CID 192: Need to update the conclusion.

As a proposed resolution, the following is suggested rewrite for the conclusion.

# Conclusion

Communication in factories has until now been mainly wired communication. There are increasing expectations for the use of wireless connectivity amongst machines in the manufacturing and factory processes. Future industrial factory networks are expected to use more wireless to reduce the installation cost as well as to enhance flexibility. As such, the factory network needs to support the successful operation of various wireless applications.

This report addresses integrated wired and wireless Internet of Things (IoT) communications in the factory environment, and includes use cases and requirements with a focus on bridged Layer 2 networks. It presents problems and challenges observed within the factory and reports on possible solutions for overcoming some of these issues in order to enable flexibility within factories.

One distinct aspect of factory networks is that the physical devices connecting to the network are used to control and monitor real-world actions and conditions. This requires the provisioning of QoS for a variety of traffic types that may be characterised as either periodic or sporadic. In a flexible factory, humans are engaged in the control and monitoring system and therefore need to be interconnected with the network in order to interact with physical devices and machinery.

When the factory network is extended over radio, some incompatibility in QoS provisioning between wired and wireless segments becomes apparent due to unpredictable variations in the available bandwidth over the radio segment. In order to overcome the variable environment for wireless communications, coordination amongst network elements is required.

The report considers communication requirements for six categories of wireless applications, which are classified according to their purpose.

For factory applications, QoS latency tolerance is classified into small, medium or large. Bandwidth tolerance is classified into wide, medium or narrow, and the tolerance for packet loss is classified into loss intolerant or loss-tolerant. This implies that factory applications may require a large number of QoS classes, more than the 8 classes specified in IEEE Std 802.1Q. To deal with a large number of QoS class requirements, defining usage of tag fields may be needed for precise and fine QoS control over L2. Any priority tag must be understood in both wired and wireless networks, which may require tag translation amongst the two.

Future industrial wireless communications will take advantage of TSN functions and features specified in IEEE 802.1. The wired/wireless integrated networks for future flexible factories IoT scenarios should be able to accommodate various applications with different end-to-end QoS requirements. These requirements can be met by closing the gaps within the following functions:

* End to end stream reservation in a wired/wireless integrated network
* Wireless link redundancy for reliability and jitter improvement
* Adaptation to rapid changes in wireless environments
* Coordination among the wireless transmissions in the unlicensed bands

Coordination mechanism is required in order to ensure end-to-end QoS provisioning over the entire factory network. The following control functions over the wired/wireless network are anticipated for coordination purpose.

1. Control of data flows across wireless links.
2. Joint coordination of frequency channel and forwarding paths.
3. Spatial control for wireless links, i.e. power and antenna directivity.

For the purpose of reliability, queueing and forwarding, mechanisms for redundancy need make use of data attributes over the network. The coordinator can set policies for transmission of application data in a way that tolerates the degradation in the network due to the bandwidth changes that can occurs over the wireless links.

Hierarchical control system consists of centralized coordinator and distributed coordination agent on each individual Bridge/AP. For the purpose of satisfying requirements of each factory applications, the following considerations need to be standardized.

1. Control policy: messages and interfaces between a coordinator and various systems.
2. Information on wireless environment: link/path quality.
3. Data attributes: common information including various requirements, e.g. data rates (or data size at an application level and data frequency), latency, affordability of packet loss.

When wireless is used in factory networks and systems, some TSN features may be required to perform seamlessly as they would over the wired portion of the network. This implies additional challenges that need further consideration, such as the impact on latency and reliability of the wireless links at Layer 1/2.

The radio environment in the factory also poses additional challenges. Characterization of radio channels in factory environments may additionally help, if available, with such planning and deployment.