
TSN

System requirements

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1 Requirements

1.1 Architecture

Requirement	Device Roles 1	Ext ID:	1020	ID:	1798220
<p>Device roles (functionality independent of a physical device, fulfilling specific requirements during the bootup or operational phase of a network) shall be defined to support modular implementations and flexibility in system configuration.</p> <p>Note: following device roles are identified:</p> <ul style="list-style-type: none"> - CNC - CUC - Clock Grandmaster 					

Requirement	Device Roles 2	Ext ID:	1030	ID:	1798222
<p>Device roles shall be independent of the physical device implementation.</p>					

Requirement	Device Role Redundancy	Ext ID:	1050	ID:	1798224
<p>Redundancy of the "device roles" shall be supported.</p> <p>Note: This refers to the mechanisms and interfaces to support the redundant device roles, and does not necessary mean the mandatory usage of the redundant device roles.</p>					

1.2 Standards

Requirement	IEEE 802.1 TSN	Ext ID:	1150	ID:	1798234
<p>A set of rules shall be defined in order to make sure that the devices that implement TSN mechanisms are interoperable.</p> <p>TSN standards shall be used, such as:</p> <ul style="list-style-type: none"> - 802.1AS(-Rev) - 802.1Qbv - 802.1Qav - 802.1CB - 802.1Qcc - 802.1Qci - 802.1Qbu + 802.3br 					

Non-Functional Requirement	supported Protocols	Ext ID:	2530	ID:	1798236
<p>TSN network shall be able to support all existing Ethernet protocol based on IEEE 802,3 technology e. g: HTTP, TLS, FTP, DCHP, UDP, SNMP, ARP, all TCP/IP protocols etc...</p>					

1.3 Integration

Non-Functional Requirement	Brown field	Ext ID:	270	ID:	1798272
The solution shall support brown field installations. Coexistent methods should be defined.					

Non-Functional Requirement	Vertical integration support	Ext ID:	320	ID:	1798274
In order to support seamless vertical integration on TSN mechanisms shall be possible to be implemented at different device types (drives, I/O, controller HMI, SCADA).					
Comment		Ext ID:	321	ID:	1798276
Input needed: Specify the resources/constrains for different type of the devices in order to support vertical integration.					

1.4 Communication

Requirement	Peer to peer communication	Ext ID:	150	ID:	1798284
The solution shall support peer to peer communication between any two devices in the network without the need to involve another device in that communication relation/data exchange." Note: in-between switches will of course somehow be involved in the communication relation.					

Requirement	Mixed Comm Speed 1	Ext ID:	230	ID:	1798286
The solution should support following communication speeds: - 100 Mbit/s - 1 Gbit/s Note: Needed for current industrial applications.					

Requirement	Mixed Comm Speed 2	Ext ID:	231	ID:	1798288
The network protocols and mechanisms of the solution shall be independent of the communication speed and PHY implementation. Note: Communication speed will influence the system performance. Wireless is excluded from this requirement. Note: Speed change will inhibit cut-through					

Requirement	PHY	Ext ID:	232	ID:	1798290
TSN based network components shall support copper PHY. 1 Gbit/s components shall support Fiber PHY					

Requirement	Communication speed	Ext ID:	233	ID:	1798292
The solution shall support following communication speeds: - 10 Mbit/s - 10 Gbit/s - 40 Gbit/s					

Requirement	Robustness against bit errors on known paths	Ext ID:	1010	ID:	1798296
The solution shall support retransmissions for the network segments with "higher" bit error rates (e.g. Wireless LAN, slip ring).					

Requirement	Nested Topology	Ext ID:	1270	ID:	1798302
It shall be possible to insert in a line a 3- or 4-port device which is the origin of a new line or ring					

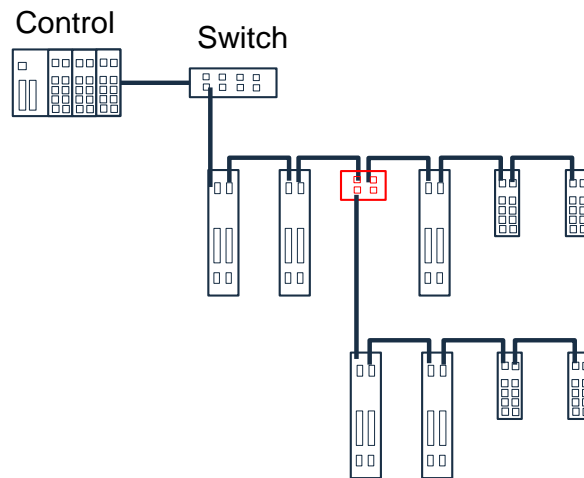


Figure 1: Nested Topology

Requirement	Multi Master 1	Ext ID:	1280	ID:	1798304
It shall be possible to use multiple controllers (PLC) in the same network, whereas each controller controls a set of Drive/IO devices.					

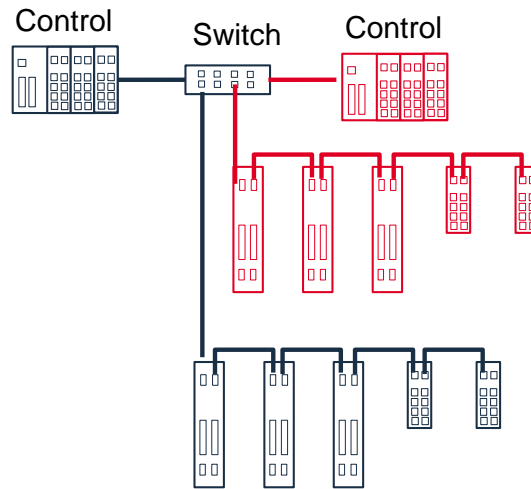


Figure 2: Multi master topology – separate control domains

Requirement	Multi Master 2	Ext ID:	1290	ID:	1798306
It shall be possible to use multiple controllers (PLC) in the same network, whereas multiple controllers can control the same set of Drive/IO devices					

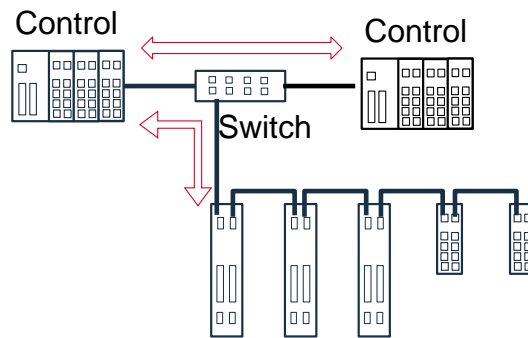


Figure 3: Multi master topology – same control domain

Requirement	Non-Cyclic Communication - Guaranteed Bandwidth	Ext ID:	1800	ID:	1798310
Communication system shall provide the possibility to reserve bandwidth for certain traffic patterns.					

Requirement	10 Mbps operation for some end devices	Ext ID:	2110	ID:	1798316
TSN network components shall support 10Mbit/s. Note: This is limited to switched Ethernet technologies.					

Comment		Ext ID:	2111	ID:	1798318
Degradation of performance and of precision of time-synchronization is acceptable on slower network branches.					

Requirement	WLAN 1	Ext ID:	2220	ID:	1798320
Methods for interfacing TSN networks with Wireless Media shall be defined including a definition/specification of the TSN functionality that is not supported by a specific Wireless protocol.					

1.5 Topology

Requirement	Flexible Topologies	Ext ID:	80	ID:	1798325
TSN based components shall supports the implementation of networks with following network topologies: star, tree, daisy chain, ring, tree with rings as leaf's and mesh.					

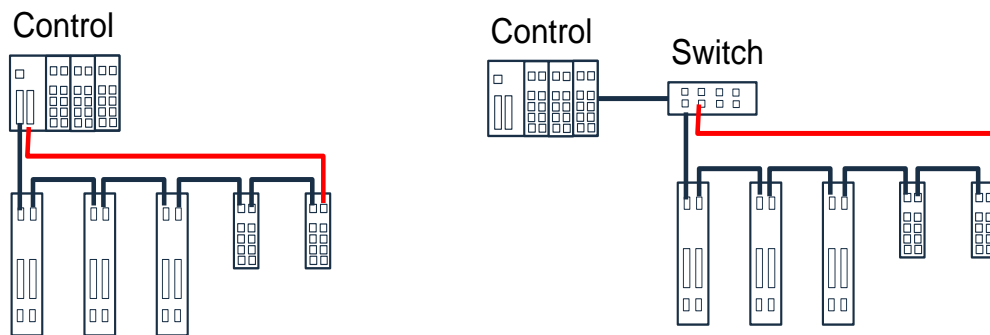


Figure 4: Ring topology without and with a switch

Requirement	Device identification by topology	Ext ID:	901	ID:	1798327
The solution shall support the mechanisms for topology detection.					

Requirement	Multi Master 3	Ext ID:	1300	ID:	1798329
TSN shall support that a field device initiates direct communication to another field device. Examples: Decentral safety communication or fast drive-to-drive communication.					

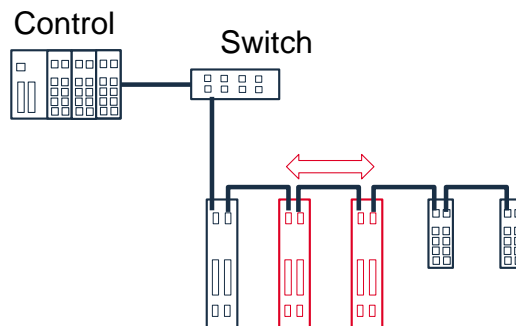


Figure 5: Ring topology without and with a switch

Requirement	Topology agnostic TSN mechanisms	Ext ID:	2200	ID:	1798331
TSN mechanisms shall be topology agnostic					

1.6 Traffic Types

Requirement	Traffic convergence	Ext ID:	50	ID:	1798336
TSN based systems shall allow mixing of time-sensitive and non-time-sensitive traffic on same wire, while guaranteeing that properties of time-sensitive traffic are not affected by the variable load of the non-time-sensitive traffic.					

Requirement	Bandwidth guaranties for time-sensitive traffic.	Ext ID:	100	ID:	1798338
The solution shall support communication with bandwidth guaranties (for time-sensitive traffic).					

Requirement	Bandwidth reservation	Ext ID:	120	ID:	1798340
The solution shall support bandwidth reservation for periodic messages.					

Requirement	Time-sensitive, non-cyclic traffic	Ext ID:	170	ID:	1798342
The solution shall support message prioritization for time-sensitive, non-cyclic traffic.					

Comment		Ext ID:	171	ID:	1798344
Different TSN mechanisms can be used for message prioritization: preemption, reserve (shared) bandwidth for non all high-priority non-cyclic traffic, use QOS priorities,...					

Requirement	Latency guaranties	Ext ID:	220	ID:	1798346
The solution shall support the development of networks with guaranteed end-to-end latencies.					

Non-Functional Requirement	Heterogeneous Communication Cycles	Ext ID:	1760	ID:	1798348
The solution shall support applications that produces periodic data with different periods.					

Requirement	Non Cyclic Communication - Best Effort 1	Ext ID:	1780	ID:	1798350
The solution shall support the exchange of best-effort traffic in any network operational state. Note: best-effort is needed in the start-up state and also in the error state.					

Comment		Ext ID:	1781	ID:	1798352
Non-cyclic communication can be mapped to best-effort traffic. Best-effort traffic is enabled even if the network is in the non-synchronized state.					

Requirement	Communication types	Ext ID:	1900	ID:	1798354
<p>The network shall support the following traffic types:</p> <ul style="list-style-type: none"> - Type 1: Isochronous - Type 2: Cyclic - Type 3: Alarms/Events - Type 4: Configuration/Diagnosis - Type 5: Network Control - Type 6: Best effort - Type 7: Video - Type 8: Audio/Voice <p>According to Whitepaper from IIC TSN testbed: https://www.iiconsortium.org/pdf/IIC_TSN_Testbed_Traffic_Whitepaper_20180418.pdf</p>					

Requirement	Communication Class 1 Isochronous	Ext ID:	1901	ID:	1798356
<p>Traffic Pattern 1 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 2 - Cyclic	Ext ID:	1902	ID:	1798358
<p>Traffic Pattern 2 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 3 - Alarms	Ext ID:	1903	ID:	1798360
<p>Traffic Pattern 3 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 4 - Configuration and Diagnosis	Ext ID:	1905	ID:	1798364
<p>Traffic Pattern 4 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 5 - Network Control	Ext ID:	1906	ID:	1798366
<p>Traffic Pattern 5 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 6 – Best Effort				
<p>Traffic Pattern 6 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 7 – Video				
<p>Traffic Pattern 7 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

Requirement	Communication Class 8 – Audio				
<p>Traffic Pattern 8 shall ensure following parameter: According to the IIC Types Whitepaper</p>					

1.7 Timing and Synchronization

Requirement	Multiple cycle times	Ext ID:	920	ID:	1798374
It shall be possible to operate more than one isochronous (Traffic Pattern 1) communication relation between devices with different cycle times within the same network.					

Non-Functional Requirement	Common timebase	Ext ID:	930	ID:	1798376
The device implementation shall enable the establishment and maintenance of a system (global) time with a precision of less than 10 μ s.					

Requirement	Wall clock	Ext ID:	950	ID:	1798378
The solution shall enable the establishment and maintenance of a wall clock with an accuracy less than 10 μ s.					

Requirement	Working clock	Ext ID:	960	ID:	1798380
A strictly monotonically increasing time base ("working clock") shall be available to all devices in the network. It shall not have leaps and support runtime of up to 10 years.					
Rationale: The working clock shall be the time base for time-triggered frame transmission of end-points and all timing-related functionality of TSN infrastructure (e.g. .1Qbv gating cycles in bridges). The working clock starts at value 0.					

Requirement	End to End Delay 1	Ext ID:	1470	ID:	1798382
The solution shall provide the mechanisms that enable the deterministic end to end message transmission delay between producing and consuming application for specific traffic patterns					

Requirement	Master Clock	Ext ID:	1820	ID:	1798390
The solution shall support redundant grand master (GM) clocks. Note: GM fail-over can be vendor specific implementation.					

1.8 Configuration

Requirement	Configuration during system operation	Ext ID:	380	ID:	1798398
TSN mechanisms shall enable the transport of the configuration data across network without impacting real-time (e.g., Traffic Type 1 and 2).					

Requirement	Configuration during system operation 2	Ext ID:	390	ID:	1798400
The solution shall support the configuration changes without affecting the existing unchanged cyclic traffic (the intended system behavior).					

Requirement	Consistent configuration	Ext ID:	400	ID:	1798402
The solution shall provide mechanisms to apply configuration changes in multiple devices in a consistent and synchronous manner.					

Non-Functional Requirement	Configuration Format	Ext ID:	490	ID:	1798404
Standardized device description (devices' features and parameters) model shall be developed to support pre-engineered networks (fully engineered in the engineering tool, without physical availability of the network or its devices).					
Note: It will be possible to import a device description (one or more files describing a devices' capabilities) into an engineering tool and fully engineer the network without having physical access to the devices.					

Non-Functional Requirement	Configuration Format	Ext ID:	493	ID:	1798406
Standardized configuration model shall be defined in order to support pre-engineered networks (fully engineered in the engineering tool, without physical availability of the network or its devices)					

Non-Functional Requirement	Modular models	Ext ID:	495	ID:	1798408
The standardized model to describe the component's TSN capability shall be modular so that it will be easy to generate configurations if specific TSN features are enhanced, or not needed.					

Requirement	Dynamic configuration support	Ext ID:	514	ID:	1798414
Online configuration shall be supported for the TSN based systems.					

Requirement	Modular Machines	Ext ID:	770	ID:	1798420
The removal or addition of optional devices from/to the network shall not affect the real-time communication of other devices in the network.					
Note: 'This requirement is to allow for configuring non-existent devices (optional) for bandwidth or stream reservation such that when the device is added, communication is already set up and the device begins working.					

Requirement	PubSub Configuration Integrity	Ext ID:	1542	ID:	1798428
Configuration mechanisms shall be available to check the integrity of configuration data.					

Requirement	Dynamic configuration without restart	Ext ID:	1930	ID:	1798458
TSN mechanisms shall allow any dynamic reconfiguration without the need for a system or component restart.					

Requirement	Performance for Traffic Classes	Ext ID:	2180	ID:	1798460
It shall be possible to configure the data stream parameters for each traffic pattern, e.g. schedule for deterministic traffic, bandwidth for event-driven traffic, QoS for on-demand traffic, bandwidth of best effort traffic.					

Requirement	Initialization of new components	Ext ID:	2255	ID:	1798468
Configuration/Initialization of new components added to the already running system shall not affect the real-time network traffic of already configured/initialized devices.					

Comment		Ext ID:	2256	ID:	1798470
Design Note: use best-effort traffic for initialization/configuration of TSN components. This implies that the initialization process can take relatively longer if a heavy loaded network. Alternatively, if timing requirements for initialization exist, bandwidth reservation for system initialization can be reserved.					

Requirement	TSN centralized diagnostics	Ext ID:	2310	ID:	1798476
The solution shall support the system monitoring and diagnostics in a centralized manner.					

Requirement	TSN centralized configuration support (CNC) 2	Ext ID:	2320	ID:	1798478
Configuration mechanisms shall support configuring networks of arbitrary sizes.					

Requirement	Dynamic configuration changes	Ext ID:	2390	ID:	1798480
The solution shall support configuration changes (on the fly) without interrupting the operation of the system.					

1.9 Device Description

Non-Functional Requirement	Device description format	Ext ID:	480	ID:	1798484
Components shall provide a standardized model to describe the TSN endpoint/switched-Endpoint capabilities.					

Comment		Ext ID:	481	ID:	1798486
The component capabilities can be described in a standard XML file format, based on YANG models that are being defined in the IEEE TSN working group.					

Requirement	Device description	Ext ID:	2120	ID:	1798490
A device description format shall be specified that allows to create configuration data for devices and to configure the integration of device data into applications in an offline fashion even before the devices themselves become available. The format shall provide:					
<ul style="list-style-type: none"> - definition of the data items a device can provide - definition of dependencies or conditions on device parameters - optionally an UI-portion that helps user to configure parameters in an efficient way 					

Non-Functional Requirement	Device description lifecycle	Ext ID:	2130	ID:	1798492
To be independent from specific target platforms or lifecycles of certain operating systems, the format of the device description shall be platform independent					

1.10 Diagnosis

Requirement	Mismatched configuration data detection.	Ext ID:	410	ID:	1798496
The solution shall implement mechanisms to detect mismatched configuration data.					

Requirement	Error handling/Diagnosis	Ext ID:	500	ID:	1798498
The solution shall support network diagnostic features similar with the existing fieldbus and Ethernet diagnostic mechanisms.					

Requirement	Error handling/Diagnosis	Ext ID:	503	ID:	1798502
The following errors shall be detected:					
- Traffic Type I/II frames arriving outside their expected reception time window or not all expected frames were received.					
- Switch-Queues for Traffic Type III and above should be supervised to detect overload (not only the queue utilization but also the queue throughput needs to be supervised)					

Requirement	Error handling/Diagnosis	Ext ID:	504	ID:	1798504
The solution shall provide means to detect clock synchronization precision exceed the specified limit.					

Requirement	Error handling/Diagnosis 2	Ext ID:	502	ID:	1798506
TSN devices shall support diagnostic mechanism for frame drops because of:					
- bandwidth violations					
- timing violations					
- CRC errors					
- Invalid frame formats					
- buffer overflows					

Requirement	Diagnosis 1	Ext ID:	1090	ID:	1798508
TSN devices shall detect, store, and make available all relevant status and errors information.					

Requirement	Actual vs Configured Topology	Ext ID:	1110	ID:	1798512
The solution shall support topology discovery, and a standardized topology model.					

Requirement	Diagnostic for device disconnected	Ext ID:	2500	ID:	1798514
Local diagnostic mechanisms shall detect a network disconnection in less than 500ms.					

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Requirement	Diagnostic scalability	Ext ID:	2330	ID:	1798516
The network diagnostic protocol (SNMP) should not have a limit on number of devices in the system.					
Comment		Ext ID:	2501	ID:	1798518
Link failure detection can be performed by the PHY.					
Comment		Ext ID:	2502	ID:	1798520
RSTP has also mechanism to remotely detect link failures. By using LLDP and SNMP topology changes (incl. link failures) can be remotely detected.					

1.11 Error Handling

Requirement	Error detection, error signaling and error reporting.	Ext ID:	501	ID:	1798524
The solution shall provide standardized means for error detection, error signaling and error reporting.					

1.12 Identification

Requirement	Unique identification	Ext ID:	550	ID:	1798528
The solution components shall use a mechanism for unique identification of the devices (endpoints, switches) in the network.					

Requirement	Device identification by topology	Ext ID:	900	ID:	1798530
The solution shall support the mechanisms for device identification based on topology detection.					

Requirement	Device identification by topology	Ext ID:	905	ID:	1798532
The solution shall support matching of a stored topology and online detected topology.					

1.13 Initialization

Requirement	Device Initialization and network operation	Ext ID:	350	ID:	1798550
Devices added after system Initialization shall not disrupt the real-time system operation of the already initialized/configured part of the system.					

Requirement	Easy device replacement	Ext ID:	360	ID:	1798552
The solution shall support device replacement without the need to attach an engineering tool.					

1.14 Hot Plug

Requirement	Hot Plug 1a	Ext ID:	1310	ID:	1798560
The solution shall support the hot-plug of (optional) devices, or network segments with a set of devices in a pre-engineered (preconfigured) system.					

Requirement	Hot Plug 1b	Ext ID:	1311	ID:	1798562
The solution shall support the hot-plug of non-preconfigured devices (single port endpoints), or network segments with a set of devices.					

Non-Functional Requirement	Hot Plug 2	Ext ID:	1320	ID:	1798564
The solution shall support the startup within 0.2s for particular devices. Note: These devices are preconfigured, and no additional information are necessary from the system (network) to perform the start-up					

Requirement	Integration into standard mechanisms 2	Ext ID:	1350	ID:	1798566
All diagnostic information (like indication of Hot-plugging) shall be passed layer to layer without by-passing, and following the standards in network communication, starting with a link at the physical layer. Note: If additional functions or more performing reaction is needed, this has to be standardized for the related layers. The mechanisms					
<ul style="list-style-type: none"> • E.g. Link detection starts the drive/IO activation • Drive/IO sends a request to the network master instance (similar to DHCP client for Address, Network parameters, Gateway and DNS) 					
Comment		Ext ID:	1361	ID:	1798568
Design note: Continued cyclic sending of broadcasts must be avoided.					

Requirement	End devices and network segments 2	Ext ID:	1390	ID:	1798570
The hot-plug configuration time of a network segment with n devices shall not be higher than the n times hot-plug configuration time of a single device.					
Comment		Ext ID:	1400	ID:	1798572
The indication mechanism (e.g. cyclic request of the slave device, if it sees a link) must be applicable in the same way as with a single device. The hot-plug procedure should be parallelized for all devices inside the segment as much as possible to reduce the over-all hot-plug network segment activation time. Note: Implementation detail of #1390					

Non-Functional Requirement	End devices and network segments 4	Ext ID:	1410	ID:	1798574
Infrastructure elements shall support online configuration changes during system operation in order to support the hot-plug mechanisms.					

Note: The network infrastructure elements (switches, repeaters, media converters) should not restrict the hot-plug mechanisms.

1.15 Performance & Scalability

Requirement	Synchronization	Ext ID:	470	ID:	1798584
The solution shall enable the implementation of the network clock synchronization precision (difference between any two clocks in the system) up to 1 μ sec with 100 hops and 100ns for 10 hops.					
Comment		Ext ID:	471	ID:	1798586
Clock Synchronization precision depends not only on the clock synchronization mechanisms of the TSN, but also on the component implementation (clock correction mechanism, drift rate), and the network size.					

Requirement	Max. Network Size	Ext ID:	710	ID:	1798588
It shall be possible to address up to 10.000 devices in single TSN network.					

Non-Functional Requirement	High availability	Ext ID:	2360	ID:	1798612
The solution shall support device redundancy. Note: This will increase the traffic load as application data between redundant devices shall be exchanged.					
Comment		Ext ID:	2361	ID:	1798614
Note: This depends on the PLC resources. To be on the safe side, redundancy mechanisms for high-availability can be implemented in dedicated HW (Switches, Endpoints)					

1.16 Redundancy

Requirement	Seamless redundancy	Ext ID:	101	ID:	1798618
The solution shall support the development of architectures with seamless redundancy mechanisms, where the maximum latency for all redundant transmissions are known and within the timing requirements of the application.					

Requirement	Ring Redundancy	Ext ID:	1070	ID:	1798620
The solution shall support network redundancy management for redundant (ring, mesh, redundant star) networks.					

Requirement	Media Redundancy	Ext ID:	1080	ID:	1798622
The solution shall support media/port redundancy.					

Requirement	Media Redundancy 2	Ext ID:	1840	ID:	1798624
The clock synchronization mechanisms shall work transparent to the media or 1CB redundancy.					

Requirement	Media Redundancy 3	Ext ID:	1850	ID:	1798626
A media path change with a different transmission delay time shall not lead to a phase shift of the synchronization instant of time.					
Comment		Ext ID:	1851	ID:	1798628
Refer Req Media Redundancy 3: An option could be to start a new transmission delay measurement immediately after a media redundancy switchover. This should be evaluated with the chosen synchronization method resp. procedure.					

Requirement	Mixing of devices with different redundancy features.	Ext ID:	1990	ID:	1798630
The features for redundancy on network level and device level shall be independent from each other so that devices with and without redundancy management features can coexist on the same network					
Comment		Ext ID:	2000	ID:	1798632
Devices with multiple ports, can be used in systems with redundant network and in systems without network redundancy.					

Requirement	Redundancy and flexible devices	Ext ID:	2010	ID:	1798634
The network redundancy protocol shall allow single and/or multiple connection of the enabled end devices					
Comment		Ext ID:	2020	ID:	1798636
A single port device may be connected into a redundant network.					

Requirement	Redundancy and legacy integration	Ext ID:	2030	ID:	1798638
The network redundancy protocol shall allow coexistence with the PRP redundancy protocols.					
Comment		Ext ID:	2040	ID:	1798640
In brown-field installations, the overall system cost and engineering costs will be reduced if the redundancy protocol is compatible with the legacy ones. Moreover, in some installations there is the requirement of a doubled network infrastructure (supported by PRP).					

Requirement	Redundancy scalability	Ext ID:	2050	ID:	1798642
Network redundancy mechanisms shall not limit the number of the participating devices.					
Comment		Ext ID:	2060	ID:	1798644
The redundancy protocol should not block large system sizes in being adopted					

Requirement	Discovery in redundant topologies	Ext ID:	2090	ID:	1798646
The redundancy protocol shall support topology discovery protocols					

Comment		Ext ID:	2100	ID:	1798648
<p>The redundancy protocol should support the propagation of TLVs related to the topology discovery. There are several protocols today, from IETF or IEEE ones till ones which relate to industrial Ethernet standards (i.e. DCP with PROFINET IO, LLDP ...)</p>					

Requirement	Device Redundancy	Ext ID:	3000	ID:	1798650
<p>The solution shall allow the implementation of device redundancy.</p>					