

## DIN EN IEC 62439-3



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Vorgesehen als Ersatz für  
DIN EN IEC 62439-3:2018-10**Entwurf**

**Industrielle Kommunikationsnetze –  
Hochverfügbare Automatisierungsnetze –  
Teil 3: Parallelredundanz-Protokoll (PRP) und nahtloser  
Hochverfügbarkeits-Ring (HSR)  
(IEC 65C/998/CDV:2020);  
Englische Fassung prEN IEC 62439-3:2020**

Industrial communication networks –  
High availability automation networks –  
Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless  
Redundancy (HSR)  
(IEC 65C/998/CDV:2020);  
English version prEN IEC 62439-3:2020

Réseaux de communication industriels –  
Réseaux de haute disponibilité pour l'automatisation –  
Partie 3: Protocole de redondance en parallèle (PRP) et redondance transparente de  
haute disponibilité (HSR)  
(IEC 65C/998/CDV:2020);  
Version anglaise prEN IEC 62439-3:2020

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Dieser Norm-Entwurf mit Erscheinungsdatum 2021-03-05 wird der Öffentlichkeit zur Prüfung und  
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Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses  
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Gesamtumfang 210 Seiten

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## Nationales Vorwort

Die Englische Fassung des europäischen Dokuments prEN IEC 62439-3:2020 „Industrielle Kommunikationsnetze – Hochverfügbare Automatisierungsnetze – Teil 3: Parallelredundanz-Protokoll (PRP) und nahtloser Hochverfügbarkeits-Ring (HSR)“ (Entwurf in der Umfrage) ist unverändert in diesen Norm-Entwurf übernommen worden.

Die Internationale Elektrotechnische Kommission (IEC) und das Europäische Komitee für Elektrotechnische Normung (CENELEC) haben vereinbart, dass ein auf IEC-Ebene erarbeiteter Entwurf für eine Internationale Norm zeitgleich (parallel) bei IEC und CENELEC zur Umfrage (CDV-Stadium) und Abstimmung als FDIS (en: Final Draft International Standard) bzw. Schluss-Entwurf für eine Europäische Norm gestellt wird, um eine Beschleunigung und Straffung der Normungsarbeit zu erreichen. Dem entsprechend ist das internationale Dokument IEC 65C/998/CDV:2020 „Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)“ unverändert in den Entwurf prEN IEC 62439-3:2020 übernommen worden.

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Das Präsidium des DIN hat mit Präsidialbeschluss 1/2004 festgelegt, dass DIN-Normen, deren Inhalt sich auf internationale Arbeitsergebnisse der Informationsverarbeitung gründet, unter bestimmten Bedingungen allein in englischer Sprache veröffentlicht werden dürfen. Diese Bedingungen sind für den vorliegenden Normentwurf erfüllt.

Da sich die Benutzer des vorliegenden Normentwurfs der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der IEC 65C/998/CDV veröffentlicht. Zu deren Einleitung und Abschnitt 1, der den Anwendungsbereich festlegt, und deren Abschnitt 3 (außer Unterabschnitte 3.2 und 3.3), der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA des vorliegenden Normentwurfs hinzugefügt. Für die meisten der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Dieser Normentwurf steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

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### Änderungen

Gegenüber DIN EN IEC 62439-3:2018-10 wurden folgende Änderungen vorgenommen:

- a) technische Korrekturen;
- b) Erweiterung der HSR-Spezifikationen (RSTP über HSR);
- c) Anpassung des Precision Time Protocol-Branchenprofils mit IEC/IEEE 61850-9-3;
- d) Berücksichtigung von IEEE 1588-2019 bei PTP über PRP/HSR;
- e) Konformitätsprüfung.

## Nationaler Anhang NA (informativ)

### Auszugsweise Übersetzung

Reihenfolge und Inhalt der folgenden Abschnitte sind identisch mit denen in den jeweiligen Abschnitten der Englischen Fassung.

#### EINLEITUNG

##### 0.1 Allgemeines

IEC 62439-3 gehört zur Serie IEC 62439 "Industrielle Kommunikationsnetze: Hochverfügbare Automatisierungsnetze". Sie wurde gemeinsam mit der IEC TC57 WG10 als Redundanzverfahren für anspruchsvolle Stationsautomatisierungsnetzwerke, die auf Layer-2-Netzwerken arbeiten, nach IEC 61850-8-1 und IEC 61850-9-3 erarbeitet und erweitert, damit auch die Bedürfnisse der Open DeviceNet Vendor Association (ODVA) berücksichtigt werden.

In ihr werden zwei verwandte Redundanzprotokolle näher beschrieben, die im Falle eines Ausfalls eines Netzwerkelements eine nahtlose Umschaltung ohne Wiederherstellungszeit ermöglichen:

- PRP (Parallelredundanz-Protokoll; Parallel Redundancy Protocol), das ein Verknüpfen von Knoten mit zwei separaten Netzwerken ermöglicht, während ein Verknüpfen von Knoten an nur ein Netzwerk erlaubt wird; und
- HSR (High-availability Seamless Redundancy; nahtloser Hochverfügbarkeits-Ring), das Threading von Knoten mit zwei Ports in einem ringförmigen oder von Knoten mit mehreren Ports in einem vermaschten Netzwerk ermöglicht.

Das Prinzip der stoßfreien Redundanz wird bei Uhren angewendet, die nach dem Precision Time Protocol (IEC 61588, Tutorial in Anhang D), das mit redundanten Netzwerken verbunden ist (Anhang A), arbeiten.

Ein PTP-Branchenprofil (PIP) legt die Leistung fest, die erforderlich ist, um eine Zeitgenauigkeit von unter einer Mikrosekunde zu erzielen. Dieses Profil kann auf jedes industrielle Kommunikationsnetzwerk, das auf einem Ethernet basiert, angewendet werden. In Anhang C werden zwei Varianten von PIP spezifiziert:

- L3E2E (Layer 3, End-to-End) für Uhren, die auf Layer-3-Netzwerken mit End-to-End-Pfadverzögerungsmessung, wie EtherNet/IP™, laufen; und
- L2P2P (Layer 2, Peer-to-Peer) für Uhren, die auf Layer 2 mit Peer-to-Peer-Verbindungsverzögerungsmessung (P2P) laufen. L2P2P wurde von IEC TC57 WG10 und der IEEE PSRC als Power Utility Profile (PUP) übernommen und auf IEC/IEEE 61850-9-3 übertragen. Die involvierten Normungsorganisationen haben vereinbart, die Inhalte der beiden Dokumente aufeinander auszurichten.

##### 0.2 Änderungen gegenüber der früheren Ausgabe

Folgende sind die Hauptänderungen gegenüber IEC 62439-3:2016:

- Die Begriffe wurden an IEC/IEEE 61850-9-3 angeglichen;
- Das PRP+HSR-Netzwerkmanagement MIB ist jetzt ein „Code-Element“, das als maschinenlesbares separates Dokument verfügbar ist; Fehler wurden korrigiert;
- Die PRP-Sequenznummer wird nur für Rahmen mit PRP-Trailer erhöht;
- Unterstützung von RSTP in HSR wird spezifiziert;
- Ausnahme der zukünftigen IEEE 802.1x-Quelladressregel für HSR;
- Anhang A (PTP-Betrieb über PRP/HSR) wurde an IEC/IEEE 61850-9-3 angeglichen;

- Anhang C (PTP-Profil) wurde an IEC/IEEE 61850-9-3 angeglichen und um Folgendes erweitert:
  - Padding von Sync Messages für Medienkonverter
  - Änderung der ClockClass-Definition (nach IEC 61588)
  - Unterstützung jedes Zeitbereichs in TCs (ermöglicht Rückwärtskompatibilität)
  - Verhalten von BCs bei Holdover und Wiederherstellung
  - Präzisierung bei timeTraceable
  - Präzisierung bei currentUtcOffsetValid
  - Empfehlung bei der Handhabung von UTC-Schaltsekunden
  - Empfehlung bei der Handhabung von ALTERNATE\_TIME\_OFFSET\_INDICATOR;
- Anhang D (Tutorial) wurde erweitert, um das Problem mit dem Medienkonverter zu erläutern;
- Anhang E (PIP-Netzwerkmanagement MIB) ist jetzt ein „Code-Element“, das als maschinenlesbares separates Dokument verfügbar ist; Fehler wurden korrigiert;
- Anhang F (Konformitätsprüfung für PRP und HSR) wurde hinzugefügt.

### 0.3 Patenterklärung

Die Internationale Elektrotechnische Kommission (IEC) macht auf die Tatsache aufmerksam, dass beansprucht wird, dass die Anwendung dieses Dokuments die Verwendung eines Patentes hinsichtlich der Filterung von redundanten Rahmen in einem Netzknoten (Siemens Aktiengesellschaft – EP 2127329, US 8184650, CN 101611615B), wie in 5.2.3.3 angegeben, umfassen kann.

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ABB Schweiz AG  
Intellectual Property CH-IP (CH-150016-L)  
Brown Boveri Strasse 6  
CH-5400 Baden, Schweiz  
ch-ip.patent@abb.com

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## 1 Anwendungsbereich

Die Normenreihe IEC 62439 gilt für hochverfügbare Automatisierungsnetzwerke auf der Basis der Ethernet-Technologie.

Dieser Teil der Normenreihe IEC 62439 beschreibt zwei verwandte Redundanzprotokolle, welche entwickelt wurden, um eine nahtlose Wiederherstellung im Falle eines einzelnen Ausfalls einer Inter-Bridge-Verbindung oder -Brücke im Netzwerk bereitzustellen, die auf dem gleichen Schema, parallele Übertragung von duplizierten Informationen, basieren.

## 3 Begriffe, Abkürzungen, Akronyme und Konventionen

### 3.1 Begriffe

Für die Anwendung dieses Dokuments gelten die Begriffe nach IEC 60050-191 und IEC 62439-1 und die folgenden Begriffe.

ISO und IEC stellen terminologische Datenbanken für die Verwendung in der Normung unter den folgenden Adressen bereit:

- IEC Electropedia: verfügbar unter <http://www.electropedia.org/>
- ISO Online Browsing Platform: verfügbar unter <http://www.iso.org/obp>

#### 3.1.1

##### **Geräte-Zeitungenauigkeit**

(en: device time inaccuracy)

Zeitungenauigkeit, ausgewertet oder gemessen zwischen dem Zeitsignal am Eingang eines Gerätes und dem Zeitsignal, das dieses Gerät generiert

Anmerkung 1 zum Begriff: Diese Definition gilt für TCs, BCs und Medienkonverter.

Anmerkung 2 zum Begriff: Die Geräte-Zitungenauigkeit beinhaltet Unsicherheiten bei der Berechnung der Peer-Verzögerung einer vorgeschalteten Peer-Uhr unter der Annahme, dass der Peer auf die Pdelay\_Req-Nachricht mit einer idealen Pdelay\_Resp-Nachricht antwortet, sowie die Unsicherheit, die durch das Antworten mit Pdelay\_Resp auf eine ideale Pdelay\_Req von einem nachgeschalteten Peer entsteht.

#### 3.1.2

##### **Rahmen**

(en: frame)

Layer-2-Protokolldateneinheit von der Präambel zur Blockprüfzeichenfolge

#### 3.1.3

##### **Grandmaster-fähig**

(en: grandmaster-capable)

einfache Uhr oder abgrenzende Uhr (Boundary Clock), die die Rolle eines Grandmasters übernehmen kann

Anmerkung 1 zum Begriff: Eine Grandmaster-fähige Uhr ist nicht zwingend mit einer anerkannten Zeitquelle verbunden.

#### 3.1.4

##### **Grandmaster-Zitungenauigkeit**

(en: grandmaster time inaccuracy)

Zeitungenauigkeit, ausgewertet oder gemessen zwischen dem Referenzzeitsignal am Eingang einer Grandmaster-Uhr und dem (den) Zeitsignal(en), das (die) der Grandmaster generiert

Anmerkung 1 zum Begriff: Die Grandmaster-Zitungenauigkeit beinhaltet die Unsicherheit, die durch das Antworten mit Pdelay\_Resp auf eine ideale Pdelay\_Req von einem nachgeschalteten Peer entsteht.

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Anmerkung 2 zum Begriff: Die PTP-ClockAccuracy (IEC 61588:2009, 7.6.2.5) des Grandmasters fügt die Messgenauigkeit der Zeitquelle der Grandmaster-Messgenauigkeit hinzu.

### 3.1.5

#### **HSR-Rahmen**

(en: HSR frame)

Datenrahmen, der als „EtherType“ den HSR\_ethertype trägt

### 3.1.6

#### **Interlink**

(en: interlink)

Verbindung, die zwei Netzwerkhierarchien miteinander koppelt

### 3.1.7

#### **Einheit für Schichtenmanagement**

(en: layer management entity)

Einheit, welche die Schicht im Auftrag des Netzwerkmanagements überwacht

### 3.1.8

#### **Einheit für Verbindungsredundanz**

(en: link redundancy entity)

Einheit, welche die Redundanz in den Knoten handhabt

### 3.1.9

#### **Nachricht**

(en: message)

Daten, die über Schicht 2 oder Schicht 3 übertragen werden

### 3.1.10

#### **Netzwerk-Zeitungenauigkeit**

(en: network time inaccuracy)

ausgewertete oder gemessene Zeitungenauigkeit zwischen einer bestimmten Slave-Uhr und dem Zeit-Referenzsignal der Grandmaster-Uhr(en), unter Berücksichtigung der schlechtesten Netzwerktopologie

### 3.1.11

#### **NodesTable**

(en: NodesTable)

Tabelle, die alle anderen Geräte beinhaltet, die positiv als DANP, DANH oder SAN identifiziert wurden

### 3.1.12

#### **Proxy node table**

(en: Proxy node table)

Liste der SAN-Geräte, die durch eine RedBox repräsentiert werden

### 3.1.13

#### **RedBox**

(en: RedBox)

Gerät, das einfach angebundene Netzwerkteilnehmer mit einem redundanten Netzwerk verbindet

### 3.1.14

#### **QuadBox**

(en: QuadBox)

Gerät mit vierfachem Netzwerkanschluss, das zwei hierarchisch gleichrangige HSR-Ringstrukturen miteinander verbindet, das sich in jedem Hochverfügbarkeitsring (HSR) wie ein HSR-Netzwerkteilnehmer verhält und den Netzwerkverkehr filtern und zwischen den zwei Ringen übertragen kann

### 3.1.15

#### **Vermittlungslogik**

(en: switching logic)

Hardware, die einen Datenrahmen von einem Netzwerkanschluss an einen anderen Netzwerkanschluss überträgt, unter Umständen durch Verwendung von „cut-through“-Übertragung

### 3.1.16

#### **Zeitfehler**

(en: time error)

Abweichung von der für die Messung oder Synchronisation verwendete Bezugszeit, welche durch ein Netzwerkelement ausgelöst wird und über eine kurze Zeitspanne (einige Sync-Intervalle) ausgewertet wird

### 3.1.17

#### **Zeitungenauigkeit**

(en: time inaccuracy)

Zeitfehler, welcher von einem hohen Prozentsatz der Messungen nicht überschritten wird, und über eine Serie von Messungen im stationären Zustand ausgewertet wird

### 3.1.18

#### **Gesamt-Zeitungenauigkeit**

(en: total time inaccuracy)

Zeitungenauigkeit, ausgewertet oder gemessen zwischen der von den internationalen Normenlaboratorien, auf denen die Zeitskalen beruhen, verzeichneten Zeit und dem Zeitsignal am Eingang einer Slave-Uhr

Anmerkung 1 zum Begriff: Bei der Abtastung von binären oder analogen Eingangsvariablen werden bei der Zeitstempel-Ungenauigkeit die Gesamt-Zeitungenauigkeit, die Ungenauigkeit der Uhr, die die Abtastung steuert, und die Ungenauigkeit der Messung berücksichtigt. Die Abbildung der Gesamt-Zeitungenauigkeit auf die Zeitstempel-Ungenauigkeit hängt deshalb von der jeweiligen Implementierung ab.

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

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:

- technical corrections;
- extension of HSR specifications (RSTP over HSR);
- alignment of the precision time protocol industry profile with IEC/IEEE 61850-9-3;
- consideration of IEEE 1588-2019 in PTP over PRP/HSR
- conformance testing

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

|            |                  |
|------------|------------------|
| FDIS       | Report on voting |
| XX/XX/FDIS | XX/XX/RVD        |

332

333 Full information on the voting for the approval of this International Standard can be found in  
334 the report on voting indicated in the above table.

335 This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

340 The committee has decided that the contents of this document will remain unchanged until the  
341 stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to  
342 the specific document. At this date, the document will be

- 343 • reconfirmed,
- 344 • withdrawn,
- 345 • replaced by a revised edition, or
- 346 • amended.

347 The National Committees are requested to note that for this document the stability date  
348 is 2025.

349 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE  
350 DELETED AT THE PUBLICATION STAGE.

351

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352

353

## INTRODUCTION

**0.1 General**

IEC 62439-3 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, according to IEC 61850-8-1 and IEC 61850-9-3 and extended to encompass the needs of the Open DeviceNet Vendor Association (ODVA).

It specifies two related redundancy protocols that in case 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.

The seamless redundancy principle has been applied to clocks operating according to the Precision Time Protocol (IEC 61588, tutorial in Annex D) attached to redundant networks (Annex A).

A PTP Industry profile (PIP) specifies 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 in Annex C:

- L3E2E (Layer 3, End-to-End) for clocks operating on layer 3 networks with end-to-end path delay measurement such as EtherNet/IP™; and
- L2P2P (Layer 2, Peer-to-Peer) for clocks operating on layer 2 with peer-to-peer link delay measurement (P2P). L2P2P has been adopted by IEC TC57 WG10 and the IEEE PSRC as the Power Utility Profile (PUP) and copied to IEC/IEEE 61850-9-3. The involved standard organisations agreed to keep the contents of the two documents aligned.

**0.2 Changes with respect to the previous edition**

The major changes with respect to IEC 62439-3:2016 are:

- Terms and abbreviations have been aligned with IEC/IEEE 61850-9-3;
- The PRP+HSR network management MIB is now a “code component” available as machine-readable separate document, errors were corrected;
- The PRP sequence number is only incremented for frames with PRP trailer;
- Support of RSTP in HSR is specified;
- Exclusion of future IEEE 802.1 source address rule for HSR;
- Annex A (PTP operation over PRP/HSR) has been aligned with IEC/IEEE 61850-9-3;
- Annex C (PTP profile) has been aligned with IEC/IEEE 61850-9-3 and extended by:
  - Padding of Sync messages for media converters
  - Change in ClockClass definition (back in line with IEC 61588)
  - Support of any time domain in TCs (ensures backward compatibility)
  - Behaviour of BCs in holdover and recovery
  - Clarification on timeTraceable
  - Clarification on currentUtcOffsetValid
  - Recommendation on handling of UTC leap seconds
  - Recommendation for handling the ALTERNATE\_TIME\_OFFSET\_INDICATOR;
- Annex D (Tutorial) has been extended to explain the media converter issue;

- 398 • Annex E (PIP network management MIB) is now a “code component” available as  
399 machine-readable separate document, errors were corrected.
- 400 • Annex F (conformance testing for PRP and HSR) has been added.

### 401 0.3 Patent declaration

402 The International Electrotechnical Commission (IEC) draws attention to the fact that it is  
403 claimed that compliance with this document may involve the use of a patent concerning  
404 filtering of redundant frames in a network node (Siemens Aktiengesellschaft – EP 2127329,  
405 US 8184650, CN 101611615B) given in 5.2.3.3.

406 IEC takes no position concerning the evidence, validity and scope of this patent right.

407 The holder of this patent right has assured the IEC that he/she is willing to negotiate licences  
408 under reasonable and non-discriminatory terms and conditions with applicants throughout the  
409 world. In this respect, the statement of the holder of this patent right is registered with IEC.  
410 Information may be obtained from:

411 Siemens Aktiengesellschaft  
412 Oto-Hahn-Ring 6  
413 81379 Munich, Germany

414 The International Electrotechnical Commission (IEC) draws attention to the fact that it is  
415 claimed that compliance with this document may involve the use of patents  
416 concerning Reception of redundant and non-redundant frames (ABB Research Ltd – EP  
417 1825657, US 8582426, CN 101057483, IN 254425) given in 4.2.7,  
418 concerning Identifying improper cabling of devices (ABB Technology AG – EP 2163024, US  
419 8344736, CN 101689985) given in 4.3,  
420 concerning Critical device with increased availability (ABB Research Ltd – EP 2090950) given  
421 in 4.4,  
422 concerning Ring coupling nodes for high availability networks (ABB Research Ltd – US  
423 8582424, EP 2327185, CN 102106121) given in 5.2.3 and  
424 concerning WO 2012/010619 A1\_1 (Frame transmission and communication network,  
425 applicable to 5.3.7).

426 IEC takes no position concerning the evidence, validity and scope of these patent rights.

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430 registered with IEC. Information may be obtained from:

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440 patents relevant to their standards. Users are encouraged to consult the data bases for the  
441 most up to date information concerning patents.

442

# INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

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

### 1 Scope

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

This part of IEC 62439 specifies 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.

### 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 60050-191, *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*

IEC 61588:2009, *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<sup>1</sup>*

IEC 62439-1:2020, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods<sup>2</sup>*

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*

ISO/IEC/IEEE 8802-3:2014, *Standard for Ethernet*

IEEE 802.1D-2004, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Bridges*

IEEE 802.1AB-2019, *IEEE Standard for Local and metropolitan area networks – Link Layer Discovery Protocol*

IEEE 802.1Q-2014, *IEEE Standard for Local and metropolitan area networks – Media Access Control (MAC) Bridges and Virtual Bridge Local Area Network*

<sup>1</sup> Edition 2 to be published

<sup>2</sup> Edition 3 to be published

479 IEEE 1588-2019 *Precision Clock Synchronization Protocol for Networked Measurement and*  
480 *Control Systems*<sup>3</sup>

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

484 IETF RFC 768, *User Datagram Protocol (UDP)*

485 IETF RFC 791, *Internet Protocol (IP)*

486 IETF RFC 792, *Internet Control Message Protocol (ICMP)*

487 IETF RFC 793, *Transmission Control Protocol (TCP)*

488 IETF RFC 826, *Address Resolution Protocol (ARP)*

489 IETF RFC 2578, *Structure of Management Information Version 2 (SMIv2)*

490 IETF RFC 3418, *Management Information Base (MIB) for the Simple Network Management*  
491 *Protocol (SNMP)*

## 492 **3 Terms, definitions, abbreviations, acronyms, and conventions**

### 493 **3.1 Terms and definitions**

494 For the purposes of this document, the terms and definitions given in definitions given in IEC  
495 60050-191 and in IEC 62439-1, and the following apply.

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

- 498 • IEC Electropedia: available at <http://www.electropedia.org/>
- 499 • ISO Online browsing platform: available at <http://www.iso.org/obp>

#### 500 **3.1.1**

##### 501 **device time inaccuracy**

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

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

505 Note 2 to entry: Device time inaccuracy includes the uncertainty in the computation of the peer delay from an  
506 upstream peer clock, assuming that the peer responds with an ideal Pdelay\_Resp message to the Pdelay\_Req  
507 message, and the uncertainty introduced in the Pdelay\_Resp to an ideal Pdelay\_Req from a downstream peer.

#### 508 **3.1.2**

##### 509 **frame**

510 the layer 2 protocol data unit from the preamble to the frame check sequence

#### 511 **3.1.3**

##### 512 **grandmaster-capable**

513 ordinary clock or boundary clock that is able to take the role of a grandmaster

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

---

<sup>3</sup> Approved 2019. to be published

**3.1.4**

**grandmaster time inaccuracy**

time inaccuracy evaluated or measured between the reference time signal at the input of a grandmaster clock 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 PTP ClockAccuracy (IEC 61588:2009 7.6.2.5) of the grandmaster adds the inaccuracy of the time source to the grandmaster inaccuracy.

**3.1.5**

**HSR frame**

frame that carries as EtherType the HSR\_EtherType

**3.1.6**

**interlink**

link that connects two network hierarchies

**3.1.7**

**layer management entity**

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

**3.1.8**

**link redundancy entity**

entity in charge of handling redundancy in the nodes

**3.1.9**

**message**

data carried over layer 2 or layer 3.

**3.1.10**

**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

**3.1.11**

**NodesTable**

table containing all other devices positively identified as DANP, DANH or SAN.

**3.1.12**

**Proxy node table**

list of the SAN devices represented by a RedBox.

**3.1.13**

**RedBox**

device attaching singly attached nodes to a redundant network

**3.1.14**

**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

**3.1.15**

**switching logic**

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

**3.1.16**

**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)

562 **3.1.17**

563 **time inaccuracy**

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

566 **3.1.18**

567 **total time inaccuracy**

568 time inaccuracy evaluated or measured between the time maintained by the international  
569 standards laboratories that form the basis for the timescale and the time signal at the input of  
570 a slave clock

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

574 **3.2 Abbreviations and acronyms**

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

|     |       |                                                                           |
|-----|-------|---------------------------------------------------------------------------|
| 577 | ARP   | Address Resolution Protocol, as defined in IETF RFC 826                   |
| 578 | ATOI  | Alternate Time Offset Indicator, as defined in IEC 61588:2009             |
| 579 | BC    | Boundary Clock, as defined in IEC 61588:2009                              |
| 580 | BMCA  | Best Master Clock Algorithm, as defined in IEC 61588:2009                 |
| 581 | CoS   | Class of Service (layer 2 quality of service) as specified in IEEE 802.1Q |
| 582 | DAC   | Doubly Attached Clock                                                     |
| 583 | DABC  | Doubly Attached Boundary Clock                                            |
| 584 | DAN   | Doubly Attached Node                                                      |
| 585 | DANH  | Doubly Attached Node implementing HSR                                     |
| 586 | DANP  | Doubly Attached Node implementing PRP                                     |
| 587 | DATC  | Doubly Attached Transparent Clock                                         |
| 588 | E2E   | End-to-End (delay measurement) as specified in IEC 61588:2009             |
| 589 | GMC   | Grandmaster Clock (the clock currently synchronizing a domain)            |
| 590 | HC    | Hybrid Clock                                                              |
| 591 | HSR   | High-availability Seamless Redundancy                                     |
| 592 | ICMP  | Internet Control Message Protocol as specified in IETF RFC 792            |
| 593 | IP    | Internet Protocol as specified in IETF RFC 791                            |
| 594 | L2P2P | Layer 2 Peer-to-Peer                                                      |
| 595 | L3E2E | Layer 3 End-to-End                                                        |
| 596 | LAN   | Local Area Network                                                        |
| 597 | LLC   | Link Layer Control                                                        |
| 598 | LLDP  | Link Layer Discovery Protocol as specified in IEEE 802.1AB-2009           |
| 599 | LME   | Layer Management Entity                                                   |
| 600 | LRE   | Link Redundancy Entity                                                    |

|     |      |                                                                         |
|-----|------|-------------------------------------------------------------------------|
| 601 | MAC  | Medium Access Control                                                   |
| 602 | MC   | Master Clock (clock generating Sync and Announce messages)              |
| 603 | MIB  | Management Information Base                                             |
| 604 | OC   | Ordinary Clock, as defined in PTP (can be master-capable or slave-only) |
| 605 | P2P  | Peer to Peer (delay measurement)                                        |
| 606 | PICS | Protocol Implementation Conformance Statement (ISO/IEC 9646-7)          |
| 607 | PRP  | Parallel Redundancy Protocol                                            |
| 608 | PT   | Protocol Type                                                           |
| 609 | PTP  | Precision Time Protocol, as specified in IEC 61588                      |
| 610 | RCT  | Redundancy Check Trailer (PRP trailer)                                  |
| 611 | RSTP | Rapid Spanning Tree Protocol, as specified in IEEE 802.1D               |
| 612 | SAN  | Singly Attached Node                                                    |
| 613 | SAC  | Singly Attached Clock                                                   |
| 614 | SLTC | Stateless Transparent Clock                                             |
| 615 | SNMP | Simple Network Management Protocol, as defined in IETF RFC 3418         |
| 616 | TC   | Transparent Clock, as defined in IEC 61588:2009                         |
| 617 | TCP  | Transport Control Protocol as specified in IETF RFC 793                 |
| 618 | UDP  | User Data Protocol, as specified in IETF RFC 768                        |
| 619 | VDAN | Virtual Doubly Attached Node (SAN as visible through a RedBox)          |

### 620 3.3 Conventions

621 This part of the IEC 62439 series follows the conventions defined in IEC 62439-1.

## 622 4 Parallel Redundancy Protocol (PRP)

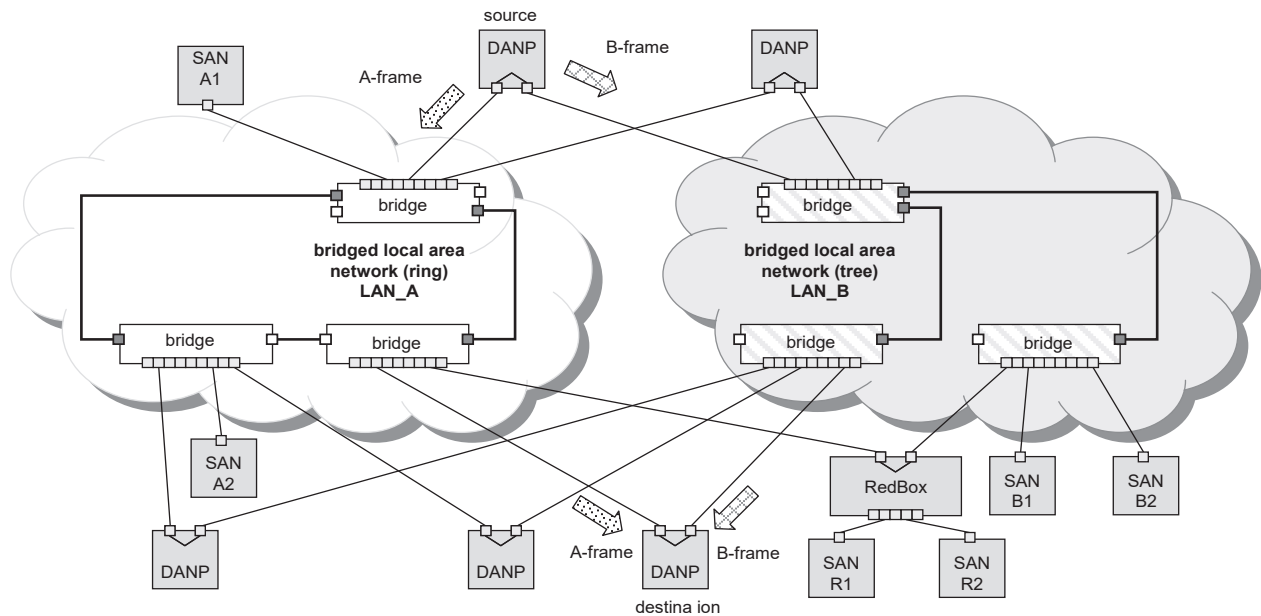
### 623 4.1 PRP principle of operation

#### 624 4.1.1 PRP network topology

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

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

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



IEC

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

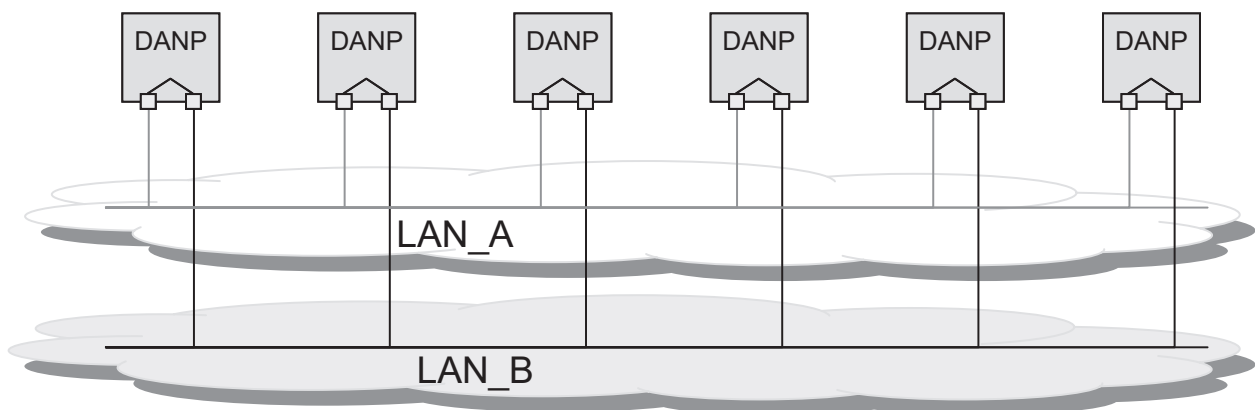
The two LANs are identical in protocol at the MAC-LLC level, but they can differ in performance and topology. Transmission delays will be different, especially if one of the networks reconfigures itself, e.g. using RSTP, to overcome an internal failure.

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.



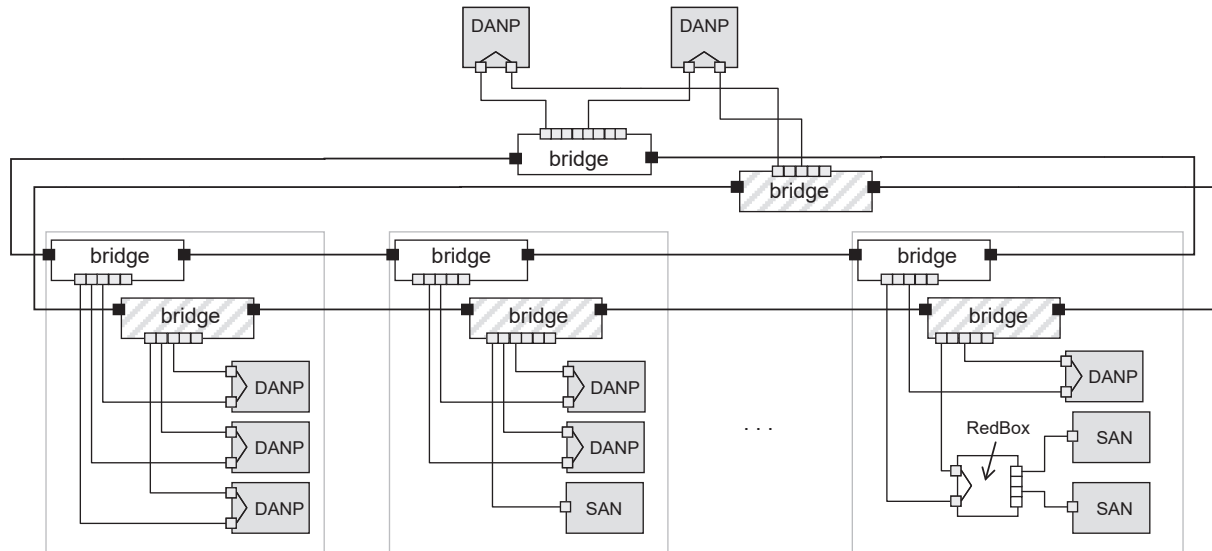
IEC

**Figure 2 – PRP example of redundant network as two LANs (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 IEEE 802.1D or in other IEC 62439 protocols.

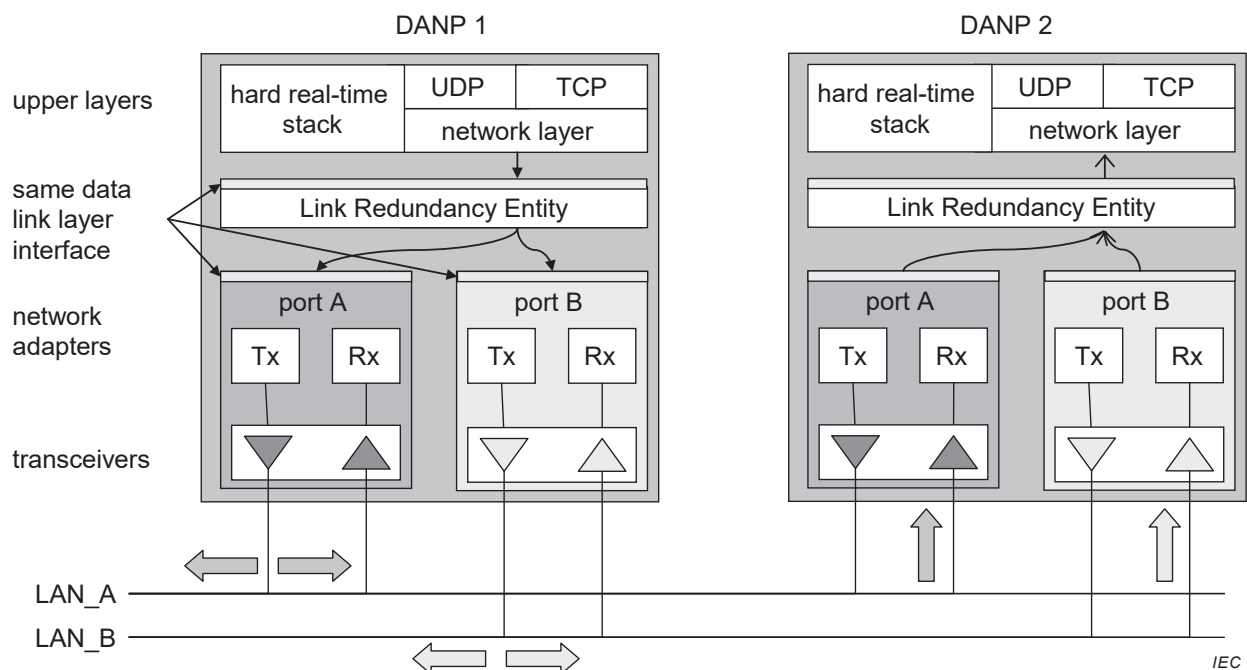


IEC

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.



IEC

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.

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

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

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

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

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

#### 677 **4.1.5 PRP attachment of singly attached nodes**

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

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

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

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

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

#### 693 **4.1.6 Compatibility between singly and doubly attached nodes**

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

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

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

#### 703 **4.1.7 Network management**

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

The mechanism of duplicate rejection can be implemented by a RedBox that does the transition between a SAN and the doubled LANs, as Figure 5 shows. The RedBox mimics the SANs connected behind it (called VDAN or virtual DANs) and multicasts supervision frames on their behalf. The RedBox is itself a DANP and has its own IP address for management purposes, but it may also perform application functions.

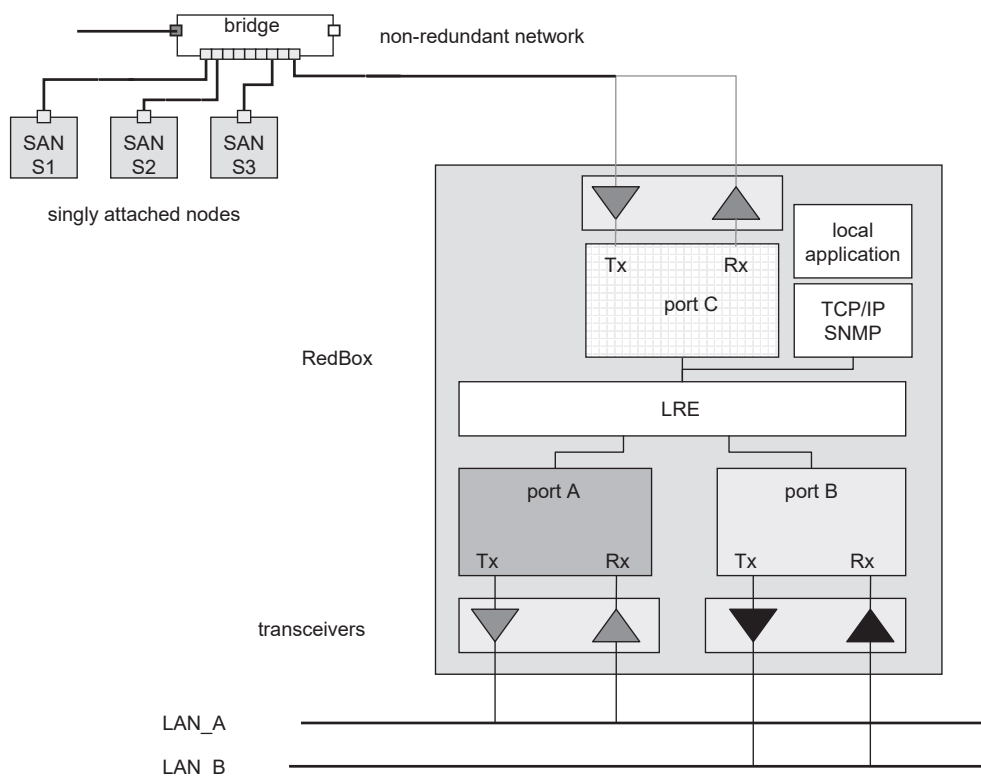


Figure 5 – PRP RedBox, transition from single to double LAN

#### 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

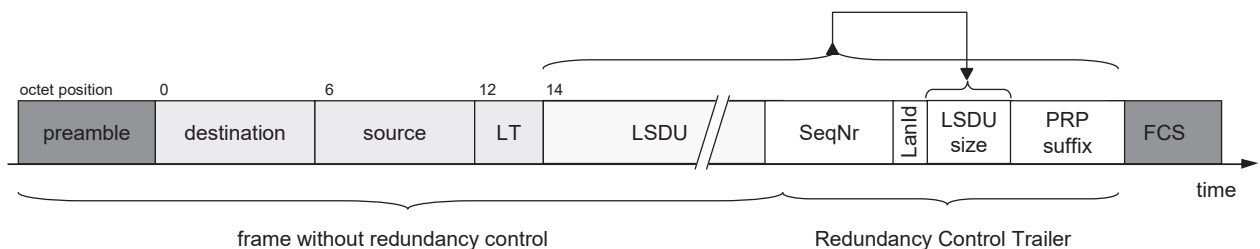
To allow the receivers to detect duplicates, the sender LRE appends a six-octet field that contains a sequence number, the Redundancy Control Trailer (RCT), to both frames it sends, as Figure 6 shows.

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).



IEC

**Figure 6 – PRP frame extended 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 will not be the same as that of a frame on the other LAN, so that a frame from an SAN will never be discarded.

NOTE 2 Reception of a well-formed RCT is no proof that the source node is a DANP. Even if the path 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.

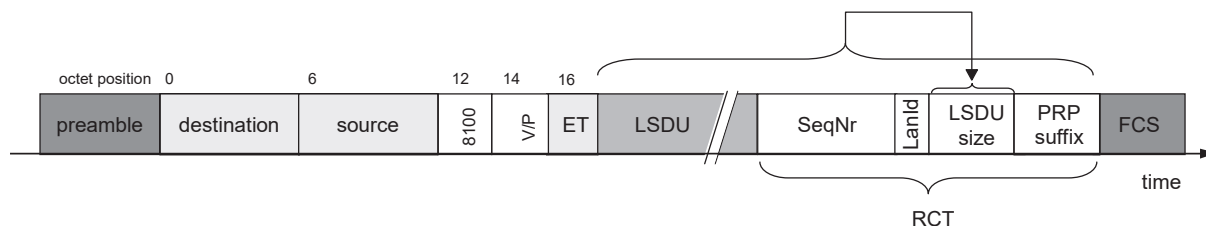


**Figure 7 – PRP VLAN-tagged frame extended by an RCT**

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.

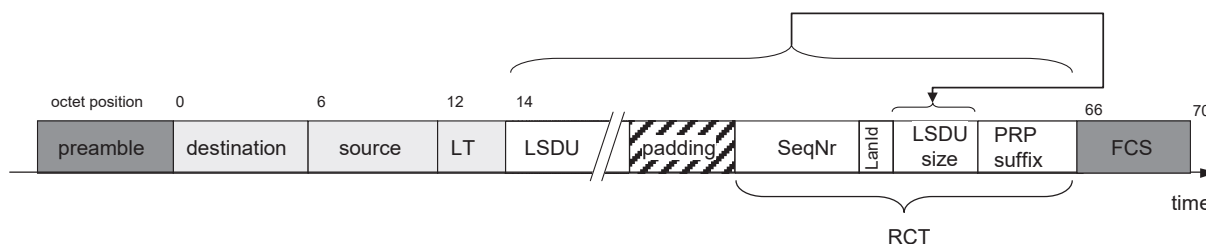


**Figure 8 – PRP padded frame closed by an RCT**

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 carries a distinct identifier for LAN\_A or LAN\_B, specifically the codes 1010 (“A”) and 1011 (“B”). Therefore, the A-frame and the B-frame differ in one bit (and in the FCS). The receiver checks 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. Since this kind of error is permanent, 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 The 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 test that sequence numbers are incremented monotonically and that their wrap-around time is larger than the aging time.

#### 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 could 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  $t_{\text{aliasMin}} = 13\,\text{s}$ .

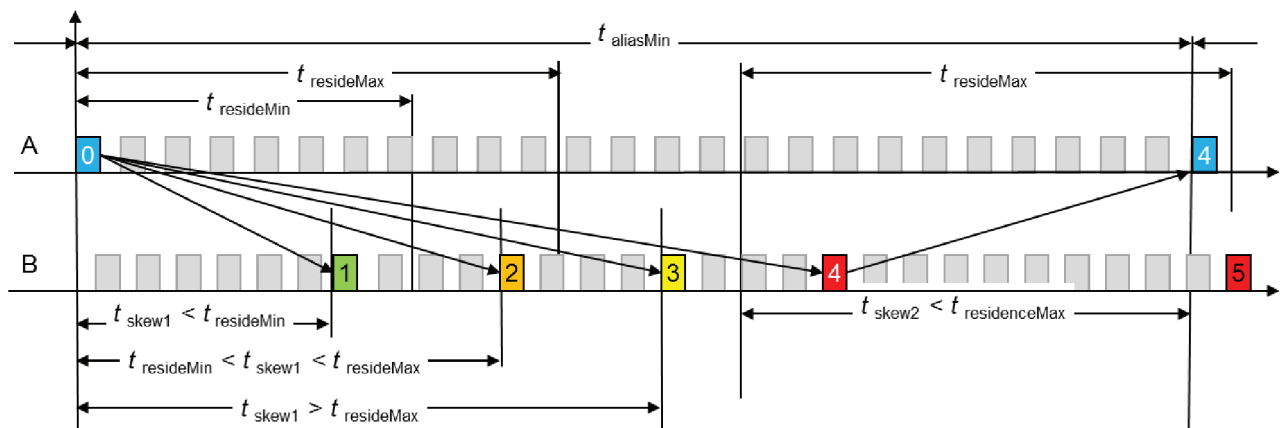


Figure 9 – Duplicate Discard algorithm boundaries

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:

835

**Table 1 – Duplicate discard cases**

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

836

837 The conditions for correct operation are as follows:

838 – For the network engineer:

839  $t_{\text{skewMax}} < (t_{\text{aliasMin}})/2$  (no aliases)

840 – For the device engineer:

841  $t_{\text{resideMin}} > t_{\text{skewMax}}$  (recognizes all duplicates), and

842  $t_{\text{resideMax}} < (t_{\text{aliasMin}})/2$  (prevents unwanted discards)

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

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

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

853 The default value of EntryForgetTime in Table 8 (400 ms) allows in principle a  $t_{\text{skewMax}}$  of  
 854 800 ms, assuming a  $t_{\text{aliasMin}}$  of 1 600 ms. This fits all envisioned applications.

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

#### 857 **4.1.10.4 Frame size restriction**

858 Appending the RCT could generate oversize frames that exceed the maxValidSize foreseen  
 859 by ISO/IEC/IEEE 8802-3:2014 (1 522 octets).

860 Hence, it is expected that every network component in the LANs supports oversize frames up  
 861 to maxValidSize foreseen by ISO/IEC/IEEE 8802-3:2014 plus 6 octets of RCT (1 528 octets).

862 NOTE Many bridges are dimensioned for double-VLAN-tagged (Q-in-Q) frames that have a maximum size of  
 863 1 526 octets. Most Ethernet controllers are certified up to 1 528 octets. Most bridges forward correctly frames of up  
 864 to 1 535 octets.

865 **4.1.11 Network supervision**

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

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

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

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

877 **4.1.12 Redundancy management interface**

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

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

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

886 **4.2 PRP protocol specifications**

887 **4.2.1 Installation, configuration and repair guidelines**

888 **4.2.1.1 General**

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

891 **4.2.1.2 LANs layout**

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

894 DANP shall be attached to both LANs.

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

897 **4.2.1.3 Labelling cables**

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

899 If colours are used to identify the cables, A should be red and B should be blue.

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

901 **4.2.1.4 Labelling bridges**

902 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 4.5).

**4.2.2 Unicast MAC addresses**

Both ports of a DANP shall be configured with the same MAC address.

This MAC address 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).

**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 Nodes**

**4.2.5.1 Node types**

Doubly attached nodes according to the parallel redundancy protocol (DANP) shall have two ports (port A and port B) that have the same abilities, and in particular could be used alternatively if only one LAN would be 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, LAN\_A should be the upper connector and LAN\_B the lower connector in the normal position of the device.

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

939 The redundant connectors shall be independently removable and insertable.

#### 940 4.2.6 Duplicate Accept mode (testing only)

##### 941 4.2.6.1 Sending

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

##### 944 4.2.6.2 Receiving

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

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

#### 948 4.2.7 Duplicate Discard mode

##### 949 4.2.7.1 Monitoring data set

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

951 **Table 2 – Monitoring data set**

| Object name                         | Character | Description                                                                                                                                                                                                                                                |
|-------------------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SendSeq                             | mandatory | 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 and CntErrorsB           | optional  | 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 and CntReceivedB       | optional  | 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 and CntErrWrongLanB | optional  | 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 LinkStatusB         | optional  | 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.                                                                                                                                                                                                      |

952

##### 953 4.2.7.2 NodesTable

954 A node may maintain a NodesTable for the purpose of network supervision. If a NodesTable  
955 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                     | Boolean1     |
| SanB            | True if the remote node is most probably a SAN accessible over port B                     | Boolean1     |

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 4.5).

NOTE 1 The NodesTable is populated by the received frames and distinguishes SANs from DANPs. The NodesTable allows a node to identify another node as SAN on one LAN only and in this case the node could send frames without an RCT over the port of that LAN only. A node without a NodesTable always sends all frames with an RCT over both ports, also when the destination is a SAN. In applications where broadcast traffic is the bulk, the impact on network load is small.

NOTE 2 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 3 Most of these attributes exist not only in one instance per physical remote node, but also as separate instances for each multi/broadcast address used by that node, and some also for each multi/broadcast address used by this (local) node.

NOTE 4 TimeTicks is a local time unit, not a global time.

#### 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 Protocol Type (PT) field as defined in ISO/IEC/IEEE 8802-3:2014 and IEEE 802.1Q (octet offset 12-13 without LAN header or 16-17 with VLAN header) to the RCT, excluding the PT 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.

989 **4.2.7.4 Sending (Duplicate Discard mode)**

990 **4.2.7.4.1 Sending**

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

|                                                                                                       |                                                                                                                                                                                                                                                               |
|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| If the destination node is not registered as a SAN in the NodesTable or if the node has no NodesTable |                                                                                                                                                                                                                                                               |
|                                                                                                       | If the frame carries a IEEE 802.1Q tag and has a size smaller than 64 octets (without FCS)                                                                                                                                                                    |
|                                                                                                       | pad the frame to 64 octets as specified in ISO/IEC/IEEE 8802-3:2014                                                                                                                                                                                           |
|                                                                                                       | If the frame does not carry a IEEE 802.1Q tag and has a size smaller than 60 octets (without FCS)                                                                                                                                                             |
|                                                                                                       | pad the frame to 60 octets as specified in ISO/IEC/IEEE 8802-3:2014                                                                                                                                                                                           |
|                                                                                                       | increment SendSeq (see 4.2.7.1), wrapping over through 0;<br>append the 6-octet RCT with a LanId "A" for portA and LanID "B" for portB;<br>append the 4-octet FCS;<br>send the frame with LanId "A" through portA and the frame with LanId "B" through portB; |
| Else                                                                                                  |                                                                                                                                                                                                                                                               |
|                                                                                                       | send the frame to the port(s) where the SAN is registered;                                                                                                                                                                                                    |

992

993 NOTE 1 Simple nodes have no NodesTable and do not register remote nodes as DANP or SAN, they always  
994 append the RCT and send over both ports.

995 NOTE 2 The total padding to 70 octets (no VLAN tag) considers that the LRE or a RedBox could remove the  
996 6-octet RC. Padding to 74 octets (with VLAN tag) considers that in addition, an edge port in a bridge could remove  
997 the 4-octet priority tag. This way, the frame given to the destination respects the minimum frame size of 64 octets  
998 and the RCT is always just before the FCS.

999 **4.2.7.4.2 Timing**

1000 The time skew between the sending of both frames of a pair should be kept at a minimum to  
1001 reduce asymmetry of the transmission delays.

1002 In particular, frames waiting for sending should be dropped from the sending queue if the  
1003 corresponding port is not operational.

1004 **4.2.7.5 Receiver (Duplicate Discard mode)**

1005 **4.2.7.5.1 Receiving**

1006 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-2004 Table 7-10, |                                                                                           |
|                                                                                                       | 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.                                                    |

1007

1008 NOTE 1 Frames with a destination MAC address according to IEEE 802.1Q:2014, Table 8-1, Table 8-2 and Table  
1009 8-3 are treated at the link layer and are not expected to carry an RCT, even if sent by a DANP.

1010 NOTE 2 Correct Ethernet Frames having wrong PRP fields shall be treated as SAN frames, and thus be passed to  
1011 the application.

#### 1012 4.2.7.5.2 Identification of frames associated with the Duplicate Discard mode

1013 A receiver shall identify a duplicate candidate as a valid frame:

- 1014 • whose last 16 bits before the checksum match the 16-bit PRPsuffix,
- 1015 • whose 12 bits before the PRPsuffix match the physical size of the LSDU (excluding the  
1016 ProtocolType PT, but including the RCT) and
- 1017 • whose LanId matches the LAN identity of the receiving port, 1010 (A) or 1011 (B).

#### 1018 4.2.7.5.3 Duplicate Discard method

1019 The Duplicate Discard method shall not discard a frame sent as single or both frames of a  
1020 pair; exceptionally, both frames of a pair may be passed to the higher protocol layers.

1021 The Duplicate Discard method shall forget an entry after EntryForgetTime (see Table 8).

#### 1022 4.2.7.5.4 Transparent reception

1023 A receiver configured for TransparentReception (default) shall not remove the RCT before  
1024 transferring the frame to its upper layers.

1025 A receiver not configured for TransparentReception shall remove the RCT on frames where it  
1026 has identified the presence of the RCT.

#### 1027 4.2.7.5.5 Receiving and NodesTable

1028 If the node supports a NodesTable, it shall, at reception of a frame:

|                                                                                                                                                  |                                                                                                                                          |                                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| If this frame is not a PRP_Supervision frame or a 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; |                                                                                                                                                        |
| Else if this frame is a PRP_Supervision frame                                                                                                    |                                                                                                                                          |                                                                                                                                                        |
|                                                                                                                                                  | If its source is not yet in the NodesTable                                                                                               |                                                                                                                                                        |
|                                                                                                                                                  |                                                                                                                                          | create an entry in the NodesTable for that source assuming DANP Duplicate Accept or Duplicate Discard according to the PRP_Supervision frame contents; |
|                                                                                                                                                  | 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, respectively 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 = 1 for that source;                                                                                                     |                                                                                                                                                        |
| If the LanId does not match the identity of the port,                                                                                            |                                                                                                                                          |                                                                                                                                                        |
|                                                                                                                                                  | increment the CntErrWrongLanA, respective CntErrWrongLanB counter of the source device.                                                  |                                                                                                                                                        |

1029

1030 NOTE 1 Updating SanA and SanB allows moving an SAN from LAN\_A to LAN\_B and vice-versa. If this happens,  
1031 the DANP will send on both LANs and after NodeForgetTime it will send only on the correct LAN.

1032 NOTE 2 Reception of a well-formed RCT is not a sufficient criterion to declare its source as DANP, since some  
1033 protocols reply with the same frame as received.

### 1034 4.3 PRP\_Supervision frame

#### 1035 4.3.1 PRP\_Supervision frame format

1036 Each DANP shall multicast a PRP\_Supervision frame over both its ports with the format  
1037 specified in Table 4 (no VLAN tag) and Table 5 (with VLAN tag) respectively, every  
1038 LifeCheckInterval (see 4.5).

**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 |                                                        |   |   |   |                 |     |     |     |                 |   |    |    |    |    |    |    |

1040

1041

1042

**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  | 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 | PT (0x8100 for VLAN)                                   |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 14 | prio                                                   |   |   | cti |                 | vlan_identifier |     |     |                 |   |    |    |    |    |    |    |
| 16 | SupEtherType = 0x88FB                                  |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 18 | SupPath                                                |   |   |     | SupVersion < 64 |                 |     |     |                 |   |    |    |    |    |    |    |
| 20 | SupSequenceNumber                                      |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 22 | TLV1.Type = 20 or 21                                   |   |   |     |                 |                 |     |     | TLV1.Length = 6 |   |    |    |    |    |    |    |
| 24 |                                                        |   |   |     |                 | msb             | U/L | 0   |                 |   |    |    |    |    |    |    |
| 26 | MacAddress (MAC address of the DANP)                   |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 28 |                                                        |   |   |     |                 |                 |     |     | lsb             |   |    |    |    |    |    |    |
| 30 | TLV2.Type = 30                                         |   |   |     |                 |                 |     |     | TLV2.Length = 6 |   |    |    |    |    |    |    |
| 32 |                                                        |   |   |     |                 | msb             | U/L | 0   |                 |   |    |    |    |    |    |    |
| 34 | RedBoxMacAddress                                       |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 36 |                                                        |   |   |     |                 |                 |     |     | lsb             |   |    |    |    |    |    |    |
| 38 | TLV0.Type = 0                                          |   |   |     |                 |                 |     |     | TLV0.Length = 0 |   |    |    |    |    |    |    |
|    | Padding to 74 octets (VLAN)                            |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 64 | SeqNr                                                  |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 66 | LanId (0x1010 or 0x1011)                               |   |   |     | LSDUsize = 52   |                 |     |     |                 |   |    |    |    |    |    |    |
| 68 | PRPsuffix = 0x88FB                                     |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 70 | FCS                                                    |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 72 |                                                        |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |
| 74 |                                                        |   |   |     |                 |                 |     |     |                 |   |    |    |    |    |    |    |

1043

1044 NOTE 1 Octets with offset 14 to 17 are inserted only if a VLAN tag according to IEEE 802.1Q is used.

1045 NOTE 2 The frame has a size of 70 octets (no VLAN tag) or 74 octets (with VLAN tag) to avoid padding if an  
1046 entity removes the VLAN tag or the RCT.

1047 NOTE 3 The SeqNr, LanId and LSDUsize are reused when the frame is passed to an HSR network. The  
1048 SupEtherType is the same as the PRP suffix. It is also used for HSR.

1049 NOTE 4 MAC addresses are assumed to have a length of 6 octets.

### 1050 4.3.2 PRP\_Supervision frame contents

1051 The contents of a PRP\_Supervision frame are defined in Table 6.

1052

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

| Field name             | Description                                                                                                                                                                                                                                                                                                                                         |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PRP_DestinationAddress | Multicast address 01-15-4E-00-01-XX reserved for the PRP protocol.<br>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" for IEC 62439-3 until further notice.<br><br>Implementation of version X of the protocol shall interpret version >X as if they were version X, ignoring any parameters and/or flags added by the more recent version, and interpret version <=X PRP_Supervision 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.<br>Other values are reserved.                                                                                                                                                                  |
| TLV1.Length            | Length of the following MAC address in octets.                                                                                                                                                                                                                                                                                                      |
| MacAddress             | MAC addresses used by both port 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                                                                                                                                                                                                                                                                                                                               |

1053

#### 1054 4.3.3 PRP\_Supervision frame for RedBox

1055 A RedBox, i.e. a node acting as a proxy for one or several SANs (called VDAN or virtual DAN)  
1056 shall append to the TLV1 field a further TLV2 field with the content given in Table 7:

1057

**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                                                                                                                                                      |

1058

#### 1059 4.3.4 Reception of a PRP\_Supervision frame and NodesTable

1060 When receiving a PRP\_Supervision frame over any LAN, a node shall create an entry in the  
1061 NodesTable corresponding to the MacAddress of that source as indicated in the message  
1062 body, not in the source address, with the Duplicate Accept or Duplicate Discard mode as  
1063 indicated in the frame.

1064 If a node ceases to receive PRP\_Supervision frames from a source for a time longer than  
1065 NodeForgetTime, but receives frames from that source over one LAN only, it shall change the  
1066 status of this node to SanA, respective SanB, depending on the LAN from which frames are  
1067 received.

NOTE 1 This rule allows moving a SAN between LAN\_A and LAN\_B, and also 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.

NOTE 2 This rule allows distinguishing an SAN from a DANP in Duplicate Accept mode with one line disconnected.

#### 4.4 Bridging node (deprecated)

If the “bridging node” setting is enabled, the node shall act as a bridging node for its two ports, according to 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.

#### 4.5 Constants

The constant parameters are shown in Table 8.

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

These parameters are not accessible over layer management since modifying those needs good knowledge of the network and reasons must exist to use other values than the default. Setting these parameters to different values in different DANPs may cause 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        |

#### 4.6 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 to roughly halve the network infrastructure. With respect to rings based on IEEE 802.1D (RSTP), IEC 62439-2 (MRP), IEC 62439-6 (DRP) or IEC 62439-7 (RRP), the network traffic is about the same.

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

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) and Figure 11 (unicast) for a ring topology.

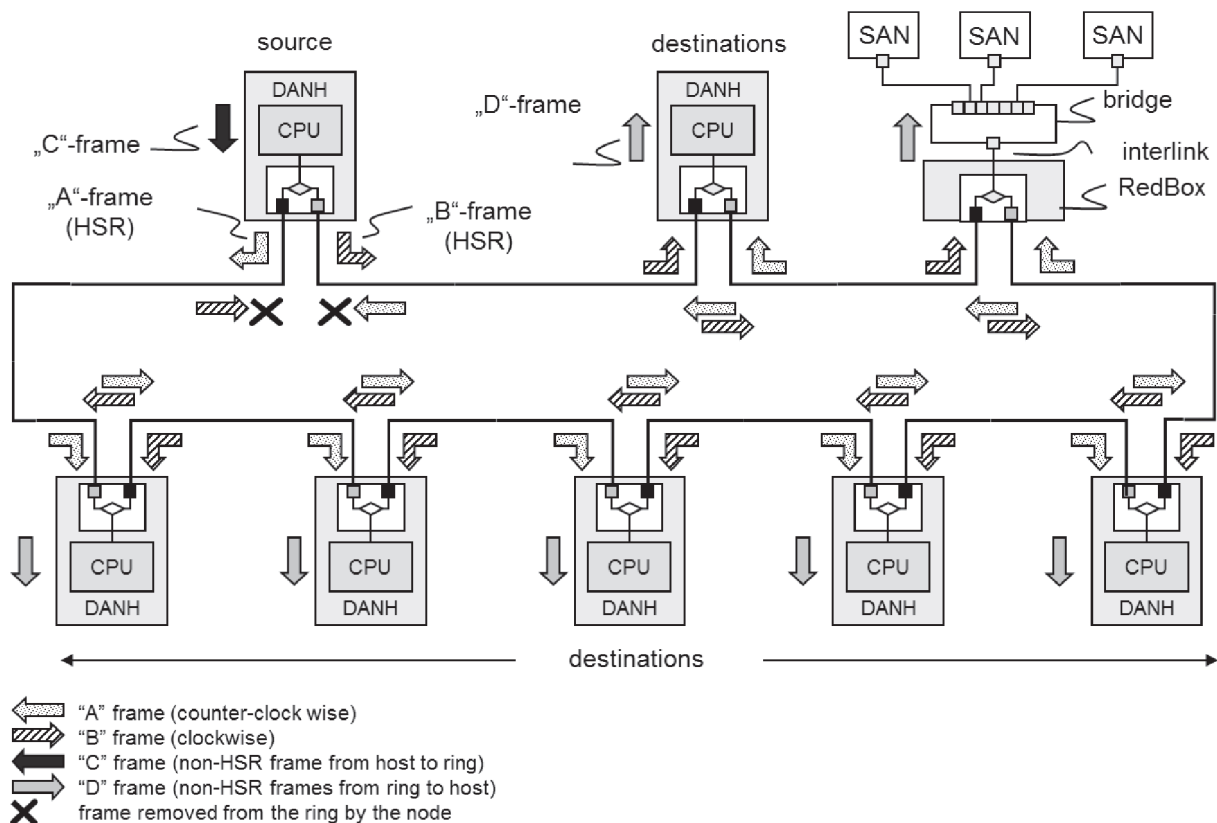


**Figure 10 – HSR example of ring configuration for multicast traffic**

A source DANH sends a frame passed from its upper layers ("C" frame), prefixes it by an HSR tag to identify frame duplicates and sends the frame over each port ("A"-frame and "B"-frame).

A destination DANH receives, in the fault-free state, two identical frames from each port within a certain interval, removes the HSR tag of the first frame before passing it to its upper layers ("D"-frame) and discards any duplicate.

The nodes support the IEEE 802.1D bridge functionality and forward frames from one port to the other, according to four rules:

- 1) a node will not forward a frame that it injected into the ring or mesh;
- 2) a node will not forward a frame for which it is the unique destination (except for special applications such as redundancy supervision);

- 1127 3) a port will not send a frame that is a duplicate of a frame that it already sent into that  
1128 same direction;
- 1129 4) a port will (optionally) refrain from sending a frame that is a duplicate of a frame that it  
1130 already received from the opposite direction (except for supervision and timing frames).

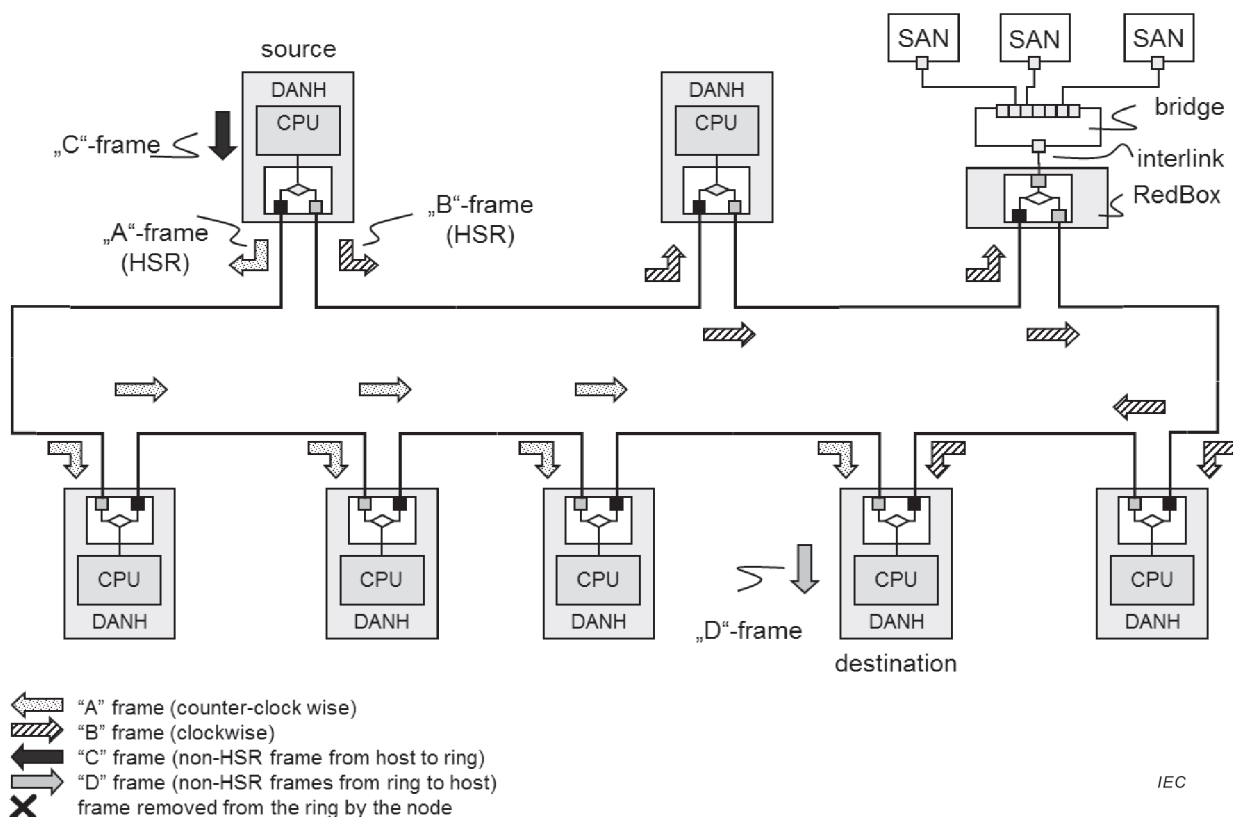


**Figure 11 – HSR example of ring configuration for unicast traffic**

1133 Frames circulating in the ring carry the HSR tag inserted by the source, which contains a  
1134 sequence number. The doublet {source MAC address, sequence number} uniquely identifies  
1135 copies of the same frame.

1136 NOTE 1 The maximum time skew between two frames of a pair depends on the relative position of the receiving  
1137 node and of the sending node. Assuming a worst case in which each node in the ring is transmitting at the same  
1138 time its own frame with the largest size of 1 536 octets (maximum length supported by the EtherType defined in  
1139 ISO/IEC/IEEE 8802-2:1998), each node could introduce 125 µs of delay at 100 Mbit/s. With 50 nodes, the time  
1140 skew can exceed 6 ms.

1141 NOTE 2 The minimum delay before a frame returns to the node that injected it depends on the ring size.  
1142 Assuming a worst case in which there is no other traffic and in which each node in the ring operates in cut-through  
1143 with 4 µs residence time, in a ring of 32 nodes, a frame with the maximum size of 1 536 octets (125 µs at  
1144 100 Mbit/s) returns to the injecting node after 124 µs, i.e. before the injecting node finished transmitting it.

## 5.2.2 DANH node structure

1146 Figure 12 shows a conceptual view of the structure of a DANH implemented in hardware;  
1147 practical implementations can be different. The two HSR port A and port B and the application  
1148 port C are connected by the LRE, which includes a switching matrix allowing to forward  
1149 frames from one port to the other. The switching matrix allows cut-through bridging. The LRE  
1150 presents to the higher layers the same interface as a standard Ethernet transceiver would do.

1151 The input circuit checks if this node is the destination of the frame and possibly does VLAN  
1152 and multicast filtering to offload the processor. The Duplicate Discard is implemented in the  
1153 output queues.

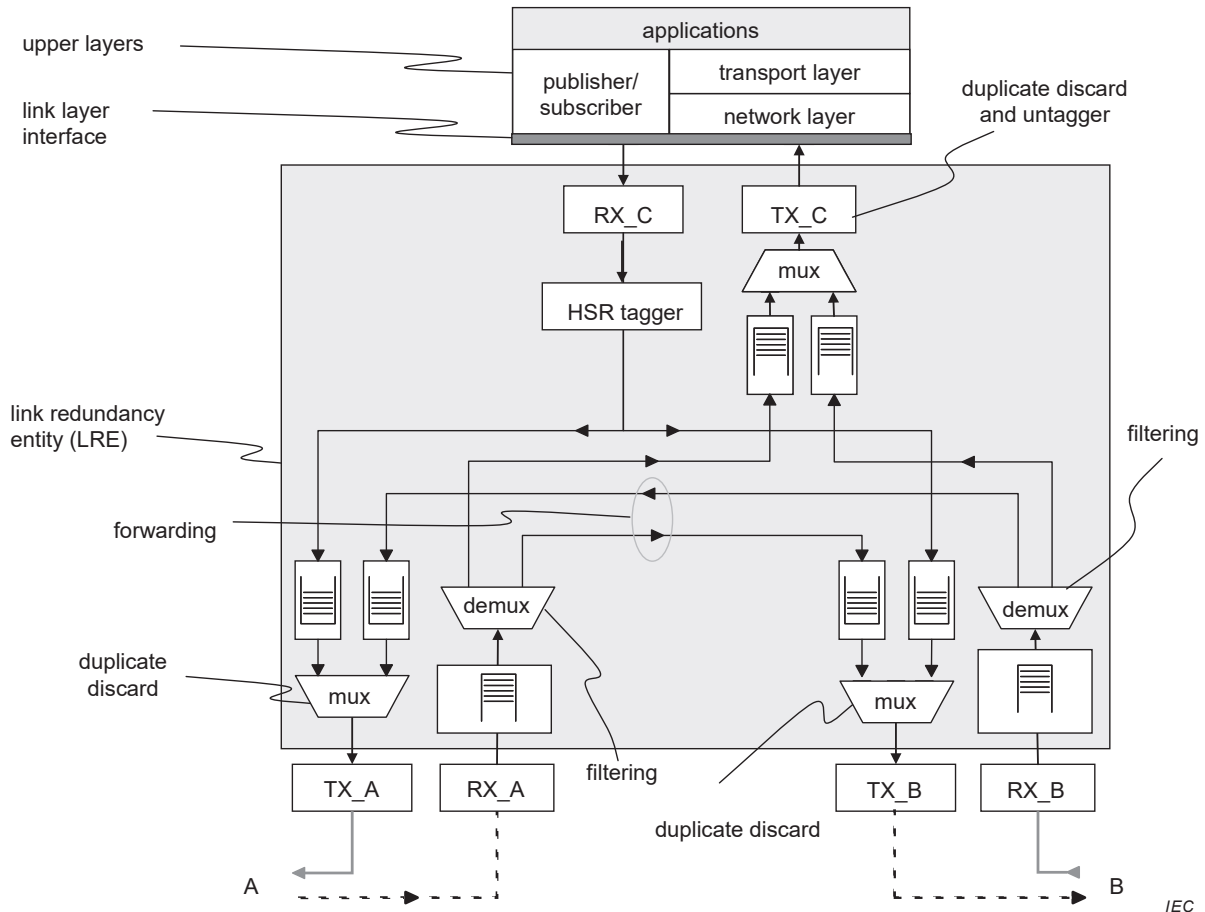


Figure 12 – HSR structure of a DANH

### 5.2.3 Topology

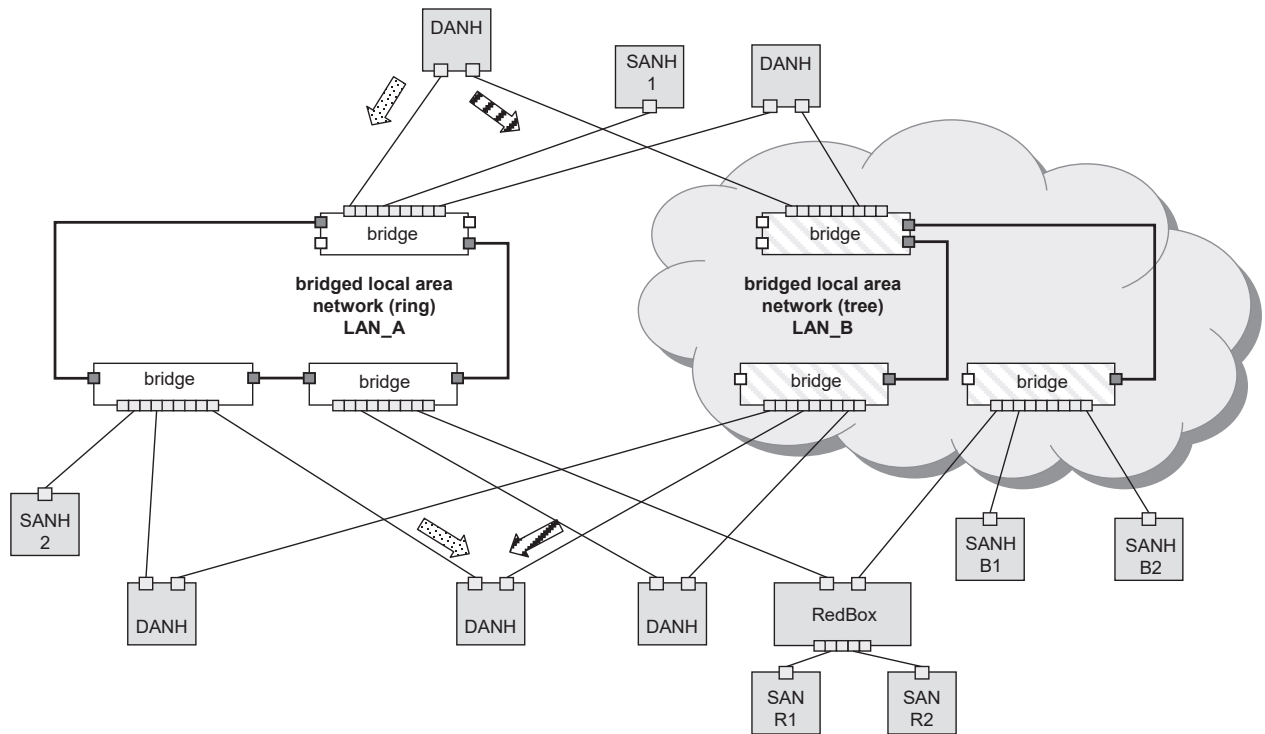
#### 5.2.3.1 Attachment of singly attached nodes

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 communicate with ring devices through a RedBox that acts as a proxy for the SANs attached to it, as shown in Figure 10 and Figure 11. The RedBox is detailed in 5.2.3.8.

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

#### 5.2.3.2 Use of HSR with separate LANs

HSR nodes can be connected in the same way as PRP nodes. To this effect, an HSR node may be set to “no forwarding” (mode N). Unlike PRP, SANs cannot be attached directly to such a duplicated network unless they are able to interpret the HSR tag.



IEC

**Figure 13 – HSR example of topology using two independent networks**

### 5.2.3.3 Peer coupling of rings

Two HSR rings may be connected by quadruple port devices with forwarding capabilities, called QuadBoxes, as Figure 14 shows. This is advantageous when the traffic flow exceeds the capabilities of a single ring. However, transmission delays from end to end are not improved.

Although one QuadBox is sufficient to conduct the traffic in the fault-free state of the network, two QuadBoxes are used to prevent a single point of failure.

A Quadbox forwards frames over each ring as any HSR node, and passes the frames unchanged to the other ring, except if the frame can be identified as a frame not to be forwarded to the other ring. To this effect, a QuadBox is expected to filter traffic based for instance on multicast filtering or on VLAN filtering. There is no learning of MAC addresses in a QuadBox, since the learning of MAC addresses on specific ports of a QuadBox device could lead to a short break in communication, if the QuadBox that has learned an address and is forwarding network traffic, fails.

With QuadBoxes realized as single physical entities, the two interconnected rings share the same redundancy domain concerning fault tolerance. If one QuadBox breaks down, both interconnected rings are in a degraded state and cannot tolerate a further fault.

Therefore, constructing QuadBoxes in the same way as a RedBox can help keep the redundancy independent. The QuadBox then consists of two devices connected by an interlink. For this reason, the RedBox specifications include the HSR connection.

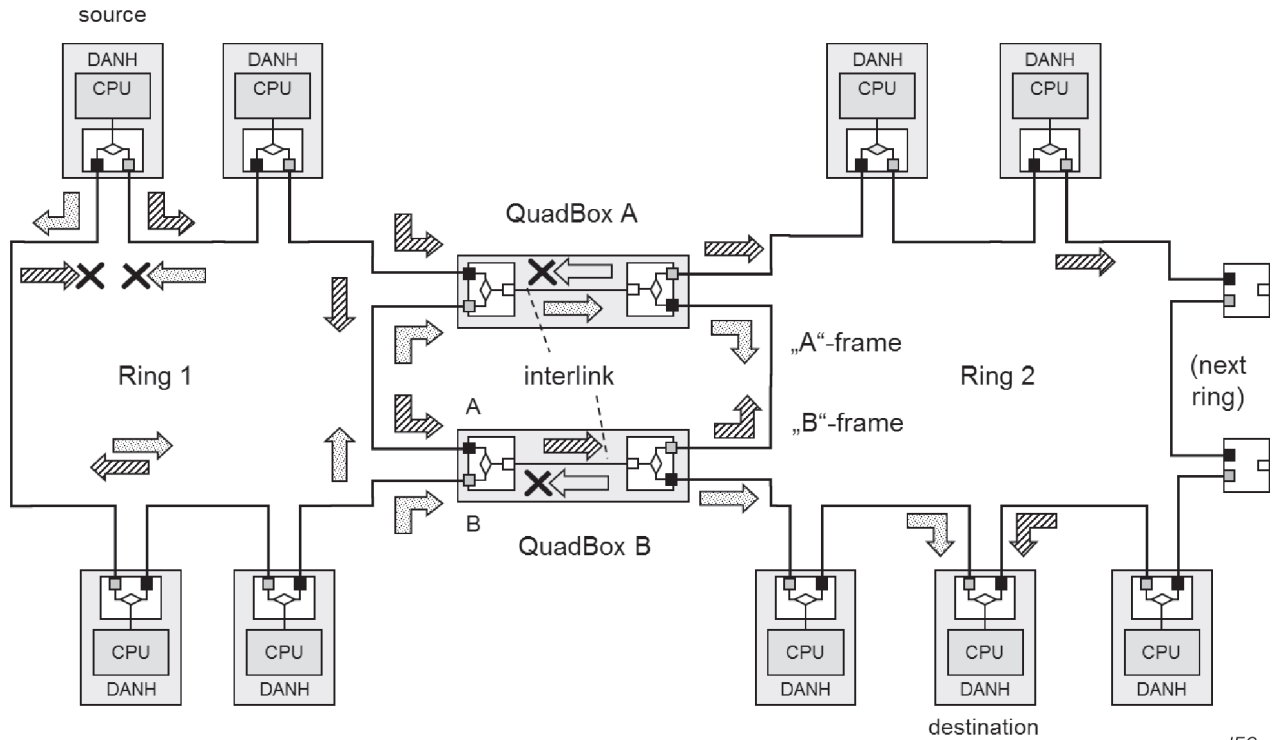


**Figure 14 – HSR example of peer coupling of two rings**

The presence of two QuadBoxes on the same ring causes that two copies of the same frame are transferred from the first ring to the second, each generating another two copies.

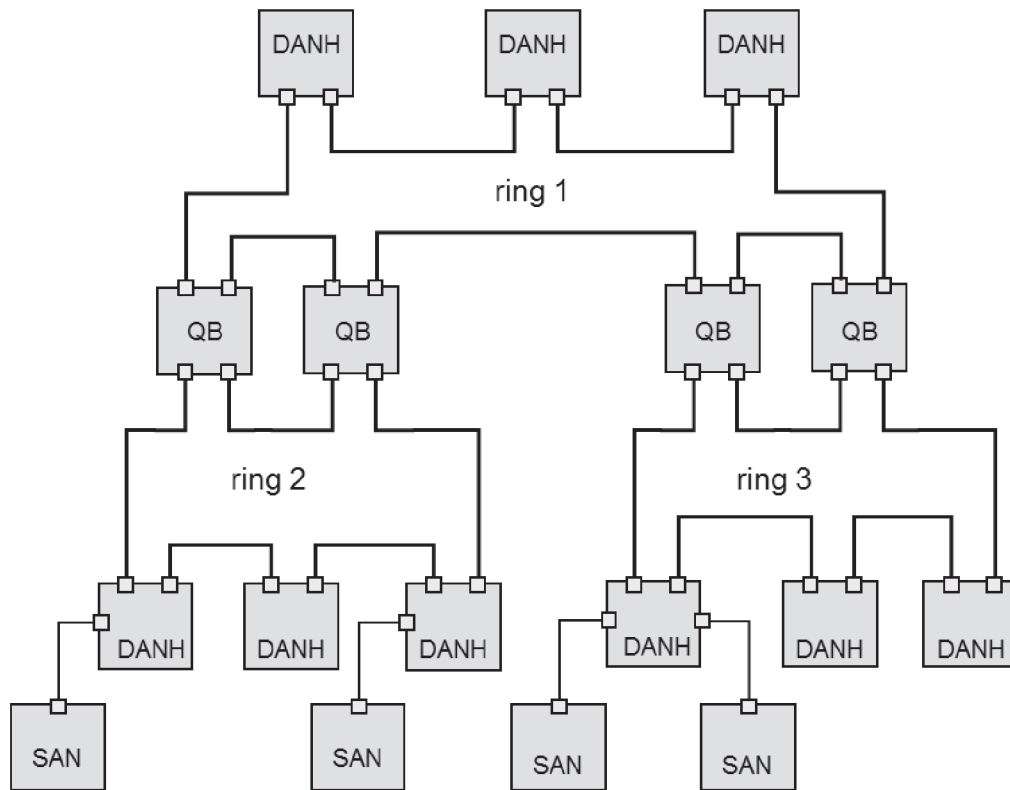
This does not cause four frames to circulate on the second ring, since, when a copy from a first QuadBox reaches the second QuadBox on the same second ring, the second QuadBox will not forward it if it already sent a copy that came from its interlink. Conversely, if the second QuadBox did not yet receive a copy from its interlink, it will forward the frame, but not the copy that comes later from the interlink.

When a QuadBox receives a frame that it itself injected into the ring or a frame that the other QuadBox inserted into the ring, it forwards it to the interlink and to its other port if it did not already sent a copy. This duplicate will be discarded at the other end of the interlink. This scheme may cause some additional traffic on the interlink, but it allows to simplify the design of the logic.

NOTE The maximum time skew between two frames of a pair is about the same as if all nodes were on the same ring.

#### 5.2.3.4 Hierarchical ring topology

An HSR network may consist of rings connected by QuadBoxes, as Figure 15 shows.



IEC

**Figure 15 – HSR example of connected rings**

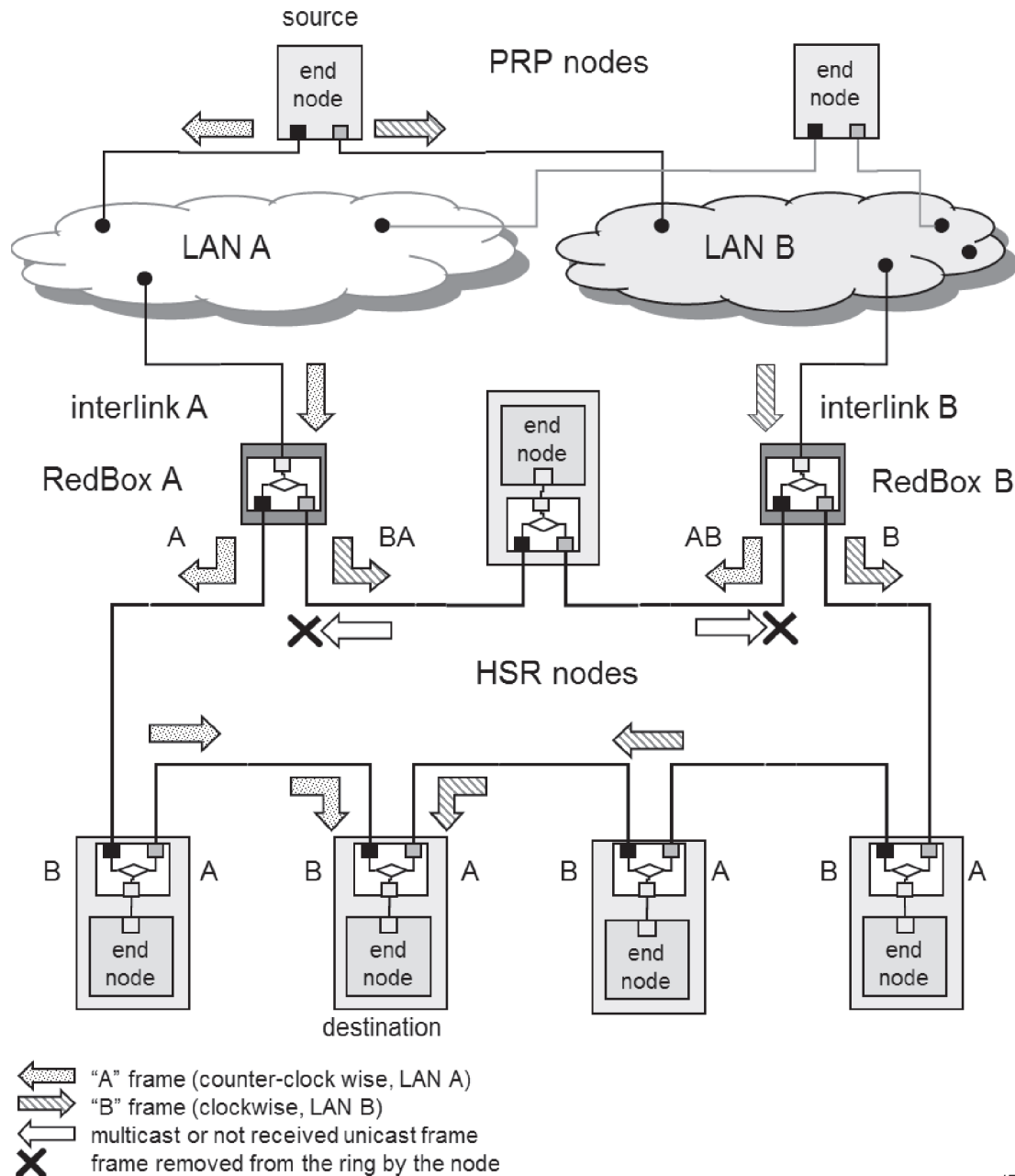
Although a single QuadBox is sufficient to sustain the traffic, two independent QuadBoxes are needed to avoid a single point of failure.

Some SANs are connected directly to the DANH that performs the duty of a simplified RedBox.

#### 5.2.3.5 Connection of an HSR ring to a PRP network

An HSR may be coupled to a PRP network through two RedBoxes, one for each LAN, as Figure 16 shows. In this case, the RedBoxes are configured to support PRP traffic on the interlink and HSR traffic on the ring ports.

The sequence number from the PRP RCT is reused for the HSR tag and vice versa, to allow frame identification from one network to the other and to identify pairs and duplicates on the HSR ring, introduced by a twofold injection into the ring through the two HSR RedBoxes.



IEC

**Figure 16 – HSR example of coupling two redundant PRP LANs to a ring**

The HSR RedBoxes for connecting the ring to a PRP network operate identically to the HSR RedBoxes used to attach SANs described in 5.2.3.1, except that they are configured as RedBox “A” or RedBox “B” to accept PRP frames on their interlink.

In Figure 16, RedBox A and RedBox B would send the same frame (A and AB and B and BA, respectively), but if a RedBox receives the frame before it could send it itself, it refrains from sending it.

In the example of Figure 16, RedBox A will not generate an “A” frame on behalf of LAN\_A if it previously received the same frame as “AB” from the ring, or conversely, RedBox “B” will generate an “AB” frame if it did not previously receive an “A” frame from the ring, which is the case whenever frame “A” is not a multicast frame.

Multicast frames or unicast frames without a receiver in the ring (void arrows in Figure 16) are removed by the RedBox that inserted them into the ring, if they originated from outside the ring. To this purpose, the frames carry a LAN identifier that is at the same time the end node identifier.