



**BSI Standards Publication**

# **Industrial communication networks — High availability automation networks**

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

## National foreword

This British Standard is the UK implementation of EN IEC 62439-3:2022. It is identical to IEC 62439-3:2021, incorporating corrigendum April 2023. It supersedes BS EN IEC 62439-3:2018, which will be withdrawn on 19 January 2025.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by IEC corrigendum April 2023 is indicated in the text by AC1 AC1.

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English Version

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de haute disponibilité (HSR)  
(IEC 62439-3:2021)

Industrielle Kommunikationsnetze - Hochverfügbare  
Automatisierungsnetze - Teil 3: Parallelredundanz-Protokoll  
(PRP) und nahtloser Hochverfügbarkeits-Ring (HSR)  
(IEC 62439-3:2021)

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## European foreword

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The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2022-10-19 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2025-01-19 document have to be withdrawn

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

|                    |      |                                                  |
|--------------------|------|--------------------------------------------------|
| IEC 61784-1        | NOTE | Harmonized as EN IEC 61784-1                     |
| IEC 61784-2        | NOTE | Harmonized as EN IEC 61784-2                     |
| IEC 61850 (series) | NOTE | Harmonized as EN 61850 (series)                  |
| IEC 61850-8-1      | NOTE | Harmonized as EN 61850-8-1                       |
| IEC 61850-9-2      | NOTE | Harmonized as EN 61850-9-2                       |
| IEC 62439-2        | NOTE | Harmonized as EN 62439-2                         |
| IEC 62439-3:2016   | NOTE | Harmonized as EN IEC 62439-3:2018 (not modified) |
| IEC 62439-4        | NOTE | Harmonized as EN 62439-4                         |
| IEC 62439-6        | NOTE | Harmonized as EN 62439-6                         |
| IEC 62439-7        | NOTE | Harmonized as EN 62439-7                         |

## Annex ZA (normative)

### Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: [www.cenelec.eu](http://www.cenelec.eu).

| <u>Publication</u>  | <u>Year</u> | <u>Title</u>                                                                                                                                                   | <u>EN/HD</u> | <u>Year</u> |
|---------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------|
| IEC 60050-192       | -           | International Electrotechnical Vocabulary (IEV) - 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 methods                                   | EN 62439-1   | -           |
| ISO/IEC/IEEE 8802-3 | 2021        | Telecommunications and exchange between information technology systems - Requirements for local and metropolitan area networks - Part 3: 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                                                                           | -            | -           |
| IETF RFC 768        | -           | User Datagram Protocol (UDP) [online]. August 1980.                                                                                                            | -            | -           |
| IETF RFC 791        | -           | Internet Protocol (IP) [online]. September 1981.                                                                                                               | -            | -           |
| IETF RFC 792        | -           | Internet Control Message Protocol [online]. September 1981.                                                                                                    | -            | -           |

## EN IEC 62439-3:2022 (E)

| <u>Publication</u> | <u>Year</u> | <u>Title</u>                                                                   | <u>EN/HD</u> | <u>Year</u> |
|--------------------|-------------|--------------------------------------------------------------------------------|--------------|-------------|
| IETF RFC 793       | -           | Transmission Control Protocol [online]. September 1981.                        | -            | -           |
| IETF RFC 826       | -           | Ethernet Address Resolution Protocol [online]. November 1982.                  | -            | -           |
| IETF RFC 2578      | -           | Structure of Management Information Version 2 (SMIv2) [online]. April 1999.    | -            | -           |
| IETF RFC 3418      | -           | Structure of Management Information Version 2 (SMIv2) [online]. December 2002. | -            | -           |

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

This International Standard is to be read in conjunction with IEC 62439-1.

A list of all parts in the IEC 62439 series, published under the general title *Industrial communication networks – High availability automation networks*, can be found on the IEC website.

This IEC standard includes Code Components, i.e., components that are intended to be directly processed by a computer. Such content is any text found between the markers <CODE BEGINS> and <CODE ENDS>, or otherwise is clearly labeled in this standard as a Code Component.

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

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## 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.

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## 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 utility 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](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)

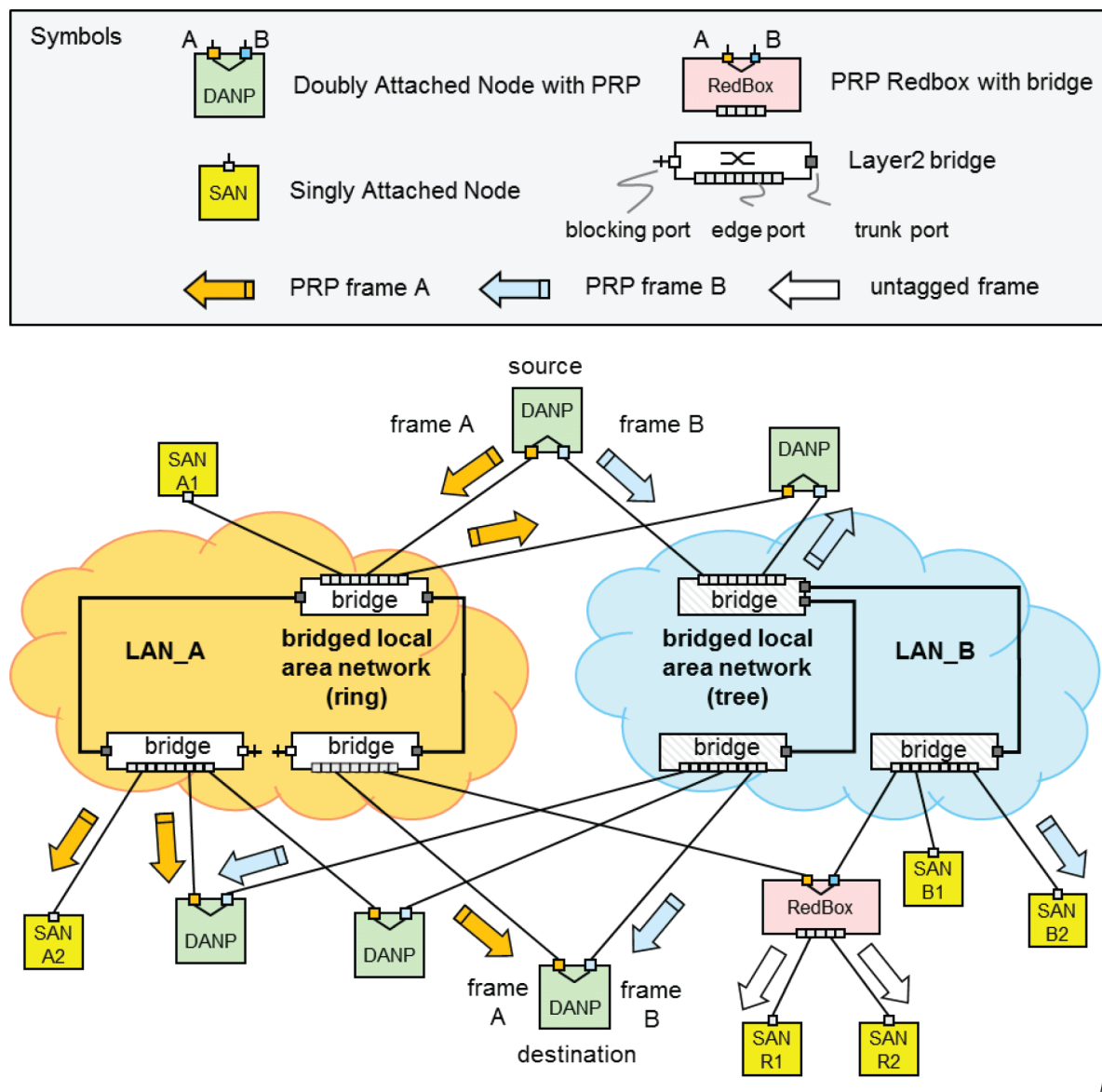
### 4.1 PRP principle of operation

#### 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).

A DANP is attached to two independent Local Area Networks (LANs) of similar topology, named LAN\_A and LAN\_B, which operate in parallel. A source DANP sends the same frame over both LANs and a destination DANP receives it from both LANs within a certain time, consumes the first frame and discards the duplicate.

Figure 1 shows a duplicated network consisting of two LANs, each of which can have any topology, e.g. tree, ring or meshed.



IEC

**Figure 1 – PRP example of general duplicated network**

The two LANs are identical in protocol at the MAC-LLC level, but they can differ in performance and topology. Transmission delays are different, especially if one of the networks reconfigures itself, e.g. using RSTP, to overcome an internal failure.

The two LANs follow configuration rules that allow the network management protocols such as Address Resolution Protocol (ARP) and Simple Network Management Protocol (SNMP) to operate correctly.

The two LANs have no connection between them and are assumed to be fail-independent. Redundancy can be defeated by single points of failure, such as a common power supply or a direct connection whose failure brings both networks down. Installation guidelines in this document provide guidance to achieve fail-independence.

#### 4.1.2 PRP LANs with linear or bus topology

As an example of a simpler topology, Figure 2 draws a PRP network as two LANs in linear topology, which may also be a bus topology.

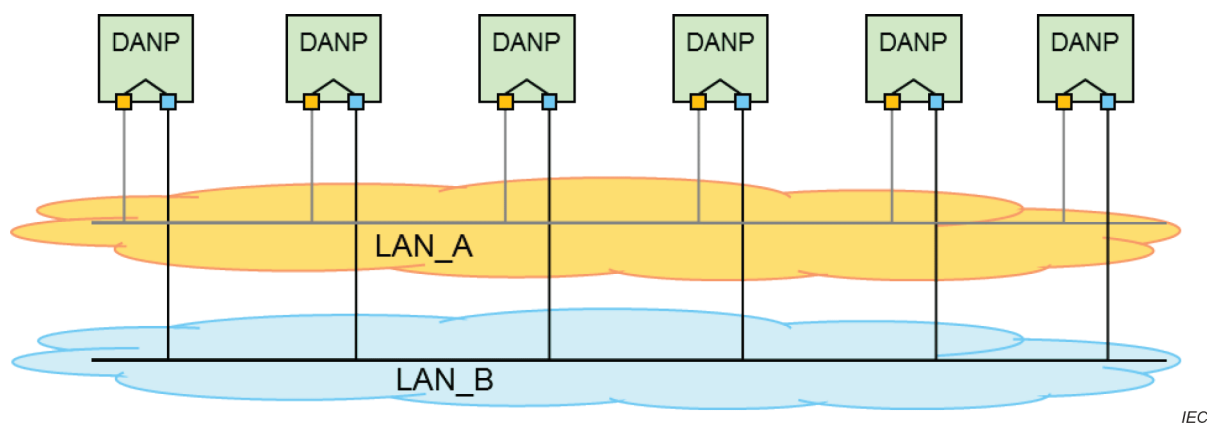


Figure 2 – PRP example of duplicated network in bus topology

#### 4.1.3 PRP LANs with ring topology

The two LANs can have a ring topology, as Figure 3 shows.

Redundancy within each ring is provided by a different mechanism, for instance as defined in RSTP or in other protocols of the IEC 62439 series.

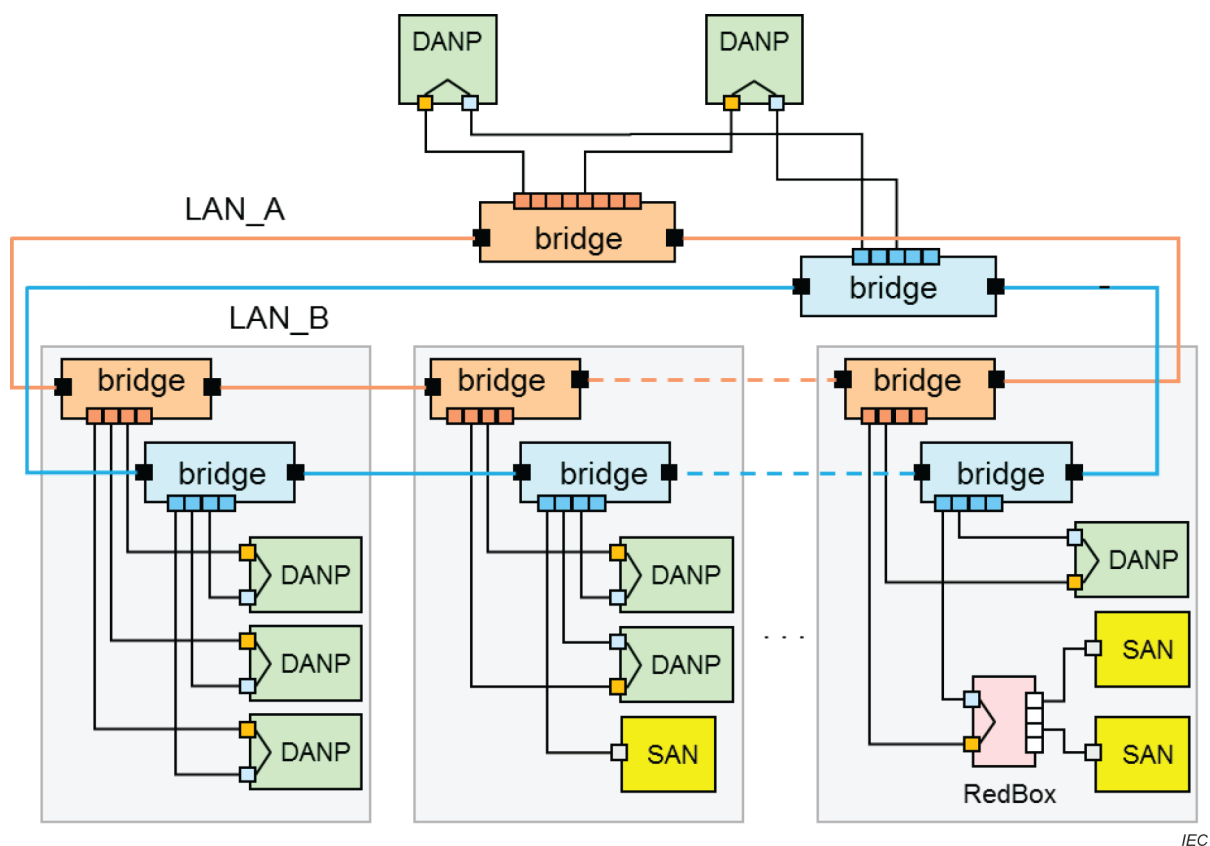


Figure 3 – PRP example of redundant ring with SANs and DANPs

#### 4.1.4 DANP node structure

Each node has two ports that operate in parallel and that are attached to the same upper layers of the communication stack through the Link Redundancy Entity (LRE), as Figure 4 shows.

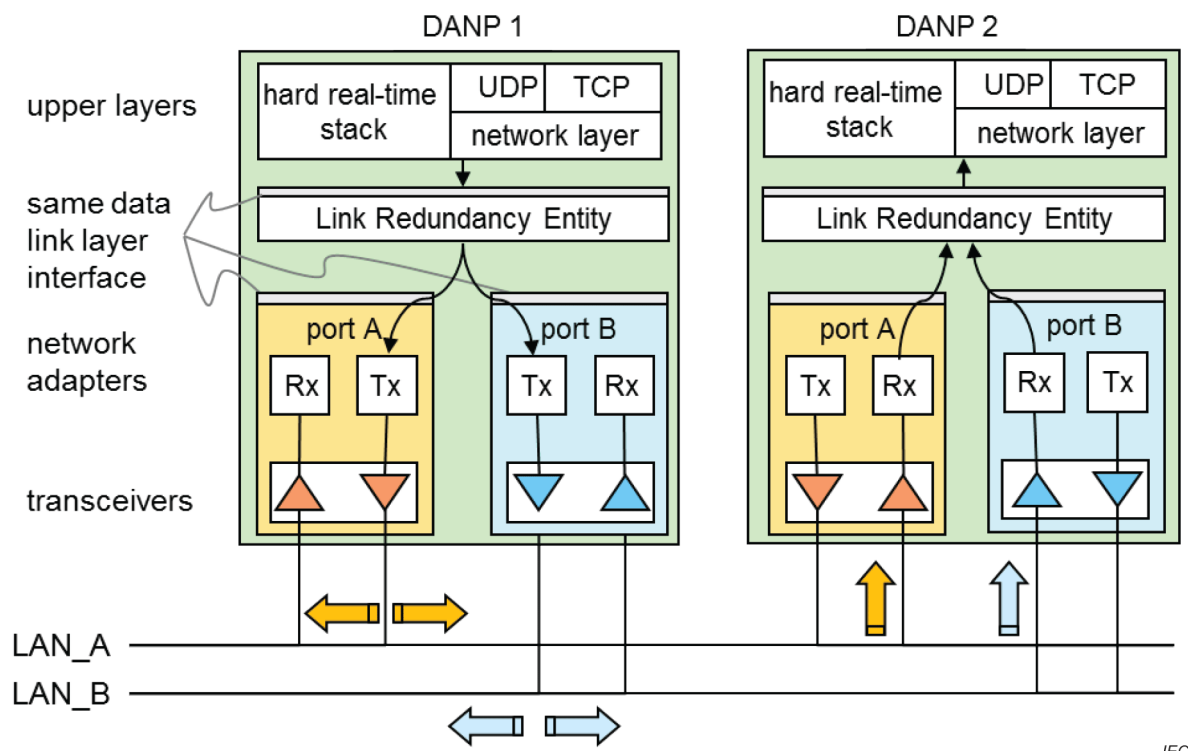


**Figure 4 – PRP with two DANPs communicating**

For the basic communication, the LRE presents toward its upper layers the same interface as a non-redundant network adapter, so the upper layers are unaware of redundancy.

The LRE has two tasks: handling of duplicates and management of redundancy.

When receiving a frame from the node's upper layers, the LRE appends to the frame a Redundancy Check Trailer (RCT) containing a sequence number and sends the frame through both its ports at nearly the same time. The two frames are nearly identical except for the LAN identifier (and the checksum).

The two frames transit through the two LANs with different delays, ideally they arrive at nearly the same time at the destination node.

When receiving frames from the network, the LRE forwards the first received frame of a pair to its node's upper layers and discards the duplicate frame (if it arrives). It removes the RCT if required.

For management of redundancy and checking of the presence of other DANPs, an LRE periodically sends PRP\_Supervision frames and can evaluate the PRP\_Supervision frames sent by other DANPs.

#### 4.1.5 PRP attachment of singly attached nodes

Singly attached nodes (SANs) can be attached in two ways:

SANs can be attached directly to one LAN only. Such SANs can only communicate with other SANs on the same LAN. For instance, in Figure 1, SAN A1 can communicate with SAN A2, but not with SAN B1 or SAN B2. SANs can communicate (not redundantly) with all DANPs.

SANs can be attached over a Redundancy Box (RedBox) to both LANs, as Figure 1 shows for SAN R1 and SAN R2 (see also 4.1.9). Such SANs can communicate with all DANP and SANs, for instance SAN A1 and SAN R1 can communicate.

NOTE 1 SANs are not aware of PRP; they are for instance off-the-shelf computers or printers.

NOTE 2 In some applications, only availability-critical devices need a double attachment, for instance the operator workplaces, while the majority of the devices are SANs. Taking advantage of the basic infrastructure of PRP, a DANP can be attached to two different bridges of the same LAN (e.g. a ring) and use protocols different from PRP to reconfigure the network in case of failure. The DANP then behaves as a bridge compliant with IEEE 802.1Q. For instance, the bridge element may implement the RSTP protocol or a subset of RSTP where there is no forwarding of traffic between the ports. This ability is deprecated and not detailed in this document; it however appears as PRP\_SRP in Clause 6 for legacy devices.

#### **4.1.6 Compatibility between singly and doubly attached nodes**

Singly attached nodes (SAN), for instance maintenance laptops or printers that belong to one LAN, can be connected to any LAN. Bridges are SANs. A SAN connected to one LAN cannot communicate directly to a SAN connected to the other LAN. These SANs are not aware of PRP redundancy, but DANPs generate a traffic that these SANs understand.

The condition is however that the SANs ignore the RCT in the frames, which is the case since a SAN cannot distinguish the RCT from the Ethernet padding.

Conversely, DANPs understand the traffic generated by SANs, since these do not append an RCT. They only forward one frame to their upper layers since the SAN traffic uses one LAN only.

#### **4.1.7 Network management**

A node has the same MAC address on both ports and has only one set of IP addresses assigned to that address. This makes redundancy transparent to the upper layers and especially allows ARP to work as with a SAN. Bridges in a LAN are not doubly attached devices, and therefore all managed bridges have different IP (and MAC) addresses. A network management tool is preferably a DANP that can access nodes and bridges in both LANs.

NOTE Therefore, the uniqueness of MAC addresses within a LAN is preserved since the redundant LANs are not connected.

#### **4.1.8 Implication on application**

When the same frame comes from the two ports with significant time difference, a frame could, in exceptional situations, be wrongly rejected as duplicate. Therefore, there exists a mechanism to age out frames. This ageing mechanism causes in seldom cases that both duplicates are forwarded to the application. The duplicate is then filtered out by the transport layer (e.g. TCP) or tolerated by the application. This is a normal case since a LAN does not guarantee absence of duplicates.

The ageing mechanism considers both the maximum repetition rate of the frames and the worst-case difference in propagation delay, as described in 4.1.10.3.

#### 4.1.9 Transition to a single-thread network

To attach singly attached nodes (SANs) to a duplicated network, a RedBox is used as Figure 5 shows. For each pair of frames it receives from the PRP LANs, the RedBox rejects the duplicate and sends only one frame towards the single-thread LAN. Conversely, the RedBox duplicates a frame it receives from a SAN on both its PRP ports after appending a sequence number. The RedBox mimics the SANs connected behind it (called VDAN or virtual DANs) and multicasts supervision frames on their behalf. For supervision and unicast filtering, the RedBox maintains in the ProxyNodeTable a list of the SANs it detects on the single thread LAN. A RedBox is itself a DANP and maintains a list of nodes on the PRP LANs in the NodesTable. It has its own IP address for management purposes, but it may also perform application functions.

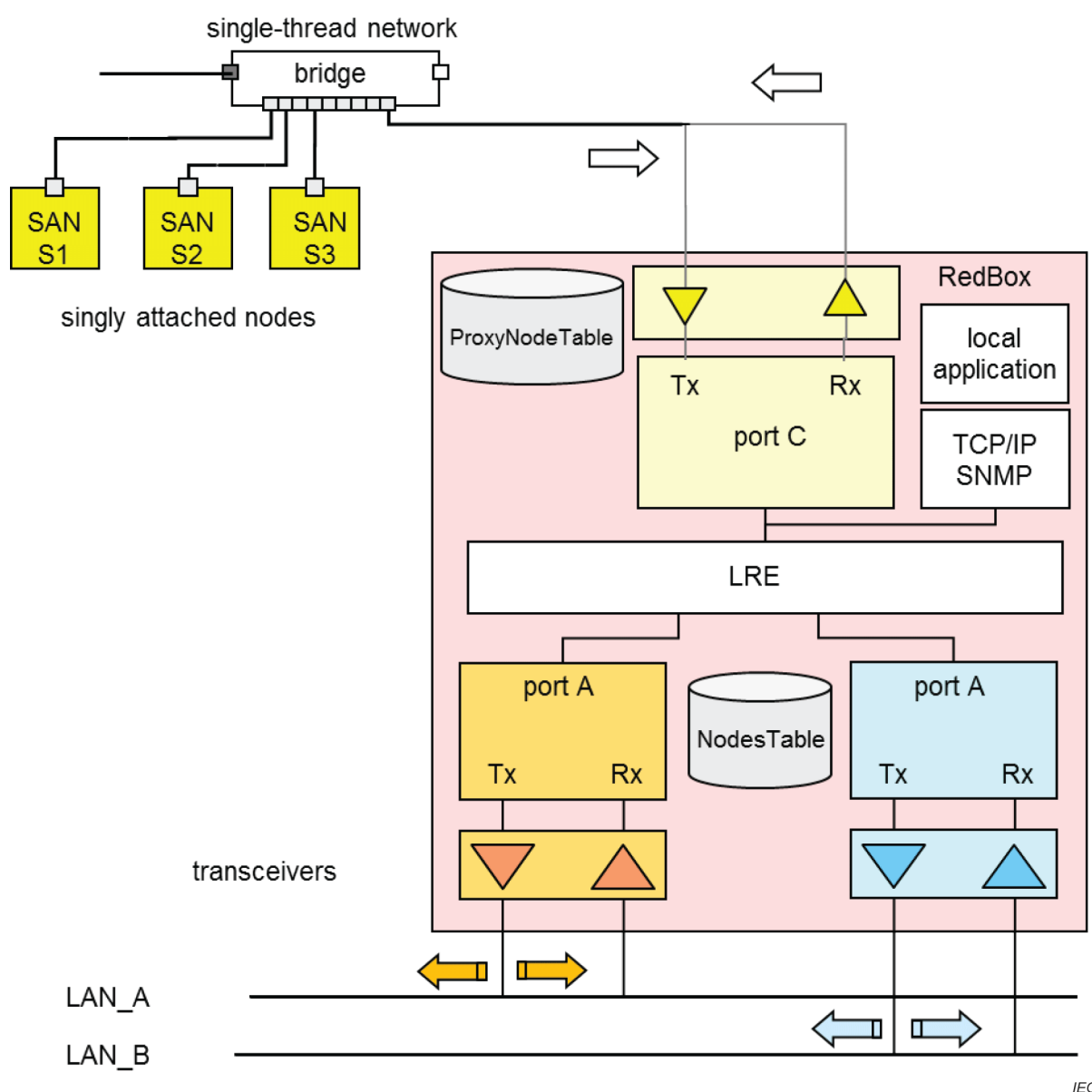


Figure 5 – PRP RedBox, transition from single to double LAN

#### 4.1.10 Duplicate handling

##### 4.1.10.1 Duplicate Accept mode (testing only)

The Duplicate Accept mode is used for testing purposes, to verify that duplicates are indeed discarded by the link layer and not by higher layer protocols.

In the Duplicate Accept mode, a sender is configured to send a normal frame over both ports.

In the Duplicate Accept mode, a receiver is configured to accept both frames and forward both of them (if both arrive) to its upper layers.

A node indicates its mode (Duplicate Accept/Duplicate Discard) in its supervision frames.

NOTE Upper layers also discard duplicates, but less effectively than the link layer.

#### 4.1.10.2 Duplicate Discard mode

##### 4.1.10.2.1 Principle

To allow the receivers to detect duplicates, the sender LRE appends a six-octet field that contains a sequence number, the Redundancy Control Trailer (RCT), to both frames it sends, as Figure 6 shows.

The receiver LRE uses the sequence number of the RCT and the source MAC address to detect duplicates. It forwards only the first frame of a pair to its upper layers. To offload the application processor, the LRE can be implemented with an independent pre-processor, an intelligent Ethernet controller or in hardware.

Keeping track of duplicates allows at the same time to improve the redundancy supervision. As an option, the receiver may remove the RCT before forwarding the (first) frame to its upper layer.

The RCT consists of the following fields:

- 16-bit sequence number (SeqNr);
- 4-bit LAN identifier (LanId);
- 12-bit frame size (LSDUsize);
- 16-bit suffix (PRPsuffix).

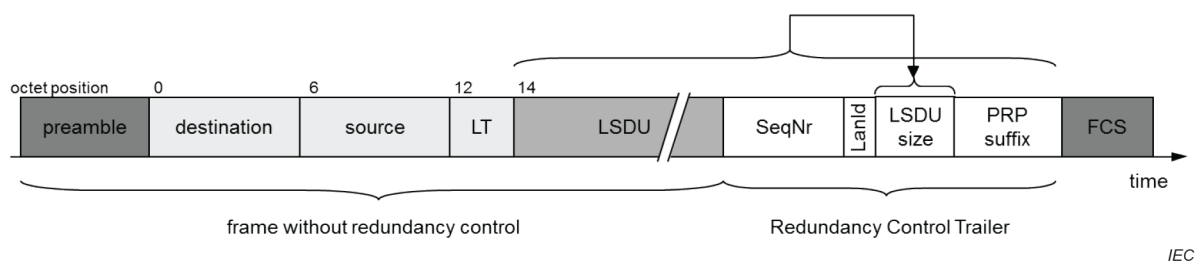


**Figure 6 – PRP frame closed by an RCT**

The LRE sends both (nearly identical) frames over both LANs.

The receiving LRE can then detect duplicates based on the RCT.

NOTE 1 This method considers that SANs also exist on the network, and that frames sent by SANs could be wrongly rejected as duplicates because they happen to have a trailing field with the correct PRP suffix, same sequence number and the same size. However, SANs send on one LAN only, therefore their source MAC address is not the same as that of a frame on the other LAN; a frame from an SAN is never discarded.

NOTE 2 Reception of a well-formed RCT is no proof that the source node is a DANP. Even if the LAN is wrong, a DANP accepts the frame.

#### 4.1.10.2.2 Use of PRPsuffix

The PRPsuffix identifies PRP frames and distinguishes PRP frames from other protocols that also append a trailer to their useful data.

#### 4.1.10.2.3 Use of LSDUsize

The 12-bit LSDUsize field contains the length of the link service data unit (LSDU) in octets. The LSDUsize field allows the receiver to distinguish PRP frames from random, non-redundant frames as an additional check.

In VLANs, frame VLAN tags can be added or removed during transit through a bridge. To make the length field independent of VLAN tagging, only the LSDU and the RCT are considered in the LSDUsize, as Figure 7 shows.

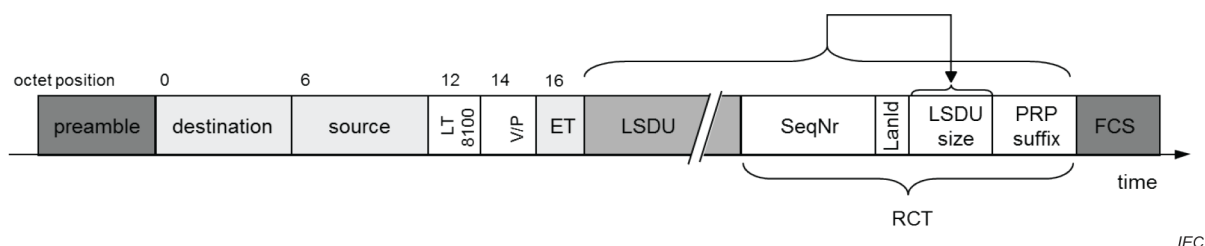


**Figure 7 – PRP VLAN-tagged frame closed by an RCT**

If the receiver detects that the frame is closed by the correct PRP suffix, that the 12 bits before the PRP suffix correspond to the LSDU size, and that the LAN identifier matches the identifier of the LAN of the receiving port, the frame is a candidate for discarding.

Since short frames need padding to achieve the minimum frame size of 64 octets, the sender already includes the padding to avoid scanning the frame backwards, as Figure 8 shows. The minimum frame size is extended to 70 octets since the LRE or a RedBox can remove the RCT.

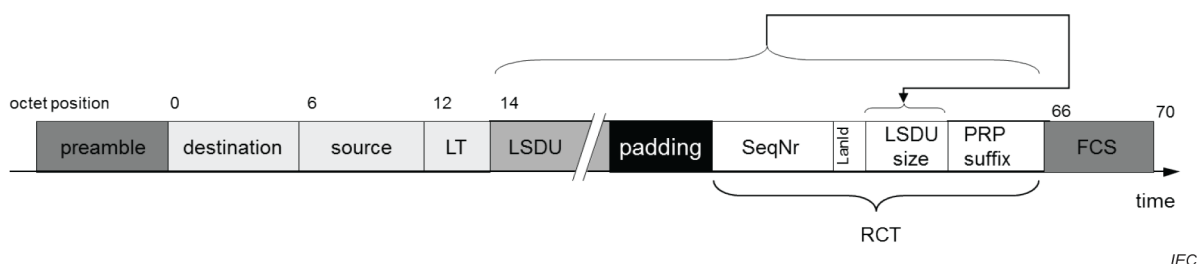


**Figure 8 – PRP padded frame closed by an RCT**

The padding size is increased to 74 octets when a VLAN tag is used.

NOTE A VLAN-tagged frame can pass several bridges, which removes or inserts VLAN tags. If the sender observes the Ethernet rule to send a minimum frame size of 68 octets for a VLAN-tagged frame and of 64 octets for a VLAN-untagged frame, there will never be a situation in which there is padding before and after the RCT.

#### 4.1.10.2.4 Use of LanId

The 4-bit LanId field of the RCT identifies the port over which a DANP sends the frame. A DANP uses LanId “1010” when sending over port A and LanId “1011” when sending over port B.

NOTE Therefore, frame A and frame B differ in the least significant bit of LanId and in the FCS.

The assumption for all DANP and RedBoxes is that their port A is connected to LAN\_A and port B is connected to LAN\_B. The receiver uses LanId to check that the frame comes from the correct LAN. It does not reject a frame that comes from the wrong LAN, since this could be a legitimate frame which happens to have the PRP suffix and the length information in its last 28 bits, but it increments the error counters CntErrWrongLanA or CntErrWrongLanB since this hints at a configuration error. If the network is not properly installed, this kind of error is permanent and it is detected rapidly.

#### 4.1.10.2.5 Use of SeqNr

The 16-bit field SeqNr is incremented by one for each frame that a DANP sends with an RCT. The doublet {source MAC address, sequence number} uniquely identifies copies of the same frame.

NOTE A LAN does not ensure that a destination can observe all frames from one specific source. Therefore, a destination cannot use the received sequence number for detecting missing frames. But a destination at any place in the network can carry out a test to check if sequence numbers are incremented monotonically (but not necessarily without gaps) and that their wrap-around time is larger than the aging time. A LAN does not ensure that frames are received in the order in which they were sent, the duplicate discard is not responsible for restoring the correct sequence.

#### 4.1.10.3 Duplicate discard algorithm and configuration

The algorithm for discarding duplicates is not specified. For instance, node tables, hash tables, fifos or sequence number tracking can be used. Whichever the algorithm, it is designed such that it never rejects a legitimate frame, while occasional acceptance of a duplicate can be tolerated. Since the 16-bit SeqNr wraps around after 65 536 frames and the sequence numbers are not necessarily contiguous, entries older than a specified time EntryForgetTime are purged.

Figure 9 shows the conditions for discarding or accepting frames.

The time  $t_{\text{skew}}$  is the time difference between the arrivals of two copies of the same frame (from LAN\_A to LAN\_B and from LAN\_B to LAN\_A) in a particular case.

The maximum delay  $t_{\text{skewMax}}$  between two copies depends on the network. The network designer estimates  $t_{\text{skewMax}}$  based on the number of bridges and the expected traffic for a particular application, e.g. 12 ms.

The time  $t_{\text{aliasMin}}$  is the minimum possible interval between two different, legitimate frames with the same sequence number (after 65 536 increments) in a particular application.

NOTE However, a node that reboots with an arbitrary sequence number can cause a shortening of time  $t_{\text{aliasMin}}$ , as will be detailed below.

In a 100 Mbit/s network,  $t_{\text{aliasMin}}$  is the theoretical minimum frame repetition interval of the smallest frame (64 octets) from the same source ( $65\,536 \times 6,72\,\mu\text{s}$ ) = 440 ms.

In a 1 Gbit/s,  $t_{\text{aliasMin}}$  is 44 ms.

This is a worst case since applications rarely send minimum size frames contiguously.

EXAMPLE An IEC 61850-9-2 device sending sampled values frames at 4,8 kHz will exhibit a  $t_{\text{aliasMin}} = 13\text{ s}$ .

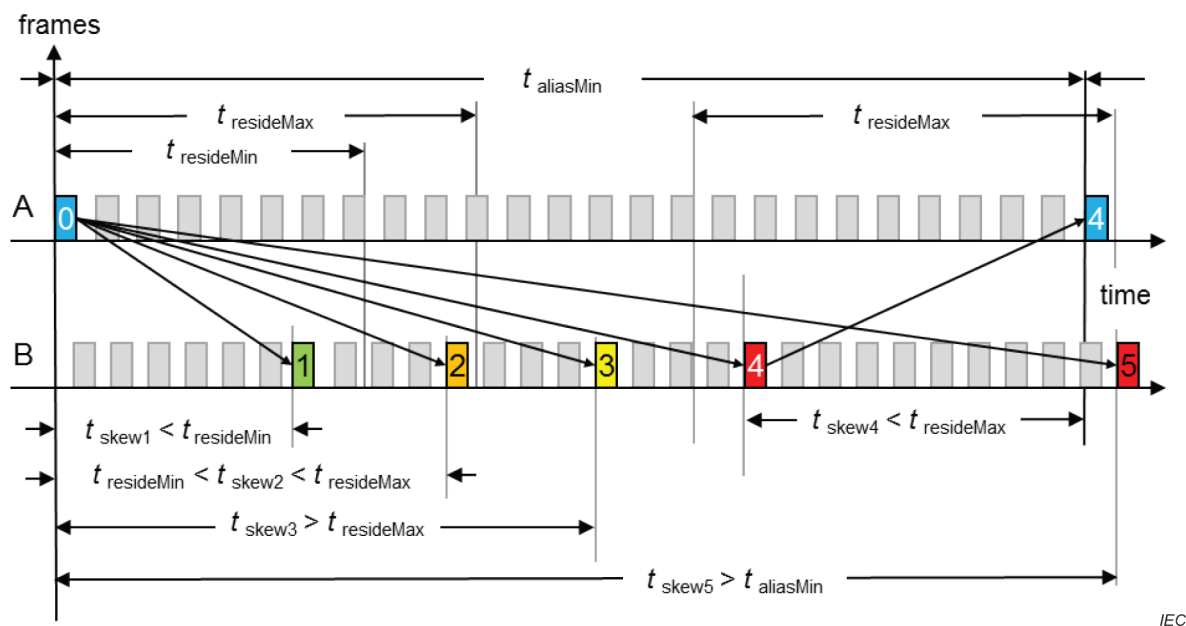


**Figure 9 – Duplicate Discard algorithm boundaries**

Considering a device, entries in the duplicates list remain recorded during a time that varies between  $t_{\text{resideMin}}$  and  $t_{\text{resideMax}}$ . These values depend on the implementation and are adequate for a number of applications, they can depend on the traffic if the list size is bound. It is recommended to make  $t_{\text{resideMin}}$  and  $t_{\text{resideMax}}$  adjustable depending on the data rate.

The following cases of Figure 9 are considered in Table 1:

**Table 1 – Duplicate discard cases**

| Case   | Condition                                                        | Description                                                                                                                                                                                                                                             |
|--------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Case 1 | $t_{\text{skew1}} < t_{\text{resideMin}}$                        | The duplicate is discarded.<br>This situation is desirable.                                                                                                                                                                                             |
| Case 2 | $t_{\text{resideMin}} < t_{\text{skew2}} < t_{\text{resideMax}}$ | The duplicate is sometimes not discarded if the entry was purged.<br>This situation is tolerable if infrequent.                                                                                                                                         |
| Case 3 | $t_{\text{skew3}} > t_{\text{resideMax}}$                        | The duplicate is never discarded, the duplicate is treated as a new frame and creates a new entry in the duplicates list.<br>This situation does not occur if the network was properly dimensioned with $(t_{\text{skewMax}} < t_{\text{resideMax}})$ . |
| Case 4 | $t_{\text{skew4}} < t_{\text{resideMax}}$                        | The duplicate is never discarded, but a legitimate frame is discarded since the entry created by LAN_B conflicts with the alias on LAN_A.<br>This situation does not occur if the nodes are properly designed.                                          |
| Case 5 | $t_{\text{skew5}} > t_{\text{aliasMin}}$                         | The duplicate is discarded for the wrong reason, but this does not impair operation.<br>This situation does not occur if the nodes are properly designed.                                                                                               |

The conditions for correct operation are as follows:

- For the network engineer:  
 $t_{\text{skewMax}} < (t_{\text{aliasMin}})/2$  (no aliases)
- For the device engineer:  
 $t_{\text{resideMin}} > t_{\text{skewMax}}$  (recognizes all duplicates), and  
 $t_{\text{resideMax}} < (t_{\text{aliasMin}})/2$  (prevents unwanted discards)

In practice,  $t_{\text{resideMin}}$  is often given by the number of frames kept in the buffer and therefore depends on the traffic, while  $t_{\text{resideMax}}$  is enforced by a timer. This value is adjustable through the management setting `IreDupListResideMaxTime` (see Clause 7).

A node that reboots could generate aliases at a lower interval than  $t_{\text{aliasMin}}$  since the sequence number at restart is arbitrary. To allow all possible destination nodes time to flush all entries of this node from the duplicates list, a node may not reboot faster than `NodeRebootInterval` (see Table 8). `NodeRebootInterval` holds for all nodes in the network and therefore it is independent from the link speed.

Therefore, all nodes flush their entries before `NodeRebootInterval`. The maximum residence time of an entry regardless of the speed (and of the value of  $t_{\text{resideMax}}$ ) is `EntryForgetTime`.

The default value of `EntryForgetTime` in Table 8 (400 ms) allows in principle a  $t_{\text{skewMax}}$  of 800 ms, assuming a  $t_{\text{aliasMin}}$  of 1 600 ms. This fits all envisioned applications.

To comply with the above equations,  $t_{\text{resideMax}}$  is usually much smaller than `EntryForgetTime`, especially in 1 Gbit/s networks.

#### 4.1.10.4 Frame size restriction

Appending the RCT could generate oversize frames that exceed the `maxFrameSizeLimit` foreseen by ISO/IEC/IEEE 8802-3:2021, 4.2.7.1 (1 522 octets).

Hence, it is expected that every network component in the LANs supports oversize frames up to `maxFrameSizeLimit` foreseen by ISO/IEC/IEEE 8802-3:2021 plus 6 octets of RCT (1 528 octets). ISO/IEC/IEEE 8802-3:2021, 4.2.9 recommends supporting envelope frames of up to 2 000 octets.

NOTE Many bridges are dimensioned for double-VLAN-tagged (Q-in-Q) frames that have a maximum size of 1 526 octets. Most Ethernet controllers are certified up to 1 528 octets. Most bridges forward correctly frames of up to 1 535 octets.

#### 4.1.11 Network supervision

The health status of each LAN and its attached devices (nodes and bridges) is monitored, otherwise redundancy helps little.

The receiver checks that frames are correctly received over both channels. It maintains error counters that network management can read.

To this effect, senders and receivers can maintain tables that record the last time a frame was received from another node, the time a multicast or broadcast frame was sent and other protocol information.

Supervision relies on each DANP sending periodically a `PRP_Supervision` frame that allows checking the integrity of the network and the presence of the nodes. At the same time, these frames allow checking which devices are DANP, the MAC addresses they use and which operating mode they support: Duplicate Accept or Duplicate Discard.

#### 4.1.12 Redundancy management interface

Redundant devices and links are useless without network management supervising redundancy and calling for maintenance actions.

The LRE presents a network management interface that allows to track the health of each LAN, and especially to detect failures early when the error rate increases. To this effect, the LRE keeps for each port a counter of received messages and of messages received with an error.

The LAN statuses appear as SNMPv1 or SNMPv2/v3 objects, allowing the same tools to manage both nodes and bridges.

## **4.2 PRP protocol specifications**

### **4.2.1 Installation, configuration and repair guidelines**

#### **4.2.1.1 General**

The guidelines in 4.2.1 apply to installations. They do not apply to conformance testing of the devices.

#### **4.2.1.2 LANs layout**

The network shall consist of two LANs that have similar properties, i.e., each one is able to carry the traffic that would exist in the absence of redundancy.

DANP shall be attached to both LANs, by port A to LAN\_A and by port B to LAN\_B.

SANs that need to communicate with one another shall be attached to the same LAN or to both LANs through a RedBox.

#### **4.2.1.3 Labelling cables**

The two LANs shall use cables distinctly and permanently identified as A and B.

If colours are used to identify the cables, cables in LAN\_A should be orange and cables in LAN\_B should be light blue.

NOTE 1 The intention is that persons with colour disability can distinguish them.

NOTE 2 This change from the previous edition has no implication on the devices.

#### **4.2.1.4 Labelling bridges**

Bridges in the two LANs should have a distinct label or colour for each A or B.

#### **4.2.1.5 Independent operation**

The layout of both LANs shall fulfil the assumption of fail-independence.

#### **4.2.1.6 Configuration**

All DANPs shall be configured with the same LifeCheckInterval (see 4.4).

### **4.2.2 Unicast MAC addresses**

Both port A and port B of a DANP shall be configured with the same MAC address.

This MAC address of a DANP shall be unique in the network.

SANs connected to one LAN only shall not have the same MAC address as another node within the whole network (LAN\_A plus LAN\_B).

### **4.2.3 Multicast MAC addresses**

All nodes in the network shall be configured to operate with the same multicast address for the purpose of network supervision (see 4.3).

The network shall be engineered such that PRP\_Supervision frames can be received by all nodes that communicate with the sender.

NOTE Network engineering ensures this by proper VLAN and multicast filtering set-up.

#### **4.2.4 IP addresses**

The IP address(es) of any node or bridge shall be unique within the whole network (LAN\_A plus LAN\_B).

NOTE 1 Uniqueness applies to all IP addresses of a device.

A DANP shall have the same IP address(es) when seen from either LAN\_A or LAN\_B.

Bridges on LAN\_A and LAN\_B are considered as SANs and shall have different IP addresses for the purpose of network management, even if they occupy the same location.

NOTE 2 A possible method is to distinguish IP addresses by one bit, e.g. allocate even IP addresses to LAN\_A devices and odd IP addresses to LAN\_B devices.

#### **4.2.5 Node specifications**

##### **4.2.5.1 Node types**

Doubly attached nodes compliant with the Parallel Redundancy Protocol (DANP) shall have two ports (port A and port B) that have the same abilities, and in particular the ports could be used alternatively if only one LAN were connected, port A being connected to LAN\_A and port B to LAN\_B.

Singly Attached Nodes (SAN) have only one port for the purpose of this protocol, no special requirements apply to them.

##### **4.2.5.2 Labelling connectors**

Labelling of connectors applies to a DANP using two LANs of similar nature.

The connectors for each LAN shall be labelled distinctly and permanently as A and B.

When connectors are ordered vertically, the port to LAN\_A should be the upper connector and the port to LAN\_B should be the lower connector of the PRP port pair, in the normal position of the device.

When connectors are ordered horizontally, the port to LAN\_A should be the left connector and the port to LAN\_B should be the right connector of the PRP port pair, as seen from the side where the cables or fibres are plugged.

The redundant connectors shall be independently removable and insertable.

#### **4.2.6 Duplicate Accept mode (testing only)**

##### **4.2.6.1 Sending**

A sender in the Duplicate Accept mode shall send the frame it receives from its upper layers unchanged over both its ports so that the two frames appear on the respective LANs.

##### **4.2.6.2 Receiving**

A receiver in the Duplicate Accept mode shall forward frames received from either port to its upper layers.

The LRE shall send the frames to the application through the interlink in the same order as it received them.

NOTE Duplicate Accept is a test setting not used for operation.

#### 4.2.7 Duplicate Discard mode

##### 4.2.7.1 Monitoring data set

A node shall maintain a monitoring data set consisting of the elements of Table 2.

**Table 2 – Monitoring data set**

| Object name                               | Character                             | Description                                                                                                                                                                                                                                                |
|-------------------------------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SendSeq                                   | optional,<br>mandatory if<br>MIB_SNMP | A 16-bit sequence counter used by this node for sending.<br>This counter is reflected in IreCntTxA, IreCntTxC and IreCntTxC (RedBox) of the LRE management interface.                                                                                      |
| CntErrorsA<br>and<br>CntErrorsB           | optional,<br>mandatory if<br>MIB_SNMP | For each port, a 32-bit counter indicating the number of frames with wrong FCS or wrong size received.<br>This counter is reflected in IreCntErrorsA, IreCntErrorsA and IreCntErrorsC (RedBox) of the LRE management interface                             |
| CntReceivedA<br>and<br>CntReceivedB       | optional,<br>mandatory if<br>MIB_SNMP | For each port, a 32-bit counter indicating the number of frames received.<br>This counter is reflected in IreCntRxA, IreCntRxB and IreCntRxC (RedBox) of the LRE management interface.                                                                     |
| CntErrWrongLanA<br>and<br>CntErrWrongLanB | optional,<br>mandatory if<br>MIB_SNMP | For each port, a 32-bit counter indicating the number of frames with a LanId that does not correspond to the port.<br>This counter is reflected in IreCntErrWrongLanA, IreCntErrWrongLanB and IreCntErrWrongLanC (RedBox) of the LRE management interface. |
| LinkStatusA and<br>LinkStatusB            | optional,<br>mandatory if<br>MIB_SNMP | For each port, the status of the communication link.<br>This object is reflected in IreLinkStatusA and IreLinkStatusB of the LRE management interface                                                                                                      |
| NodesTable                                | optional                              | A table of all other nodes that this node identified.                                                                                                                                                                                                      |

##### 4.2.7.2 NodesTable

A node may maintain a NodesTable for the purpose of network supervision. The NodesTable allows to identify another node as a SAN (on one LAN only) or as a DANP (on LAN\_A or LAN\_B).

If a NodesTable is used, it shall consist of the elements given in Table 3 for each entry.

**Table 3 – NodesTable attributes**

| Argument        | Definition                                                                                | Data Type    |
|-----------------|-------------------------------------------------------------------------------------------|--------------|
| MacAddress      | MAC address of the remote source node (6 octets)                                          | OctetString6 |
| CntReceivedA    | Number of frames received from that node over LAN_A                                       | Unsigned32   |
| CntReceivedB    | Number of frames received from that node over LAN_B                                       | Unsigned32   |
| CntErrWrongLanA | Number of frames that were received from that node with the wrong LAN identifier on LAN_A | Unsigned32   |
| CntErrWrongLanB | Number of frames that were received from that node with the wrong LAN identifier on LAN_B | Unsigned32   |
| TimeLastSeenA   | Time at which the latest frame was received from that node over LAN_A                     | TimeTicks    |
| TimeLastSeenB   | Time at which the latest frame was received from that node over LAN_B                     | TimeTicks    |
| SanA            | True if the remote node is most probably a SAN accessible over port A                     | Boolean      |
| SanB            | True if the remote node is most probably a SAN accessible over port B                     | Boolean      |

NOTE 1 The key attribute of the NodesTable is MacAddress as received in the PRP\_Supervision frame sent by a DANP or in any frame received from a SAN.

NOTE 2 TimeTicks is a local time scale, not a global time.

A node shall clear a NodesTable entry of a given other node when the time elapsed since reception of a frame from that node over both TimeLastSeenA and TimeLastSeenB exceeds NodeForgetTime (see 4.4).

**[AC1]** Even if the NodesTable is populated by observing normal traffic, it also needs to be populated by supervision frames sent at regular intervals to detect quiet nodes. Since SANs do not send supervision frames, some regular traffic from these devices is assumed. **[AC1]**

#### 4.2.7.3 Redundancy Control Trailer (RCT)

The Redundancy Control Trailer (RCT) appended to DANP frames shall consist of six octets, structured in the following way (in the order of transmission):

- a 16-bit sequence number (SeqNr) transmitted with the most significant 8 bits in the first octet, which reflects the counter SendSeq (see 4.2.7.1);
- a 4-bit LAN identifier (LanId) transmitted as the most significant 4 bits of the third octet, which carries the sequence “1010” for LAN\_A and the sequence “1011” for LAN\_B, respectively;
- a 12 bit LSDU size (LSDUsize) whose most significant 4 bits are transmitted in the least significant 4 bits of the third octet and the least significant 8 bits in the fourth octet, that indicates the size in octets of the LSDU starting from the end of the Length/Type (LT) field as defined in ISO/IEC/IEEE 8802-3:2021, 3.2.6 and IEEE 802.1Q-2018, Figure 6-4 (octet offset 12-13 without LAN header or 16-17 with VLAN header) to the RCT, excluding the LT and including possible padding and the RCT itself;
- a 16-bit PRPsuffix, set to 0x88FB.

NOTE 1 Padding inserted before the RCT is included in the LSDU size.

NOTE 2 The intention is that the LSDUsize is the same in PRP and HSR.

#### 4.2.7.4 Sending (Duplicate Discard mode)

##### 4.2.7.4.1 Sending

When sending a frame coming from its upper layers, a node shall:

|                                                                                                                                            |                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| If the frame is a multicast frame or if the node has no NodesTable or if the destination node is not registered as a SAN in the NodesTable |                                                                                                                                                                                                                                                                               |
|                                                                                                                                            | If the frame carries a VLAN tag and has a size smaller than 64 octets (without FCS)                                                                                                                                                                                           |
|                                                                                                                                            | pad the frame to 64 octets as specified in ISO/IEC/IEEE 8802-3:2021 4.2.3.3                                                                                                                                                                                                   |
|                                                                                                                                            | If the frame does not carry a VLAN tag and has a size smaller than 60 octets (without FCS)                                                                                                                                                                                    |
|                                                                                                                                            | pad the frame to 60 octets as specified in ISO/IEC/IEEE 8802-3:2021 3.2.8                                                                                                                                                                                                     |
|                                                                                                                                            | increment SendSeq (see 4.2.7.1), wrapping over through 0;<br>append the 6-octet RCT with a LanId "1010" for port A and LanId "1011" for port B;<br>append the 4-octet FCS;<br>send the frame with LanId "1010" through port A and the frame with LanId "1011" through port B; |
| Else (the frame is unicast and the destination is not registered as a DANH)                                                                |                                                                                                                                                                                                                                                                               |
|                                                                                                                                            | send the frame to the port(s) where the SAN is registered;                                                                                                                                                                                                                    |

NOTE 1 Sending a unicast frame to a SAN over one LAN only and without an RCT reduces traffic and is justified in rare cases when a SAN cannot receive oversize frames. Multicast frames always carry an RCT.

NOTE 2 Simple nodes have no NodesTable and do not register remote nodes as DANP or SAN, they append the RCT and send over both ports.

NOTE 3 The total padding to 70 octets (no VLAN tag) considers that the LRE or a RedBox could remove the 6-octet RC. Padding to 74 octets (with VLAN tag) considers that in addition, an edge port in a bridge could remove the 4-octet priority tag. This way, the frame given to the destination respects the minimum frame size of 64 octets and the RCT is located just before the FCS.

##### 4.2.7.4.2 Timing

The time skew between the sending of both frames of a pair should be kept at a minimum to reduce asymmetry of the transmission delays.

In particular, frames waiting for sending should be dropped from the sending queue if the corresponding port is not operational.

#### 4.2.7.5 Receiver (Duplicate Discard mode)

##### 4.2.7.5.1 Receiving

On reception of a frame over either port, the receiver shall:

|                                                                                                      |                                                                                           |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| If the frame is malformed (wrong FCS or wrong size),                                                 |                                                                                           |
|                                                                                                      | increment the error counter of the respective port CntErrorsA or CntErrorsB (see 4.2.7.1) |
|                                                                                                      | ignore the frame;                                                                         |
| Else if the destination MAC address belongs to the reserved addresses in IEEE 802.1Q-2018 Table 8-1, |                                                                                           |
|                                                                                                      | treat the frame at the link layer;                                                        |
| Else if the frame is a duplicate (see 4.2.7.5.2 and 4.2.7.5.3),                                      |                                                                                           |
|                                                                                                      | discard the frame;                                                                        |
| Else                                                                                                 |                                                                                           |
|                                                                                                      | forward the frame to the upper layers.                                                    |

The LRE shall, after duplicate discard, send the frames to the application to the interlink in the same order as it received them.

NOTE 1 Frames with a destination MAC address compliant with IEEE 802.1Q-2018, Table 8-1, Table 8-2 and Table 8-3 are treated at the link layer and are not expected to carry an RCT, even if sent by a DANP.

NOTE 2 Correct Ethernet frames having wrong PRP fields are treated as SAN frames and passed to the application.

##### 4.2.7.5.2 Identification of frames associated with the Duplicate Discard mode

A receiver shall identify a duplicate candidate as a valid frame:

- whose last 16 bits before the checksum match the 16-bit PRPsuffix,
- whose 12 bits before the PRPsuffix match the physical size of the LSDU (excluding the Length/Type, but including the RCT) and
- whose LanId matches the identity of the receiving port, “1010” (port A) or “1011” (port B).

##### 4.2.7.5.3 Duplicate Discard method

The Duplicate Discard method shall not discard a frame sent as single or both frames of a pair; exceptionally, both frames of a pair may be passed to the higher protocol layers.

The Duplicate Discard method shall forget an entry after EntryForgetTime (see Table 8).

##### 4.2.7.5.4 Transparent reception

A receiver configured for TransparentReception (default) shall not remove the RCT before transferring the frame to its upper layers.

A receiver not configured for TransparentReception shall remove the RCT on frames where it has identified the presence of the RCT.

#### 4.2.7.5.5 Receiving and NodesTable

If the node supports a NodesTable, it shall, at reception of a frame:

|                                                                                                                                                  |                                            |                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [AC1] If this frame is neither a PRP_Supervision frame nor an HSR_Supervision frame and its source MAC address is not yet in the NodesTable,     |                                            |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  |                                            | create an entry in the NodesTable for that source MAC address assuming it is a SanA or a SanB, depending which LAN the frame arrives on; (see Note 1)                                                                                                         |
| Else (i.e. if this frame is a PRP_Supervision frame or an HSR_Supervision frame)                                                                 |                                            |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  | If its source is not yet in the NodesTable |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  |                                            | create an entry in the NodesTable for that source, using the MacAddress of that source as indicated in the TLV1 of the supervision frame and setting DANP Duplicate Accept or Duplicate Discard according to the PRP_Supervision frame contents; (see Note 2) |
|                                                                                                                                                  | Else                                       |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  |                                            | update the source status to DANP Duplicate Accept or Duplicate Discard;                                                                                                                                                                                       |
| record the local time at which the frame was received in the TimeLastSeenA, respectively TimeLastSeenB fields of the NodesTable for that source; |                                            |                                                                                                                                                                                                                                                               |
| increment by one (wrapping through 0) the counters CntReceivedA and CntReceivedB of the NodesTable for that source.                              |                                            |                                                                                                                                                                                                                                                               |
| If it receives the frame from LAN_B from a node registered as SanA, or over LAN_A from a node registered as SanB,                                |                                            |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  |                                            | set SanA = SanB = True for that source; (See Note 3)                                                                                                                                                                                                          |
| If the LanId does not match the identity of the port,                                                                                            |                                            |                                                                                                                                                                                                                                                               |
|                                                                                                                                                  |                                            | increment the CntErrWrongLanA and CntErrWrongLanB counter of the source device. [AC1]                                                                                                                                                                         |

A node may identify another node positively as a DANP if it receives from that node a frame with a correct RCT on one LAN and the duplicate of that frame over the other LAN within tresideMax.

NOTE 1 Reception of [AC1] a well-formed RCT on one port only [AC1] is not a sufficient criterion to declare its source as DANP, since some protocols reply with the same frame as received.

NOTE 2 [AC1] The NodesTable is populated by observing the supervision frames, which identify positively a node as a DANP, even if a supervision frame is received on one LAN only. [AC1]

NOTE 3 This rule allows moving a SAN between LAN\_A and LAN\_B. If this happens, the DANP will send on both LANs and after NodeForgetTime it will send only on the LAN where the SAN now resides. It also serves to obtain the operating mode for a SAN if it was first registered at sending and not at receiving, since a DANP starts by sending on both LANs.

### 4.3 PRP\_Supervision frame

#### 4.3.1 PRP\_Supervision frame format

Each DANP shall multicast a PRP\_Supervision frame over both its ports with the format specified in Table 4 (no VLAN tag) and Table 5 (with VLAN tag) respectively, every LifeCheckInterval (see 4.4).

**Table 4 – PRP\_Supervision frame with no VLAN tag**

|    | 0                                                      | 1 | 2 | 3 | 4               | 5   | 6   | 7   | 8               | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|----|--------------------------------------------------------|---|---|---|-----------------|-----|-----|-----|-----------------|---|----|----|----|----|----|----|
| 0  |                                                        |   |   |   |                 | msb | U/L | I/G |                 |   |    |    |    |    |    |    |
| 2  | PRP_DestinationAddress = multicast (01-15-4E-00-01-XX) |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 4  |                                                        |   |   |   |                 |     |     |     | lsb             |   |    |    |    |    |    |    |
| 6  |                                                        |   |   |   |                 | msb | U/L | 0   |                 |   |    |    |    |    |    |    |
| 8  | SourceAddress (MAC address of the node)                |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 10 |                                                        |   |   |   |                 |     |     |     | lsb             |   |    |    |    |    |    |    |
| 12 | SupEtherType = 0x88FB                                  |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 14 | SupPath                                                |   |   |   | SupVersion < 64 |     |     |     |                 |   |    |    |    |    |    |    |
| 16 | SupSequenceNumber                                      |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 18 | TLV1.Type = 20 or 21                                   |   |   |   |                 |     |     |     | TLV1.Length = 6 |   |    |    |    |    |    |    |
| 20 |                                                        |   |   |   |                 | msb | U/L | 0   |                 |   |    |    |    |    |    |    |
| 22 | MacAddress (MAC address of the DANP)                   |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 24 |                                                        |   |   |   |                 |     |     |     | lsb             |   |    |    |    |    |    |    |
| 26 | TLV2.Type = 30                                         |   |   |   |                 |     |     |     | TLV2.Length = 6 |   |    |    |    |    |    |    |
| 28 |                                                        |   |   |   |                 | msb | U/L | 0   |                 |   |    |    |    |    |    |    |
| 30 | RedBoxMacAddress                                       |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 32 |                                                        |   |   |   |                 |     |     |     | lsb             |   |    |    |    |    |    |    |
| 34 | TLV0.Type = 0                                          |   |   |   |                 |     |     |     | TLV0.Length = 0 |   |    |    |    |    |    |    |
| 36 |                                                        |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
|    | Padding to 70 octets (no VLAN)                         |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
|    |                                                        |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 60 | SeqNr                                                  |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 62 | LanId (0x1010 or 0x1011)                               |   |   |   | LSDUsize = 52   |     |     |     |                 |   |    |    |    |    |    |    |
| 64 | PRPsuffix = 0x88FB                                     |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 66 | FCS                                                    |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 68 |                                                        |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |
| 70 |                                                        |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |

**Table 5 – PRP\_Supervision frame with (optional) VLAN tag**

|    | 0 | 1 | 2 | 3 | 4 | 5   | 6   | 7   | 8 | 9   | 10 | 11 | 12 | 13 | 14 | 15 |
|----|---|---|---|---|---|-----|-----|-----|---|-----|----|----|----|----|----|----|
| 0  |   |   |   |   |   | msb | U/L | I/G |   |     |    |    |    |    |    |    |
| 2  |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 4  |   |   |   |   |   |     |     |     |   | lsb |    |    |    |    |    |    |
| 6  |   |   |   |   |   | msb | U/L | 0   |   |     |    |    |    |    |    |    |
| 8  |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 10 |   |   |   |   |   |     |     |     |   | lsb |    |    |    |    |    |    |
| 12 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 14 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 16 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 18 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 20 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 22 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 24 |   |   |   |   |   | msb | U/L | 0   |   |     |    |    |    |    |    |    |
| 26 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 28 |   |   |   |   |   |     |     |     |   | lsb |    |    |    |    |    |    |
| 30 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 32 |   |   |   |   |   | msb | U/L | 0   |   |     |    |    |    |    |    |    |
| 34 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 36 |   |   |   |   |   |     |     |     |   | lsb |    |    |    |    |    |    |
| 38 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 40 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 42 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 44 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 46 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 48 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 50 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 52 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 54 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 56 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 58 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 60 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 62 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 64 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 66 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 68 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 70 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 72 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |
| 74 |   |   |   |   |   |     |     |     |   |     |    |    |    |    |    |    |

NOTE 1 Octets with offset 14 to 17 are inserted only if a VLAN tag compliant with IEEE 802.1Q is used.

NOTE 2 The frame has a size of 70 octets (no VLAN tag) or 74 octets (with VLAN tag) to avoid padding if an entity removes the VLAN tag or the RCT.

NOTE 3 The SeqNr and the LSDUsize are reused when the frame is passed to an HSR network. The SupEtherType is the same as the PRP suffix. It is also used for HSR.

NOTE 4 MAC addresses are assumed to have a length of 6 octets.

#### 4.3.2 PRP\_Supervision frame contents

The contents of a PRP\_Supervision frame are defined in Table 6.

**Table 6 – PRP\_Supervision frame contents**

| Field name             | Description                                                                                                                                                                                                                                                                                                          |
|------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PRP_DestinationAddress | Multicast address 01-15-4E-00-01-XX reserved for the PRP protocol. By default XX is "00", but if conflicts arise, XX can be configured to take any value between 0x00 and 0xFF.                                                                                                                                      |
| SourceAddress          | MAC address of the node                                                                                                                                                                                                                                                                                              |
| SupEtherType           | Ethertype 0x88FB reserved for the PRP protocol.                                                                                                                                                                                                                                                                      |
| SupPath                | Reserved, set to 0                                                                                                                                                                                                                                                                                                   |
| SupVersion             | Protocol version, set to "1" until further notice.<br><br>Implementation of version X of the protocol shall interpret version >X frames as if they were version X frames, ignoring any parameters and/or flags added by version >X, and interpret version <=X frames exactly as specified for the version concerned. |
| SupSequenceNumber      | Sequence number incremented by 1 for each supervision frame sent.                                                                                                                                                                                                                                                    |
| TLV1.Type              | Operation mode, a value of 20 indicates that the node supports the Duplicate Discard or a value of 21 indicates that it implements Duplicate Accept. Other values are reserved.                                                                                                                                      |
| TLV1.Length            | Length of the following MAC address in octets.                                                                                                                                                                                                                                                                       |
| MacAddress             | MAC addresses used by both ports of the node.                                                                                                                                                                                                                                                                        |
| TLV2.Type              | Not present if the node is not a RedBox                                                                                                                                                                                                                                                                              |
| TLV2.Length            | Not present if the node is not a RedBox                                                                                                                                                                                                                                                                              |
| RedBoxMacAddress       | Not present if the node is not a RedBox                                                                                                                                                                                                                                                                              |
| TLV0.Type              | Closing TLV, set to 0                                                                                                                                                                                                                                                                                                |
| TLV0.Length            | Closing TLV, set to 0                                                                                                                                                                                                                                                                                                |

#### 4.3.3 PRP\_Supervision frame for RedBox

A RedBox, i.e., a node acting as a proxy for one or several SANs (called VDAN or virtual DAN) shall append to the TLV1 field a further TLV2 field with the content given in Table 7:

**Table 7 – PRP\_Supervision TLV for Redbox**

| Field name       | Description                                                                                                                                                                |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TLV1.Type        | Operation mode with a value of 20 to indicate that the node supports the Duplicate Discard mode, since this is the only mode a RedBox supports. Other values are reserved. |
| TLV1.Length      | Length of the following MAC address in octets.                                                                                                                             |
| MacAddress       | MAC address of the VDAN                                                                                                                                                    |
| TLV2.Type        | RedBox identifier with a value of 30 to indicate that the node is a RedBox                                                                                                 |
| TLV2.Length      | Length of the following MAC address in octets.                                                                                                                             |
| RedBoxMacAddress | MAC address of the RedBox that acts as proxy for the other device (VDAN)                                                                                                   |
| TLV0.Type        | Closing TLV, set to 0                                                                                                                                                      |
| TLV0.Length      | Closing TLV, set to 0                                                                                                                                                      |

#### 4.3.4 Bridging node (deprecated)

If the "bridging node" setting is enabled, the node shall act as a bridging node for its two ports, in accordance with an unspecified protocol, i.e. HSR, RSTP or MRP, but shall not append an RCT to the frames it sends.

NOTE 1 The bridging node setting supports attachment of a DANP to two bridges of the same LAN to implement a partial redundancy topology. There is no requirement that normal frames be bridged in case of a double failure, but implementers are free to include this feature.

NOTE 2 The presence of nodes in bridging mode is potentially dangerous for a PRP network since it breaches the assumption of fail-independence of the two LANs.

#### 4.4 Constants

The constant parameters are shown in Table 8.

The default values should be used whenever possible; other values may be set under the user's responsibility.

These parameters are not accessible over layer management, since their modification requires good knowledge of the network and reasons need to exist in order to use values other than the defaults. Setting these parameters to different values in different DANPs causes unpredictable behaviour.

**Table 8 – PRP constants**

| Constant           | Description                                                                                                    | Default value |
|--------------------|----------------------------------------------------------------------------------------------------------------|---------------|
| LifeCheckInterval  | Typical interval between two successive PRP_Supervision frames sent by the same node.                          | 2 000 ms      |
| NodeForgetTime     | Time after which a node entry is cleared from the NodesTable after frames from this node cease to be received. | 60 000 ms     |
| EntryForgetTime    | Maximum time an entry may reside in the duplicate table, independently from link speed.                        | 400 ms        |
| NodeRebootInterval | Minimum time during which a node remains silent after reboot, independently from link speed.                   | 500 ms        |

#### 4.5 PRP layer management entity (LME)

Objects in the LRE, e.g., error counters, can be accessed from an application running on the same node using direct calls or from an application on another node using a management protocol such as SNMP or a specific protocol such as IEC 61850.

All LRE objects are described in Clause 7 as a Management Information Base (MIB) conformant to SNMP (RFC 2578, RFC 3418), which is common for PRP and HSR.

### 5 High-availability Seamless Redundancy (HSR)

#### 5.1 HSR objectives

Clause 5 describes the application of the PRP principles of Clause 4 to implement a High-availability Seamless Redundancy (HSR), retaining the PRP property of zero recovery time, applicable to any topology, in particular rings and rings of rings.

NOTE With respect to PRP, HSR allows roughly halving the network infrastructure. With respect to rings based on RSTP, the network traffic is slightly higher.

Nodes within the ring are restricted to be HSR-capable bridging nodes, thus avoiding the use of dedicated bridges. Singly Attached Nodes (SANs) such as laptops or printers cannot be attached directly to the ring, but need attachment through a Redundancy Box (RedBox).

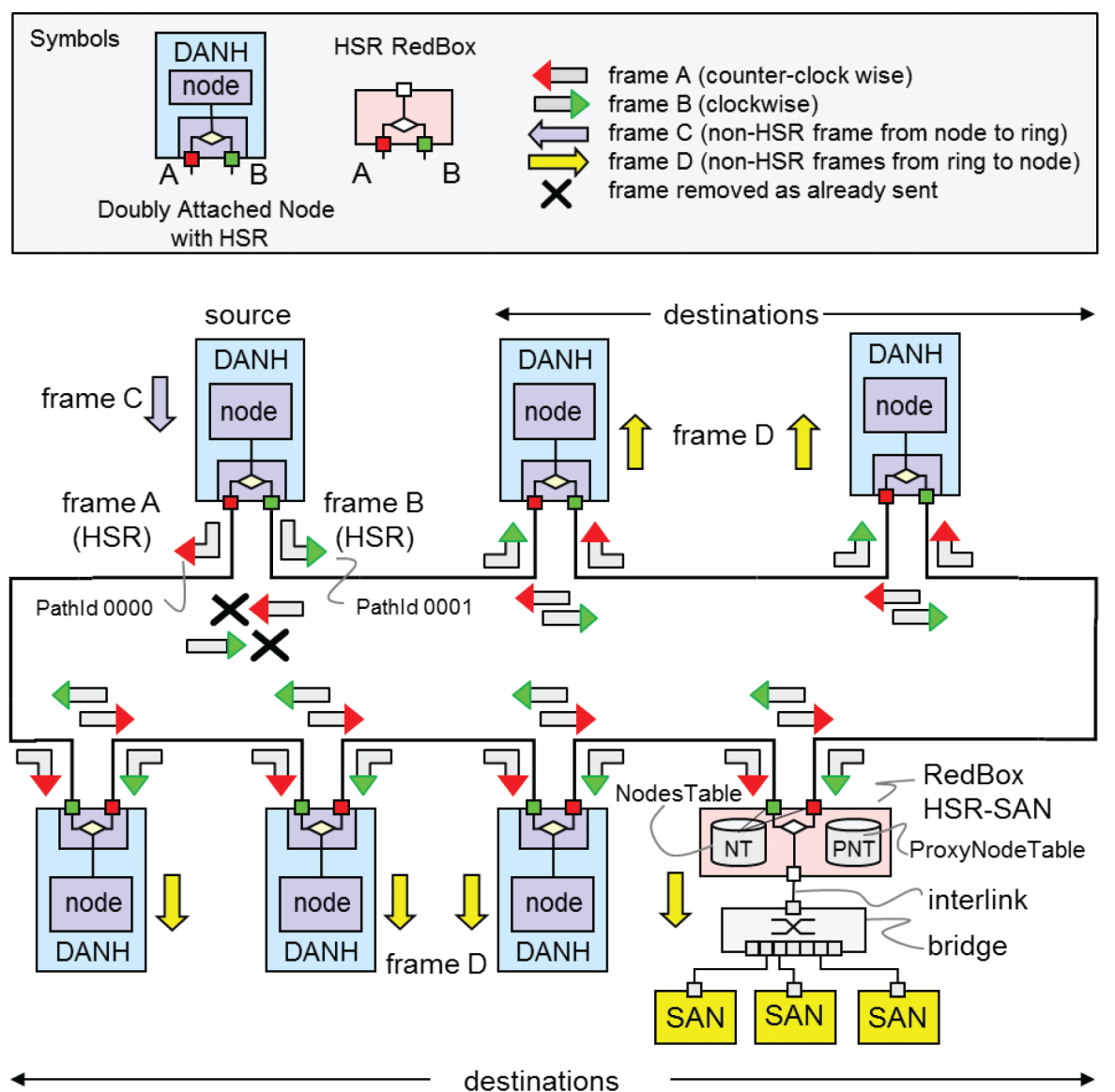
## 5.2 HSR principle of operation

### 5.2.1 Basic operation with a ring topology

#### 5.2.1.1 HSR handling of multicast frames

As in PRP, a node has two ports operated in parallel; it is a DANH (Doubly Attached Node with HSR protocol).

A simple HSR network consists of doubly attached bridging nodes, each having two ring ports, interconnected by full-duplex links, as shown in the example of Figure 10 (multicast frame) and Figure 11 (unicast frame) for a ring topology.



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Figure 10 – HSR example of ring traffic for multicast frames

A source DANH sends a frame passed from its upper layers (frame C), prefixes it by an HSR tag containing a sequence number and a PathId and sends the frame over each port as frame A and frame B. The doublet {source MAC address, sequence number} uniquely identifies copies of the same frame.

An intermediate node in the ring forwards both frames from one port to the other, except if its port already sent the same frame into that same direction. When a frame returns to the source DANH that injected it, this node refrains from forwarding that frame since it detects its own address as a source and thus removes that frame from the ring.

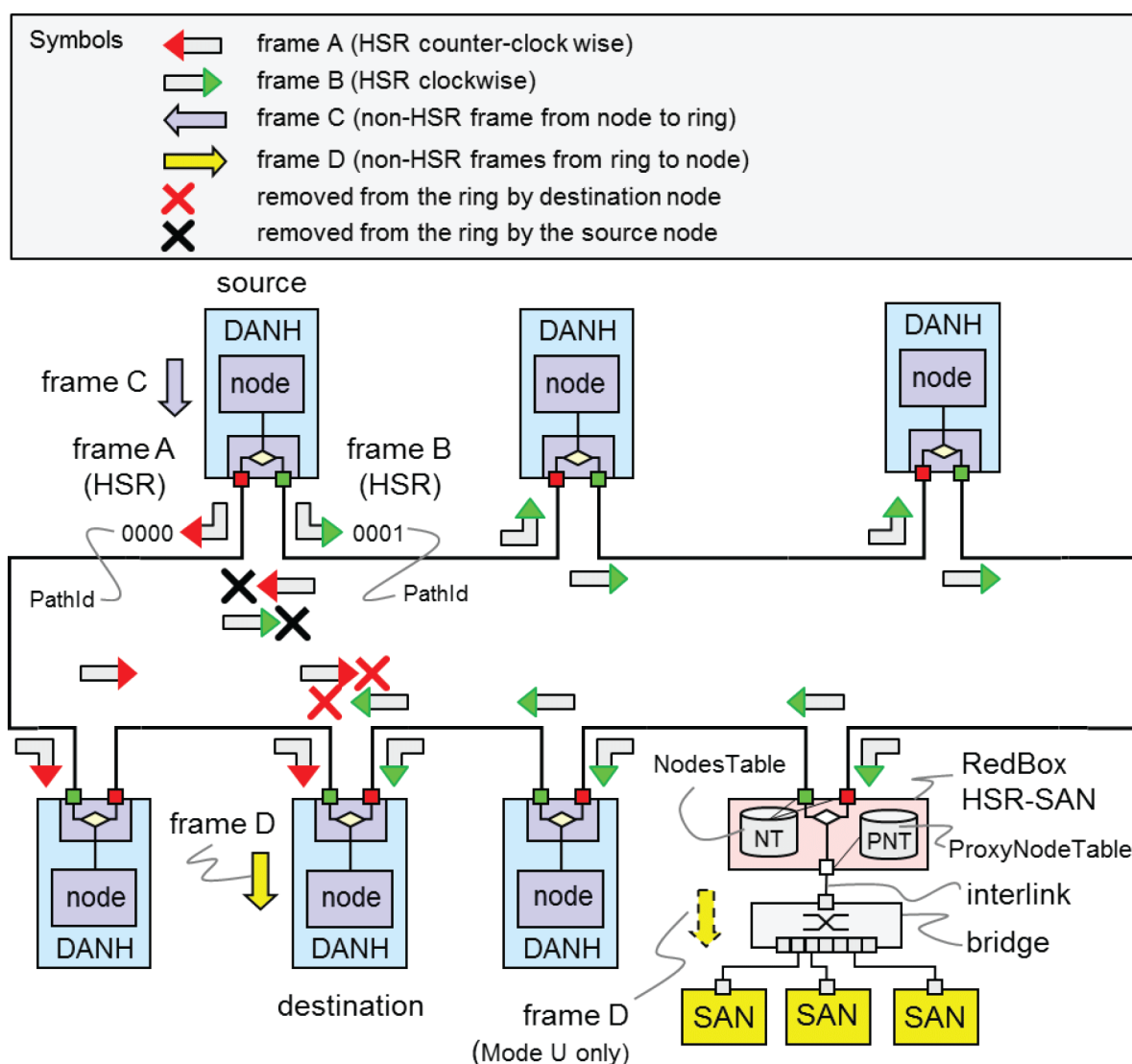
A destination DANH receives, in the fault-free state, two identical frames from each port within a certain interval, it passes the first frame to its upper layers after removing the HSR tag (frame D) and discards the second frame or any duplicate.

NOTE 1 The maximum time skew between two frames of a pair depends on the relative position of the receiving node and of the sending node. Assuming a worst case in which each node in the ring is transmitting at the same time its own frame with the largest size of 1 535 octets (maximum length supported by the LT defined in ISO/IEC/IEEE 8802-3:2021, 3.2.6), each node could introduce 125 µs of delay at 100 Mbit/s. With 50 nodes, the time skew can exceed 6 ms.

NOTE 2 The minimum delay before a frame returns to the node that injected it depends on the ring size. Assuming a worst case in which there is no other traffic and in which each node in the ring operates in cut-through with 4 µs residence time, in a ring of 32 nodes, a frame with the maximum size of 1 536 octets (125 µs at 100 Mbit/s) returns to the injecting node after 124 µs, i.e. before the injecting node finished transmitting it.

### 5.2.1.2 HSR handling of unicast frames

When unicast frames are sent, traffic can be reduced as shown in Figure 11.



IEC

Figure 11 – HSR example of ring traffic for unicast frames

A DANH forwards a frame received from one port to the other, except if this node is the (unique) destination, for example DANH “destination” in Figure 11. This also applies to RedBoxes, if the destination is registered on the single-thread LAN, see 5.2.2.2.

If no node in the ring considers itself as destination, the frame is removed by the source, as is the case for multicast frames

## 5.2.2 HSR connection to other networks

### 5.2.2.1 Direct connection of SAN to the ring

Connecting non-HSR nodes to ring ports, breaking the ring, is allowed to enable configuration. Non-HSR traffic within the open ring is supported in an optional mode.

#### 5.2.2.2 HSR-SAN RedBox for attachment to a single-thread LAN

Singly attached nodes (SAN), for instance maintenance laptops or printers, cannot be inserted directly into the ring since they have only one port and cannot interpret the HSR tag in the frames.

SANs and ring nodes communicate through a HSR-SAN RedBox. The RedBox acts as a proxy for the SANs attached to it. For this purpose, the HSR-SAN RedBox registers all SANs that it detects on its interlink in its ProxyNodeTable and maintains a sequence number for each, as shown in Figure 10 and Figure 11. Additionally, it maintains a list of nodes on the ring in its NodesTable.

When receiving a frame over a ring port, the HSR-SAN RedBox forwards it to the other ring port and to the interlink, after removal of the HSR tag.

When receiving a frame on its interlink, the HSR-SAN RedBox creates an HSR tag with a PathId of 000x and the next sequence number maintained for each source node in the ProxyNodeTable.

The RedBox participates in traffic reduction:

- When receiving a unicast frame on one HSR port, a HSR-SAN RedBox forwards the frame to the other HSR port, except if the destination is a SAN registered on the interlink, in which case it forwards the frame to its interlink after removal of the HSR tag.
- When a RedBox receives a unicast frame from its interlink, it injects it into the ring except if the unicast destination is registered on the interlink.
- When receiving a unicast frame on one HSR port from a device registered on the ring, a RedBox forwards it to interlink except if the destination is registered on the ring.

NOTE This traffic reduction can be disabled when using Mode “U”.

The HSR-SAN RedBox is specified in 5.4.1.

#### 5.2.2.3 HSR-PRP RedBox for ring connection to a PRP network

##### 5.2.2.3.1 Configuration and operation

An HSR may be coupled to a PRP network through a pair of RedBoxes, a RedBox A for LAN\_A and a RedBox B for LAN\_B, as Figure 12 shows.

The HSR-PRP RedBoxes operate similarly to the HSR-SAN RedBoxes described in 5.2.2.2, except that they are configured as RedBox A or RedBox B depending on which PRP LAN they are connected to. They also do not create a sequence number (except for frames that they generate), but reuse the sequence number of the RCT PRP frame for the HSR frames.