

# Enhancement Considerations for Flexible Factories with Wireless Links

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## Author(s):

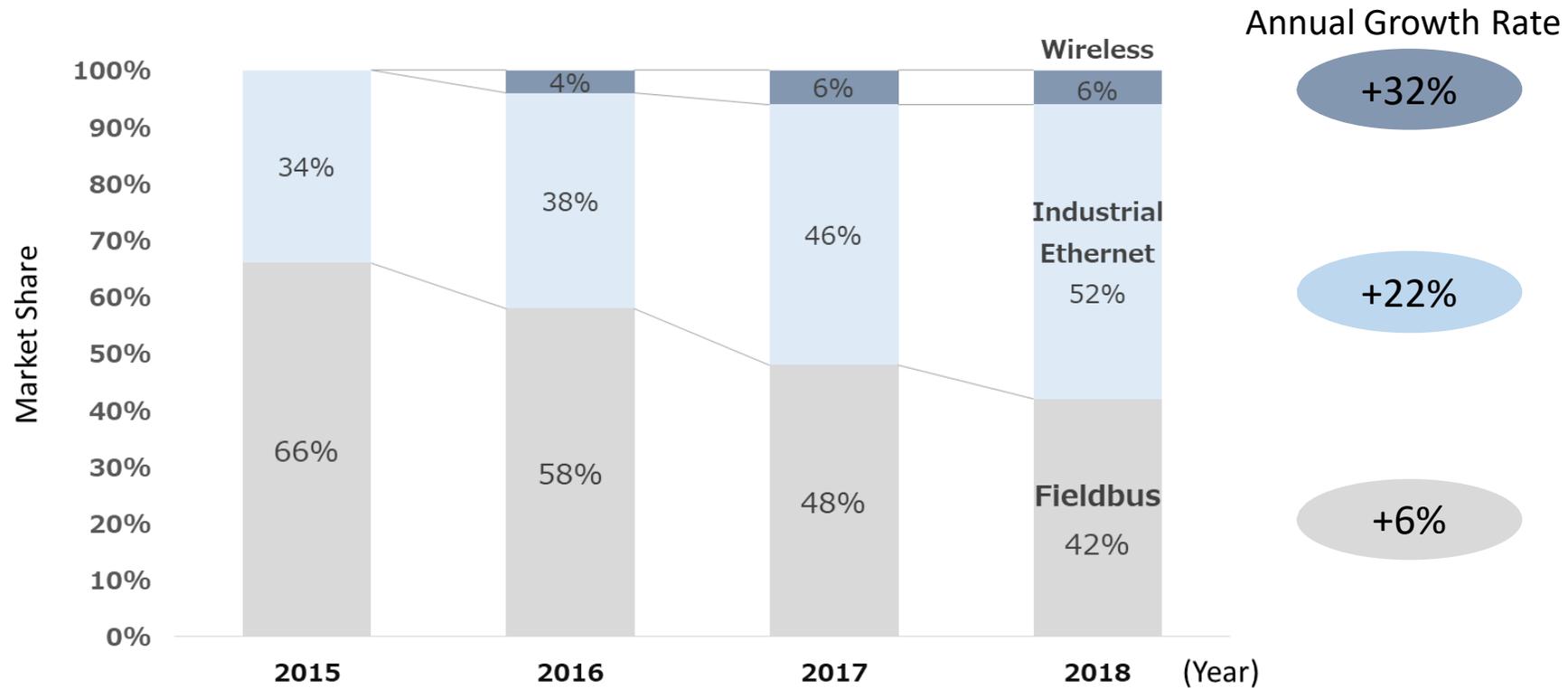
Name	Company	email
Kondo, Yoshihisa	Advanced Telecommunications Research Institute International (ATR)	kondo@atr.jp
Hamaminato, Makoto	Fujitsu Laboratories Ltd.	hamamy@jp.fujitsu.com
Nishikawa, Takurou	Fujitsu Limited	nisikawa.taku@jp.fujitsu.com
Sato, Shinichi	Fujitsu Limited	sato_shinichi@jp.fujitsu.com
Wang, Hao	Fujitsu R&D Center Co., Ltd	wangh@cn.fujitsu.com
Itaya, Satoko	National Institute of Information and Communications Technology (NICT)	itaya@nict.go.jp
Kojima, Fumihide	National Institute of Information and Communications Technology (NICT)	f-kojima@nict.go.jp
Koto, Hajime	National Institute of Information and Communications Technology (NICT)	h-koto@nict.go.jp
Ohsawa, Tomoki	National Institute of Information and Communications Technology (NICT)	tohsawa@nict.go.jp
Maruhashi, Kenichi	NEC Corporation	k-maruhashi@bl.jp.nec.com
Zein, Nader	NEC Europe Ltd.(NLE GmbH)	Nader.Zein@emea.nec.com
Ohue, Hiroshi	Panasonic Corporation	ohue.hiroshi@jp.panasonic.com

# Introduction

- This document shows an opportunity to increase market potential of TSN in a manufacturing area.
- “Flexible Factory,” where many and various equipment and devices coexist and attached to the wired network via wireless connections, is introduced.
- Communications between human and things are addressed. With the direction toward “Industry Automation” mainly for machine to machine communication, widely adoption of TSN is promoted in the factory networks.

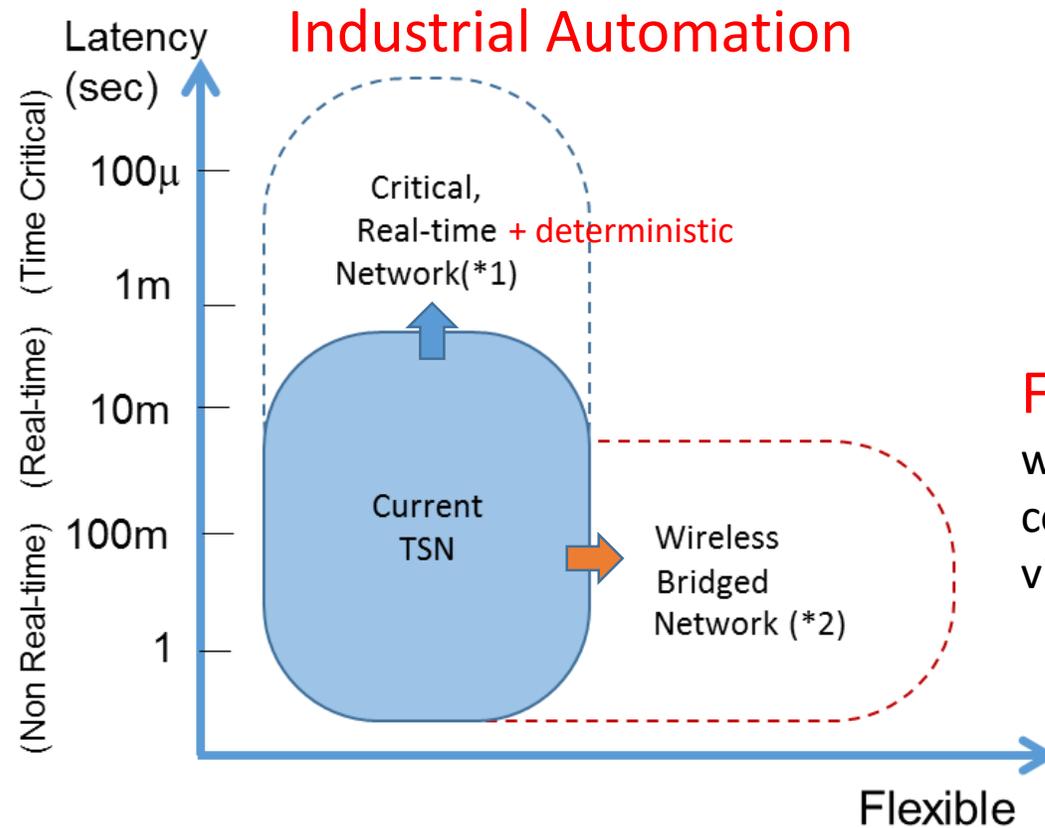
# Increasing Wireless Nodes in Factories

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



Industrial network market shares within factory automation

# Direction



## Flexible Factory

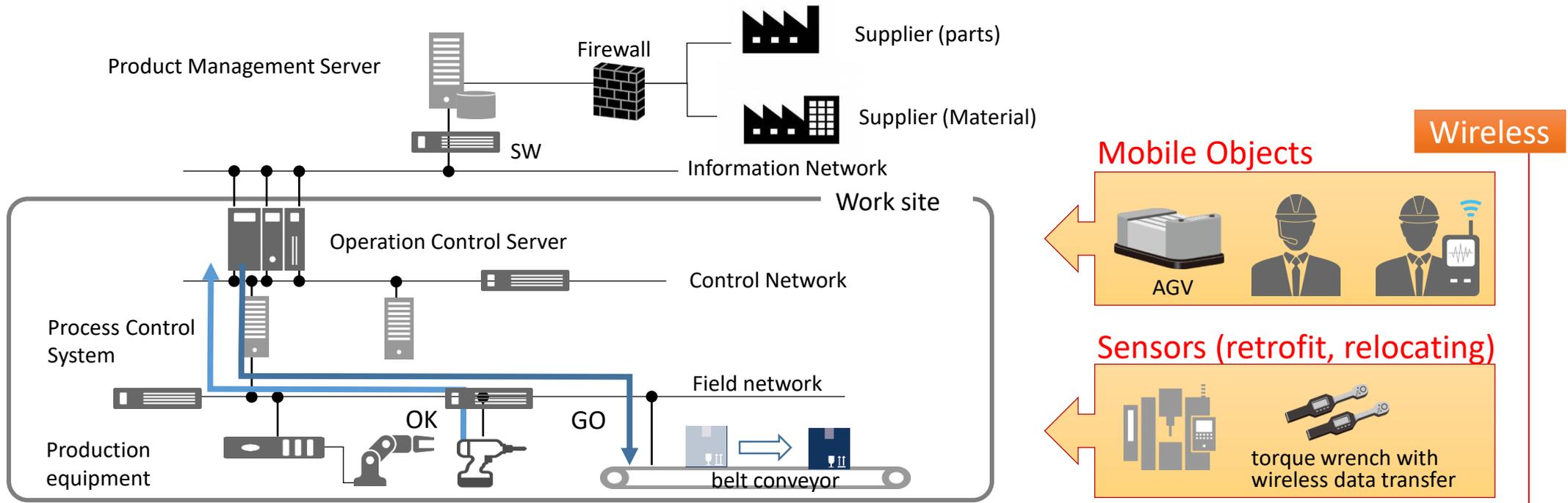
where many and various equipment and devices coexist and are attached to the wired network via wireless connections.

\*1 [https://www.vdi.de/uploads/media/Stellungnahme\\_Cyber-Physical\\_Systems.pdf](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>

# 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., FFloT[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 FFloT Whitepaper, <https://mentor.ieee.org/802.1/dcn/17/1-18-0025-05-ICne.pdf>

# Factory Applications in Flexible Factory Scenario

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

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

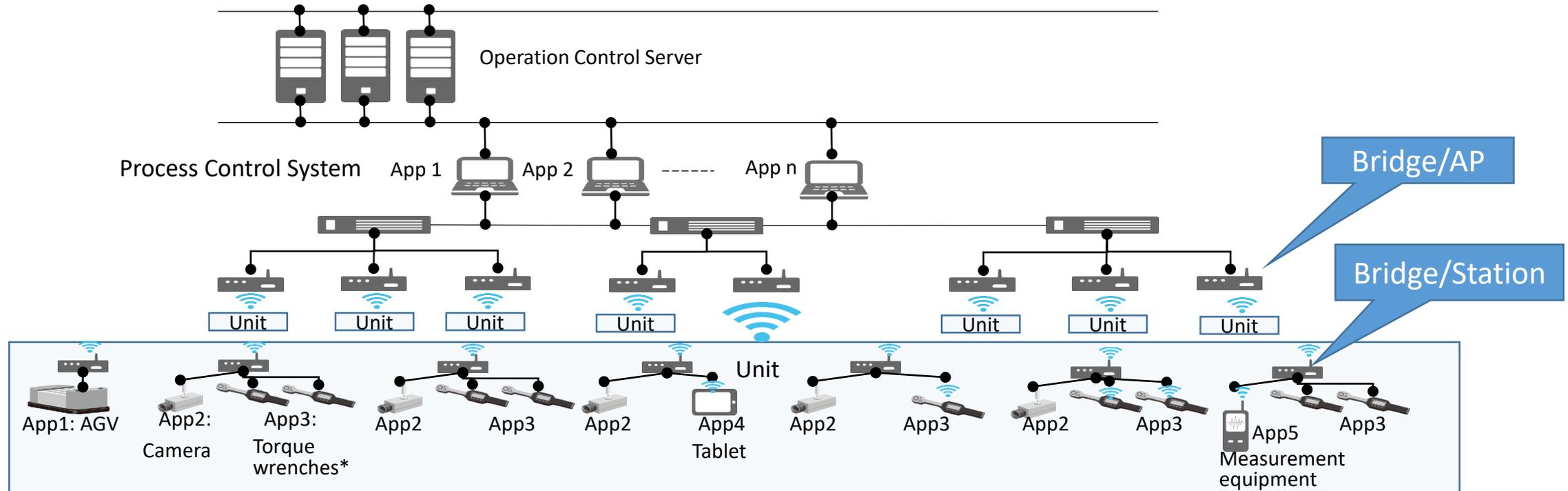
Category	Description	Classification according to the purpose
Equipment Control	sending commands to mobile vehicles, production equipment	(1) Controlling, operating and commanding of production equipment, auxiliary equipment
Quality Supervision	collecting information related to products and states of machines during production	(2) Checking that products are being produced with correct precision (3) 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 <sup>[1]</sup> contributing to productivity enhancement are being managed appropriately	(4) Checking that the production environment is being appropriately managed (5) Monitoring movement of people and things <sup>[1]</sup> (6) Checking the management status of equipment and materials (stock) (7) Checking that the production equipment is being maintained (8) Appropriate recording of work and production status
Display	For workers, receiving necessary support information, for managers, monitoring the production process and production status	(9) Providing appropriate work support (10) Visually display whether the process is proceeding without congestion or delay (11) Visually display the production status
Human Safety	collecting information about dangers to workers	(12) Ensuring the safety of workers
Other	Communication infrastructure with non-specific purposes	(13) Cases other than the above

<sup>[1]</sup> 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 are used 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 FFloT		Communication requirements			
	Purpose	Corresponding Information	Transmit Data Size (bytes)	Communication Rate	Delivery Time Tolerance	Node density(*)
22	Checking completion of process	Torque waveform	100K	<u>1 per sec.</u>	1 sec.	<u>14</u>
		OK, NG	100	<u>1 per sec.</u>	1 sec.	<u>14</u>
<u>added</u>	<u>AGV control</u>	<u>Go, signal, positioning</u>	<u>100</u>	<u>once per 1 min.</u>	<u>100 msec.</u>	<u>10</u>
38	Relay of images for moving	video	<u>20K</u>	30 per sec.	<u>20 msec.</u>	1

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

\*Area:20 m x 20 m

# What are Different?

	Flexible Factory	Industrial Automation
Scale of timing for data transmission/reception	<ul style="list-style-type: none"><li>No strict timing for actions of workers who are collaborating with production machines and systems. <b>Human reaction time is beyond few hundred milliseconds[1].</b></li></ul>	<ul style="list-style-type: none"><li>Precise timing (Cycle time, latency, and jitter) for machine control. <b>Cycle time down to 1msec, delay less than 1us, and jitter less than 1ns are required in some cases[2].</b></li></ul>
Technical issues	<ul style="list-style-type: none"><li>Accommodating mobile objects and relocating equipment and devices with wireless connectivity resulting in dynamic network configuration.</li><li><b><u>Queuing and forwarding at bridges from wired to wireless links,</u></b> considering narrow and fluctuating bandwidth for wireless links[3].</li></ul>	<ul style="list-style-type: none"><li>Ensuring precise timing for data transmission/reception.</li><li>Deterministic network.</li></ul>

[1] Robert J. Kosinski, "A Literature Review on Reaction Time,"

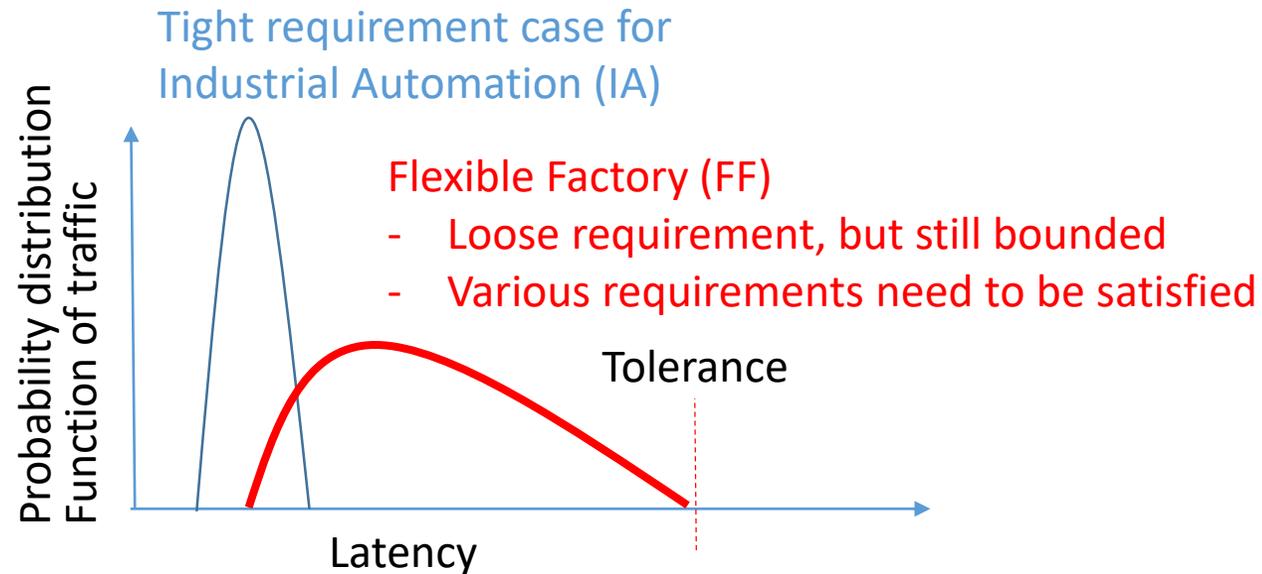
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[2] P60802 document, <http://www.ieee802.org/1/files/public/docs2018/60802-industrial-use-cases-0918-v13.pdf>

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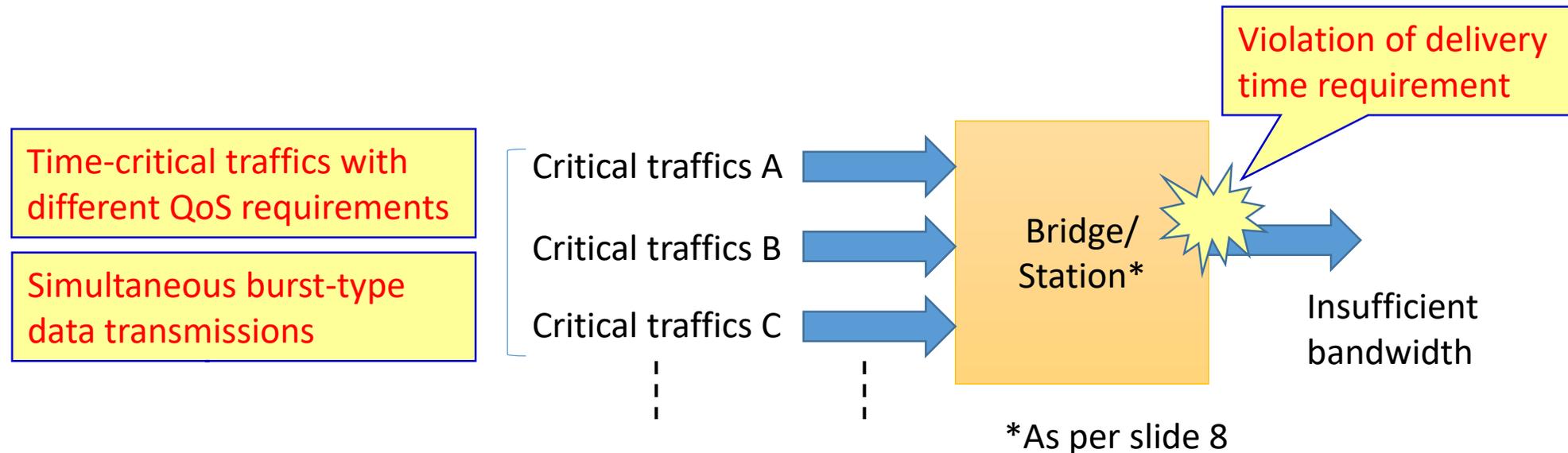
# Observations for factory network

- (a) Many time-critical traffics shall be handled. They require specific latency and are never best effort traffics.
- (b) Simultaneous burst-type data transmissions cause higher latency occasionally at a bridge. It is rare but brings high impact for factory applications.



# Problem statement

- Violation of latency requirement at a bridge of which bandwidth in the outgoing link changes time by time.
  - Time-critical traffics with different QoS requirements for prioritizing.
  - Simultaneous burst-type data transmissions occasionally rushing into the bridge. (Problem is significant for the wireless link )



# Summary

- Flexible factory scenario becomes real where many and various equipment and devices coexist and are attached to the wired network via wireless connections.
- The problem is violation of the latency requirement at a bridge of which bandwidth in the outgoing link changes time by time.
- Issues are:
  - ✓ Accommodating mobile objects and relocating 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.