

DIN EN IEC 62439-3



ICS 25.040.40; 35.110; 35.240.50

Ersatz für
DIN EN IEC 62439-3:2018-10
Siehe Anwendungsbeginn

**Industrielle Kommunikationsnetze –
Hochverfügbare Automatisierungsnetze –
Teil 3: Parallelredundanz-Protokoll (PRP) und nahtloser
Hochverfügbarkeits-Ring (HSR)
(IEC 62439-3:2021 + COR1:2023);
Englische Fassung EN IEC 62439-3:2022 + AC:2023**

Industrial communication networks –
High availability automation networks –
Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless
Redundancy (HSR)
(IEC 62439-3:2021 + COR1:2023);
English version EN IEC 62439-3:2022 + AC:2023

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 62439-3:2021 + COR1:2023);
Version anglaise EN IEC 62439-3:2022 + AC:2023

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DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE

Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2022-01-19 angenommene Europäische Norm als DIN-Norm ist 2023-12-01.

Für DIN EN IEC 62439-3:2018-10 besteht eine Übergangsfrist bis 2025-01-19.

Diese Norm enthält die Berichtigung EN IEC 62439-3:2022/AC:2023, die das Corrigendum 1:2023 zu IEC 62439-3:2021 übernimmt.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN IEC 62439-3:2021-04.

Für dieses Dokument ist das nationale Arbeitsgremium DKE/K 956 „Industrielle Kommunikation“ der DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik in DIN und VDE (www.dke.de) zuständig.

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- geändert.

 Das IEC-Corrigendum 1, von CENELEC angenommen als AC, wurde eingearbeitet und mit den Änderungsmarken AC am Textanfang und Textende gekennzeichnet. 

Für den Fall einer undatierten Verweisung im normativen Text (Verweisung auf ein Dokument ohne Angabe des Ausgabedatums und ohne Hinweis auf eine Abschnittsnummer, eine Tabelle, ein Bild usw.) bezieht sich die Verweisung auf die jeweils aktuellste Ausgabe des in Bezug genommenen Dokuments.

Für den Fall einer datierten Verweisung im normativen Text bezieht sich die Verweisung immer auf die in Bezug genommene Ausgabe des Dokuments.

Der Zusammenhang der zitierten Dokumente mit den entsprechenden deutschen Dokumenten ergibt sich, soweit ein Zusammenhang besteht, grundsätzlich über die Nummer der entsprechenden IEC-Publikation. Beispiel: IEC 60068 ist als EN 60068 als Europäische Norm durch CENELEC übernommen und als DIN EN 60068 ins Deutsche Normenwerk aufgenommen.

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 die vorliegende Norm erfüllt.

Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die Englische Fassung der EN IEC 62439-3 veröffentlicht. Zu deren Einleitung, Abschnitt 1, der den Anwendungsbereich festlegt und Abschnitt 3, der die Begriffe und Abkürzungen festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm 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. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Das Original-Dokument enthält Bilder in Farbe, die in der Papierversion in einer Graustufen-Darstellung wiedergegeben werden. Elektronische Versionen dieses Dokuments enthalten die Bilder in der originalen Farbdarstellung.

Änderungen

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

- a) Verweisungen auf das Precision Time Protocol (PTP) IEC 61588:2021 ersetzen die Verweisungen auf IEC 61588:2009, es sei denn, die vorige Version wird ausdrücklich bevorzugt (Abschnitt 2);
- b) Verweisungen auf IEC 61850-90-4:2020 ersetzen Verweisungen auf IEC 61850-90-4:2013 mit entsprechenden Änderungen in den logischen Knoten (Abschnitt 2);
- c) Begriffe und Abkürzungen sind an die nächste Ausgabe der IEC/IEEE 61850-9-3 angepasst (derzeit in Vorbereitung) (Abschnitt 3);
- d) RSTP-Unterstützung in HSR ist festgelegt (5.2.2.10);
- e) Spezifikationen für RedBoxes und QuadBoxes sind auf TCs erweitert (5.5);
- f) Das Netzwerkmanagement (MIB) für PRP und HSR ist verfügbar als „Code-Element“, d. h. maschinenlesbares separates Dokument (Abschnitt 7);
- g) PTP über PRP legt einen einheitlichen Betrieb von DATC- und SLTC-RedBoxes fest (A.2.6.4);
- h) PTP über HSR legt den Betrieb von RedBoxes für TCs fest (A.4.3);
- i) PTP-Datensätze sind an IEC 61588:2021 angepasst (Abschnitt A.6);
- j) Das PTP-Branchenprofil wird erweitert:
 - Ergänzung von Sync-Meldungen zur Unterstützung von Medienkonvertern (C.5.4);
 - ClockClass-Definition angeglichen an IEC 61588:2021 Option a) (C.7.4.3);
 - TC-Betrieb über verschiedene Domains (C.7.5.3);
 - Verhalten von BCs bei Holdover und Wiederherstellung (C.7.6.2);
 - PICS-Einträge umbenannt und erweitert (C.13.2);
 - Flags-Semantik in TimePropertyDS aktualisiert (C.14.1);
 - Handhabung von UTC-Ereignissen während einer festgelegten Schaltsekunde (C.14.2);
 - UTC-Schaltsekunden-Zeitdarstellung angepasst an IEEE C37.118.2 (C.14.2.2);
 - Sommerzeit- und Schaltsekunden-Ereignisse empfohlen im ALTERNATE_TIME_OFFSET_INDICATOR TLV (C.14.3.2);
- k) Tutorial erweitert, um das Problem mit dem Medienkonverter zu erläutern (D.8.3);
- l) PTP-Netzwerkmanagement MIB (Anhang E) ist als „Code-Element“, d. h. als maschinenlesbares separates Dokument verfügbar und berücksichtigt IEC 61588:2021-Objekte;
- m) Konformitätsprüfung für PRP, HSR und die zweifach angeschlossene PTP-Uhr (Anhang F) wurde hinzugefügt.
- n) Fragen der Interoperabilität mit früheren Ausgaben dieser Internationalen Norm werden in einer Anmerkung am Ende des entsprechenden Abschnitts angesprochen.

Frühere Ausgaben

DIN EN 62439: 2009-01
 DIN EN 62439-3: 2010-09, 2013-06
 DIN EN IEC 62439-3: 2018-10

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

Dieses Dokument gehört zur Normenreihe IEC 62439 „*Industrial communication networks – High availability automation networks*“. Es 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 61850-9-2 erarbeitet und erweitert, damit die Erfordernisse der CPF 2 aus IEC 61784-1 und IEC 61784-2 für Layer 3 berücksichtigt werden.

In diesem Dokument werden zwei verwandte Redundanzprotokolle festgelegt, die im Falle eines Ausfalls eines Netzwerkelements eine nahtlose Umschaltung ohne Wiederherstellungszeit ermöglichen:

- Parallelredundanz-Protokoll (PRP, en: 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
- nahtloser Hochverfügbarkeits-Ring (HSR, en: High-availability Seamless Redundancy), das Threading von Knoten mit zwei Ports in einem ringförmigen oder von Knoten mit mehreren Ports in einem vermaschten Netzwerk ermöglicht.

Dieses Dokument wendet das Prinzip der nahtlosen Redundanz auf Uhren an, die mit dem Precision Time Protocol (PTP) kompatibel sind.

Dieses Dokument legt ein PTP-Branchenprofil (PIP, en: PTP Industry profile) fest, das die Leistung bietet, 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. Zwei Varianten von PIP werden spezifiziert:

- L3E2E (Layer 3, End-to-End) für Uhren, die auf Layer-3-Netzwerken mit End-to-End-Pfadverzögerungsmessung wie CP 2/2 aus IEC 61784-1 und IEC 61784-2 laufen; und
- L2P2P (Layer 2, Peer-to-Peer) für Uhren, die auf Layer 2 mit Peer-to-Peer-Verbindungsverzögerungsmessung (P2P) laufen.

Auf der Grundlage von L2P2P wurden IEC TC57 WG10 und der IEEE PSRC gemeinsam als Power Utility Profile (PUP) festgelegt und auf IEC/IEEE 61850-9-3 übertragen. IEC und IEEE sind übereingekommen, den Inhalt dieses Dokuments und der IEC/IEEE 61850-9-3 unter dem Dach des Dual Logo Maintenance Teams (DLMT), das von IEEE PSCC P20 geleitet wird, aufeinander abzustimmen.

Die Spezifikationen von PRP und HSR stellen keine Probleme bezüglich der Abwärtskompatibilität dar, da es sich bei den Änderungen um kompatible Erweiterungen des Protokolls handelt. Die untergeordnete Version dieser Protokolle wird auf dem Wert „1“ gehalten.

Die Spezifikationen des Taktprofils PIP basieren auf IEC 61588:2021, die einige Unterschiede gegenüber IEC 61588:2009 aufweist. Die minorVersionPTP wurde auf 1 erhöht.

Dieses Dokument enthält Leitlinien für Konformitätsprüfungen, die für PRP, HSR und die PIP- und PUP-Uhrsynchrisationsprofile gelten.

Dieses Corrigendum 1 korrigiert Fehler und mögliche Fehlinterpretationen in IEC 62439 3:2021, die bei den ersten Feldimplementierungen auf der Grundlage dieser Internationalen Norm entdeckt wurden. Alle Korrekturen dienen lediglich der Verbesserung der Konsistenz der Implementierungen der Spezifikationen und führen keine neuen Merkmale in die Technologie ein.

ANMERKUNG Dieses Corrigendum 1 enthält Korrekturen für die MIBs im Abschnitt 7 und Anhang E. Die MIB in 10.3 wird als Codekomponente in einem Begleitdokument zur Verfügung gestellt, siehe <https://www.iec.ch/sc65c/supportingdocuments>. Die (geringfügige) Korrekturen für den Abschnitt 7 und Anhang E werden der Einfachheit halber zur Verfügung gestellt, während die Versionen in den Begleitdokumenten IEC_62439-3_2021B1.mib und IEC_62439-100_2021B1.mib den korrigierten Code enthält und im Falle von Unstimmigkeiten maßgeblich ist.

0.2 Erklärung zu Patenten

Die Internationale Elektrotechnische Kommission (IEC) macht auf die Tatsache aufmerksam, dass beansprucht wird, dass die Anwendung dieser Norm die Verwendung eines Patents umfassen kann. Die IEC nimmt keine Stellung zur Rechtmäßigkeit, Gültigkeit und Tragweite dieses Patentrechts.

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1 Anwendungsbereich

1.1 Allgemeines

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

Dieses Dokument:

- legt PRP und HSR als zwei verwandte Redundanzprotokolle fest, welche entwickelt wurden, um eine nahtlose Wiederherstellung im Falle eines einzelnen Ausfalls einer Inter-Bridge-Verbindung oder Bridge im Netzwerk bereitzustellen, die auf dem gleichen Schema, parallele Übertragung von duplizierten Informationen, basieren;
- legt den Betrieb des Präzisionszeitprotokolls (PTP) in Netzen fest, die die beiden Redundanzprotokolle einsetzen (Anhang A);
- legt PTP-Profil mit einer Leistung fest, die für die Energieversorgungsautomatisierung (Anhang B) und die industrielle Automatisierung (Anhang C) geeignet ist;
- enthält zum besseren Verständnis ein Tutorial (Anhang D) über die PTP-Funktionen, die in hochverfügbaren Automatisierungsnetzen effektiv genutzt werden;
- enthält eine Verwaltungsinformationsbasis für PTP (Anhang E);
- definiert eine Konformitätsprüfung für die oben genannten Protokolle (Anhang F).

1.2 Code-Element-Verbreitung

Dieses Dokument steht in Zusammenhang mit Code-Elementen. Jedes Code-Element besteht aus einem ZIP-Paket, das mindestens die elektronische Darstellung des Code-Elements selbst sowie eine Datei mit einer Beschreibung des Inhalts des Pakets (IECManifest.xml) enthält.

Das IECManifest enthält verschiedene Abschnitte mit Informationen über:

- den Urheberrechtshinweis;
- die Identifizierung des Code-Elements;
- die mit dem Code-Element in Bezug stehende Herausgabe;
- die Liste der elektronischen Dateien, aus denen sich das Code-Element zusammensetzt;
- eine optionale Liste von Verlaufsdateien, um Änderungen während des Entwicklungsprozesses des Code-Elements zu verfolgen.

Die in dieser IEC-Norm enthaltenen Code-Elemente sind ein Satz von SNMP-MIBs. Das Code-Element IEC-62439-3-MIB.mib ist eine Datei, die die MIBs für PRP/HSR und PTP_SNMP enthält. Sie ist in einer Vollversion verfügbar, die die in diesem Dokument definierte MIB mit der zugehörigen Dokumentation enthält, wobei der Zugriff auf den Käufer dieses Dokuments beschränkt ist.

Die Code-Elemente sind auf der IEC-Internetseite zum Download frei verfügbar unter: https://www.iec.ch/sc65c/supportingdocuments/IEC_62439-3.MIB.{VersionStateInfo}.full.zip, jedoch unterliegt die Nutzung den Lizenzbedingungen.

Der Lebenszyklus eines Code-Elements ist nicht auf den Lebenszyklus der zugehörigen Herausgabe begrenzt. Der Lebenszyklus der Herausgabe durchläuft zwei Stufen: „Version“ (entsprechend einer Ausgabe) und „Revision“ (entsprechend einer Änderung). Demzufolge darf/dürfen (eine) neue Veröffentlichung(en) des/der Code-Elemente(s) veröffentlicht werden, die die vorherige Veröffentlichung ersetzt/ersetzen, und diese Veröffentlichung(en) wird/werden über die IEC-Internetseite unter folgendem Link zur Verfügung gestellt: <https://www.iec.ch/sc65c/supportingdocuments>.

Die neueste Version/Veröffentlichung des Dokuments ist zu finden durch Auswahl der Datei IEC_62439-3.MIB.{VersionStateInfo}.full.zip für das Code-Element mit dem höchsten Wert für VersionStateInfo.

Falls sich der herunterladbare Code von dem veröffentlichten Inhalt der PDF-Datei von IEC unterscheidet, ist/sind der/die herunterladbare(n) Code(s) gültig; dies kann Updates unterliegen. Siehe Verlaufsdateien.

3 Begriffe, Abgekürzungen und Vereinbarungen

3.1 Begriffe

Für die Anwendung dieses Dokuments gelten die Begriffe nach IEC 60050-192 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 <https://www.electropedia.org/>
- ISO Online Browsing Platform: verfügbar unter <https://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-Zeitungenauigkeit 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

EtherType

2-Oktett-Wert, der die Art des MAC-Client-Protokolls angibt

Anmerkung 1 zum Begriff: Die Typwerte werden von der IEEE-Registrierungsbehörde zugewiesen.

3.1.3

Rahmen

en **frame**

Layer-2-Protokolldateneinheit vom Beginn der Präambel zum Ende der Blockprüfzeichenfolge, synonym für DLPDU (Data-Link-Protokolldateneinheit, en: Data Link Protocol Data Unit)

3.1.4

Grandmaster-Uhr

en **Grandmaster Clock**

Master-fähige einfache Uhr, die durch ein absolutes Zeitreferenzsignal synchronisiert werden kann

Anmerkung 1 zum Begriff: Diese Definition der Grandmaster-Uhr unterscheidet sich von der Definition in IEC 61588:2021, 3.1.17 und wird verwendet, um die Rolle vom Gerät zu unterscheiden. Es können mehrere Grandmaster-Uhren in derselben Domain existieren, die beste wird voraussichtlich die Rolle des grandmaster (kleines „g“) übernehmen. Eine Grenzuhr kann auch die Rolle eines grandmaster übernehmen, wenn keine Grandmaster-Uhr vorhanden ist, hat aber keinen Zugang zu einem Referenzsignal. Somit sind die Grandmaster-Uhr als Gerät und die Rolle „grandmaster“ unterschiedlich.

3.1.5

grandmaster

gewöhnliche Uhr oder Grenzuhr, von der alle anderen Uhren in derselben Domain ihre Zeit erhalten

3.1.6

grandmaster-fähig

en **grandmaster-capable**, adj

einfache Uhr oder Grenzuhr (Boundary Clock), die die Rolle eines grandmasters übernehmen kann

Anmerkung 1 zum Begriff: Eine grandmaster-fähige Uhr ist nicht zwingend mit einer Zeitreferenz verbunden.

3.1.7

Grandmaster-Zeitungenauigkeit

en **grandmaster time inaccuracy**

Zeitungenauigkeit, ausgewertet oder gemessen zwischen der primären Referenzzeitsignalquelle am Eingang eines grandmaster und dem (den) Zeitsignal(en), das (die) der grandmaster generiert

Anmerkung 1 zum Begriff: Die Grandmaster-Zeitungenauigkeit beinhaltet die Unsicherheit, die durch das Antworten mit Pdelay_Resp auf eine ideale Pdelay_Req von einem nachgeschalteten Peer entsteht.

Anmerkung 2 zum Begriff: Die ClockAccuracy (IEC 61588:2021 7.6.2.6) des grandmasters fügt die Messgenauigkeit der Zeitquelle der grandmaster-Messgenauigkeit hinzu.

3.1.8

HSR-Rahmen

en **HSR frame**

Datenrahmen, der als EtherType den HSR_EtherType trägt

3.1.9

Interlink

en **interlink**

Verbindung, die zwei Netzwerkhierarchien miteinander koppelt

3.1.10

Einheit für Schichtenmanagement

en **layer management entity**

Einheit, welche die Schicht im Auftrag des Netzwerkmanagements überwacht

3.1.11

Einheit für Verbindungsredundanz

en **link redundancy entity**

Einheit, welche die Redundanz in den Knoten handhabt

3.1.12

Master-Uhr

en **master clock**

einfache Uhr oder Grenzuhr, die Announce- und Sync-Meldungen erzeugt

3.1.13

Nachricht

en **message**

Daten, die über Schicht 2 oder Schicht 3 übertragen werden

3.1.14

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

3.1.15

NodesTable

en **NodesTable**

Tabelle, die alle anderen Geräte beinhaltet, die positiv als DANP, DANH oder SAN identifiziert wurden, und die für Überwachung und Trailer-Kontrolle verwendet werden

3.1.16

ProxyNode-Tabelle

en **ProxyNodeTable**

Liste der SAN-Geräte, die durch eine RedBox repräsentiert werden, und die für Überwachung und Unicast-Frame-Filterung verwendet wird

3.1.17**RedBox**en **RedBox**

Gerät zur Verbindung von PRP-, HSR- oder Single-Thread-Netzwerken

3.1.18**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

3.1.19**Vermittlungslogik**en **switching logic**

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

3.1.20**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

3.1.21**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

3.1.22**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.

3.2 Abkürzungen

Für die Anwendung dieses Dokuments gelten die Abkürzungen nach IEC 62439-1 und die folgenden Abkürzungen.

ARP	Adressen-Auflösungsprotokoll (en: Address Resolution Protocol), nach Definition in IETF RFC 826
ATOI	Anzeige für Versatz alternativer Zeit (en: Alternate Time Offset Indicator) nach Definition in IEC 61588:2021, 16.3.3
BC	Grenzuhr (en: Boundary Clock), nach Definition in IEC 61588:2021
BIPM	Bureau International des Poids et Mesures
BMCA	Best-Master-Clock-Algorithmus, nach Definition in IEC 61588:2021
CoS	Dienstklasse (en: Class of Service) (Layer-2-Qualität des Dienstes) wie in IEEE 802.1Q festgelegt
DAC	zweifach angeschlossene Uhr (en: Doubly Attached Clock)
DABC	zweifach angeschlossene Grenzuhr (en: Doubly Attached Boundary Clock)
DAN	zweifach angeschlossener Knoten (en: Doubly Attached Node)

DANH	zweifach angeschlossener Knoten, der HSR implementiert (en: Doubly Attached Node implementing HSR)
DANP	zweifach angeschlossener Knoten, der PRP implementiert (en: Doubly Attached Node implementing PRP)
DATC	zweifach angeschlossene transparente Uhr (en: Doubly Attached Transparent Clock)
E2E	Ende-zu-Ende (en: End-to-End) (Verzögerungsmessung) wie in IEC 61588:2021 festgelegt
GC	Grandmaster-Uhr (en: Grandmaster Clock) (eine Master-fähige Uhr mit ausreichender Genauigkeit)
GM	Grandmaster (die Uhr, die aktuell eine Domain synchronisiert)
GNSS	weltweites Navigations-Satellitensystem (en: Global Navigation Satellite Systems)
HC	Hybriduhr (en: Hybrid Clock) (Kombination von OC und TC)
HSR	nahtloser Hochverfügbarkeits-Ring (en: High-availability Seamless Redundancy)
IERS	International Earth Rotation and Reference Systems Service
IETF	Projektgruppe zur technischen Weiterentwicklung des Internets (en: Internet Engineering Task Force)
ICMP	Internet-Kontrollnachrichtenprotokoll (en: Internet Control Message Protocol) wie in IETF RFC 792 festgelegt
IP	Internetprotokoll (en: Internet Protocol), wie in IETF RFC 791 festgelegt
L2P2P	Layer 2 Peer-to-Peer

3.3 Vereinbarungen

Das vorliegende Dokument folgt den in IEC 62439-1 festgelegten Vereinbarungen.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

**EN IEC 62439-3:2022-02
+ AC:2023-04**

ICS 25.040.40; 35.100.05

Supersedes EN IEC 62439-3:2018 and all of its amendments
and corrigenda (if any)

English version

**Industrial communication networks – High availability automation
networks – Part 3: Parallel Redundancy Protocol (PRP)
and High-availability Seamless Redundancy (HSR)
(IEC 62439-3:2021 + COR1:2023)**

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 62439-3:2021 + COR1:2023)

Industrielle Kommunikationsnetze – Hochverfügbare
Automatisierungsnetze – Teil 3: Parallelredundanz-
Protokoll (PRP) und nahtloser Hochverfügbarkeits-Ring (HSR)
(IEC 62439-3:2021 + COR1:2023)

This European Standard was approved by CENELEC on 2022-01-19. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

The Corrigendum AC:2023 becomes effective on 28 April 2023 for incorporation in the English language version of the EN.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 65C/1120/FDIS, future edition 4 of IEC 62439-3, prepared by SC 65C “Industrial networks” of IEC/TC 65 “Industrial-process measurement, control and automation” was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 62439-3:2022.

The following dates are fixed:

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

This document supersedes EN IEC 62439-3:2018 and all of its amendments and corrigenda (if any).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

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Endorsement notice

The text of the International Standard IEC 62439-3:2021 was approved by CENELEC as a European Standard without any modification.

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

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

Endorsement notice to EN IEC 62439-3:2022/AC:2023-04

The text of the corrigendum IEC 62439-3:2021/COR1:2023 was approved by CENELEC as EN IEC 62439-3:2022/AC:2023-04 without any modification.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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

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

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

Publication	Year	Title	EN/HD	Year
IEC 60050-192	–	International Electrotechnical Vocabulary (IEV) – Part 192: Dependability	–	–
IEC 61588	2021	Precision Clock Synchronization Protocol for Networked Measurement and Control Systems	–	–
IEC/TR 61850-90-4	2020	Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines	–	–
IEC 62439-1	–	Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods	EN 62439-1	–
ISO/IEC/IEEE 8802-3	2021	Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – Part 3: Standard for Ethernet	–	–
IEC/IEEE 61850-9-3	2016	Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation	–	–
IEEE 802.1Q	2018	IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Network	–	–
IETF RFC 768	–	User Datagram Protocol (UDP) [online]. August 1980.	–	–
IETF RFC 791	–	Internet Protocol (IP) [online]. September 1981.	–	–
IETF RFC 792	–	Internet Control Message Protocol [online]. September 1981.	–	–
IETF RFC 793	–	Transmission Control Protocol [online]. September 1981.	–	–
IETF RFC 826	–	Ethernet Address Resolution Protocol [online]. November 1982.	–	–
IETF RFC 2578	–	Structure of Management Information Version 2 (SMIv2) [online]. April 1999.	–	–
IETF RFC 3418	–	Structure of Management Information Version 2 (SMIv2) [online]. December 2002.	–	–

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INTRODUCTION

0.1 General

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

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

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

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

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

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

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

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

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

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

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

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

0.2 Patent declaration

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

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

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

INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

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

1 Scope

1.1 General

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

This document:

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

1.2 Code component distribution

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

The IECManifest contains different sections giving information on:

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

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

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

The life cycle of a code component is not restricted to the life cycle of the related publication. The publication life cycle goes through two stages, "Version" (corresponding to an edition) and "Revision" (corresponding to an amendment). Consequently, new release(s) of the Code Component(s) may be released, which supersede(s)

the previous release, and will be distributed through the IEC web site at: <https://www.iec.ch/sc65c/supportingdocuments>.

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

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

2 Normative references

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3 Terms, definitions, abbreviated terms, and conventions

3.1 Terms and definitions

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

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

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

3.1.1

device time inaccuracy

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

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

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

3.1.2

Ethertype

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

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

3.1.3

frame

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

3.1.4

Grandmaster Clock

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

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

3.1.5

grandmaster

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

3.1.6

grandmaster-capable, adj

ordinary Clock or Boundary Clock that is able to take the role of a grandmaster

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

3.1.7

grandmaster time inaccuracy

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

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

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

3.1.8

HSR frame

frame that carries as Ethertype the HSR_EtherType

3.1.9

interlink

link that connects two network hierarchies

3.1.10

layer management entity

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

3.1.11

link redundancy entity

entity in charge of handling redundancy in the nodes

3.1.12

master clock

Ordinary Clock or Boundary Clock generating Announce and Sync messages

3.1.13

message

data carried over layer 2 or layer 3

3.1.14

network time inaccuracy

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

3.1.15

NodesTable

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

3.1.16

ProxyNodeTable

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

3.1.17

RedBox

device connecting PRP, HSR or single-thread networks

3.1.18

QuadBox

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

3.1.19

switching logic

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

3.1.20

time error

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

3.1.21

time inaccuracy

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

3.1.22

total time inaccuracy

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

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

3.2 Abbreviated terms

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

ARP	Address Resolution Protocol, as defined in IETF RFC 826
ATOI	Alternate Time Offset Indicator, as defined in IEC 61588:2021, 16.3.3
BC	Boundary Clock, as defined in IEC 61588:2021
BIPM	Bureau International des Poids et Mesures
BMCA	Best Master Clock Algorithm, as defined in IEC 61588:2021
CoS	Class of Service (layer 2 quality of service) as specified in IEEE 802.1Q
DAC	Doubly Attached Clock
DABC	Doubly Attached Boundary Clock
DAN	Doubly Attached Node
DANH	Doubly Attached Node implementing HSR
DANP	Doubly Attached Node implementing PRP
DATC	Doubly Attached Transparent Clock
E2E	End-to-End (delay measurement) as specified in IEC 61588:2021
GC	Grandmaster Clock (a master-capable clock of sufficient precision)
GM	Grandmaster (the clock currently synchronizing a domain)
GNSS	Global Navigation Satellite Systems
HC	Hybrid Clock (combination of OC and TC)
HSR	High-availability Seamless Redundancy
IERS	International Earth Rotation and Reference Systems Service
IETF	Internet Engineering Task Force
ICMP	Internet Control Message Protocol as specified in IETF RFC 792
IP	Internet Protocol as specified in IETF RFC 791
L2P2P	Layer 2 Peer-to-Peer
L3E2E	Layer 3 End-to-End
LAN	Local Area Network
LLC	Link Layer Control
LLDP	Link Layer Discovery Protocol as specified in IEEE 802.1AB-2016
LME	Layer Management Entity
LRE	Link Redundancy Entity

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

3.3 Conventions

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

4 Parallel Redundancy Protocol (PRP)

4.1 PRP principle of operation

4.1.1 PRP network topology

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

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

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

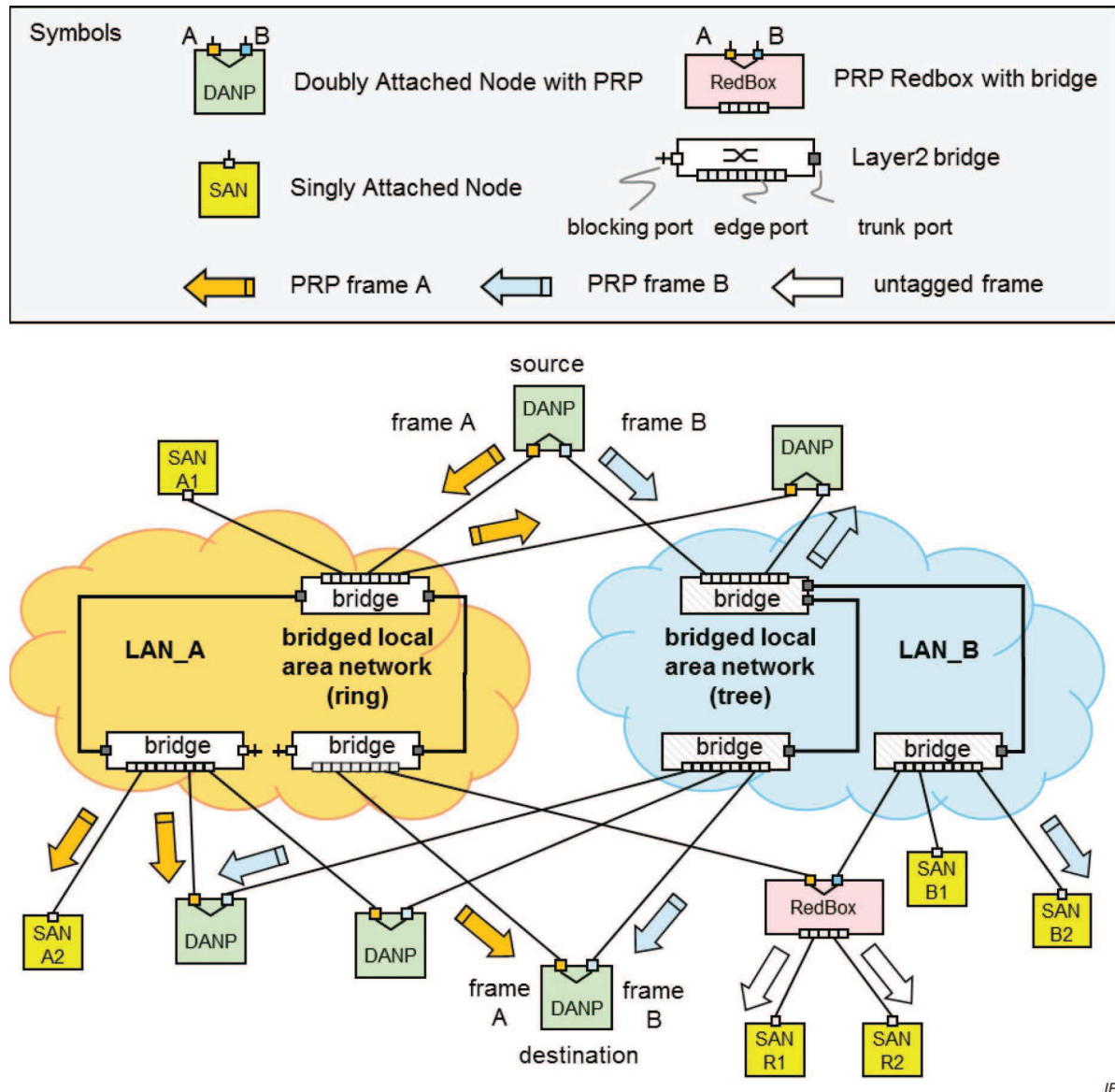


Figure 1 – PRP example of general duplicated network

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

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

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

4.1.2 PRP LANs with linear or bus topology

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

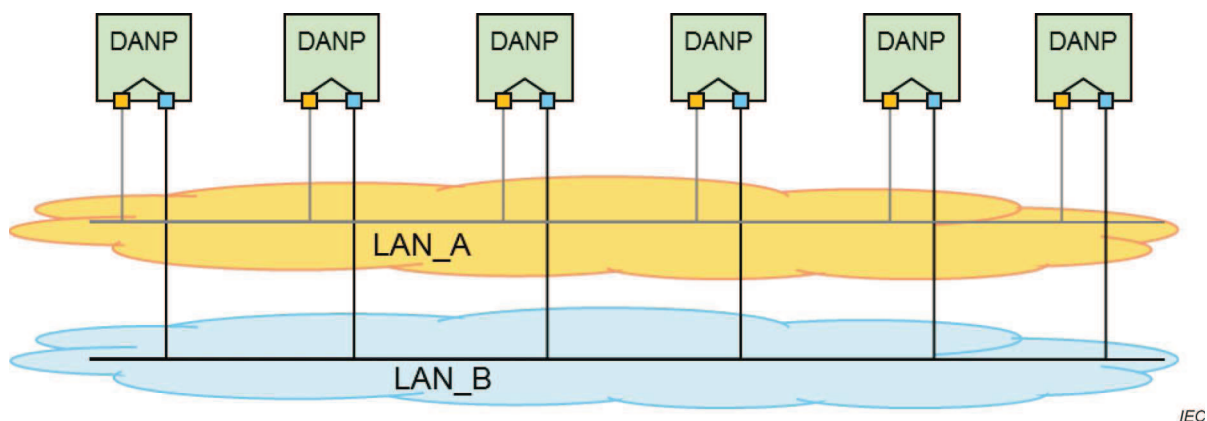


Figure 2 – PRP example of duplicated network in bus topology

4.1.3 PRP LANs with ring topology

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

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

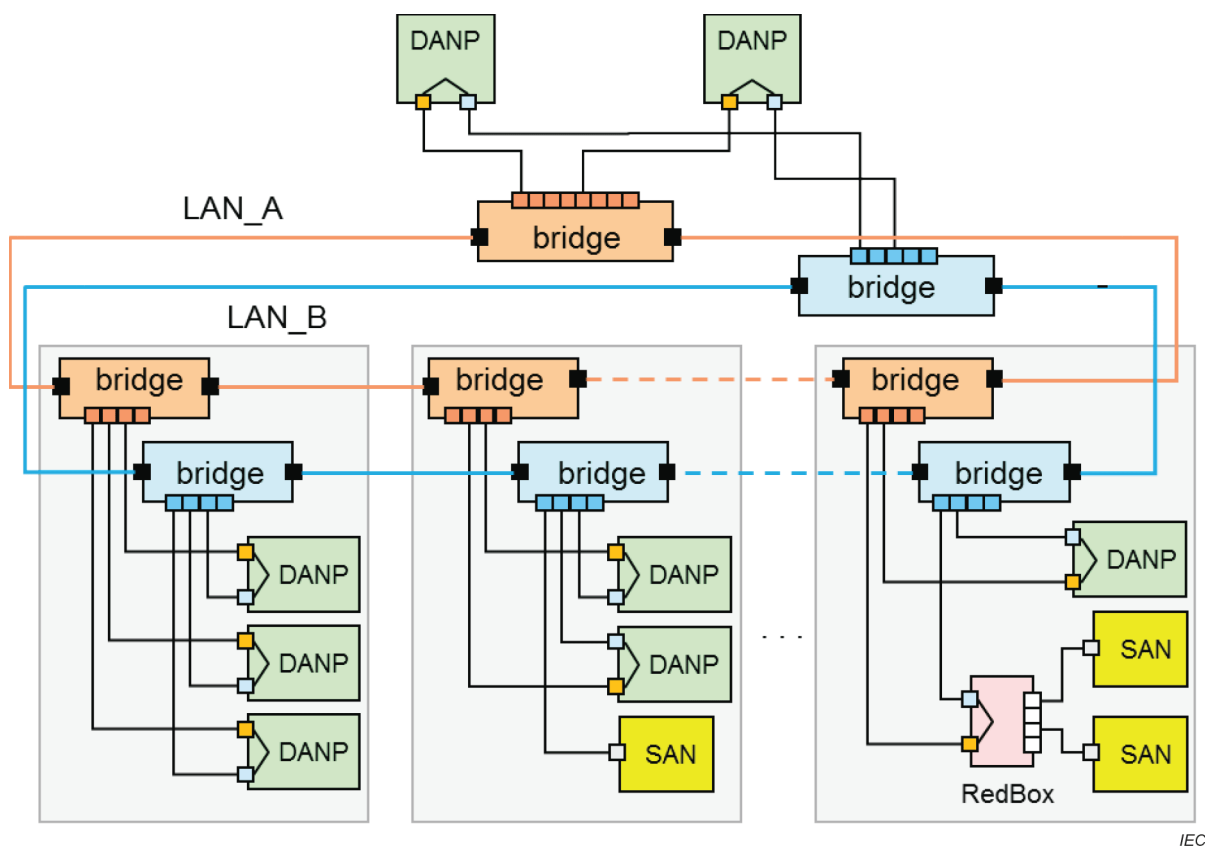


Figure 3 – PRP example of redundant ring with SANs and DANPs

4.1.4 DANP node structure

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

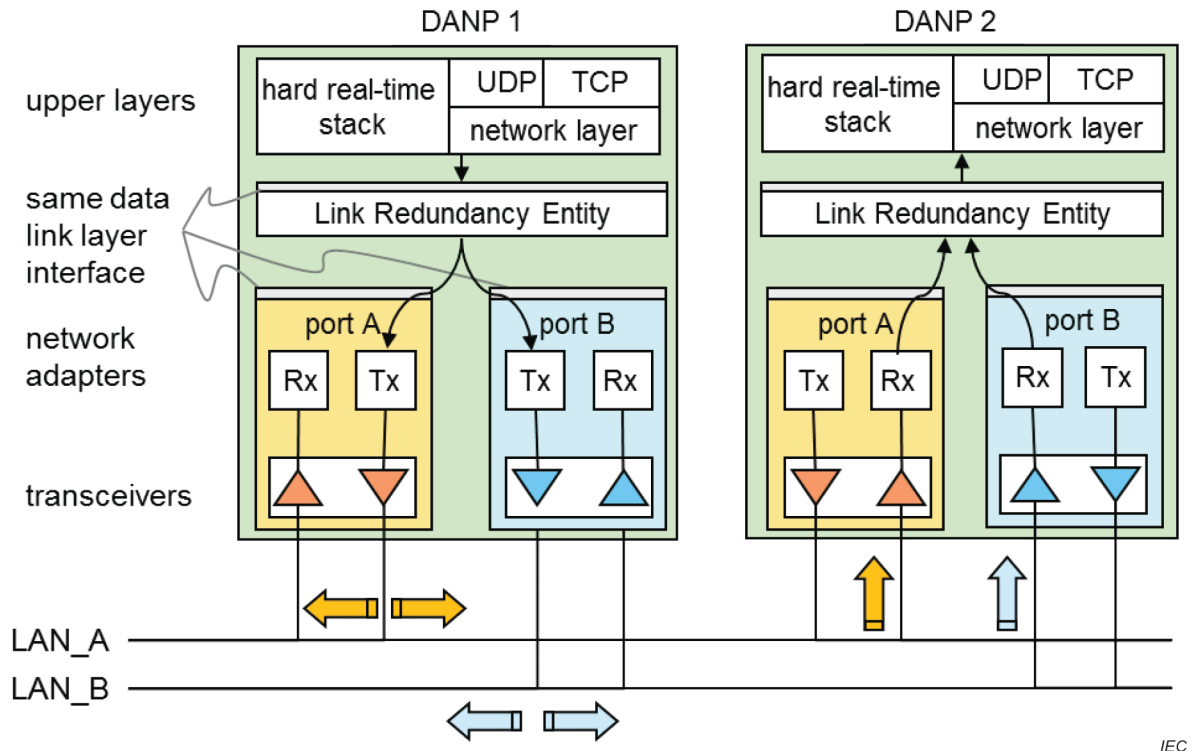


Figure 4 – PRP with two DANPs communicating

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

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

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

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

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

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

4.1.5 PRP attachment of singly attached nodes

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

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

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

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

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

4.1.6 Compatibility between singly and doubly attached nodes

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

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

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

4.1.7 Network management

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

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

4.1.8 Implication on application

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

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

4.1.9 Transition to a single-thread network

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

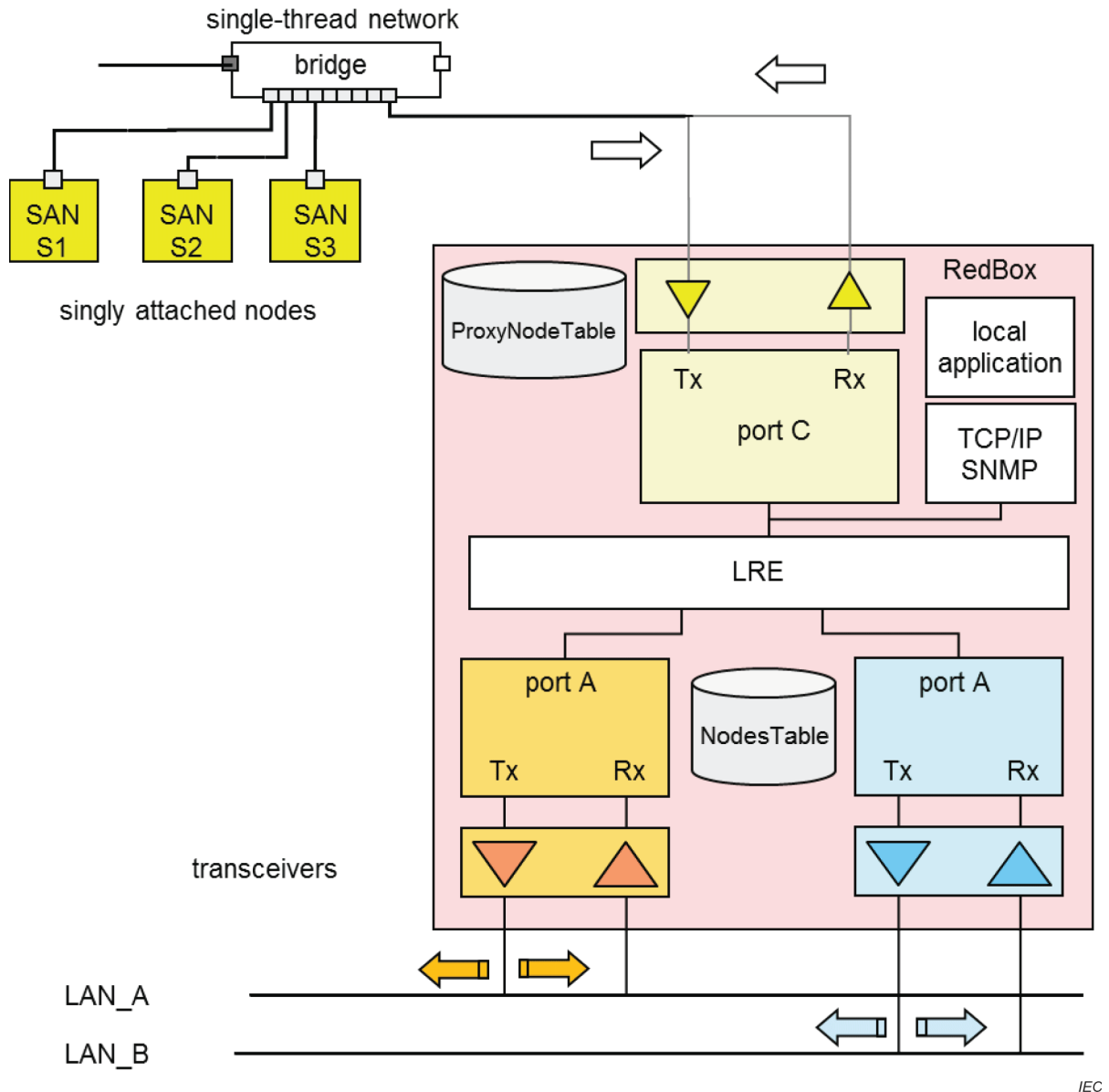


Figure 5 – PRP RedBox, transition from single to double LAN

4.1.10 Duplicate handling

4.1.10.1 Duplicate Accept mode (testing only)

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

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

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

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

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

4.1.10.2 Duplicate Discard mode

4.1.10.2.1 Principle

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

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

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

The RCT consists of the following fields:

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

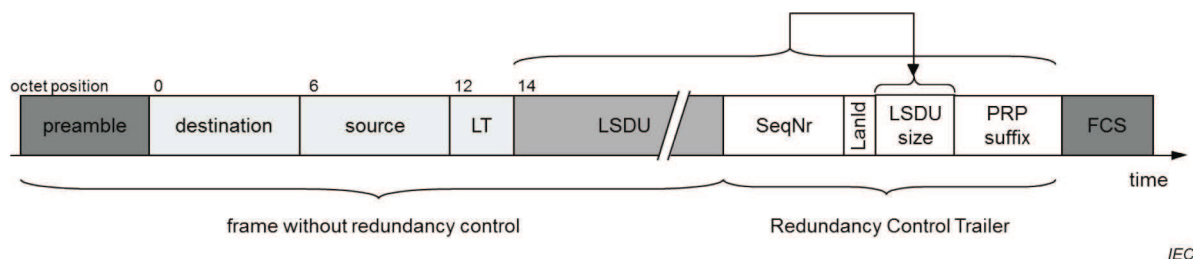


Figure 6 – PRP frame closed by an RCT

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

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

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

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

4.1.10.2.2 Use of PRPsuffix

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

4.1.10.2.3 Use of LSDUsize

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

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

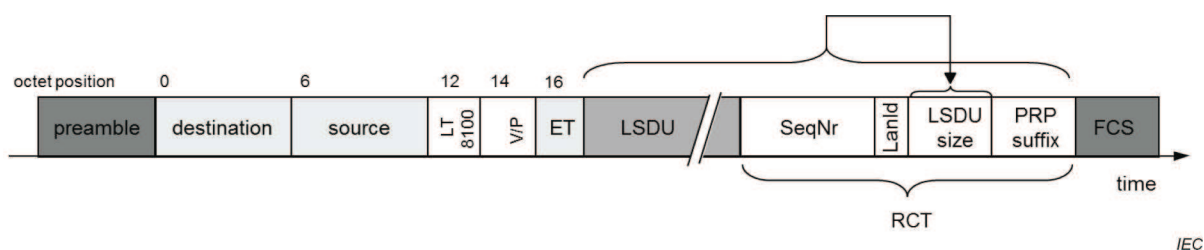


Figure 7 – PRP VLAN-tagged frame closed by an RCT

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

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

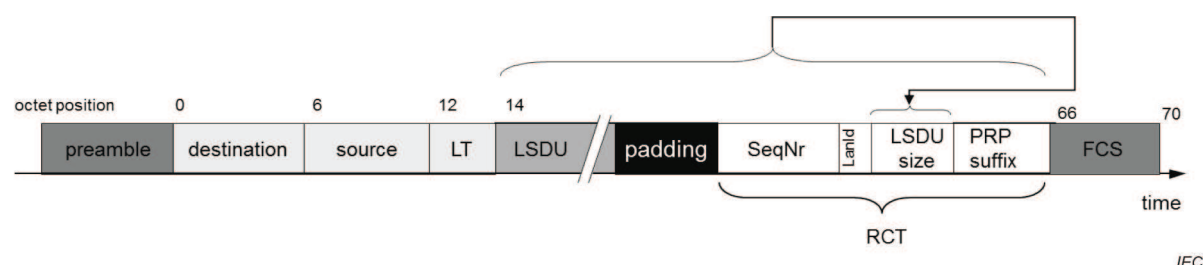


Figure 8 – PRP padded frame closed by an RCT

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

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

4.1.10.2.4 Use of LanId

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

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

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

4.1.10.2.5 Use of SeqNr

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

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

4.1.10.3 Duplicate discard algorithm and configuration

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

Figure 9 shows the conditions for discarding or accepting frames.

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

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

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

In a 100 Mbit/s network, t_{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_{aliasMin} is 44 ms.

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

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

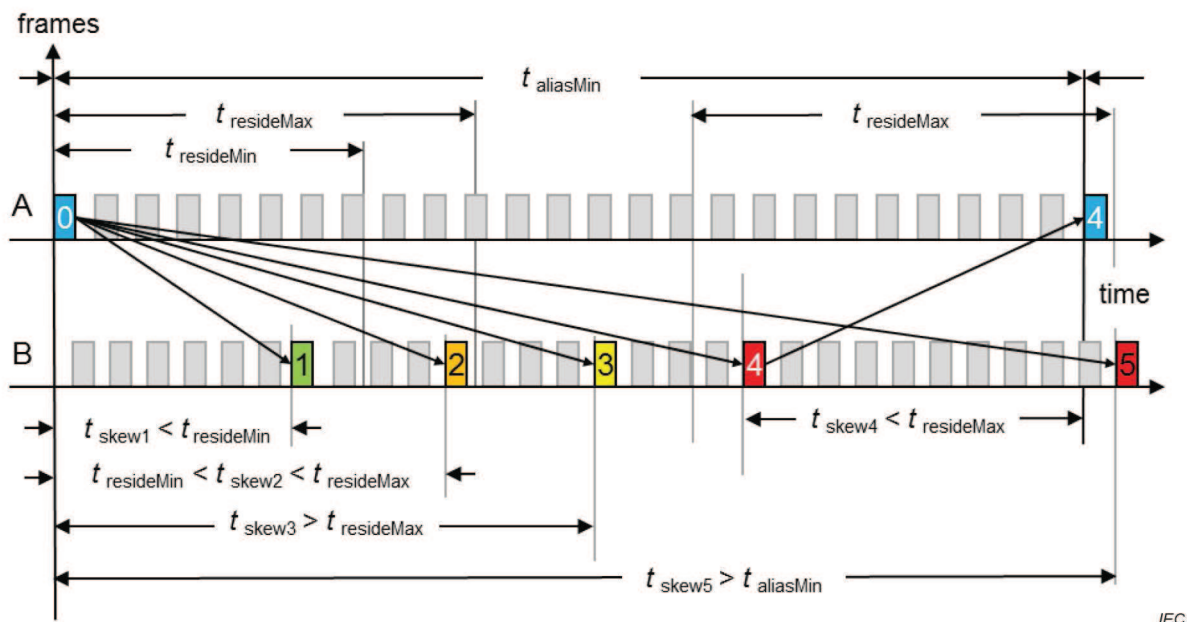


Figure 9 – Duplicate Discard algorithm boundaries

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

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

Table 1 – Duplicate discard cases

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

The conditions for correct operation are as follows:

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

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

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

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

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

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

4.1.10.4 Frame size restriction

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

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

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

4.1.11 Network supervision

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

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

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

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

4.1.12 Redundancy management interface

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

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

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

4.2 PRP protocol specifications

4.2.1 Installation, configuration and repair guidelines

4.2.1.1 General

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

4.2.1.2 LANs layout

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

DANP shall be attached to both LANs, by port A to LAN_A and by port B to LAN_B.

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

4.2.1.3 Labelling cables

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

If colours are used to identify the cables, cables in LAN_A should be orange and cables in LAN_B should be light blue.

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

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

4.2.1.4 Labelling bridges

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

4.2.1.5 Independent operation

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

4.2.1.6 Configuration

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

4.2.2 Unicast MAC addresses

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

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

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

4.2.3 Multicast MAC addresses

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

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

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

4.2.4 IP addresses

The IP address(es) of any node or bridge shall be unique within the whole network (LAN_A plus LAN_B).

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

A DANP shall have the same IP address(es) when seen from either LAN_A or LAN_B.

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

NOTE 2 A possible method is to distinguish IP addresses by one bit, e.g. allocate even IP addresses to LAN_A devices and odd IP addresses to LAN_B devices.

4.2.5 Node specifications

4.2.5.1 Node types

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

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

4.2.5.2 Labelling connectors

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

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

When connectors are ordered vertically, the port to LAN_A should be the upper connector and the port to LAN_B should be the lower connector of the PRP port pair, in the normal position of the device.

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

The redundant connectors shall be independently removable and insertable.

4.2.6 Duplicate Accept mode (testing only)

4.2.6.1 Sending

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

4.2.6.2 Receiving

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

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

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

4.2.7 Duplicate Discard mode

4.2.7.1 Monitoring data set

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

Table 2 – Monitoring data set

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

4.2.7.2 NodesTable

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

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

Table 3 – NodesTable attributes

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

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

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

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

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

4.2.7.3 Redundancy Control Trailer (RCT)

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

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

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

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

4.2.7.4 Sending (Duplicate Discard mode)

4.2.7.4.1 Sending

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

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

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

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

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

4.2.7.4.2 Timing

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

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

4.2.7.5 Receiver (Duplicate Discard mode)

4.2.7.5.1 Receiving

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

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

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

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

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

4.2.7.5.2 Identification of frames associated with the Duplicate Discard mode

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

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

4.2.7.5.3 Duplicate Discard method

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

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

4.2.7.5.4 Transparent reception

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

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

4.2.7.5.5 Receiving and NodesTable

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

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

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

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

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

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

4.3 PRP_Supervision frame

4.3.1 PRP_Supervision frame format

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

Table 4 – PRP_Supervision frame with no VLAN tag

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0						msb	U/L	I/G								
2																
4									lsb							
6						msb	U/L	0								
8																
10									lsb							
12																
14																
16																
18																
20						msb	U/L	0								
22																
24									lsb							
26																
28						msb	U/L	0								
30																
32									lsb							
34																
36																
60																
62																
64																
66																
68																
70																

Table 5 – PRP_Supervision frame with (optional) VLAN tag

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0						msb	U/L	I/G								
2	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	LT (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																

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

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

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

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

4.3.2 PRP_Supervision frame contents

The contents of a PRP_Supervision frame are defined in Table 6.

Table 6 – PRP_Supervision frame contents

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

4.3.3 PRP_Supervision frame for RedBox

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

Table 7 – PRP_Supervision TLV for Redbox

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

4.3.4 Bridging node (deprecated)

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

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

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

4.4 Constants

The constant parameters are shown in Table 8.

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

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

Table 8 – PRP constants

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

4.5 PRP layer management entity (LME)

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

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

5 High-availability Seamless Redundancy (HSR)

5.1 HSR objectives

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

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