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INTERNATIONAL STANDARD

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Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)

Réseaux de communication industriels – Réseaux de haute disponibilité pour l'automatisation –
Partie 3: Protocole de redondance en parallèle (PRP) et redondance transparente de haute disponibilité (HSR)



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INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)

FOREWORD

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IEC 62439-3 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) References to Precision Time Protocol (PTP) IEC 61588:2021 replace references to IEC 61588:2009, unless the previous version is explicitly referenced (Clause 2);
b) References to IEC 61850-90-4:2020 replace references to IEC 61850-90-4:2013 with corresponding changes in the Logical Nodes (Clause 2);

c) Terms and abbreviations are aligned with the next edition of IEC/IEEE 61850-9-3 (currently under preparation) (Clause 3);

d) RSTP support in HSR is specified (5.2.2.10);

e) RedBoxes and QuadBoxes specifications are extended to TCs (5.5);

f) Network management (MIB) for PRP and HSR is available as a "Code Component", machine-readable separate document (Clause 7);

g) PTP over PRP specifies a unified operation of DATC and SLTC RedBoxes (A.2.6.4);

h) PTP over HSR specifies the operation of RedBoxes for TCs (A.4.3);

i) PTP datasets are aligned with IEC 61588:2021 (Clause A.6);

j) PTP industry profile is extended:

- Sync messages padding to support media converters (C.5.4);
- ClockClass definition aligned with IEC 61588:2021 option a) (C.7.4.3);
- TC operation over different domains (C.7.5.3);
- BCs behaviour in holdover and recovery (C.7.6.2);
- PICS entries renamed and extended (C.13.2);
- Flags semantics in TimePropertyDS actualized (C.14.1);
- UTC events handling during a leap second specified (C.14.2);
- UTC leap second time representation aligned with IEEE C37.118.2 (C.14.2.2);
- Daylight saving time and leap second events recommended in the ALTERNATE_TIME_OFFSET_INDICATOR TLV (C.14.3.2);

k) Tutorial extended to explain the media converter issue (D.8.3);

l) PTP network management MIB (Annex E) is available as a "Code Component", machine-readable separate document and considers IEC 61588:2021 objects;

m) Conformance testing for PRP, HSR and the doubly attached PTP clocks (Annex F) has been added.

n) Interoperability issues with previous editions of this International Standard are mentioned in a note at the end of the corresponding clause.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65C/1120/FDIS	65C/1139/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

The contents of the corrigendum 1 (2023-04) have been included in this copy.

INTRODUCTION

0.1 General

This document belongs to the IEC 62439 series *"Industrial communication networks – High availability automation networks"*. It was developed jointly with IEC TC57 WG10 as the redundancy method for demanding substation automation networks operating on layer 2 networks, in accordance with IEC 61850-8-1 and IEC 61850-9-2, and extended to encompass the needs of CPF 2 of IEC 61784-1 and IEC 61784-2 for layer 3 networks.

This document specifies two related redundancy protocols that, in the event of failure of any network element, provide seamless switchover with zero recovery time:

- PRP (Parallel Redundancy Protocol), which allows attaching nodes to two separate networks while allowing attachment of nodes to one network only; and
- HSR (High-availability Seamless Redundancy), which allows threading two-port nodes in a ring or multi-port nodes in a meshed network.

This document applies the seamless redundancy principle to clocks compliant with the Precision Time Protocol (PTP).

This document specifies a PTP Industry profile (PIP) that offers the performance needed to achieve sub-microsecond time accuracy. This profile can be applied to any industrial communication network based on Ethernet. Two variants of PIP are specified:

- L3E2E (Layer 3, end-to-end) for clocks operating on layer 3 networks with end-to-end path delay measurement such as CP 2/2 of IEC 61784-1 and IEC 61784-2; and
- L2P2P (Layer 2, peer-to-peer) for clocks operating on layer 2 with peer-to-peer link delay measurement (P2P).

Based on L2P2P, IEC TC57 WG10 and the IEEE PSRC jointly specified the Power Utility Profile (PUP) and copied it to IEC/IEEE 61850-9-3. IEC and IEEE agreed to keep the contents of this document and IEC/IEEE 61850-9-3 aligned, under the umbrella of the Dual Logo Maintenance Team (DLMT) hosted by IEEE PSCC P20.

The specifications of PRP and HSR present no backward compatibility issues as the changes are compatible extensions of the protocol. The minor version of these protocols is kept at value "1".

The specifications of the clock profile PIP are based on IEC 61588:2021, which presents some differences compared with IEC 61588:2009. The minorVersionPTP has been increased to 1.

This document includes guidelines for conformance testing, applicable to PRP, HSR and to the PIP and PUP clock synchronization profiles.

0.2 Patent declaration

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this standard may involve the use of a patent. IEC takes no position concerning the evidence, validity, and scope of this patent right.

The holder of this patent right has assured IEC that s/he is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with IEC. Information may be obtained from the patent database available at http://patents.iec.ch.

Attention is drawn to the possibility that some of the elements of this standard may be the subject of patent rights other than those in the patent database. IEC shall not be held responsible for identifying any or all such patent rights.

INTRODUCTION to Corrigendum 1

This Corrigendum 1 corrects errors and possible misinterpretations in IEC 62439-3:2021, which were discovered during the first field implementations based on this International Standard. All corrections are only intended to improve the consistency of implementations of the specifications and do not introduce new features to the technology.

NOTE This Corrigendum 1 includes corrections for the MIBs in Clause 7 and Annex E. These MIBs are provided as code components in companion documents, see https://www.iec.ch/sc65c/supportingdocuments. The corrections for Clause 7 and Annex E are provided for convenience, while the versions in the companion documents IEC_62439-3_2021B1.mib and IEC_62439-100_2021B1.mib contain the corrected code and prevail in case of discrepancies.

INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)

1 Scope

1.1 General

The IEC 62439 series is applicable to high-availability automation networks based on the Ethernet technology.

This document:

- specifies PRP and HSR as two related redundancy protocols designed to provide seamless recovery in case of single failure of an inter-bridge link or bridge in the network, which are based on the same scheme: parallel transmission of duplicated information;
- specifies the operation of the precision time protocol (PTP) in networks that implement the two redundancy protocols (Annex A);
- specifies PTP profiles with performance suitable for power utilty automation (Annex B) and industrial automation (Annex C);
- includes for better understanding a tutorial (Annex D) on the PTP features effectively used in high-availability automation networks;
- includes a management information base for PTP (Annex E);
- defines a conformance test suite for the above protocols (Annex F).

1.2 Code component distribution

This document is associated with Code components. Each Code Component is a ZIP package containing at least the electronic representation of the Code Component itself and a file describing the content of the package (IECManifest.xml).

The IECManifest contains different sections giving information on:

- the copyright notice;
- the identification of the code component;
- the publication related to the code component;
- the list of the electronic files which compose the code component;
- an optional list of history files to track changes during the evolution process of the code component.

The Code Components associated with this IEC standard are a set of SNMP MIBs. The Code Component IEC-62439-3-MIB.mib is a file containing the MIBs for PRP/HSR and PTP_SNMP. It is available in a full version, which contains the MIBs defined in this document with the documentation associated and access is restricted to purchaser of this document.

The Code Components are freely accessible on the IEC website for download at: https://www.iec.ch/sc65c/supportingdocuments/IEC_62439-3.MIB.{VersionStateInfo}.full.zip but the usage remains under the licensing conditions.

The life cycle of a code component is not restricted to the life cycle of the related publication. The publication life cycle goes through two stages, "Version" (corresponding to an edition) and "Revision" (corresponding to an amendment). Consequently, new release(s) of the Code Component(s) may be released, which supersede(s) the previous release, and will be distributed through the IEC web site at: https://www.iec.ch/sc65c/supportingdocuments.

The latest version/release of the document will be found by selecting the file IEC_62439-3.MIB.{VersionStateInfo}.full.zip for the code component with the highest value for VersionStateInfo.

In case of any differences between the downloadable code and the IEC pdf published content, the downloadable code(s) is(are) the valid one; it may be subject to updates. See history files.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-192, *International Electrotechnical Vocabulary – Part 192: Dependability*

IEC 61588:2021, *Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*

IEC TR 61850-90-4:2020, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC 62439-1, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation method*

ISO/IEC/IEEE 8802-3:2021, *Standard for Ethernet*

IEC/IEEE 61850-9-3:2016, *Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

IEEE 802.1Q-2018, *IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Network*

NOTE IETF references are dated with the original Request for Comment (RFC). Subsequent versions receive a new RFC number. Since IETF amends or extends documents and publishes errata on-line, the valid version can be found on the internet at *https://tools.ietf.org/*.

IETF RFC 768, *User Datagram Protocol (UDP)* [online]. August 1980 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc768

IETF RFC 791, *Internet Protocol (IP)* [online]. September 1981 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc791

IETF RFC 792, *Internet Control Message Protocol* [online]. September 1981 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc792

IETF RFC 793, *Transmission Control Protocol* [online]. September 1981 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc793

IETF RFC 826, *Ethernet Address Resolution Protocol* [online]. November 1982 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc826

IETF RFC 2578, *Structure of Management Information Version 2 (SMIv2)* [online]. April 1999 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc2578

IETF RFC 3418, *Structure of Management Information Version 2 (SMIv2)* [online]. December 2002 [viewed 2020-05-07]. Available at https://tools.ietf.org/html/rfc3418

3 Terms, definitions, abbreviated terms, and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192 and in IEC 62439-1, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
device time inaccuracy
time inaccuracy evaluated or measured between the time signal applied to the input of a device and the time signal that this device generates

Note 1 to entry: This definition applies to TCs, BCs and media converters.

Note 2 to entry: Device time inaccuracy includes the uncertainty in the computation of the peer delay from an upstream peer clock, assuming that the peer responds with an ideal Pdelay_Resp message to the Pdelay_Req message, and the uncertainty introduced in the Pdelay_Resp to an ideal Pdelay_Req from a downstream peer.

3.1.2
Ethertype
2 octet value that indicates the nature of the MAC client protocol

Note 1 to entry: Type values are assigned by the IEEE Registration Authority.

3.1.3
frame
layer 2 protocol data unit from the start of the preamble to the end of the frame check sequence, synonym for DLPDU (Data Link Protocol Data Unit)

3.1.4
Grandmaster Clock
master-capable Ordinary Clock that can be synchronized by an absolute time reference signal

Note 1 to entry: This definition of Grandmaster Clock is different from that given in IEC 61588:2021, 3.1.17 and is used to distinguish the role from the device. Several Grandmaster Clocks can exist in the same domain, the best one is expected to take the role of grandmaster (lower case “g”). A Boundary Clock can also take the role of a grandmaster in the absence of a Grandmaster Clock, but it has no access to a reference signal. Thus, the Grandmaster Clock as a device and the role “grandmaster” are separate.

3.1.5
grandmaster
ordinary Clock or Boundary Clock from which all other clocks in the same domain receive their time

3.1.6
grandmaster-capable, adj
ordinary Clock or Boundary Clock that is able to take the role of a grandmaster

Note 1 to entry: A grandmaster-capable clock is not necessarily connected to a time reference.

3.1.7
grandmaster time inaccuracy
time inaccuracy evaluated or measured between the primary reference time source signal at the input of a grandmaster and the time signal(s) that the grandmaster generates

Note 1 to entry: Grandmaster time inaccuracy includes the uncertainty introduced in the Pdelay_Resp to an ideal Pdelay_Req from a downstream peer.

Note 2 to entry: The clockAccuracy (IEC 61588:2021, 7.6.2.6) of the grandmaster adds the inaccuracy of the time source to the grandmaster inaccuracy.

3.1.8
HSR frame
frame that carries as Ethertype the HSR_EtherType

3.1.9
interlink
link that connects two network hierarchies

3.1.10
layer management entity
entity in charge of supervising a layer on behalf of network management

3.1.11
link redundancy entity
entity in charge of handling redundancy in the nodes

3.1.12
master clock
Ordinary Clock or Boundary Clock generating Announce and Sync messages

3.1.13
message
data carried over layer 2 or layer 3

3.1.14
network time inaccuracy
time inaccuracy evaluated or measured between a particular slave clock and the time reference signal of its grandmaster clock(s), considering the worst network topology

3.1.15
NodesTable
table containing all other devices positively identified as DANP, DANH or SAN, used for supervision and for trailer control

3.1.16
ProxyNodeTable
list of the SAN devices represented by a RedBox, used for supervision and unicast frame filtering

3.1.17
RedBox
device connecting PRP, HSR or single-thread networks

3.1.18
QuadBox
quadruple port device connecting two peer HSR rings, which behaves as an HSR node in each ring and is able to filter the traffic and forward it from ring to ring

3.1.19
switching logic
hardware that transmits a frame from one port to another port, possibly providing cut-through

3.1.20
time error
deviation from the time reference used for measurement or synchronization caused by a network element, evaluated over a short time span (a few Sync intervals)

3.1.21
time inaccuracy
time error not exceeded by a high percentage of the measurements, evaluated over a large series of measurements in steady state

3.1.22
total time inaccuracy
time inaccuracy evaluated or measured between the time maintained by the international standards laboratories that forms the basis for the timescale and the time signal at the input of a slave clock

Note 1 to entry: When sampling binary or analog input variables, the time-stamp inaccuracy considers the total time inaccuracy, the inaccuracy of the clock that controls the sampling and the inaccuracy of the measurement. Therefore, the mapping from total time inaccuracy to the time stamping inaccuracy is implementation-dependent.

3.2 Abbreviated terms

For the purposes of this document, the abbreviations and acronyms given in IEC 62439-1, as well as the following apply.

ARP	Address Resolution Protocol, as defined in IETF RFC 826
ATOI	Alternate Time Offset Indicator, as defined in IEC 61588:2021, 16.3.3
BC	Boundary Clock, as defined in IEC 61588:2021
BIPM	Bureau International des Poids et Mesures
BMCA	Best Master Clock Algorithm, as defined in IEC 61588:2021
CoS	Class of Service (layer 2 quality of service) as specified in IEEE 802.1Q
DAC	Doubly Attached Clock
DABC	Doubly Attached Boundary Clock
DAN	Doubly Attached Node
DANH	Doubly Attached Node implementing HSR
DANP	Doubly Attached Node implementing PRP
DATC	Doubly Attached Transparent Clock
E2E	End-to-End (delay measurement) as specified in IEC 61588:2021
GC	Grandmaster Clock (a master-capable clock of sufficient precision)
GM	Grandmaster (the clock currently synchronizing a domain)
GNSS	Global Navigation Satellite Systems
HC	Hybrid Clock (combination of OC and TC)
HSR	High-availability Seamless Redundancy
IERS	International Earth Rotation and Reference Systems Service
IETF	Internet Engineering Task Force
ICMP	Internet Control Message Protocol as specified in IETF RFC 792
IP	Internet Protocol as specified in IETF RFC 791
L2P2P	Layer 2 Peer-to-Peer

L3E2E Layer 3 End-to-End
LAN Local Area Network
LLC Link Layer Control
LLDP Link Layer Discovery Protocol as specified in IEEE 802.1AB-2016
LME Layer Management Entity
LRE Link Redundancy Entity
LT Length/Type field in frames
MAC Medium Access Control
MC Master-capable Clock (not necessarily current master or grandmaster)
MIB Management Information Base
OC Ordinary Clock, as defined in PTP (can be master-capable or slave-only)
P2P Peer to Peer (delay measurement)
PICS Protocol Implementation Conformance Statement (ISO/IEC 9646-7)
PIP Precision Time Protocol Industrial Profile (Annex C)
PPS Pulse Per Second
PRP Parallel Redundancy Protocol
PTP Precision Time Protocol, as specified in IEC 61588:2021
PUP Precision Time Protocol Power Utility Profile (Annex B and IEC/IEEE 61850-9-3)
QB QuadBox
RCT Redundancy Check Trailer (PRP trailer)
RSTP Rapid Spanning Tree Protocol, as specified in IEEE 802.1Q-2018, Clause 13
SAN Singly Attached Node
SAC Singly Attached Clock
SLTC Stateless Transparent Clock
SNMP Simple Network Management Protocol, as defined in IETF RFC 3418
TAI Temps Atomique International
TC Transparent Clock, as defined in IEC 61588:2021
TCP Transport Control Protocol as specified in IETF RFC 793
TWBC Three-Way Boundary Clock
UDP User Data Protocol, as specified in IETF RFC 768
UTC Coordinated Universal Time
VDAN Virtual Doubly Attached Node (SAN as visible through a RedBox)

3.3 Conventions

For the purposes of this document, the conventions defined in IEC 62439-1 apply.

4 Parallel Redundancy Protocol (PRP)

4.1 PRP principle of operation

4.1.1 PRP network topology

This redundancy protocol implements redundancy in the nodes rather than in the network (see the definitions in IEC 62439-1), using Doubly Attached Nodes obeying PRP (DANPs).