



# Concept of Industry 4.0: PLC network extensions and Real Time Networks

**Asean-Factori 4.0 project**

**Grenoble-Valence , February 2022**

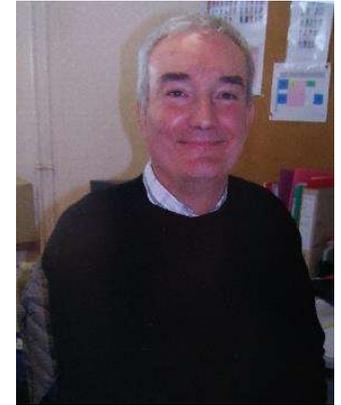
[denis.genon-catalot@univ-grenoble-alpes.fr](mailto:denis.genon-catalot@univ-grenoble-alpes.fr)  
[jean-marc.thiriet@univ-grenoble-alpes.fr](mailto:jean-marc.thiriet@univ-grenoble-alpes.fr)





# 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 $\mu$ , BGLE- ADN4SE,..  
Supervising many industrials PhD : Critical Fieldbus Networks, Smart Buildings, DC autonomous Buildings,..

Contact : [Denis.genon-catalot@univ-grenoble-alpes.fr](mailto: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<sup>e</sup> position over 1000 Universities



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





## Summary :

### **UGA-1 From Sensors to PLC :**

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



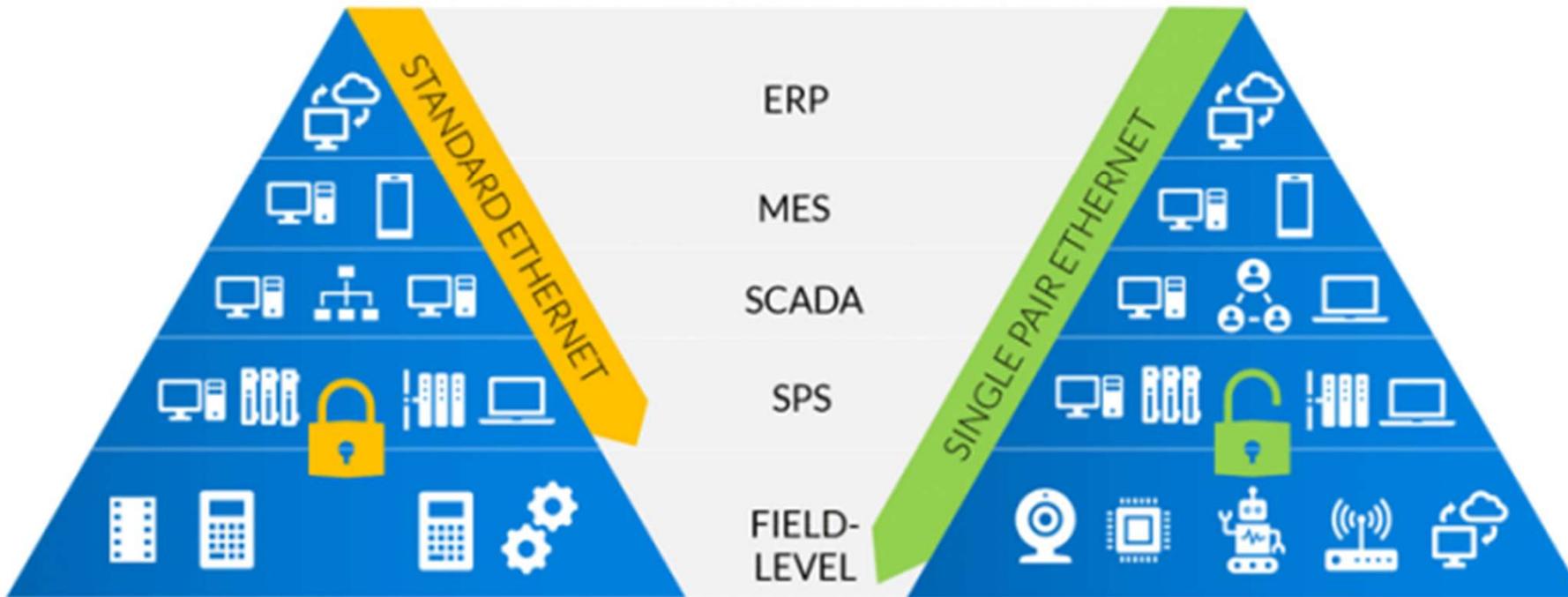
# 2. Automation architecture



Industrial communications will be the common thread of our PLC presentation



# Communications : CIM pyramid

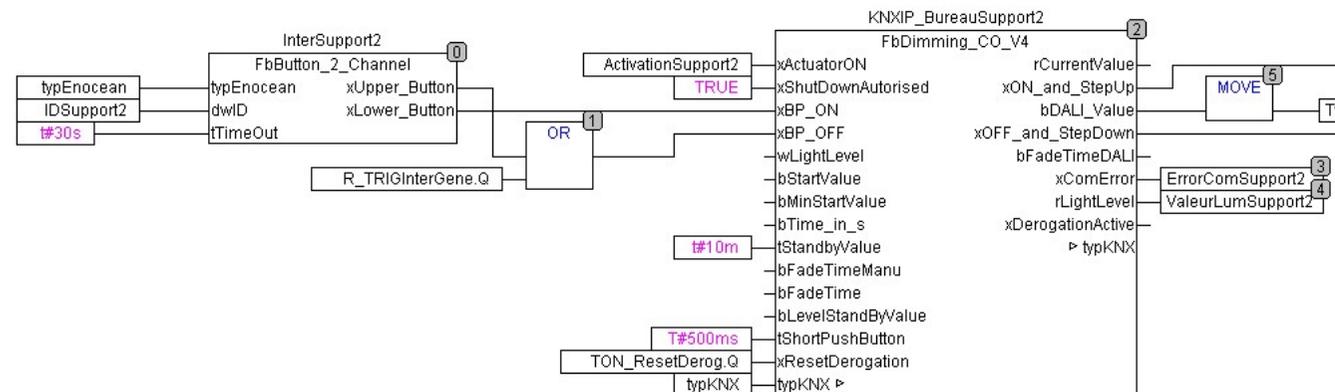
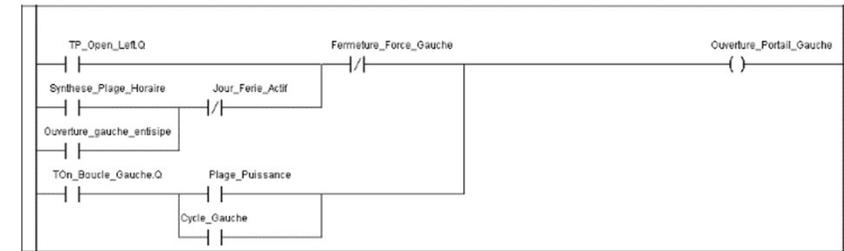
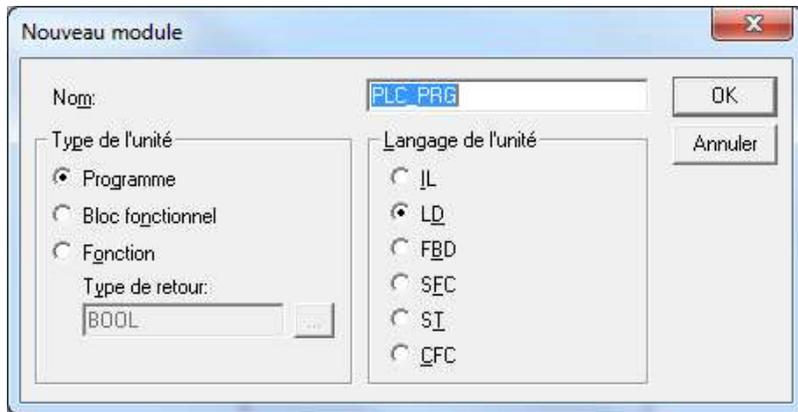


**Computer Integrated manufacturing (CIM)** : Describe integration layers

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



# 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

```

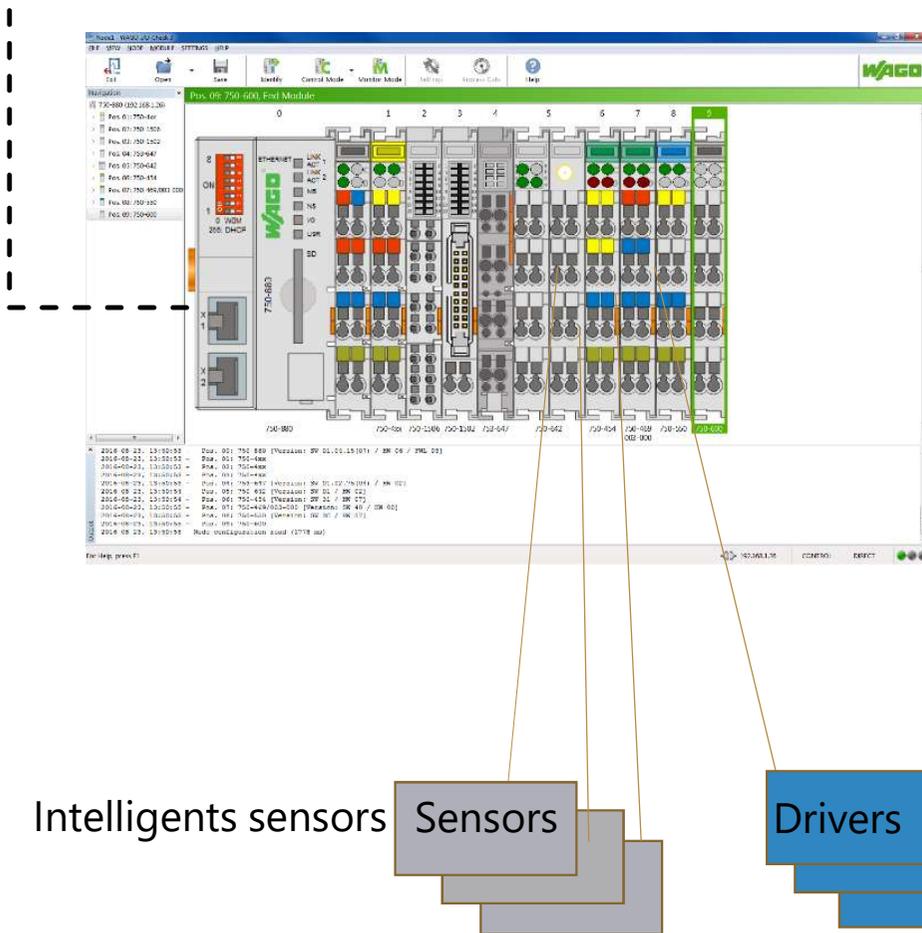
## PLC languages according IEC 61131:

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



# 2.2 Intelligent centralized automation

SCADA



Analog sensors actuators information's become numerical information !

Connexions systems needs to understand each other ....must be more "smart"

Point to point communication protocol with "intelligent" sensors

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

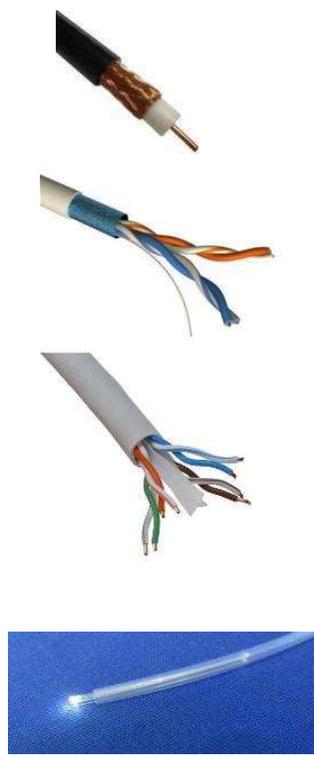


# 2.3 Communication : physical layer

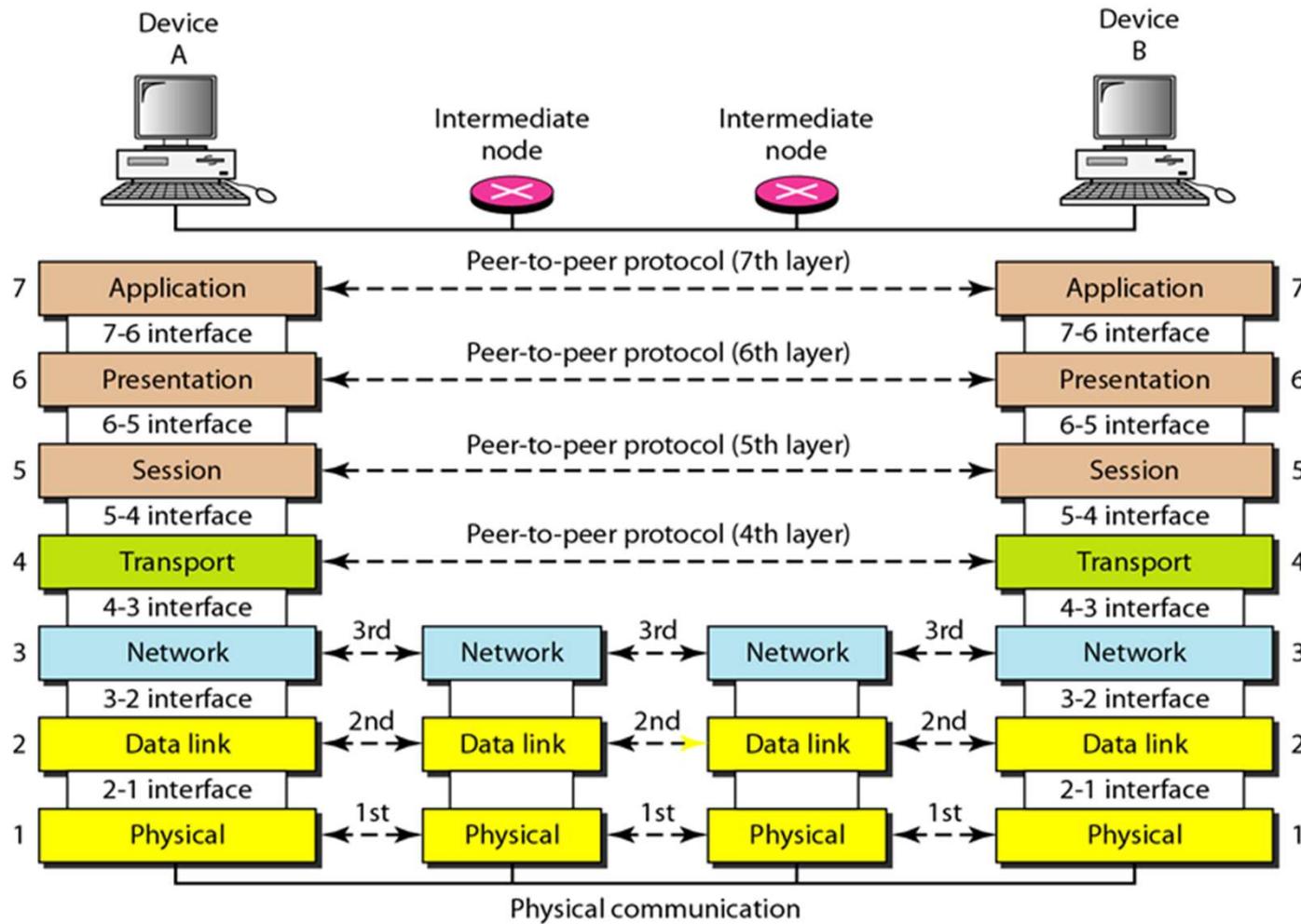
**TIA :**  
Telecommunication  
Industry  
Association  
previously  
**EIA : Electrical**  
Industry Association

**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
<b>Interface</b>	Bipolar	Differential	Differential	Current Loop
<b>Signal level</b>	± 25 V max	± 5 V	± 5 V	0-20 mA
<b>Sensibility</b>	± 3 V	± 0,2 V	± 0,2 V	± 0,4 mA
<b>Distance</b>	10 to 15 m	1200 m	1200 m	1 to 2 km
<b>Maximum throughput</b>	19200 bds	10 Mbds	10 Mbds	19200 bds
<b>Multipoint</b>	Point to point	Point to multipoint	Point to multipoint	Point to multipoint
<b>Nb. Transmitter</b>	1	1	32	
<b>Nb. Receivers</b>	1	10	32	

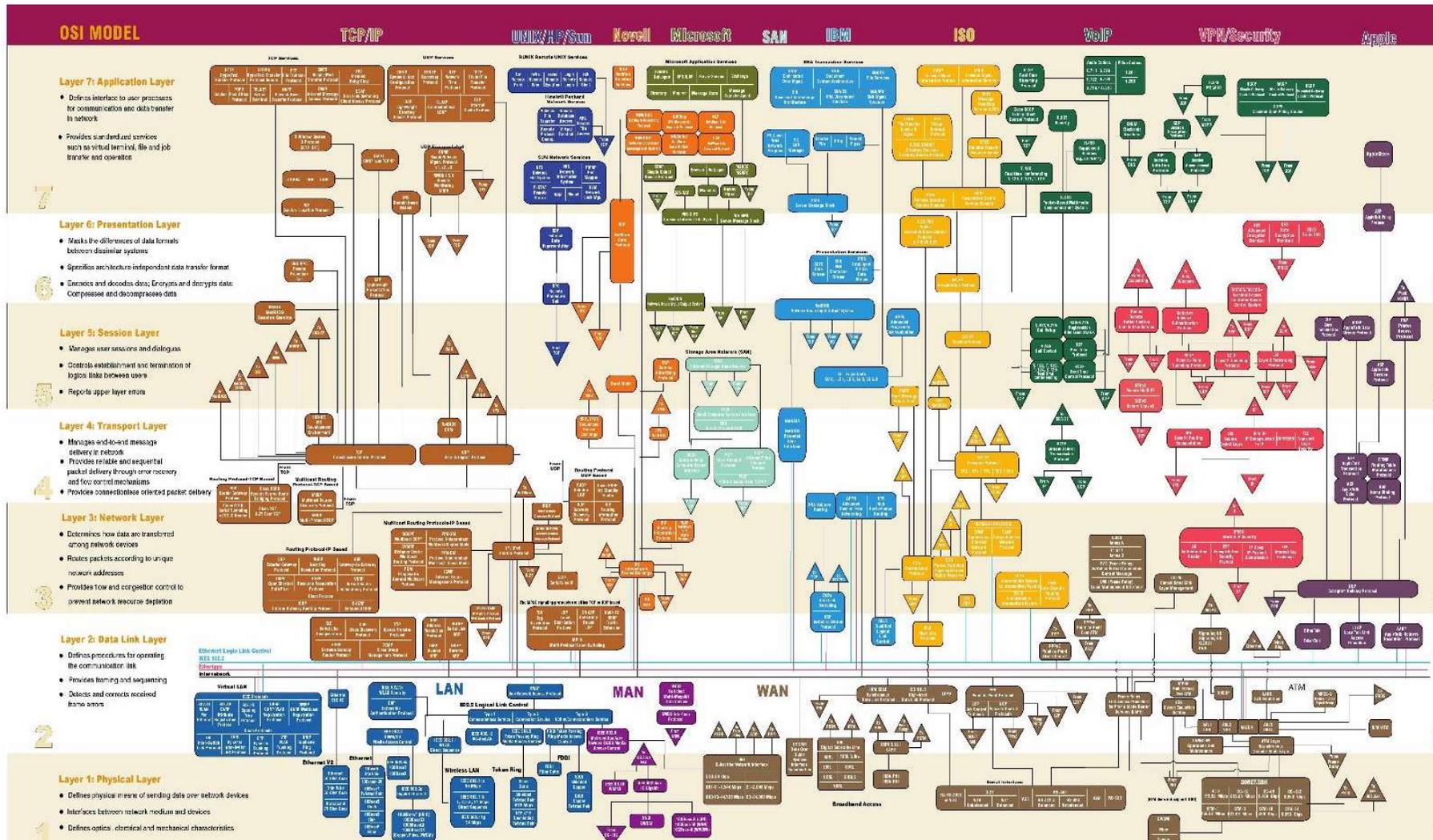


# 2.4 Point to point connexion





# 2.5- Network layers protocols map





## Network Models

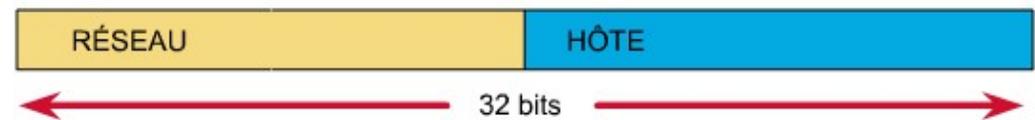
TCP/IP MODEL	OSI MODEL	PROTOCOLS
Application Layer	Application Layer	FTP,HTTP,Telnet
	Presentation Layer	JPEG,MPEG
	Session Layer	NFS,SQL,PAP
Transport Layer	Transport Layer	TCP,UDP
Network Layer	Network Layer	IPv4,IPv6
Network Access Layer	Data Link Layer	ARP,CDP,STP
	Physical Layer	Ethernet,Wi-Fi

# Adressage IP

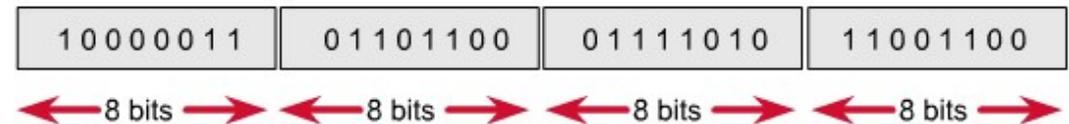


- Adresse Internet Protocole (Version 4 -) :

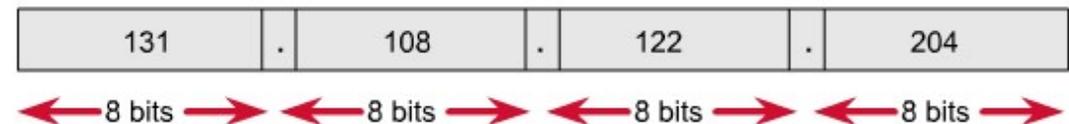
- 32 bits address encoded (4 bytes)
- Split in 2 complementary parts :
  - Network reference number network()
  - Unit/machine host number (host)



- Division en groupe de 8 bits (1 octet) séparé par des points

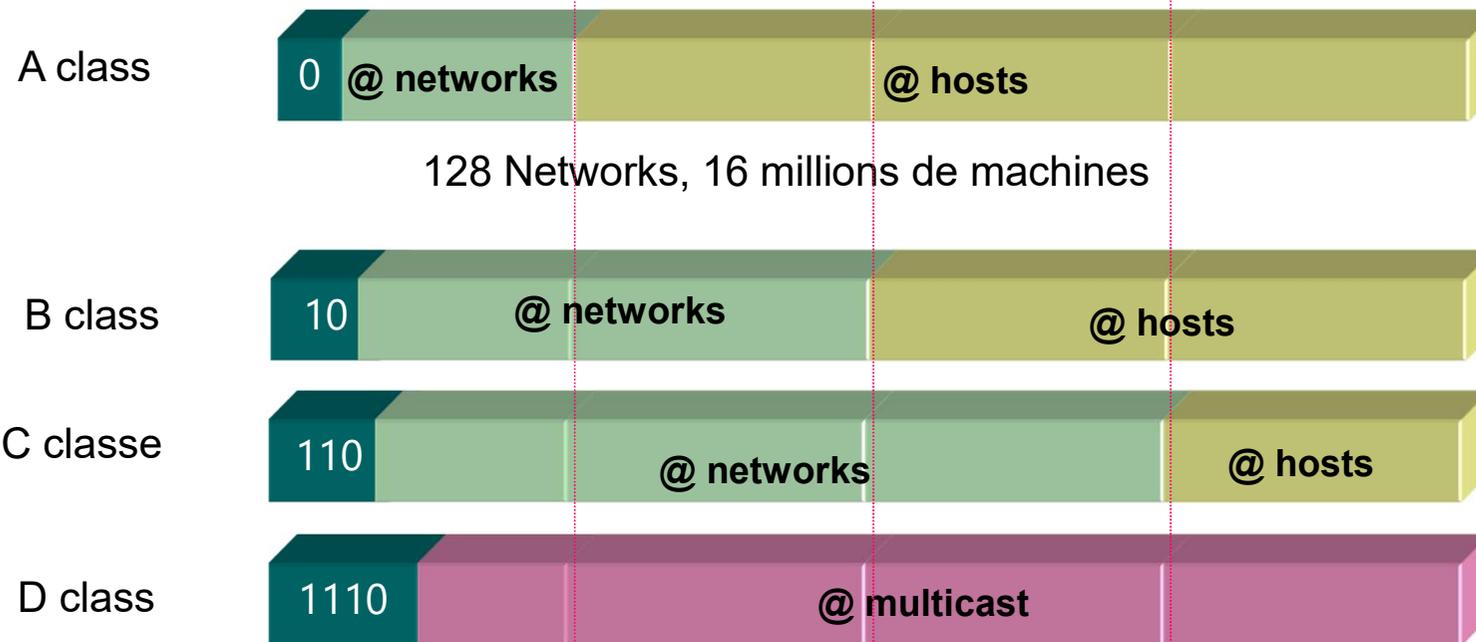


- Par souci de simplicité, représentation au format décimal





# Internet Protocol addresses classes



Dedicated adress: for example in classe A: 0.0.0.0

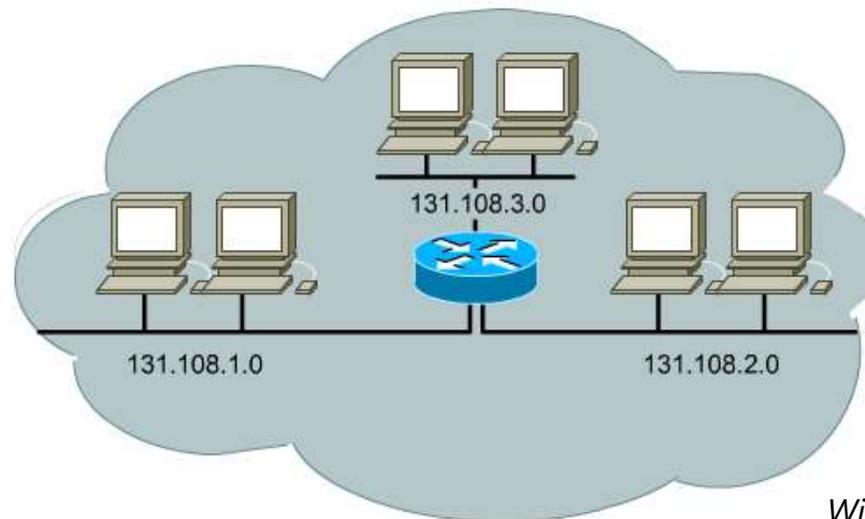
loopback adresse in class A: 127.0.0.0

Broadcast adress : class A: X.255.255.255



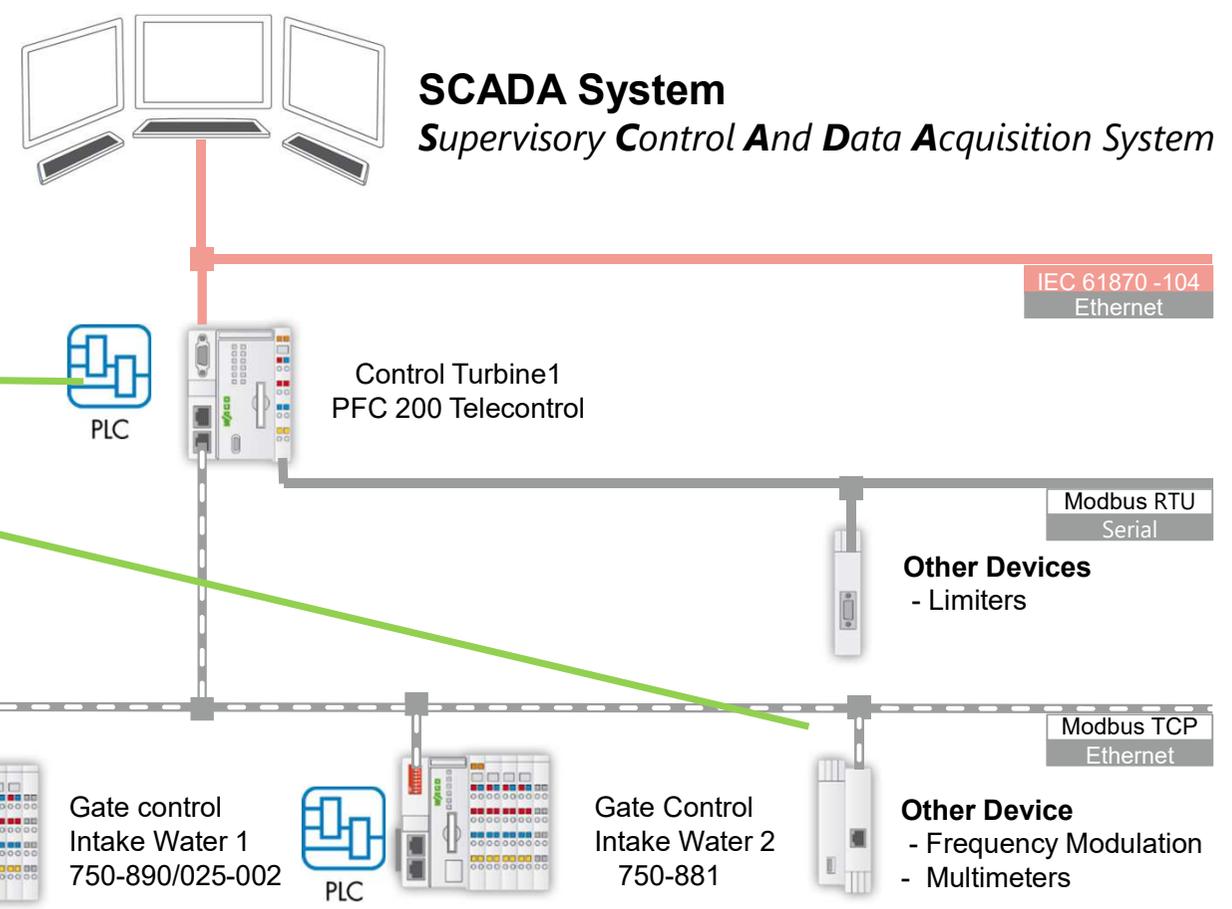
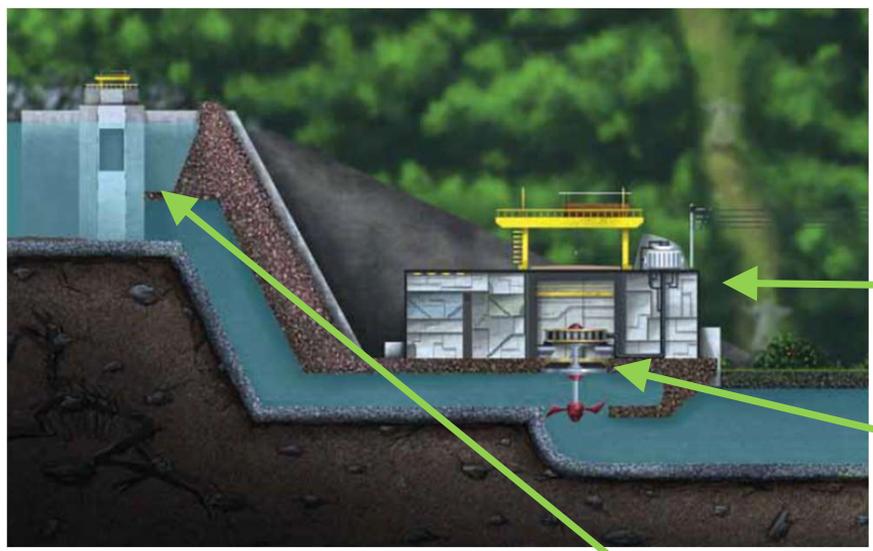
# IP Subnets network exemple

- Exemple:
  - **B class** with IP address : **131.108.0.0**,
  - We want to split or local area network (LAN) in **3 subnets class network with the adress :**
    - 131.108.1.0
    - 131.108.2.0
    - 131.108.3.0



*With the courtesy – JMT- UGA Mistre*

# Small Hydro Power Plant : Automation Architecture

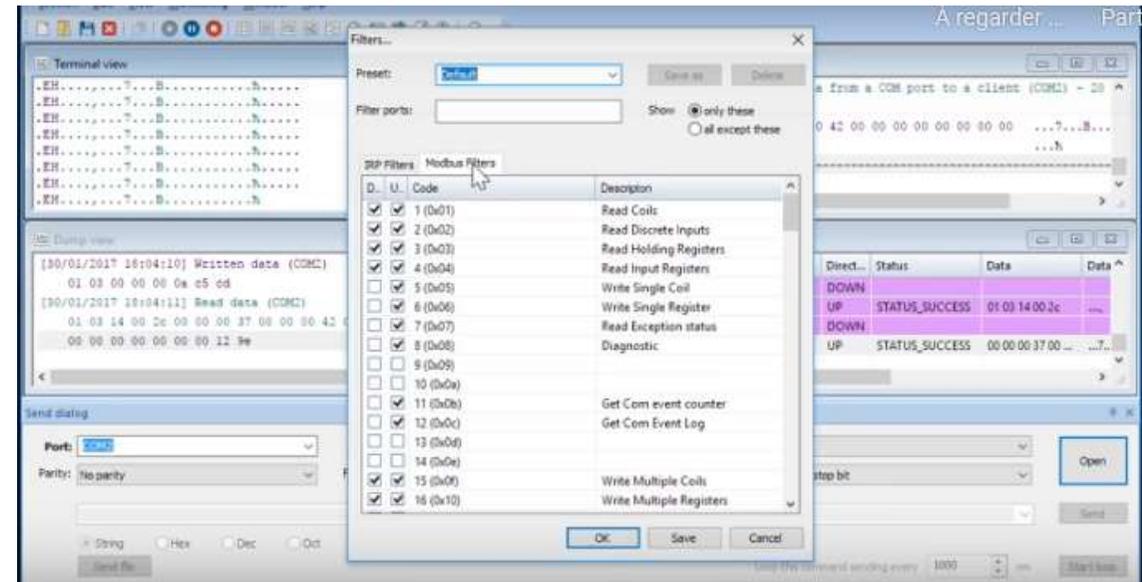
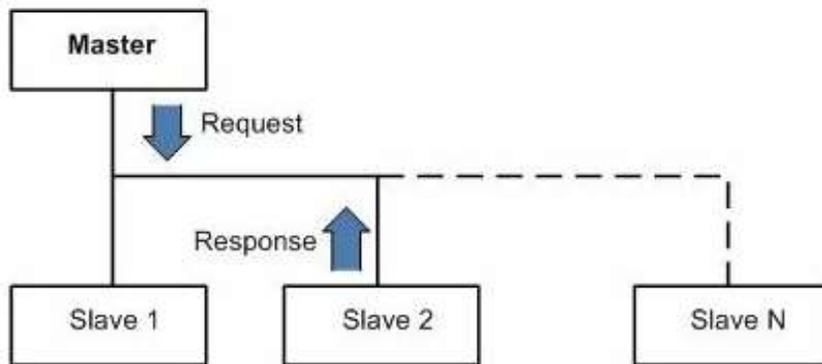




# 2-7 ModBus Protocol



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



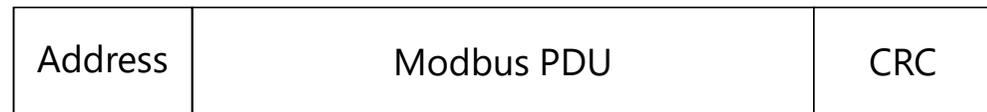
# 2.10- Modbus frames

## Basic Frame layer Link layer independent

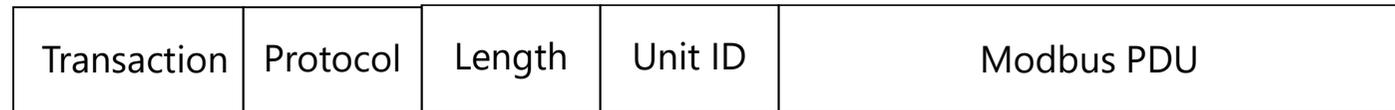
- PDU :  
(Protocol Data Unit)



- ADU : RTU  
(Application Data Unit)

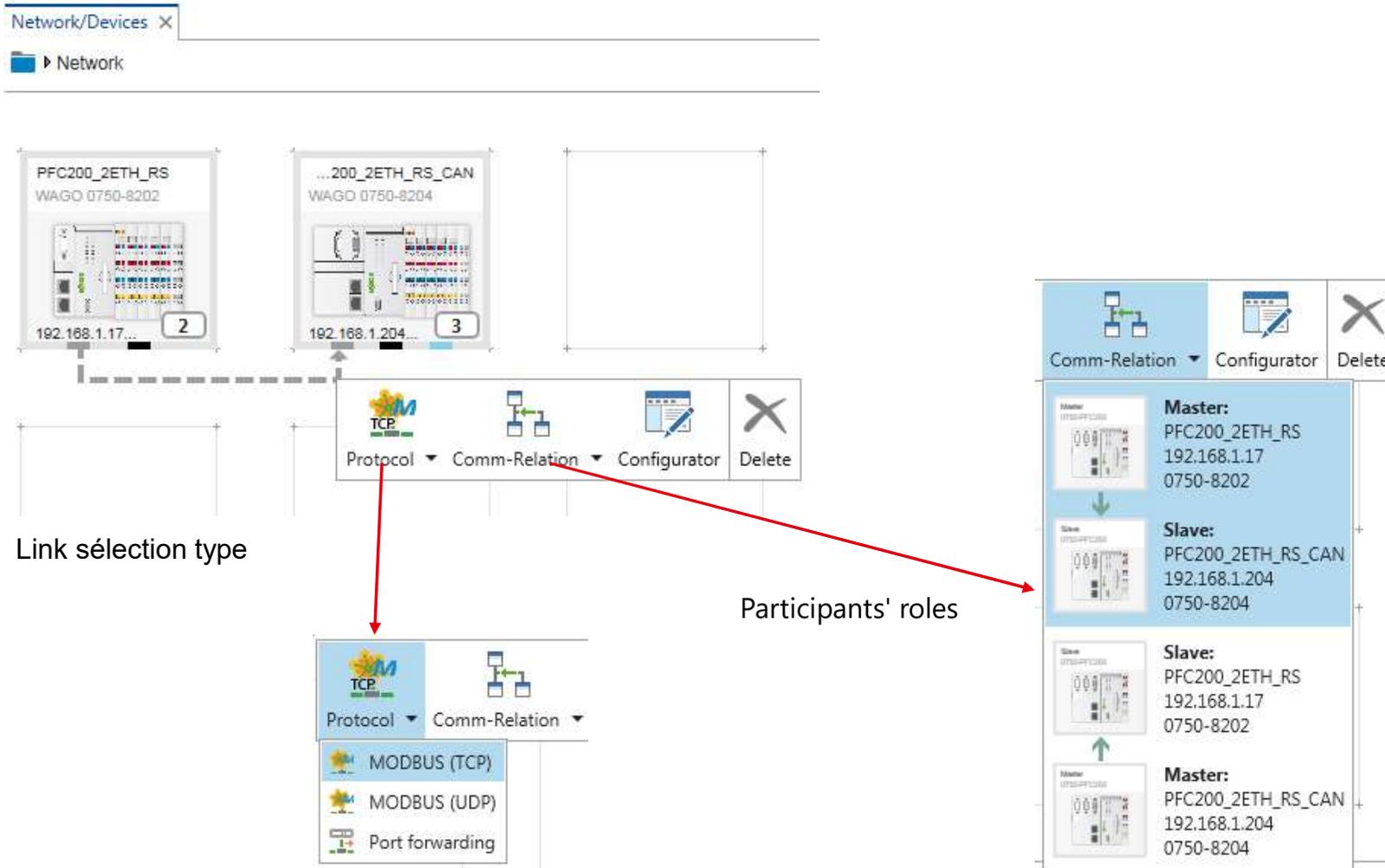


- ADU : TCP



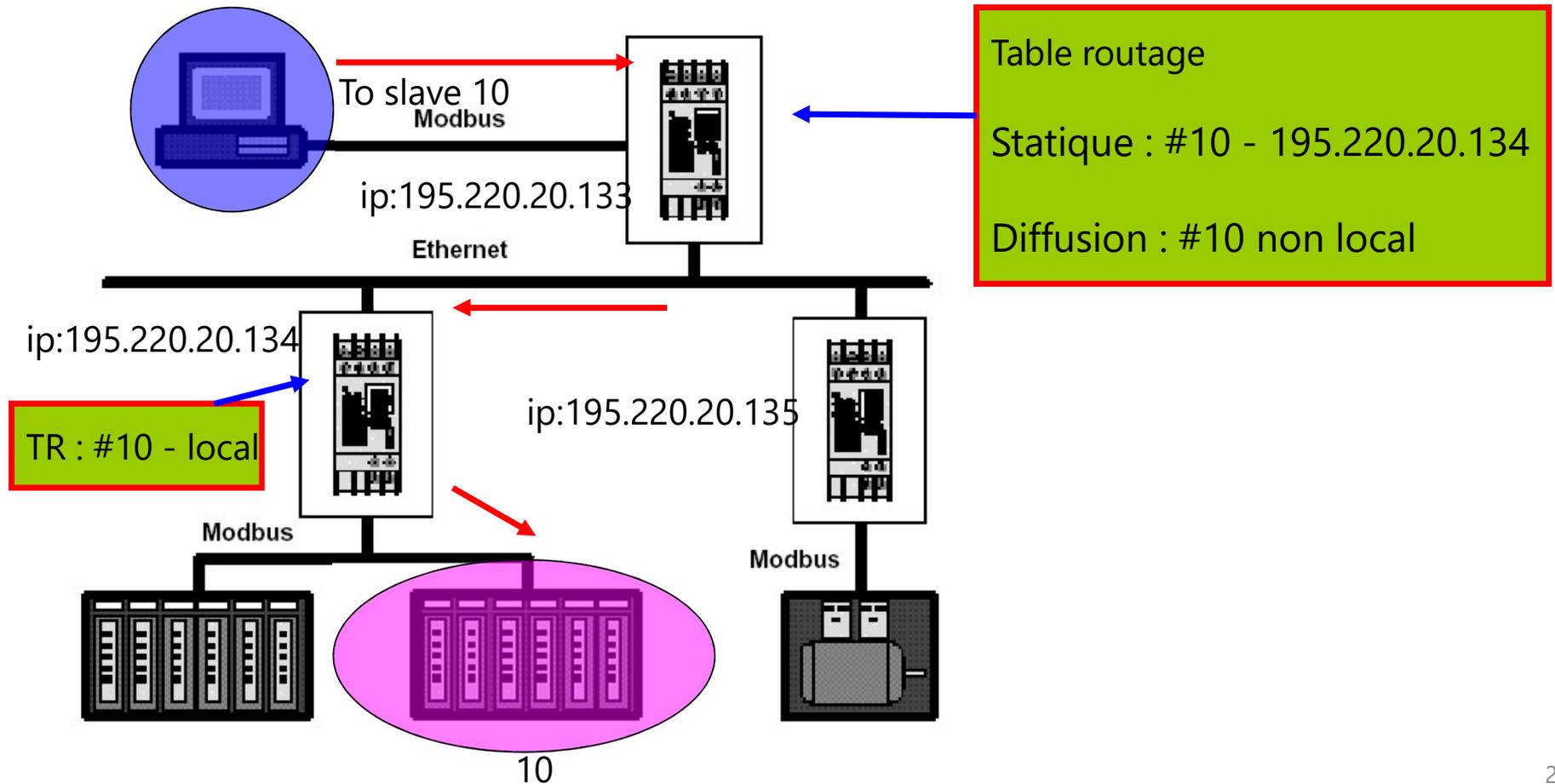
(Transmission Control Protocol  
.....over Internet Protocol)

# 2-9 Modbus – Simple configuration link layer





# 2.11- Modbus bridging



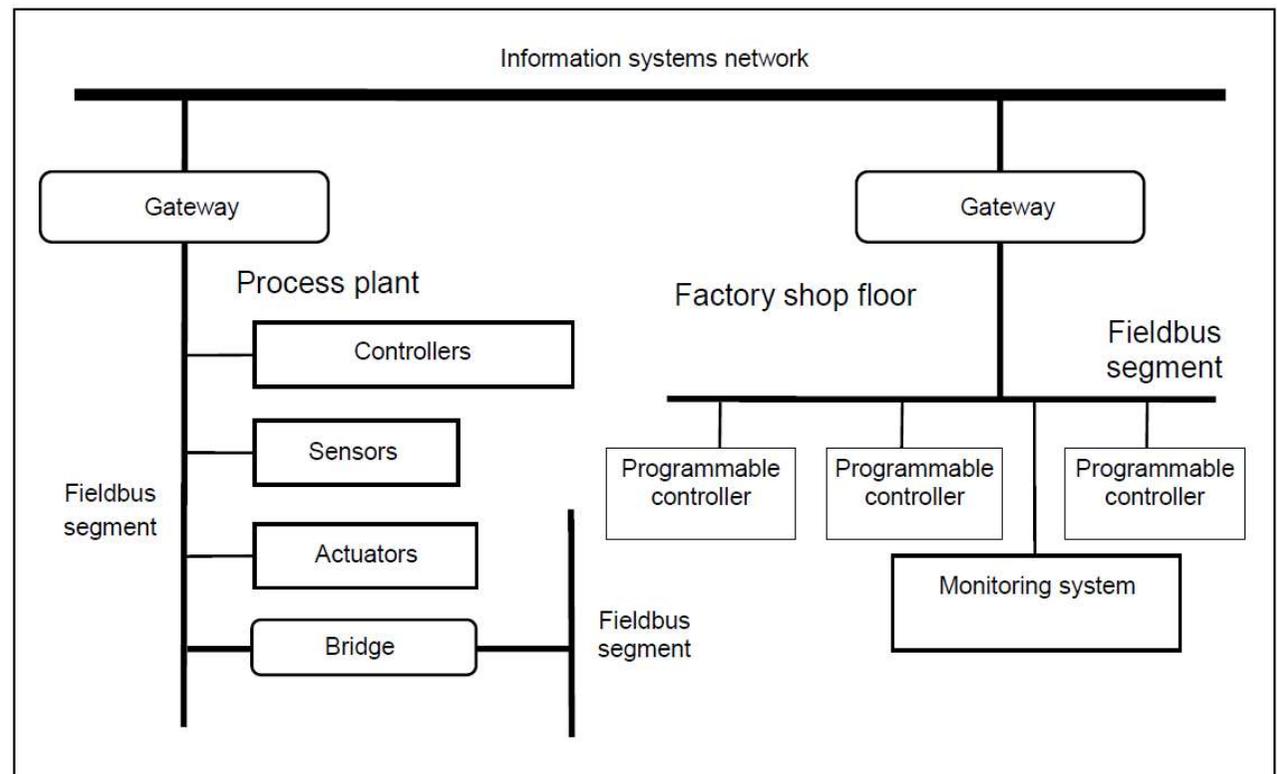
# 3-Fieldbus specifications : IEC 61158/ 61784 series

## Industrial communication networks

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



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)

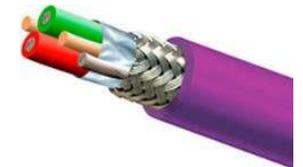
For highly communicative tasks, the Profibus-FMS (Field bus Message Specification) protocol, which is particularly complex, was specified.



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.

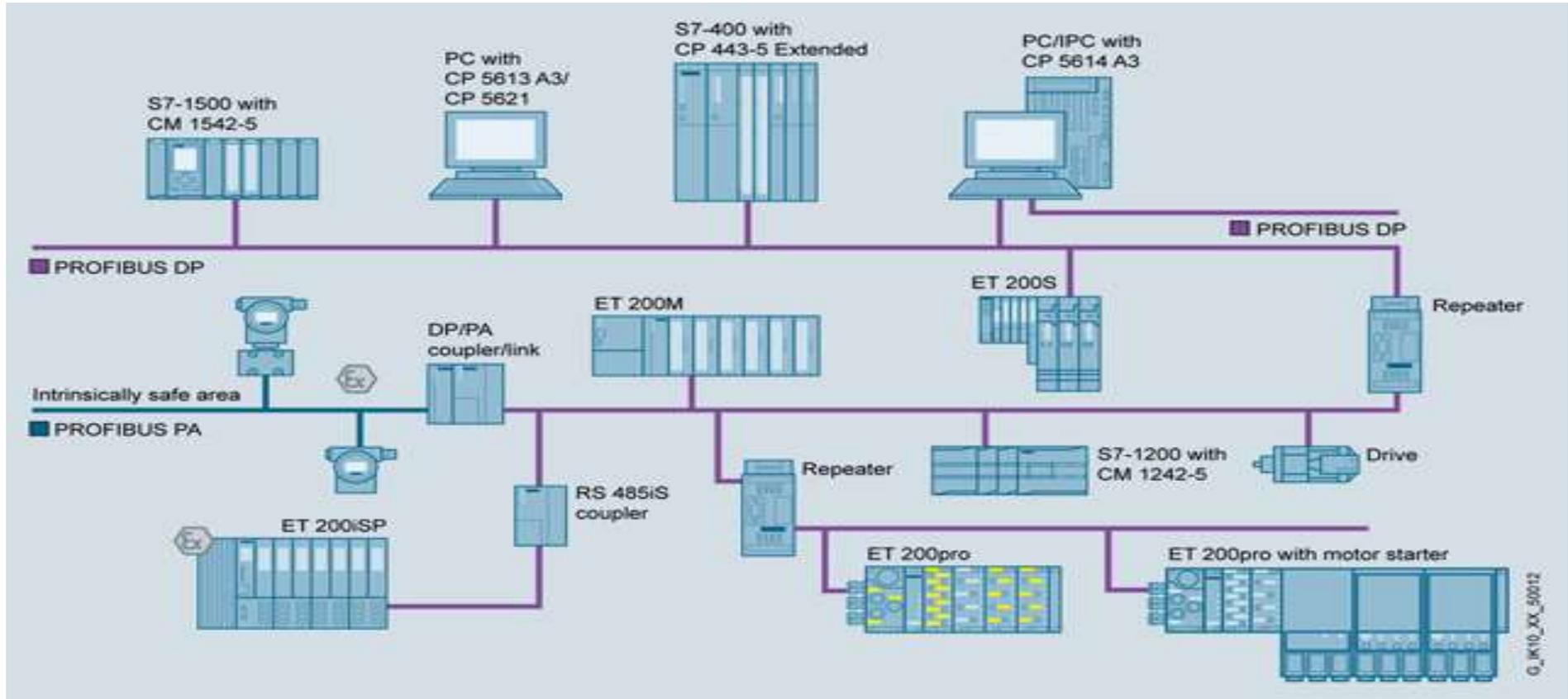
Communication over twisted pair RS-485 type (characteristic impedance 150 ohms)  
Data transmission support numerical base band in NRZ mode on physical medium.



# 3.3 Profibus DP/ PA



Bus or tree topology with repeaters  
RS-485 transmission line





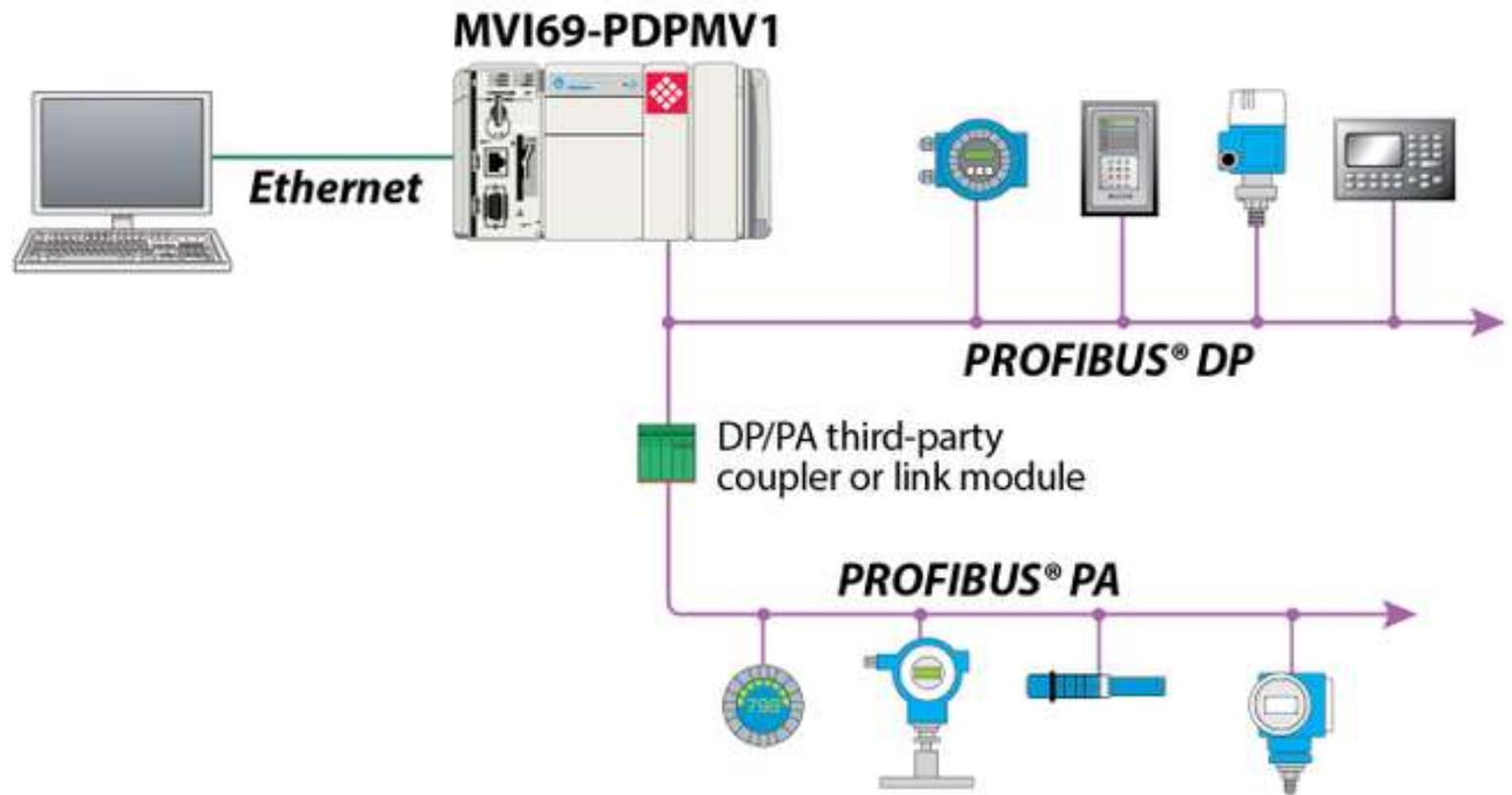
# 3.4 Profibus DP : Ethernet version

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

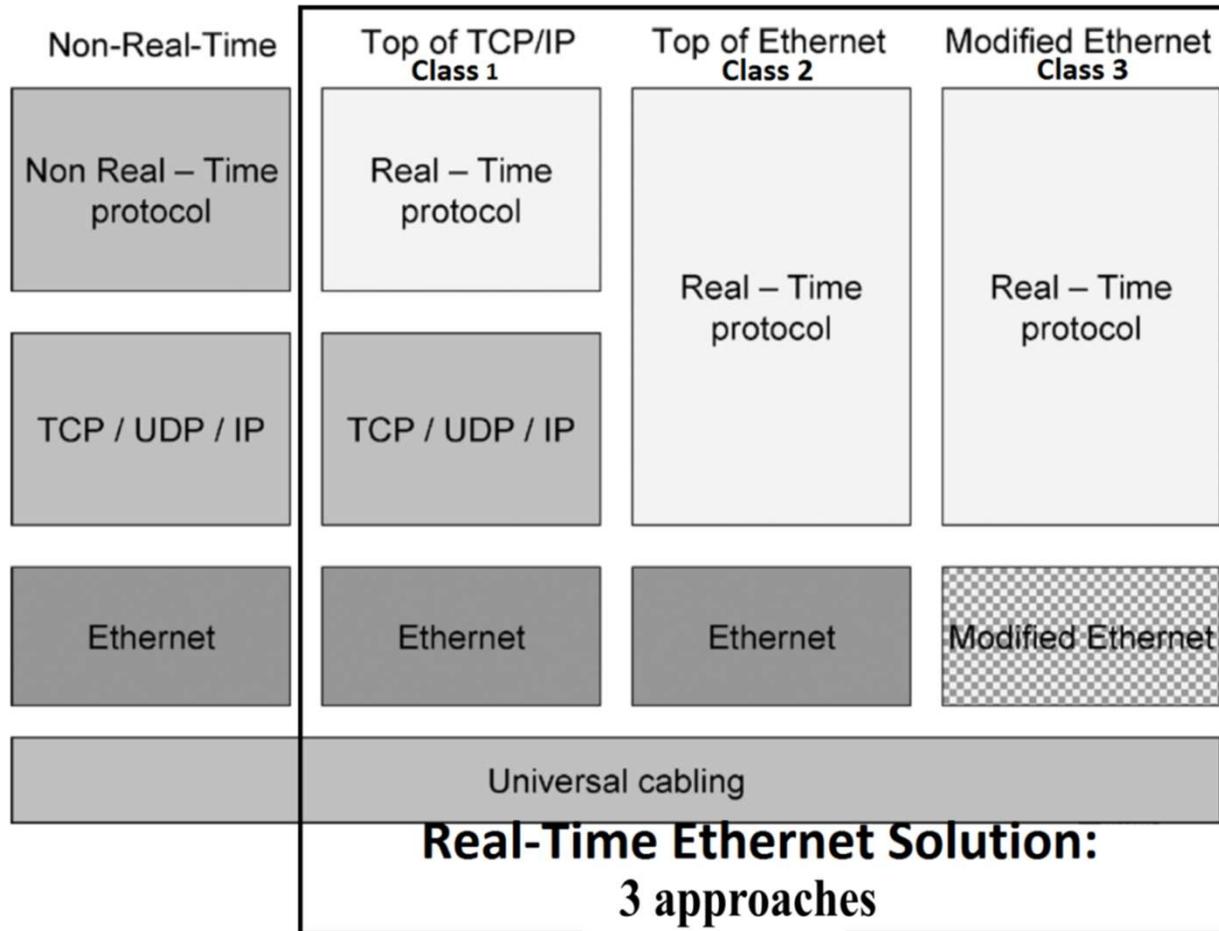
Used for the connection of a "distributed intelligence",

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



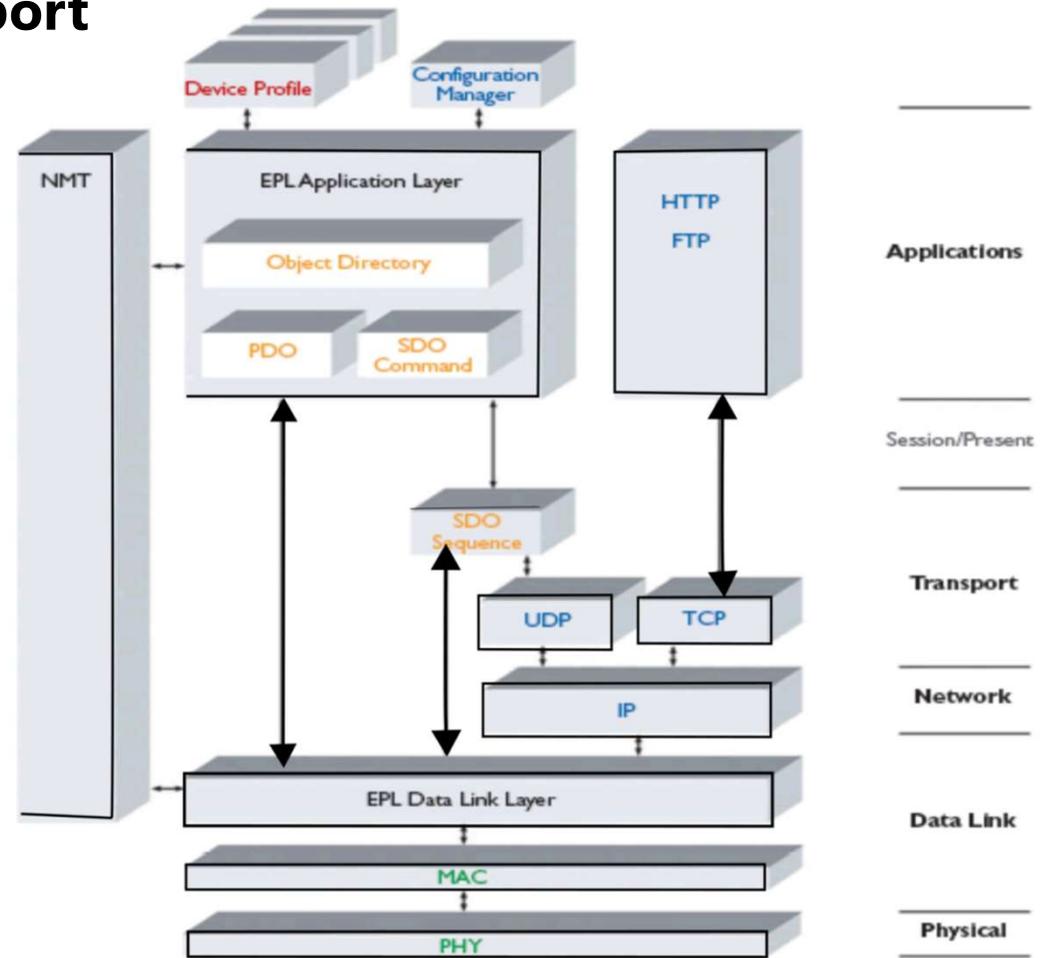
Ethernet protocol is not deterministic  
best effort for frames distribution

Industrial reality required time constraints  
and need Ethernet evolution.

# 4. Industrial Ethernet : Powerlink

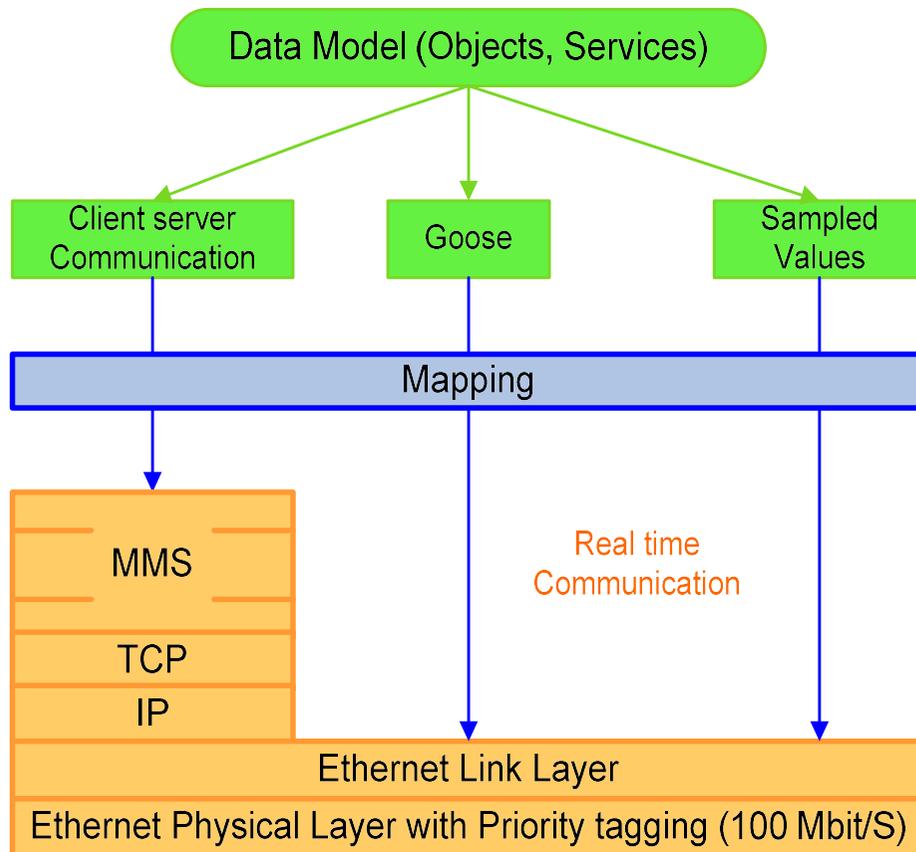


## CAN protocol over Ethernet support





# 4. Switched Ethernet : IEC 61850



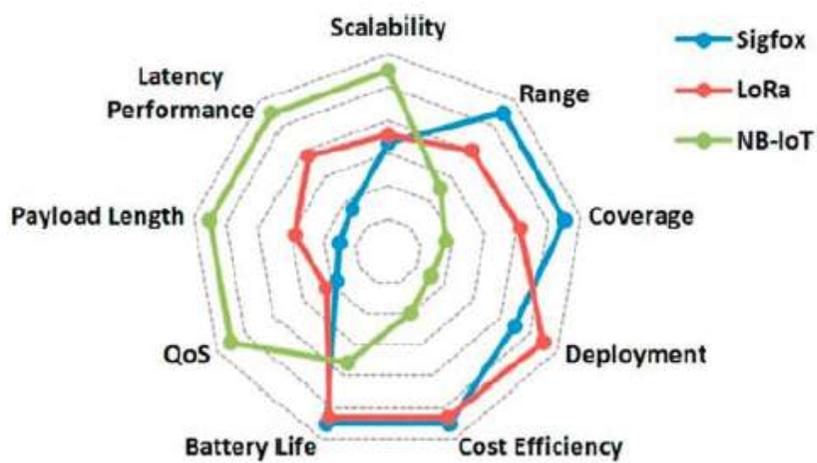
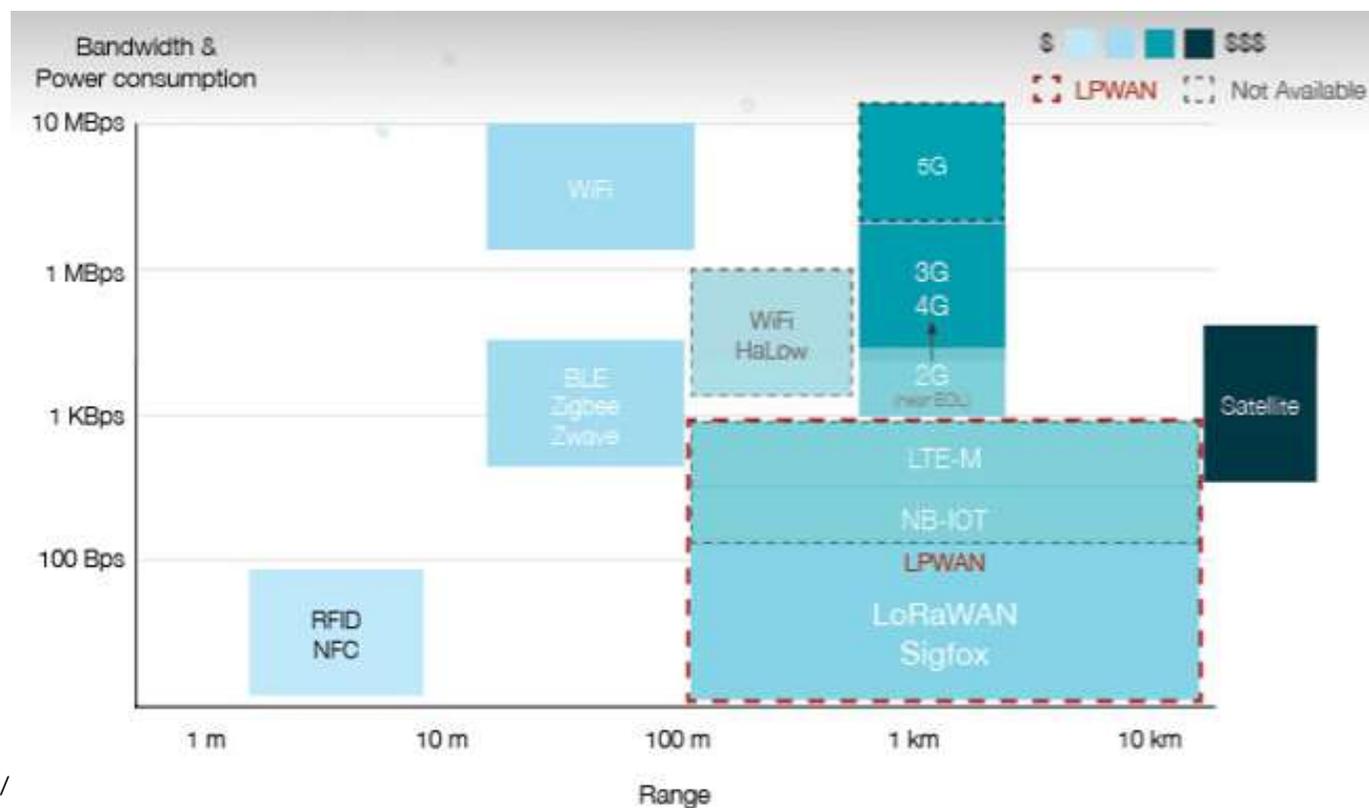
## Network for Smart Grids

- 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

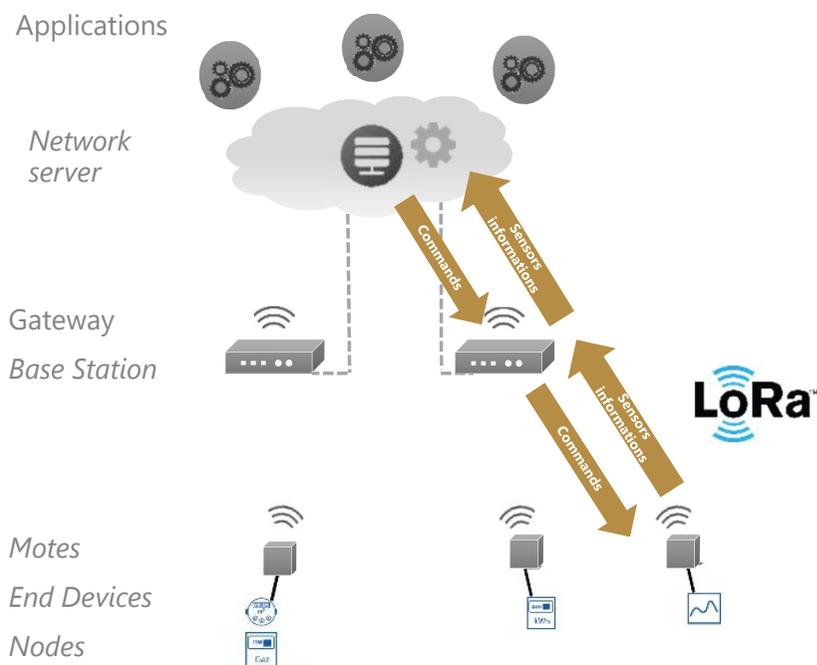


Source <https://iotfactory.eu/>

# 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

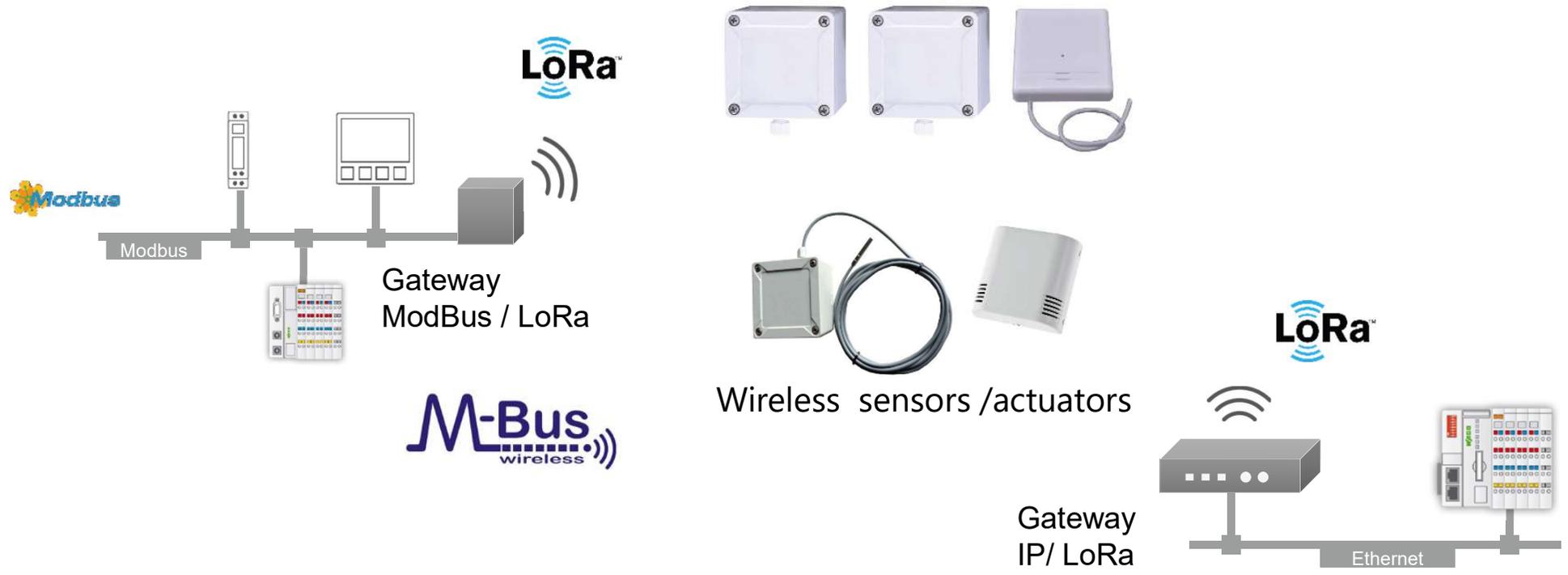
***Several gateways listening  
frequencies Motes messages  
Only the gateway with the best signal  
sends messages to the network server***

**Sensors Motes  
Actuators Motes**



# 5- Wireless Mbus or LoRa

- Wireless Modbus versus Lora transmetteur

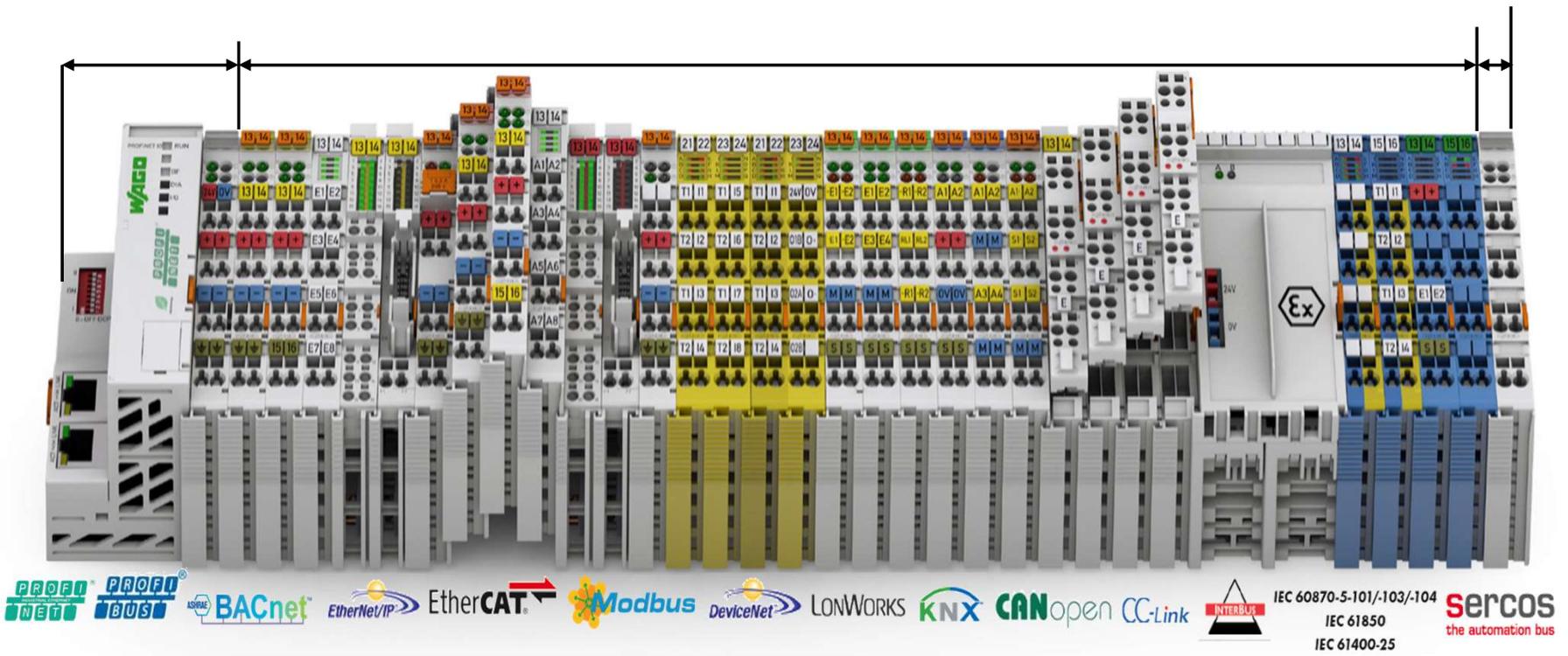


# 6- Convergent information through various fieldbus network and IT network

1 PLC Ethernet controller

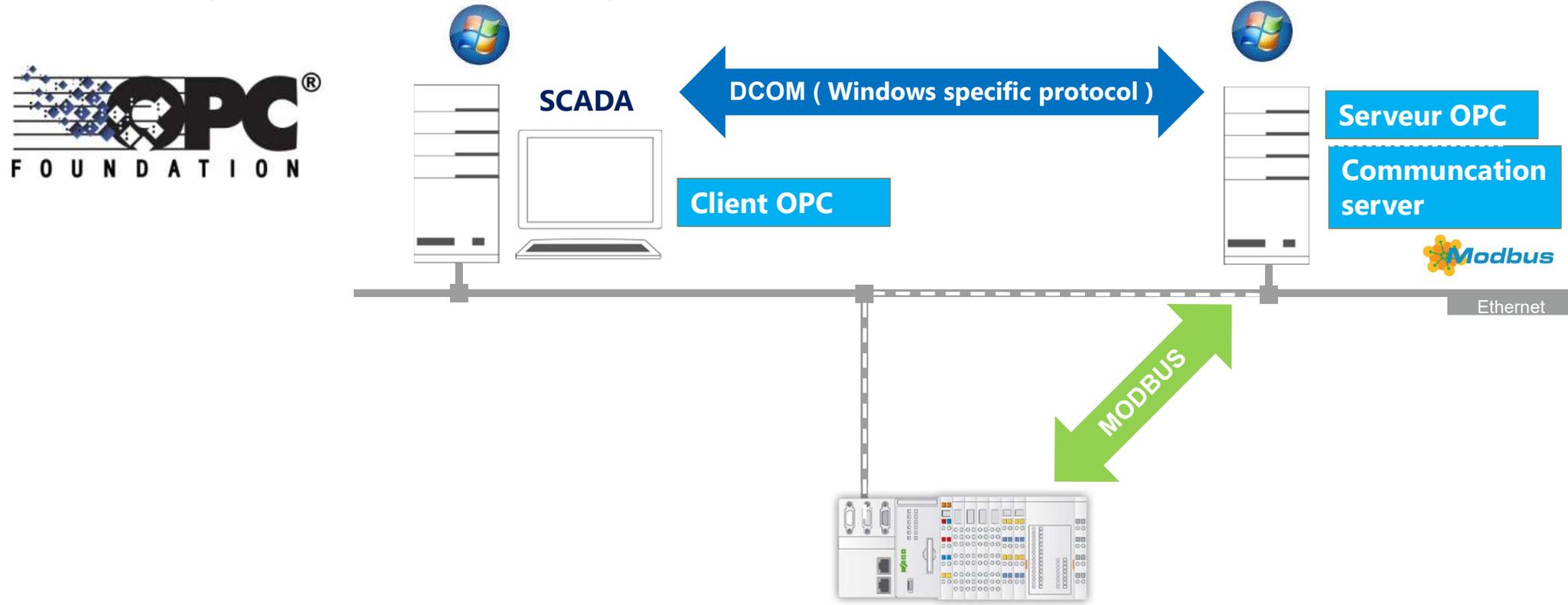
2 I/O connexions

3 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

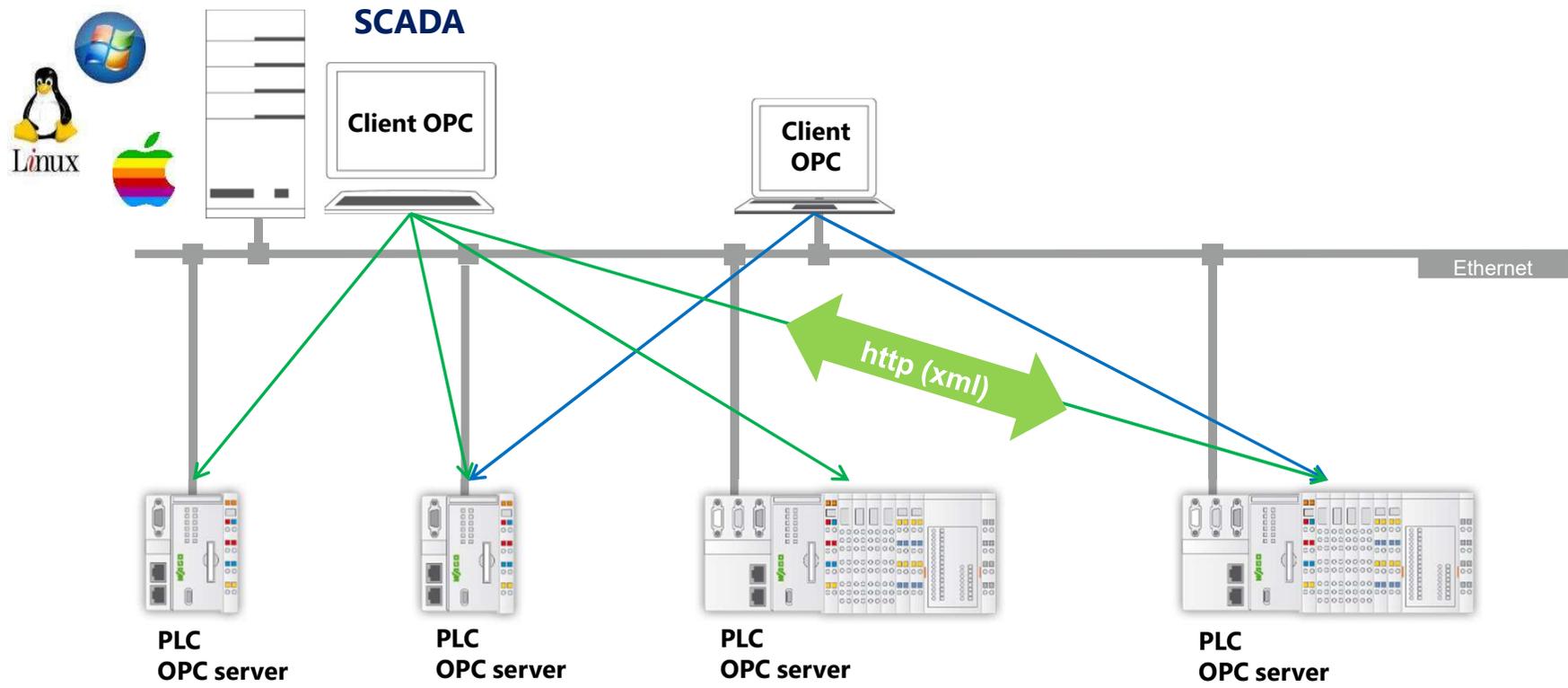


# 6.2 -OPC Unified Architecture

- **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

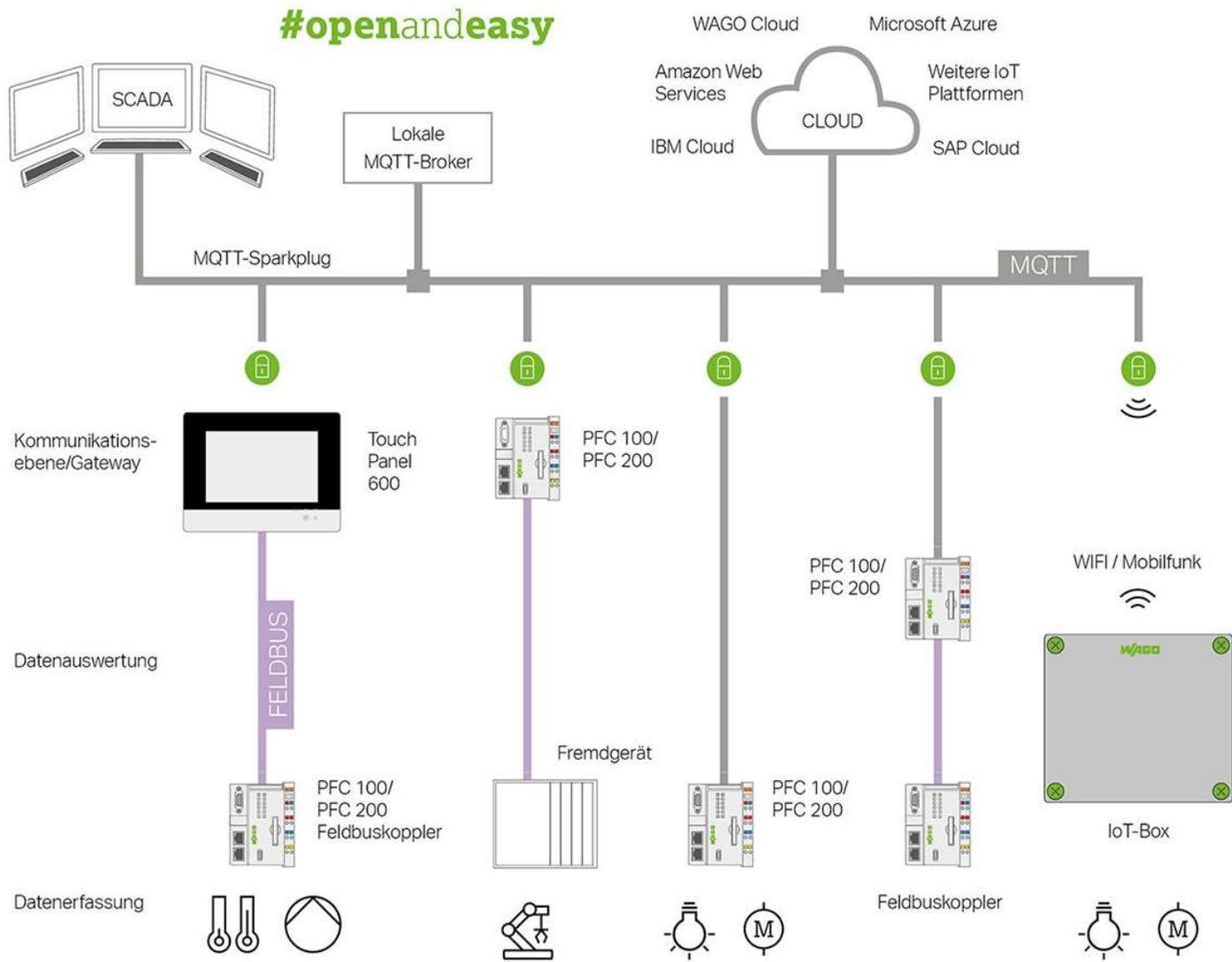
Version :  
 MQTT 1.0 (1999)  
 ...  
 MQTT 3.1.1 (2019)

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

Data virtualization over networks and cloud

Proposed by IBM & Eurotech

Asean-Factori 4.0



36 - DGC

UGA Grenoble  **Université Grenoble Alpes** February 2022

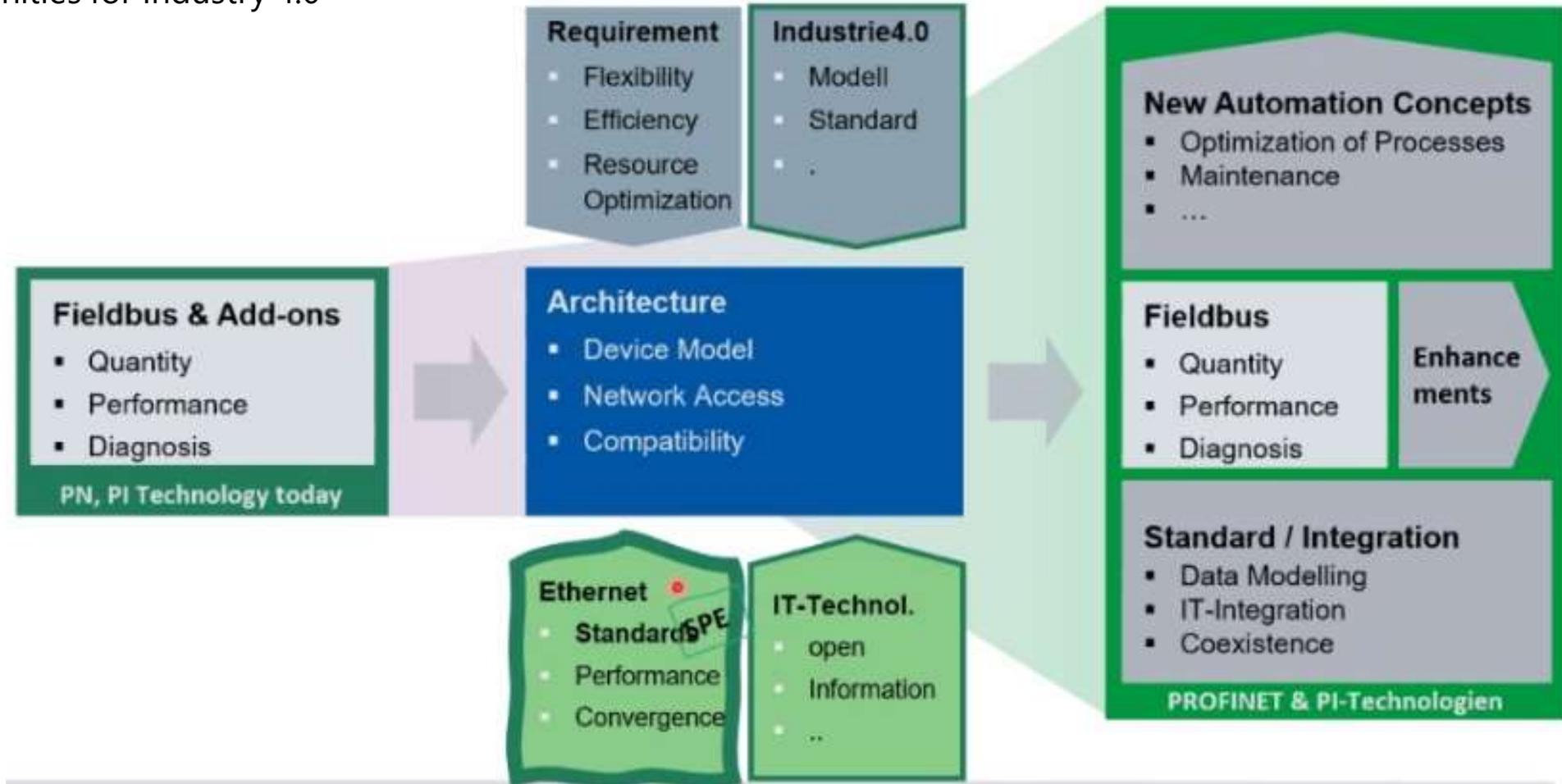
# Conclusion



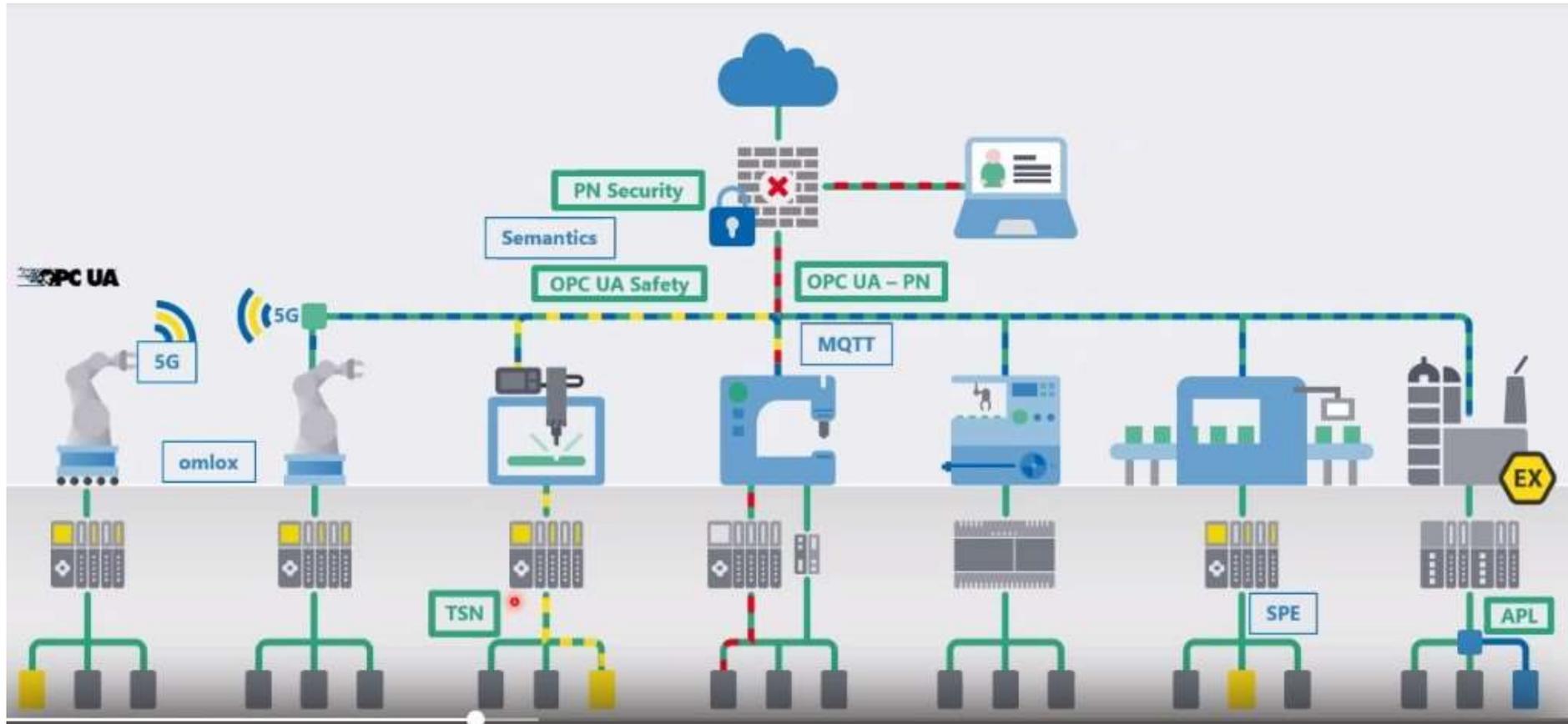
- Industry 4.0
  - Process information's systems  
from the process information (sensors, actuators) « the field »  
to the higher levels of management (SCADA / IA) for optimization
  - Various functionalities: Production, but also Maintenance, Logistics, Transport
- Based on PLC, Programmable Logic 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



---

**Thank you for  
your attention**

---



Natural bridge over the river

Contact : [Denis.genon-catalot@univ-grenoble-alpes.fr](mailto:Denis.genon-catalot@univ-grenoble-alpes.fr)