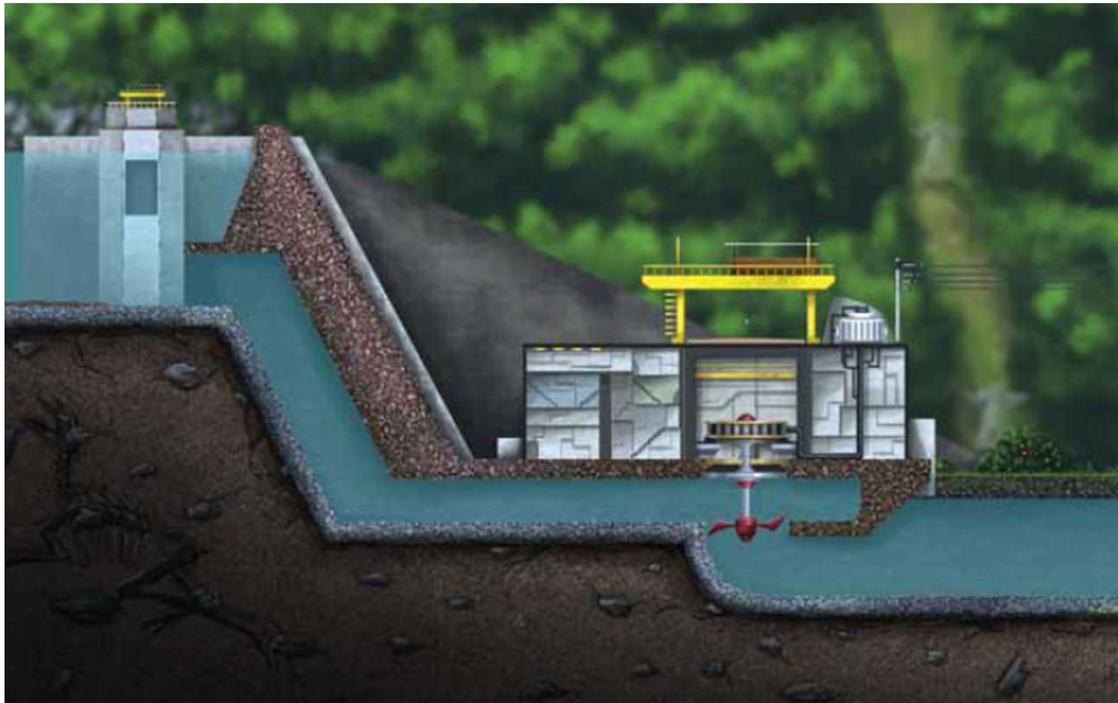


Muriaé -Brazil

courtesy **WAGO**

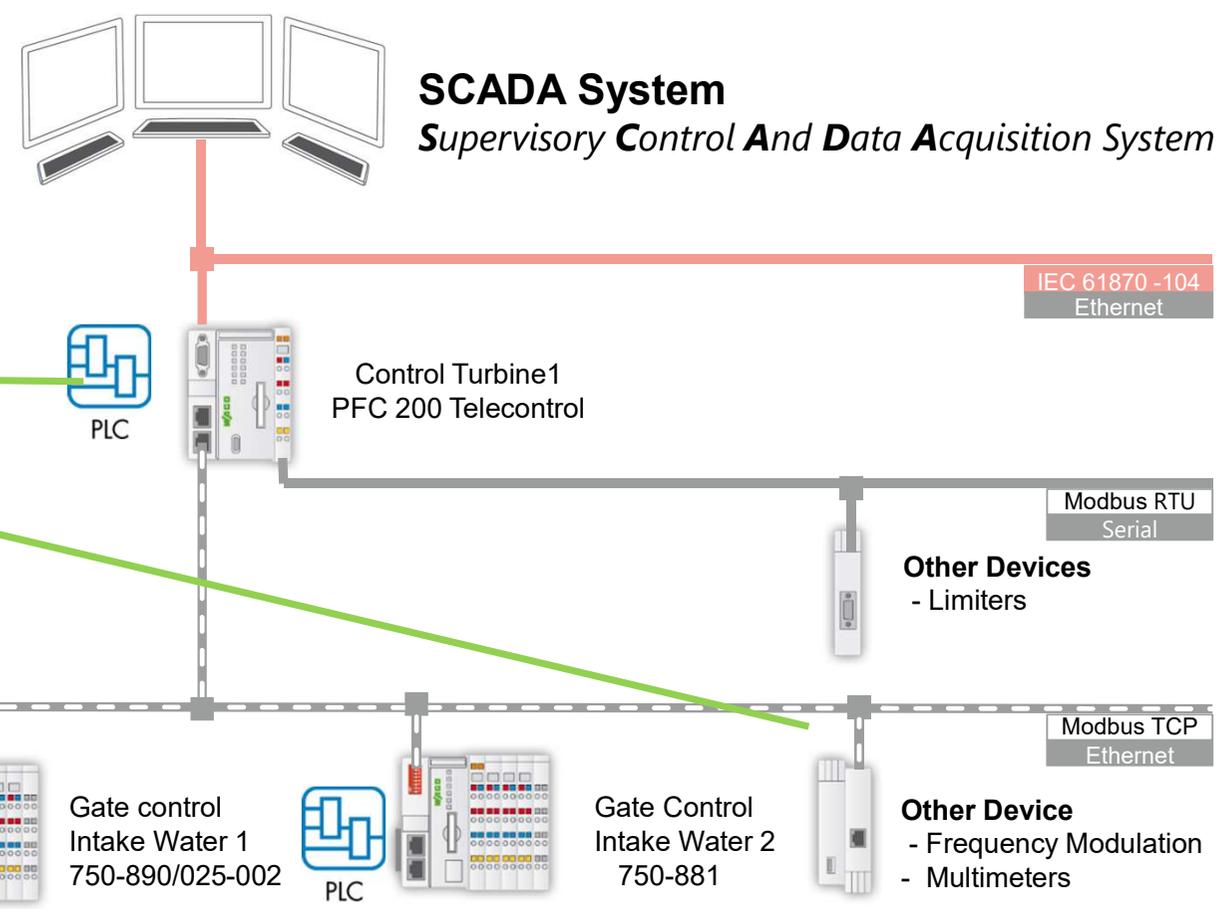
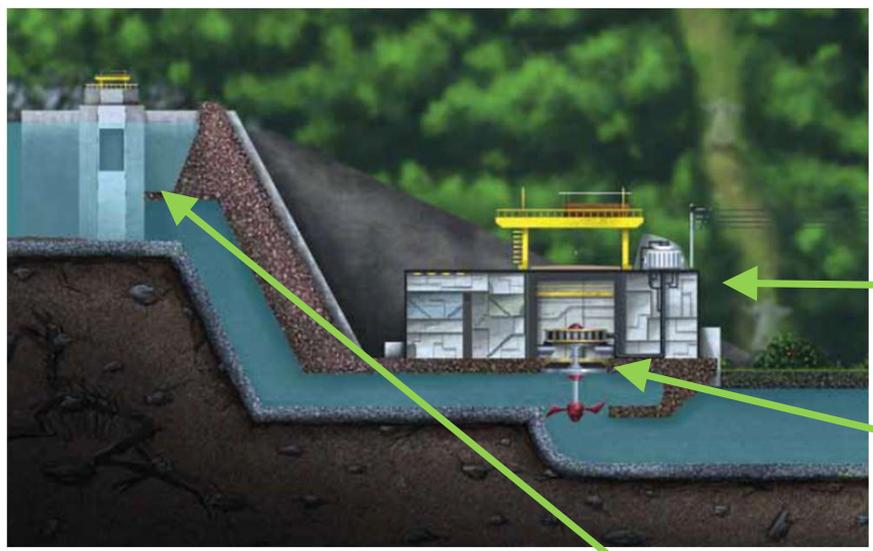


Small Hydro Power Plant – Cutted View



courtesy **WAGO**

Small Hydro Power Plant : Automation Architecture





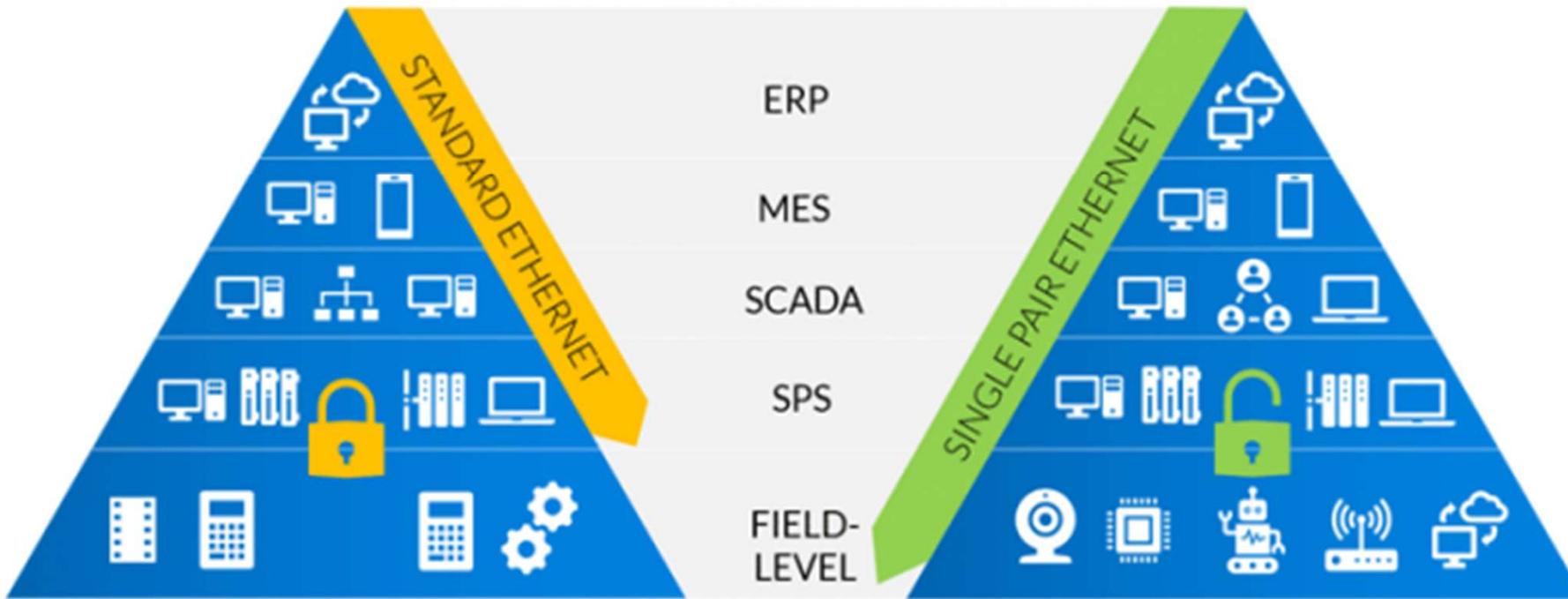
2. Automation architecture



The hydro power plan will be the common thread of our PLC presentation



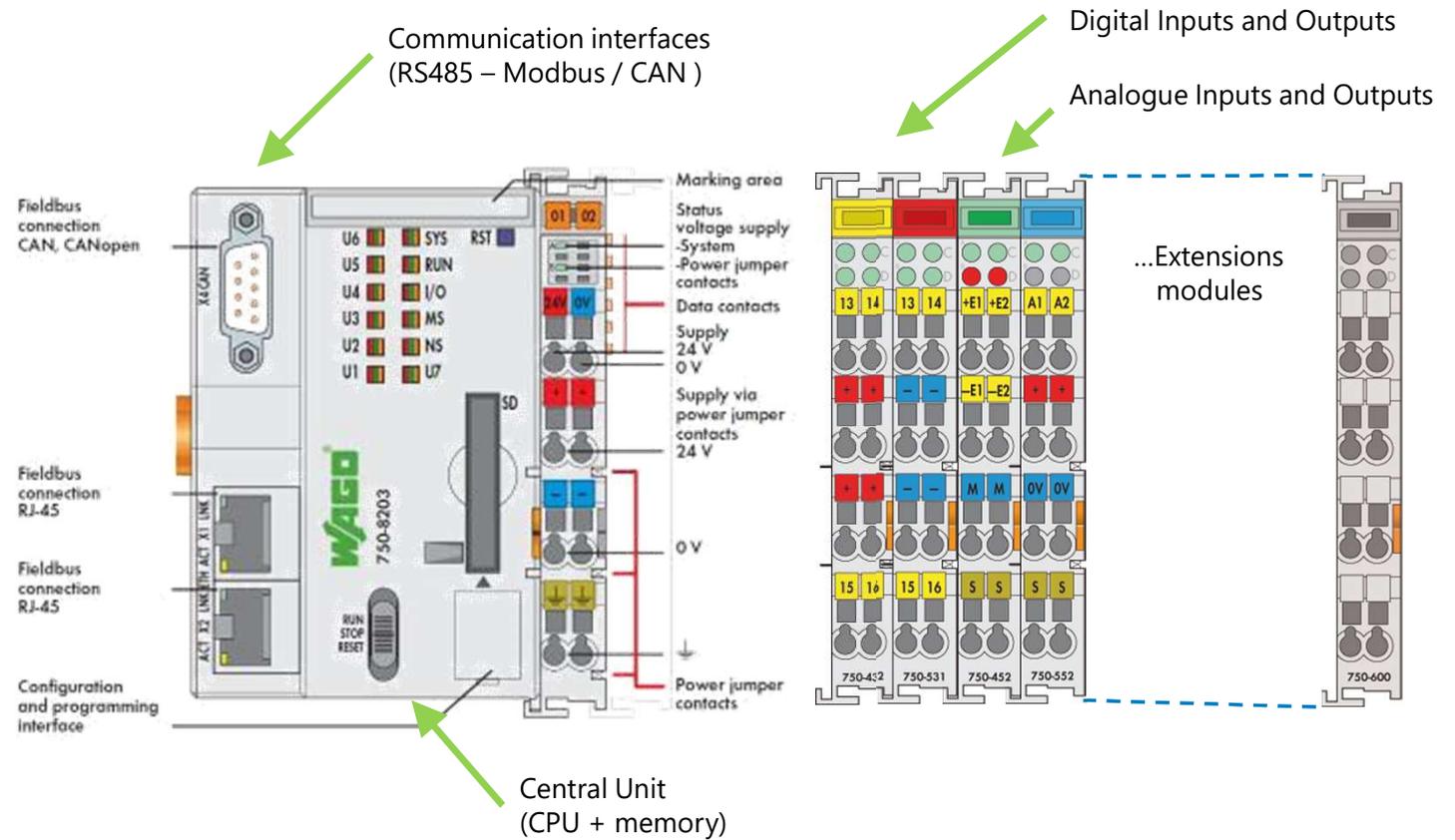
Communications : CIM pyramid



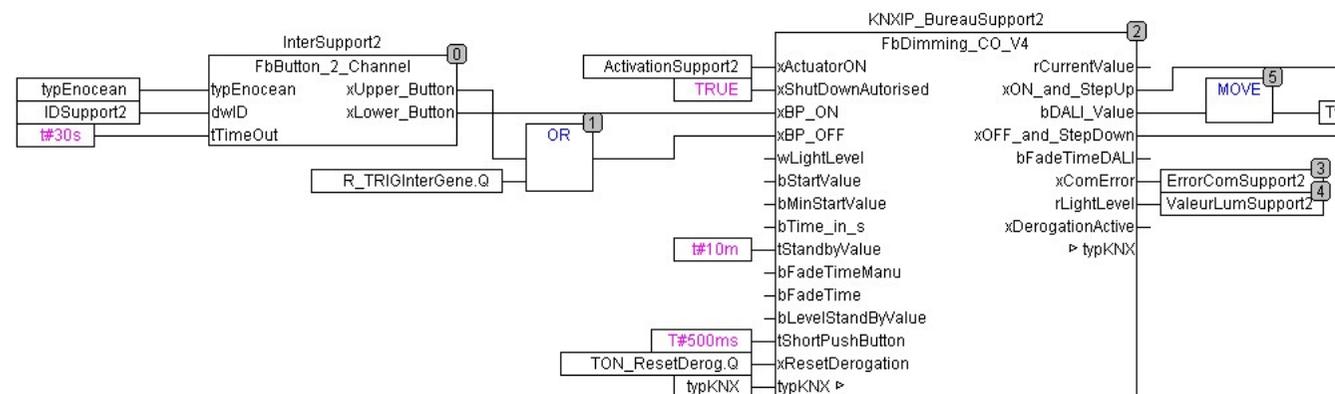
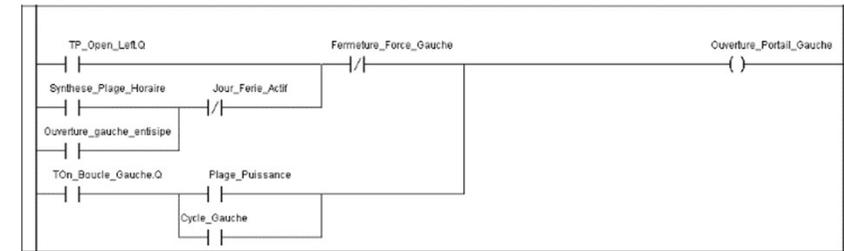
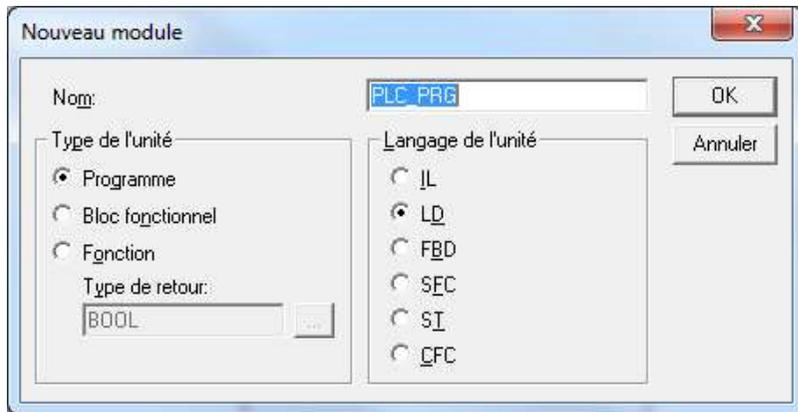
Computer Integrated manufacturing (CIM) : Describe integration layers

Example with the actual Ethernet standard (4 twisted pairs)
versus the new Single Pair Ethernet (1 twisted pair)

Programmable Logic Controller (PLC)



PLC languages: IEC 61131



```

(*****Gestion du bit de vie (Requête 6)*****)
TON_Vie(IN:=NOT TON_Vie.Q, PT:=T#5s);
IF TON_Vie.Q THEN
  IF Requete_To_Send=0 THEN
    Requete_To_Send:=1;
  END_IF
  z:=1;
  WHILE Z<Requete_To_Send AND Buffer_Request_To_Send[z]<>6 DO
    z:=z+1;
  END_WHILE
  IF Z=Requete_To_Send THEN
    Buffer_Request_To_Send[Requete_To_Send]:=6;
    Requete_To_Send:=Requete_To_Send+1;
    Start_Com:=TRUE;
  END_IF
END_IF

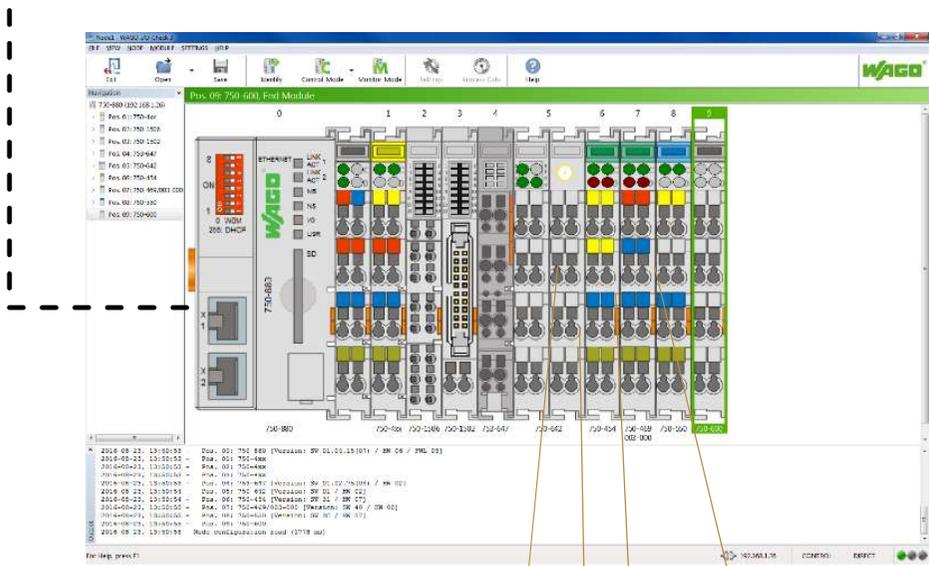
```

PLC languages according IEC 61131:

- IL (*Instruction List*)
- LD (*Ladder, Schematic relais*)
- FBD (*Function Bloc Diagramm*)
- SFC (*Sequence Flow Chart, GRAFCET*)
- ST (*Structured Text*)
- CFC (*Continuous Function Chart*)

2.1 -Centralized automation

SCADA



Passives sensors

Sensors

Actuators

Pos.2: 750-14xx

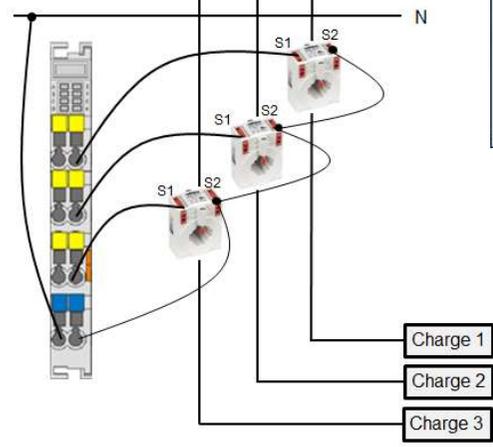
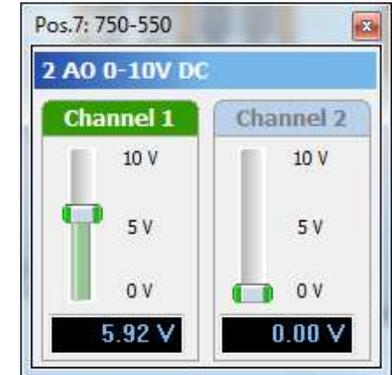
Description	Value
I 1: Digital Input	ON
I 2: Digital Input	OFF
I 3: Digital Input	ON
I 4: Digital Input	ON
I 5: Digital Input	OFF
I 6: Digital Input	OFF
I 7: Digital Input	OFF
I 8: Digital Input	OFF
I 9: Digital Input	ON
I 10: Digital Input	ON
I 11: Digital Input	ON
I 12: Digital Input	OFF
I 13: Digital Input	OFF
I 14: Digital Input	ON
I 15: Digital Input	OFF
I 16: Digital Input	OFF

Pos.3: 750-15xx

Description	Value
O 1: Digital Output	OFF
O 2: Digital Output	ON
O 3: Digital Output	OFF
O 4: Digital Output	OFF
O 5: Digital Output	ON
O 6: Digital Output	ON
O 7: Digital Output	OFF
O 8: Digital Output	OFF
O 9: Digital Output	OFF
O 10: Digital Output	ON
O 11: Digital Output	OFF
O 12: Digital Output	OFF
O 13: Digital Output	OFF
O 14: Digital Output	ON
O 15: Digital Output	OFF
O 16: Digital Output	ON

Pos.6: 750-454

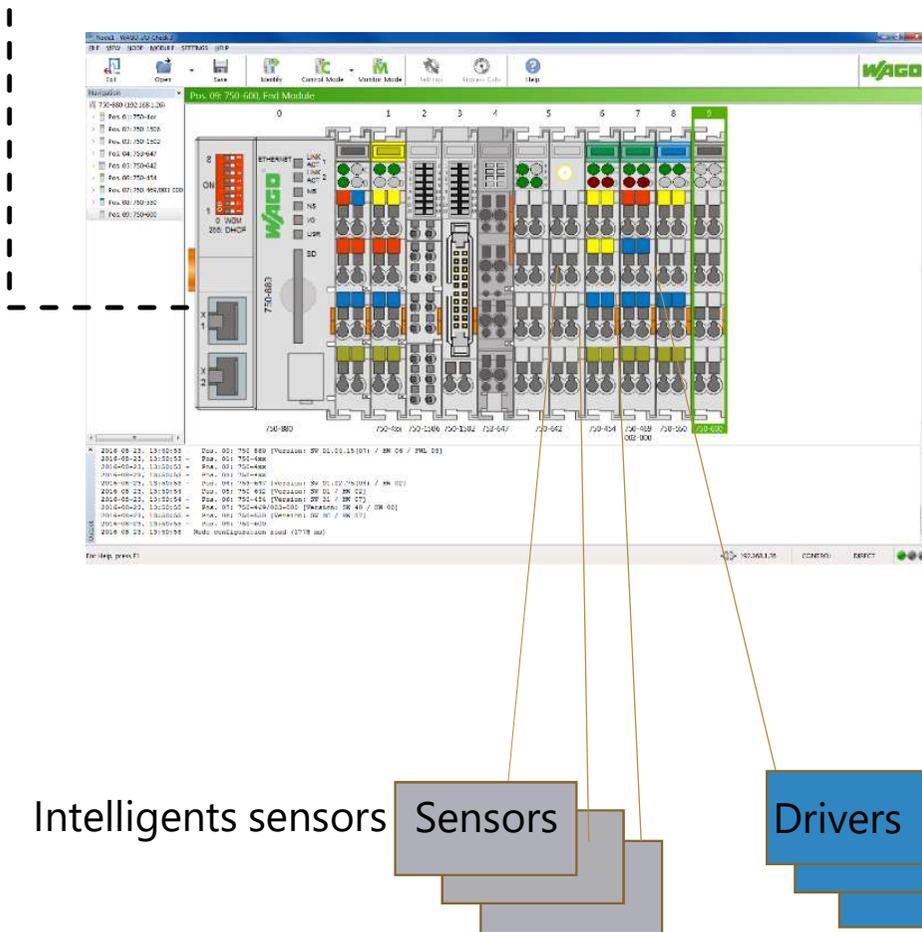
Description	Input
I 1: Analog Input	4.00 mA
I 2: Analog Input	- ? -





2.2 Intelligent centralized automation

SCADA



Analog sensors actuators information's become numerical information !

Connexions systems needs to understand each othermust be more "smart"

Point to point communication protocol with "intelligent" sensors

Protocol specifications for energy metering : Modbus
Binary date exchange with differents ranges

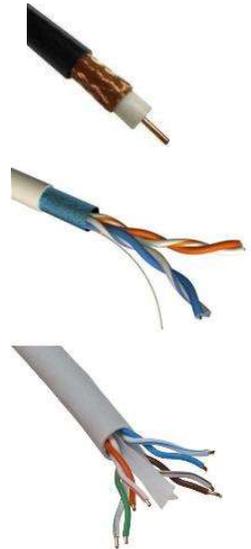


2.3 Communication : physical layer

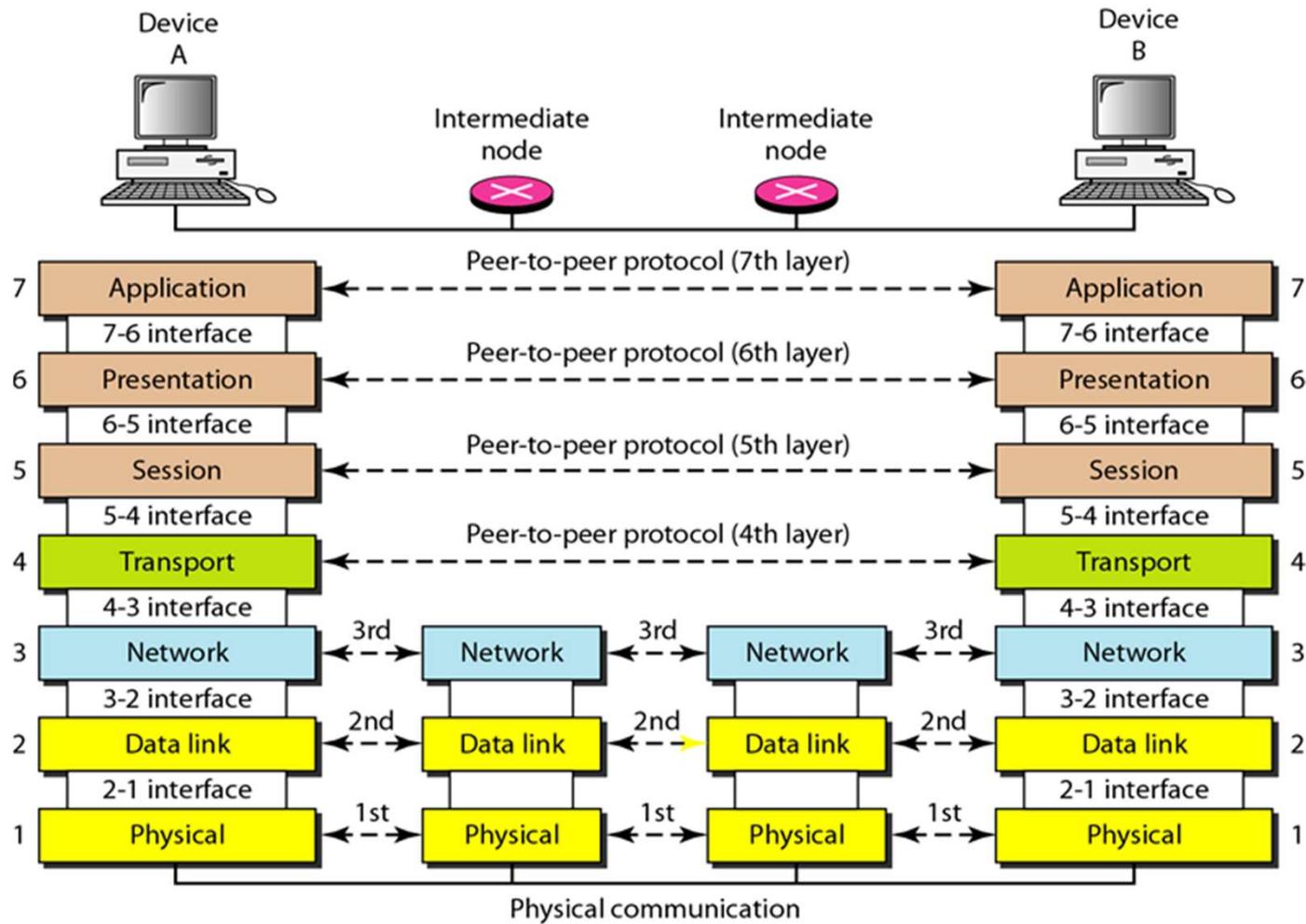
TIA :
Telecommunication
Industry
Association
previously
EIA : Electrical
Industry Association

ITU-T :
International
Telecommunicaiton
Union
- **Technical (normalization)**
previously
CCITT :
Consultative
Comity
International
Telephony Telegraphique

TIA/ EIA ITU-T / CCITT	RS232C V24/V28	RS422 V11/X27	RS485 V11/X27	TTY
Interface	Bipolar	Differential	Differential	Current Loop
Signal level	± 25 V max	± 5 V	± 5 V	0-20 mA
Sensibility	± 3 V	± 0,2 V	± 0,2 V	± 0,4 mA
Distance	10 to 15 m	1200 m	1200 m	1 to 2 km
Maximum throughput	19200 bds	10 Mbds	10 Mbds	19200 bds
Multipoint	Point to point	Point to multipoint	Point to multipoint	Point to multipoint
Nb. Transmitter	1	1	32	
Nb. Receivers	1	10	32	

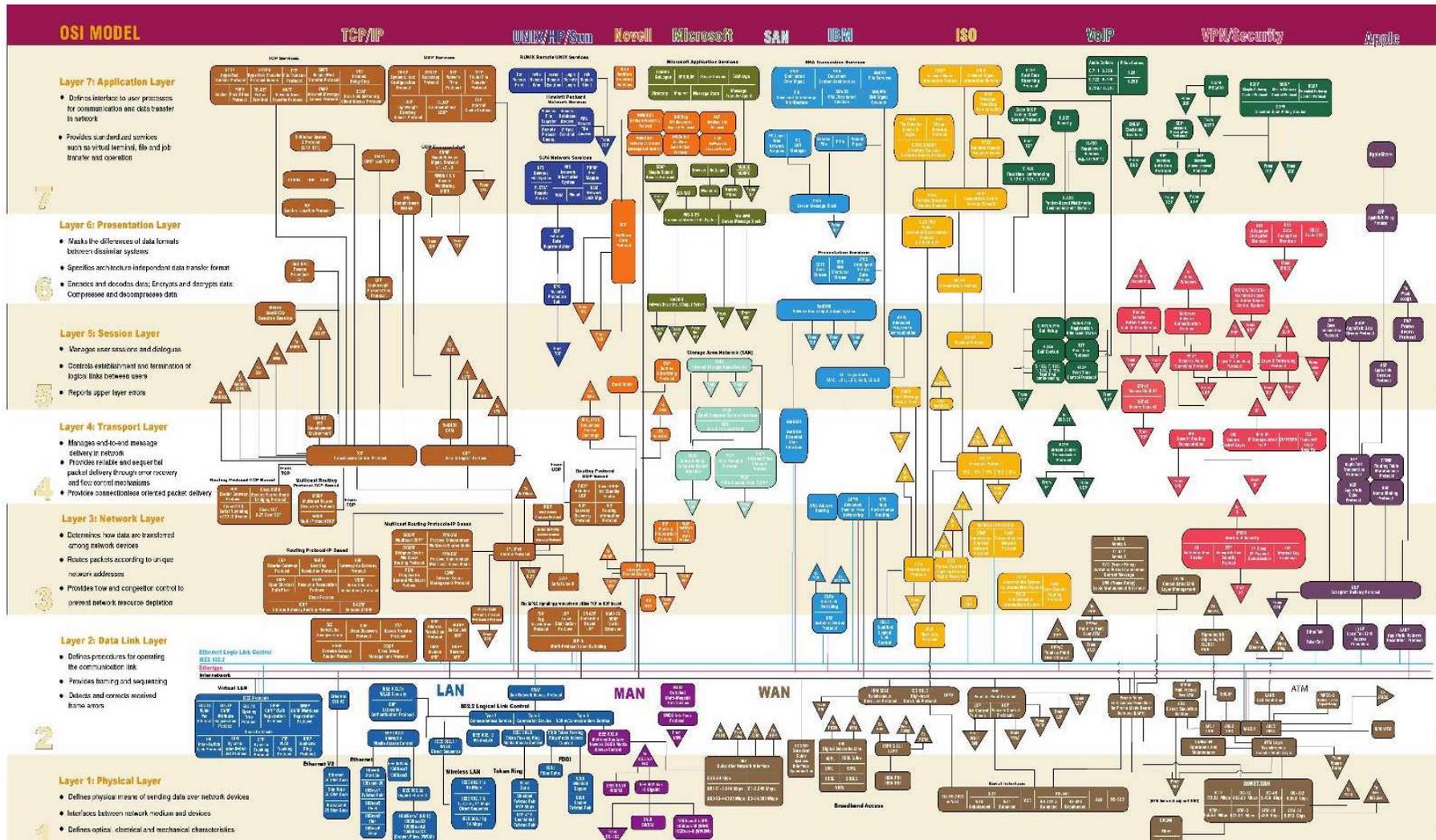


2.4 Point to point connexion





2.5- Network layers protocols map





Network Models

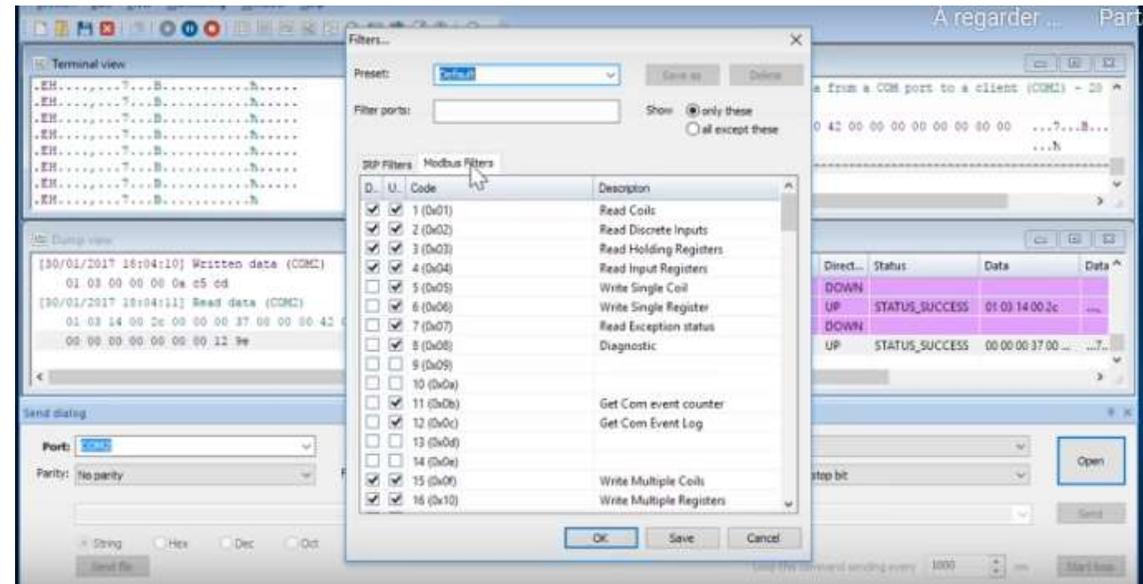
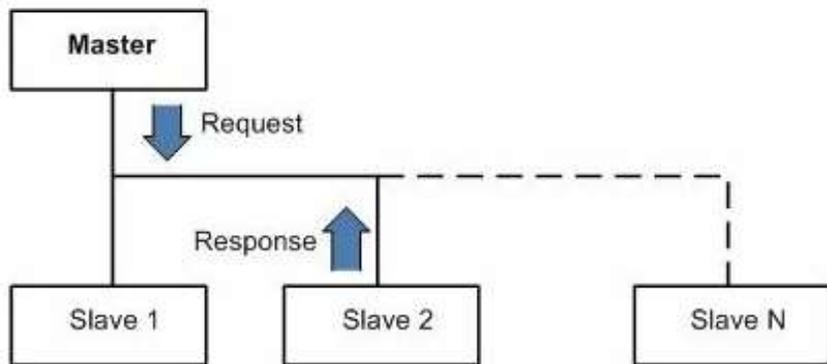
TCP/IP MODEL	OSI MODEL	PROTOCOLS
Application Layer	Application Layer	FTP,HTTP,Telnet
	Presentation Layer	JPEG,MPEG
	Session Layer	NFS,SQL,PAP
Transport Layer	Transport Layer	TCP,UDP
Network Layer	Network Layer	IPv4,IPv6
Network Access Layer	Data Link Layer	ARP,CDP,STP
	Physical Layer	Ethernet,Wi-Fi



2-7 ModBus Protocol



Serial protocol based on master (s) / slave (s) dialogue
Data exchange with “Request / Response”



Extension on Internet protocol
Internet Protocol based on Client / Server dialogue

Data exchange in the form “Request / Response”

Most PLC support both Client/Server modes

2-8 Modbus frames



First and simple implementation

ASCII Mode

ASCII : American Standard Code
for Information Interchange

Start sequence	Address	Function	Payload Data	LRC	End sequence
“.” .”	1 Byte	1 Byte	Nb Bytes	1 Byte	“CR + LF”

95% of deployed installations

RTU Mode

RTU : Remote Terminal Unit

Start sequence	Address	Function	Payload Data	CRC	End sequence
3.5 Ts	1 Byte	1 Byte	Nb Bytes	2 Bytes	4 Ts



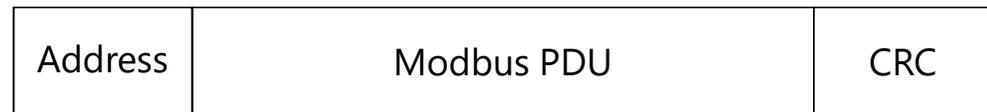
2.10- Modbus frames

Basic Frame layer Link layer independent

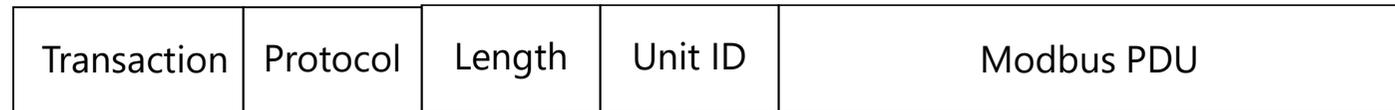
- PDU :
(Protocol Data Unit)



- ADU : RTU
(Application Data Unit)

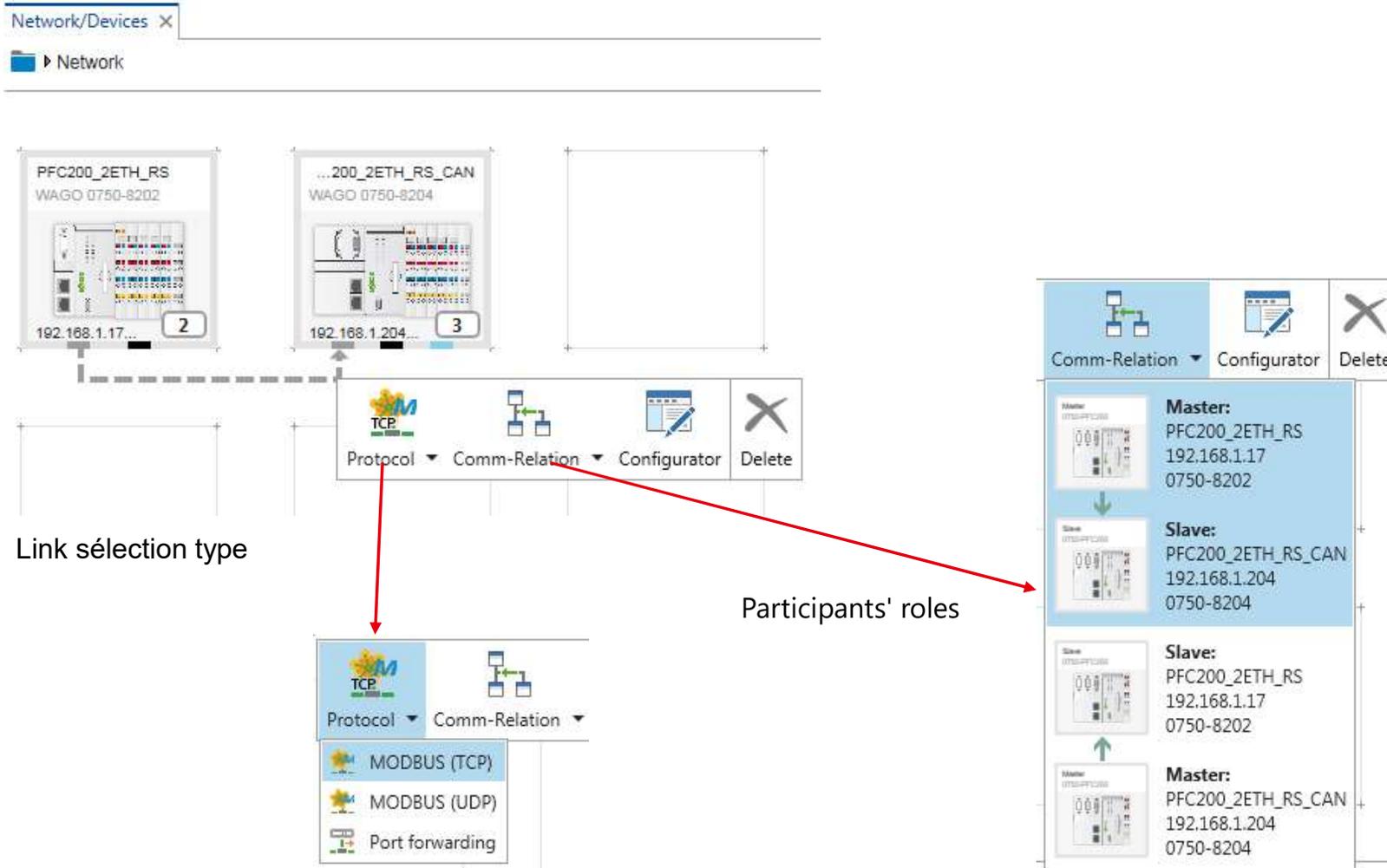


- ADU : TCP



(Transmission Control Protocol
.....over Internet Protocol)

2-9 Modbus – Simple configuration link layer

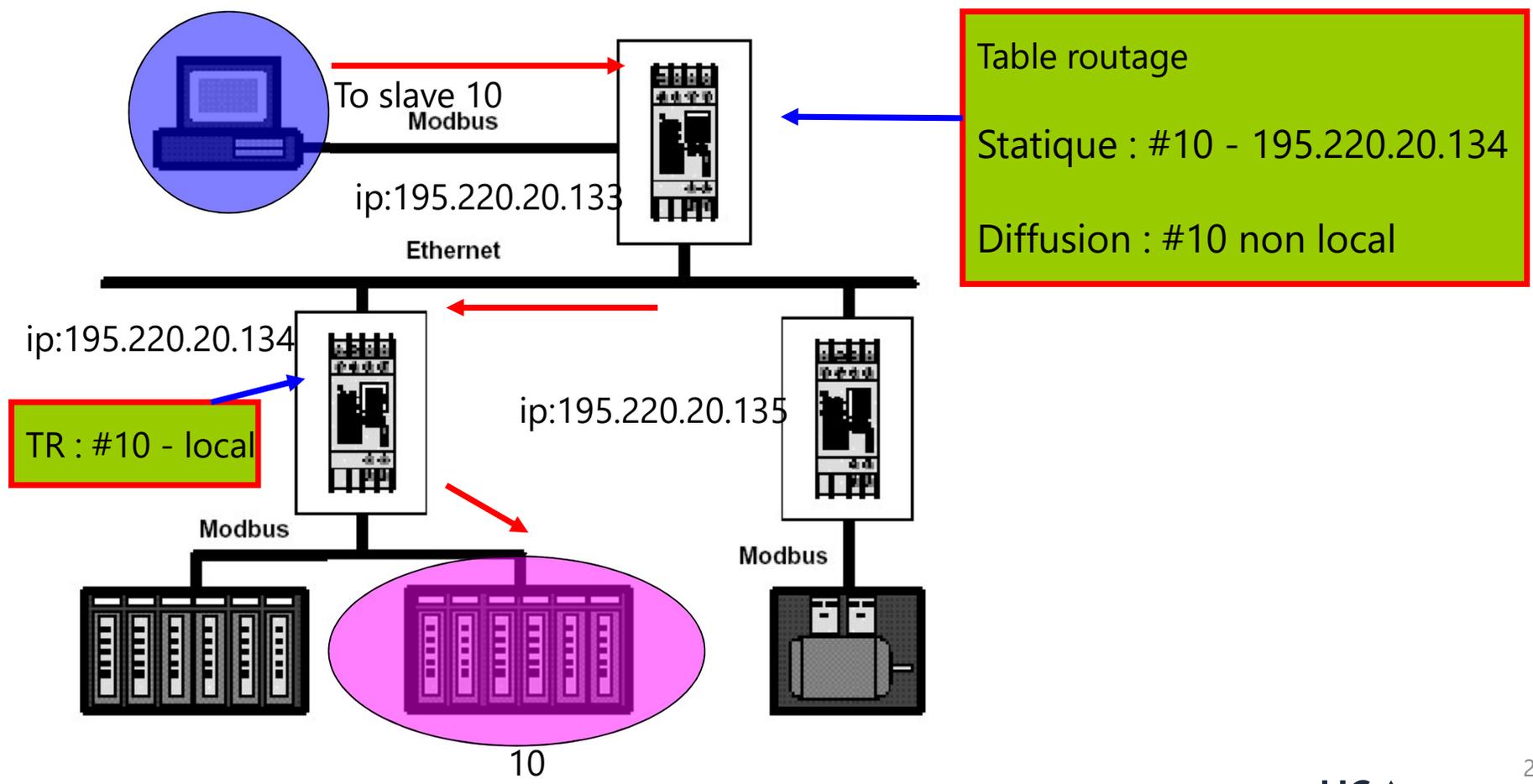


Link selection type

Participants' roles



2.11- Modbus bridging

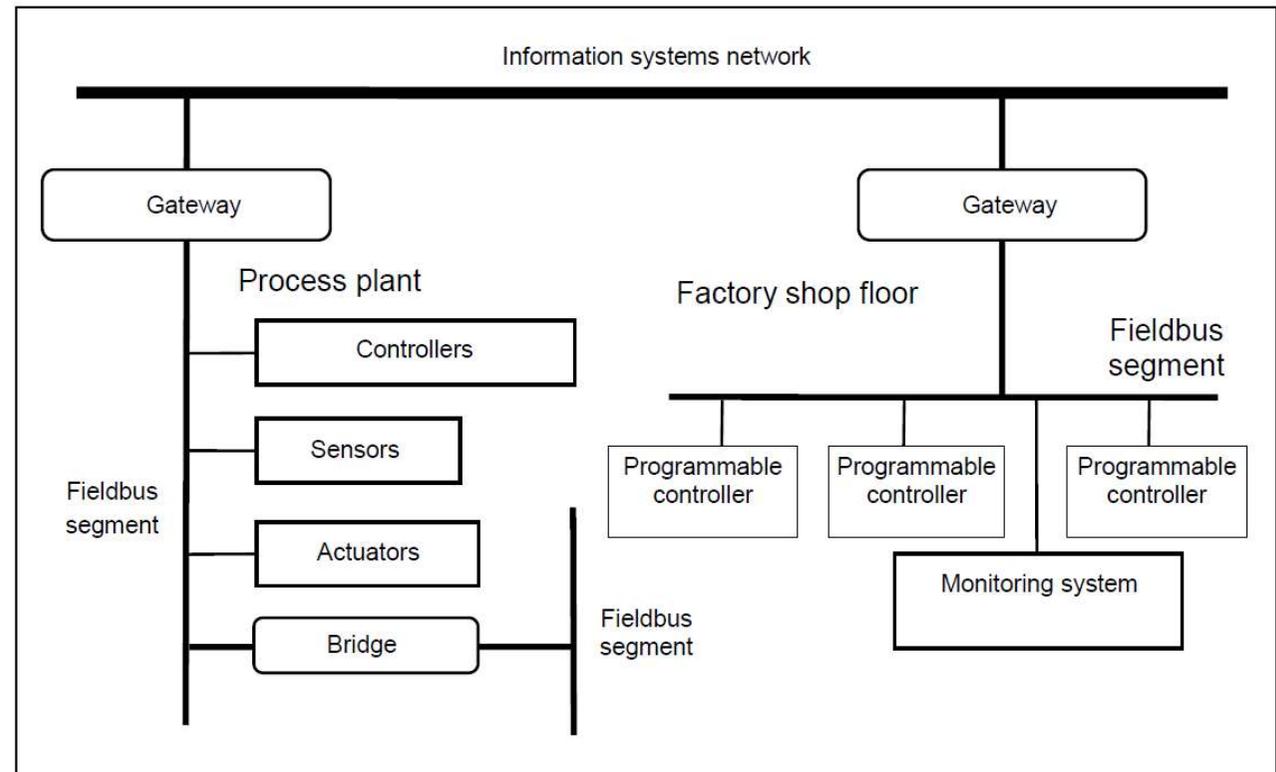




3-Fieldbus specifications : IEC 61158/ 61784 series

Industrial communication networks

Industrial process measurement and control
Data communication networks
Multilayer applications



3.1 Protocols normalized by IEC 61138/ 61784

Co-funded by the
Erasmus+ Programme
of the European Union



	Name	Vendor
1.	Fieldbus Foundation,	EU
2.	ControlNet, EtherNet/IP, DeviceNet	ODVA
3.	PROFIBUS, PROFINet	Siemens
4.	P-Net,	Danmark
5.	WordFIP	Alstom, Cegelec
6.	INTERBUS	Phoenix Contact
7.	Swiftnet (retired)	Boeing
8.	CC-Link	Mitsubishi
9.	HART	Hart
10.	Vnet/IP	Yokogawa
11.	Tcnet	Japon
12.	EtherCAT	EtherCAT group
13.	ETHERNET Powerlink	Open source
14.	EPA	Chine
15.	MODBUS-RTPS	Schneider
16.	SERCOS	Sercos
17.	RAPIEnet	Korea
18.	SafetyNET p	Pilz GmbH

All these protocols are incompatible each other
IP gateway is the solution to transfer data



3.2 Profibus – Serial Bus

In 1987, in Germany, 21 companies (mainly Germans including Siemens)) and institutions joined forces to work on a project called “field bus”. The goal was to develop a serial communication field bus. These association members have agreed on a common technical concept for production and for automation.

First denomination : Profibus-PA (Process Automation)

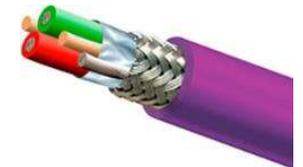
For highly communicative tasks, the Profibus-FMS (Field bus Message Specification) protocol, which is particularly complex, was specified.



In 1993, the Profibus-DP (Decentralized Peripherals) protocol improved its predecessor in terms of simplicity and above all speed.

Profibus is part of the IEC 61158 recommendation.

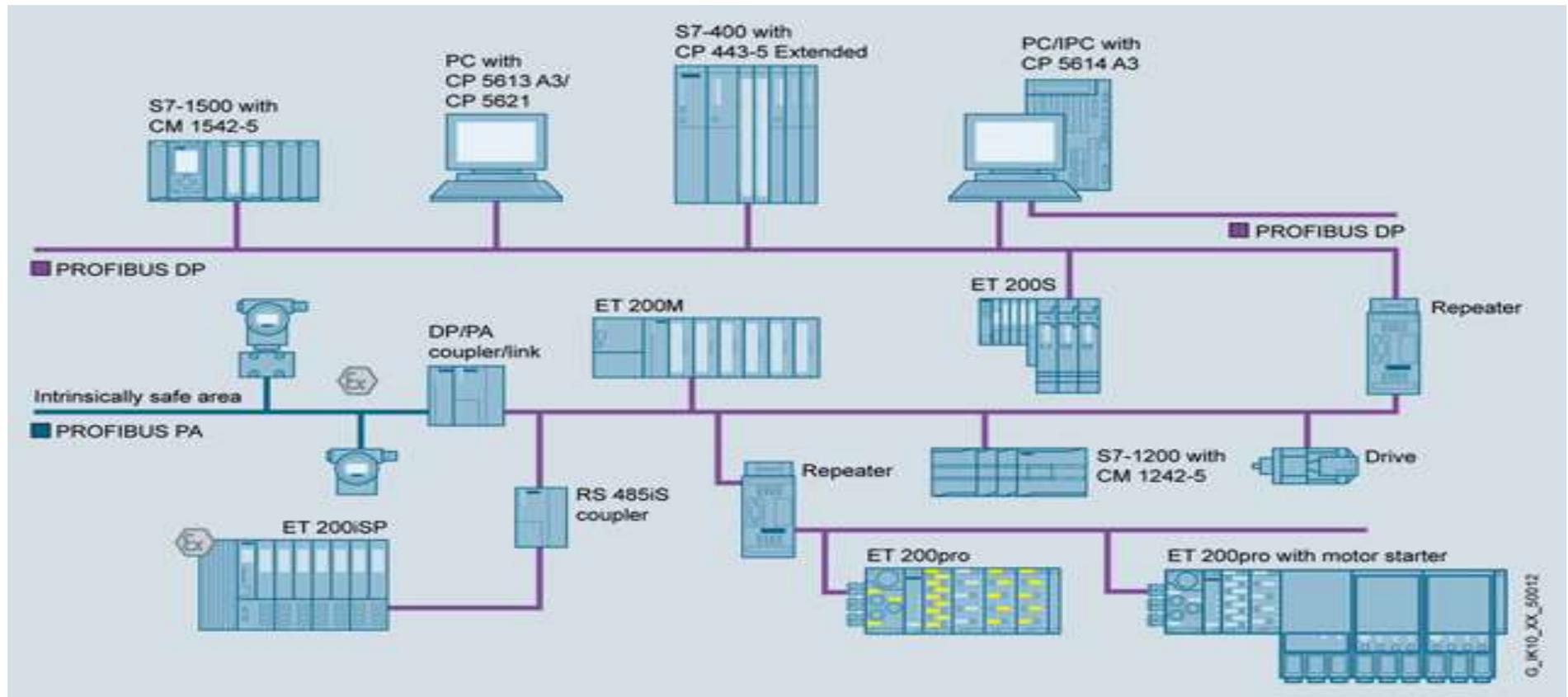
Communication over twisted pair RS-485 type (characteristic impedance 150 ohms)
Data transmission support numerical base band in NRZ mode on physical medium.





3.3 Profibus DP/ PA

Bus or tree topology with repeaters
RS-485 transmission line



courtesy **SIEMENS**



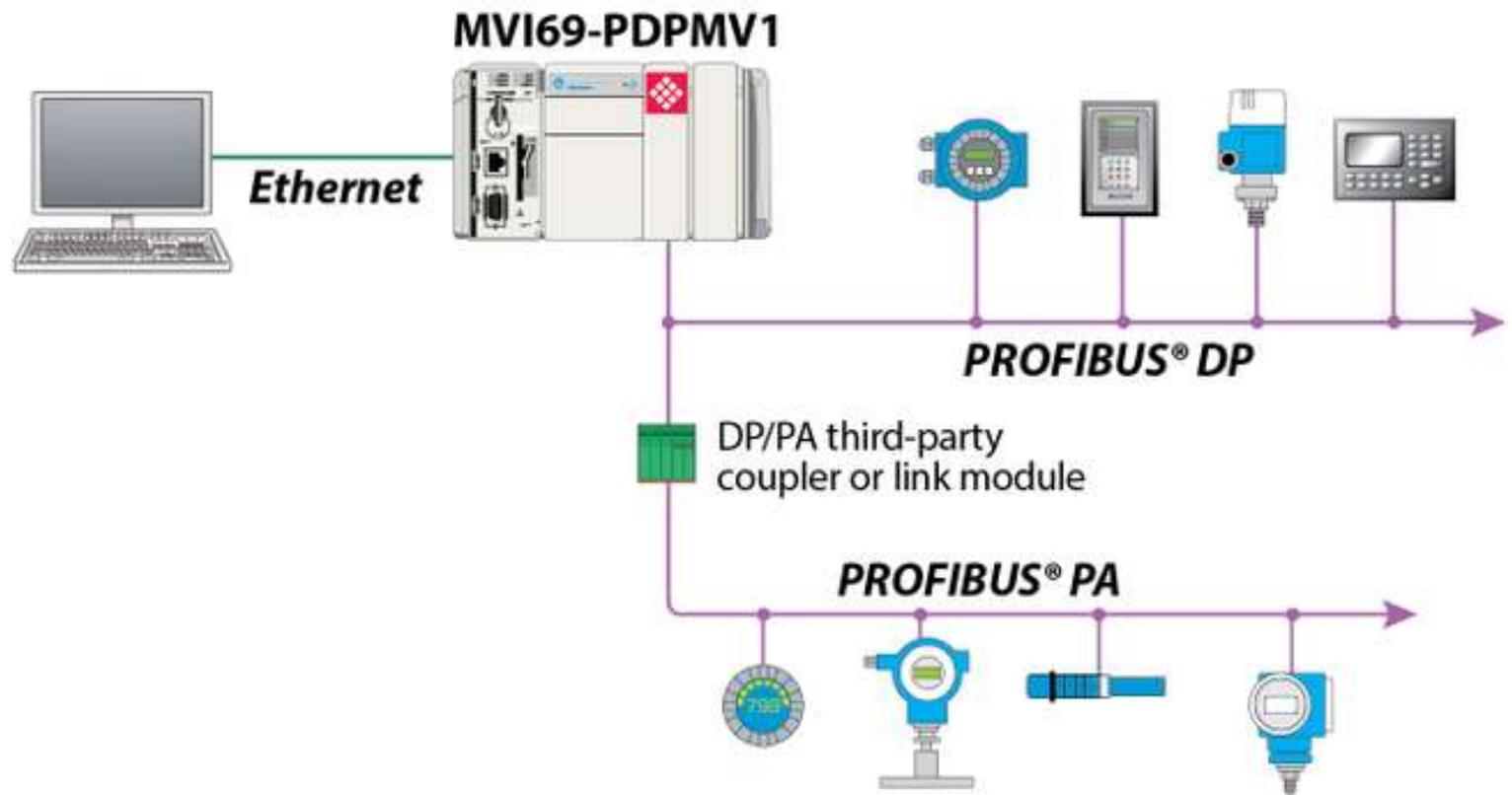
3.4 Profibus DP : Ethernet version

Profibus-DP for Decentralized Peripheral bus is used "real-time" deterministic control of sensors and actuators by performing automation and regulation functions on PLC.

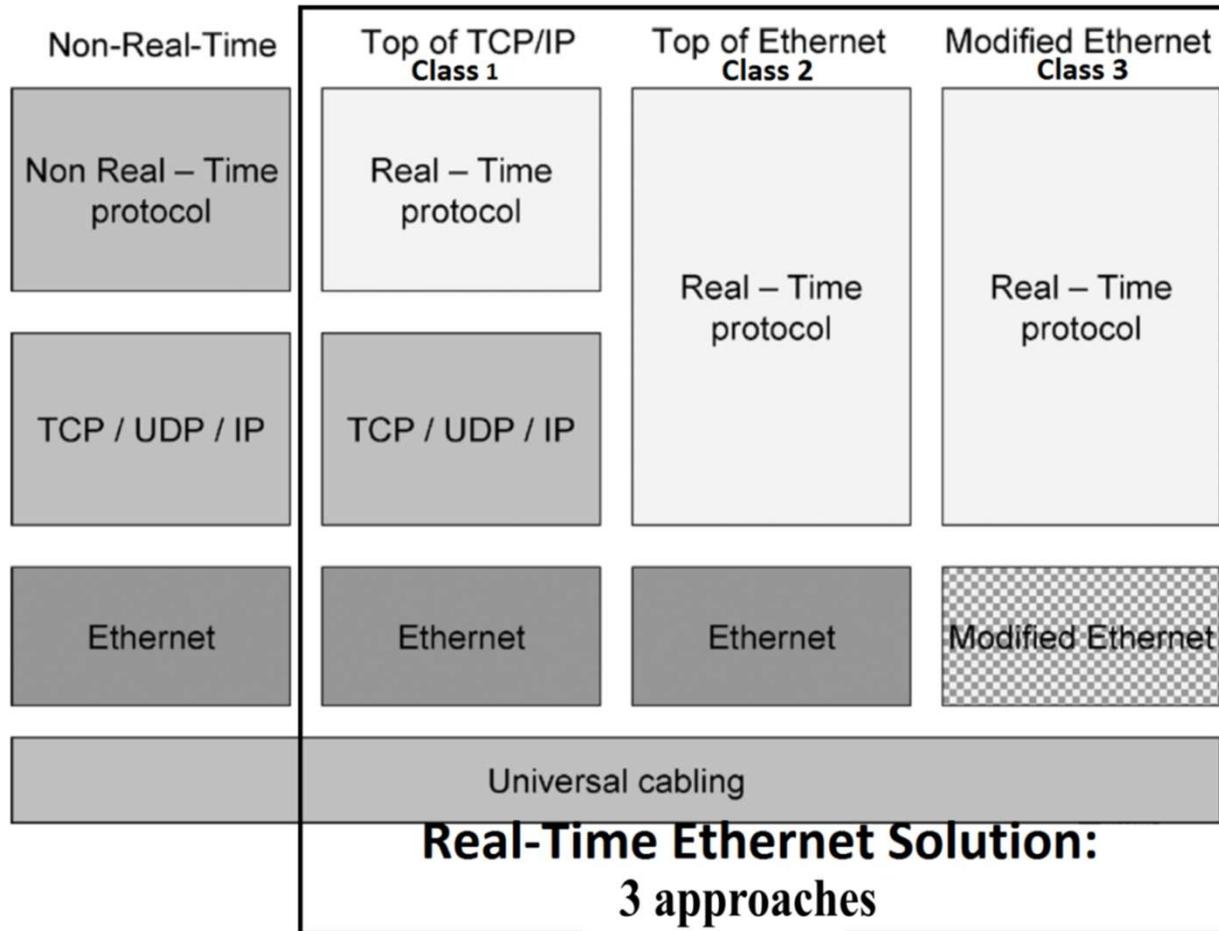
Used for the connection of a "distributed intelligence",

Communication between several PLCs (with each other analog and digital input/output) supporting PROFIBUS-FMS.

Data rate reach up to 12 Mbits/s on Twisted pair : STP, UTP, FTP or optical fiber.



4. Industrial Ethernet



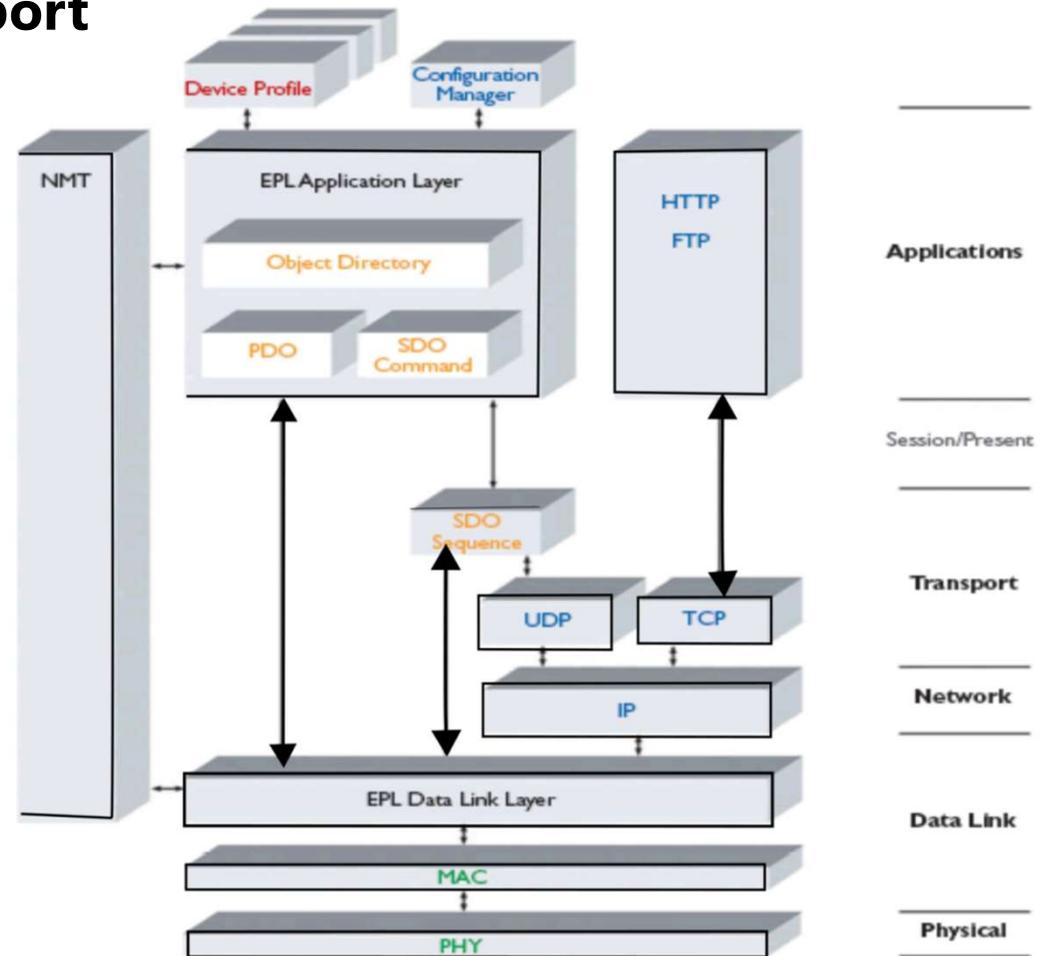
Ethernet protocol is not deterministic
best effort for frames distribution

Industrial reality required time constraints
and need Ethernet evolution.

4. Industrial Ethernet : Powerlink

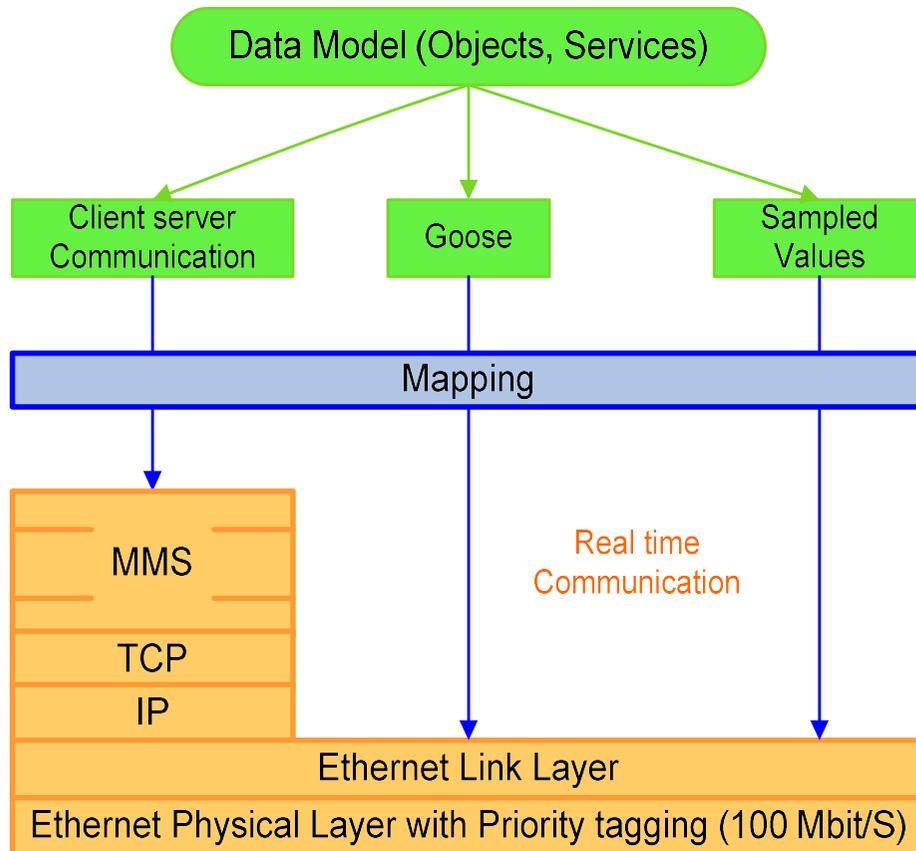


CAN protocol over Ethernet support





4. Switched Ethernet : IEC 61850



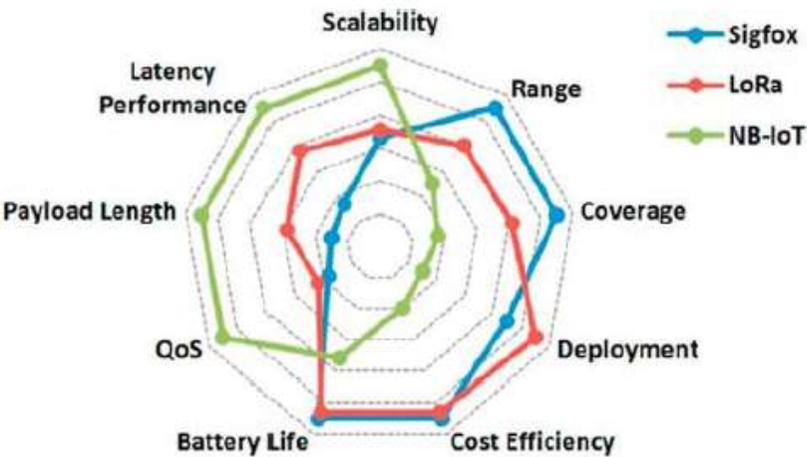
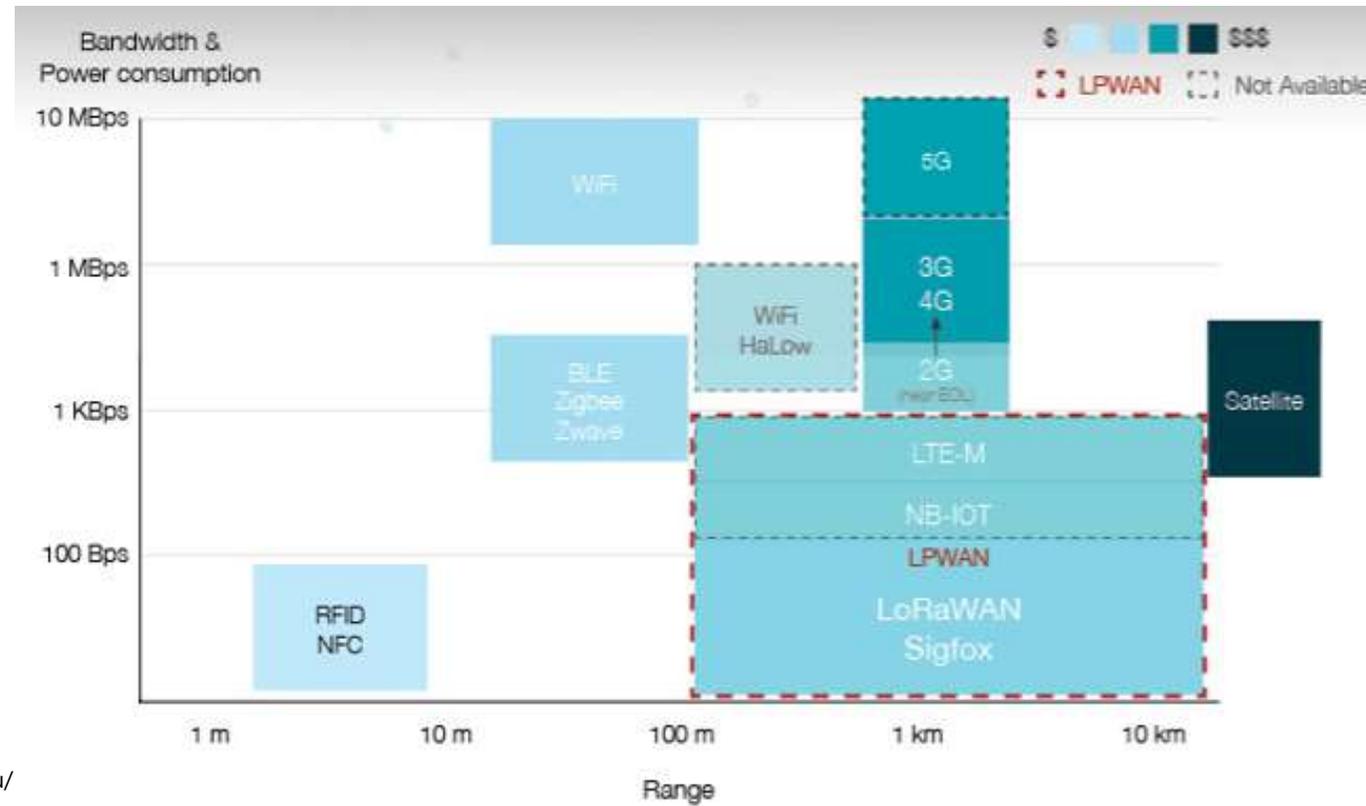
Network for Smart Grids

- Satisfying real-time performance by the standard in developing extension cards that can transmit critical real-time signals at network level
- Development of a new application layer allowing to track the dialogue according to the IEC 61850 standard
- New equipment design playing the role of Ethernet switch/ IEC 61850

5. Wireless network

The main evaluation criteria for Low Power Wide Area Network - LPWAN:

- Range / Coverage
- Deployment / infrastructure cost
- Payload / Latency / Performance
- Consumption (battery life)
- Quality of service / Latency

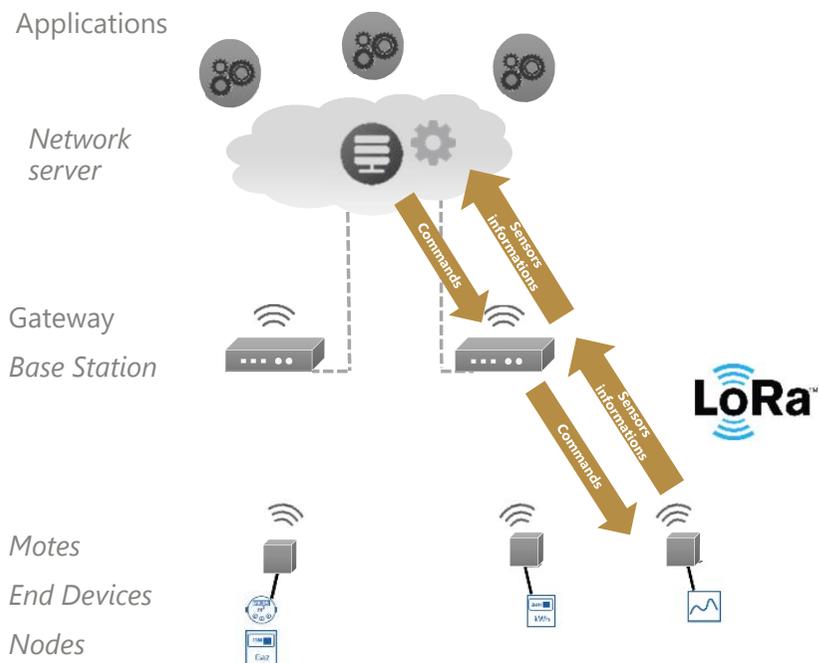


Source <https://iotfactory.eu/>

5. Wireless network



Low Power Wide Area Network LWPAN : LoRa Long Range Wireless Network



Nom	DevEUI	OTA_AppKey	OTA_AppEUI
Temp extérieure	70:B3:D5:E7:5E:00:2F:07	45B36F05429E6B3D74AAAA2A12740***	70B3D5E75F600000
Contact porte	70:B3:D5:E7:5E:00:35:72	49A5495E312BBB614CD354140341***	70B3D5E75F600000
Compteur Gaz	70:B3:D5:E7:5E:00:36:C4	718E1F2F315B0D933DCCC1F725D53***	70B3D5E75F600000
Temp Humidité RDC	70:B3:D5:E7:5E:00:37:F4	7EE54A7745E82D5AAAAE5E3A25B839***	70B3D5E75F600000
Anémomètre	70:B3:D5:E7:5E:00:41:93	23411FF30200BBB560A226527713***	70B3D5E75F600000
Temp Etage 1	70:B3:D5:E7:5E:00:41:B3	1ED153B417E60DF35233CC1C716D4***	70B3D5E75F600000
Centrale de mesure	70:B3:D5:E7:5E:00:44:75	74730B42770D752AAAD1BEA47D53***	70B3D5E75F600000

**Several gateways listening
frequencies Motes messages
Only the gateway with the best signal
sends messages to the network server**

**Sensors Motes
Actuators Motes**



5- Wireless Mbus or LoRa

- Wireless Modbus versus Lora transmetteur



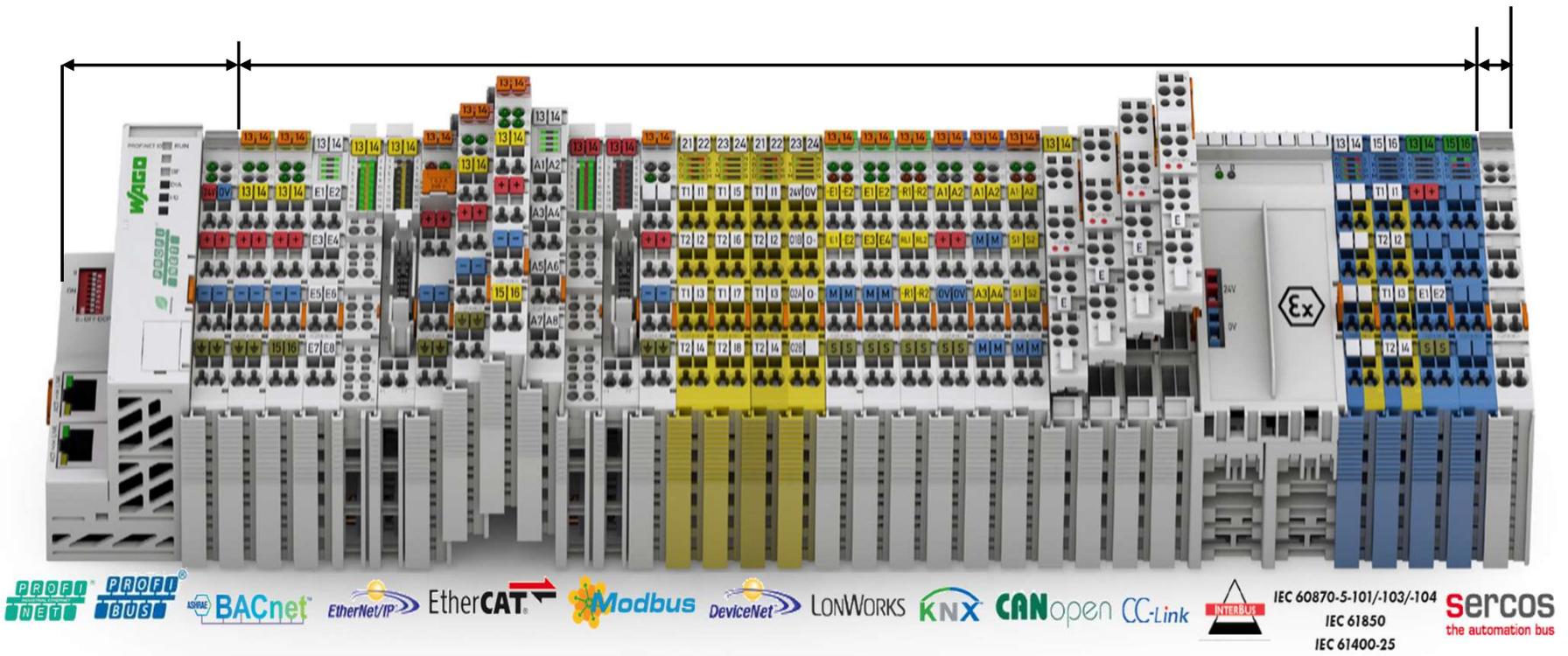


6- Convergent information through various fieldbus network and IT network

❶ PLC Ethernet controller

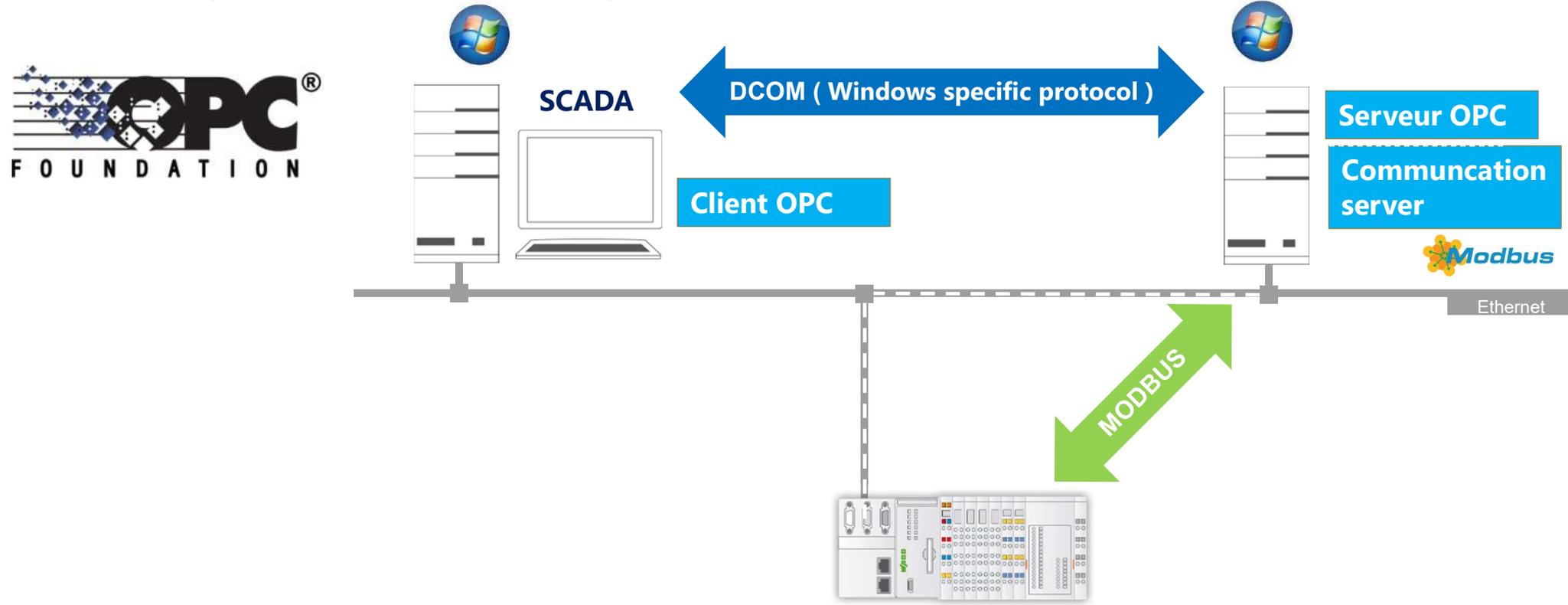
❷ I/O connexions

❸ Borderline



6-1 Open Platform Communications

- First implementation with Microsoft system sharing informations over DCOM for SCADA
 - First reference OPC: O(bject Linking and Embedding) for Process Control
 - Reference (2011) : Open Platform Communications
- OPC standard exchange based on Windows technologies



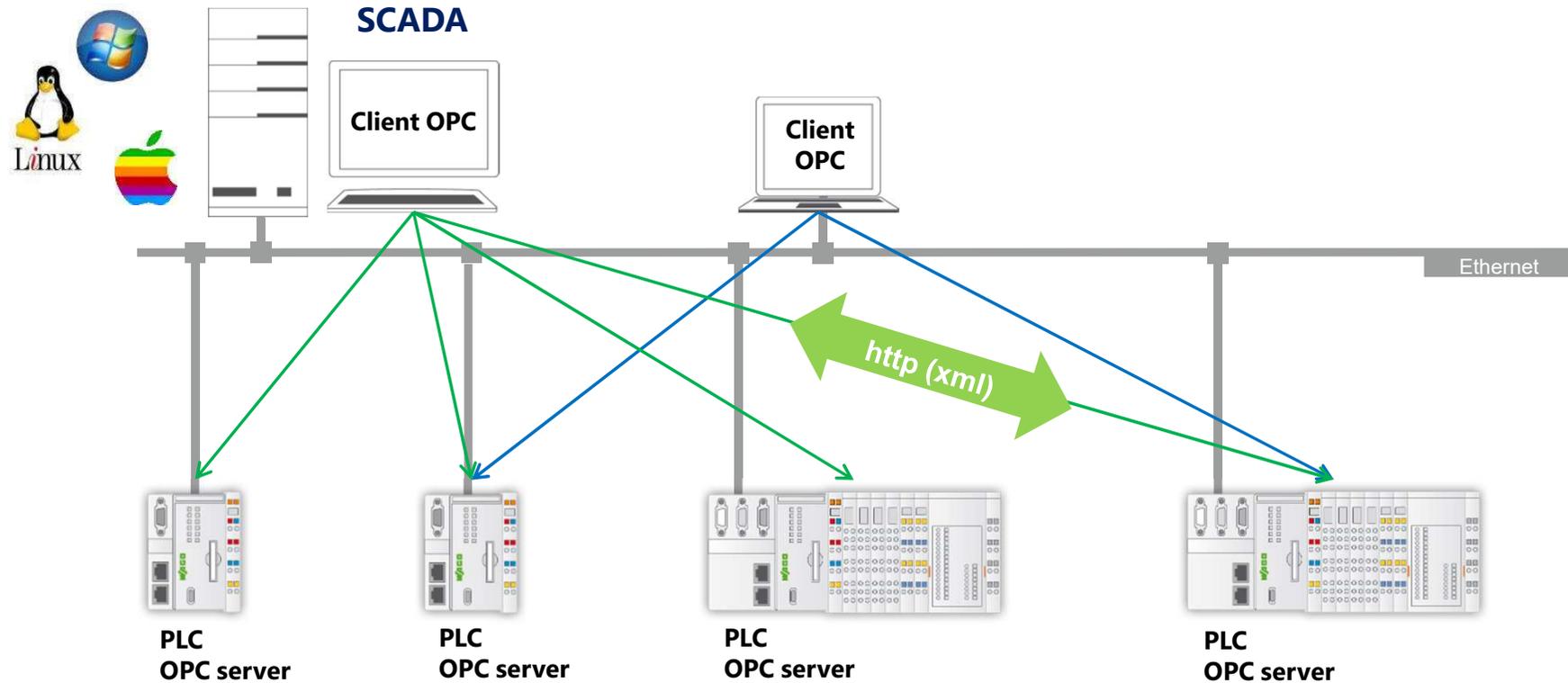


6.2 -OPC Unified Architecture

- **Open Platform Communications - Unified Architecture : OPC-UA**

Objectives :

- Communication protocol abstraction
- No more dependence on Microsoft Windows
- OPC server directly implemented in the PLC equipment



6.3 -Message Queuing Telemetry Transport

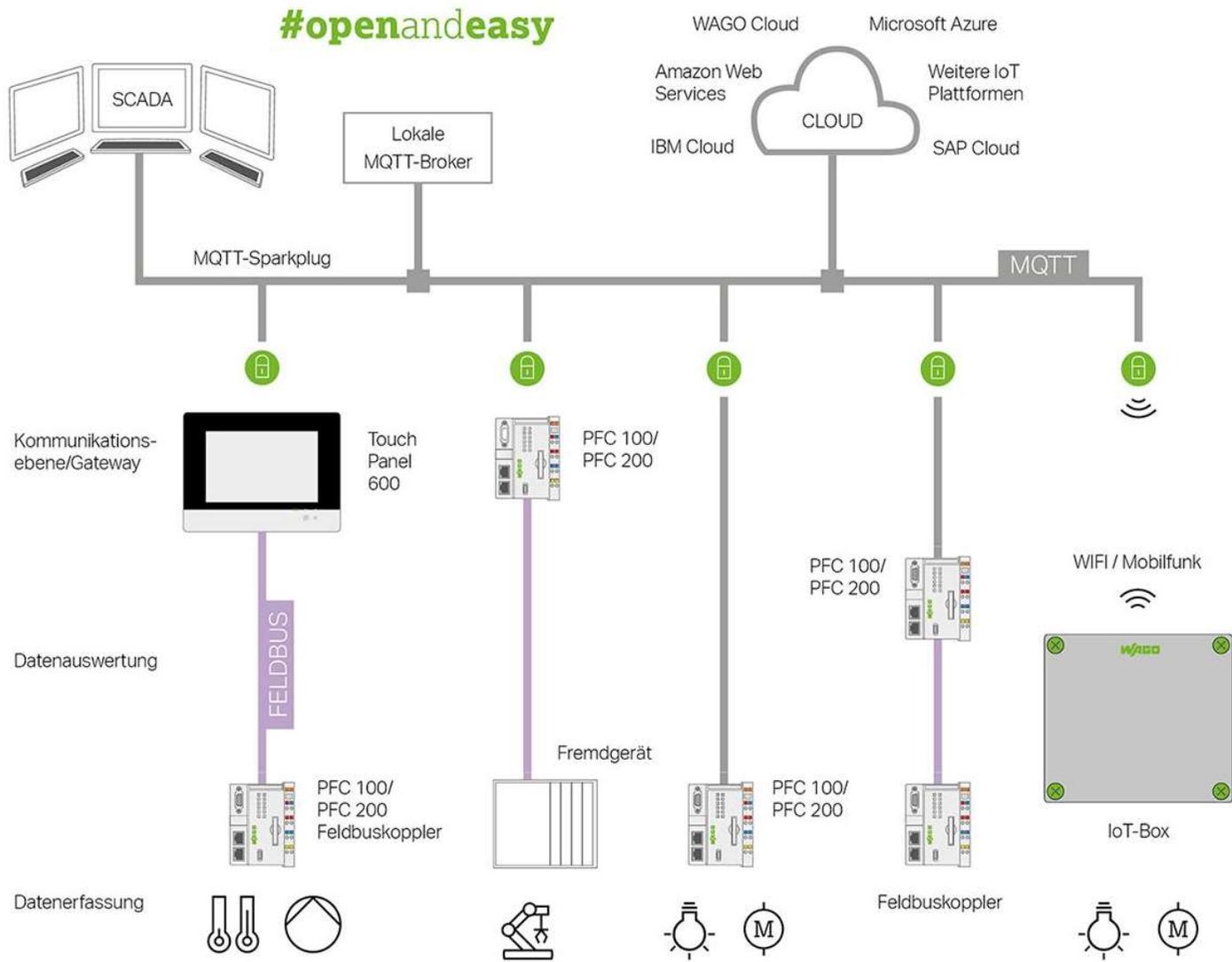
Version :
 MQTT 1.0 (1999)
 ...
 MQTT 3.1.1 (2019)

Publish-subscribe messaging protocol based on the TCP / IP protocol.

Data virtualization over networks and cloud

Proposed by IBM & Eurotech

Asean-Factori 4.0



38 - DGC

UGA Grenoble

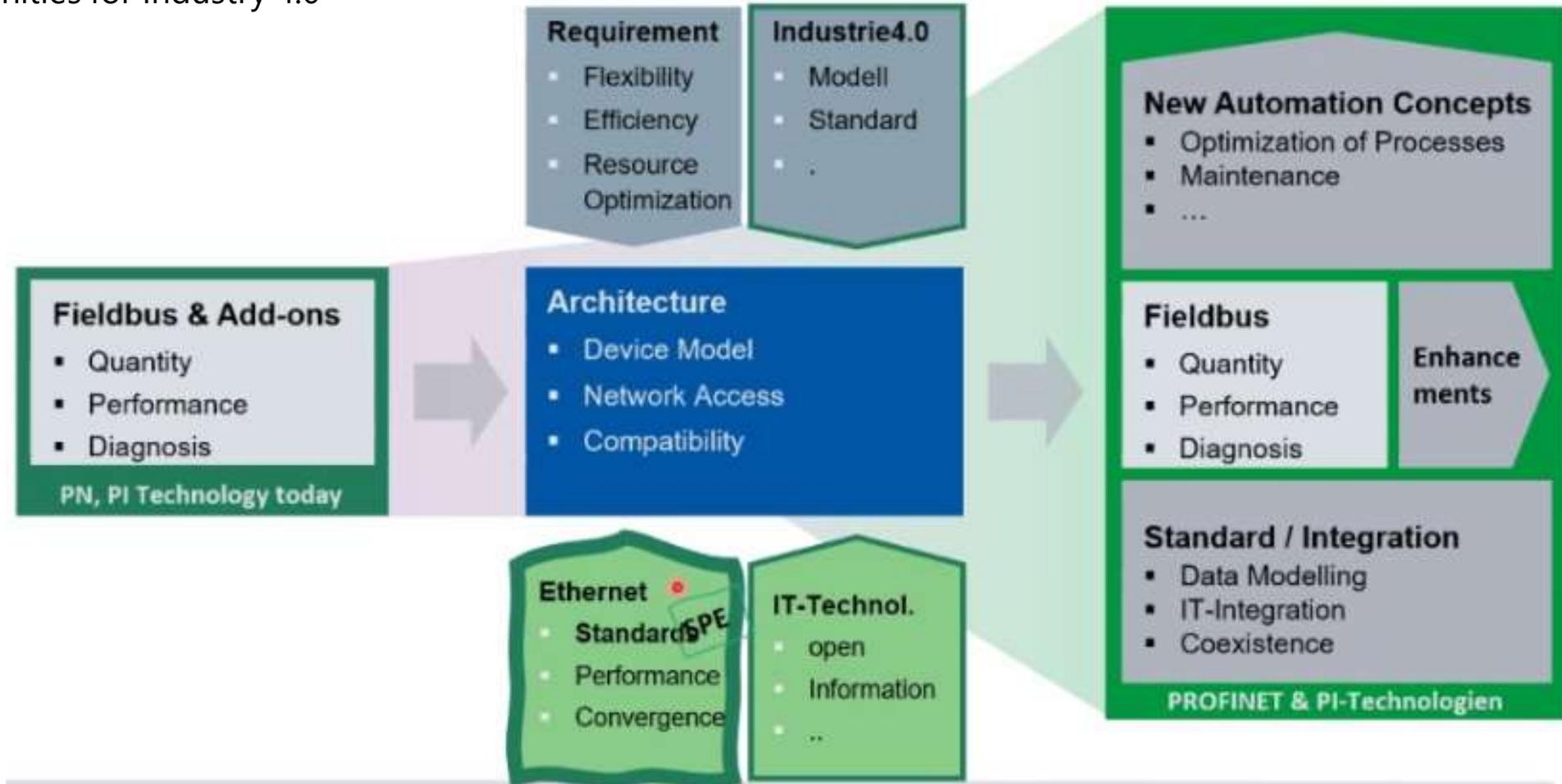
Conclusion



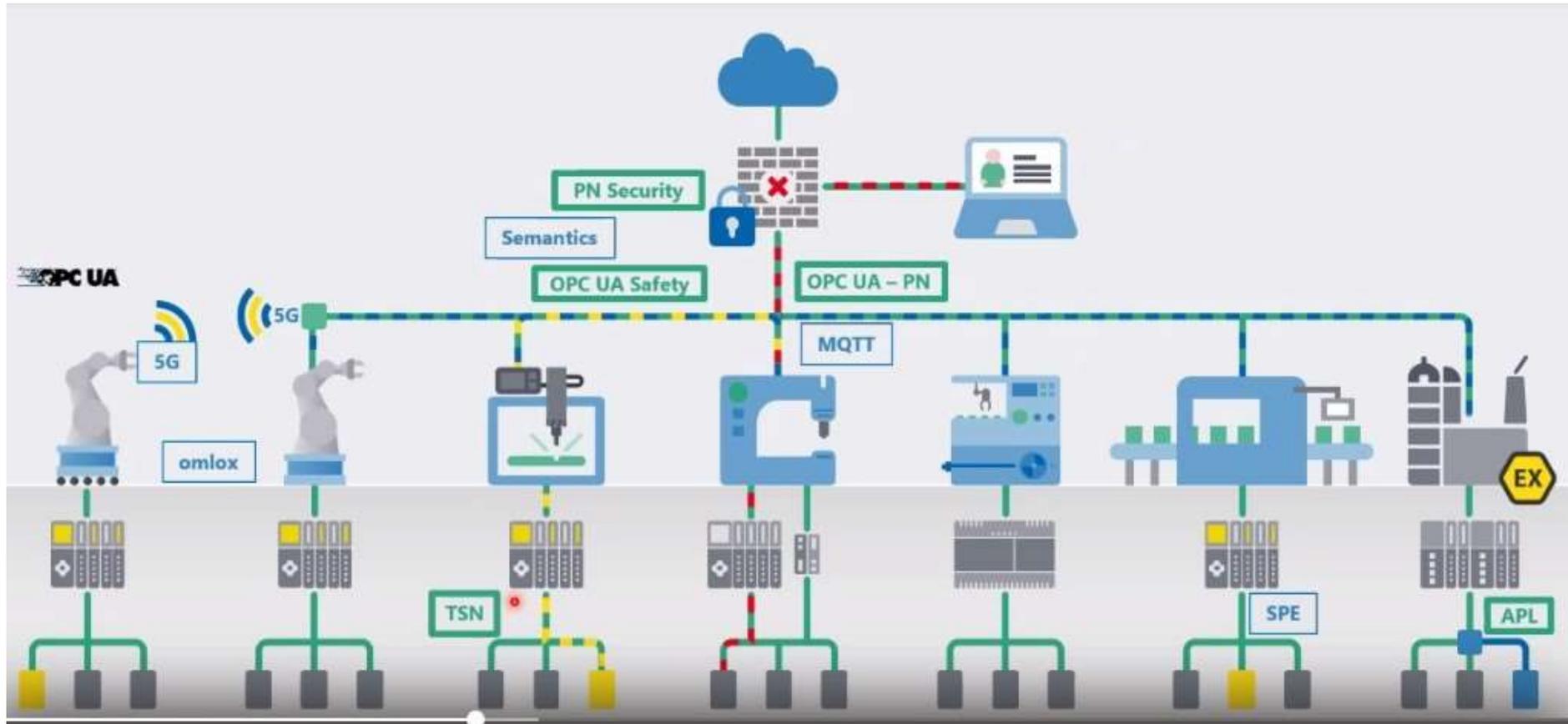
- Industry 4.0
 - Process information's systems
from the process information (sensors, actuators) « the field »
to the higher levels of management (SCADA / IA) for optimization
 - Various functionalities: Production, but also Maintenance, Logistics, Transport
- Based on PLC, Programmable Logic Controller
 - Today dedicated modules ..soon versatile Industrial computer with programs and connectivity
 - Inputs/outputs to be connected to physical processes
 - Communication interface
 - Fieldbus networks, « Industrial networks »,
 - Ethernet networks for supervision
 - Gateways to Cloud devices (virtualization of the control)
- Integration IT (Information Technology) versus ICS (Industrial Control Systems)
- Next course : « Challenges in Dependability/Safety and « Cyber-Security »
Pr Jean-Marc Thiriet

Conclusion

New opportunities for Industry 4.0



Future of industry 4.0



Next PLC architecture network generation will be IP (end to end)

Merci pour votre attention
Merci pour votre attention



Grignan castle

UGA
Université
Grenoble Alpes

**Thank you for
your attention**



Natural bridge over the river

Contact : Denis.genon-catalot@univ-grenoble-alpes.fr