Wired/Wireless Convergence for Factory IoT

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Motivation

- Within the wired and wireless networks for factory IoT, we are considering the application of 802 technologies to support the requirements in the following combined situations:

(1) End-to-end(E2E) reliable and robust connectivity required by factory applications

(2) Dynamically changing wireless environment

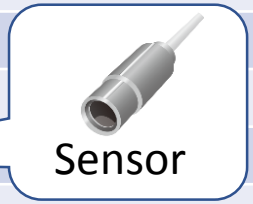
(3) Wired and wireless bridge in heterogeneous networks

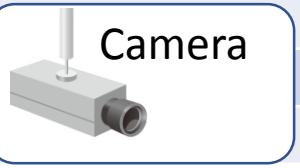
→Goal: E2E Network Topology for Factory IoT

(1) E2E Reliable and Robust Connectivity

Applications in red require to ensure latency.

Category	Wireless Applications
Control	Machine, Robots
	AGV w/wo Rails
	Rotary Equipment
Quality	Inline Inspection, Pokayoke (notifying process failure or stop process)
	Machine Monitoring, Production Recoding
	Logging
Management	Preventive Maintenance for Tools and Machines
	Positioning and Motion Analysis for flow line analysis, Inventory Control (management of materials and products)
	Facility Environment Control
Display	Work Instruction
	Andon (notifying quality or process problems to managers and workers)
Safety	Dangerous Behavior Detection
	Vital Sign Monitoring
	Emergency Warning

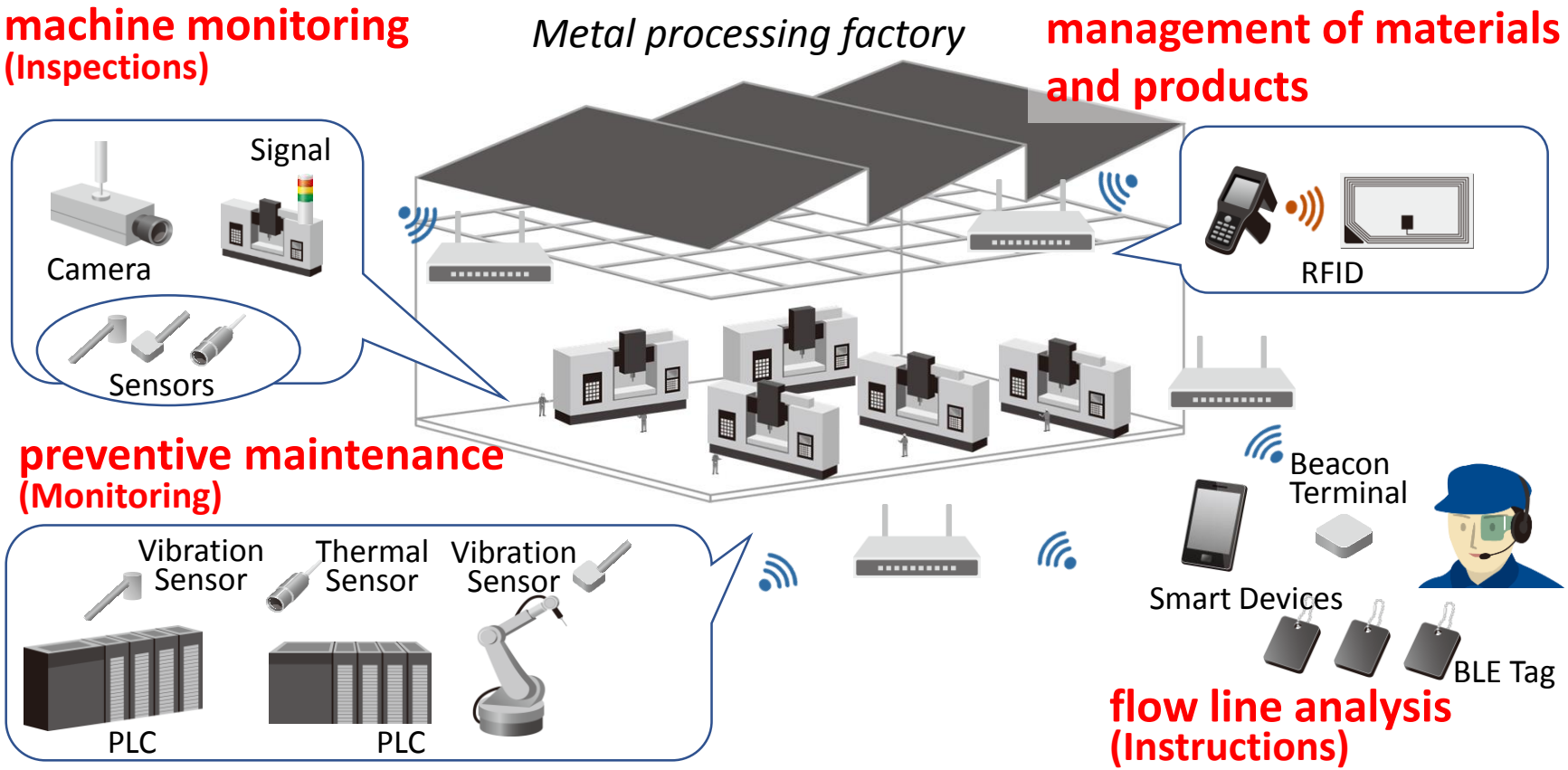




Source: Flexible Factory Project

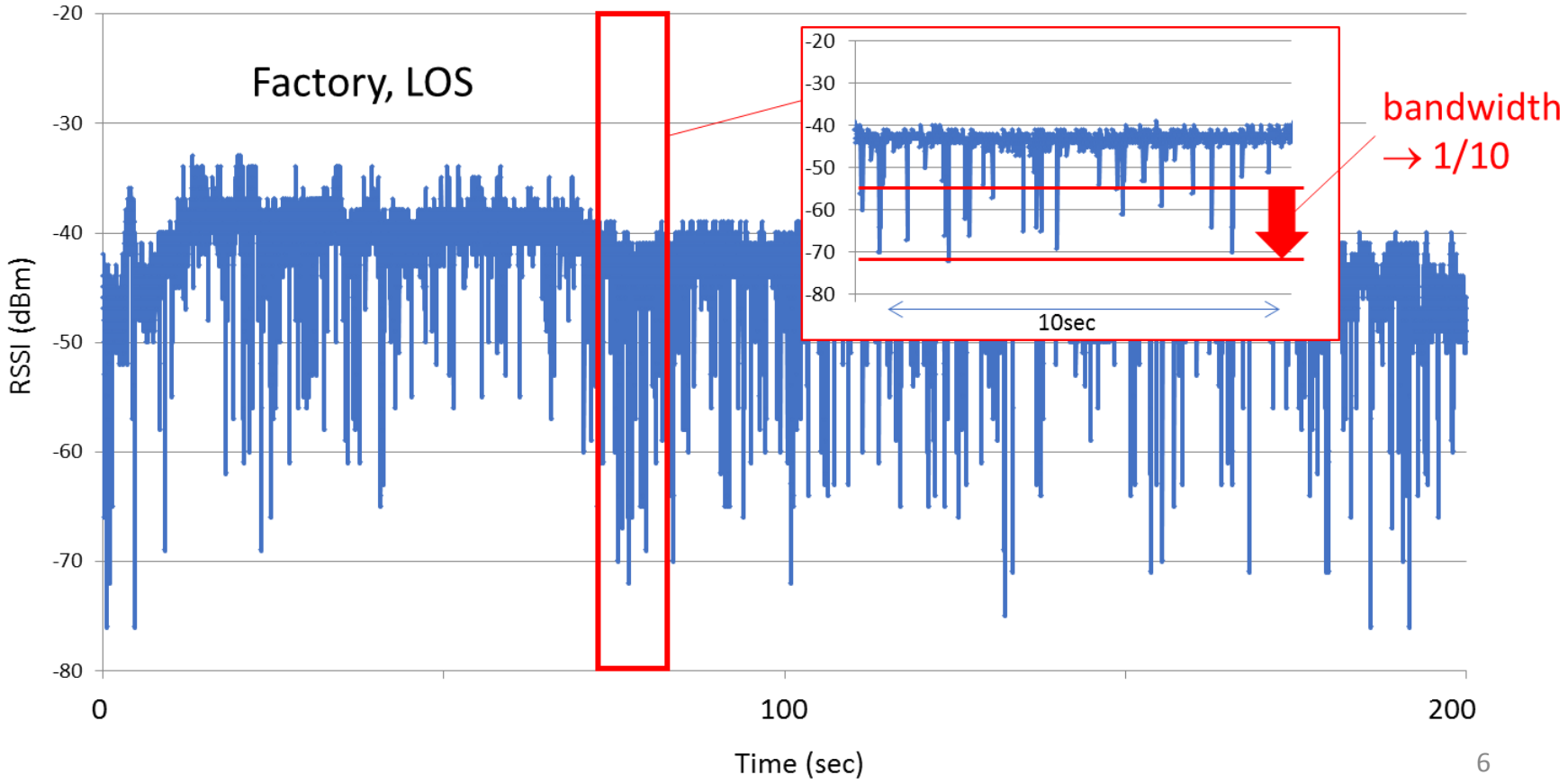
Example: Wireless Applications for Factory IoT

- On-the-spot feedback for inspections, monitoring, and instructions require 20-100^{+}msec latency for factory IoT.



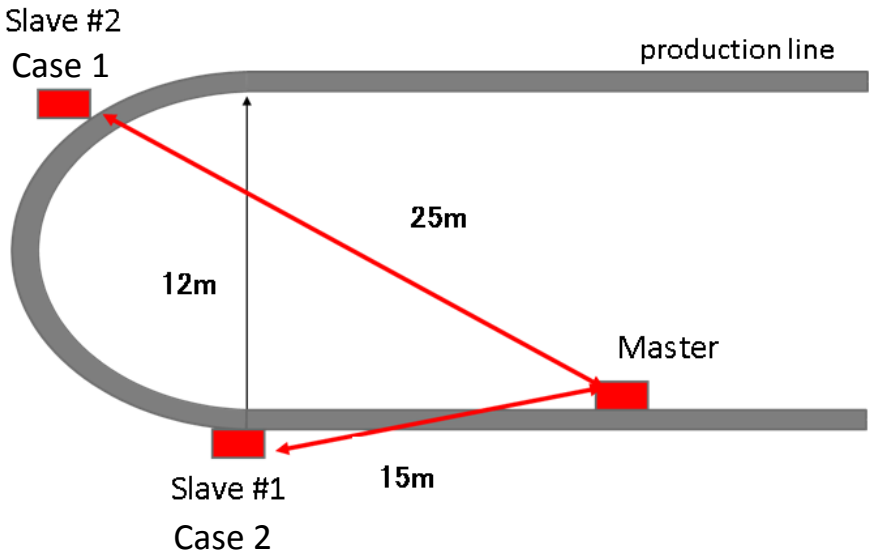
(2) Dynamically Changing Wireless Environment

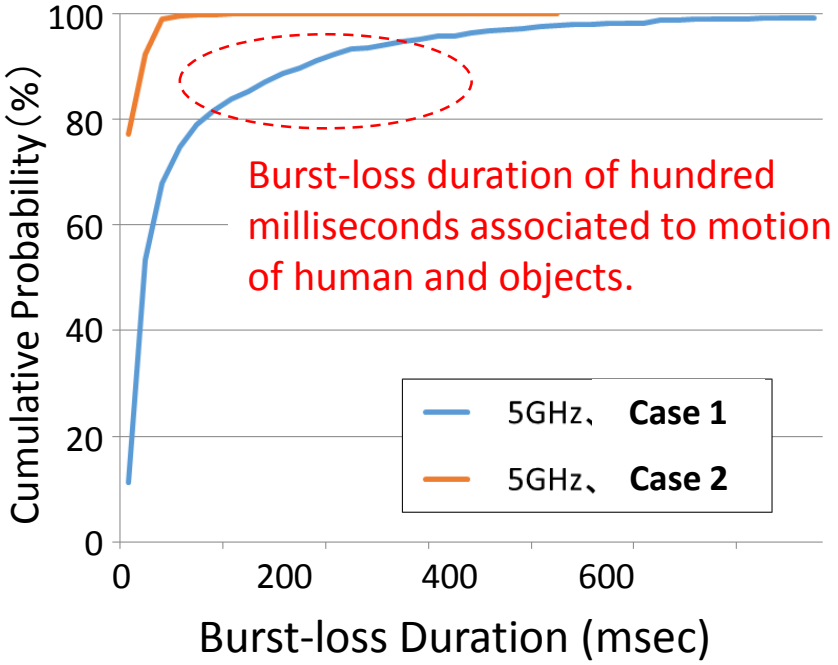
- 20dB drop in RSSI corresponds to 1/10 down in bandwidth.
- Packet loss or fixed low-rate if rate-control does not follow.



Burst-loss at fixed data rate

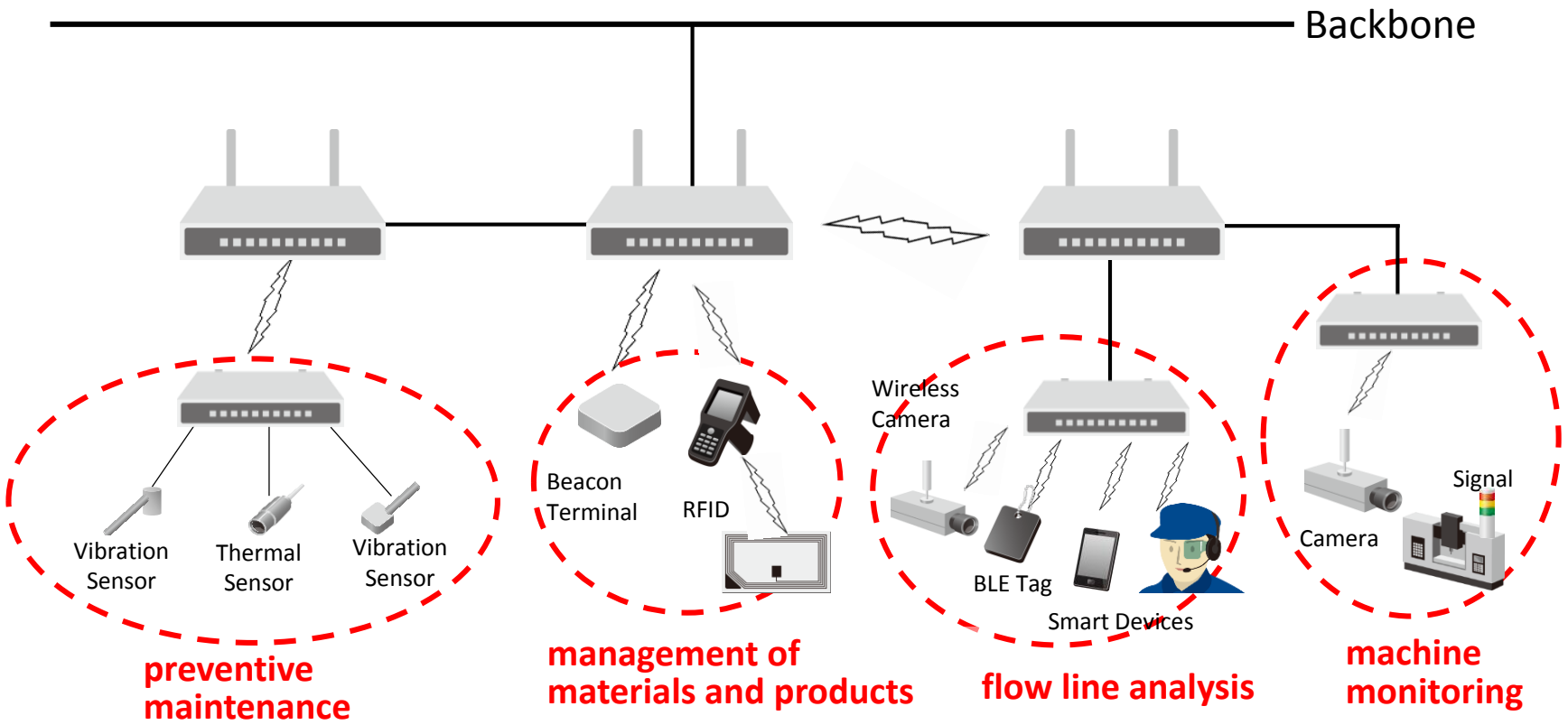
- Long burst-loss duration observed at fixed rate.
- Unaffordable delay may occur in the worse case.





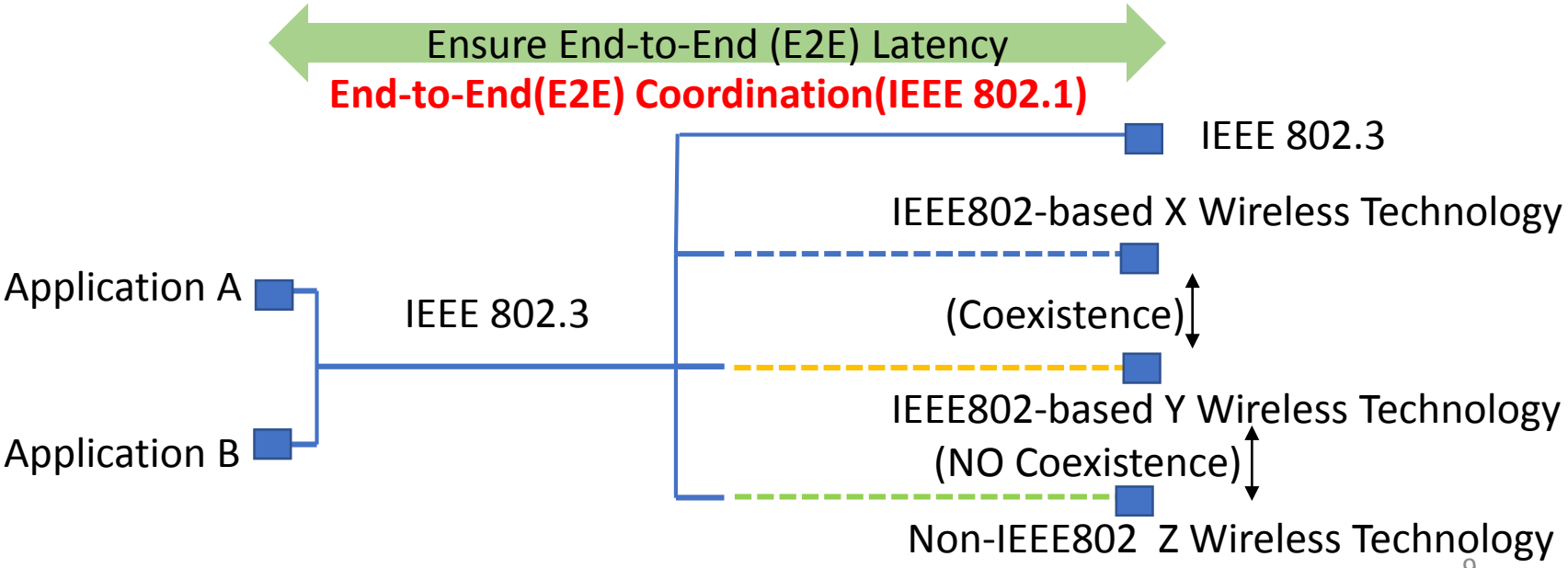
(3) Wired and Wireless Bridges in Heterogeneous Networks

- Many wired and wireless links are mixed up to have bridges in heterogeneous networks.



Goal:E2E Network Topology for Factory IoT

- End-to-End (E2E) network topology for a factory today is configured by a mix of wired links such as 802.3, and wireless links as IEEE802-based and non-IEEE802 technologies.
- In order for factory IoT system to work well under such network topology, data streams need to be managed by high-level E2E coordination.

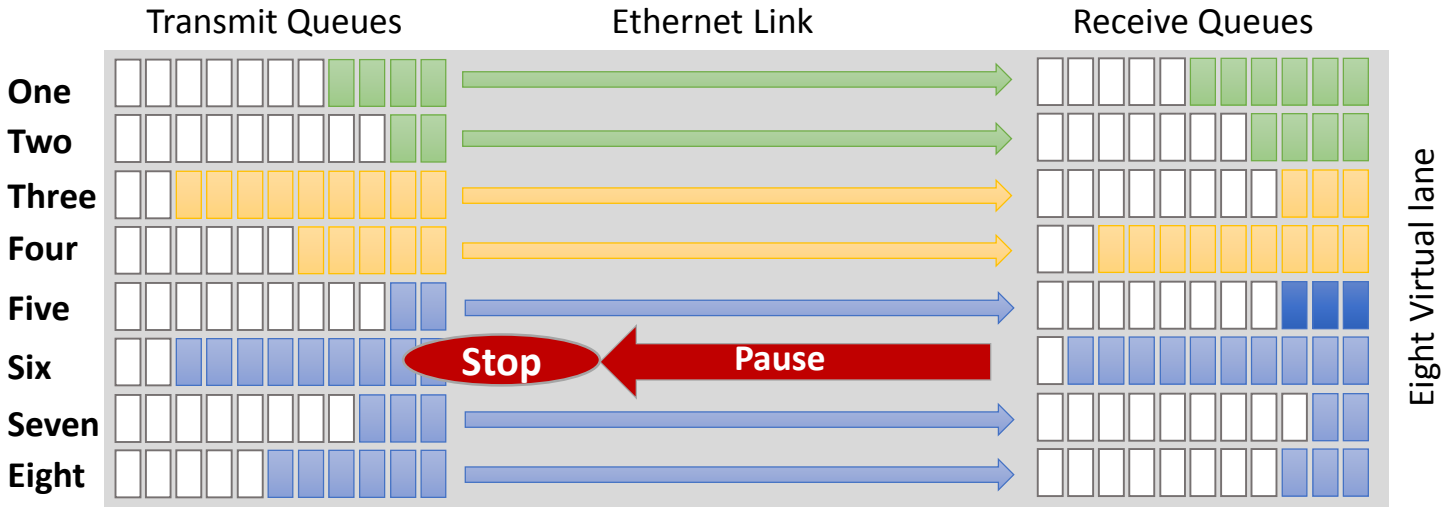


Observations

- Many functions of 802.1Q may be used for the provision of low-latency, low-jitter, bandwidth reservation, and priority control in heterogeneous networks.
  - ✓ Stream Reservation Protocol (SRP)/Multiple Stream Reservation Protocol (MSRP). [802.1Qat]
  - ✓ Forwarding and Queuing for Time-Sensitive Streams (FQTSS) [802.1Qav]
  - ✓ Priority-based Flow Control (PFC) [802.1Qbb]
  - ✓ Congestion Notification (CN) [802.1Qbb]
  - ✓ Enhanced Transmission Selection (ETS) [802.1Qaz]
  - ✓ (Generalized Precision Time Protocol (gPTP)[802.1AS])

Example of PFC in IEEE 802.1Qbb

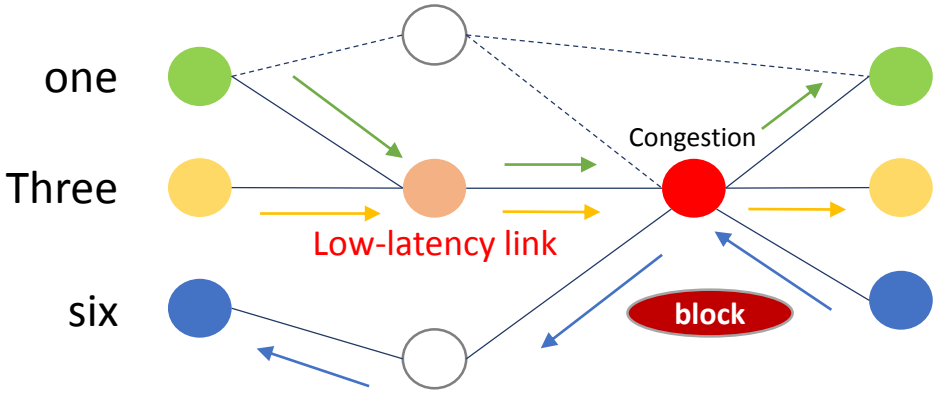
- Priority-based Flow Control（PFC）creates eight separate virtual links on the physical link. It enables pause based on user priorities or classes of service.
- What happens if wireless links are mixed in the virtual Ether link without coordination?



Pier to Pier Virtual Ether Link

Example of Shortcoming with Multi-hop Links

- Data streams rush into the physical link with the lowest latency regardless of actual bandwidth at that time.
- Unnecessary stopping/interruption may occur in some cases without dynamic load balance among physical links
- A situation become more serious due to narrow and fluctuating bandwidth of the wireless link.

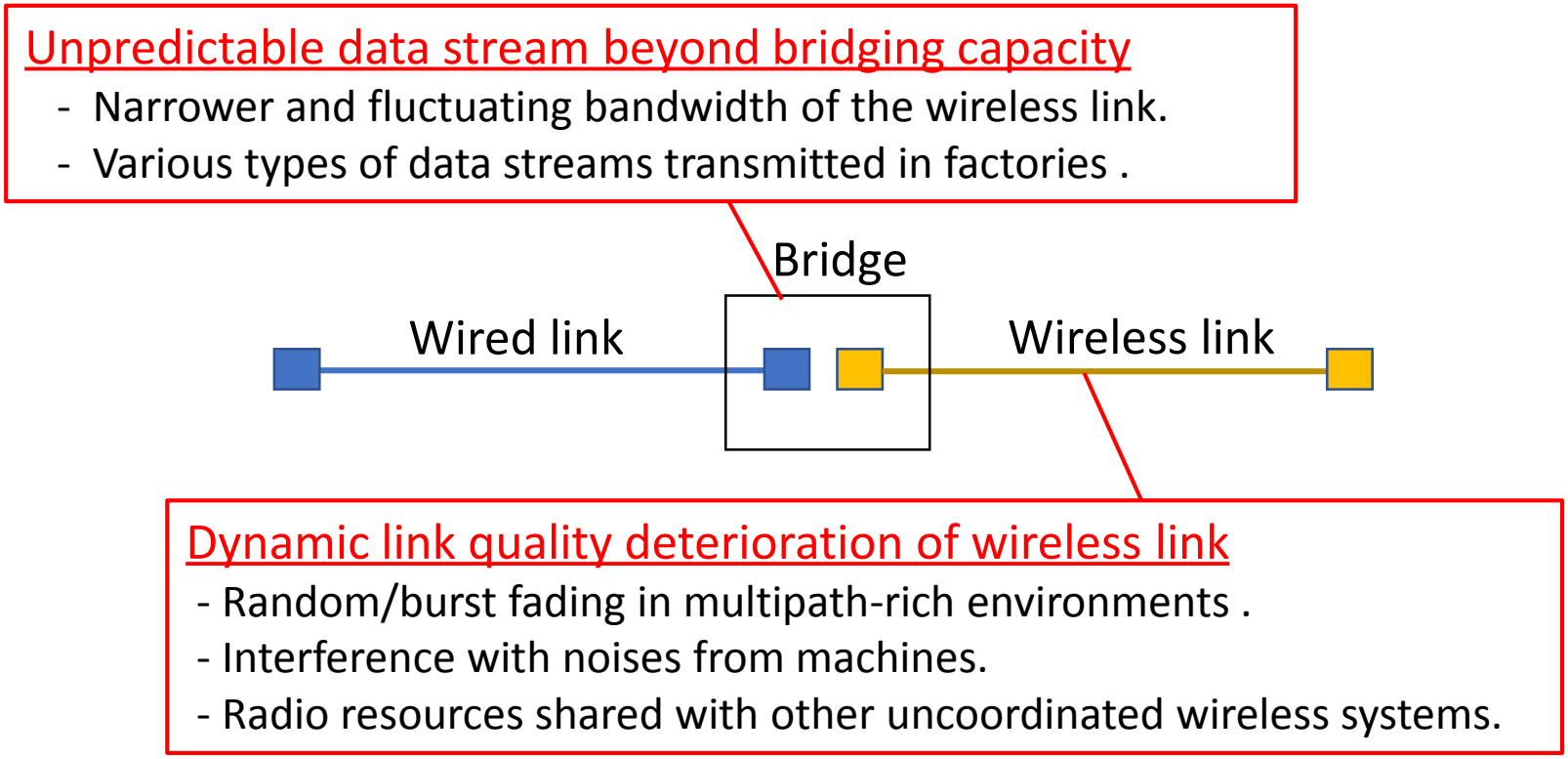


Physical Network with Multi-hop Links

Data streams No. “one” and “three” rush into the lowest-latency link that causes congestion. It results in blocking data stream No. “six.”

What are Essentials?

- For the physical network of wired/wireless links, unaffordable delay (or stopping data stream) may occur at the wired-wireless bridging with the wireless link.

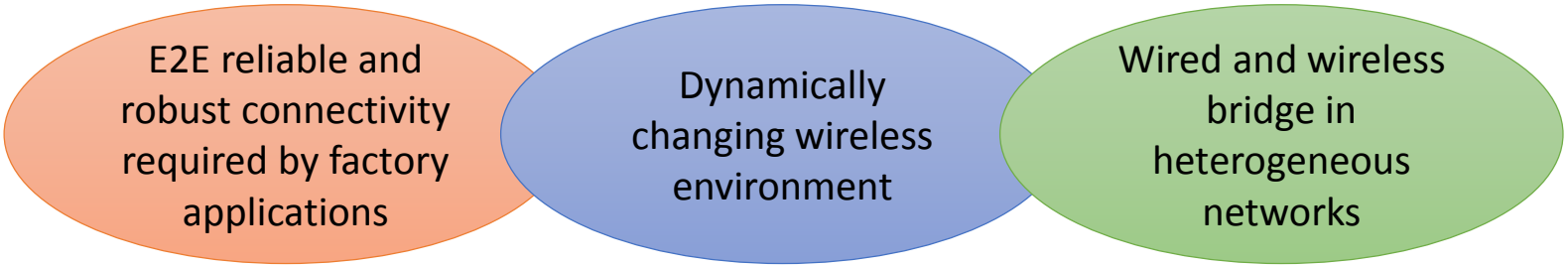


Our Major Concerns for Networks in Factories

- Unpredictable data stream beyond bridging capacity.
  - ✓Wireless links, which are characterized by variable delays and bandwidth change dynamically, may become bottlenecks in the virtual LANs.
- Dynamic link quality deterioration of wireless link.
  - ✓Fast and large fluctuation of the wireless-link performance may be unavoidable in some factories.

Special Requirements for Networks in Factories

- Analysis of use cases reveal special requirements for achieving robust and reliable E2E streams for a network in factory environment.
- *As for the next step, we will develop a system profile for E2E connectivity in factory environment.*



Factory Environment