Flexible Factory IoT (FFIoT) - Enhancement to 802 technologies

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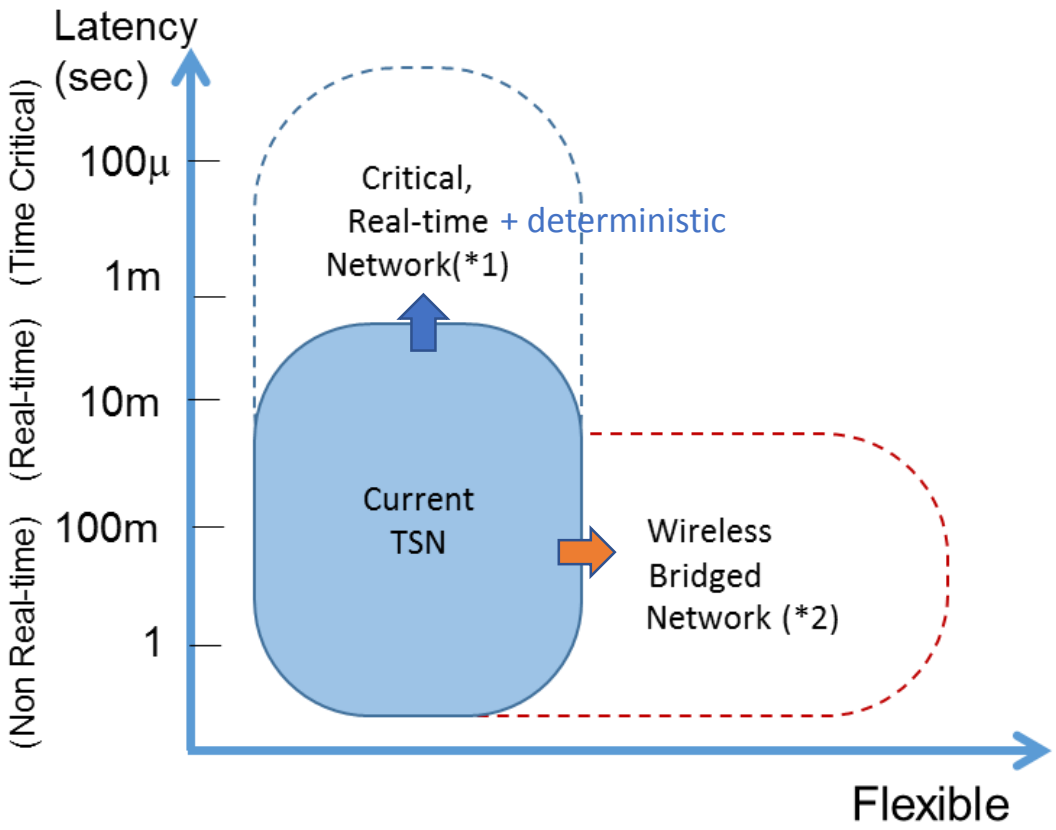
Motivation

- This presentation is intended to show potential enhancements by introducing network flexibility where wired and wireless networks are integrated for industry applications.
- Our target is to enhance 802 functions within factory environment for which stringent requirements are imposed by factory applications and radio propagation condition.
- Details are described in the draft report for FFIoT that is being developed by the IEEE 802 NENDica group (Network Enhancements for the Next Decade Industry Connections Activity).

TSN prospects

- Should see new direction for flexibility in industry connection.

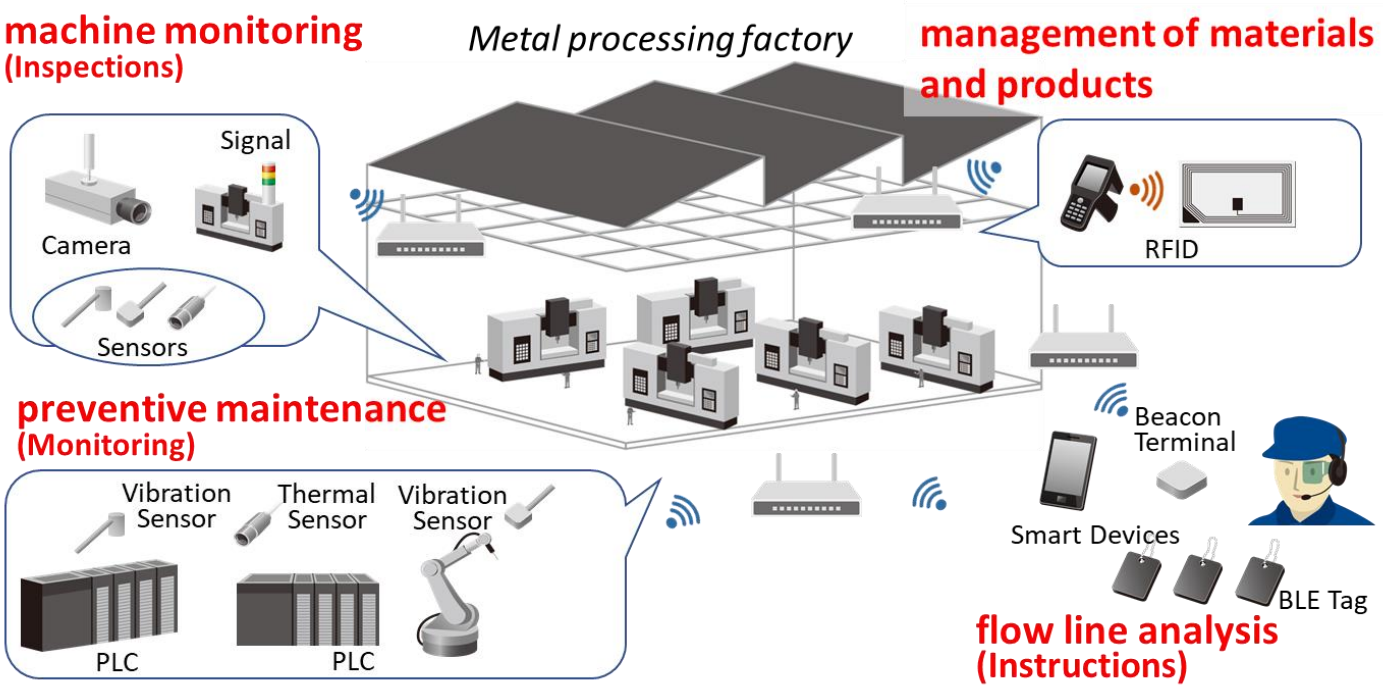


*1 https://www.vdi.de/uploads/media/Stellungnahme_Cyber-Physical_Systems.pdf
*2 Nendica Draft report on Wired/Wireless Use Cases and Communication Requirements for Flexible Factories IoT Bridged Network https://mentor.ieee.org/802.1/dcn/17/1-18-0025-00-ICne.pdf

Prospects

- In factory automaton, wireless nodes are increasing with annual growth rate of 32%.

https://www.hms-networks.com/press/2018/02/27/industrial-ethernet-is-now-bigger-than-fieldbuses

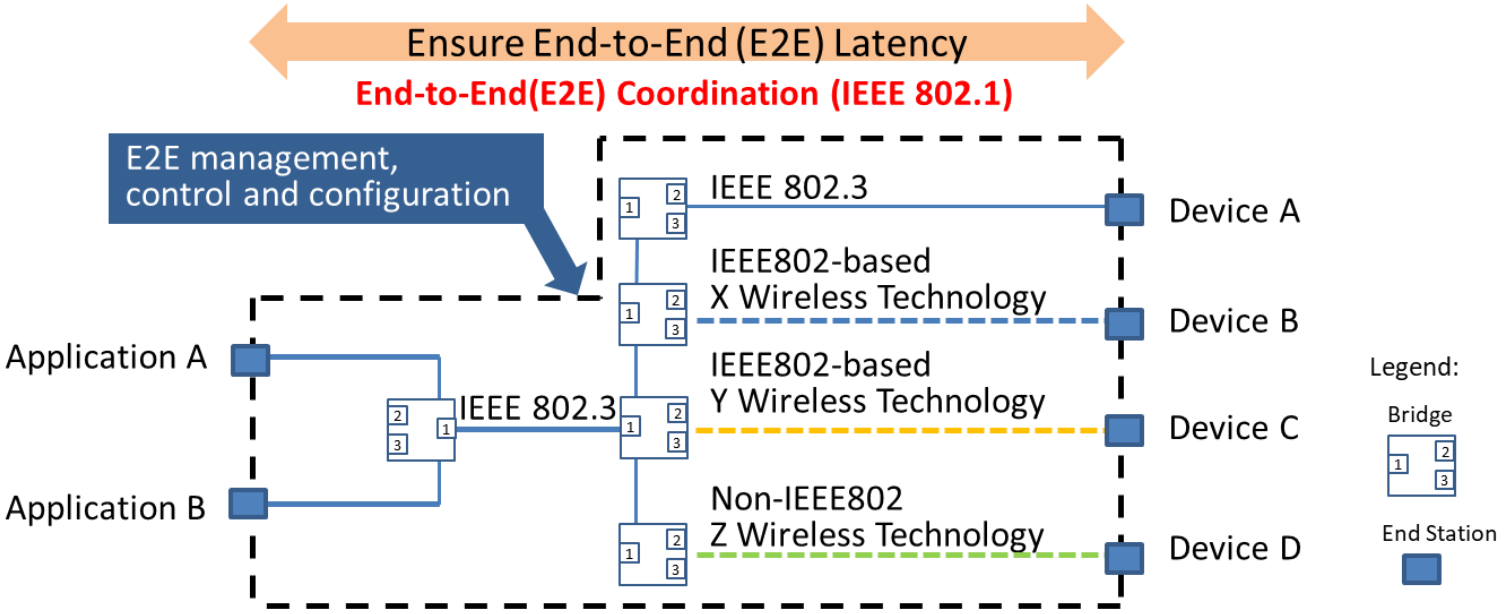


Metal working site

See other usage scenarios in [NENDica FFIoT draft repot]

Concept

- The future flexible factory communication system comprises integrated wired/wireless-combined networking which needs to accommodate various system applications with different communication requirements for end-to-end QoS.
- These requirements are satisfied for end-to-end communications by reinforcing priority control and coordinating with those system applications to adapt to rapid change in links and paths quality.



Gaps in existing IEEE 802 technologies

- Gap analysis presented in the draft report of FFIoT
  - ✓ Coexisting of wide variety of factory applications with different requirements
  - ✓ QoS management for factories
  - ✓ Adaptation to rapid changes in wireless environments
  - ✓ Competition of wireless systems in unlicensed bands
  - ✓ Wireless link aggregation

Coexisting of wide variety of factory applications with different requirements

- Examples of QoS Tolerances in Factory Applications

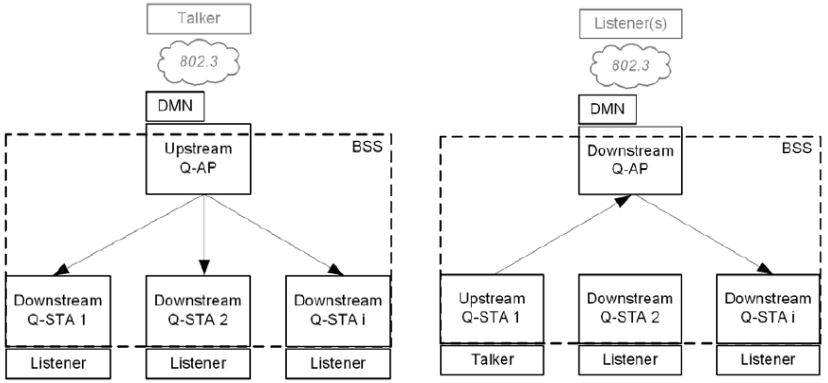
Category of Wireless Applications	QoS Tolerances							
	Latency (msec)			Bandwidth (kbps)			Packet Loss	
	<100	100~ 1000	>1000	>1000	100~ 1000	<100	Loss less	Non-Loss less
Equipment Control	✓	✓				✓	✓	
Quality Supervision	✓	✓	✓	✓	✓	✓	✓	
Factory Resource Management		✓	✓	✓	✓	✓	✓	✓
Display		✓	✓	✓	✓	✓	✓	✓
Human Safety	✓		✓	✓	✓	✓	✓	✓
Others		✓	✓	✓			✓	✓

QoS management for factories

- Several functions and protocols within existing IEEE802 standards that may be used for the provision of QoS and priority control over bridged network.
  - ✓ 802.11e MAC enhancement for QoS
  - ✓ 802.1Qat Stream Reservation Protocol (SRP)
  - ✓ 802.1Qcc SRP Enhancements and Performance Improvements
  - ✓ 802.11aa MAC enhancement for robust AV streaming

SRP on IEEE 802.11 media

- Each STA-AP / STA-AP-STA link is equivalent to the path from an input to an output Bridge's port.
- An IEEE 802.11 BSS provides a single entity called the Designated MSRP Node (DMN) to manage the BSS bandwidth resources for the MSRP streams.

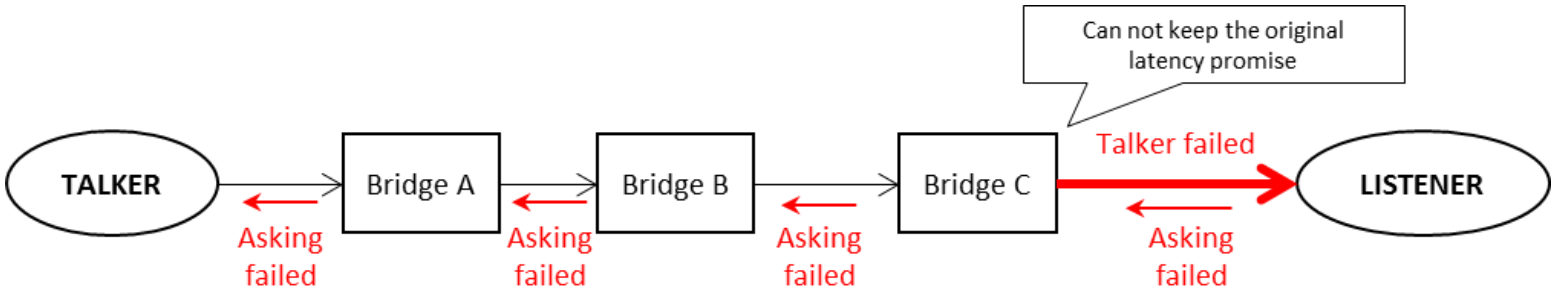


Bandwidth reservation—bridge model for IEEE 802.11 BSS (from Figure C-7, C-8 in Std 802.1Q-2014)

  - ✓ 802.1Qbb Flow-based Priority Control (FPC)
  - ✓ 802.1Qaz Enhanced Transmission Selection (ETS)

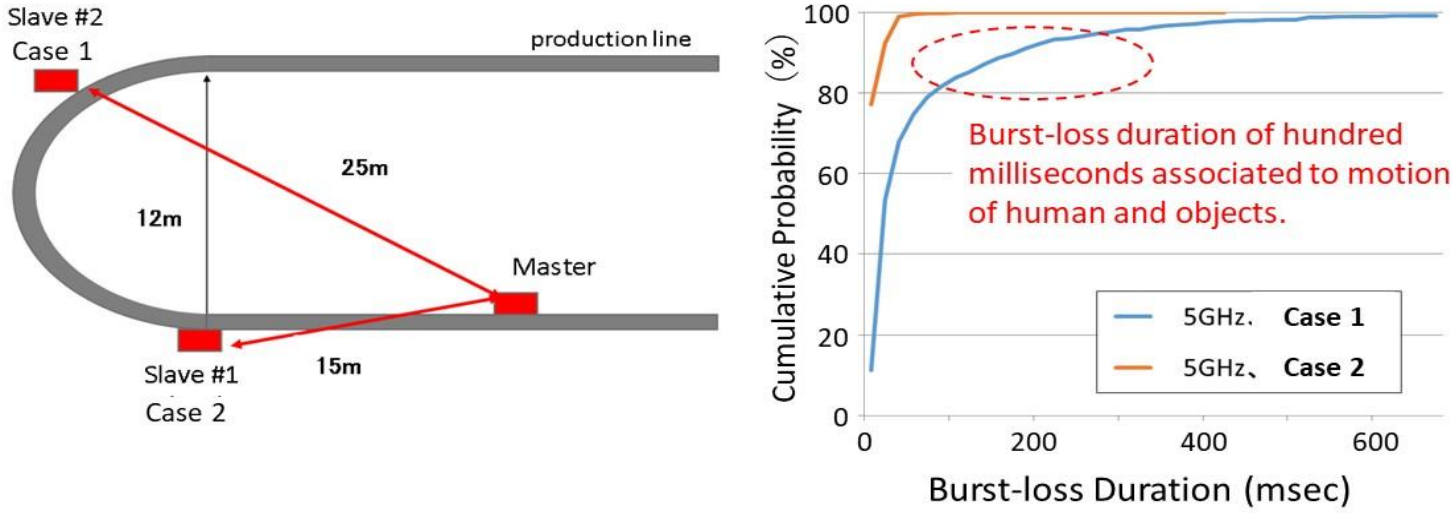
QoS management for factories – cont.

- SRP issue in factory environment
  - *Accumulated Latency* is used to estimate the worst-case latency that a stream could encounter from Talker to Listener.
  - Talker initializes the value and each bridge along the path will add the maximum expected delay.
  - Latency fluctuation over radio link in factory is large, which would increase the latency beyond the original guarantee, MSRP will then change the 'Talker Advertise' to a 'Talker Failed' causing the end-to-end reservation to be failed.



Adaptation to rapid changes in wireless environments

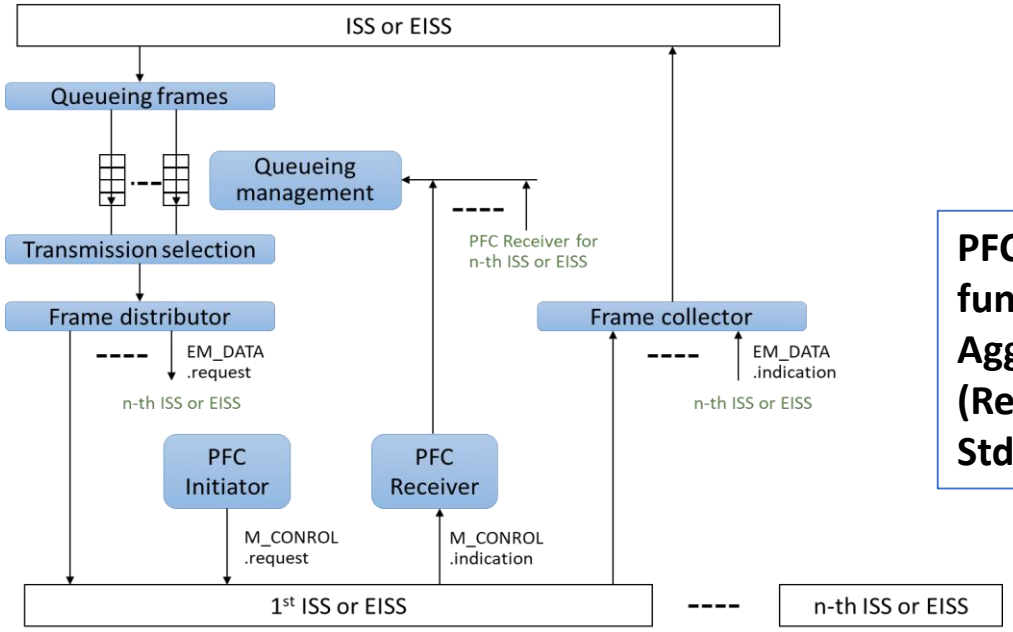
- In the network accommodating factory applications such as quality supervision, factory resource management, display, and some of equipment control and safety, permissible latencies around 100 msec or less for communications.
- An example of measurement indicated burst-loss occurred for the duration of several hundred msec due to multipath fading and shadowing.



Burst-loss measurement in a large machine assembly site. (from Nendica FFIoT report)

Adaptation to rapid changes in wireless environments – cont.

- We considered the applicability of the PFC (Priority-base Flow Control) protocol under the radio condition in factory.
  - To ensure transfer of information between terminals in a dynamically changing wireless environment within the permissible latency.
  - To be a possible fast and efficient queueing control and forwarding mechanism to multiple links over bridges while maintaining required QoS.



PFC aware system queue functions with Link Aggregation (Rewritten Figure 36-4 in Std. 802.1Q-2014)

Adaptation to rapid changes in wireless environments – cont.

- Example- a real time video streaming
  - When the bandwidth of the link is low and the video quality is degraded below its usable level even with high-priority, incoming packets shall be discarded while critical traffic shall continue to be sent.
  - No loss is assumed for PFC which has been designed for data center environment.

Gaps between Current PFC (Std.802.1Q-2014) and Functions to be enhanced

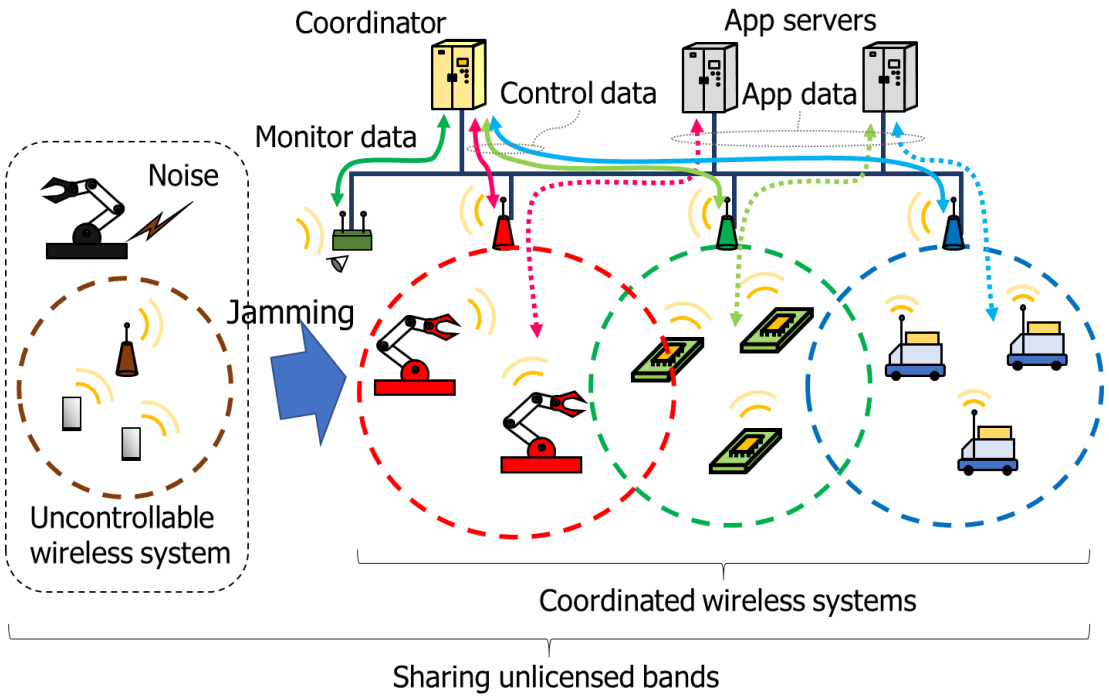
Current PFC (Std.802.1Q-2014)	Functions to be enhanced
8(max) links can be independently paused and restarted by queue control. Only no loss is acceptable for data center environment.	Not only “pause” but also “discard” are acceptable depending on data attributes to express a variety of QoS requirements in factory applications.
There is no specific description about “frame distributor”	Dynamic frame distributor mechanism is required to follow rapid changing bandwidth and to avoid burst losses for each ISS/EISS connected to a wireless media. Also see later description in Wireless link aggregation.

Competition of wireless systems in unlicensed bands

- unlicensed bands are used in many cases because they have large cost advantage in network deployment
- CSMA/CA of Wi-Fi and frequency hopping of Bluetooth are examples of simple mechanism used to allow coexistence operation in unlicensed bands

  stable quality of service is difficult to maintain in such dense shared radio resources
- Some kind of coordination is required to mitigate impact of many wireless system competing to radio resources
- A simple mechanism would be to assign channel of each wireless system according to required bandwidth of applications

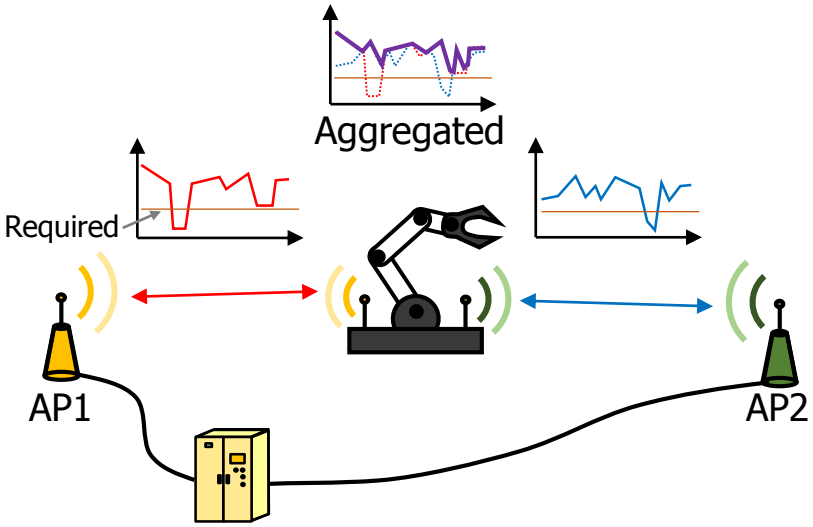
Example of Simple coordinated wireless systems

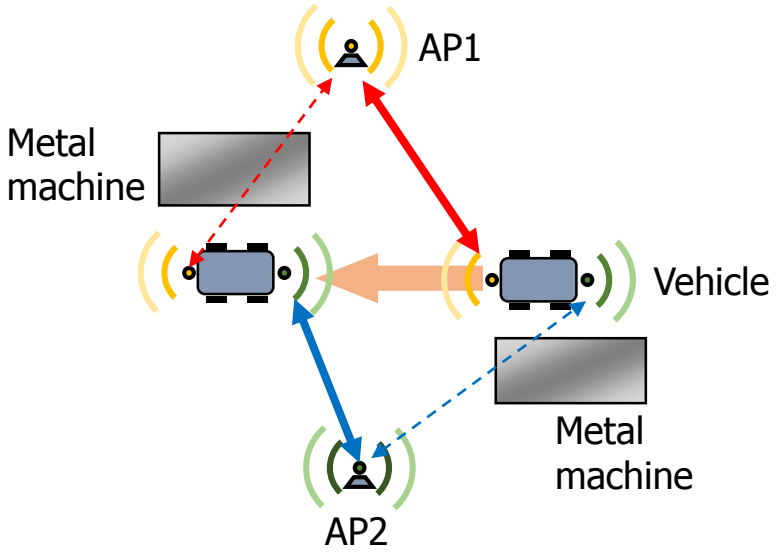


uncontrollable wireless systems and noise from non-communication devices like machine tools also need to be monitored, analyze behavior of interferers and estimate available wireless resources accurately for allocating wireless resources according to demands of applications

Wireless link aggregation

- It is difficult to keep stable wireless link quality in factory
- Use of multiple wireless links can improve the stability



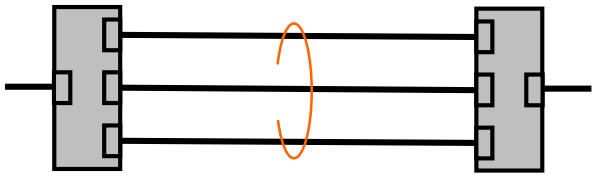


- Correlation between wireless links is low in general
- Intermittent low bandwidth can be compensated by redundant data transmission through multiple links

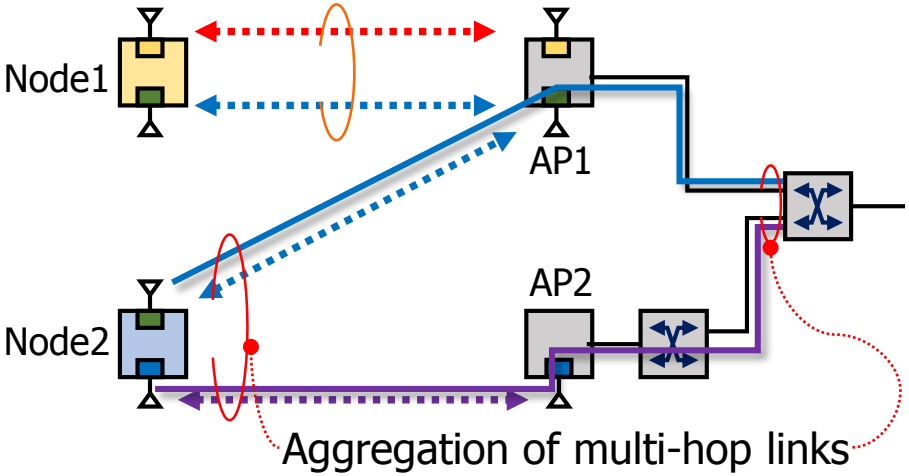
- Handover occurs <u>after link quality becomes bad</u>
- Use of multiple links can also mitigate impact of the handover

Wireless link aggregation – cont.

- Link aggregation is defined in 802.1AX, but it is not applicable to the wireless link aggregation directly



Aggregation of single-hop links



802.1AX	Wireless link aggregation
• 802.1AX assumes single-hop links between 2 switches	• Aggregation of multi-hop links needs to be assumed
• Redundant frame transmission is not allowed for maximizing throughput	• Redundant frame transmission needs to be allowed for making data path robust

Summary

- Latest Pre-draft FFIoT whitepaper 1-18-0025-01-Icne is available in the NENDica document area for Flexible Factory IoT project (FFIoT)
- Includes description of the factory environment, list of wireless applications and requirements and how they are used within factories (Usage Scenarios)
- Examples of Gap in IEEE802 technologies are analysed for meeting these requirements and enhancing IEEE802 functionalities
- You are invited to review the draft white paper and contribute with your ideas and expertise toward enhancing IEEE802 technologies for Flexible Factory IoT…

You can submit your ideas to the FFIoT whitepaper by submitting it in a contribution and upload to NENDica document area
https://mentor.ieee.org/802.1/documents?is_group=ICne
Please also send an email to Nader.Zein@emea.nec.com