Future Industrial Network Requirement Discussion for TSN

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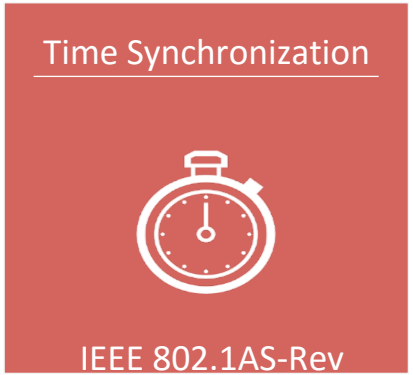
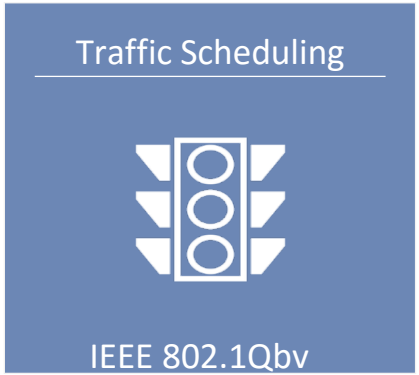
Sep 2017, St. John's NL, IEEE 802.1 Interim

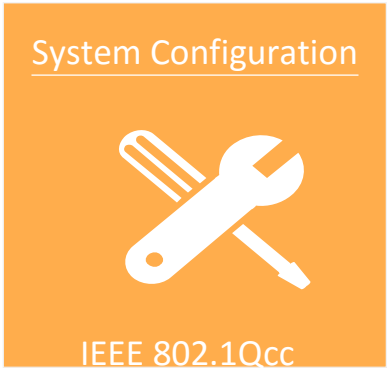
Presentation Objectives

- To discuss potential issues/requirements of future industrial network for TSN standards.
- To discuss potential actions to be taken to address the issues/requirements.

How TSN Guarantee Extremely Low-latency for Industrial Network

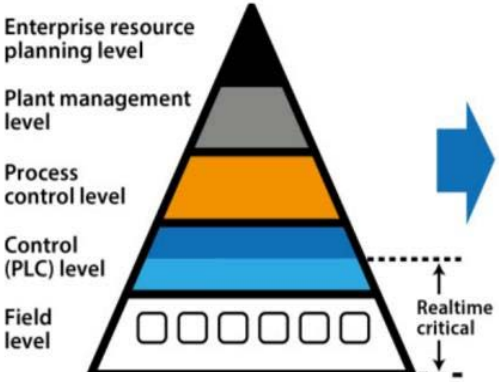




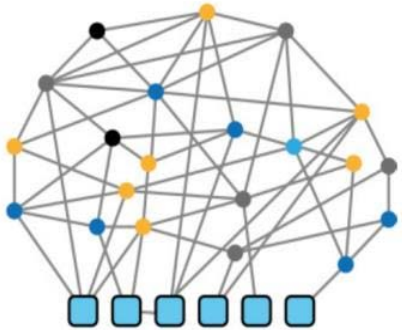


- **Static timeslot schedule in every node**:
  - ✓ Schedule computation according to a priori knowledge (network topology, end station locations, hops, communication requirements).
  - ✓ Configure timeslots before streams run.
  - ✓ Every node send frames in specified timeslots.
- **Carry out computation and configuration procedures statically when new streams are added into the network or the communication requirement changes.**
- **Low latency and zero congestion loss is guaranteed but with the cost of global synchronization/planning.**

New Changes Brought by of Industry 4.0



Traditional Automation Pyramid



CPS*-Based Automation

*CPS: Cyber Physical Systems

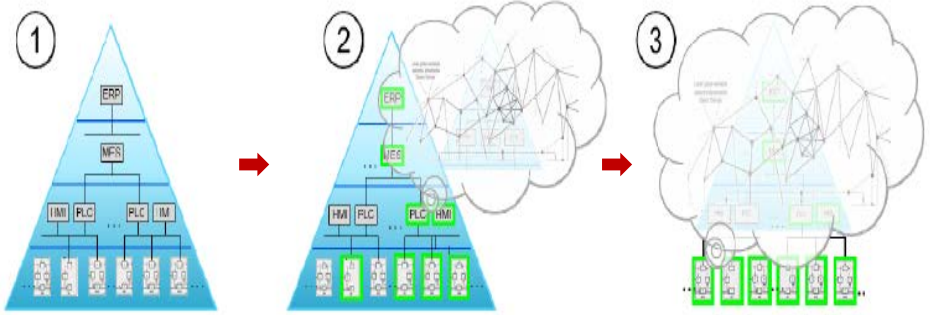
- Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies**.
- One of key components is Smart Manufacturing, which may bring new changes to traditional automation system :

Pyramid Architecture	Flattened Architecture
Separated IT & OT Network	Converged IT & OT Network
Static/fixed Network	Dynamic/flexible Network

https://www.vdi.de/uploads/media/Stellungnahme_Cyber-Physical_Systems.pdf

**https://en.wikipedia.org/wiki/Industry_4.0

Example: Programmable Logic Controller Moving to the Cloud



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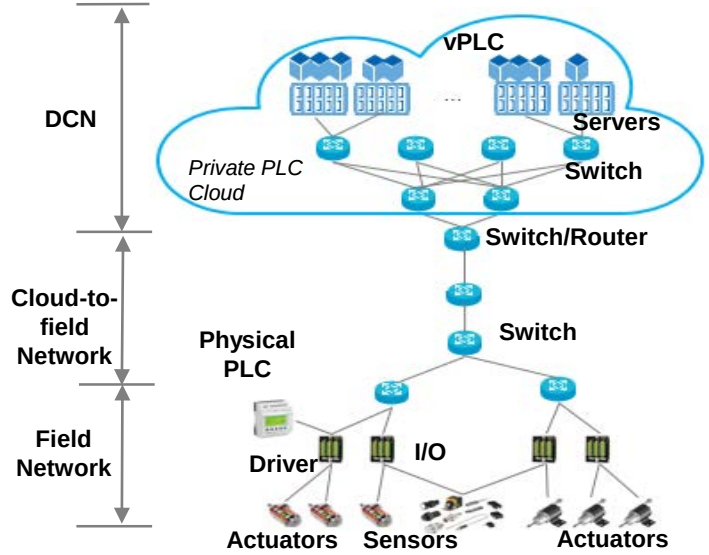
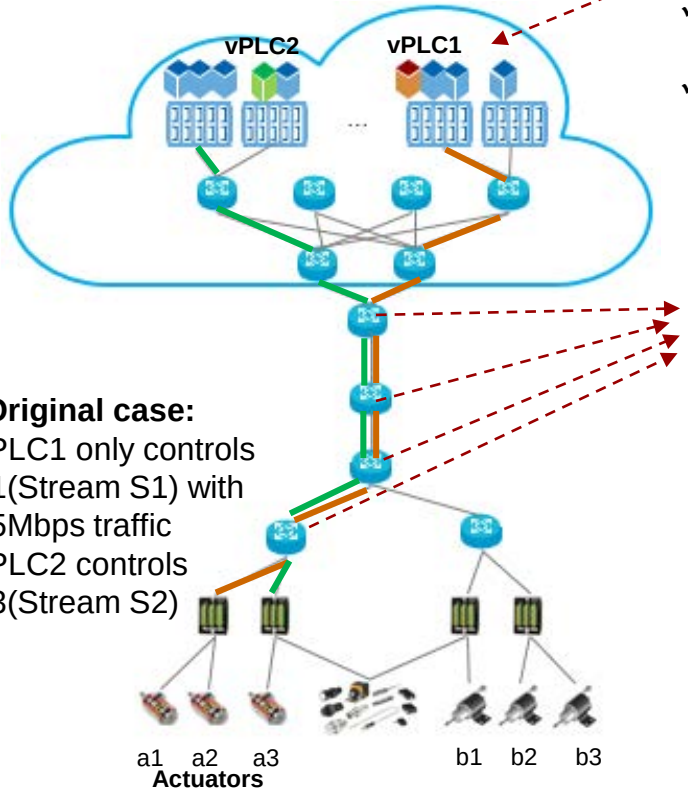


Cloud computing is taken into consideration for Programmable Logic Controller (PLC)

- ✓ From dedicated hardware PLC to virtualized software PLC (cloud-based)
- ✓ More cost-effective, flexible, scalable and agile production line for Smart Manufacturing
- ✓ Well accepted by industry such as ABB, Fraunhofer, Rockwell, Intel..
- ✓ A larger scale, more dynamic time-sensitive network is required.

Use Case 1: PLC Reprogramming



1. Original case:

- ✓ vPLC1 only controls a1(Stream S1) with 15Mbps traffic
- ✓ vPLC2 controls a3(Stream S2)

2. New changes on vPLC1: vPLC1 needs to control a2 as well

- ✓ Control logic reprogramming(Only controlling actuator 1 -> controlling actuator 1&2)
- ✓ Traffic model: Bandwidth: 15M -> **25M**, timeslot: (3,4 -> 3,4,**5,8,9**)

Timeslot schedule

Timeslot	Stream
3	S1
4	S1
6	S2
7	S2

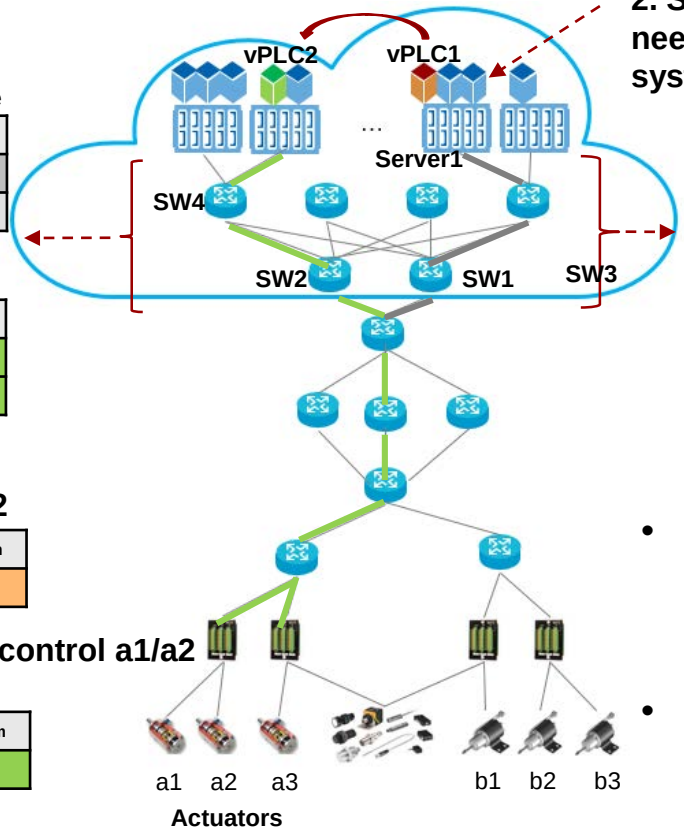
Timeslot	Stream
3	S1
4	S1
5	S1
6	S2
7	S2
8	S1
9	S1

3. Network change required

- ✓ Timeslot for stream S1 should be reconfigured along E2E path**.**

- **The network needs to be re-scheduled and re-configured, which may cause all other streams (such as S2) to be interrupted.**
- **Incremental scheduling might be possible but with the cost of non-optimal solution.**

Use Case 2– vPLC Migration



2. Server1 failed or needs to restart for system upgrade

4b. For SW2/SW4, timeslot entries for S1 should be added

Timeslot schedule

Timeslot	Stream

Timeslot	Stream
3	S1
4	S1

4a. For SW1/SW3, timeslot entries for S1 should be removed

Timeslot schedule

Timeslot	Stream
3	S1
4	S1

Timeslot	Stream

1.vPLC1 controls a1/a2

vPLC	Actuators	BW	Stream
1	a1/a2	25M	S1

3.vPLC2 take over to control a1/a2

vPLC	Actuators	BW	Stream
2	a1/a2	25M	S1

- Since the new VM location is not predictable, the timeslot for new traffic (after VM migration) can't be computed in advance.
- Service will be interrupted when the network is re-scheduled.

Other Potential Issues?

- Schedule computing of IEEE 802.1Qbv is very complex and time-consuming. Some study shows that computing schedules for about 1500 flows requires about 3.2 hrs.*
  - Long time wait for restoring service
- Current TSN deterministic behavior is achieved through configuration of both end nodes and network devices. Can the deterministic behavior be achieved by the network devices alone?
  - No more synchronization is required between end nodes and network devices.
- Smart Factory/Flexible Manufacturing will cause any other impact for the industrial network?
  - Customized production may needs a more frequently-changing production line(such as adding, deleting, modifying nodes…), which requires a more flexible and dynamic network. Static engineered network may not work well.

*No-wait Packet Scheduling for IEEE Time-sensitive Networks (TSN), RTNS '16 Proceedings of the 24th International Conference on Real-Time Networks and Systems Pages 203-212 , Frank Dürr, University of Stuttgart. http://dl.acm.org/citation.cfm?id=2997494

Summary

- More dynamic and flexible requirement will be brought up in future industrial network.
- Current TSN might not be sufficient to address them.
- More investigation and analysis will be performed.

Thank you