Industrial Campus Network for
Virtual Programmable Logic Controller

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Objective

➢ In previous slides, we have talked about the following points:

◻ Approaches of virtual PLC to get over the requirements raised to production system from Industry 4.0 and Smart Manufacturing, the requirements include more data to be processed, more flexible to adjust the control functionalities, more coordinated to implement control.

◻ Comparison of Hard PLC, Soft PLC and Virtual PLC in items such as: hardware, software, decoupling of hardware & software, spot of deployment, computing power, reliability, etc.

◻ E2E network / protocol to connect and interact between virtual PLCs and field devices.

◻ And corresponding challenges to the industrial campus network to virtual PLC and field devices.

➢ This presentation is to talk about the trend of virtual PLC from another view, and corresponding network scenarios for virtual PLC.

Virtual PLC Related Practices from Venders

Vender	Product / Technology	Description of Practice
SIEMENS	SIMATIC S7-1500V	• The SIMATIC S7-1500V is **an entirely virtual PLC**. • It is **based on the functions and operation of the SIMATIC S7-1500 PLC** and **independent of its hardware**. • The virtual PLC can be downloaded **similar to an app** and **integrated directly into the IT environment**. • Siemens has **worked with Audi on the application of a virtual PLC**, testing implementation possibilities, and Audi anticipates the implementation of virtual PLCs in its factories.
CODESYS	CODESYS VIRTUAL CONTROL	• Via using state-of-the-art IT technologies, such as containers, hypervisor/VM, Kubernetes etc., the virtual CODESYS SoftPLC is now **hardware-independent, runs** on conventional controllers as well as **on edge servers, private or even public clouds**, depending on **the application's requirements for determinism and cycle time**. • The **software defines the function**, the **hardware provides the resources for it**.
Software Defined Automation	Virtual PLC Management	• SDA is to empower Automation Engineers with a PLC management and code versioning platform to become more productive and efficient in their heterogeneous PLC environments. • Virtual PLC Management is to **eliminate hardware dependencies**, and provide complete management solution for virtual PLCs **running on commercial off-the-shelf IT servers**.

Enlightening

➤ The virtual PLC has **the same functionalities** as the conventional PLC, they will **exist side by side** according to different application requirements.

➤ The software program implements the control function based the capabilities of hardware.

➤ The hardware capabilities include the computing capabilities, the network capabilities.

➤ **More powerful the performances** (response time, bandwidth / latency, jitter, etc.) of computing capability and network capability, **more application practices** of virtual PLC in the industrial automation.

Virtual PLC Related Reports from Standard Organizations

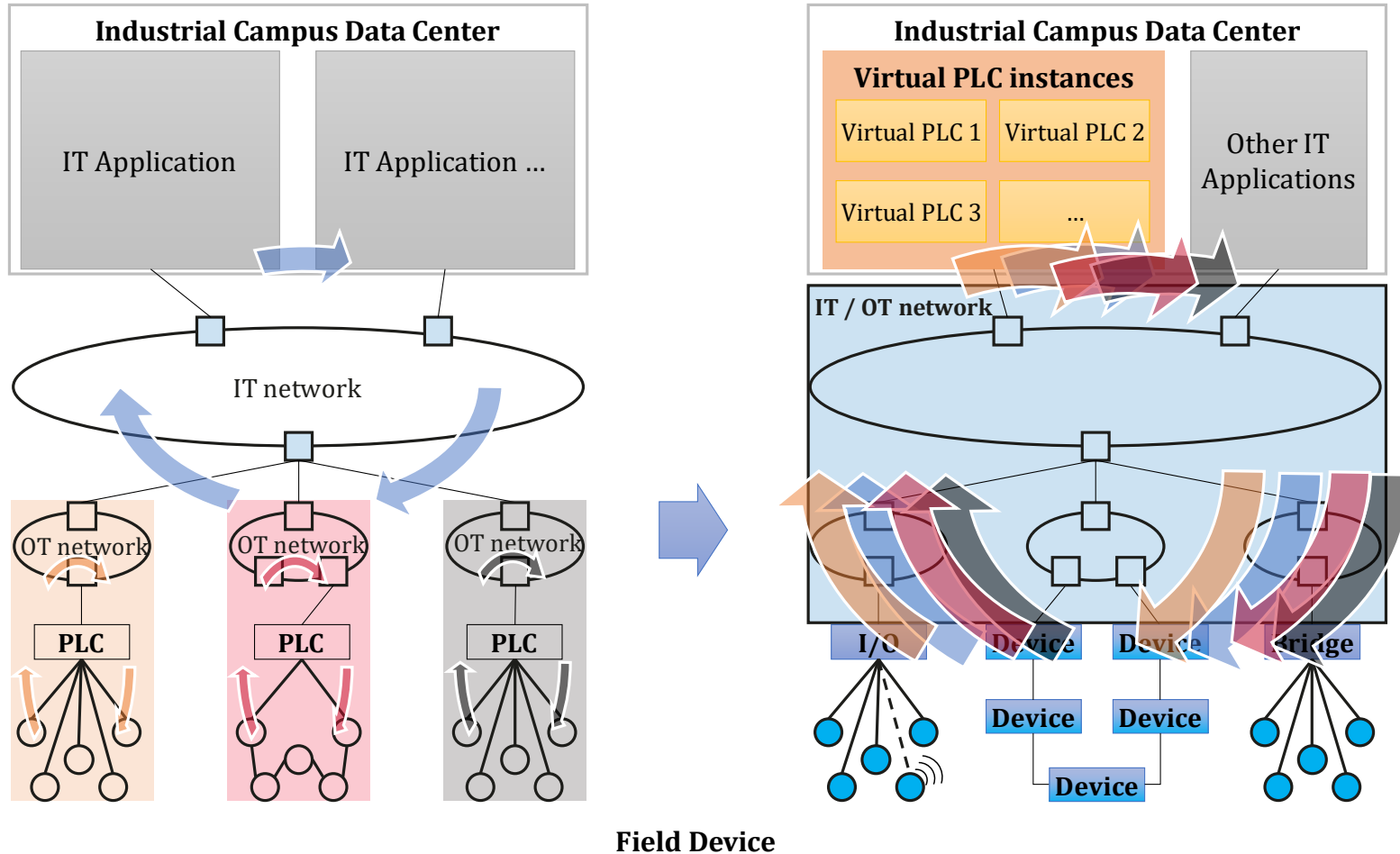| Organization	Report	Description from the Report
ITU-T (Sub-Group 1 of the ITU-T FG NET-2030)	Representative use cases and key network requirements for Network 2030	• Use case description of Industrial IoT with cloudification • Control functions traditionally carried out by customized hardware platforms, such as programmable logic controllers (PLC), have been **slowly virtualized** and **moved onto the edge or into the cloud** in order to **reduce the capital expenditure (CAPEX) and the operational expenditure (OPEX) of the system**, and to provide increased system flexibility and capability to handle and analyze 'big data'. • This industrial cloudification places even **higher requirements on underlying networks, as the same latency, jitter, security and reliability requirements need to be implemented** at larger scales.
IEEE (2022 IEEE 27th International Conference on ETFA)	How Real (Time) Are Virtual PLCs?	• In this paper, the virtual PLC is implemented and evaluated to determine **whether virtual PLCs can satisfy the requirements** for specific domains of industrial automation, and **compare multiple virtual PLC configurations to a SoftPLC without a hypervisor**. • The results indicate that virtual PLCs in servers with a hypervisor is currently **a viable option for important domains of factory automation**. • The observations made in this work indicate that networking and I/O module enhancements **are needed and these would improve the response times** measured in the configurations implemented.

Enlightening
- The virtual PLC will help to increase system flexibility and capability **to process more data**.
- **More systems and devices are involved into this network**, this network might be **larger scales**.
- From virtual PLC to field devices, there might be **optimization points for the end to end industrial network**.
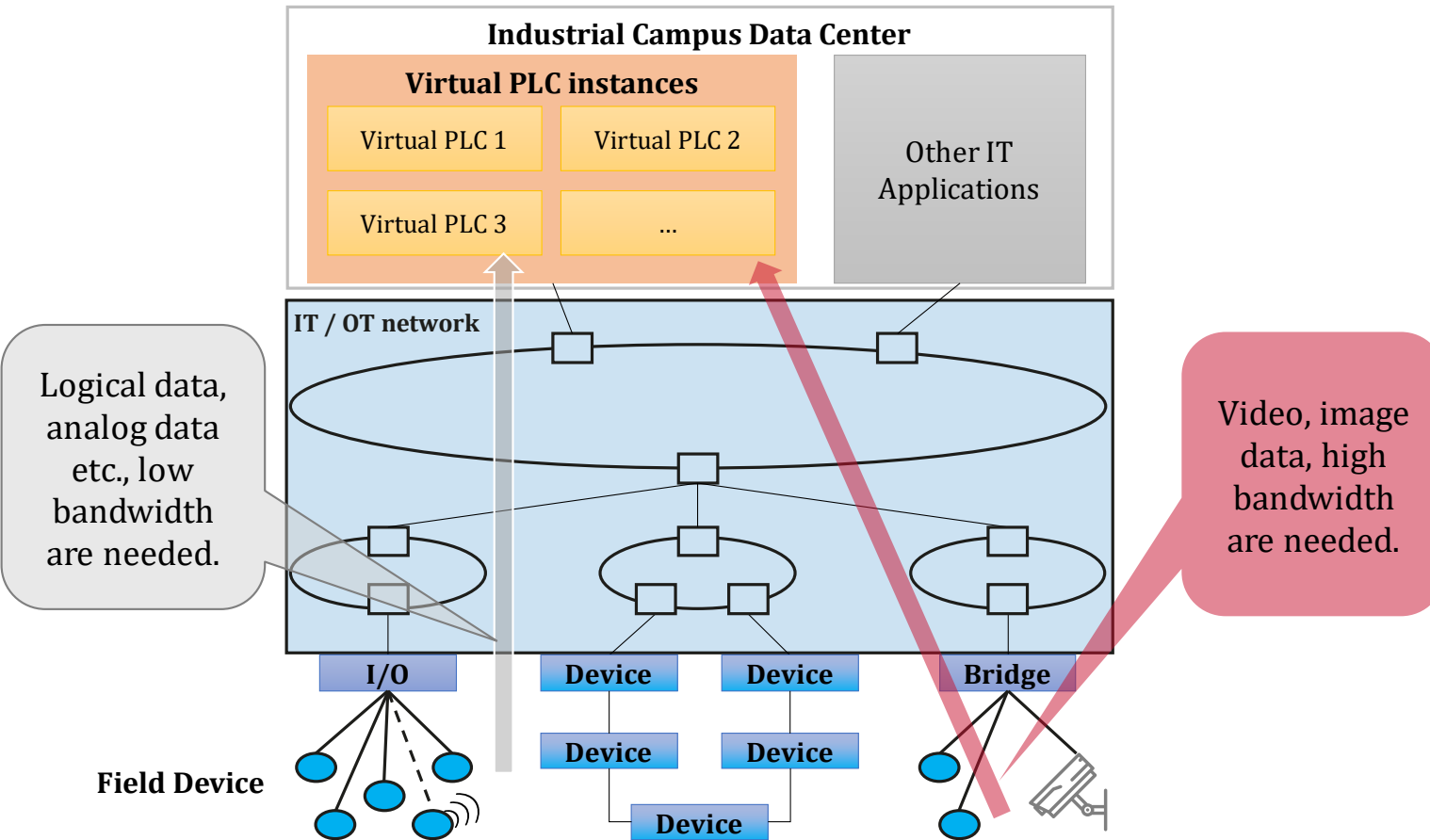
FG NET-2030 : Focus Group on Network 2030
ETFA : Emerging Technologies and Factory Automation

Network Scenario for Virtual PLC — More Larger Scale

Industrial Campus Data Center

IT Application   IT Application ...

IT network

OT network   OT network   OT network

PLC   **PLC**   **PLC**

Industrial Campus Data Center

Virtual PLC instances

Virtual PLC 1   Virtual PLC 2   Other IT Applications

Virtual PLC 3   ...

IT / OT network

I/O   Device   Device   Bridge

Device   Device

Device

Field Device

- ➢ In some new projects, maybe, hundreds of independent control devices are move onto edge as virtual PLC, that is to control the field devices remotely via network
- ➢ Then, different kind of streams including OT streams and IT streams are transferring in the OT / IT network.
- ➢ That is, several smaller scale network to bearing its own streams respectively, are converging to be a larger scale network to bear different kind of streams.
- ➢ In such large scale of industrial network, it might be challenging to assure the low latency, determinism, reliability etc.

Network Scenario for Virtual PLC — More Bigger Data Traffic

Industrial Campus Data Center

Virtual PLC instances

Virtual PLC 1 | Virtual PLC 2 | Virtual PLC 3 | ...

Other IT Applications

IT / OT network

Logical data, analog data etc., low bandwidth are needed.

Video, image data, high bandwidth are needed.

I/O | Device | Device | Bridge | Device | Device | Device

Field Device

- ➤ in some production lines of electronic industry, in order to improve the efficiency and precision of quality inspection, AOI (Automatic Optical Inspection) is introduced.

- ➤ The industrial camera acquires and transfers video or image of the object to data center in which the inspection algorithms are running to extract the features of the acquired videos or images and classify them according to rules based on requirements.

- ➤ The inspection algorithms might integrate with virtual PLC, and virtual PLC finally control the filed devices of production line to separate the defective products from the good ones.

- ➤ Bandwidth usage 100Mbps per camera, hundreds of cameras may request total bandwidth of 10Gbps nearly.

Call for Interest to Discuss and Initiate a Work Item

➢ Call for interest to discuss about the scenarios and possible technologies evolution.

- ❑ From the end to end routine of industrial campus network which connects virtual PLCs and filed devices, there are different kind of networks / protocols involved (e.g. TSN, existing industrial field bus based on Ethernet or non-Ethernet, etc.).

- ❑ Compare with the conventional PLC, the virtual PLC are deploy in the data center remotely and centrally, there might be some changing to the end to end industrial network.

- ❑ Is there any gaps respectively for each related network, bus, protocol?

- ❑ There might be possible optimization directions to be studied and analyzed.

➢ Based on fullness of discussion, to initiate a new Work Item within Nendica to develop an IEEE 802 Nendica Report.

- ❑ To analyze the end to end industrial campus network / protocol for virtual PLC.

- ❑ To analyze the challenges of the end to end industrial campus network / protocol to support virtual PLC.

- ❑ To frame high-level solutions to issues and challenges.

- ❑ Possible standardization considerations.

- ❑ Other aspects, etc..

Thank you.