BS EN 62439-3:2012

BSI Standards Publication

Industrial communication networks — High availability automation networks

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

National foreword

This British Standard is the UK implementation of EN 62439-3:2012. It is identical to IEC 62439-3:2012. It supersedes BS EN 62439-3:2010 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee AMT/7, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2012

ISBN 978 0 580 73809 8

ICS 25.040.01; 35.040

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2012.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62439-3

September 2012

ICS 25.040; 35.040

Supersedes EN 62439-3:2010

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.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 62439-3:2012 E

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).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-191	-	International Electrotechnical Vocabulary (IEV) - 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	EN 62439-1	-
IEC 62439-2	-	Industrial communication networks - High availability automation networks - Part 2: Media Redundancy Protocol (MRP)	EN 62439-2	-
IEC 62439-6	-	Industrial communication networks - High availability automation networks - Part 6: Distributed Redundancy Protocol (DRP)	EN 62439-6	-
IEC 62439-7	-	Industrial communication networks - High availability automation networks - Part 7: Ring-based Redundancy Protocol (RRP)	EN 62439-7	-
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 - Virtual Bridged Local Area Networks	-	-

CONTENTS

INTRODUCTION

The IEC 62439 series specifies relevant principles for high availability networks that meet the requirements for industrial automation networks.

In the fault-free state of the network, the protocols of the IEC 62439 series provide ISO/IEC 8802-3 (IEEE 802.3) compatible, reliable data communication, and preserve determinism of real-time data communication. In cases of fault, removal, and insertion of a component, they provide deterministic recovery times.

These protocols retain fully the typical Ethernet communication capabilities as used in the office world, so that the software involved remains applicable.

The market is in need of several network solutions, each with different performance characteristics and functional capabilities, matching diverse application requirements. These solutions support different redundancy topologies and mechanisms which are introduced in IEC 62439-1 and specified in the other Parts of the IEC 62439 series. IEC 62439-1 also distinguishes between the different solutions, giving guidance to the user.

The IEC 62439 series follows the general structure and terms of IEC 61158 series.

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 detection of redundant frames given in 4.1.10.3, and concerning coupling of PRP and HSR LANs given in 5.4 (patent pending).

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 either free of charge or 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:

ABB Switzerland Ltd
Corporate Research
Segelhofstr 1K
5405 Baden
Switzerland

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

ISO (www.iso.org/patents) and IEC (http://www.iec.ch/tctools/patent_decl.htm) maintain on-line data bases of patents relevant to their standards. Users are encouraged to consult the data bases for the most up to date information concerning patents.

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 (IEEE 802.3) (Ethernet) technology.

This part of the IEC 62439 series specifies two redundancy protocols based on the duplication of the LAN, resp. duplication of the transmitted information, designed to provide seamless recovery in case of single failure of an inter-switch link or switch in the network.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-191:1990, *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*

IEC 62439-1:2010, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods*

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 Local and metropolitan area networks Media Access Control (MAC) Bridges*

IEEE 802.1Q*, IEEE standards for local and metropolitan area network. Virtual bridged local area networks*

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, apply, in addition to the following.

3.1.1
extended frame
frame that has been extended by a Redundancy Control Trailer

3.1.2

interlink
link that connects two network hierarchies

3.1.3
RedBox
device allowing to attach single attached nodes to a redundant network

3.1.4

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

3.1.5

HSR frame
frame that carries the HSR EtherType

3.2 Abbreviations and acronyms

For the purposes of this document, the following abbreviations and acronyms apply, in addition to those given in IEC 62439-1:

DANH	Double attached node implementing HSR
DANP	Double attached node implementing PRP
ICMP	Internet Control Message Protocol (part of the Internet protocol suite)
RCT	Redundancy Check Tag
SRP	Serial Redundancy Protocol
VDAN	Virtual Doubly Attached Node (SAN as visible through a RedBox)

3.3 Conventions

This document 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 devices, through doubly attached nodes operating according to PRP (DANPs).

A DANP is attached to two independent 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 switched LANs, which can have any topology, e.g. tree, ring or meshed.

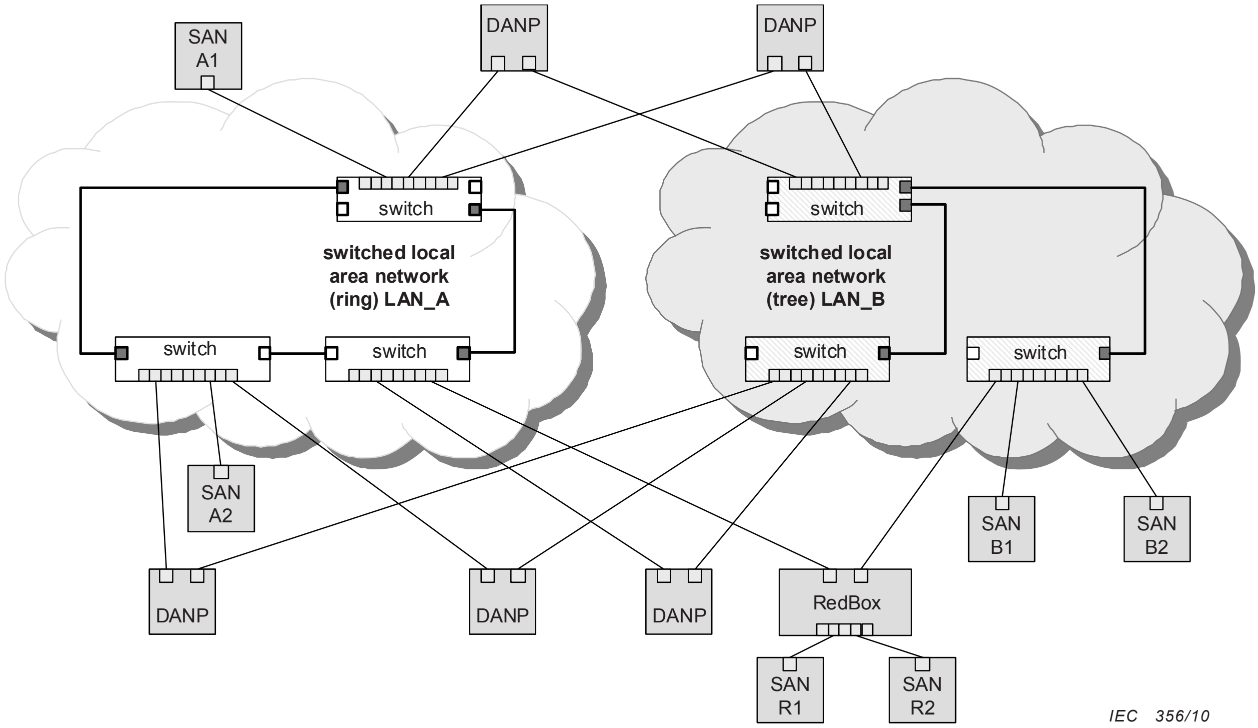


Figure 1 – PRP example of general redundant network

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) 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 configuration,

Figure 2 draws a PRP network as two LANs in linear topology, which may also be a bus topology.

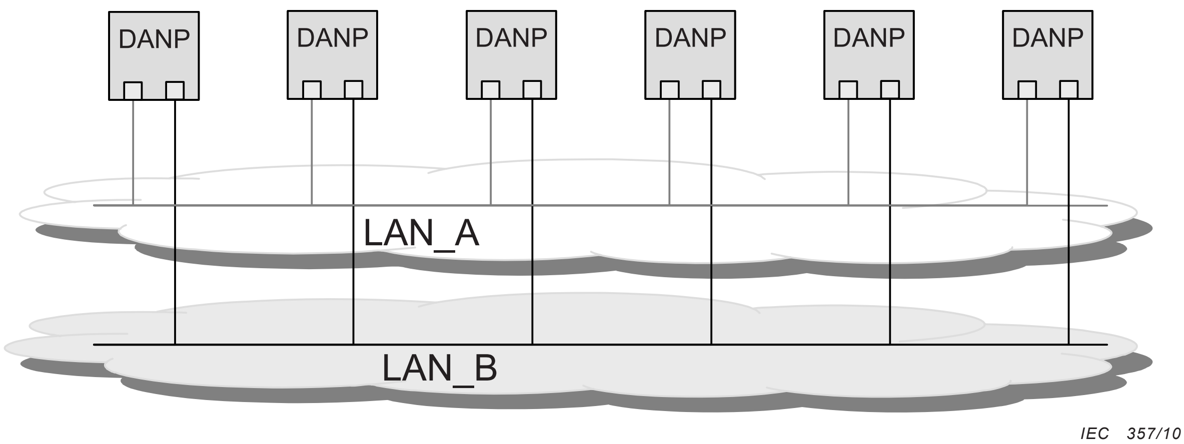


Figure 2 – PRP example of redundant network as two LANs (bus topology)

4.1.3 PRP LANs with ring topology

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

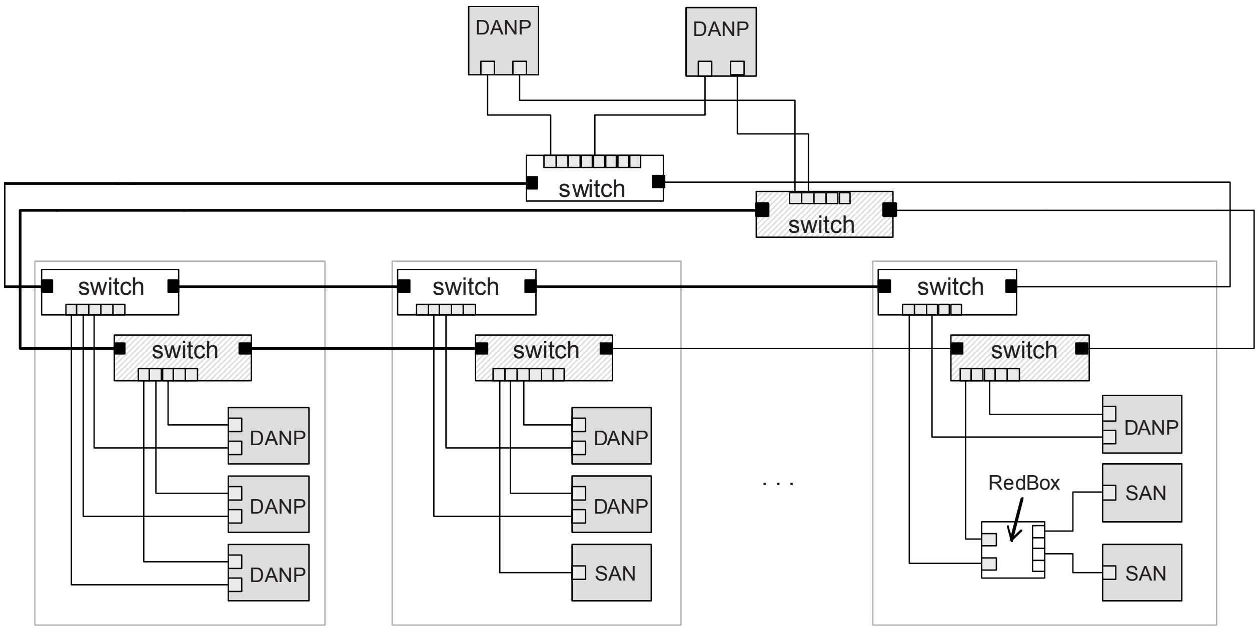


Figure 3 – PRP example of redundant ring with SANs and DANPs

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.

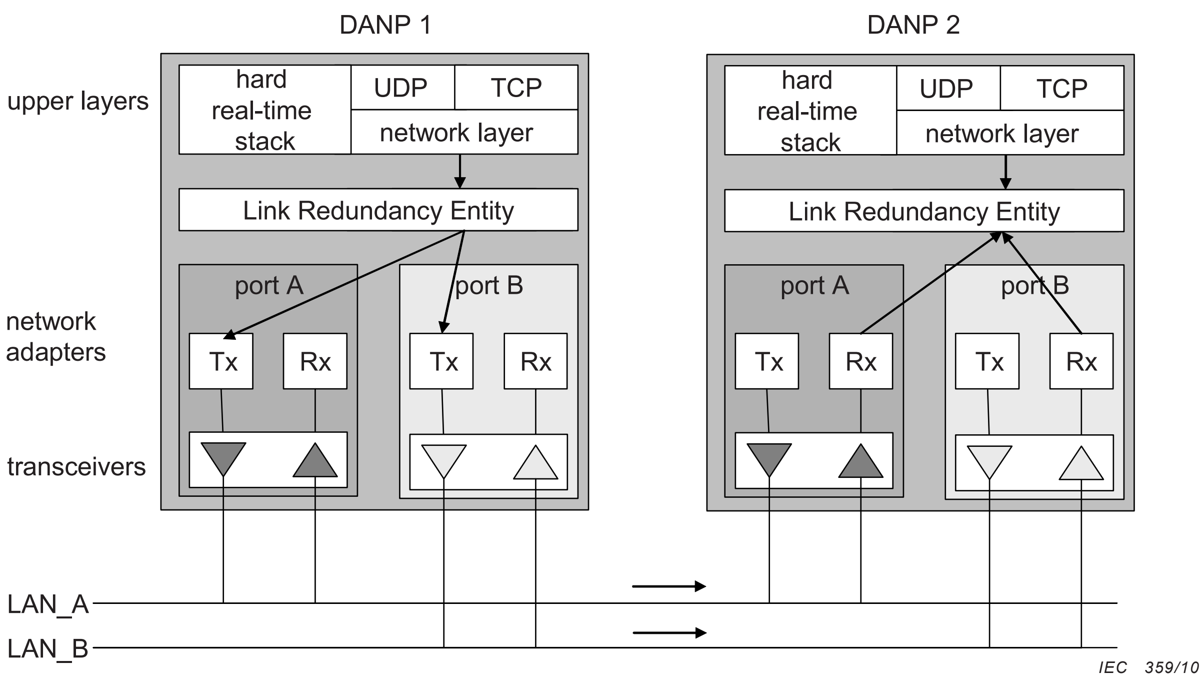


Figure 4 – PRP with two DANPs communicating

The Link Redundancy Entity (LRE) has two tasks: handling of duplicates and management of redundancy. This layer presents toward its upper layers the same interface as the network adapter of a non-redundant adapter.

When receiving a frame from the node's upper layers, the LRE sends the frame through both its ports at nearly the same time.

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

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

For management of redundancy, the LRE can append a Redundancy Check Trailer (RCT) including a sequence number to the frames it sends to keep track of duplicates. In addition, the LRE periodically sends PRP_Supervision frames and evaluates the PRP_Supervision frames of the 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. 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 with all DANPs.
- SANs can be attached over a RedBox (redundancy box) to both LANs, as Figure 1 shows for R1 and R2 (see also 4.1.9). Such SANs can communicate with all SANs, for instance SAN A1 and SAN R1 can communicate.

NOTE SANs do not need to be aware of PRP, they can be off-the-shelf computers.

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 switches 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 switch element according to IEEE 802.1D. For instance, the switch element may implement the MRP protocol, 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 6).

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. A SAN connected to one LAN cannot communicate directly to a SAN connected to the other LAN. Switches are always SANs. These SANs are not aware of PRP redundancy, so 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 ISO/IEC 8802-3 (IEEE 802.3) 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. If a DANP cannot positively identify that the remote device is a DANP, it considers it as a SAN.

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. Especially, this allows the Address Resolution Protocol (ARP) to work the same as with a SAN. Switches in a LAN are not doubly attached devices, and therefore all managed switches have different IP addresses. A network management tool is preferably a DANP and can access nodes and switches as if they all belong to the same network. Especially, network management implemented in a DANP is able to see SANs connected to either LAN.

Some applications require different MAC addresses on the redundant ports, and these MAC addresses may be different from the default MAC address of that node. This involves address substitution mechanisms which are not specified in this International Standard. However, the basic protocol and the frame format are prepared for such extension. Nodes that support MAC address substitution are indicated as supporting PICS_SUBS.

4.1.8 Implication on configuration

Since the same frame can come from the two ports with significant time difference, the period of cyclic time-critical data must be chosen so that it considers the difference between worst case and best case path latency between publisher and subscriber.

4.1.9 Transition to non-redundant networks

The mechanism of duplicate rejection can be implemented by the 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 VDA or virtual DANs) and multicasts supervision frames on their behalf, appending its own information. The RedBox is itself a DANP and has its own IP address for management purposes, but it may also perform application functions.

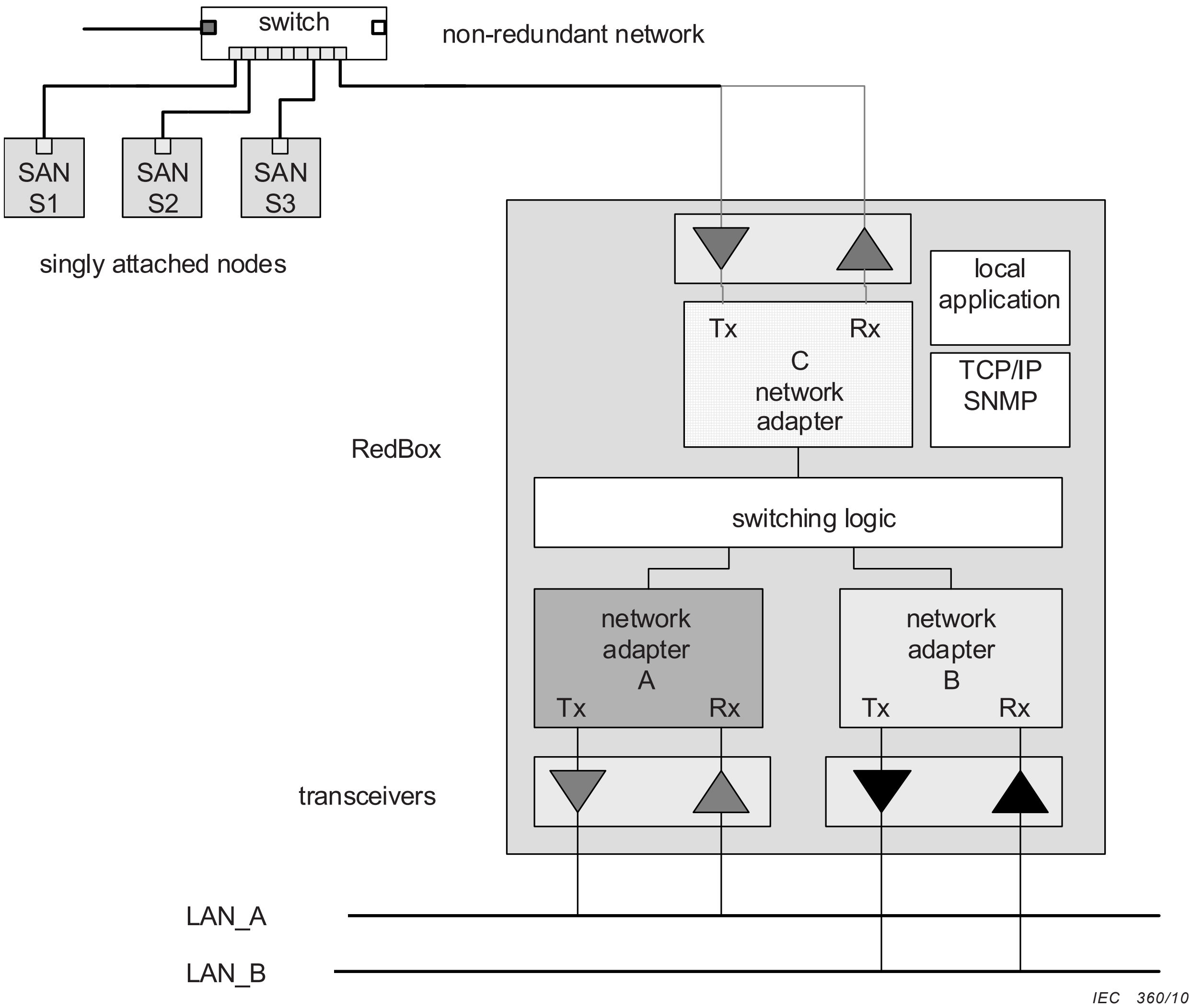


Figure 5 – PRP RedBox, transition from single to double LAN

4.1.10 Duplicate handling

4.1.10.1 Methods for handling duplicates

Since a DANP receives the same frame over both adapters, when both are operational, it should keep one and ignore the duplicate.

There are two methods for handling duplicates:

a) duplicate accept, in which the sender LRE uses the original frames and the receiver LRE forwards both frames it receives to its upper protocol layers;

b) duplicate discard, in which the sender LRE appends a redundancy control trailer to both frames it sends and the receiver LRE uses that redundancy control trailer to send only the first frame of a pair to its upper layers and filter out duplicates.

4.1.10.2 Duplicate accept

This method does not attempt to discard duplicates at the link layer. The sender LRE sends the same frame as it would in the non-redundant case over both LANs. The receiver's LRE forwards both frames of a pair (if both arrive) to its upper layers, assuming that well-designed network protocols and applications are able to withstand duplicates – indeed IEEE 802.1D explicitly states that it cannot ensure freedom of duplicates.

The internet stack, consisting of a network layer with an UDP and a TCP transport layer, is assumed to be resilient against duplicates. The TCP protocol is designed to reject duplicates, so it discards the second frame of a pair. The UDP layer is by definition connectionless and unacknowledged. All applications that use UDP are assumed to be capable of handling duplicates, since duplication of frames can occur in any network. In particular, a UDP frame is assumed to be idempotent, i.e. sending it twice has the same effect as sending it once. Administrative protocols of the internet such as ICMP and ARP are not affected by duplicates, since they have their own sequence numbering.

Real-time stack that operate on the publisher-subscriber principle are not affected by duplicates, since only the latest value is kept. Duplicate reception increases robustness since a sample that gets lost on one LAN is usually received from the other LAN.

Therefore, one can assume that handling of duplicates is taken care of by the usual network protocols, but one has to check if each application complies with these assumptions.

This simple duplicate accept method does not provide easy redundancy supervision, since it does not keep track of correct reception of both frames. The receiver would need hash tables to know that a frame is the first of a pair of a duplicate, and could for this effect store the CRC and length of each frame as a hash code. Such redundancy supervision method is however not specified in this International Standard, but it is not excluded.

4.1.10.3 Duplicate discard in the link layer

4.1.10.3.1 Principle

It is advantageous to discard duplicates already at the link layer.

Without duplicate discard, the processor receives twice as many interrupt requests as when only one LAN is connected. To offload the application processor, the LRE can perform Duplicate Discard, possibly with an independent pre-processor or an intelligent Ethernet controller. This allows at the same time to improve the redundancy supervision.

The duplicate discard protocol uses an additional four-octet field in the frame, the Redundancy Control Trailer (RCT), which the LRE inserts into each frame that it receives from the upper layers before sending, as Figure 6 shows. The RCT consists of the following parameters:

a) 16-bit sequence number (SequenceNr);

b) 4-bit LAN identifier (Lan);

c) 12 bit frame size (LSDU_size).

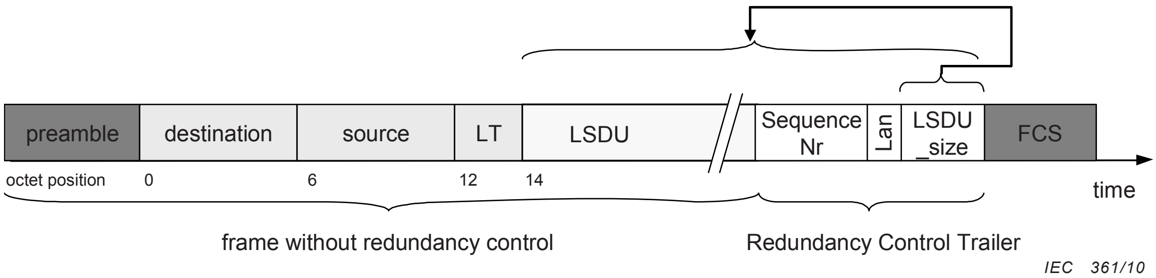


Figure 6 – PRP frame extended by an RCT

4.1.10.3.2 Use of SequenceNr

Each time a LRE sends a frame to a particular destination, it increases the sequence number corresponding to that destination and sends both (nearly identical) frames over both LANs.

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

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 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 a SAN will never be discarded.

4.1.10.3.3 Use of LAN

The field LAN can take one of two values: 1 010 indicating that the frame has been sent over LAN_A and 1 011 indicating that the frame has been sent over LAN_B. This allows detecting installation errors.

4.1.10.3.4 Use of LSDU_size

To allow the receiver LRE to distinguish easily frames coming from nodes that obey to the PRP from the non-redundant ones, the sender LRE appends to the frame the length of the link service data unit (LSDU) in octets in a 12-bit field.

EXAMPLE If the frame carries a 100-octets LSDU, the size field equals LSDU+RCT: 104 = 100 + 4.

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

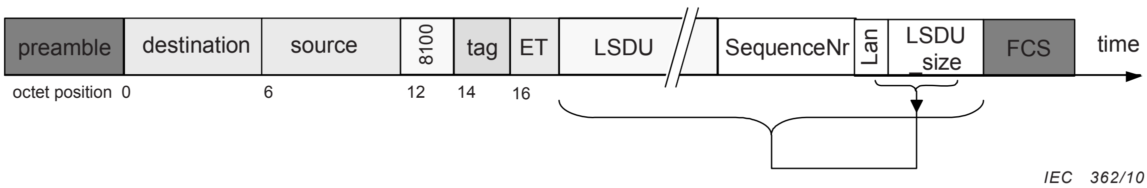


Figure 7 – PRP VLAN-tagged frame extended by an RCT

The receiver scans the frames, preferably starting from the end. If it detects that the 12 bits before the end correspond to the LSDU size, and that the LAN identifier matches the identifier of the LAN it is attached to (see 4.1.11), the frame is a candidate for rejection.

Since short frames need padding to meet the minimum frame size of 64 octets, the sender already includes the padding to speed up scanning from behind, as Figure 8 shows.

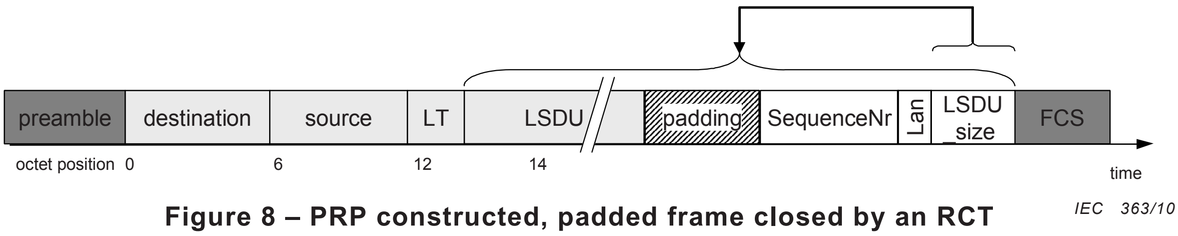


Figure 8 – PRP constructed, padded frame closed by an RCT

NOTE A VLAN-tagged frame can pass several switches which may remove or insert VLAN tags. If the sender observes the ISO/IEC 8802-3 (IEEE 802.3) rule to send a minimum frame size of 68 octets for a VLAN-tagged frame and of 64 for a VLAN-untagged frame, there should never be a situation in which there is padding before and after the RCT. Scanning from behind is specified as a matter of precaution.

4.1.10.3.5 Frame size restriction

Appending the RCT could generate oversize frames that exceed the maxValidSize foreseen by ISO/IEC 8802-3 (IEEE 802.3).

To maintain compliance with IEEE 802.3:2005, the communication software in a DANP using duplicate discard is configured for a maximum payload size of 1 496 octets.

NOTE Longer payloads would work in most cases, but this requires previous testing. Many switches are dimensioned for double-VLAN-tagged (non-IEEE 802.3 compliant) frames that have a maximum size of 1 526 octets. Most Ethernet controllers are certified up to 1 528 octets. Most switches would forward correctly frames of up to 1 536 octets, but this cannot be relied upon.

4.1.10.3.6 Discard algorithm

The following algorithm is optional, other methods such as hash table can be used.

The receiver assumes that frames coming from a DANP are sent in sequence with increasing sequence numbers. The sequence number expected for the next frame is kept in the variables ExpectedSeqA, respectively ExpectedSeqB.

At reception, the correct sequence can be checked by comparing ExpectedSeqA with the received sequence number in the RCT, CurrentSeqA. Regardless of the result, ExpectedSeqA is set to one more than CurrentSeqA to allow checking the next expected sequence number on that line. The same applies to ExpectedSeqB and CurrentSeqB on LAN_B.

Both LANs thus maintain a sliding drop window of contiguous sequence numbers, the upper bound being ExpectedSeqA (the next expected sequence number on that LAN), excluding that value, the lower bound being StartSeqA (the lowest sequence number that leads to a discard on that LAN) as Figure 9 shows for LAN_A. The same applies to ExpectedSeqB and StartSeqB on LAN_B.

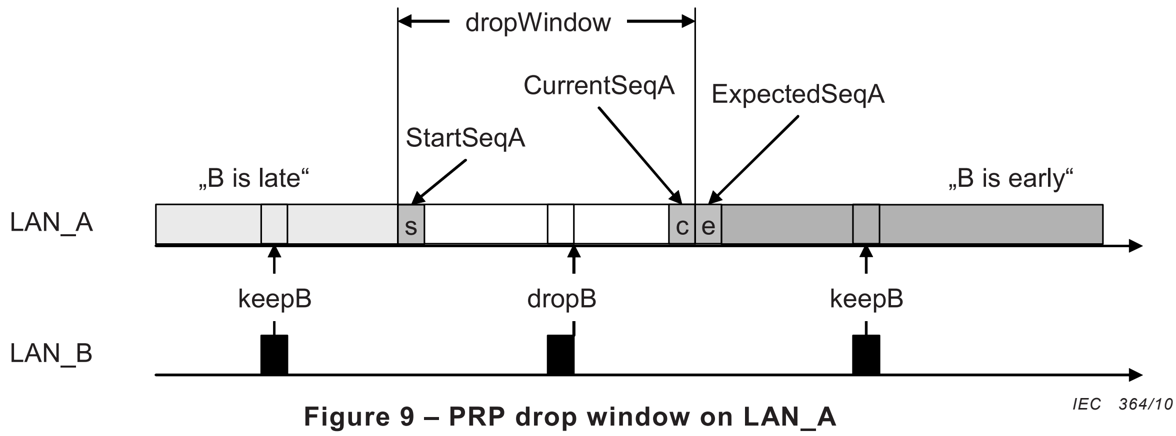


Figure 9 – PRP drop window on LAN_A

After checking the correct sequence number, the receiver decides whether to discard the frame or not. Assuming that LAN_A has established a non-void drop window (as in Figure 9), a frame from LAN_B whose sequence number CurrentSeqB fits into the drop window of A is discarded (dropB in Figure 9). In all other cases, the frame is kept and forwarded to the upper protocol layers (keepB in Figure 9).

Discarding the frame (dropB in Figure 9) shrinks the drop window size on LAN_A since no more frames from B with an earlier sequence number are expected, thus StartSeqA is increased to one more than the received CurrentSeqB. Also, the drop window on B is reset to a size of 0 (StartSeqB = ExpectedSeqB), since obviously B lags behind A and no frames from A should be discarded, as Figure 10 shows.

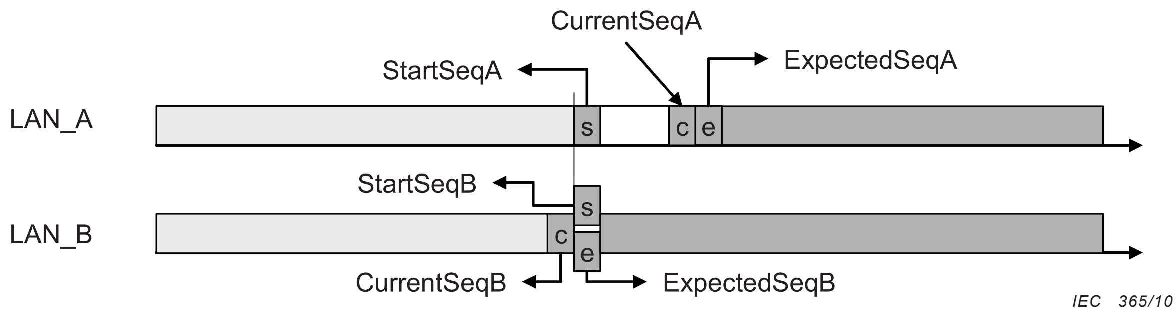


Figure 10 – PRP drop window reduction after a discard

In the situation of Figure 10, if several frames come in sequence over the same LAN_A, but none on LAN_B, they are kept since their CurrentSeqA is outside the drop window of LAN_B, and the drop window of LAN_A grows by one position. If frames keep on coming over LAN_A but not LAN_B when the maximum drop window size is reached, StartSeqA is also incremented to slide the drop window.

When a received frame is out of the drop window of the other LAN, it is kept and the drop window of that line is reduced to a size of 1, meaning that only a frame from the other line with the same sequence number is discarded, while the drop window of the other line is reset to 0, meaning that no frame is discarded, as Figure 11 shows.

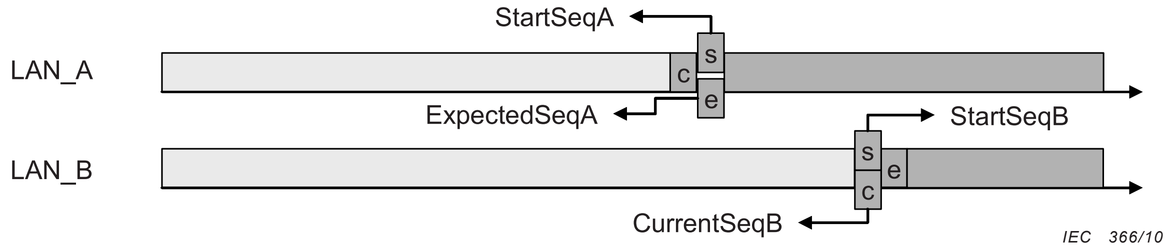


Figure 11 – PRP frame from LAN_B was not discarded

The most common situation is when the two lines are synchronized and both drop windows are reduced to 0, meaning that the first frame to come next is kept and the drop window is opened by one to allow only a frame with the same sequence number as the one already received, as Figure 12 shows.

Figure 12 – PRP synchronized LANs

The sequence counter has 16 bits, which allows a drop window size of 32 768, a size large enough so that even under the worst case network delays and highest frame rate the sequence numbers do not wrap-around.

There is no change to this algorithm when frames come out of sequence.

This method can be defeated by some situations, for instance nodes failing and recovering or reconnection of a damaged LAN after a long time, but in case of doubt, duplicates are accepted so that no frame is lost.

Annex A discloses a pseudo-code for the duplicate discard algorithm.

4.1.11 Configuration check

The remaining 4 bits of the RCT carry a distinct identifier for LAN_A or LAN_B, specifically the codes 1 010 (“A”) and 1 011 (“B”). Therefore, the frames 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 length information in its last 12 bits, but it increments the error counters CntErrWrongLanA or CntErrWrongLanB since this could hint at a configuration error. Since this kind of error is permanent, it is detected rapidly.

4.1.12 Network supervision

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

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

To this effect, all senders and receivers maintain tables of nodes with which they communicate 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.

At the same time, these tables allow to establish connections to synchronize the sequence numbers and detect sequence gaps and missing nodes.

Since the protocol is loosely connection oriented, the sequence numbers corresponding to non-existent nodes are cleaned up by a low priority task after a time NodeForgetTime.

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.

4.1.13 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 adapter (each LAN) a counter of received messages and of messages received with an error.

The LAN statuses appear as SNMPv1 or SNMPv2/v3 variables. This allows using the same tools for managing the nodes and the switches.

NOTE SNMP is part of the IP protocol suite.

4.2 PRP protocol specifications

4.2.1 Installation, configuration and repair guidelines

NOTE These guidelines are to be followed at installation time, they do not apply to conformance testing of the devices.

4.2.1.1 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.

4.2.1.2 Labelling cables

The two LANs shall be labelled A and B and shall use cables distinctly identified.

4.2.1.3 Labelling switches

Switches in the two LANs shall have a distinct label or colour for each A or B.

4.2.1.4 Independent operation

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

4.2.1.5 Configuration

All DANPs shall be configured with the same multicast address for PRP_Supervision frames.

All DANPs shall be configured with the same LifeCheckInterval.

4.2.2 MAC addresses

Both adapters A and B of a DANP 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).

If a DANP implements PICS_SUBS, the MAC address shall be the MAC address of adapter A and adapter B may use a different MAC address, which shall be unique within the whole network (LAN_A plus LAN_B).

NOTE Nodes supporting PICS_SUBS are expected to behave as a DANP that has the default MAC address. Address substitution is not specified in this International Standard.

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 4.2.7.6.

4.2.4 IP addresses

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

NOTE A device may have several IP addresses.

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

Switches on LAN_A and LAN_B are considered as SANs and shall have different IP addresses for the purpose of network management.

4.2.5 Nodes

4.2.5.1 Node types

Doubly attached nodes according to the parallel redundancy protocol (DANP) shall have two network adapters (adapter A and adapter B) that have the same abilities, and in particular could be used alternatively if only one LAN is connected, adapter A being connected to LAN_A and adapter B to LAN_B.

Singly Attached Nodes (SAN) have only one adapter for the purpose of this protocol and may be attached to either LAN.

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

4.2.5.2 Labelling connectors

This subclause applies to a DANP 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 shall be the upper connector and LAN_B the lower connector in its normal position.

When connectors are ordered horizontally, the left connector shall 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

4.2.6.1 Sending

The sender shall send the frame it receives from its upper layers unchanged over both its adapters so that the two frames appear on the respective LANs.

4.2.6.2 Receiving

The receiver shall forward frames received from both adapters to the upper layers.

NOTE This specification is only testable indirectly, by counting the number of frames over the MIB.

4.2.7 Duplicate discard mode

4.2.7.1 Nodes table

A node shall maintain a table with an entry for each node (SAN or DANP) to which it sends a frame, or from which it receives a frame, using the MAC address as a key. The table shall contain the following information for each unicast, multicast or broadcast address sent by that node:

a) SendSeq
a 16-bit sequence number used by this node for sending to that remote node or multicast or broadcast address (wrapping through zero)

b) ExpectedSeqA and ExpectedSeqB
for each adapter A and B, a 16-bit sequence number indicating the sequence number used last by the remote node to communicate with this node on that LAN, incremented by one (wrapping through zero)

c) CntErrOutOfSequenceA and CntErrOutOfSequenceB
for each adapter A and B, a 32-bit error counter indicating that a frame from the remote node was not received in sequence over that LAN

d) StartSeqA and StartSeqB
for each adapter A and B, a 16-bit cursor that limits the drop window

e) CntReceivedA and CntReceivedB
for each adapter A and B, a 32-bit counter indicating the number of frames received over the adapter

f) CntErrWrongLanA and CntErrWrongLanB
for each adapter A and B, a 32-bit counter indicating the number of mismatches on each adapter

g) TimeLastSeenA and TimeLastSeenB
for each adapter A and B, a time field indicating when this node received last a frame from the remote node. This field is in some cases updated at sending to keep track of ageing.

h) SanA and SanB
for each adapter A and B, a boolean indicating that the remote node is probably a SAN and/or that the remote node uses duplicate accept (see 4.2.7.4.2).

NOTE 1 The table contains for each remote node one row for the unicast frames and one row for each multicast or broadcast address that remote node is sending. It contains one row for each unicast, multicast of broadcast address this node is sending.

NOTE 2 Some fields are irrelevant for a SAN.

NOTE 3 This is a conceptual view, distinct tables for destination and source nodes could be implemented.

4.2.7.2 Redundancy Control Trailer (RCT)

The Redundancy Control Trailer (RCT) inserted into each DANP frame shall consist of four octets, structured in the following way (in the order of transmission):

a) a 16-bit sequence number (SequenceNr) transmitted with the most significant 8 bits in the first octet, which reflects the counter SendSeq of the nodes table for the destination of the frame (see 4.2.7.1).

b) a 4-bit LAN identifier (Lan) 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.

c) a 12 bit LSDU size (LSDU_size) whose most significant 4 bits are transmitted in the least significant 4 bits of the 3rd 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 (IEEE 802.3) and IEEE 802.1Q (octet offset 12-13 without LAN header or 16-17 with VLAN header) to the RCT, excluding the PT, and the frame part after the RCT, but including the RCT itself.

NOTE Padding inserted before the RCT is included in the LSDU size, padding inserted after the RCT is not included in the LSDU size.

4.2.7.3 Sending (duplicate discard mode)

4.2.7.3.1 Frame size control

The sender shall have the ability to limit the LSDU size so that the complete frame, including the four-octet redundancy control trailer, does not exceed the maximum size allowed on the LAN when it operates in the duplicate discard mode.

NOTE 1 This maximum size is currently 1 518 octets for VLAN untagged frames according to IEEE 802.3:2005.

NOTE 2 This specification does not apply to the LRE, but to its upper layers.

4.2.7.3.2 Sending and nodes table

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

a) update the nodes table:

- if the destination address (single cast, multicast or broadcast address) is not yet in the nodes table, create an entry in that table and record as TimeLastSeenA and TimeLastSeenB the current time. If the destination is a unicast address, set the SanA and the SanB to 1, if it is a multicast or broadcast address set them to 0. All other values shall be reset to 0, except for the sequence number SendSeq that may take an arbitrary value, preferably the value 1;
- if the destination address (single cast, multicast or broadcast address) is already in the nodes table, increment the sequence number SendSeq for that address, wrapping over through 0;
- if the destination address is a multicast address or the broadcast address, update in addition the TimeLastSeenA and TimeLastSeenB counters.

NOTE 1 Updating TimeLastSeenA, respectively TimeLastSeenB at sending initializes the ageing time for the remote node. The receiving process actualizes this time value when it receives a frame from that node. A time-out process removes the entry.

NOTE 2 Duplicate discard is assumed for multicast/broadcast addresses, since no PRP_Supervision frame tells the mode. For unicast addresses, the remote node is likely a SAN on LAN_A or LAN_B. If the destination is a DANP, an entry in the nodes table probably exists due to a previously received PRP_Supervision frame, or one is coming soon.

b) send

- if either SanA or SanB is set, send the frame unchanged over the corresponding adapter;
- if both are set, send the frame unchanged over both adapters;

- if none is set, append the Redundancy Control Trailer (RCT) between the LSDU (payload) and before the FCS, preferably just before the FCS if padding is used and send the appended frame with LAN identifier “A” through its adapter A and the frame with LAN identifier “B” through its adapter B, under the same conditions as 4.2.6.1.

4.2.7.4 Receiver (duplicate discard mode)

4.2.7.4.1 Receiving and nodes table

On reception of a frame that is not a BPDU according to IEEE 802.1Q over either adapter, a node shall:

a) if the adapter signals that the frame is in error, increment the error counter of the respective adapter CntErrorsA or CntErrorsB and ignore the frame;

b) otherwise
   - if this frame is not a PRP_Supervision frame and not a BPDU and its source is not yet in the nodes table, create an entry in the nodes table for that source MAC address assuming it is a SANA or a SANB, depending which LAN the frame arrives on;
   - if the frame is received 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 this frame is a PRP_Supervision frame, and its source is not yet in the nodes table, create an entry in the nodes table for that source assuming DANP duplicate accept or duplicate discard according to the PRP_Supervision frame contents. If the source is already in the nodes table, 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 nodes table for that source;
   - increment by one (wrapping through 0) the counters CntReceivedA, respectively CntReceivedB of the nodes table for that source and address kind.

NOTE Updating SanA and SanB allows to move a 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.

4.2.7.4.2 Identification of frames associated with the duplicate discard mode

A receiver shall identify as a duplicate candidate a frame whose last 12 bits before the FCS match the physical size of the LSDU as defined in Figure 6, except for small frames that use padding, for which the receiver shall scan the frame backwards until it finds a matching size field, stopping when reaching the LT field.

NOTE 1 Small frames using padding are smaller than 64 octets.

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

4.2.7.4.3 LAN identification

A receiver shall check for a frame identified as a duplicate candidate that the four bits previous to the size are either 1 010 (A) or 1 011 (B).

A receiver shall increment the CntErrWrongLanA, respective CntErrWrongLanB counter of the source device in the nodes table if the LAN identifier does not match the adapter from which it received the frame and forward the unchanged frame to its upper layers.

NOTE If one SAN is moved from LAN_A to LAN_B, it will first be considered DANP duplicate accept for the duration of NodeForgetTime before it becomes a SAN B.

4.2.7.4.4 Duplicate discarding

A receiver can use any method to discard duplicates, provided that this method does not discard a frame sent as single or both frames of a pair, while it is permitted that in case of doubt, both frames of a pair can be passed to the higher protocol layers.

The following drop window algorithm is recommended and uses the following fields: source MAC address, destination MAC address (or multicast address), RCT.

4.2.7.4.5 Drop window

A receiver shall consider for each LAN and source node the drop window as the range of sequence numbers from StartSeqA to (excluded) ExpectedSeqA, respectively StartSeqB to (excluded) ExpectedSeqB, in Modulo 16 arithmetic.

4.2.7.4.6 Sequence check

The receiver shall check if the received frame is in sequence by comparing it with the ExpectedSeqA, respectively ExpectedSeqB of the LAN over which it was received, and increment the error counter CntErrOutOfSequenceA, respectively CntErrOutOfSequenceB if they are not equal, and then increment ExpectedSeqA, respectively ExpectedSeqB.

4.2.7.4.7 Frame discard

If the sequence number of a frame that is a duplicate candidate is within the drop window of the other LAN, the receiver shall discard that frame, reset the drop window of the LAN over which the frame was received to 0 (StartSeqA := ExpectedSeqB respectively StartSeqB := ExpectedSeqA) and move the lower bound of the drop window on the other LAN to one position ahead of the received frame (StartSeqA := StartSeqB).

4.2.7.4.8 Frame keeping

If the sequence number of a frame that is a duplicate candidate is outside the drop window of the other LAN, the receiver shall forward the frame to the upper layers.

If the sequence number is in sequence on that LAN, the receiver shall, if the maximum window size DropWindowMax (see 4.2.7.8) has been reached, increase by one the lower drop window bound for the LAN over which the frame was received, StartSeqA or StartSeqB.

If the received sequence number is out-of-sequence, the receiver shall reset the drop window on that LAN to one (e.g. StartSeqB := CurrentSeqB).

4.2.7.4.9 Transparent reception

If the configuration setting TransparentReception of the node is set, the receiver shall not remove the RCT before transferring the frame to the upper layers.

If the configuration setting TransparentReception of the node is not set, the receiver shall remove the RCT on frames where it has identified the presence of the RCT.

4.2.7.5 Cleanup of the nodes table

A node shall clear a nodes table entry when the time elapsed since reception of a frame from that source over both TimeLastSeenA and TimeLastSeenB exceeds NodeForgetTime (see 4.2.7.8).

NOTE It is sufficient to check the whole nodes table every NodeForgetTime for stale entries.

4.2.7.6 PRP_Supervision frame

4.2.7.6.1 Sending

Each DANP shall multicast a PRP_Supervision frame over both its adapters with the format specified in Table 1 every LifeCheckInterval (see 4.2.7.8). This format shall also be used when the node is operating in duplicate accept mode.

Table 1 – PRP_Supervision frame with 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	PRP_SourceAddress (MAC address of the adapter)															
10									lsb							
12	ptid (0x8100 for VLAN or 0x88FB for PRP)															
14	prio			cti	vlan_identifier											
16	pt (= 0x88FB for PRP)															
18	LID				PRP_Ver < 64											
20	PRP_TLV.Type = 20 or 21								PRP_TLV.Length = 12							
22						msb	U/L	0								
24	MacAddressA (MAC address A of the DANP)															
26									lsb							
28						msb	U/L	0								
30	MacAddressB (MAC address B of the DANP)															
32									lsb							
34	PRP_TLV2.Type = 30 or 31								PRP_TLV2.Length = 6							
36						msb	U/L	0								
38	RedBoxMacAddress															
40									lsb							
	Padding to 64 octets (no VLAN) or to 68 octets (VLAN)															
60	SequenceNr															
62	Lan (0x1010 or 0x1011)					LSDU_size = 46										
64	FCS															
66																

4.2.7.6.2 PRP_Supervision frame contents

PRP_DestinationAddress
Reserved multicast address 01-15-4E-00-01-XX shall be used for this protocol. By default XX is "00", but if conflicts arise, XX can be configured to take any value between 0x00 and 0xFF.

PRP_SourceAddress
MAC address of the sending adapter.

PRP_Ver
Indicates the protocol version, set to “0” (zero) for this version of PRP.
Implementation of version X of the protocol shall interpret version >X as if they were version X, ignoring any parameters and/or flags added by the more recent version, and interpret version <=X PRP_Supervision frames exactly as specified for the version concerned. The version shall not exceed the value of 64, since the same beacon is used for HSR.

PRP_TLV.Type
Indicates the operation mode and shall have a value of 20 to indicate that the node supports the duplicate discard or a value of 21 to indicate that it implements duplicate accept. Other values are reserved.

PRP_TLV.Length
Indicates the length of the following MAC addresses (12).

MacAddressA and MacAddressB
MAC addresses used by each port. These addresses shall be identical except if address substitution (PICS=PRP_SUBS) is supported by the sender.

PRP_TLV2
This field shall be set to 0 if the source node is not a RedBox (see 4.2.7.6.3)

SequenceNr
Sequence number used for PRP_Supervision frames.

Lan
LAN over which this PRP_Supervision frame is sent.

LSDU_size
Size of the LSDU, always 46 (independently if VLAN tagging is used or not).

The following fields are only sent by a RedBox when it relays frames on behalf of a SAN and at least the next two octets shall be 0 for other nodes.

NOTE 1 Octets with offset 14 to 17 are inserted only if VLAN according to 802.1D is used.

NOTE 2 The frame has a size of 68 octets if VLAN-tagging is used to avoid padding if a switch removes the VLAN tag.

4.2.7.6.3 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 TLV field a second TLV field with the following contents:

PRP_TLV2.Type
Indicates the operation mode and shall have a value of 30 to indicate that the node is a RedBox or a value of 31 to indicate that it is a VDAN. Other values are reserved. This field shall only be sent by a RedBox, otherwise it shall be zero.

PRP_TLV2.Length
Indicates the length of the following MAC address (6 for a RedBox, 0 otherwise).

RedBoxMacAddress
MAC address of the RedBox that acts as proxy for the other device. This field shall only be sent by a RedBox, otherwise it shall be zero.

4.2.7.6.4 Reception of a PRP_Supervision frame

When receiving a PRP_Supervision frame over any LAN, a node shall create an entry in the nodes table corresponding to the MacAddressA of that source as indicated in the message body, not in the source address, with the duplicate accept or duplicate discard mode as indicated in the frame.

If MacAddressA and MacAddressB are different, this indicates that the sending node supports PICS_SUBS. If the receiving node supports PICS_SUBS, a receiving node shall, in all frames it receives from that node over adapter A respective adapter B, substitute the received MAC address by the default MAC address of that node (which may be identical to MacAddressA) before forwarding the frame to the upper layers.

4.2.7.6.5 Non-Reception of a PRP_Supervision frame

If a node ceases to receive PRP_Supervision frames from a source for a time longer than NodeForgetTime, but receives frames from that source over one LAN only, it shall change the status of this node to SANA, respective SANB, depending on the LAN from which frames are received.

NOTE 1 This rule allows moving a SAN between LAN_A and LAN_B, and also to obtain the right mode for a SAN if it was first registered at sending and not at receiving, since a DANP starts by sending on both LANs.

NOTE 2 This rule allows distinguishing a SAN from a DANP in duplicate accept mode with one line disconnected.

4.2.7.7 Switching end node

If this setting is enabled, the node shall act as a switching end node for its two ports, implementing either:

- SRP (serial redundancy protocol), a subset of IEEE 802.1D Clause 8 in which its ports may only have the root or alternate/backup role, subject to PICS_SRP or
- RSTP, (rapid spanning tree protocol), the IEEE 802.1D Clause 8 in which its ports can take the root, alternate/backup or designated role, subject to the PICS PRP_RSTP or
- MRP, see IEC 62439-2, subject to the PICS PRP_MRP.

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

NOTE 2 No RCT is appended when one of these modes is enabled.

4.2.7.8 Constants

The constant parameters are shown in Table 2.

NOTE Other values may be defined at the user's responsibility.

Table 2 – PRP constants

Constant	Description	Default value
LifeCheckInterval	How often a node sends a PRP_Supervision frame	2 000 ms
NodeForgetTime	Time after which a node entry is cleared	60 000 ms
DropWindowMax	Max size of drop window	32 768 frames

4.3 PRP service specification

4.3.1 Arguments

These arguments are used in both the command and the response (see Table 3 below). In a command (PRP write), they indicate the desired setting and in a status (PRP read), they indicate the actual setting.

Table 3 – PRP arguments

Argument	Definition	Data type
NodeName	Node name in the LRE	VisibleString32
ManufacturerName	Name of the LRE manufacturer	VisibleString255 (can be read only)
VersionName	Version of the LRE software	VisibleString32
MacAddressA	MAC address to be used by network interface A	Unsigned48
MacAddressB	MAC address to be used by network interface B	Unsigned48
AdapterActiveA	Adapter A is commanded to be active or responds that it is active if true	Boolean1
AdapterActiveB	Adapter B is commanded to be active or responds that it is active if true	Boolean1
DuplicateDiscard	Duplicate discard algorithm is (to be) used at reception and the RCT is (to be) appended at sending if true	Boolean1
TransparentReception	RCT is not (to be) removed when forwarding to the upper layers if true	Boolean1
SwitchingEndNode	if 0: LRE is not (to be) configured as a switching node if 1: LRE is (to be) configured as an SRP switching node if 2: LRE is (to be) configured as an RSTP switching node if 4: LRE is (to be) configured as an MRP switching node if 5: LRE is (to be) configured as an HSR switching node if 6: LRE is (to be) configured as a RedBox in H mode if 7: LRE is (to be) configured as a RedBox in A mode if 8: LRE is (to be) configured as a RedBox in B mode	Integer8
NodesTableClear	Nodes table is (to be) cleared if true	Boolean1
SupervisionAddress	Address to be used for PRP_Supervision frames	Unsigned 48
LifeCheckInterval	Interval at which the PRP_Supervision frame is (to be) sent in milliseconds	Unsigned16
NodeForgetTime	Interval at which the nodes table entry of a node is (to be) cleared, in seconds	Unsigned16
DropWindowMax	Maximum size of the drop window to be used	Unsigned16
CntTotalSentA	Number of frames sent over adapter A	Unsigned32
CntTotalSentB	Number of frames sent over adapter B	Unsigned32
CntTotalReceivedA	Number of frames received over adapter A	Unsigned32
CntTotalReceivedB	Number of frames received over adapter B	Unsigned32
CntErrorsA	Number of transmission errors on adapter A, as signalled by the adapter	Unsigned32
CntErrorsB	Number of transmission errors on adapter B, as signalled by the adapter	Unsigned32
CntNodes	Number of nodes in NodesTable	Unsigned16
NodesTable	Records for all nodes that have been detected within the last NodeForgetTime the following fields	Sequence, see 4.3.2

4.3.2 NodesTable

The node table (Table 4) keeps for network management purpose the record of all nodes that have been detected on the network.

NOTE 1 The key attribute of the Nodes table is MacAddressA as received in the PRP_Supervision frame sent by a DANP.

NOTE 2 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 (See 4.2.7.1).

Table 4 – PRP arguments

Argument	Definition	Data Type
MacAddressA	MAC address of the source node (6 octets)	OctetString6
MacAddressB[a]	MAC address of the source node (6 octets) as seen over adapter B, as advertised by the PRP_Supervision frame	OctetString6
CntReceivedA	Number of frames received from that source over LAN_A	Unsigned32
CntReceivedB	Number of frames received from that source over LAN_B	Unsigned32
CntKeptFramesA	Number of frames that were kept because they were out of the drop window on LAN_A	Unsigned32
CntKeptFramesB	Number of frames that were kept because they were out of the drop window on LAN_B	Unsigned32
CntErrOutOfSequenceA	Number of frames that were out of sequence on LAN_A	Unsigned32
CntErrOutOfSequenceB	Number of frames that were out of sequence on LAN_B	Unsigned32
CntErrWrongLanA	Number of frames that were received with the wrong LAN identifier on LAN_A	Unsigned32
CntErrWrongLanB	Number of frames that were received with the wrong LAN identifier on LAN_B	Unsigned32
TimeLastSeenA	UTC time at which the latest frame was received over LAN_A	UTCTime
TimeLastSeenB	UTC time at which the latest frame was received over LAN_B	UTCTime
SanA	True if the remote device is most probably a SAN accessible over adapter A	Boolean1
SanB	True if the remote device is most probably a SAN accessible over adapter B	Boolean1
SendSeq	Sequence number used to communicate with that remote device	Unsigned16
[a] MacAddressB is not a key attribute.		

4.3.3 PRP write

This service shall be used to write values to the LRE of a DANP to control the PRP. Table 5 shows the parameters of this service.

Table 5 – PRP write

Parameter name	Req	Ind	Rsp	Cnf
Argument	M	M(=)		
NodeName	M	M(=)		
ManufacturerName	M	M(=)		
VersionName	M	M(=)		
MacAddressA	M	M(=)		
MacAddressB	M	M(=)		
AdapterActiveA	M	M(=)		
AdapterActiveB	M	M(=)		
DuplicateDiscard	M	M(=)		
TransparentReception	M	M(=)		
SwitchingEndNode	M	M(=)		
NodesTableClear	M	M(=)		
Supervision Address	M	M(=)		
LifeCheckInterval	U	U(=)		

Parameter name	Req	Ind	Rsp	Cnf
NodeForgetTime	U	U(=)		
DropWindowMax	U	U(=)		
Result (+)			S	S(=)
Status			M	M(=)
Result (-)			S	S(=)
Status			M	M(=)
NOTE For the meaning of Req, Ind, Rsp, Cnf, M, U and S, refer to ISO/IEC 10164-1.				

Argument
The argument shall convey the service specific parameters of the service request as defined in 4.3.1.

Result(+)
This parameter indicates that the service request succeeded.

Status
This parameter shall return 0 (no error condition detected)

Result(-)
This parameter indicates that the service request failed

Status
This parameter specifies the error condition (see MIB in Clause 7)

4.3.4 PRP read

This service shall be used to read the current status of the LRE from a DANP. Table 6 shows the parameters of this service.

Table 6 – PRP read

Parameter name	Req	Ind	Rsp	Cnf
Argument	M	M(=)		
none				
Result (+)			S	S(=)
NodeName			M	M(=)
ManufacturerName			M	M(=)
VersionName			M	M(=)
MacAddressA			M	M(=)
MacAddressB			M	M(=)
AdapterActiveA			M	M(=)
AdapterActiveB			M	M(=)
DuplicateDiscard			M	M(=)
TransparentReception			M	M(=)
SwitchingEndNode			M	M(=)
NodesTableClear			M	M(=)
SupervisionAddress			M	M(=)
LifeCheckInterval			M	M(=)
NodeForgetTime			M	M(=)
DropWindowMax			M	M(=)

Parameter name	Req	Ind	Rsp	Cnf
CntTotalSentA			M	M(=)
CntTotalSentB			M	M(=)
CntErrorsA			M	M(=)
CntErrorsB			M	M(=)
CntNodes			M	M(=)
NodesTable			M	M(=)
Result (-)			S	S(=)
Status			M	M(=)
NOTE For the meaning of Req, Ind, Rsp, Cnf, M, U and S, refer to ISO/IEC 10164-1.				

Argument
The argument shall convey the service specific parameters of the service request as defined in 4.3.1.

Result(+)
This parameter indicates that the service request succeeded.

Result(-)
This parameter indicates that the service request failed.

Status
This parameter specifies the error condition (see MIB in Clause 7).

5 High-availability Seamless Redundancy (HSR)

5.1 HSR objectives

Clause 5 describes the application of the PRP principles (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.

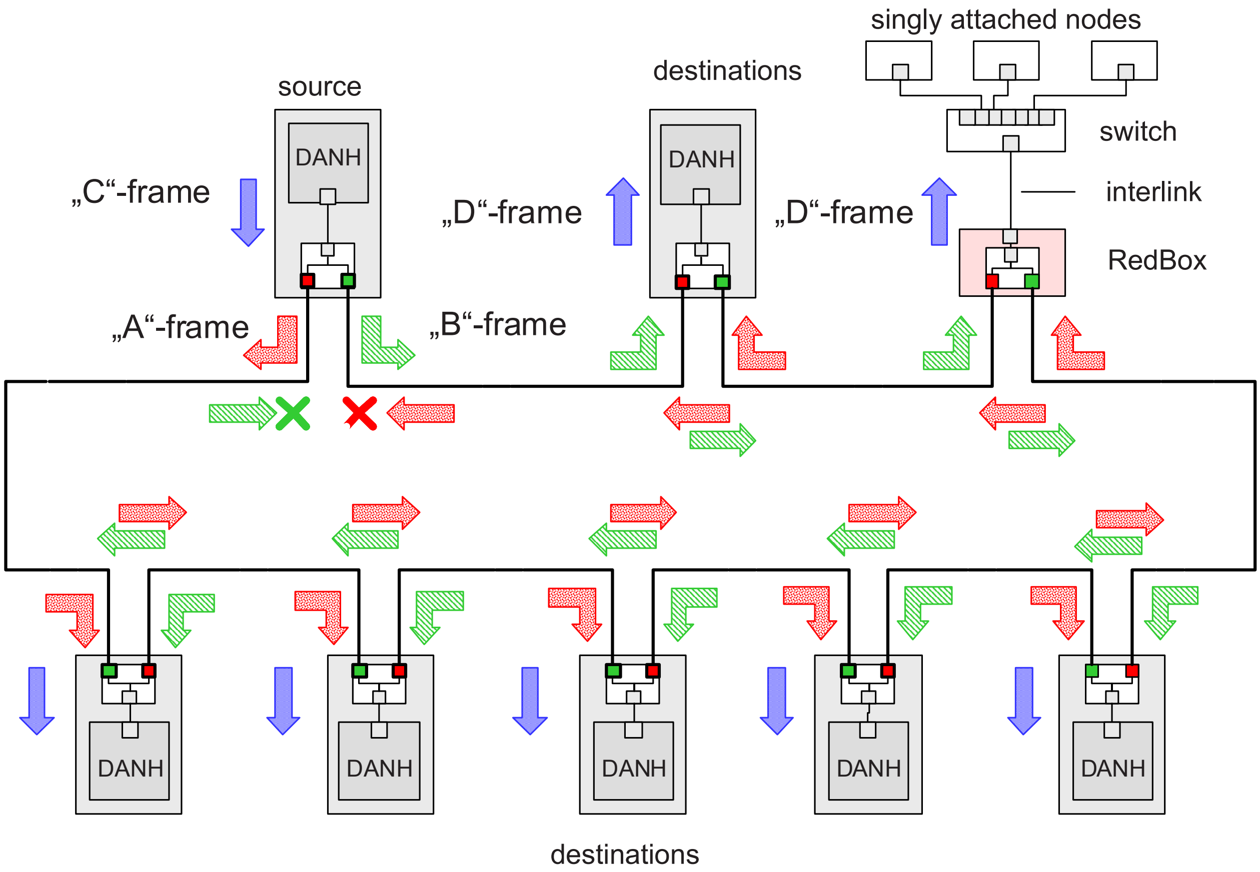
With respect to PRP, HSR allows to roughly halve the network infrastructure. With respect to rings based on IEEE 802.1D (RSTP), IEC 62439-2 (MRP) or IEC 62439-6 (DRP), the available network bandwidth for network traffic is roughly halved. Nodes within the ring are restricted to be HSR-capable switching end nodes. General-purpose nodes (SANs) cannot be attached directly to the ring, but need attachment through a RedBox (redundancy box).

5.2 HSR principle of operation

5.2.1 Basic operation with a ring topology

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

A simple HSR network consists of doubly attached switching nodes, each having two ring ports, interconnected by full-duplex links, as shown in the example of Figure 13 (multicast) and Figure 14 (unicast) for a ring topology.



Key

red, dotted arrows	“A” frames
green, cross-hatched arrows	“B” frames
blue arrows	non-HSR frames exchanged between ring and host
cross	frame is removed from the ring by the next node

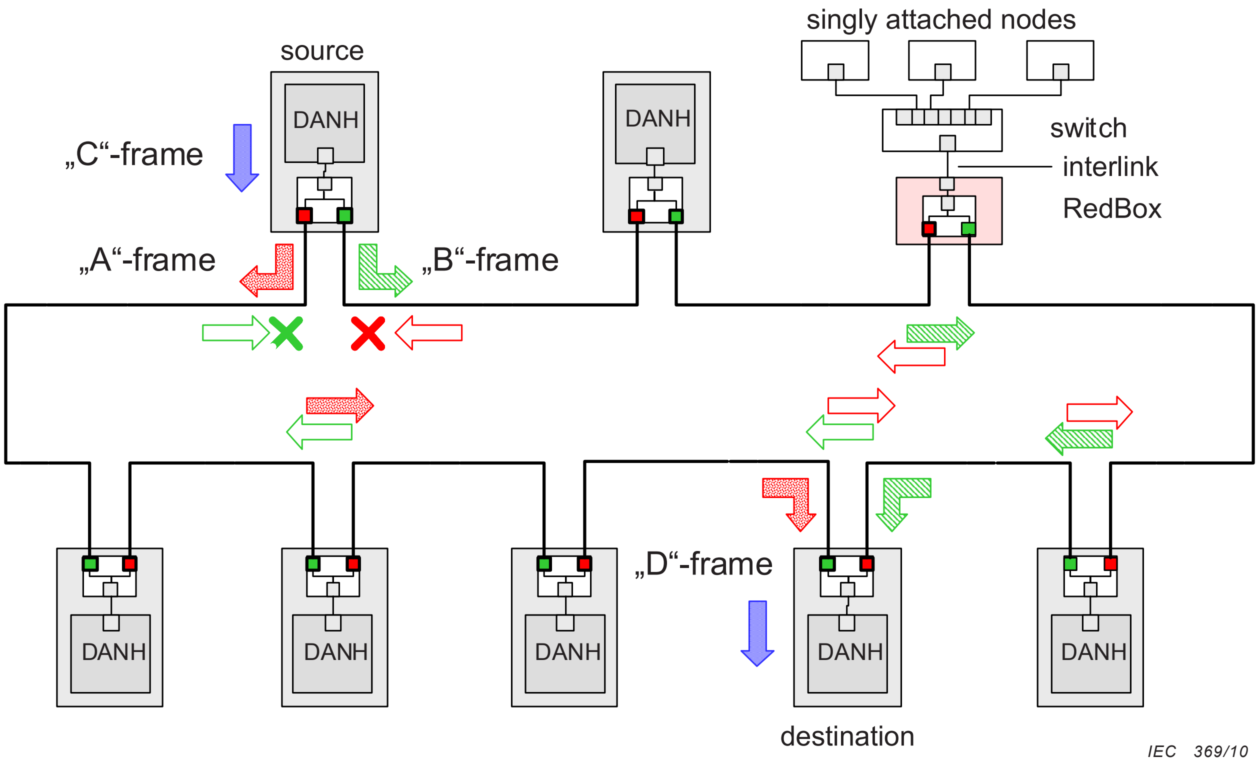
Figure 13 – HSR example of ring configuration for multicast traffic

A source DANH sends a frame passed from its upper layers (“C” frame), inserts an HSR tag to identify frame duplicates and sends a frame over each port (“A”-frame and “B”-frame).

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

The nodes support the IEEE 802.1D bridge functionality and forward frames from one port to the other, except if they already sent the same frame in that same direction.

In particular, the node will not forward a frame that it injected into the ring.



Key

red dotted arrows	"A" frames
green cross-hatched arrows	"B" frames
blue arrows	non-HSR frames exchanged between ring and host
cross	frame is removed from the ring by the next node

Figure 14 – HSR example of ring configuration for unicast traffic

A destination node of a unicast frame does not forward a frame for which it is the only destination.

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

NOTE The time skew between two frames of a pair depends on the relative position of the receiving node and of the sending node. Assuming a worst case in which each node in the ring is transmitting at the same time its own frame with the largest size of 1 536 octets (maximum length supported by the Ethertype defined in ISO/IEC 8802-2 (IEEE 802.2) definition), each node could introduce 125 µs of delay at 100 Mbit/s. With 50 nodes, the time skew may exceed 6 ms.

5.2.2 DANH node structure

Figure 15 shows a conceptual view of the structure of a DANH implemented in hardware, practical implementations can be different. The two HSR ports A and B and the device port C are connected by the LRE, which includes a switching matrix allowing to forward frames from one port to the other. The switching matrix allows cut-through switching. The LRE presents to the higher layers the same interface as a standard Ethernet transceiver would do.

The input circuit checks if this node is the destination of the frame and possibly does VLAN and multicast filtering to offload the processor. The duplicate discard is implemented in the output queues.

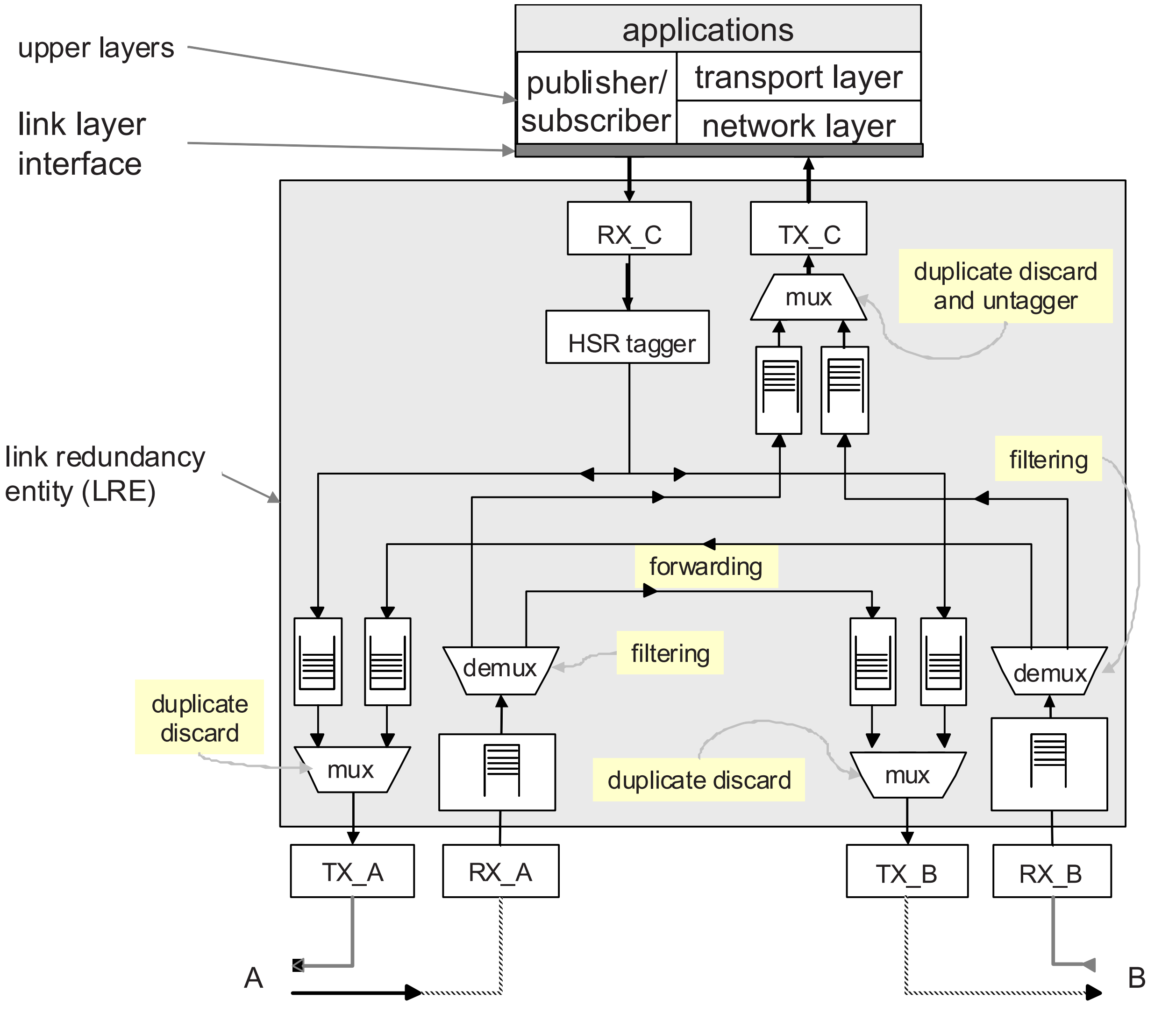


Figure 15 –HSR structure of a DANH

5.2.3 Topology

5.2.3.1 Attachment of singly attached nodes

Singly attached nodes (SAN), for instance maintenance laptops or printers cannot be inserted directly into the ring since they have only one port and cannot interpret the HSR tag in the frames. SANs communicate with ring devices through a RedBox (redundancy box) that acts as a proxy for the SANs attached to it, as shown in Figure 13 and Figure 14. The RedBox is detailed in 5.2.4.

Connecting non-HSR nodes to ring ports, breaking the ring, is not covered by this document. Non-HSR traffic within the ring is not permitted.

5.2.3.2 Use of HSR with separate LANs

HSR nodes can be connected in the same way as PRP nodes. In this case, the HSR nodes do not forward frames from port to port (HSR_PRP mode).

However, SANs cannot be attached directly to such a duplicated network unless they are able to interpret the HSR tag. See Figure 16 below.

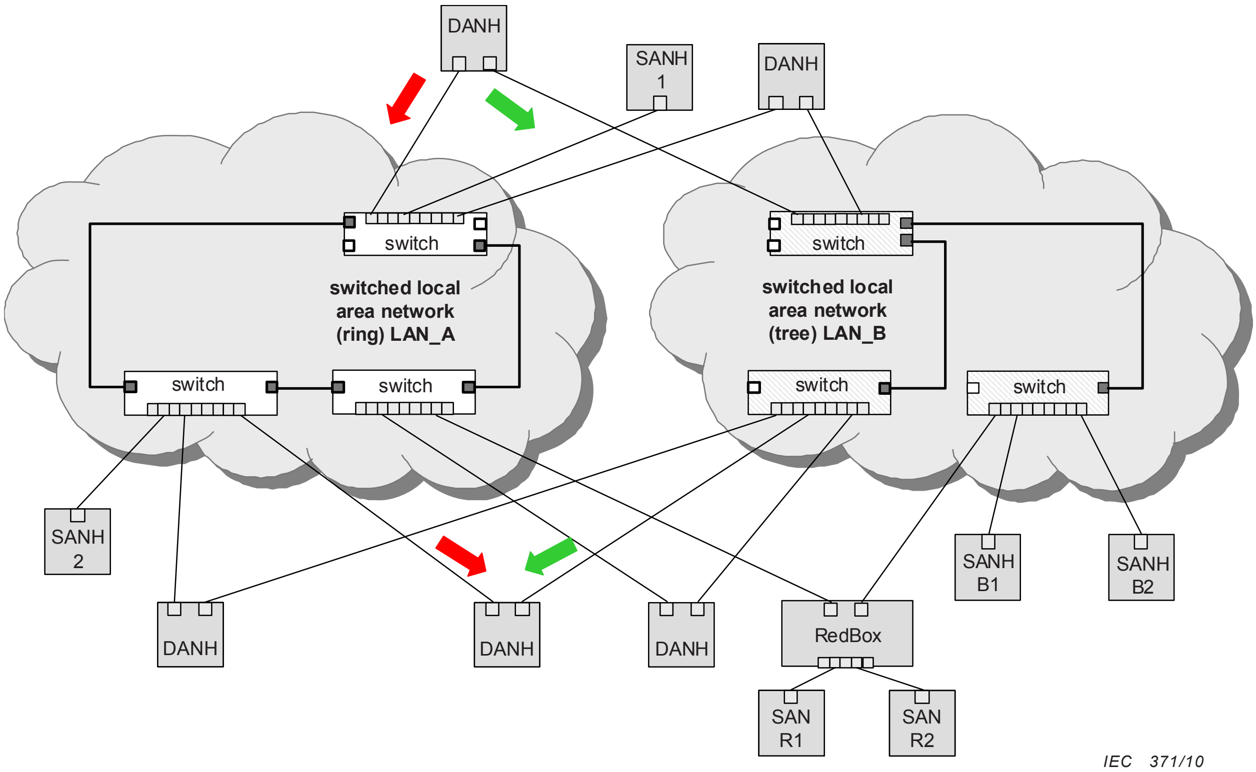


Figure 16 – HSR example of topology using two independent networks

5.2.3.3 Peer coupling of rings

Two HSR rings may be connected by quadruple port devices with forwarding capabilities, called QuadBoxes, as Figure 17 shows. This is advantageous when the traffic flow exceeds the capabilities of a single ring. However, transmission delays from end to end are not improved.

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

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

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

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

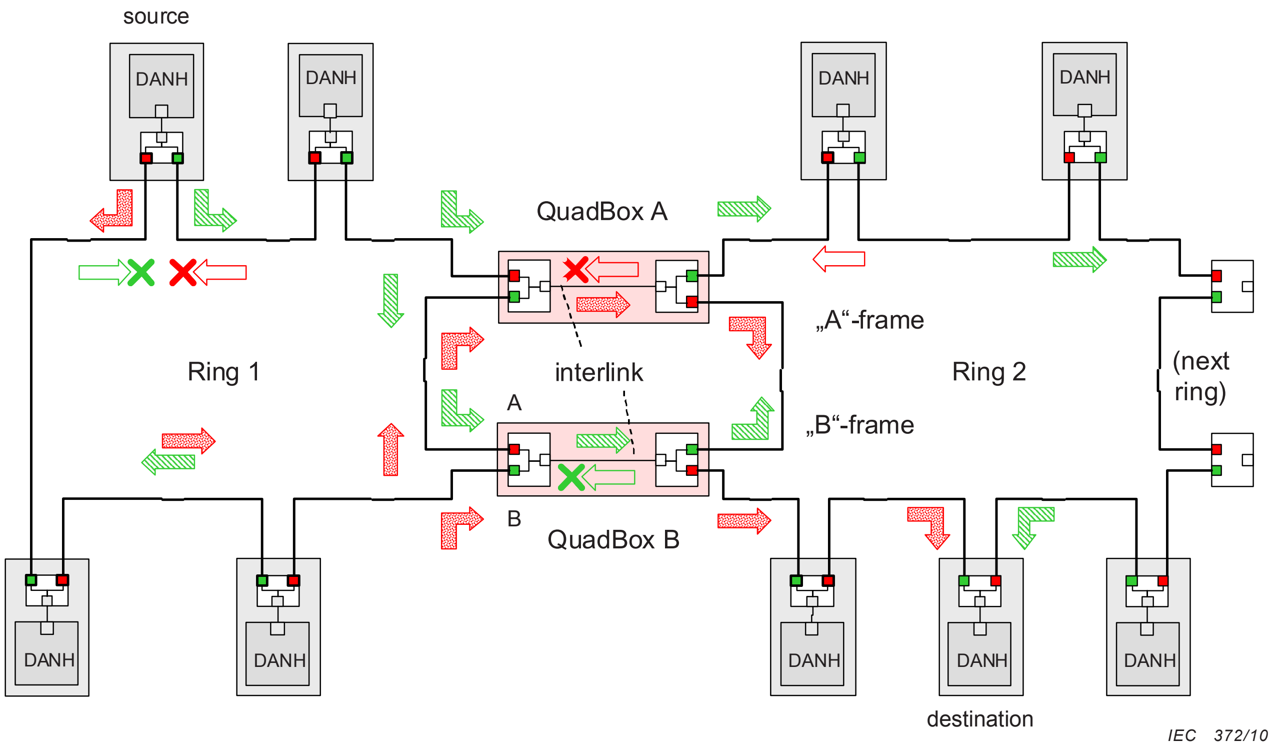


Figure 17 – HSR example of peer coupling of two rings

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

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

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

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

5.2.3.4 Hierarchical ring topology

An HSR network may consist of rings connected by QuadBoxes, as Figure 18 shows.

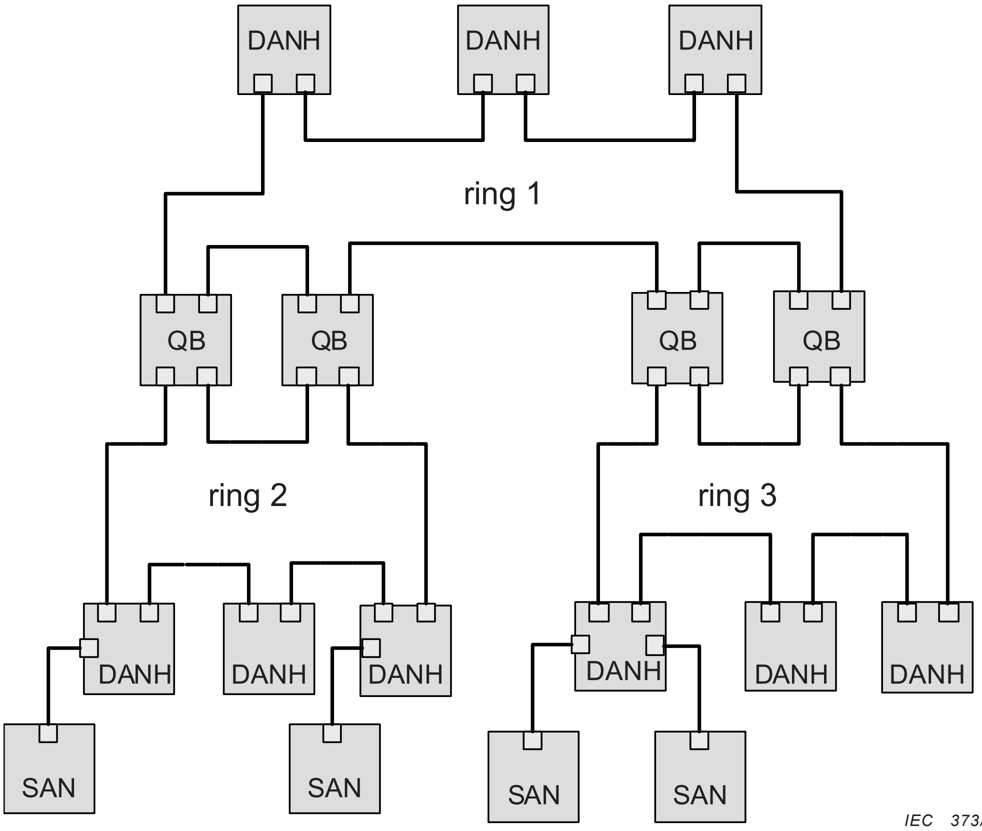


Figure 18 – HSR example of connected rings

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

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

5.2.3.5 Connection of an HSR ring to a PRP network

A HSR may be coupled to a PRP network through two RedBoxes, one for each LAN, as Figure 19 shows. In this case, the RedBoxes are configured to support PRP traffic on the interlink and HSR traffic on the ring ports.

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

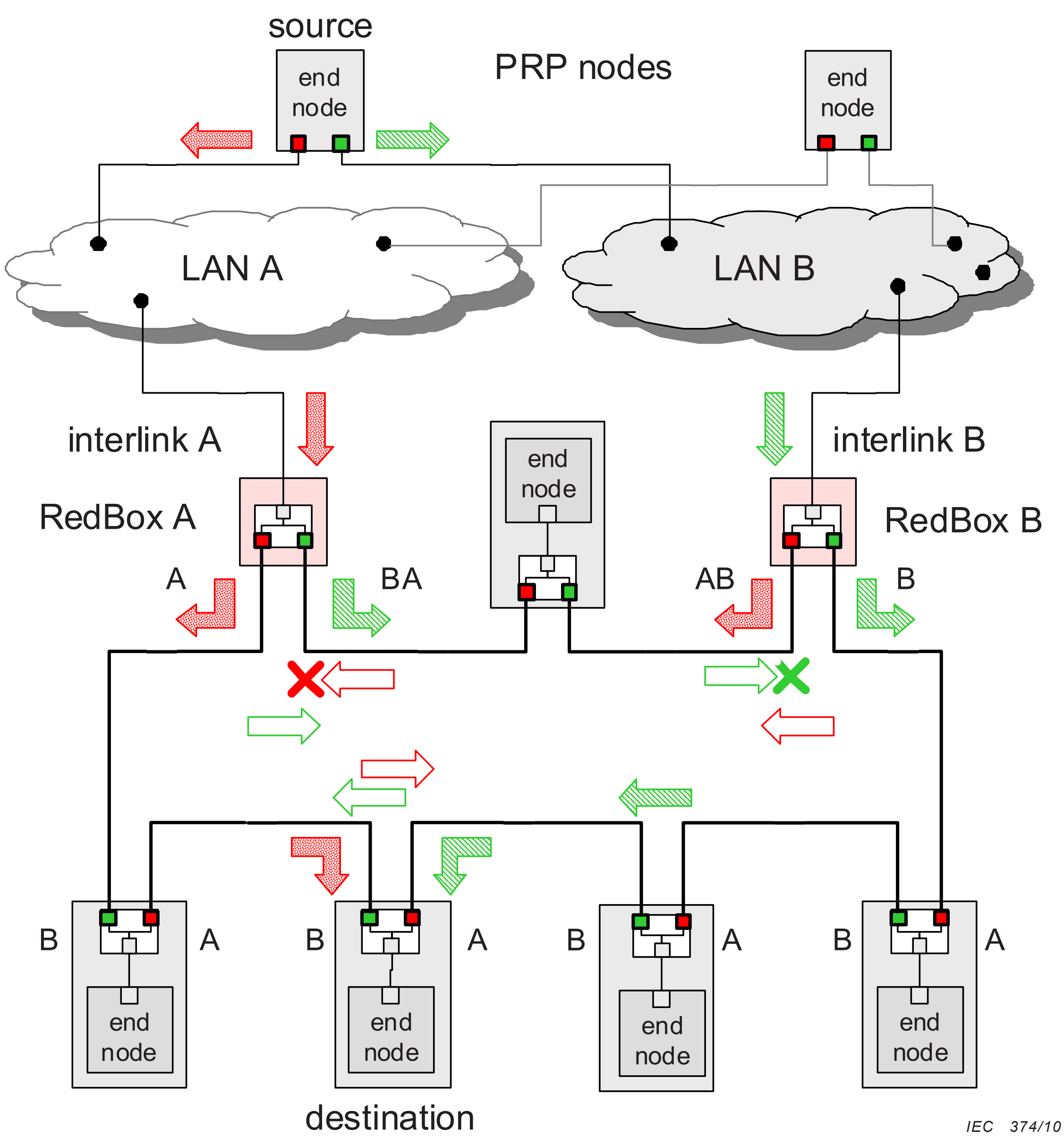


Figure 19 – HSR example of coupling two redundant PRP LANs to a ring

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

In Figure 19, RedBox A and RedBox B would send the same frame (A and AB, respectively B and BA), but if a RedBox receives the frame before it could send it itself, it refrains from sending it.

In the example of Figure 19, RedBox A will not generate an "A" frame on behalf of LAN A if it previously received the same frame as "AB" from the ring, or conversely, RedBox "B" will generate an "AB" frame if it did not previously receive an "A" frame from the ring, which is the case whenever frame "A" is not a multicast frame.

Multicast frames or unicast frames without a receiver in the ring (void arrows in Figure 19) are removed by the RedBox that inserted them into the ring, if they originated from outside the ring.

Figure 20 shows the same coupling when the source is within the ring.

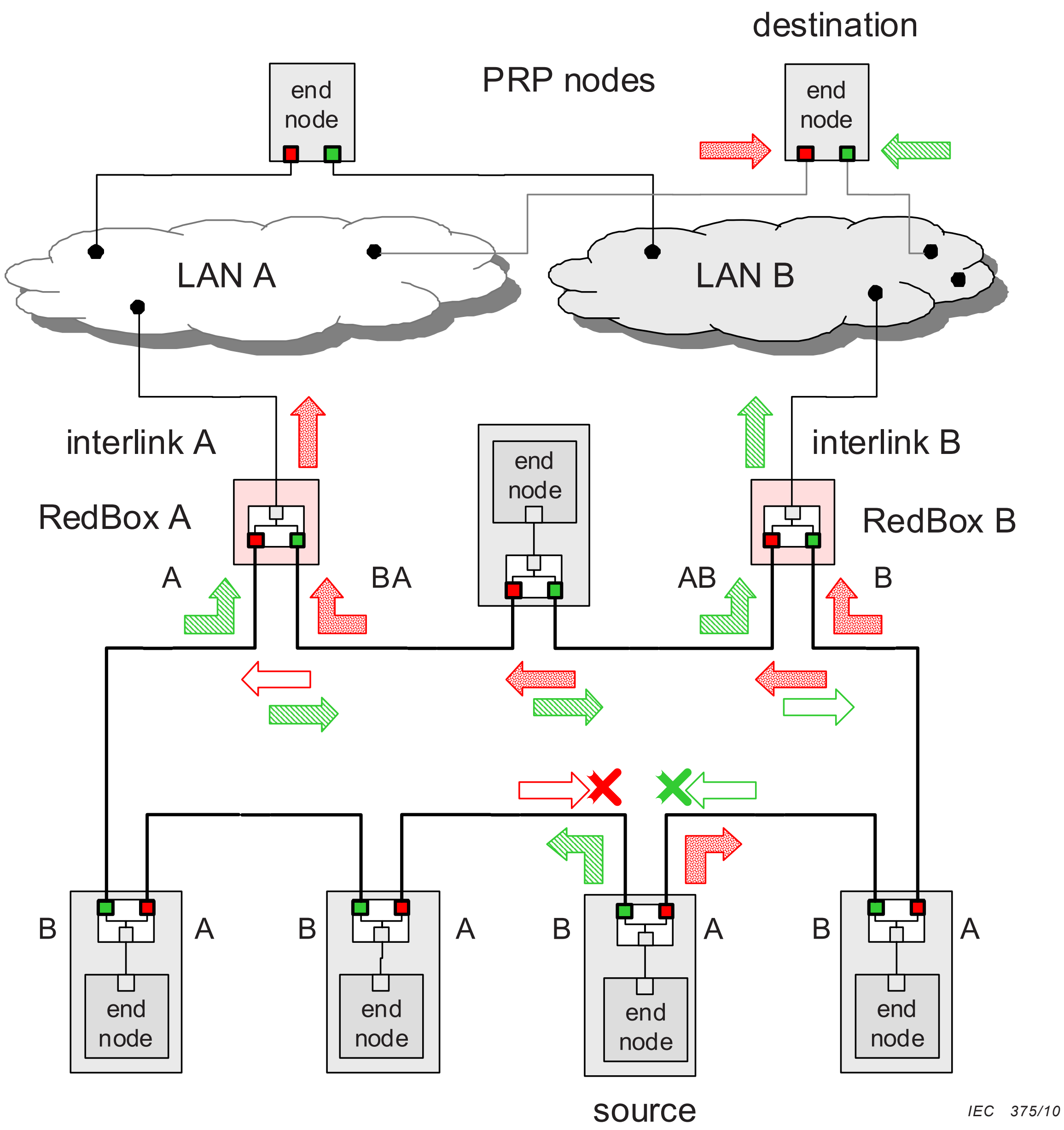


Figure 20 – HSR example of coupling from a ring node to redundant PRP LANs

It is necessary to configure the RedBox as a connexion to SAN or to PRP since the RedBox must insert the PRP trailer. However, letting the RedBox operate always in PRP mode does not harm, since the PRP trailer is invisible to the SANs.

5.2.3.6 Meshed topology

HSR allows any kind of meshing, and provides redundancy as long as the structure is free from single point of failure. For instance, Figure 21 shows for a matrix arrangement of nodes. In this case, nodes have more than two ports operated in parallel that operate like the QuadBoxes. A frame received from one port is forwarded to all other ports except the one that received it, and each port forwards the frame unless it already sent a duplicate.

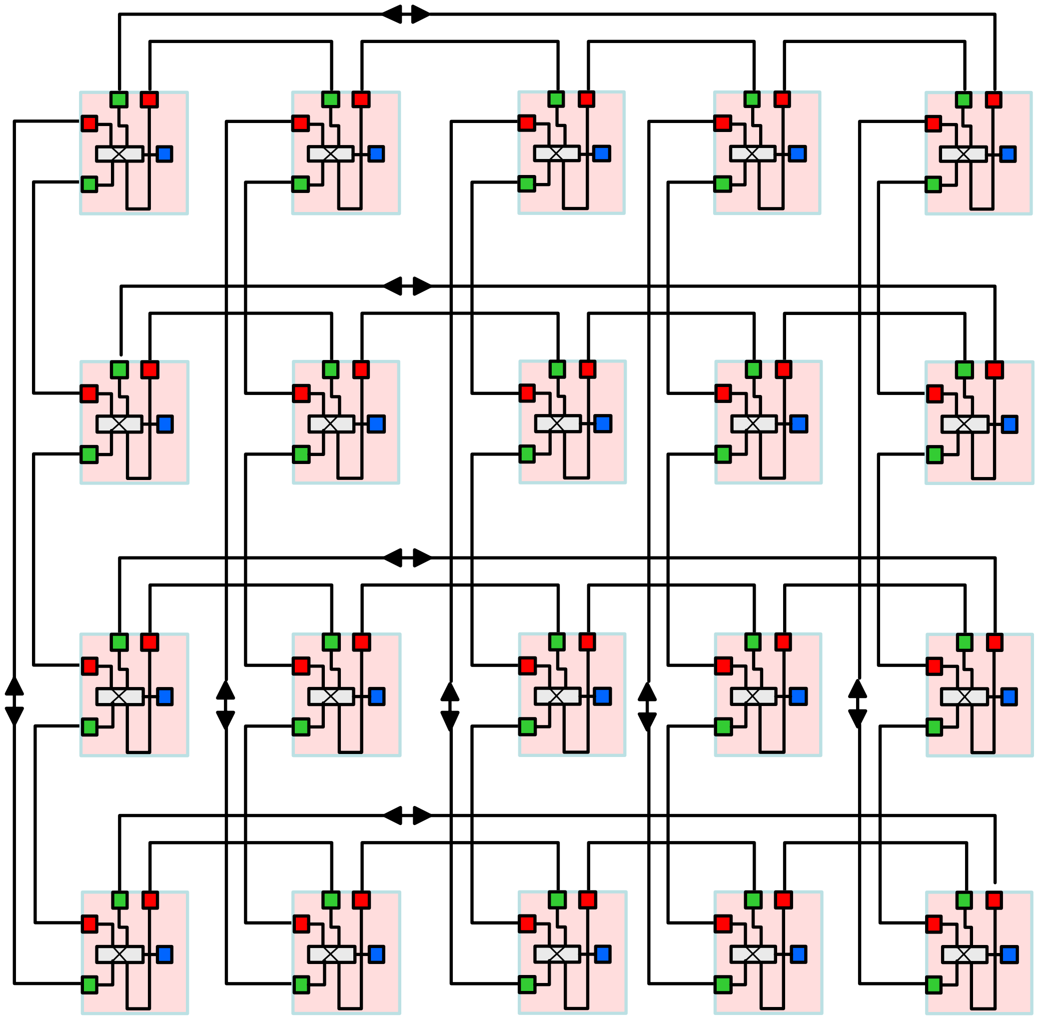


Figure 21 – HSR example of meshed topology

5.2.4 RedBox structure

Figure 22 shows the general structure of a RedBox.

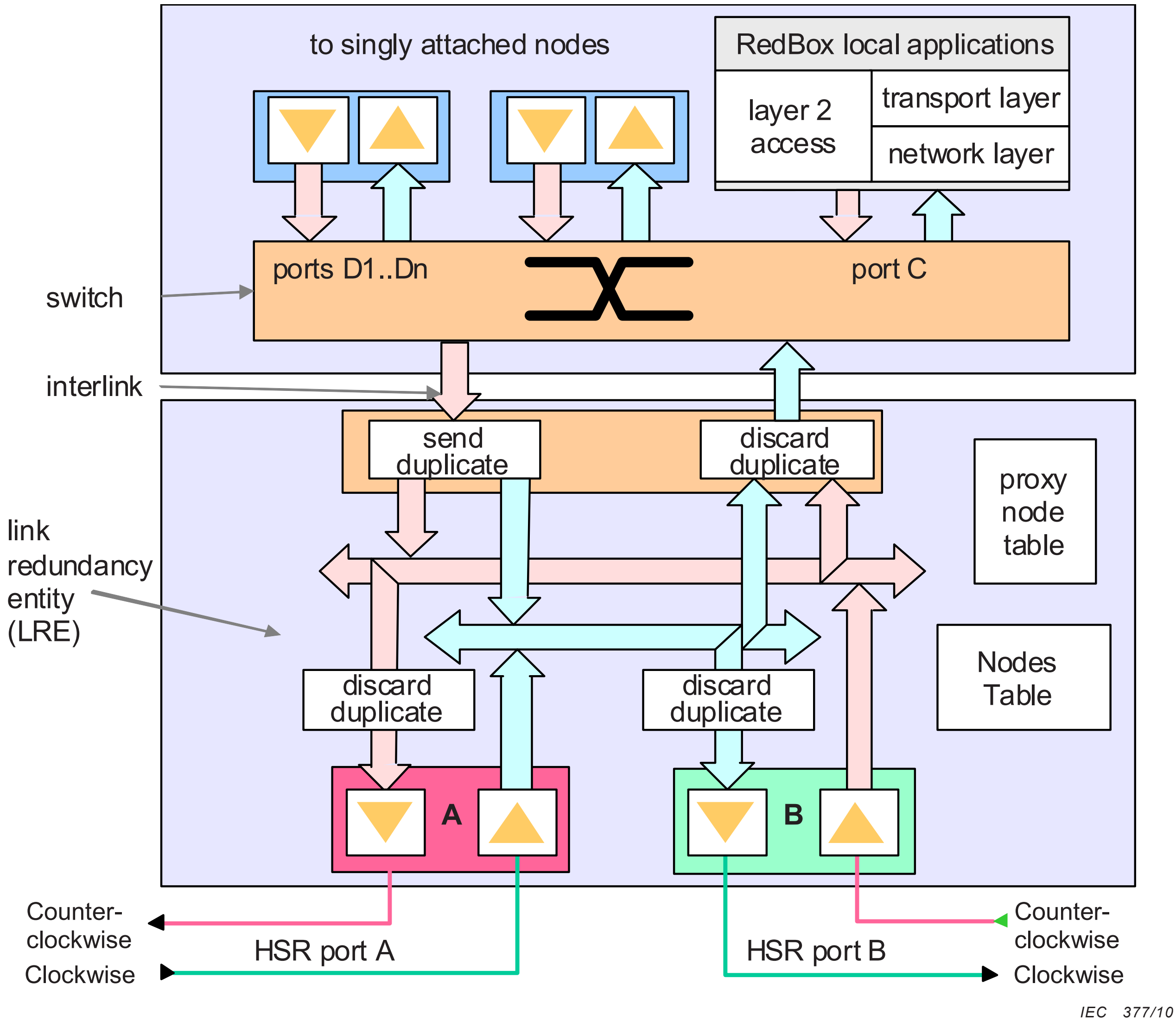


Figure 22 – HSR structure of a RedBox

The RedBox has a LRE that performs the duties of the HSR protocol.

A RedBox may be operated in three modes: as a SAN, a PRP or as an HSR connection. Depending on the mode of operation, the frame handling at the interlink interface of the RedBox differs.

The RedBox receives the frames to be sent from its own upper layers or from other nodes over its interlink.

The RedBox registers the presence of the source node in its proxy node table, and, if the node does not yet exist, it creates an entry for that node with a sequence number of 0.

If the frame has an HSR tag, the Redbox does not modify it.

If the frame has a PRP trailer, the RedBox reuses the PRP sequence number of the RCT for the HSR tag.

If the frame has no PRP trailer, the RedBox uses the sequence number of its proxy node table and increments it.

The RedBox forwards the frames received from one port to the other, unless the frame was sent already or was sent on behalf of one of the nodes registered in the proxy node table.

The RedBox receives frames addressed to its own upper protocols or to one of the devices that it represents.

If the destination node has been registered as an HSR node, the RedBox forwards the frame unchanged.

If the destination node has been registered as PRP, the RedBox removes the HSR tag and inserts the PRP tag, reusing the sequence number of the HSR tag for the RCT.

If the destination node is neither a PRP nor an HSR node, the RedBox removes the HSR tag.

The switch in Figure 22 may be incorporated into the RedBox, so the interlink becomes an internal connection.

A simple RedBox is present in every node, since the LRE makes a transition to a single non-HSR host. Also, it is usual to have more than one host in a node, since a port for maintenance often exists.

5.3 HSR node specifications

5.3.1 Host sequence number

An HSR node shall maintain a sequence number on behalf it its host for each MAC address the host uses. The sequence number is initialized with 0.

NOTE The LRE is expected to detect the MAC address of the host by listening to the frames it receives from it. The host MAC address can also be configured in the LRE. Without knowledge of the host MAC address, the LRE forwards all HSR traffic to the host, treating unicast frames as multicast.

5.3.2 DANH receiving from its link layer interface

For each frame to send on behalf of its link layer interface, a source node shall:

```
If this frame is HSR or the destination node has been registered as non-HSR
        Do not modify the frame;
else (non-HSR frame and destination node not registered as non-HSR)
        Insert the HSR tag with the sequence number of the host;
        Increment the sequence number, wrapping through 0
Duplicate the frame, enqueue it for sending into both HSR ports
```

NOTE 1 Enqueuing means that the frame will be sent as soon as no former or higher-priority frames are in the queue and the medium is ready.

NOTE 2 Sending a non-HSR frame to both ports should not cause circulating frames since such frames will not be forwarded by the adjacent HSR node. This mechanism is intended to allow off-ring configuration of an HSR node through a normal PC.

5.3.3 DANH receiving from an HSR port

A node receiving a frame from one of its HSR ports shall:

If this frame is not HSR-tagged:

Register the source in its node table as non-HSR node;

Enqueue the unchanged frame for passing to its link layer interface.

(the frame is not forwarded)

Else (HSR-tagged frame):

Register the source in its node table as HSR node;

If this node is the (unicast or multicast) destination:

If this is the first occurrence of the frame over the link layer interface:

Register the occurrence of that frame;

Remove the HSR tag and pass the modified frame to its link layer interface.

Else (this is not the first occurrence of the frame over the link layer interface):

Register the occurrence of that frame;

Do not pass the frame to the link layer interface.

Else (if this node is not a destination):

Do not pass the frame to the link layer interface.

If this node is not the only destination (multicast or unicast for another node):

If this is the first occurrence of the frame over the second port:

Register the occurrence of that frame;

Enqueue the unmodified frame for sending over the second port.

Else (this is not the first occurrence of the frame over the second port):

Register the occurrence of that frame;

Discard the frame.

Else (If this node is the only (unicast) destination):

Discard the frame.

NOTE 1 It is possible that more than one duplicate arrives, especially when rings are coupled.

5.3.4 DANH forwarding rules

A node shall not send over a port a frame that is a duplicate of a frame previously sent over that port in that same direction. This can also be seen in the behavioural description in 5.3.3.

A node shall not send back a frame over the port which received it.

A node that detects on the base of the signal quality supervision that the frame is damaged or truncated, shall not forward it. However, if the node operating in cut-through already started forwarding and then detects that the frame is damaged or truncated, it shall append the error sequence foreseen in 27.3.1.4.2 of ISO/IEC 8802-3:2000 and then stop transmission of that frame.

If a previously connected port is disconnected from the network, a node shall purge the port's buffer so that it cannot send an obsolete frame, and only allow buffering when the port is reconnected.

If a node receives a supervision frame from a previously connected node indicating reinitialization, it shall purge the buffers from the entries corresponding to that node.

NOTE 1 These rules remove circulating HSR frames and open the ring, in the same way as an RSTP or similar protocol. It applies to frames originally sourced by the node and to frames circulating in case a device is removed after having sent a frame, and the ring is closed again, for instance by a mechanical bridging device or when a DANH is powered down. In a ring of 50 nodes, there may be a delay of some 6 ms until a frame comes back to its originator, so this possibility must be cared for.

NOTE 2 These conditions enable a node to operate either in store-and-forward or in cut-through mode. Delaying the forwarding of a frame does not affect the worst-case ring delay.

NOTE 3 The duplicate discard method of PRP is not a preferred method for discarding duplicates in HSR, since HSR aims at preventing duplicates from circulating.

NOTE 4 The fact that the sequence numbers of the frames sent by one source are not monotonically increasing is not a reason for discarding the frame. This observation can however be used for supervision of the network.

NOTE 5 For cut-through operation, the node must wait approximately 5 (s at 100 Mbit/s until the HSR tag has been completely received and the node decided to forward or not. By contrast, store-and-forward takes at least 122 (s at 100 Mbit/s for the maximum size frame (1 522 octets).

5.3.5 CoS

For the operation of HSR, priorities and VLANs are not required.

An HSR node is expected, as expressed in its PICS:

- to support at least 2 levels of priority according to IEEE 802.1D (IEEE 802.1p);
- to filter VLAN traffic according to IEEE 802.1Q;
- to filter multicast traffic.

5.3.6 Clock synchronization

HSR does not specify the clock synchronization method that has to be used.

In case IEC 61588 (IEEE 1588) is used, and due to the fact that clock synchronization frames can arrive on both ports with different delays, it is recommended to use transparent – ordinary clocks (hybrid clocks) together with one-step mode, according to IEC 61588 (IEEE 1588) v2, the P-delay measurement being done directly between adjacent nodes.

NOTE One-step clocks require on-the-fly modification of the clock correction, which is only practical when done in hardware.

5.3.7 Deterministic medium access

HSR does not specify the traffic control that has to be used for deterministic, real-time operation.

However, it is a recommended practice to buffer the hard real-time, high priority frame, wait until the clock reaches a certain time, the same in all devices with the same period, and let all these nodes send this traffic at that time, in order to leave sufficient contiguous free space for the non-real-time traffic.

5.4 HSR RedBox specifications

5.4.1 RedBox properties

A RedBox is a device with at least three ports, two of them being ring ports for the HSR protocol, the third port being connected to an interlink.

A RedBox shall be configurable for one of three modes:

1) HSR-SAN: the traffic on the interlink is not HSR, not PRP,
2) HSP-PRP: the traffic on the interlink is PRP-tagged as “A” or “B”,
3) HSR-HSR the traffic on the interlink is HSR-tagged.

A RedBox shall behave as a DANH for all traffic for which it is the source or the destination.

NOTE 1 A RedBox is expected to have its own IP address, especially for configuration messages. It can be accessed over the interlink or over the HSR ports.

NOTE 2 The interlink can be an internal connection if the RedBox serves as switch at the same time.

5.4.2 RedBox receiving from interlink

When receiving a frame from its interlink port, a RedBox shall:

If the frame carries a HSR tag:
  Register the source as an HSR source;
  If the RedBox operates in HSR-HSR mode
    If the RedBox is a destination of the frame
      If this is not the first occurrence of the frame at the link layer interface
        Register the occurrence
        Discard the frame
      Else (If this is the first occurrence of the frame at the link layer interface)
        Register the occurrence
        Remove the HSR tag
        Enqueue to the link layer interface of the RedBox
    If the frame is to be injected into the ring (RedBox is not only destination, Multicast/VLAN is ok)
      If this is not the first occurrence of the frame at each HSR port
        Register the occurrence
        Discard the frame (already sent over that port)
      Else (If this is the first occurrence of the frame at each HSR port)
        Enqueue the unmodified frame into each HSR port
  Else (If the RedBox does not operate in HSR-HSR mode)
    Discard the frame

Else if the frame carries a PRP RCT
  If the source MAC address is not already registered:
    Create an entry in the proxy node table;
    Register that source as PRP “A” or “B” (depending on the PRP mode of the RedBox)
  If the PRP tag does not correspond to the mode of the RedBox “A” or “B”
    Register the error;
    Discard the frame
  Else (If the PRP tag corresponds to the mode of the RedBox “A” or “B”)
    If the PRP frame was already received
      Register the occurrence
      Discard the frame
    Else (if the PRP frame was not already received)
      Register the occurrence
      If the RedBox is a destination of the frame
        Enqueue to the link layer interface of the RedBox (with the PRP RCT)
      If the frame is to be injected into the ring (RedBox is not sole destination and multicast/VLAN is ok)
        If this is not the first occurrence of the frame at each HSR port
          Register the occurrence
          Discard the frame (already sent over that port)
        Else (If this is the first occurrence of the frame at each HSR port)

Reuse the PRP sequence number and path identifier to build the HSR tag

Enqueue the unmodified frame into each HSR port

Else (if the frame carries neither a HSR tag nor a PRP RCT)

If the source MAC address is not already registered:

Create an entry in the proxy node table with a sequence number of 0;

Register that source as SAN

Else (If the source is already registered)

Register the presence of that source;

If the RedBox is a destination of the frame:

Enqueue to the link layer interface of the RedBox

If the frame is to be injected into the ring (RedBox is not sole destination and multicast/VLAN is ok)

If this is not the first occurrence of the frame at each HSR port

Register the occurrence

Discard the frame (already sent over that port)

Else (If this is the first occurrence of the frame at each HSR port)

Append the HSR tag using the sequence number of that node

Increment the sequence number of that source;

Enqueue the tagged frame into each HSR port

NOTE Reception of an HSR frame over the interlink is considered as a configuration error in PRP connection mode. If the RedBox is used as one half of a QuadBox in HSR connection mode, then the interlink will only carry HSR traffic.

5.4.3 RedBox forwarding on the ring

In addition to the forwarding rules of 5.3.4 , a RedBox shall not forward in the ring a unicast frame that is intended for one of the nodes that are registered in the proxy node table. This condition is enabled by default and can be disabled for debugging purposes.

5.4.4 RedBox receiving from an HSR port

A RedBox that receives a valid frame over one HSR port shall:

If this frame is not HSR-tagged:

Register the source as a non-HSR source;

Enqueue the frame for passing to the link layer interface of the RedBox;

(do not forward it)

Else (frame is HSR-tagged):

If this is the first occurrence of the frame in direction of the second HSR port

Register the occurrence of the frame;

Enqueue the frame to the second port;

Else (If this is not the first occurrence of the frame in direction of the second HSR port)

Register the occurrence of the frame;

Do not enqueue the unchanged frame to the second HSR port;

If this is the first occurrence of the frame in direction of the interlink:

Register the occurrence of the frame;

If the RedBox is in SAN mode:

Remove the HSR tag;

Else if the RedBox is in PRP mode:

Remove the HSR tag and append the PRP RCT “A” or “B” reusing the HSR sequence number.

Else (if the RedBox is in HSR mode)

Do not modify the frame.

Enqueue frame for passing to the interlink.

Else (If this is not the first occurrence of the frame in direction of the interlink):

Register the occurrence;

Discard the frame;

NOTE A RedBox does not check if the frame was sent by one of the nodes for which it is a proxy since it cannot distinguish if the frame could have been sent by a redundant RedBox.

5.4.5 Redbox proxy node table handling

A RedBox shall hold a proxy node table containing an entry for each represented association, which shall support at least ProxyTableMaxEntries entries.

A RedBox shall purge the entry of a node in the Proxy Node Table with a configurable time-out (default of ProxyTableForgetTime) for non-receiving frames of this node.

NOTE The actual size of the proxy node table is indicated in the PICS.

5.4.6 RedBox CoS

Same as 5.3.5, except that RedBox is expected to support more VLANs and more complex and comprehensive options for engineering traffic flow in the network on higher protocol layers, e.g. multicast filtering rules, than a simple node.

5.4.7 RedBox clock synchonization

Same as 5.3.6.

5.4.8 RedBox medium access

Same as 5.3.7., except that the RedBox must be able to aggregate several nodes for which it acts as a proxy.

5.5 QuadBox specification

A Quadbox shall operate conceptually as two RedBoxes in HSR-HSR mode, back-to-back.

5.6 Association definition

For the purpose of duplicate discard, a frame shall be identified by:

– its source MAC address;
– a sequence number;
– the VLAN identifier.

NOTE It is possible to use other fields of the frame such as the checksum to aid in duplicate detection.

5.7 Frame format for HSR

5.7.1 HSR-tagged frame format

Frames to be treated HSR are identified uniquely by their source MAC address, destination MAC address and HSR tag.

If the frame carries a VLAN tag according to IEEE 802.1Q, it shall be inserted before the HSR tag.

The HSR tag is announced by the dedicated EtherType = 0x88FB, which is the same as the EtherType used in 4.2.7.6.

The 4 most significant bits of the next 16 bits distinguish a HSR management frame from a PRP management frame or a HSR payload.

a) 4-bit path identifier
b) 12 bit frame size (LSDU_size) or version if smaller than 64
c) 16-bit sequence number (SequenceNr)

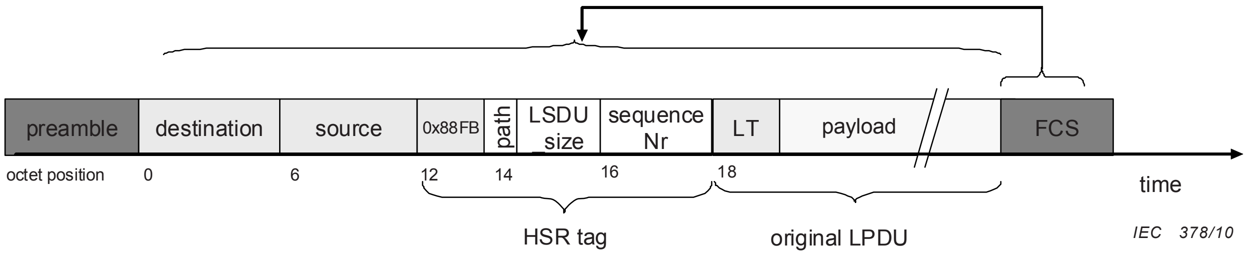


Figure 23 – HSR frame without VLAN tag

The definition of the 4-bit path field is:

- 0000: PRP management (supervision frames),
- 0001 – 1001: ring identifier (regular HSR frames),
- 1010 – 1011: frames from PRP network (“A” and “B”),
- 1011 – 1100: reserved,
- 1111: HSR management (supervision frames),
- other: reserved.

The same frame with a VLAN tag is shown in Figure 24.

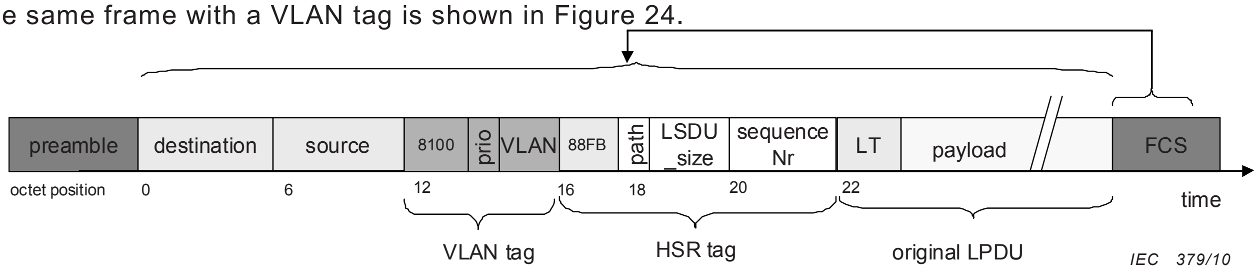


Figure 24 – HSR frame with VLAN tag

NOTE 1 The frames used within the ring include the HSR tag at the beginning of the frame to allow early identification of frames for cut-through operation.

NOTE 2 The LSDU_Size has the same definition as in PRP; it does not include the MAC header and VLAN tag, but includes the HSR tag itself and the original LPDU. The VLAN tag can be removed by intermediate switches.

NOTE 3 The reason for inserting the HSR tag after the VLAN tag is to provide faster MAC address lookup in case IVL (Independent VLAN learning as defined in IEEE 802.1Q) is used.

5.7.2 HSR_Supervision frame

5.7.2.1 Sending

Each DANH shall multicast a HSR_Supervision frame over its ports with the format specified in Table 7. After initialization, the node shall send three HSR_Supervision frames with HSR_TLV.Type = 22 in a row at an interval of AnnounceInterval to allow other devices to clear their duplicate records, afterwards it shall send a HSR_Supervision frame with HSR_TLV.Type = 23 every LifeCheckInterval as specified in Table 8.

A RedBox in PRP mode shall be considered as a DANP when seen over its PRP interlink and broadcast the PRP_Supervision frame on its PRP interlink.

Table 7 – HSR_Supervision frame with optional VLAN tag

<table>
<tr><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th></tr>
<tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td>msb</td><td>U/L</td><td>I/G</td><td colspan="8"></td></tr>
<tr><td>2</td><td colspan="16">HSR_DestinationAddress = multicast (01-15-4E-00-01-XX)</td></tr>
<tr><td>4</td><td colspan="8"></td><td>lsb</td><td colspan="7"></td></tr>
<tr><td>6</td><td colspan="5"></td><td>msb</td><td>U/L</td><td>0</td><td colspan="8"></td></tr>
<tr><td>8</td><td colspan="16">HSR_SourceAddress (MAC address of the adapter)</td></tr>
<tr><td>10</td><td colspan="8"></td><td>lsb</td><td colspan="7"></td></tr>
<tr><td>12</td><td colspan="16">ptid (= 0x8100 for VLAN)</td></tr>
<tr><td>14</td><td colspan="3">prio</td><td>cti</td><td colspan="12">vlan_identifier</td></tr>
<tr><td>16</td><td colspan="16">pt (= 0x88FB for HSR)</td></tr>
<tr><td>18</td><td colspan="4">path</td><td colspan="12">HSR_Ver (< 64)</td></tr>
<tr><td>20</td><td colspan="16">sequenceNumber</td></tr>
<tr><td>22</td><td colspan="8">HSR_TLV.Type = 22 or 23</td><td colspan="8">HSR_TLV.Length = 12</td></tr>
<tr><td>24</td><td colspan="5"></td><td>msb</td><td>U/L</td><td>0</td><td colspan="8"></td></tr>
<tr><td>26</td><td colspan="16">MacAddressA (MAC address A of the DANH)</td></tr>
<tr><td>28</td><td colspan="8"></td><td>lsb</td><td colspan="7"></td></tr>
<tr><td>30</td><td colspan="5"></td><td></td><td></td><td></td><td colspan="8"></td></tr>
<tr><td>32</td><td colspan="16">unused</td></tr>
<tr><td>34</td><td colspan="8"></td><td></td><td colspan="7"></td></tr>
<tr><td>36</td><td colspan="8">HSR_TLV2.Type = 30 or 31</td><td colspan="8">HSR_TLV2.Length = 6</td></tr>
<tr><td>38</td><td colspan="5"></td><td>msb</td><td>U/L</td><td>0</td><td colspan="8"></td></tr>
<tr><td>40</td><td colspan="16">RedBoxMacAddress</td></tr>
<tr><td>42</td><td colspan="8"></td><td>lsb</td><td colspan="7"></td></tr>
<tr><td></td><td colspan="16">Padding to 64 octets (no VLAN) or to 68 octets (VLAN)</td></tr>
<tr><td>64</td><td colspan="16">FCS</td></tr>
<tr><td>66</td><td colspan="16"></td></tr>
</table>

NOTE The format of the frame is nearly identical to that of the PRP supervision frames.

5.7.2.2 HSR_Supervision frame contents

HSR_DestinationAddress
Reserved multicast address 01-15-4E-00-01-XX shall be used for this protocol. By default XX is “00”, but if conflicts arise, XX can be configured to take any value between 0x00 and 0xFF.

HSR_SourceAddress
MAC address of the sending adapter.

HSR_Ver
Indicates the protocol version, set to “0” (zero) for this version of HSR.
Implementation of version X of the protocol shall interpret version >X as if they were version X, ignoring any parameters and/or flags added by the more recent version, and

interpret version <=X exactly as specified for the version concerned. The version shall not exceed the value of 64.

HSR_TLV.Type
Indicates the operation mode and shall have a value of 20 to indicate that the node supports the Duplicate Discard or a value of 21 to indicate that it implements Duplicate Accept. Other values are reserved.

HSR_TLV.Length
Indicates the length of the following MAC addresses (12).

MacAddressA and MacAddressB
MAC addresses used by each port. These addresses shall be identical except if address substitution (PICS=PRP_SUBS) is supported by the sender.

HSR_TLV2
This field shall be set to 0 if the source node is not a RedBox (see 4.2.7.6.3)

If this node is a RedBox, this field shall have a value of 30.

If this node is a VDAN, this field shall have a value of 31.

Other values are reserved.

PRP_TLV2.Length
Indicates the length of the following MAC address (6 for a RedBox, 0 otherwise).

RedBoxMacAddress
MAC addresses used by the RedBox on its interlink. This field shall only be sent by a RedBox, otherwise it shall be zero.

NOTE 1 Octets with offset 14 to 17 are inserted only if VLAN according to IEEE 802.1D is used.

NOTE 2 The frame has a size of 68 octets if VLAN-tagging is used to avoid padding if a switch removes the VLAN tag.

5.7.2.3 Reception of a HSR_Supervision frame

When receiving a first HSR_Supervision frame over any ring port, a node shall create an entry in the Nodes Table corresponding to the MacAddressA of that source as indicated in the message body, not in the source address of the frame, and register the port over which this frame came.

Subsequent reception of frames shall be registered with the objective of identifying reception errors.

5.7.2.4 Non-Reception of a HSR_Supervision frame

The mechanism to detect non-existing devices is not specified, it can be assumed that reading the NodesTable resets or reads a frame counter.

5.7.3 Constants

The constant parameters are shown in Table 2.

NOTE Other values may be defined at the user's responsibility.

Table 8 – HSR Constants

Constant	Description	Default value
LifeCheckInterval	How often a node sends a HSR_Supervision frame	2 000 ms
NodeForgetTime	Time after which a node entry is cleared in the NodesTable	60 000 ms
ProxyTableForgetTime	Time after which a node entry is cleared in the ProxyTable	60 000 ms
ProxyTableMaxEntries	Maximum number of entries in the ProxyTable	512

AnnounceInterval	Interval between initialization supervisory frames	100 ms

6 Protocol Implementation Conformance Statement (PICS)

The PICS shall indicate if the following options are supported:

- PRP_MIB: ability to support the SNMP MIB
- PRP_SRP: ability to perform as reduced RSTP switch without designated port role
- PRP_RSTP: ability to perform as a RSTP switch element with designated port role
- PRP_MRP: ability to perform as a MRP switch element (client or master)
- PRP_SUBS: ability to substitute MAC addresses.
- HSR_MIB ability to support forwarding according to HSR
- HSR_PRP ability to use the HSR tag to reject duplicates, without frame forwarding from port to port
- HSR_EXT: ability to distinguish HSR from non-HSR traffic based on the EtherType
- HSR_RBX: RedBox capable of supporting singly attached nodes
- HSR_QBX: QuadBox integrating two RedBoxes
- HSR_PNT: number of entries in the proxy node table

7 PRP/HSR Management Information Base (MIB)

The MIB objects reflect the arguments of the service parameters which bear the same name, with an uppercase first letter. If the PICS option PRP_MIB or HSR_MIB is true, the MIB data structures defined in this clause shall be available at OID = 1.0.62439 in addition to the MIBs that the adapters provide, with the following definition.

```
-- ***************************************************************************

IEC-62439-3-MIB DEFINITIONS ::= BEGIN

-- ***************************************************************************
-- Imports
-- ***************************************************************************

IMPORTS

   OBJECT-TYPE, Counter32,
   TimeTicks, Integer32 FROM SNMPv2-SMI
   Boolean      FROM HOST-RESOURCES-MIB
   MacAddress     FROM BRIDGE-MIB
   iso       FROM RFC1155-SMI;


-- ***************************************************************************
-- Root OID
-- ***************************************************************************

iec  OBJECT IDENTIFIER ::= { iso 0 }

iec62439-3 MODULE-IDENTITY
   LAST-UPDATED "200811100000Z" -- November 10, 2008
   ORGANIZATION "IEC/SC 65C"
   CONTACT-INFO ""

   DESCRIPTION "This MIB module defines the Network Management interfaces
       for the redundancy protocols defined by the IEC 62439 suite."

   REVISION  "200612160000Z" -- December 16, 2006
   DESCRIPTION "Initial version of the Network Management interface for the
       Parallel Redundancy Protocol"
```

```
   REVISION    "200811100000Z"  --  November 10, 2008
   DESCRIPTION  "
       Separation of IEC 62439 into a suite of documents
       This MIB applies to IEC 62439-3, added HSR functionality
                "
   ::= { IEC 62439 }


-- ***************************************************************************
-- Redundancy Protocols
-- ***************************************************************************
hsr                 OBJECT IDENTIFIER ::= { iec62439 1 }
mrp                 OBJECT IDENTIFIER ::= { iec62439 2 }
prp                 OBJECT IDENTIFIER ::= { iec62439 3 }
crp                 OBJECT IDENTIFIER ::= { iec62439 4 }
brp                 OBJECT IDENTIFIER ::= { iec62439 5 }
drp                 OBJECT IDENTIFIER ::= { iec62439 6 }
-- ***************************************************************************
-- Objects of the PRP Network Management
-- ***************************************************************************

nodeName OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(1..32))
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies the node name"
   ::= { prp 1 }

manufacturerName OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(1..255))
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies the name of the manufacturer (can be read only)"
   ::= { prp 2 }

versionName OBJECT-TYPE
   SYNTAX OCTET STRING (SIZE(1..32))
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
    "specifies the version of the LRE software (can be read-only)"
   ::= { prp 3 }

macAddressA OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies the MAC address to be used by network interface A"
   ::= { prp 4 }

macAddressB OBJECT-TYPE
   SYNTAX MacAddress
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies the MAC address to be used by network interface B"
   ::= { prp 5 }

adapterActiveA OBJECT-TYPE
   SYNTAX INTEGER {
    notActive (0),
    active (1)
    }
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies whether the adapter A shall be active"
   ::= { prp 6 }

adapterActiveB OBJECT-TYPE
   SYNTAX INTEGER {
    notActive (0),
    active (1)
    }
   MAX-ACCESS read-write
```

```
   STATUS  mandatory
   DESCRIPTION
    "specifies whether the adapter B shall be active"
   ::= { prp 7 }

duplicateDiscard OBJECT-TYPE
   SYNTAX INTEGER {
    doNotDiscard (0),
    discard (1)
    }
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "specifies whether the duplicate discard algorithm is used at reception and
     that the RCT is appended at sending"
   ::= { prp 8 }

transparentReception OBJECT-TYPE
   SYNTAX INTEGER {
    removeRCT (0),
    passRCT (1)
    }
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "if 0, the RCT is removed when forwarding to the upper layers"
   ::= { prp 9       }

switchingEndNode OBJECT-TYPE
   SYNTAX INTEGER {
    not switching (0),
    switching_SRP (1)
    switching_RSTP (2)
    switching_MRP(4)
    }
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "act as a switching end node according to SRP, RSTP or MRP"
   ::= { prp 10 }

cntTotalSentA OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
    "number of frames sent over network interface A"
   ::= { prp 11 }

cntTotalSentB OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
    "number of frames sent over network interface B"
   ::= { prp 12 }

cntErrorsA OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
    "number of frames with errors received from network interface A"
   ::= { prp 13 }

cntErrorsB OBJECT-TYPE
   SYNTAX Counter32
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
    "number of frames with errors received from network interface B"
   ::= { prp 14 }

cntNodes OBJECT-TYPE
   SYNTAX INTEGER
   MAX-ACCESS read-only
   STATUS  mandatory
   DESCRIPTION
```

```
    "number of nodes in the Nodes Table"
   ::= { prp 15 }

nodesTableClear OBJECT-TYPE
   SYNTAX INTEGER {
    noOp (0),
    clearNodesTable (1)
    }
   MAX-ACCESS write-only
   STATUS  mandatory
   DESCRIPTION
    "specifies that the Nodes Table is to be cleared"
   ::= { prp 16 }

-- ***************************************************************************
-- Nodes Table
-- ***************************************************************************

nodesTable OBJECT-TYPE
   SYNTAX SEQUENCE OF NodesTableEntry
   MAX-ACCESS read-write
   STATUS  mandatory
   DESCRIPTION
    "Nodes Table containing information about the unidirectional connections"
   ::= { prp 17 }

nodesTableEntry OBJECT-TYPE
     SYNTAX NodesTableEntry
   ACCESS read-only
   STATUS mandatory
   DESCRIPTION
    "Row of Nodes Table"
   INDEX { nodesTableIndex }
   ::= { nodesTable 1 }

NodesTableEntry ::= SEQUENCE {
   macAddressA    MacAddress,
   macAddressB    MacAddress,
   cntReceivedA   Counter32,
   cntReceivedB   Counter32,
   cntKeptFramesA   Counter32,
   cntKeptFramesB   Counter32,
   cntErrOutOfSequenceA Counter32,
   cntErrOutOfSequenceB Counter32,
   cntErrWrongLANA   Counter32,
   cntErrWrongLANB   Counter32,
   timeLastSeenA   TimeTicks,
   timeLastSeenB   TimeTicks,
   sanA      Boolean,
   sanB      Boolean,
   sendSeq     INTEGER
   }
END
```

Annex A
(informative)

PRP duplicate discard algorithm as pseudo-code

A.1 Constants

```
integer32     MaxErrors;            // maximum number of errors considered
timeMilli     LifeCheckInterval;    // how often the presence of a node is checked
timeMilli     NodeForgetTime;       // time after which node entry is cleaned
integer16     DropWindowMax;        // max size of capture window
integer16     TwoPi                 // window size = DropWindowMax
integer16     OnePi                 // half the window size = DropWindowMax / 2
integer16     NodeTableEntryNrMax   // max number of entries in the NodeTable
```

A.2 Data structures

A.2.1 Base data types

```
integerXX                           // integer with a size of XX bits
octetString                         // string of unspecified octets
timeMicro                           // time in microseconds (32 bits)
timeMilli                           // time in milliseconds (32 bits)
boolean1                            // boolean that is not part of a set
```

A.2.2 Ethernet frame

This structured data type expresses a frame processed by the driver:

```
typedef FrameType = struct {
 integer48    sourceMacAddress;
 integer12    r_size;               // field before CRC
 integer4     r_LAN;                // nibble in length filled before CRC
 integer16    r_SequenceNr;         // sequence number before CRC
 integer16    physicalSize;         // size as detected by the controller
 timeMilli    timeStamp;            // time of reception
 octetString  lsdu                  // payload, not used in algortihm
 }
```

A.2.3 Source device

This structured data type expresses each source device in the LRE:

```
typedef SourceType = struct {
 integer48      nodeMacAddress;         // normally identical to nodeMACAddressA
 integer48      nodeMacAddressB;        // in case they are different
 timeMilli      timNodeLastSeen;
 integer16      cntStartSeqLanA;        // sequence number that starts the interval
 integer16      cntStartSeqLanB;
 integer16      cntExpectedtSeqLanA;    // next expected sequence number
 integer16      cntExpectedtSeqLanB;
 timeMilli      lastTimeReceivedLanA;   // time of latest reception
 timeMilli      lastTimeReceivedLanB;   // time of latest reception
 integer32      cntErrWrongLanA;        // error counter
 integer32      cntErrWrongLanB;
 integer32      cntErrOutOfSequenceA;     // error counter
 integer32      cntErrOutOfSequenceB;
 enum           stateLanA;              // normal, disabled
 enum           stateLanB;              // normal, disabled
 }
```

A.2.4 Receiver

This structured data type expresses the receiver state:

```
 typedef ReceiverType = struct {
  integer16     sourceQty;              // quantity of registered sources
  integer32     cntErrorsLanA;          // sum of errors on LAN_A
  integer32     cntErrorsLanB;          // sum of errors on LAN_B
  SourceType    sources[0..NodeTableEntryNrMax];      // number of expected partners
  }
```

```
typedef senderType = struct {
 sendSequenceNr;                        // valid for both LANs
 }
```

A.3 Procedures

A.3.1 Sender initialization

```
sendSequenceNr = 0;                     // but could be random as well
```

A.3.2 Sending a frame

```
frame.r_size = computeFrameSize(frame);
frame.sequenceNr = sendSequenceNr;
sendSequenceNr = sendSequenceNr + 1;     //modulo TwoPi = 65536

frame.r_LAN = 0xA;  // the sequence number is the same on both LANs
send(frame, LANA);
frame.r_LAN = 0xB;  //
send(frame, LANB);
```

A.3.3 Receiver initialization

```
SourceType   sourceList [0..MaxSourceNr-1];
ReceiverType receiver;
Initialize(receiver)
```

A.3.4 Receiver reception of a frame

```
// this modulo arithmetic is simplified to work with 16-bit registers.
// the modulo arithmetic is emulated with the TwoPi and OnePi constants

if (frame.r_size == frame.physicalSize) &&
 ((frame.r_LAN == LANA) || (frame.r_LAN == LANB)) {
                // frame with redundancy info
 if (~ InSourceList(frame.source)) {
  Insert (frame.source, sourceList, index);  // register only DANP sources
  Initialize_source_object (frame.source);
  }
                // known node
  // thisLAN = LAN over which frame was received (can be a field in frame)
  otherLAN = (thisLAN + 1) Mod 2;     // index of other LAN
  currentSeq(thisLAN) = sequenceNr;
  if (((currentSeq(thisLAN) - startSeq(otherLAN) + TwoPi) Mod TwoPi) =< OnePi) _
  && (((expectedSeq(otherLAN) - currentSeq(thisLAN) + TwoPi -1) Mod TwoPi) < OnePi) {
                // drop frame
  if ~ (currentSeq(thisLAN) == expectedSeq(thisLAN)) {
                // check sequence
   cntErrOutOfSequence(thisLAN) = (cntErrOutOfSequence(thisLAN) + 1)
                // increase seq errors for A or B
  }

  expectedSeq(thisLAN) = (currentSeq(thisLAN) + 1) Mod TwoPi
                // new expected sequence nr
  startSeq(otherLAN) = expectedSeq(thisLAN);
                // reduce other window
  startSeq(thisLAN) = expectedSeq(thisLAN)
                // disable this LAN
  Drop (thisLAN)
                // drop, already received
  }
  else {
            // forward frame
   if (~ (currentSeq(thisLAN) == expectedSeq(thisLAN)) {
            // check monotonicity of sequence
    cntErrOutOfSequence(thisLAN) = (cntErrOutOfSequence(thisLAN) + 1)
            // increase sequence errors
    startSeq(thisLAN) = currentSeq(thisLAN)
            // reset dropWindow to one
    }
   else {
            // correct sequence, slide window
    if ((expectedSeq(thisLAN) - startSeq(thisLAN) + TwoPi) Mod TwoPi >
    dropWindowMax) {
     if expectedSeq(otherLAN) == startSeq(thisLAN) {
              // register sequence error
      cntErrStall(otherLAN) = cntErrStall(otherLAN) + 1
      }
```

```
     startSeq(thisLAN) = (expectedSeq(thisLAN) + TwoPi - dropWindowMax)
     Mod TwoPi
                // adjust window
     }            // slide window
    }             // correct sequence
   startSeq(otherLAN) = expectedSeq(otherLAN)
                // disable the other LAN
   expectedSeq(thisLAN) = (currentSeq(thisLAN) + 1) Mod TwoPi
                // new expected sequence nr
   Forward_To_UpperLayer (thisLAN)
  }
```

A.3.5 Timeout process

```
// execute at CheckLiveTime interval

for each source in sourcelist do
 if (source.timeLastSeenA - currentTime) then
  source.missingErrorLANB++ // just register the error, no impact on algorithm
 endif
```

Bibliography

IEC 61588, *Precision clock synchronization protocol for networked measurement and control systems* (IEEE 1588)

IEC 62439 (all parts), *Industrial communication networks – High availability automation networks*

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

IEC 62439-4, *Industrial communication networks – High availability automation networks – Part 4: Cross-network Redundancy Protocol (CRP)*

IEC 62439-5, *Industrial communication networks – High availability automation networks – Part 5: Beacon Redundancy Protocol (BRP)*

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

ISO/IEC 8802-2, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 2: Logical link control* (IEEE 802.2)

ISO/IEC 10164-1, *Information technology – Open Systems Interconnection – Systems Management : Object Management Function*

____

This page deliberately left blank

British Standards Institution (BSI)

BSI is the independent national body responsible for preparing British Standards and other standards-related publications, information and services. It presents the UK view on standards in Europe and at the international level.

BSI is incorporated by Royal Charter. British Standards and other standardisation products are published by BSI Standards Limited.

Revisions

British Standards and PASs are periodically updated by amendment or revision. Users of British Standards and PASs should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using British Standards would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Similary for PASs, please notify BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001

BSI offers BSI Subscribing Members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of British Standards and PASs.

Tel: +44 (0)20 8996 7669 Fax: +44 (0)20 8996 7001
Email: plus@bsigroup.com

Buying standards

You may buy PDF and hard copy versions of standards directly using a credit card from the BSI Shop on the website **www.bsigroup.com/shop.** In addition all orders for BSI, international and foreign standards publications can be addressed to BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001
Email: orders@bsigroup.com

In response to orders for international standards, BSI will supply the British Standard implementation of the relevant international standard, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Knowledge Centre.

Tel: +44 (0)20 8996 7004 Fax: +44 (0)20 8996 7005
Email: knowledgecentre@bsigroup.com

BSI Subscribing Members are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.

Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001
Email: membership@bsigroup.com

Information regarding online access to British Standards and PASs via British Standards Online can be found at **www.bsigroup.com/BSOL**

Further information about British Standards is available on the BSI website at **www.bsi-group.com/standards**

Copyright

Tel: +44 (0)20 8996 7070
Email: copyright@bsigroup.com

BSI

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards

raising standards worldwide™