Requirements IEC/IEEE 60802

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Abstract

This document describes requirements for industrial automation based on TSN. The requirements are extracted and derived from:

[1] “Industrial Use Cases”, IEC/IEEE JWG Contributor group;
http://www.ieee802.org/1/files/public/docs2018/60802-industrial-use-cases-0618-v07.pdf

[2] “IEC preCD 60802”
http://www.ieee802.org/1/files/private/liaisons/65c-60802-Ed1-IS-preCD-OE_20180430_rev6p0.pdf

[3] Contribution “60802-Steindl-Synchronization”
http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-Synchronization-0718-v02.pdf

[4] Contribution “60802-Steindl-Configuration”
http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-Configuration-0718-v02.pdf

Log

V0.1	2018-05-23	Initial revision presented and reviewed at Pittsburgh
V0.2	2018-06-18	Incorporated Pittsburgh comments
V0.3	2018-07-20	Incorporated requirements from use cases and contributions Reworked document structure
V0.4	2018-07-26	Updated in Frankfurt meeting

1 60802 Requirements

The following requirements for the TSN-IA Profile are derived from [1], [2], [3] and [4].

1.1 General

See [2] clause “Purpose”

R1	Interoperability of bridges and the TSN function of end stations from different vendors need to be assured.
R2	Bridges shall support standardized stream establishment.
R3	TSN domain effectivity and efficiency is independent from the order in which streams were established and/or removed (in a non-overloaded situation)
R4	Bridges shall support a standardized network configuration/management interface.
R5	A default set of parameters shall be provided.

1.2 Synchronization

See [2] clause “Purpose”

R6	The TSN-IA Profile shall support synchronization of multiple timescales with gPTP (e.g. universal time, working clock, redundant working clock).

More detailed synchronization requirements are provided in [1], [2] and [3]:

Universal Time – UC1: Sequence of Events [1]

R6.1	The TSN-IA Profile shall support plant wide high precision Universal Time synchronization with: - A maximum deviation to the grandmaster time up to +/- 100 µs; - Shall support redundant sync masters; - May support redundant universal time domains; - Non-zero failover time in case of redundant universal time domains.

Working Clock [1]

R6.2	The TSN-IA Profile shall support high precision working clock synchronization with: - A maximum deviation to the grandmaster time up to +/- 1 µs; - Shall support redundant sync masters; - Shall support redundant working clock domains; - Zero failover time in case of redundant working clock domains;

Topologies [3]

R6.3	All synchronization requirements shall be fulfilled even for linear topologies with up to 100 nodes;

Sync Trees [3]

R6.4	Sync trees shall be externally administrable for all needed domains;
R6.5	Grandmaster switchover hierarchy shall be externally administrable for all needed domains;
R6.6	Sync domain boundaries shall be externally administrable, particularly for Working Clock domains;

Link delay (for one link MDI – MDI) [3]

R6.7	Valid link delay shall be available in less than 1s;
R6.8	Valid link delay shall be available even with asymmetric cable delay;
R6.9	The maximum valid link delay shall be externally administrable;
R6.10	Maximum link delay error per link shall be < 10ns;

Bridge delay for one Bridge MDI – MDI [3], [2]

R6.11	Port dependent bridge delays shall be covered by management model and objects;
R6.12	Maximum bridge delay error per network node shall be < 50ns;

Expected PHY, MAC and Bridge delays are given in [1].

Sync forwarding delay [3]

R6.13	The maximum sync forwarding delay shall be <10ms; - One step sync or two step sync in hardware reduces the sync forwarding delay to <1ms;

Synchronization interval [3]

R6.14	Synchronization intervals down to 31,25ms shall be supported for Working Clock domains;

Grandmaster loss [3]

R6.15	Working clock grandmaster loss shall be detectable in less than 100ms to avoid destruction of machines; see R6.13: needs <1ms sync forwarding delay

In Sync [3]

R6.16	The state “in sync with <1µs accuracy” needs to be defined (not defined in .1AS). The state “in sync within <1µs accuracy” shall be achieved in less than 1s per device;

Managed objects [3]

R6.17	Mandatory/optional IEEE802.1AS-2019 management objects for diagnostics and parameterization shall be defined;

Independent sync domains [3]

R6.18	Adding/removing a sync domain shall not influence the running sync domains;

Timestamp accuracy [2]

R6.19	The minimal timestamp accuracy shall be <= 8ns for universal time and working clock;

1.3 Industrial automation mode of operation

See [2] clause “Purpose”

R7	The requirements of the various industrial traffic types (see [1], clause “Industrial automation traffic types”) shall be met.

More detailed requirements are provided in [1]:

R7.1	The TSN-IA Profile shall support Control Loop implementations - With guaranteed low latency, - With bounded latency, - With multiple application cycle times, - Without a common application cycle.

Multiple isochronous domains (see Figure xx) [1]

R7.2	All isochronous real-time domains may run independently, loosely coupled or tightly coupled.
R7.3	All isochronous real-time domains shall be able to share a cyclic real-time domain.

1.4 Industrial automation networks

1.4.1 Topologies

See [2] clause “Purpose”

R8	All industrial topologies, which are defined in IEC 61918 (e.g. linear, ring, star) – including topologies with redundant links as defined in IEC 62439-1 – shall be supported.
R9	The TSN–IA profile shall support redundancy for streams. TSN Network management should support reporting of independent physical paths and control of stream setup to allow management of redundancy.
R10	The TSN network may allow redundancy recovery time to be calculated.

More detailed network requirements are provided in [1]:

High Availability [1]

R8.1	The TSN-IA Profile shall support High Availability networks. i.e. a single network failure shall not create process disturbance – e.g. keep air flow active / fire control active. The number of acceptable concurrent failures without process disturbance depends on the application requirements.
R8.2	Parameter, program and topology changes shall be supported with minimal disturbance.

Wireless [1]

R8.3	The TSN-IA Profile may support wireless communication for - cyclic real-time traffic, and - non-real-time traffic.

10 Mbit/s end-stations (Ethernet Sensors) [1]

R8.4	The TSN-IA Profile shall support of 10 Mbit/s or higher link speed attached sensors (end-stations) together with provisioning for delivering power and the following 10Mbit/s standards: 10BASE-TX, 10BASE-T1S, 10BASE-T1L

Fieldbus gateway [1]

R8.5	The TSN-IA Profile may support non-Ethernet fieldbus devices via gateways either transparent or hidden. Tbd: update with new use case version

1.4.2 Brownfield

See [2] clause “Purpose”

R11	The TSN-IA profile shall support the extension of brownfield installations.
R12	The TSN-IA profile shall support connection of existing (for e.g. migration) or non-TSN devices to TSN domains with as little as possible disturbance of existing modes of operation.

More detailed network requirements are provided in [1]:

New machine with brownfield devices [1]

R12.1	It shall be possible to decouple/protect all TSN domain internal traffic (stream traffic and non-stream traffic) from the brownfield cyclic real-time traffic.
R12.2	Brownfield cyclic real-time data traffic QoS requirements shall be met within the TSN domain.

1.4.3 Link Speeds

See [2] clause “Purpose”

R13	Different Link Speeds within and/or connecting to a TSN domain shall be supported.

More requirements are provided in [1]:

Mixed link speeds [1]

R13.1	Multiple links with different link speeds can share the same TSN-IA profile based TSN domain at the same time.

1.4.4 TSN Domain Protection

See [2] clause “Purpose”

R14	TSN domain boundaries are enforced by TSN bridges and can optionally be controlled by network management to not interfere with TSN traffic and to support non-TSN traffic
R15	The TSN-IA profile shall consider protecting TSN domains against traffic from outside the domain – examples shall be provided.

More requirements are provided in [1]:

Auto domain protection [1]

R14.1	A TSN domain shall not expand automatically when e.g. two machines get connected via an unplanned and unintended link.

1.4.5 Network Configuration

Requirements are provided in [4]:

R16	The TSN-IA Profile shall provide a vendor independent solution for network configuration - The profile shall list the mandatory managed objects of the selected TSN features; - A bootstrap configuration of TSN devices shall be defined by the managed objects from the profile;; - The profile shall support preconfigured streams; - The profile shall select the management protocols.

1.5 Quantities

See [2] clause “Purpose”

R17	Minimum supported quantities (e.g. VLAN, number of queues) shall be defined.

More detailed representative examples are provided in [1]:

Vast number of connected stations [1]

R17.1	The massive amount of stations in e.g. car production sites, airport logistics or process automation systems (see [6]) shall work together with the TSN-IA profile.

1.6 Bridge Resources

Requirements are provided in [1]:

R18	TSN-IA conformant Bridges shall provide means to ensure that congestion loss of frames is avoided for TSN streams and minimized for critical non-TSN traffic.

1.7 Industrial automation machines, production cells, production lines

Requirements are provided in [1]:

R19	The TSN-IA Profile shall support realization of the various use cases for industrial automation machines, production cells and production lines described in [1].

Machine-to-machine communication [1]

R19.1	All machine internal communication (stream traffic and non-stream traffic) shall be protected from additional traffic – especially M2M traffic - and vice versa.
R19.2	1-to-1 and 1-to-many communication relations shall be possible.

Pass-through traffic [1]

R19.3	All machine internal communication (stream traffic and non-stream traffic) shall be protected from additional “pass-through” traffic.

Modular machine assembly [1]

R19.4	Modules can be assembled to a working machine variably on-site (either in run, stop or power down mode) as necessary. The machine produces the selected variety of a product. Communication relying on TSN features is established automatically after the modules are connected without user management/configuration interaction.

Tool changer [1]

R19.5	Added portion of the network needs to be up and running (power on to operate) in less than 500ms.
R19.6	Extending and removing portions of the network (e.g. 16 devices) in operation shall be supported - by one connection point (one robot using a tool) - by multiple connection points (multiple robots using a tool)

Dynamic plugging and unplugging of machines, production cells or production lines [1]

See [2] clause “Purpose”

R20	A TSN domain can be expanded dynamically at any time by attaching an additional TSN bridge to a spare port – without effect on established streams in the network.
R21	Removal of a Bridge out of a TSN Domain which is in use will only affect streams which are using that Bridge.
R22	Streams can be established and removed at any time in ad-hoc manner without effect on other established streams in the TSN domain, i.e. particularly without re-initialization of the TSN domain.

R22.1	Adding a machine/cell/production line shall not disturb existing installations.
R22.2	The traffic relying on TSN features from/to AGVs is established/removed automatically after plug/unplug events. - Different AGVs may demand different traffic layouts. - Thousands of AGVs may be used concurrently, but only a defined amount of AGVs is connected at a given time.

Energy saving [1]

R22.3	Turning off a portion of the network for energy saving reasons shall not create a process disturbance.
R22.4	Communication paths through the energy saving area between end-stations, which do not belong to the energy saving area, shall be avoided.

Multiple applications in a station using the TSN-IA profile [1]

R22.5	Stations with multiple applications using TSN traffic classes shall be supported.

Functional safety [1]

See [2] clause “Purpose”

R23	The addition of TSN functionality to an Ethernet network shall not impact proper operation of upper functional safety layers used on top of Ethernet based fieldbuses or networks (see IEC 61784-3).

R23.1	Safety applications (as black channel) and standard applications share the same TSN-IA profile based communication system at the same time.

1.8 DCS reconfiguration

Requirements are provided in [1]:

R24	The TSN-IA Profile shall support DCS reconfiguration use cases without disturbances to the production.
	• Device level reconfigurations, e.g.:
	  - SW modifications,
	  - Device Exchange/Replacement,
	  - Add/remove device.
	• System level reconfigurations, e.g.:
	  - Plant extension,
	  - security policy update.

1.9 Further Industrial automation use cases

Network monitoring and diagnostics [1]

See [2] clause “Purpose”

R25	In case of stream failure, sufficient diagnostics information is provided, so that the error cause and potential recovery measures can be identified.

R25.1	Monitoring and diagnostics data including used TSN features shall be provided, e.g. established streams, failed streams according to stream control plane, stream classes, bandwidth consumption, …
R25.2	A discovery protocol such as IEEE 802.1AB shall be leveraged to meet the needs of TSN-IA.

Security [1]

R26	Optional support of confidentiality, integrity, availability and authenticity. Protection against rogue applications running on authenticated stations are out of scope.
R26.1	Security shall not limit real-time communication.

Firmware update [1]

R27	The system should support FW updates of stations with minimal disturbance.

Virtualization [1]

R28	vBridge and vPort can become members of TSN domains.

Digital twin [1]

R29	Reliable planning, development, testing, simulation and optimization results shall be possible for digital twins.

Device replacement without engineering [1]

R30	In case of repair it shall be possible to replace end-stations, bridged end-stations or bridges without the need of an engineering tool.

2 Additional Literature

[5] Contribution “60802-Steindl-TimelinessUseCases”
http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-TimelinessUseCases-0718-v02.pdf

[6] Contribution “60802-Sato-PA-System-Quantities”
http://www.ieee802.org/1/files/public/docs2018/60802-sato-pa-system-quantities-0718-v01.pdf

3 Abbreviations

AGV	Autonomous Guided Vehicle
DCS	Distributed Control System
FW	Firmware
PA	Process Automation

4 Annex A – deleted requirements

The following requirements from [2] clause “Purpose” were deleted at the Pittsburgh interim meeting:

~~R3~~	~~Applications in end nodes need not depend on how the network is organized (trees, etc.).~~[1)]
~~R10~~	~~Several independent applications (e.g. multiple CPx systems, OPC UA@TSN…) are supported at the same time.~~[2)]
~~R12~~	~~Network can be partitioned according to the user's wishes into individual functional domains between bridges – optionally within a bridge so that streams of one functional domain do not cross into another functional domain~~[3)]
~~R17~~	~~The TSN-IA profile defines an upper limit for the redundancy recovery time. The TSN-IA profile shall provide means for calculating the recovery time for given topologies.~~[4)]

[1)] Deleted at the Pittsburgh interim: This is a requirement to applications, therefore out of scope for the profile.
[2)] Deleted at the Pittsburgh interim: This is a requirement to applications, therefore out of scope for the profile.
[3)] Deleted at the Pittsburgh interim: This requirement will be replaced by a contribution.
[4)] Deleted at the Pittsburgh interim