Requirements IEC/IEEE 60802

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Abstract

This document describes requirements for industrial automation based on TSN. These requirements are intended to guide the specification process: WHAT shall be part of the dual logo International Standard IEC/IEEE 60802. The content of IEC/IEEE 60802 specifies the HOW to achieve the requirements. Some requirements are on a system level of an industrial automation system. Even if the scope of IEC/IEEE 60802 does not cover the overall system level, the IEC/IEEE 60802 shall enable or at least do not prevent the features described in this requirement document.

The requirements are mainly 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-0918-v13.pdf

Additional detailed requirements are extracted from contributions:

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

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

[4] Contribution “60802-Steindl-NetworkDiagnostics”
http://www.ieee802.org/1/files/public/docs2018/60802-Steindl-NetworkDiagnostics-0718-v01.pdf

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

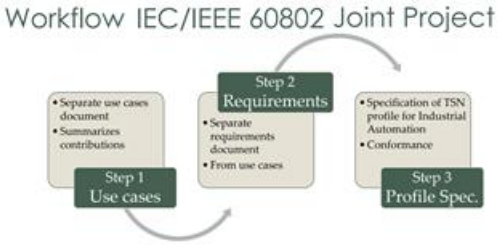
[6] Contribution “60802-Stanica-Qbv-Statemachine”
http://www.ieee802.org/1/files/public/docs2018/60802-stanica-qbv-statemachine-0918-v03.pdf

Additional information on the requirements is provided in:

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

[8] Contribution “60802-Sato-PA-System-Quantities”
http://www.ieee802.org/1/files/public/docs2018/60802-sato-pa-system-quantities-0718-v01.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
V0.5	2018-08-03	Added requirements from updated use case document and from contributions **Fehler! Verweisquelle konnte nicht gefunden werden.** and [5].
V0.6	2018-09-03	Abstract: added note about intention of the document; R6.13: maximum sync forwarding delay shall be <1ms to be in line with R6.3 and R6.15.
V1.0	2018-09-13	Updated in Oslo meeting
V1.1	2018-11-30	Updated after review at Bangkok plenary • Incorporated comments from 60802-enzinger-comments-industrial-requirements-1118-v01.pdf • Requirements must be related to Use Cases and may be further detailed in contributions.  → Document structure is strictly aligned to the structure of the Use Case document. → Removed “IEC preCD 60802” from the list of documents, where requirements are extracted and derived from. → Most “IEC preCD 60802” requirements are adopted with a relation to some use case. → “IEC preCD 60802” requirements are deleted, if - they are not covered by a use case, or - they are redundant to a use case derived requirement.

Content

1 60802 Requirements

1.1 Interoperability and Interconnection

The following requirements are derived from [1] clause “2.1 Interoperability”:

R1	The TSN-IA Profile shall assure interoperability of bridges and end stations regarding - network configuration (managed objects according to IEEE definitions), and - stream configuration and establishment. ~~The TSN-IA Profile shall assure interoperability of bridges and the TSN functions of end stations from different vendors.~~
R2	Bridges and end-stations 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 and end-stations shall support a standardized network configuration/management interface.
~~R5~~	~~A default set of parameters shall be provided.~~

The following requirements are derived from [1] clause “2.2.2 Interconnection of TSN Domains”:

R2.1	The TSN-IA Profile shall support TSN domain interconnections via - Bridges (Layer 2), or - Routers (Layer 3), or - Application Gateways (Layer 7).
R2.2	To support connectivity between multiple TSN domains via Bridges or Routers a method for reserving time-sensitive streams over multiple TSN domains shall be specified, including: - find the communication partner, - identify the involved TSN domains, - identify the involved management entities independent from the configuration model (centralized, hybrid, fully distributed), - ensure the needed resources, - parameterize the TSN domain connection points to allow stream forwarding between domains if needed.

1.2 Synchronization

The following requirements are derived from [1] clause “2.3 Synchronization” and

- Use Case 01 – Sequence of Events

R6	The TSN-IA Profile shall support synchronization of multiple time domains using different timescales with gPTP (e.g. universal time, working clock, redundant working clock).
R6.1	**Universal Time: UC01 – Sequence of Events** 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.
R6.2	**Working Clock** 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.

The following detailed synchronization requirements are provided in [2]:

Topologies

R6.3	All synchronization requirements shall be fulfilled ~~even for linear topologies~~ with sync trees of up to 100 ~~nodes~~hops.

Sync Trees

R6.4	Sync trees shall be externally configurable for all needed domains;
R6.5	Grandmaster switchover hierarchy shall be externally configurable for all needed domains;
R6.6	Sync domain boundaries shall be externally configurable, particularly for Working Clock domains; A Sync domain shall not expand automatically when e.g. two stations of different Sync domains get connected via an unplanned and unintended link after a user maloperation.

Link delay (for one link MDI – MDI)

R6.7	After physically connecting a link 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 configurable;
R6.10	Maximum link delay error per link shall be < 10ns;

Bridge delay for one Bridge MDI – MDI

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].

Residence Time

R6.13	The maximum residence time of a sync/delay message shall be <1ms;

Synchronization interval

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

Grandmaster loss

R6.15	Working clock grandmaster loss shall be detectable in less than 100 ms to avoid production disturbance, loss of production or even destruction of machines;

In/Out of Sync

R6.16	The state “in sync within <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; The state “out of sync” needs to be defined (not defined in .1AS).

Managed objects

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

Independent sync domains

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

Timestamp accuracy

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

The following additional synchronization requirements are provided in [6]:

Scheduled Traffic State Machine: List Execute state machine

Problem statement [IEEE 802.1Q-2018]

The scheduled traffic state machine is not synchronized to the working clock, but to a “Implementation-specific system clock”; thus the execution is device specific and not synchronized within the TSN domain.

General requirement

The execution of the scheduled traffic state machine shall be synchronized to the working clock within the TSN domain.

R6.20	The “Implementation-specific system clock” shall be synchronized by default to the working clock.

R6.21	The “Implementation-specific system clock” shall have upper bounds for accuracy and granularity.

1.3 Industrial automation mode of operation

The following requirements are derived from [1] clause “2.4 Industrial automation modes of operation” with

- Use Case 02 – Isochronous Control Loops with guaranteed low latency
- Use Case 03 – Non-Isochronous Control Loops with bounded latency
- Use Case 04 – Reduction ratio of network cycle
- Use Case 05 – Drives without common application cycle
- Use Case 06 – Drives without common application cycle but common network cycle
- Use Case 14 – Multiple isochronous domains

R7	The TSN-IA Profile shall define industrial traffic types and the mapping on traffic classes. ~~The requirements of the various industrial traffic types (see [1], clause “Industrial automation traffic types”) shall be met.~~
R7.1	The TSN-IA Profile shall support each of the following Control Loop implementations ~~With bounded latency~~ - UC02: Isochronous with guaranteed low latency, - UC03: Non-isochronous with bounded latency, - UC04: Reduction ratio of network cycle (multiple application cycle times), - UC05/UC06: Drives without a common application cycle.

Bidirectional communication relations

R7.2	The TSN-IA Profile shall support bidirectional streams. A sequence of actions how to establish bidirectional streams shall be specified.

UC14 - Multiple isochronous domains

R7.3	All isochronous real-time domains may run independently, loosely coupled or tightly coupled.
R7.4	All isochronous real-time domains shall be able to share a cyclic real-time domain.

1.4 Industrial automation networks

The following requirements are derived from [1] clause “2.5 Industrial automation networks” with

- Use Case 07 – Redundant networks
- Use Case 08 – High Availability
- Use Case 09 – Wireless
- Use Case 10 – 10 Mbit/s end-stations (Ethernet sensors)
- Use Case 11 – Fieldbus gateway
- Use Case 12 – New machine with brownfield devices
- Use Case 13 – Mixed link speeds
- Use Case 15 – Auto domain protection
- Use Case 16 – Vast number of connected stations

UC07 - Redundant networks

R8	The TSN-IA Profile shall define the supported industrial topologies (e.g. linear, ring, star, selection out of IEC 61918 and IEC 62439-1) ~~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 define the support of redundant streams (e.g. seamless or switchover). ~~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	Redundancy recovery times of the supported industrial topologies shall be predictable. ~~The TSN network may allow redundancy recovery time to be calculated.~~

UC08 - High Availability

R8.1	The TSN-IA Profile shall support High Availability networks. A single network failure or multiple network failures 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	Dynamic reconfiguration of parameter, program and topology shall be supported without disturbance.

UC09 - Wireless

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

UC10 - 10 Mbit/s end-stations (Ethernet Sensors)

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

UC11 - Fieldbus gateway

R8.5	The TSN-IA Profile ~~may~~ shall support non-Ethernet and Ethernet-based fieldbus devices via gateways either transparent or hidden. ~~TSN scheduling may need configuration to meet the requirements of subordinate systems.~~

UC12 - New machine with brownfield devices

R11	The TSN-IA Profile shall support the extension of brownfield installations (see UC12: Add TSN machine to brownfield machine). ~~The TSN-IA profile shall support the extension of brownfield installations.~~
R12	The TSN-IA Profile shall support integration of brownfield devices (see UC12: New machine with brownfield devices). ~~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.~~
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.

UC13 - Mixed link speeds

R13	Multiple links with different link speeds can share the same TSN-IA profile based TSN domain at the same time. Different link speeds can be used for connecting TSN domains.

UC15 - Auto domain protection

R14	A TSN domain shall not expand automatically when e.g. two machines of different TSN domains get connected via an unplanned and unintended link after a user maloperation.
~~R15~~	~~The TSN-IA profile shall consider protecting TSN domains against traffic from outside the domain – examples shall be provided.~~

Network Configuration

The following more detailed requirements for network configuration/management interoperability are provided in [3]:

R16	The TSN-IA Profile shall provide a vendor independent solution for network configuration.
R16.1	- 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 configuration of preconfigured streams; - The profile shall select the management protocols;
R16.2	Problem: Missing managed objects for online and offline configuration shall be identified and defined.

UC16 - Vast number of connected stations / Minimum required quantities

R17	The TSN-IA Profile shall provide required quantities for VLANs, queues, … ~~Minimum supported quantities (e.g. VLAN, number of queues) shall be defined.~~
R17.1	The ~~massive~~ amount of stations in e.g. car production sites, airport logistics or process automation systems (see also [5] and clause “Minimum required quantities” in [1]) shall work together with the TSN-IA profile.

Bridge Resources

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.

Stream DA-MAC requirements [5]

R18.1	A Stream DA-MAC address range (e.g. based on a TSN-IA profile specific OUI) for efficient address handling shall be defined.

1.5 Industrial automation machines, production cells, production lines

The following requirements are derived from [1] clause “2.6 Industrial automation machines, production cells, production lines” with

- Use Case 17 – Machine to Machine/Controller to Controller (M2M/C2C) Communication
- Use Case 18 – Pass-through Traffic
- Use Case 19 – Modular machine assembly
- Use Case 20 – Tool changer
- Use Case 21 – Dynamic plugging and unplugging of machines (subnets)
- Use Case 22 – Energy Saving
- Use Case 23 – Add machine, production cell or production line
- Use Case 24 – Multiple applications in a station using the TSN-IA profile
- Use Case 25 – Functional safety
- Use Case 26 – Machine cloning

UC17 - Machine-to-machine communication

R19	The TSN-IA profile shall support communication of preconfigured TSN machines with their own TSN domains with - other preconfigured TSN machines with their own TSN domains, - a supervisory PLC of the production cell (with its own TSN domain) or line (with its own TSN domain), or - an Operations Control HMI (with its own TSN domain). ~~The TSN-IA Profile shall support realization of the various use cases for industrial automation machines, production cells and production lines described in [1].~~
R19.1	All machine internal communication (stream traffic and non-stream traffic) shall be protected from ~~additional~~ M2M traffic ~~– especially M2M traffic~~ – and vice versa.

R19.2	1-to-1 and 1-to-many communication relations shall be possible.
R19.3	The TSN-IA Profile shall allow scheduling in a way that interleaved operation with machine intervals is possible. ~~Scheduling in a way that interleaved operation with machine intervals may be supported.~~

UC18 - Pass-through traffic

R19.4	All machine internal communication (stream traffic and non-stream traffic) shall be protected from additional “pass-through” traffic.

UC19 - Modular machine assembly

R19.5	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.

UC20 - Tool changer

R19.6	Added portion of the network needs to be up and running (power on to operate) in less than 500ms.
R19.7	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)

UC21 - Dynamic plugging and unplugging of machines, production cells or production lines

R20	A TSN domain can be expanded dynamically at any time by attaching an additional TSN station 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	The TSN-IA Profile shall support adding and removing end-stations/bridges/machines/ cells/production lines without disturbance of existing installations.

UC23 - Add machine, production cell or production line

R22.1	Adding and removing 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.

UC22 - Energy saving

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.

UC24 - Multiple applications in a station using the TSN-IA profile

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

UC25 - Functional safety

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

UC26 - Machine cloning

R24	Support of unique TSN domain identification (e.g. using LLDP) also for cloned machines; Define handling of specific addresses (e.g. IP addresses) for global identification and how they are managed within the machine set-up procedures.

1.6 DCS reconfiguration

The following requirements are derived from [1] clause “2.7 DCS Reconfiguration” with

- Use Case 27 – DCS Device level reconfiguration
- Use Case 28 – DCS System level reconfiguration

R25	The TSN-IA Profile shall support DCS reconfiguration use cases without disturbances to the production.
R25.1	The TSN-IA Profile shall support device level reconfigurations, e.g.: - SW modifications, - Device Exchange/Replacement, - Add/remove device.
R25.2	The TSN-IA Profile shall support system level reconfigurations, e.g.: - Plant extension, - security policy update, - virtualization of controllers (for e.g. load balancing).

1.7 Further Industrial automation use cases

The following requirements are derived from [1] clause “2.8 Further Industrial Automation Use Cases” with

- Use Case 29 – Network monitoring and diagnostics
- Use Case 30 – Security
- Use Case 31 – Firmware update
- Use Case 32 – Virtualization
- Use Case 33 – Offline configuration
- Use Case 34 – Digital twin
- Use Case 35 – Device replacement without engineering

UC29 - Network monitoring and diagnostics

R26	The TSN-IA Profile shall support monitoring and diagnostics of TSN networks to support error cause detection and potential recovery measures. ~~In case of stream failure, sufficient diagnostics information is provided, so that the error cause and potential recovery measures can be identified.~~
R26.1	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, …
R26.2	A topology discovery protocol such as IEEE 802.1AB shall be leveraged to meet the needs of TSN-IA.
R26.3	Reporting of detailed diagnostics information for TSN features shall be supported.

The following more detailed network diagnostics requirements are provided in [4]:

R26.4	A comparison between expected topology and real topology shall be supported.
R26.5	Adjust and check MAUtype (expected vs. real) with signaling of MAUtype mismatch shall be supported.
R26.6	Check path delay / bridge delay (expected vs. real) and signaling for mismatch shall be supported.
R26.7	Check of asymmetric path delay deviation and signaling for mismatch shall be supported.
R26.8	Port statistics of MIB-2 ~~and IEEE802.3br~~ including extensions for pre-emption shall be supported.

UC30 - Security

R27	Optional support of confidentiality, integrity, availability and authenticity. Protection against rogue applications running on authenticated stations are out of scope.
R27.1	Security shall not limit real-time communication.

UC31 - Firmware update

R28	The system should support FW updates of stations during normal operation without disturbance.

UC32- Virtualization

R29	The TSN-IA Profile shall allow vBridges and vPorts to become members of TSN domains. ~~vBridge and vPort can become members of TSN domains.~~

UC33 - Offline configuration

R30	The TSN-IA Profile shall support offline configuration of TSN-IA conformant devices.
R30.1	Device type description of IEC/IEEE 60802 components containing all necessary managed objects shall be defined.
R30.2	Means to store machine configuration offline in a textual form (e.g. XML) may be defined.
R30.3	Offline – Online comparison of machine configuration shall be supported.

UC34 - Digital twin

R31	Reliable planning, development, testing, simulation and optimization results shall be possible for digital twins.

UC35 - Device replacement without engineering

R32	In case of repair it shall be possible to replace end-stations, bridged end-stations or bridges without the need of an engineering tool.

Abbreviations

AGV	Autonomous Guided Vehicle
DCS	Distributed Control System
FW	Firmware
IA	Industrial Automation
PA	Process Automation
UC	Use Case

Annex A: IEC preCD requirements

The following requirements from the “Purpose” clause of the “IEC preCD 60802” document (http://www.ieee802.org/1/files/private/liaisons/65c-60802-Ed1-IS-preCD-OE_20180430_rev6p0.pdf) are included as informative annex. They are not included in the list of 60802 requirements, because they are not directly related to the use cases of [1].

1) *Streams can be established and removed at any time in ad-hoc manner without effect on other established streams in the network, i.e. particularly without reboot of the network.*
2) *Network effectivity and efficiency is independent from the order in which streams were established and/or removed (in a non-overloaded situation).*
3) *Applications in end nodes need not depend on how the network is organized (trees, etc.).*
4) *In case of stream failure, sufficient diagnostics information is provided, so that the error cause and potential recovery measures can be identified.*
5) *The network can be expanded dynamically at any time by attaching an additional TSN bridge – without effect on established streams in the network.*
6) *Removal of a bridge which is in use will only affect streams which are using that bridge.*
7) *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 in a deterministic manner.*
8) *The requirements of the various industrial traffic types are met (see Clause **Fehler! Verweisquelle konnte nicht gefunden werden.**).*
9) *Applications manageaccess to the TSN network via a standardized interface.*
10) *Several independent applications (e.g. multiple CPx systems, OPC UA@TSN…) are supported at the same time.*
11) *Interoperability of TSN bridges and the TSN function of end nodes from different vendors need to be assured.*
12) *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.*
13) *A default set of parameters shall be provided. [not yet decided]*
14) *All industrial topologies (IEC 61918: linear, ring, star) – including topologies with redundant links as defined in IEC 62439-1 – shall be supported.*
15) *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).*
16) *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.*
17) *The TSN network should also allow redundancy recovery time to be calculated. 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.*
18) *The TSN-IA profile shall support the extension of brownfield installations.*
19) *The TSN-IA profile shall support connection of existing or non-TSN devices to TSN networks with as little as possible disturbance of existing modes of operation.*
20) *The TSN-IA profile shall consider protecting functional domains against traffic from outside the domain – examples shall be provided.*