

DIN EN 62439-3

ICS 35.110

Ersatz für
DIN EN 62439-3:2010-09
Siehe Anwendungsbeginn

**Industrielle Kommunikationsnetze –
Hochverfügbare Automatisierungsnetze –
Teil 3: Parallelredundanz-Protokoll (PRP) und nahtloser
Hochverfügbarkeits-Ring (HSR)
(IEC 62439-3:2012);
Englische Fassung EN 62439-3:2012**

Industrial communication networks –
High availability automation networks –
Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy
(HSR)
(IEC 62439-3:2012);
English version EN 62439-3:2012

Réseaux industriels de communication –
Réseaux d'automatisme à haute disponibilité –
Partie 3: Protocole de redondance parallèle (PRP) et redondance transparente de haute
disponibilité (HSR)
(CEI 62439-3:2012);
Version anglaise EN 62439-3:2012

Gesamtumfang 88 Seiten

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Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2012-08-09 angenommene Europäische Norm als DIN-Norm ist 2013-06-01.

Für DIN EN 62439-3:2010-09 besteht eine Übergangsfrist bis 2015-08-09.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN 62439-3/A1:2011-08.

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

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Änderungen

Gegenüber DIN EN 62439-3:2010-09 wurden folgende Änderungen vorgenommen:

- a) Festlegung der Verbindung zwischen PRP- und HSR-Netzen;
- b) Einführung eines Zusatzes für PRP-Rahmen;
- c) Verbesserungen im Hinblick auf Interoperabilität;
- d) Lockerung der Spezifikation, um verschiedene Ausführungen zu ermöglichen;
- e) Berücksichtigung der Uhrzeitsynchronisation nach IEC 61588;
- f) Einführung einer Prüfbetriebsart, um Prüfen und Instandhaltung zu unterstützen.

Frühere Ausgaben

DIN EN 62439: 2009-01
DIN EN 62439-3: 2010-09

Nationaler Anhang NA (informativ)

3.1 Begriffe

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

3.1.1

interlink

(en: **interlink**)

Verbindung, die zwei Netzwerkhierarchien miteinander koppelt

3.1.2

RedBox

(en: **RedBox**)

Gerät, das einfach angebundene Netzwerkteilnehmer mit einem redundanten Netzwerk verbindet

3.1.3

QuadBox

(en: **QuadBox**)

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

3.1.4

HSR-Datenrahmen

(en: **HSR frame**)

Datenrahmen, der als auszeichnendes Merkmal „EtherType“ den HSR_ethertype trägt

3.1.5

Vermittlungslogik

(en: **switching logic**)

Hardware, die einen Datenrahmen von einem Netzanschluss an einen anderen Netzanschluss vermittelt, unter Umständen durch Verwendung von cut-through-Übertragung

ANMERKUNG 1 zum Begriff: In diesem Dokument werden die Begriffe „Netzwerkbrücke (en: bridge)“ beziehungsweise „bridging“ und „Netzwerkweiche (en: switch)“ beziehungsweise „switching“ synonym verwendet, wenn sie angewendet werden, um Verbindungen auf der Sicherungsschicht („layer 2“) zu beschreiben.

– Leerseite –

English version

**Industrial communication networks -
High availability automation networks -
Part 3: Parallel Redundancy Protocol (PRP) and High-availability
Seamless Redundancy (HSR)
(IEC 62439-3:2012)**

Réseaux industriels de communication -
Réseaux d'automatisme à haute
disponibilité -
Partie 3 : Protocole de redondance
parallèle (PRP) et redondance
transparente de haute disponibilité (HSR)
(CEI 62439-3:2012)

Industrielle Kommunikationsnetze -
Hochverfügbare Automatisierungsnetze -
Teil 3: Parallelredundanz-Protokoll (PRP)
und nahtloser Hochverfügbarkeits-Ring
(HSR)
(IEC 62439-3:2012)

This European Standard was approved by CENELEC on 2012-08-09. 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.

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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CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Foreword

The text of document 65C/687/FDIS, future edition 2 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 62439-3:2012.

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) 2013-05-09
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-08-09

This document supersedes EN 62439-3:2010.

EN 62439-3:2012 includes the following significant technical changes with respect to EN 62439-3:2010:

- specification of the interconnection of PRP and HSR networks;
- introduction of a suffix for PRP frames;
- clarification and modification of specifications to ensure interoperability;
- slackening of the specifications to allow different implementations;
- consideration of clock synchronization according to IEC 61588;
- introduction of test modes to simplify testing and maintenance.

This standard is to be used in conjunction with EN 62439-1:2010.

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

Endorsement notice

The text of the International Standard IEC 62439-3:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 61580 series NOTE Harmonized in EN 61580 series (not modified).

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0 INTRODUCTION

0.1 General

IEC 62439-3 standard belongs to IEC 62439 series, *Industrial communication networks – High availability automation networks*, specifying the HSR and PRP redundancy protocols, and was adopted by TC57 WG10 as the redundancy method for demanding substation automation networks based on IEC 61850 series, introducing new requirements.

0.2 Changes with respect to the previous edition

The major changes with respect to IEC 62439-3:2010 are listed below.

Aligning the sequence number between PRP and HSR, to enable coupling of HSR and PRP networks and simplify the implementation of dual-mode nodes in hardware. At the same time, introduce a suffix in the PRP Redundancy Control Trailer to allow better identification, future extensions and coexistence with other protocols that also happen to use a trailer. This change is not backwards-compatible, so means are provided to identify the version and ensure that the networks are homogeneous.

Removing all implementation restrictions on the Duplicate Discard algorithm (especially references to the drop window algorithm and references to connection orientation) since other methods such as hash tables can be used.

Removing the purging of the duplicate table. Replace this specific method by requiring that any Duplicate Discard algorithm provides a mechanism to remove old entries, thus ensuring that a node can properly reboot.

Making node tables optional for simple nodes to simplify hardware implementation.

Suppression of explicit mention of the HSR-PRP mode (PRP with HSR Tags), but allow it through the Mode N (no forwarding).

Introducing Mode T (forward through) to allow maintenance laptops to configure an open ring when attached to one end and Mode M (mixed) to allow forwarding of non-HSR-tagged frames in a closed ring.

Recommending the position of connectors, rather than impose it.

Defining the behaviour of an HSR node when non-HSR frames are encountered without requiring the recording of the source addresses and specify how IEEE 802.1D:2004, Table 7-10 frames are treated.

Prefixing the supervision frames on HSR by an HSR tag to simplify the hardware implementation and introduce a unique EtherType for HSR to simplify processing.

Changing the rule for the RedBox to allow more than one PRP network to be connected to an HSR ring, and introduce an identifier per RedBox pair.

Specifying tagging of IEC 61588 frames to follow IEEE C37.238 recommendations (informal).

Suppressing MAC address substitution.

Adapting the MIB to above changes.

0.3 Patent declaration

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning Filtering of redundant frames in a network node given in 5.2.3.3.

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

The holder of this patent right has assured the IEC that he/she 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:

Siemens Aktiengesellschaft
80333 München, Germany

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning Reception of redundant and non-redundant frames (ABB Schweiz AG – WO 2006/053459 A1, EP 1825657, US 20070223533, CN 101057483) given in 4.2.7, concerning Identifying improper cabling of devices (ABB Schweiz AG – EP 2 015 501 A1) given in 4.3, concerning Critical device with increased availability (ABB Schweiz AG – EP 2 090 950 A1) given in 4.4, concerning Ring coupling nodes for high availability networks (ABB Schweiz AG – WO 2010/010120 A1) given in 5.2.3.

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INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

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

1 Scope

The IEC 62439 series is applicable to high-availability automation networks based on the ISO/IEC 8802-3 (Ethernet) technology.

This part of the IEC 62439 series specifies two 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: duplication of the LAN, resp. duplication of the transmitted information.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Precision clock synchronization protocol for networked measurement and control systems*

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

IEC 62439-2, *Industrial communication networks – High availability automation networks – Part 2: Media Redundancy Protocol (MRP)*

IEC 62439-6, *Industrial communication networks – High availability automation networks – Part 6: Distributed Redundancy Protocol (DRP)*

IEC 62439-7, *Industrial communication networks – High availability automation networks – Part 7: Ring-based Redundancy Protocol (RRP)*

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

IEEE 802.1D:2004, *IEEE Standard for Local and Metropolitan Area Networks – Media Access Control (MAC) Bridges*

IEEE 802.1Q:2011, *IEEE Standard for Local and Metropolitan Area Networks – Media Access Control (MAC) Bridges and Virtual Bridge Local Area Network*

3 Terms, definitions, abbreviations, acronyms, and conventions

3.1 Terms and definitions

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

3.1.1

interlink

link that connects two network hierarchies

3.1.2

RedBox

device attaching single attached nodes to a redundant network

3.1.3

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

3.1.4

HSR frame

frame that carries as EtherType the HSR_ethertype

3.1.5

switching logic

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

Note 1 to entry: In this document, the words “bridge” respectively “bridging” are synonymous to the words “switch”, respectively “switching” when they apply to layer 2 connectivity.

3.2 Abbreviations and acronyms

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

CoS	Class of Service (layer 2 quality of service)
DANH	Double attached node implementing HSR
DANP	Double attached node implementing PRP
RCT	Redundancy Check Trailer
VDAN	Virtual Doubly Attached Node (SAN as visible through a RedBox)

3.3 Conventions

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

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, using doubly attached nodes obeying to 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 redundant network consisting of two LANs, each of which can have any topology, e.g. tree, ring or meshed.

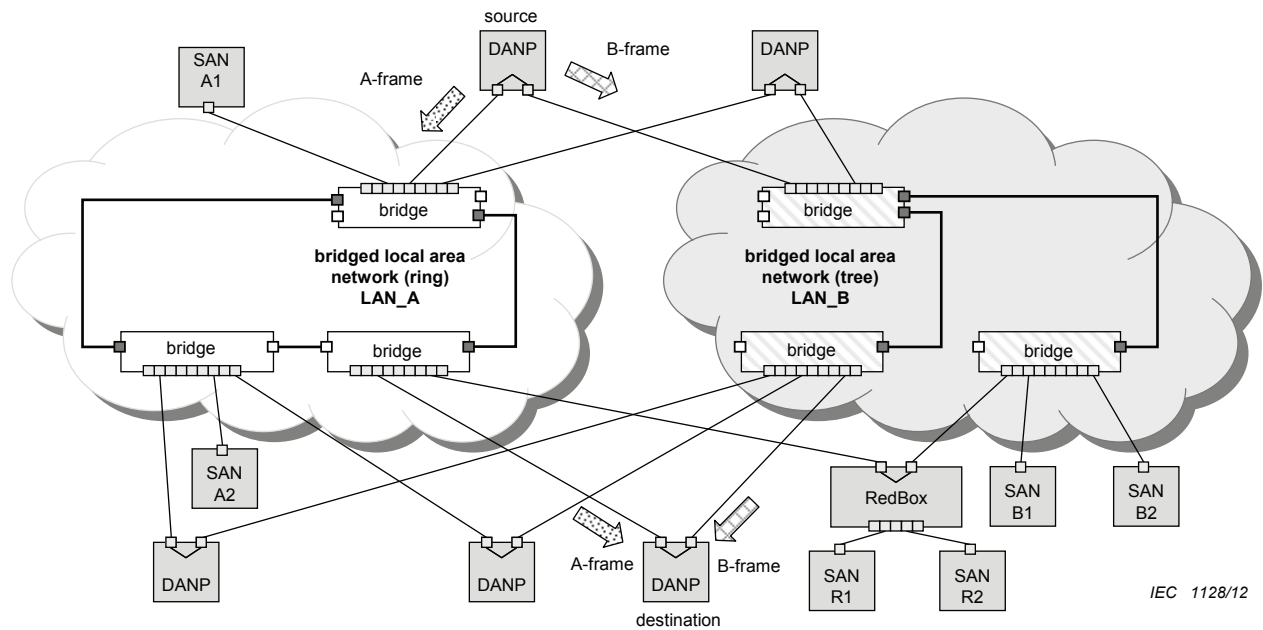


Figure 1 – PRP example of general redundant network

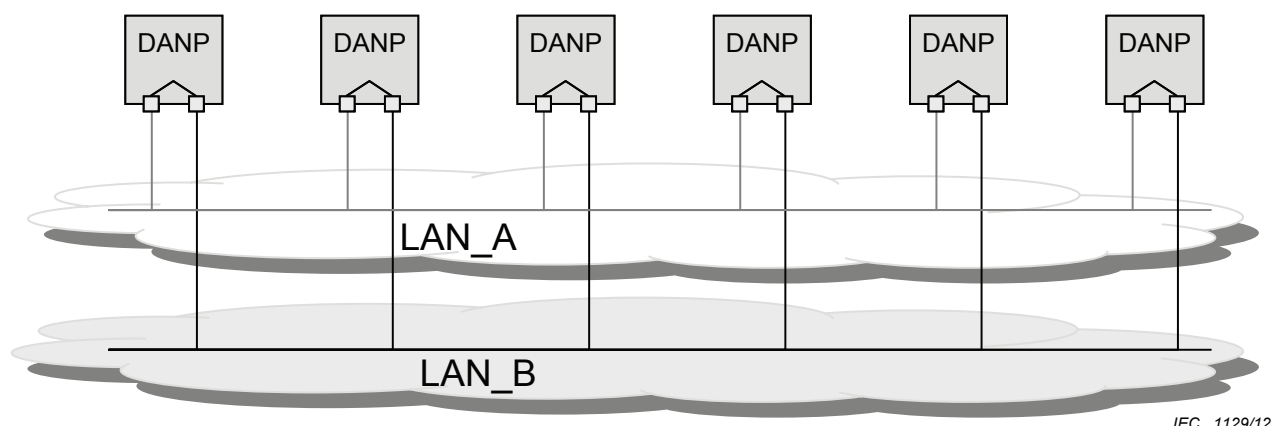
The two LANs are identical in protocol at the MAC-LLC level, but they can differ in performance and topology. Transmission delays may also be different, especially if one of the networks reconfigures itself, e.g. using RSTP, to overcome an internal failure.

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 the installer 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.

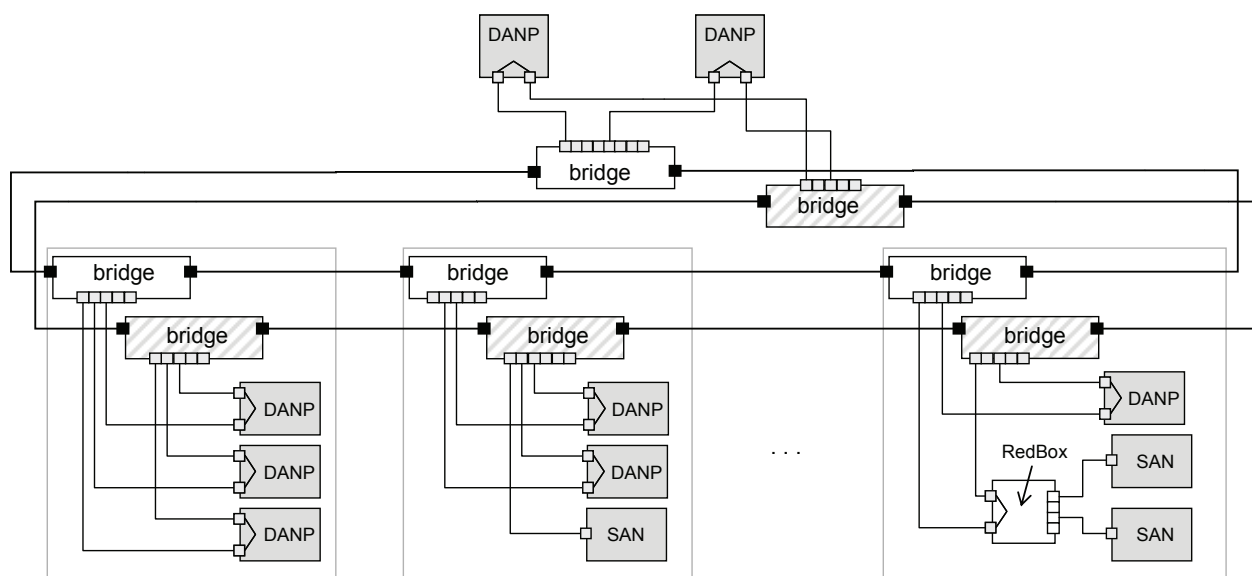


IEC 1129/12

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.



IEC 1130/12

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

NOTE In this case ring redundancy is provided by a different mechanism, for instance as defined in IEEE 802.1D or in other IEC 62439 protocols, i.e. MRP.

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.

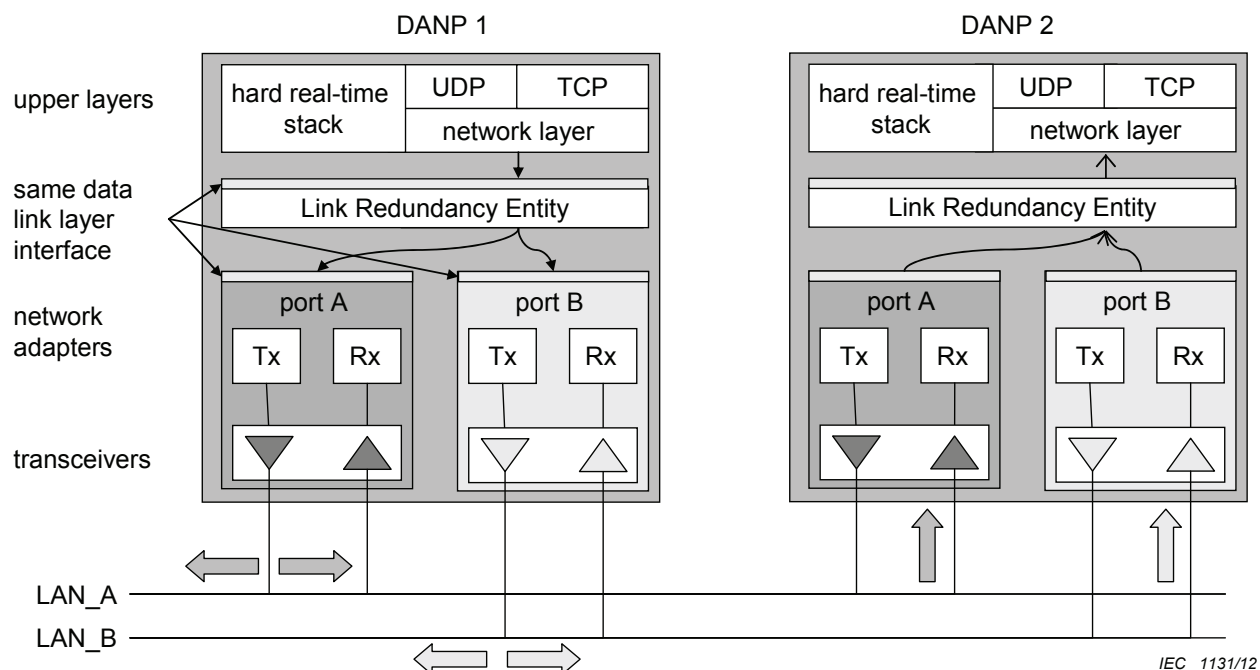


Figure 4 – PRP with two DANPs communicating

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 RedBox (redundancy box) 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 SANs are not aware of PRP; they can be off-the-shelf computers or printers.

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 according to IEEE 802.1D. 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. These abilities are optional and not detailed in this International Standard. The supported mode is specified in the PICS (see 5.9).

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 always 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 should be 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 a 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 only one set of IP addresses assigned to that address. This makes redundancy transparent to the upper layers and especially allows the Address Resolution Protocol (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 and can access nodes and bridges in both LANs.

4.1.8 Implication on configuration

Since the same frame can come from the two ports with significant time difference, a frame could be wrongly rejected as duplicate in exceptional situations, so mechanisms exist to age out frames, which is seldom cases cause both duplicates to be accepted – a situation applications tolerate. Possibly the heaviest traffic comes from sampled data, whose period should be chosen considering the worst-case difference in propagation delays.

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.

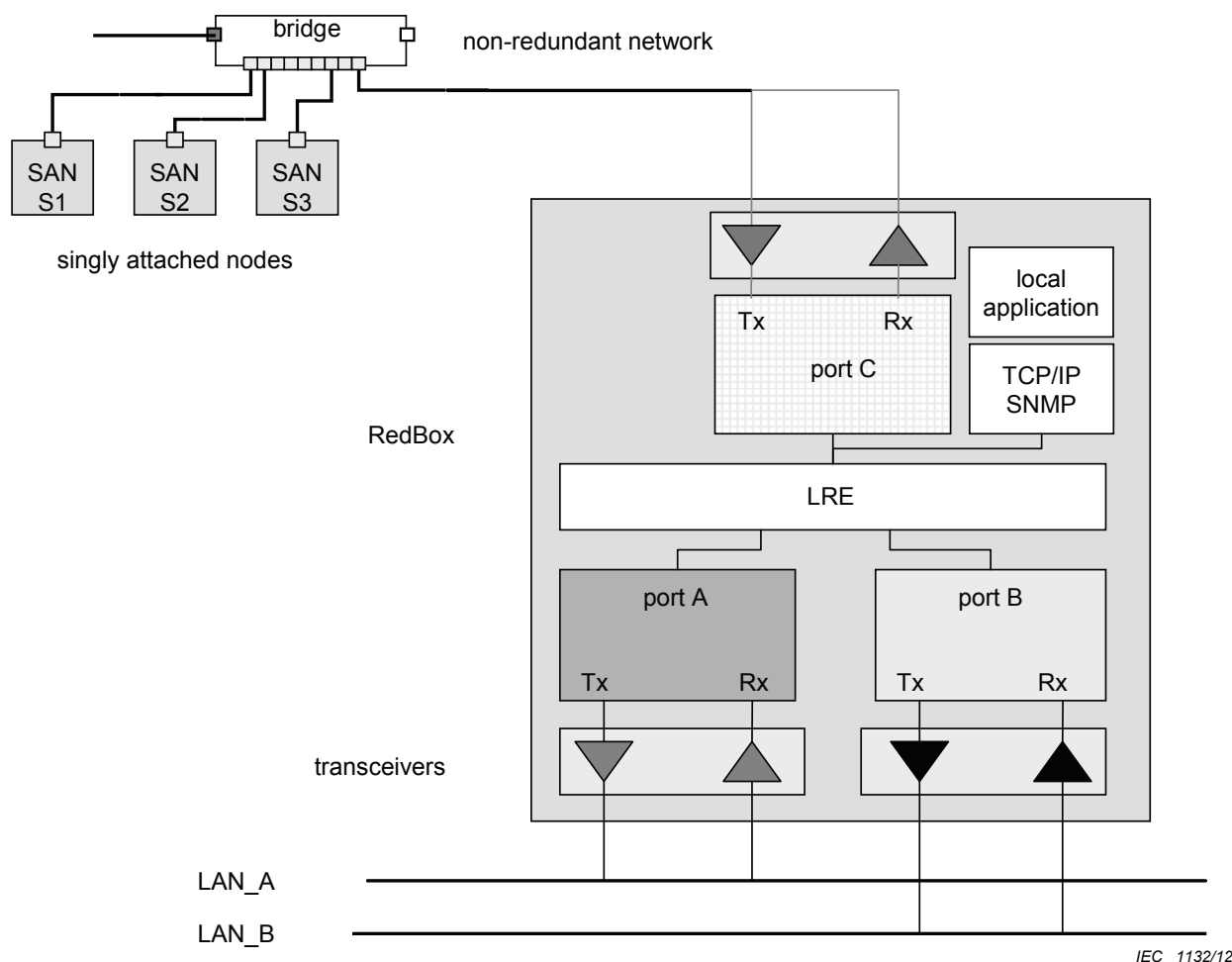


Figure 5 – PRP RedBox, transition from single to double LAN

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 this mode, a sender is configured to send both frames without RCT.

In this 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 do this, 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).

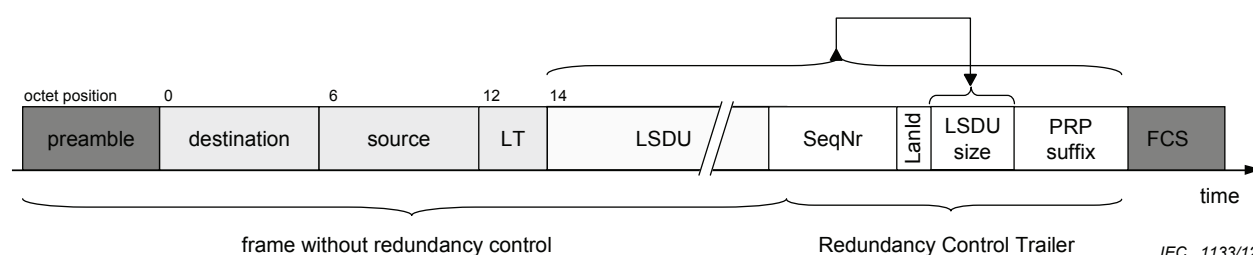


Figure 6 – PRP frame extended by an RCT

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 PRPsuffix, same sequence number and the same size. However, SANs send on one LAN only, and the source will not be the same as that of another frame, so 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, the DANP nevertheless 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. This 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.

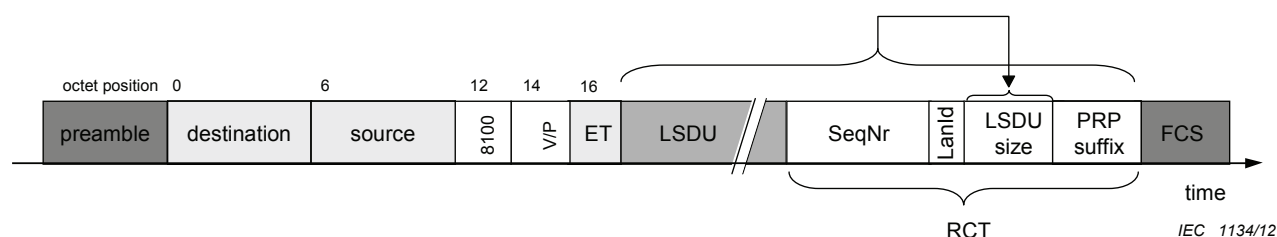


Figure 7 – PRP VLAN-tagged frame extended by an RCT

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.

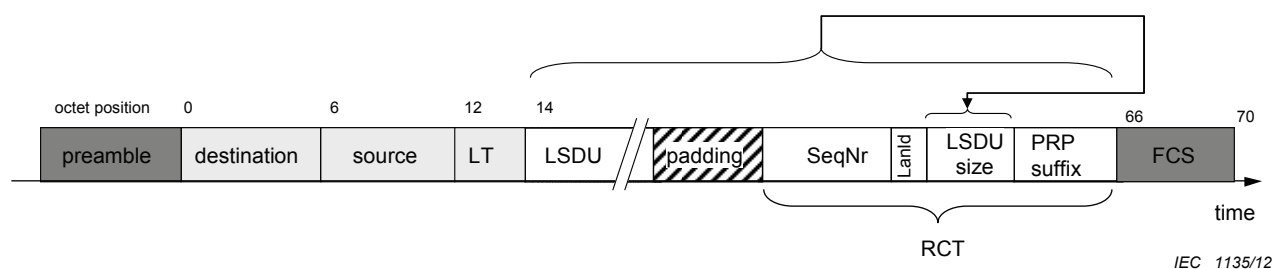


Figure 8 – PRP padded frame closed by an RCT

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 ISO/IEC 8802-3 rule to send a minimum frame size of 68 octets for a VLAN-tagged frame and of 64 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 a DANP sends. The doublet {source MAC address, sequence number} uniquely identifies copies of the same frame.

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. This also allows node reboot at any sequence number position.

The diagram illustrates five cases for duplicate detection in a table-based system. It shows two horizontal timelines, A and B, with various time intervals marked. The top timeline A represents the 'SeqNr = X' and the bottom timeline B represents the 'SeqNr = X' as well. The time intervals are defined as follows:

- $t_{wrapMin}$: The time interval between the start of the first frame and the start of the next frame.
- $t_{resideMin}$: The minimum time a frame can stay in the table.
- $t_{resideMax}$: The maximum time a frame can stay in the table.
- t_{skew1} : The time skew between the start of the first frame and the start of the next frame.
- t_{skew} : The time skew between the start of the first frame and the start of the next frame.
- $t_{residenceMax}$: The maximum time a frame can stay in the table.

The cases are summarized in the following table:

Case	SeqNr Status	Duplicate Detection	Condition
Case 1	SeqNr in table.	Duplicate always detected	$t_{skew} < t_{resideMin}$
Case 2	SeqNr possibly in table.	Duplicate sometimes not detected, treated as new	
Case 3	SeqNr out of table.	Duplicate treated as new frame -> SeqNr now in table, only safe if	$t_{residenceMax} < t_{wrapMin}$
Case 4	SeqNr still in table.	Next alias frame discarded as duplicate danger !	
Case 5	SeqNr in table.	Duplicate detected on wrong alias	

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The time t_{wrapMin} is the minimum possible time between two repetitions of the same sequence number by legitimate frames after 65 536 increments (as dictated by the application and network constraints).

The time t_{skew} is the time difference between the arrivals of two copies of the same frame.

Rules for reliable discard: $t_{\text{skew}} < t_{\text{resideMin}}$

Rule for safe accept: $t_{\text{residenceMax}} < t_{\text{aliasRepMin}}$

A node that reboots avoids generating aliases by not sending frames during a time longer than `EntryForgetTime` (see Table 4) on start-up. During this time, the receivers will age out the entry from the duplicate tables.

4.1.10.2.6 Frame size restriction

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

Hence, it is expected that every network component in the LANs supports oversized frames up to `maxValidSize` foreseen by ISO/IEC 8802-3 plus 6 bytes of RCT (1 528 octets).

NOTE Many bridges are dimensioned for double-VLAN-tagged (non- ISO/IEC 8802-3 compliant) frames that have a maximum size of 1 526 octets. Most Ethernet controllers are certified up to 1 528 octets. Most bridges would forward correctly frames of up to 1 536 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 this 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. This allows using the same tools for managing the nodes and the bridges.

NOTE SNMP is part of the IP protocol suite.

4.2 PRP protocol specifications

4.2.1 Installation, configuration and repair guidelines

4.2.1.1 General

The following guidelines apply at installation time. 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.

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 identified as A and B.

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

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

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 4.5).

4.2.2 MAC addresses

Both ports A and B of a DANK shall be configured with the same MAC address.

This 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 (LAN_A plus LAN_B) shall be unique within the whole network.

NOTE 1 A device may have several IP addresses.

A DANK 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 scheme 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 (DANK) shall have two ports (portA and portB) that have the same abilities, and in particular could be used alternatively if only one LAN would be connected, portA being connected to LAN_A and portB 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

This subclause applies to a DANK using two LANs of similar nature.

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

When connectors are ordered vertically, LAN_A should be the upper connector and LAN_B the lower connector in its normal position.

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.

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.

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 following elements:

SendSeq	mandatory	A 16-bit sequence counter used by this node for sending
CntErrorA and CntErrorB	optional	For each port A and B, a 32-bit counter indicating the number of erroneous frames received
CntReceivedA and CntReceivedB	optional	For each port A and B, a 32-bit counter indicating the number of frames received
CntErrWrongLanA and CntErrWrongLanB	optional	For each port A and B, a 32-bit counter indicating the number of mismatches
ActiveA and ActiveB	optional	For each port A and B, the status of the communication link
NodesTable	optional	A table of all other nodes that this node detects

4.2.7.2 NodesTable

A node may maintain a NodesTable for the purpose of network supervision. If a NodesTable is used, it shall consist of the elements given in Table 1 for each entry.

Table 1 – 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 portA	Boolean1
SanB	True if the remote node is most probably a SAN accessible over portB	Boolean1

A node shall clear a NodesTable entry when the time elapsed since reception of a frame from that a given 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. A node could send frames without an RCT and over one port only if it can identify the destination as a SAN. 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 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 1st 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, respectively the sequence “1011” for LAN_B;
- 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 8802-3 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.

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 destination node is not registered as a SAN in the 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 8802-3

 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 8802-3

 increment SendSeq (see 4.2.7.1), wrapping over through 0;

 append the 6-octet RCT with a LanId "A" for portA and LanID "B" for portB;

 append the 4-octet FCS;

 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;

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

NOTE 2 The total padding to 70 octets (no VLAN tag) considers that the LRE or a RedBox could remove the 6-octet RCT; padding to 74 (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 always 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 erroneous,

 increment the error counter of the respective port CntErrorsA or CntErrorsB (see 4.2.7.1) and

 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 it;

Else

 forward the frame to the upper layers.

NOTE Frames with a destination MAC address according to IEEE 802.1Q -2004 Table 7-10 are treated at the link layer and expected not to carry an RCT, even if sent by a DANP.

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 ProtocolType PT, but including the RCT) and
- whose LanId matches the LAN identity of the receiving port, 1010 (A) or 1011 (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, while 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 4).

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:

If this frame is not a PRP_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, and 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. If the source is already in the NodesTable,
 update its 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.

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

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

4.3 PRP_Supervision frame

4.3.1 Supervision frame for DANP

Each DANP shall multicast a PRP_Supervision frame over both its ports with the format specified in Table 2 (no VLAN), respectively Table 3 (with VLAN) every LifeCheckInterval (see 4.5).