May 2026

Addition TSN Industrial Automation Use Cases – Requirements Discussion

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References

[1] “Additional TSN Industrial Automation Use Cases v04”, collaborative document, IEEE 802.1 TSN TG, March 2026

Content

- Introduction
- Use Cases & Potential Requirments – For Discussion
  - Covers use cases 1 to 5 in order

Introduction

- Document [1] outlines several distinct potential use cases but includes very few firm requirements.
  - Without firm requirements, it is difficult to know what functionality and performance to target, and impossible to determine whether a proposed solution will deliver what the ecosystem requires.
- This presentation is intended to provoke discussion of requirements for each individual use case.
  - Following this discussion, a revision of this presentation may be made, including the results.
  - Based on the discussion a further revision of [1] may be created.

Ground Rules

- Tend to include vs. exclude at this stage
- Initially, it's more important to identify requirement categories (e.g. minimum bandwidth) than specific requirements (e.g. >20 Mbps)

Use Cases

1. Deterministic Wireless Communication
2. Redundant Communication (FRER for Relays)
3. Virtual PLCs (FRER; Virtual NICs)
4. Remote Virtual PLCs (Multi-subnet Operation)
5. Bumpless Joining of Two Machines

SECURITY

6. Maintain security during Device Replacement and Modular Machine Assembly
7. Resilience Against Attacks via LLDP (Control Plane)
8. Resilience Against Attacks via Time Sync (Control Plane)
9. Resilience Against Increasingly Sophisticated Attacks (excluding Quantum Computing)
10. Resilience Against Attacks Using Quantum Computation
11. Robust Supply of Security Core Function

1. Deterministic Wireless Comms

Use Case

Wireless communications can be used in multiple scenarios. For example:

- Autonomous Mobile Robots (AMRs) and other mobile applications.
- Sensors and actuators where wired communications are impossible due to environmental conditions or movement.
- Communications where wired connectivity is expensive and wireless offers cost saving.

Within these scenarios, the ability to easily build heterogeneous networks with wired and one or more wireless technologies is desirable. The industrial automation use cases often require the same or similar capabilities from wireless connectivity when it comes to determinism and reliability. The use of existing wireless technologies is preferable. For example:

a) IEEE 802.11
b) IEEE 802.15.1
c) IEEE 802.15.3
d) IEEE 802.15.4
e) 5G / 6G

Are all of these required?

1. Deterministic Wireless Comms

Requirements?

60802 1st Edition capabilities?

- Time Sync – Accuracy over X hops?
- Hot Standby (ASdm)
- Scheduled Traffic (Time-Aware Traffic Shaper; Qbv) – Number of Queues?
- Pre-Emption (Qbu)
- Credit-Based Shaper (Qav)
- FRER (Frame Replication & Elimination for Reliability; CB)

- Wireless-specific Management (YANG)?

2. Redundant Communications – FRER for Relays

Use Case

For critical applications, where loss of communication is unacceptable, networks are constructed to provide redundant paths. Data is replicated at one point in the network; copies of the data travers redundant pathways across the network; at a later point in the network, the pathways join and redundant data is eliminated.

The points of replication and elimination can be at the source (talker), sink (listener), or any point between (e.g. a bridge).

Existing Support & Potential Additions

IEC/IEEE 60802 1st Edition includes optional support for replication and elimination at an End Station (ccA or ccB), but not at a bridge (see 5.10.1b and 5.10.1c). Support for replication and/or elimination at a bridge is a possibility for 2nd Edition.

2. Redundant Communications – FRER for Relays

Requirements?

Just add equivalent FRER relay requirements?

Note: possible connection with support for Virtual PLCs…

- Virtual PLC may have Virtual NIC. Multiple Virtual NICs "connected" to a single Physical NIC. Physical NIC could be modelled (for CNC) as a bridge **and** be responsible for Replication / Elimiation.

3. Virtual PLCs (FRER; Virtual NICs)

Use Case

Historically, Industrial Automation (IA) workloads have executed on PLCs running RTOSs. In the future it is expected that some workloads will execute on virtual PLCs (vPLCs) in containers or Virtual Machines (VMs) running general purpose OSs (e.g. Linux) with real-time capabilities.

The latter architecture enables distributed control systems that are much more dynamic, with workloads potentially being short-lived and/or rapidly moving from one location in a network to another. The network itself may also include a combination of physical NICs and virtual NICs, the latter running as part of a virtual machine.

The network protocols, and network configuration and management tools need to cope with the dynamic orchestration of workloads and nature of virtual NICs, specifically the fact that multiple virtual NICs' capabilities may be constrained by the resources available in a single physical NIC.

3. Virtual PLCs (FRER; Virtual NICs)

Existing Support & Potential Additions

IEC/IEEE 60802 1st Edition includes optional support for replication and elimination at an End Station (ccA or ccB), but not at a bridge (see 5.10.1b and 5.10.1c). Concerns have been raised that some aspects of the current FRER recovery algorithms may be problematic for dynamic, virtual environments (see [11]) and may be addressed by maintenance actions that the 802.1 TSN TG is currently considering (see [12]).

Contributions would be appreciated on the challenges and potential solutions related to the uses of virtual NICs.

3. Virtual PLCs (FRER; Virtual NICs)

Requirements?

FRER for relays (i.e. 2)? Simplified for vPLCs?

Revised FRER Vector Sequence Recovery algorithm? (CBec)

Modelling for virtual NICs and physical NICs?

- Is a physical NIC understood as a (limited function?) bridge?

4. Remote Virtual PLCs (Multi-subnet Operation)

Use Case

Architectures that support consolidation of workloads from multiple PLCs to a single, higher-powered industrial PC (see Use Case 03) also enable the physical location of the PC and it's workloads to be more easily moved away from the production line to, for example, and on-premises data centre or the Cloud. This location is typically not on the same IP subnet as the production line. Thus, network traffic from the workload to the production line has to traverse multiple subnets.

There are two potential use cases:

a) Integration of determinitstic IETF, IP-Level, cross-subnet, dynamic routing (DETNET)

b) Ability to set up a cross-subnet, QoS "tunnel" that can be comprehended and used by dynamic routing that is otherwise restricted to single subnet operation.

Are both of these required?

4. Remote Virtual PLCs (Multi-subnet Operation)

Requirements?

For IETF DetNet…

- Support for which 60802 features? With what level of performance?

For QoS “tunnel”…

- What metrics would be guaranteed? (<X latency provide bandwidth doesn’t exceed Y Mbps?)
- How would the tunnel be presented to a CNC (YANG)?

5. Bumpless Joining of Two Machines

Use Case

In some production environments, machines can connect and disconnect to and from multiple different networks during normal operation. For example, multiple AGVs (automatic guided vehicles) accessing various docking stations to communicate with a supervisory PLC. At times, an AGV may operate as a self-contained CPS (Cyber-Physical System). At other times, an AGV may act as one part of a larger CPS.

As networks are separated and joined, the operation of the AGVs must not be interrupted, i.e. there can be no “bump”; the separation and joining must be “bumpless”.

5. Bumpless Joining of Two Machines

Existing Support & Potential Additions

IEC/IEEE 60802 1st Edition covered alignment of a 2nd machine's time domain with a 1st machine's in a bumpless manner (see D.2.3). It also states that if 2nd machine's time domains ceases to exist (i.e. replaced by first machine's) "Typically, in this case, the second machine is not operational while it is joined to the first.", i.e. BUMP!

Discussions in IEC/IEEE 60802 have included suggestions that further informative guidance could be provided on how to enable bumpless separation and joining either with or without normative additions to the specification.

5. Bumpless Joining of Two Machines

Requirements?

Can we, at this early stage, decide whether this could be informative?

If not…what are use case requirements?

Thank you!