Enhancement Considerations for Flexible Factories with Wireless Links

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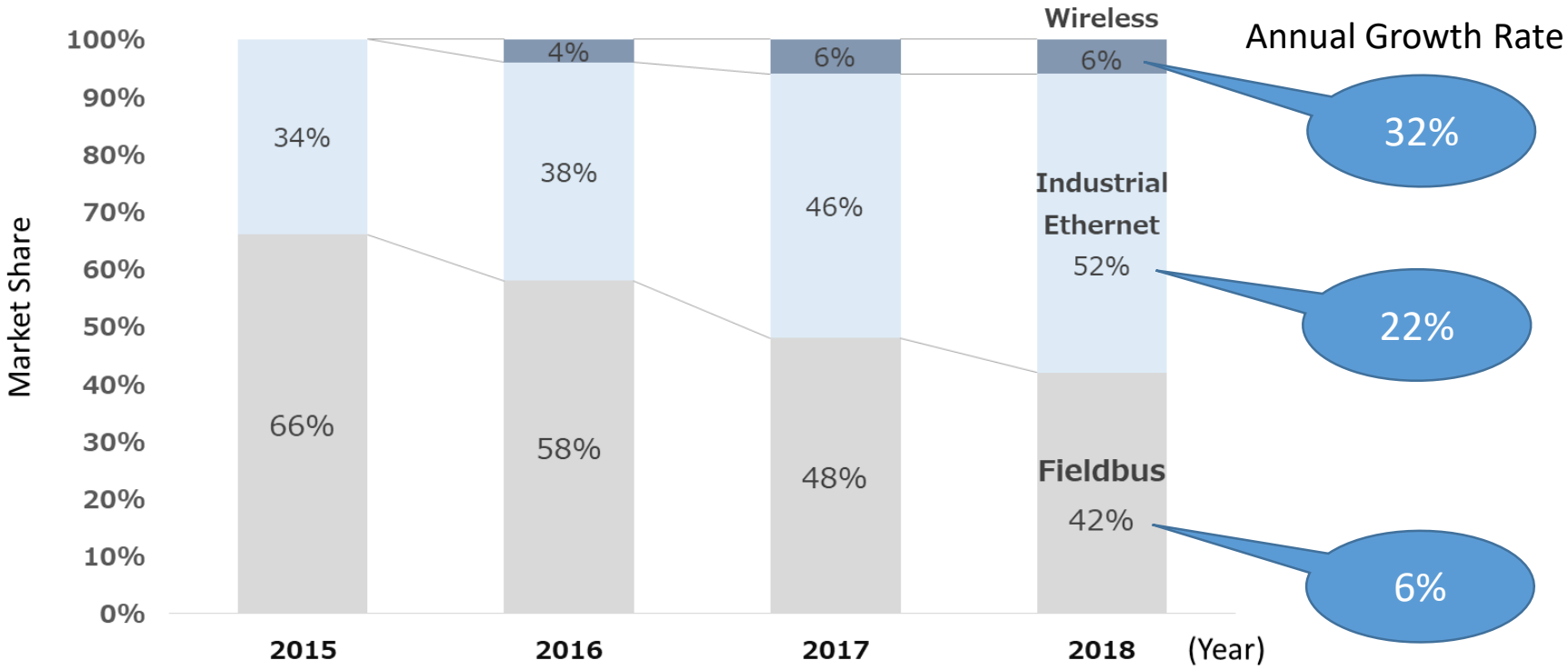
Introduction

- This document is prepared to have a consensus on a possible new work item in TSN – “Flexible Factory” where many and various equipment and devices coexist and are attached to the wired network via wireless connections.

- Technical issues regarding queuing and forwarding at bridges from wired to wireless links are addressed in the next presentation by Yoshihisa Kondo.

Increasing Wireless Nodes in Factories

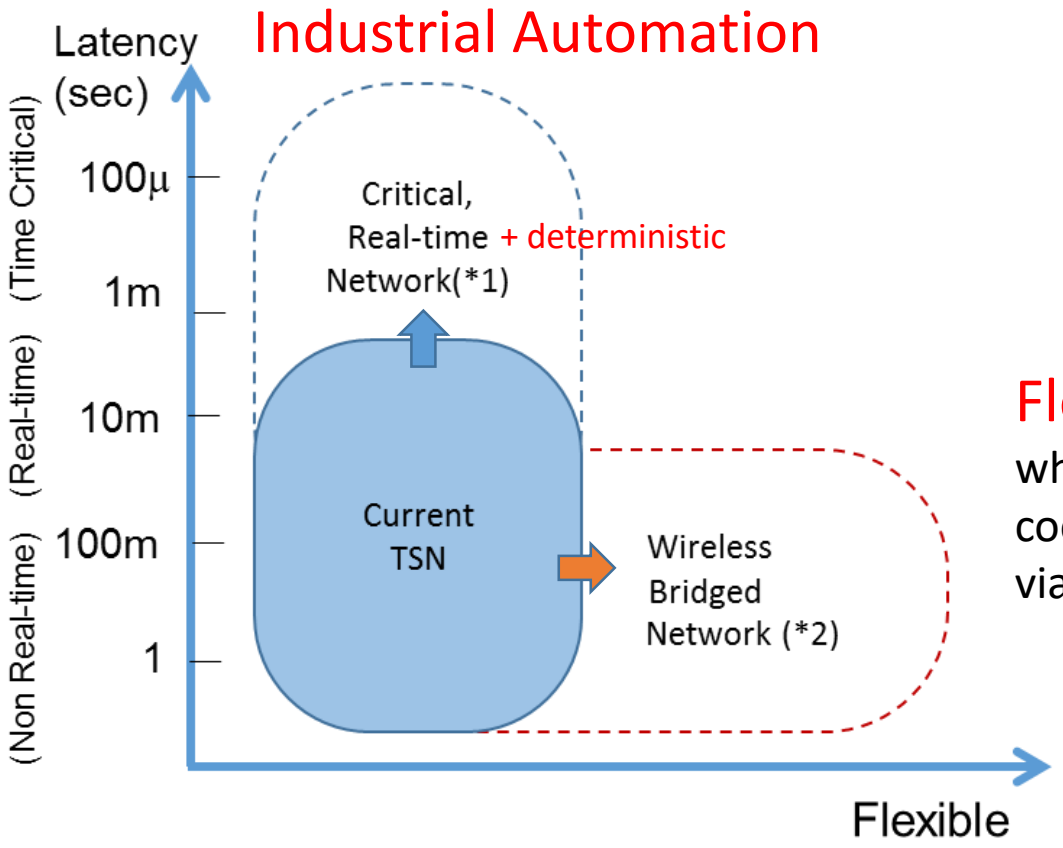
- Share of wireless nodes is increasing at an annual growth rate of 32%.



Industrial network market shares within factory automation

Source: HMS's estimation,
https://www.hms-networks.com/press/2018/02/27/industrial-ethernet-is-now-bigger-than-fieldbuses

Direction



Flexible Factory

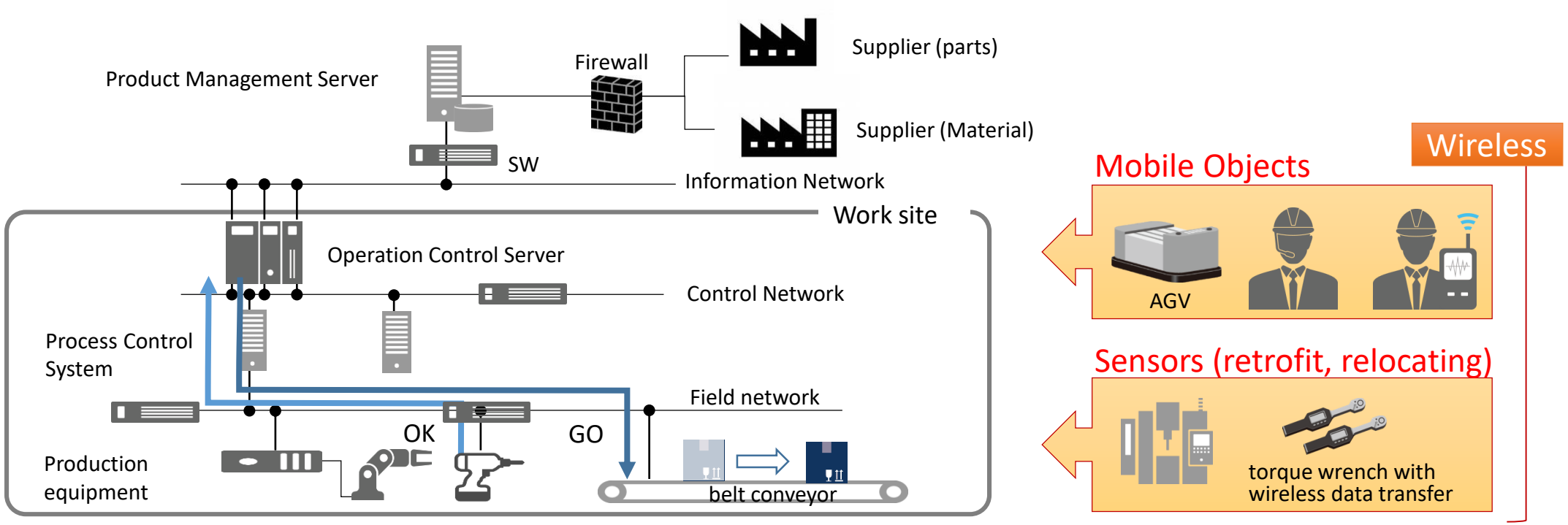
where many and various equipment and devices coexist and are attached to the wired network via wireless connections.

*1 https://www.vdi.de/uploads/media/Stellungnahme_Cyber-Physical_Systems.pdf
*2 Nendica Draft report on Wired/Wireless Use Cases and Communication Requirements for Flexible Factories IoT Bridged Network
https://mentor.ieee.org/802.1/dcn/17/1-18-0025-00-ICne.pdf

Source http://www.ieee802.org/1/files/public/docs2018/new-FFIoT-Zein-FFIoT-Enhancement-to-802-technologies-0518-v00.pdf

Factory Network

- Flexible Factory with wireless connectivity.
  - ✓Mobile objects to reduce workers' efforts: AGVs, tablet, handy tolls, etc.
  - ✓Retrofit sensors and monitoring systems for remote management: systems for preventive maintenance, in-line inspection, etc..



Communications in Advanced Factories

- Scope extended for management and operation of production process.

Industrial Automation, e.g., P60802 [1]

For system control

- Controlling robots and production machines.
- Monitoring and diagnostics of machines and networks.
- Shutdown at emergency.

Flexible Factory, e.g., FFIoT[2]

Wireless

For management and operation of production process

- Collecting information from machines and tools for preventive maintenance, inline inspection, remote monitoring, and etc.
- Collecting status of material/part stocks and environment.
- Information supporting immediate localized decision in management and operation with QoS management for data flow.

[1] P60802 document, http://www.ieee802.org/1/files/public/docs2018/60802-industrial-use-cases-0918-v13.pdf
[2] Pre-draft FFIoT Whitepaper, https://mentor.ieee.org/802.1/dcn/17/1-18-0025-05-ICne.pdf

Factory Applications in Flexible Factory Scenario

- Communications among human, things, and equipment are included, unlike industrial automation with machine to machine communication via network.

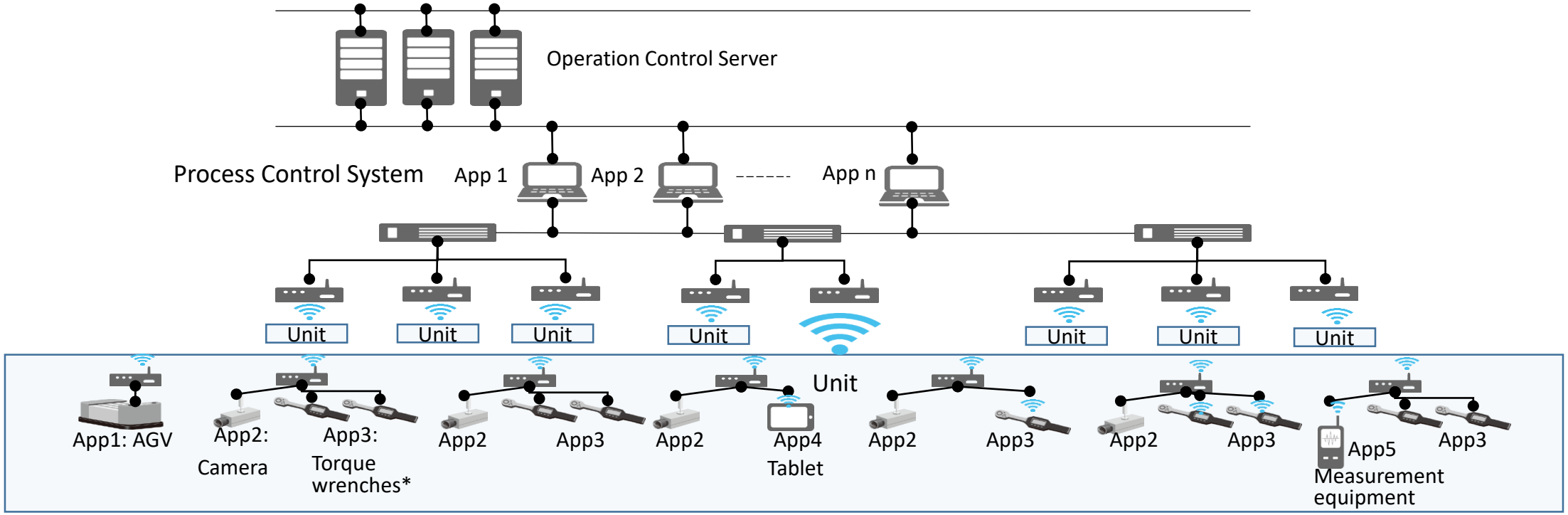
Category of factory applications defined in the FFIoT draft report in Nendica.

Category	**Description**	**Classification according to the purpose**
Equipment Control	sending commands to mobile vehicles, production equipment	(1) Controlling, operating and commanding of production equipment, auxiliary equipment
Quality Supervision	collecting information related to products and states of machines during production	(1) Checking that products are being produced with correct precision (2) Checking that production is proceeding with correct procedure and status
Factory Resource Management	collecting information about whether production is proceeding under proper environmental conditions, and whether personnel and things[1] contributing to productivity enhancement are being managed appropriately	(1) Checking that the production environment is being appropriately managed (2) Monitoring movement of people and things[1] (3) Checking the management status of equipment and materials (stock) (4) Checking that the production equipment is being maintained (5) Appropriate recording of work and production status
Display	For workers, receiving necessary support information, for managers, monitoring the production process and production status	(1) Providing appropriate work support (2) Visually display whether the process is proceeding without congestion or delay (3) Visually display the production status
Human Safety	collecting information about dangers to workers	(1) Ensuring the safety of workers
Other	Communication infrastructure with non-specific purposes	(1) Cases other than the above

[1] Physical objects such as materials and equipment related to production are called “things”

Network Topology
(Vehicle Assembly and Testing, Chassis Line)

- Many automatic machines, feeders(e.g. AGVs) and systems to support workers (e.g. torque wrenches with wireless data transfer, tablets, measurement equipment.)



* Typical vehicle assembly line needs many torque wrenches:
https://drishtikona.files.wordpress.com/2012/08/ch8.pdf

Communications Requirements (example)

- What characterizes communications in factories?
  - ✓ Many and variety of equipment and devices coexist in the same site.

No.	Wireless application in FFIoT		Communication requirements			
	Purpose	Corresponding Information	Transmit Data Size (bytes)	Communication Rate	Delivery Time Tolerance	Node density(*)
22	Checking completion of process	Torque waveform	100K	1 per sec.	1 sec.	14
		OK, NG	100	1 per sec.	1 sec.	14
added	AGV control	Go, signal, positioning	100	once per 1 min.	100 msec.	10
38	Relay of images for moving	video	20K	30 per sec.	20 msec.	1

Note: underlined values and words represent “to be updated” in the FFIoT report.

*Area:20 m x 20 m

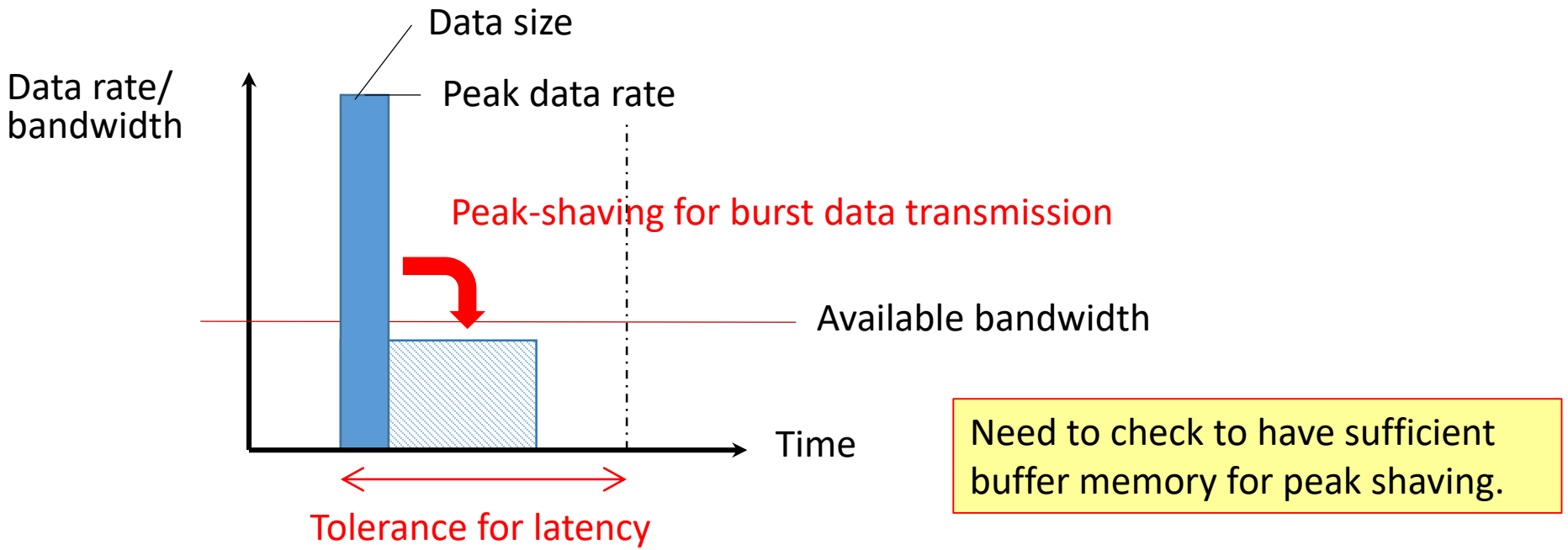
What are Different?

	Flexible Factory	Industrial Automation
Timing for data transmission/ reception	• Not strictly timing for actions of workers with collaborating with production machines and systems. Human reaction time is beyond few hundred milliseconds[1].	• Precise timing (Cycle time, latency, and jitter, and cycle) for machine control. Cycle time down to 1msec, delay less than 1us, and jitter less than 1ns are required in some cases[2].
Technical issues	• Accommodating mobile objects and relocating equipment and devices with wireless connectivity resulting in dynamic network configuration. • Queuing and forwarding at bridges from wired to wireless links, considering narrow and fluctuating bandwidth for wireless links[3].	• Ensuring precise timing for data transmission/reception. • Deterministic network.

[1] Robert J. Kosinski, "A Literature Review on Reaction Time," https://homepage.univie.ac.at/andreas.franz.reichelt/intro2cogsci2/data/literature_review_reaction_time.pdf
[2] P60802 document, http://www.ieee802.org/1/files/public/docs2018/60802-industrial-use-cases-0918-v13.pdf
[3] Pre-draft FFIoT Whitepaper, https://mentor.ieee.org/802.1/dcn/17/1-18-0025-05-ICne.pdf

Mitigating congestion at bridge (1)

- Peak-shaving is effective for burst data transmission.
- The bridge needs to know data size, peak data rate and tolerance for latency.

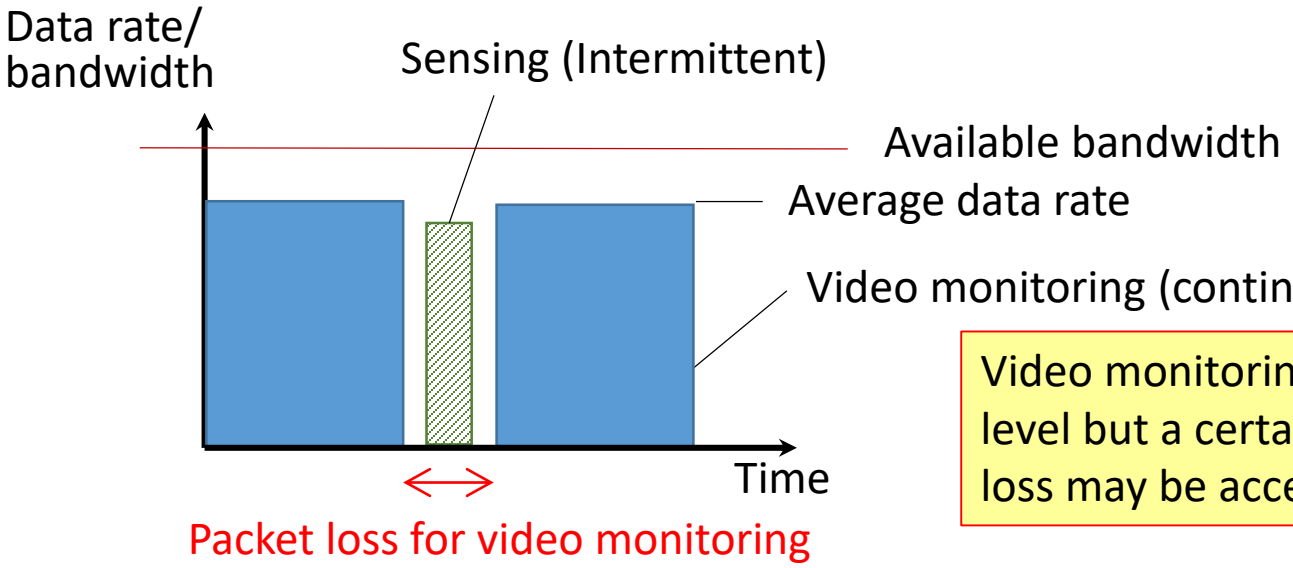


Need to check to have sufficient buffer memory for peak shaving.

Mitigating congestion at bridge (2)

- Packet loss* consideration from two different view.
  - ✓QoS at network level
  - ✓Impact on user experience
- The bridge needs to know average data rate and tolerance for packet loss.

* Packet loss is defined at MAC SAP



Video monitoring does not permit packet loss at a network level but a certain amount of frame drops due to packet loss may be acceptable for user experience.

Summary

- Flexible factory scenario becomes real where many and various equipment and devices coexist and are attached to the wired network via wireless connections.
- It is complementary to industrial automation scenario for the factory network.
- Issues are:
  - ✓ Accommodating mobile objects and reallocating equipment and devices with wireless connectivity resulting in dynamic network configuration and enabling “Flexible Factory” scenarios.
  - ✓ Queuing and forwarding at bridges from wired to wireless links, considering narrow and fluctuating bandwidth for wireless links.
- Detail analysis based on 1Qcc will be shown at the next presentation.
  - ✓ Technical problem in real scenario and advanced forwarding.