



BSI Standards Publication

# Industrial communication networks — High availability automation networks

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

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### 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 It supersedes BS EN 62439-3:2010 which is withdrawn.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.

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

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

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

This European Standard was approved by CENELEC on 2012-08-09. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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Comité Européen de Normalisation Electrotechnique  
Europäisches Komitee für Elektrotechnische Normung

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## Foreword

The text of document 65C/687/FDIS, future edition 2 of IEC 62439-3, prepared by SC 65C, "Industrial networks", of IEC TC 65, "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62439-3:2012.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2013-05-09
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-08-09

This document supersedes EN 62439-3:2010.

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

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

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

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## Endorsement notice

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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	-	-

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## 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.

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## INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

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

#### 1 Scope

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

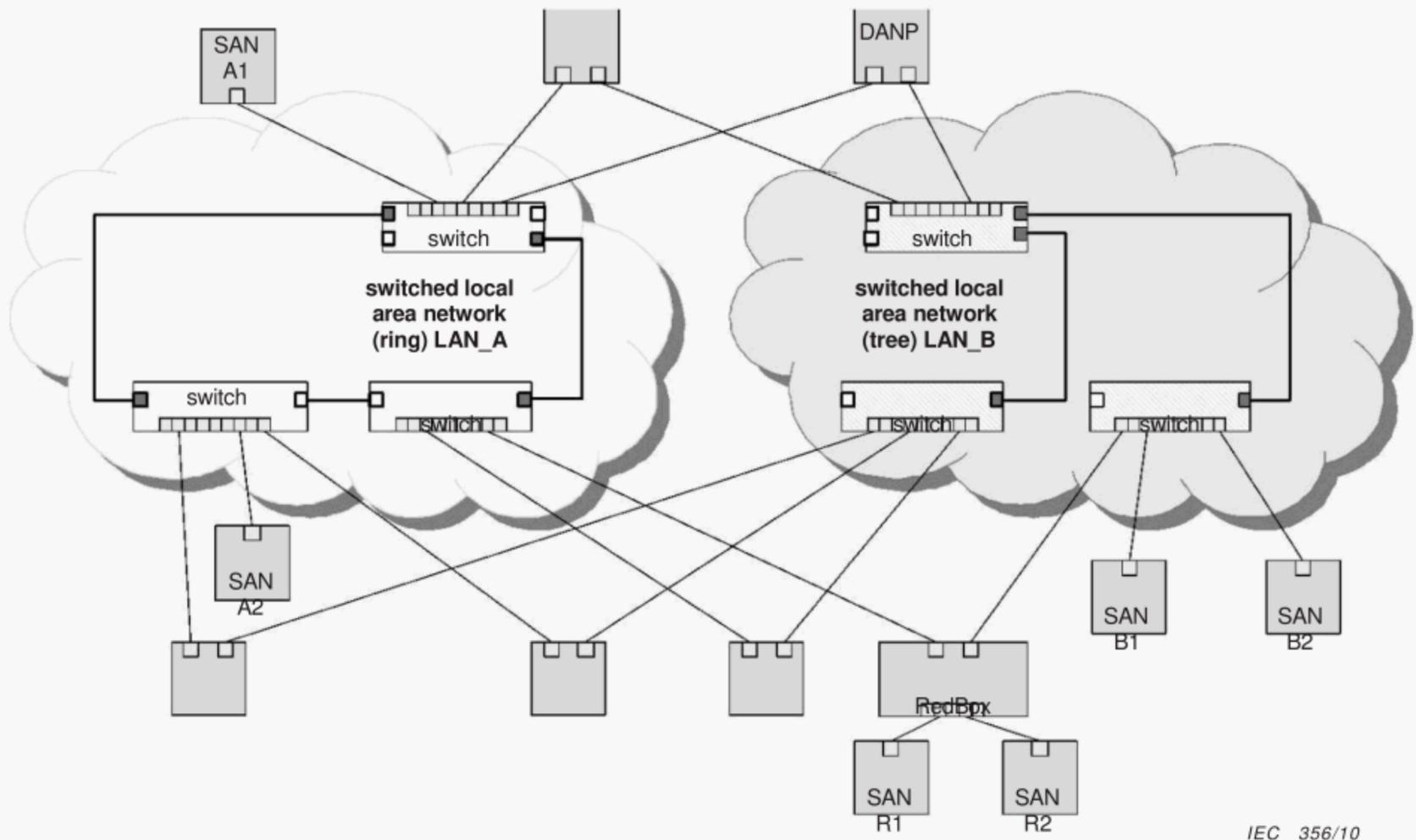
### 4.1 PRP principle of operation

#### 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.

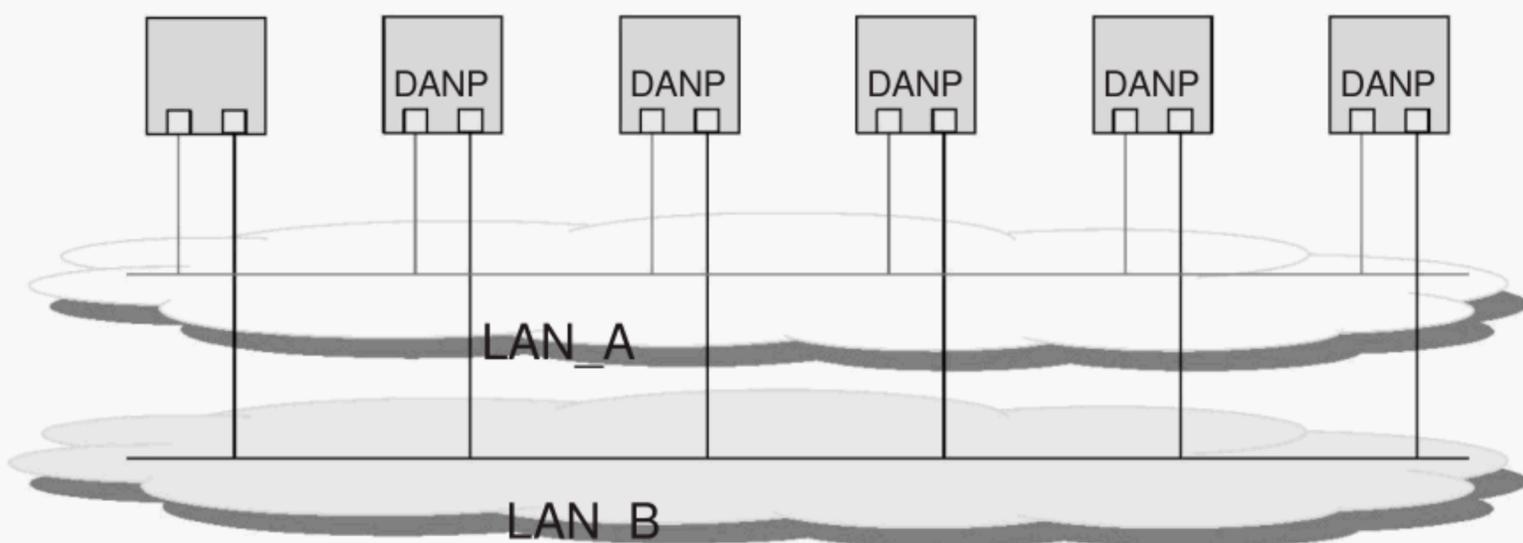
The two LANs follow configuration rules that allow the network management protocols such as Address Resolution Protocol (ARP) to operate correctly.

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,**

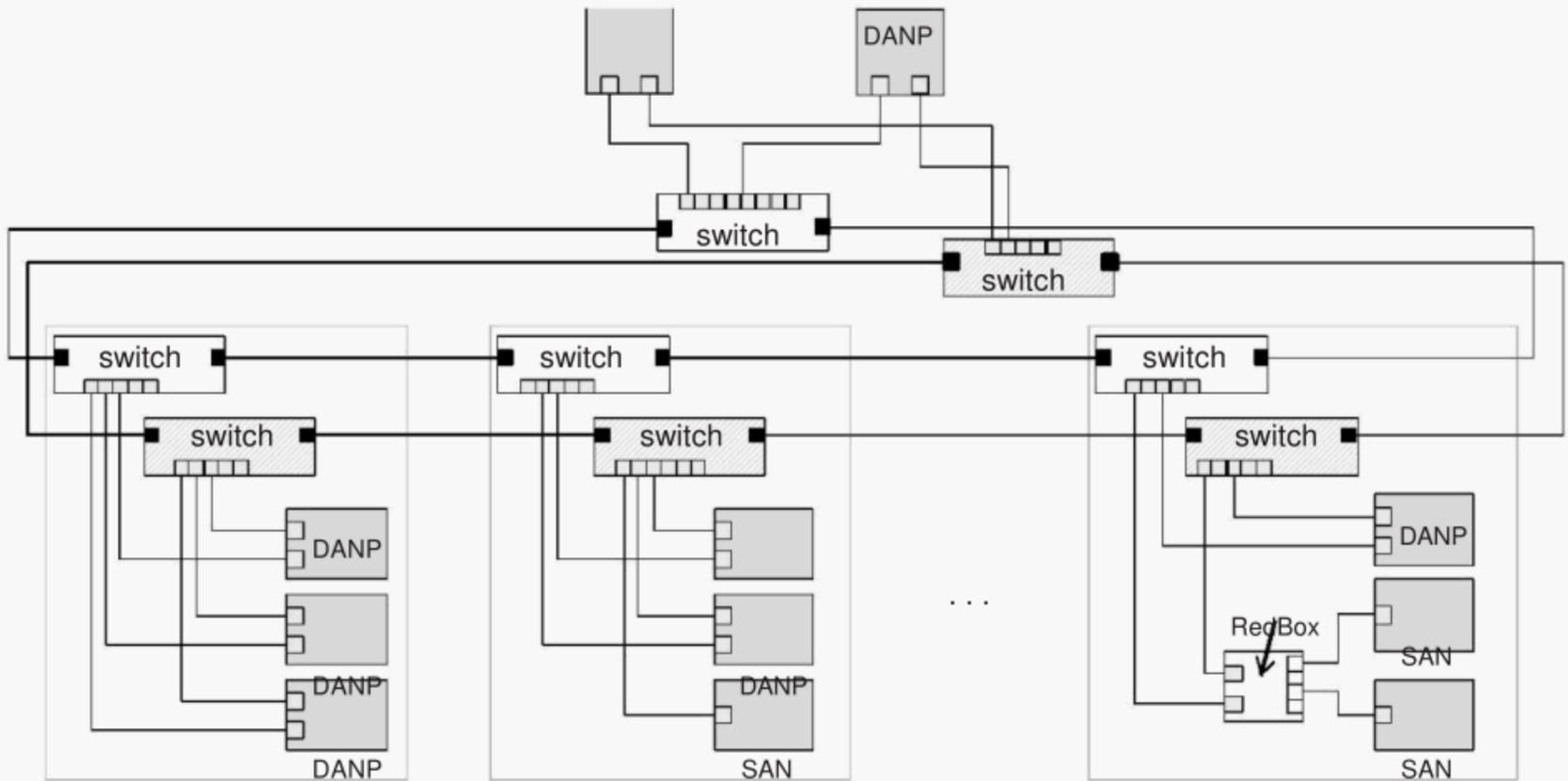
Figure 2 draws a PRP network as two LANs in linear topology, which may also be a bus topology.



**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.

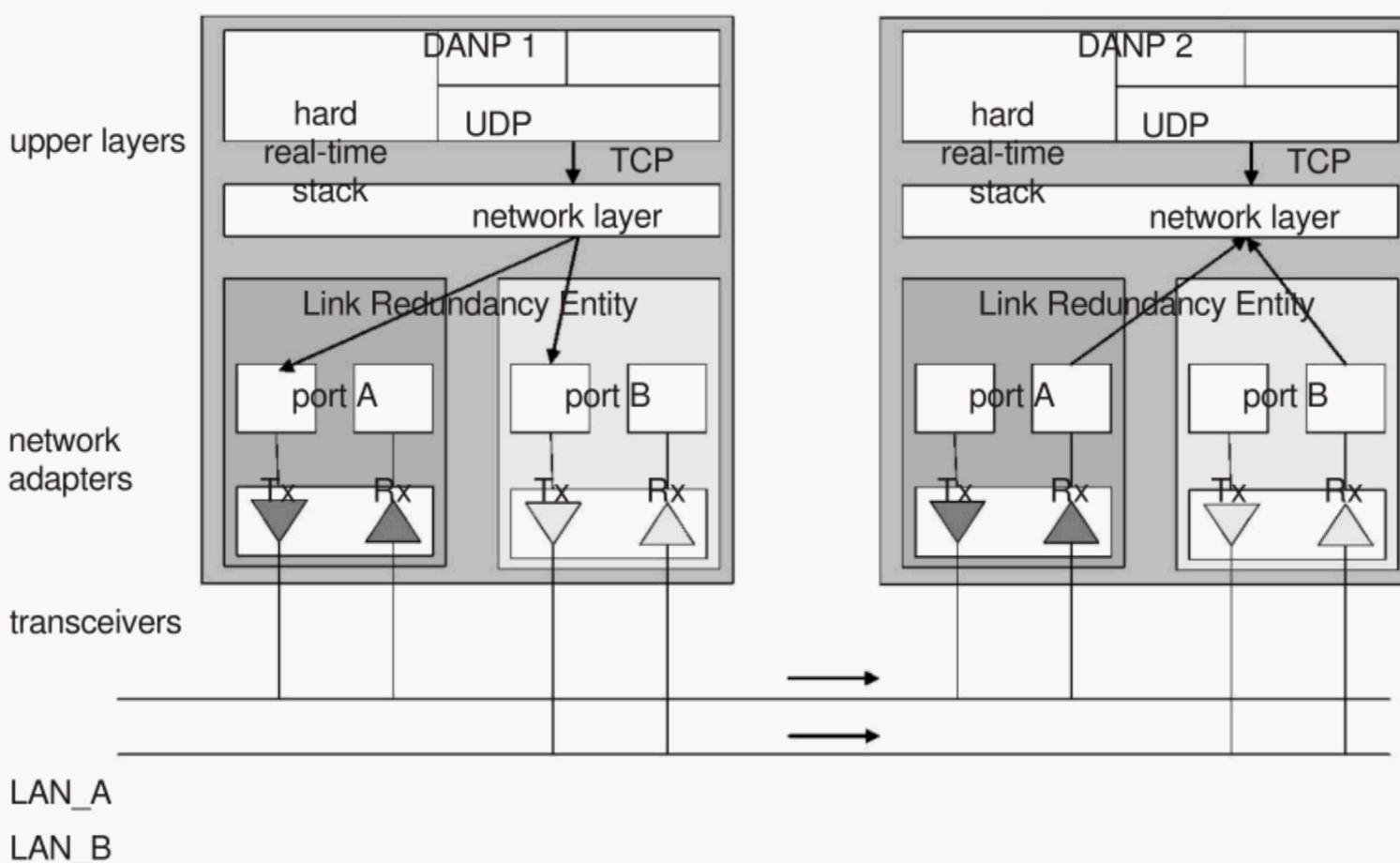


IEC 358/10

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

**4.1.4 DANP node structure**

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



IEC 359/10

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





## 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

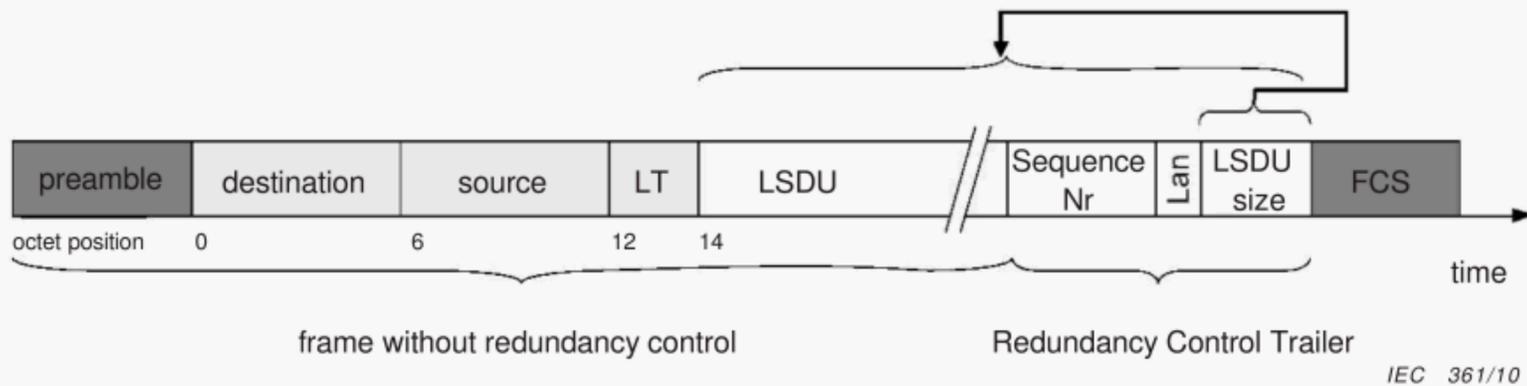
#### 4.1.10.3.1 Principle

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

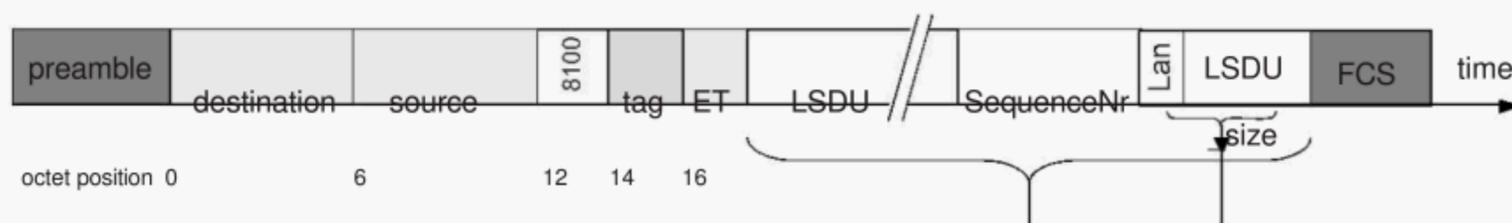
The field LAN can take one of two values: 1 010 indicating that the frame has been sent over LAN\_A and 1 011 indicating that the frame has been sent over LAN\_B. This allows detecting installation errors.

#### 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:  $104 = 100 + 4$ .

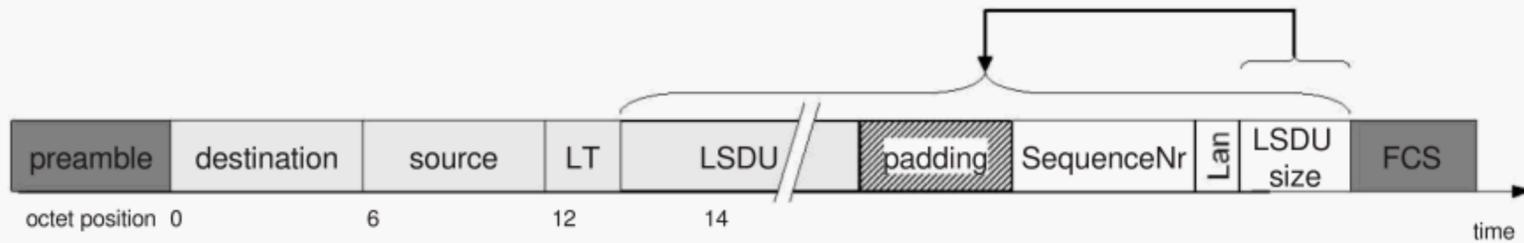
In VLANs, frame VLAN tags may be added or removed during transit through a switch. To make the length field independent of VLAN tagging, only the LSDU and the RCT are considered in the LSDU\_size, as Figure 7 shows.



**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**

IEC 363/10

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.

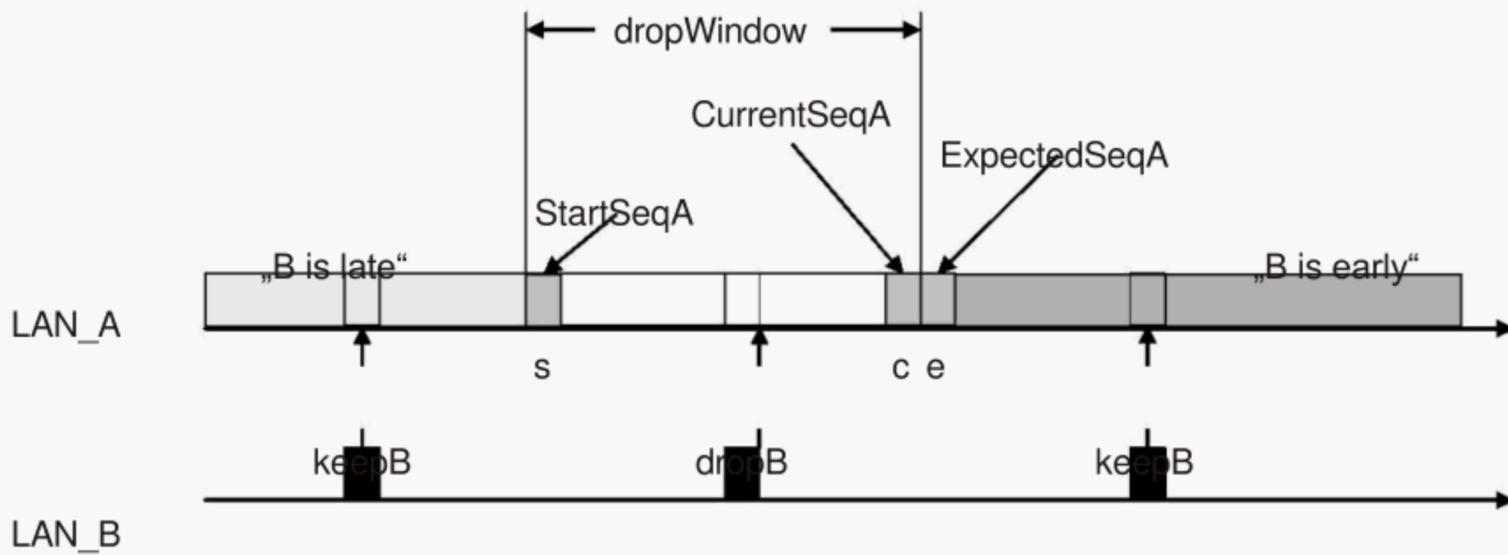
#### 4.1.10.3.6 Discard algorithm

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.

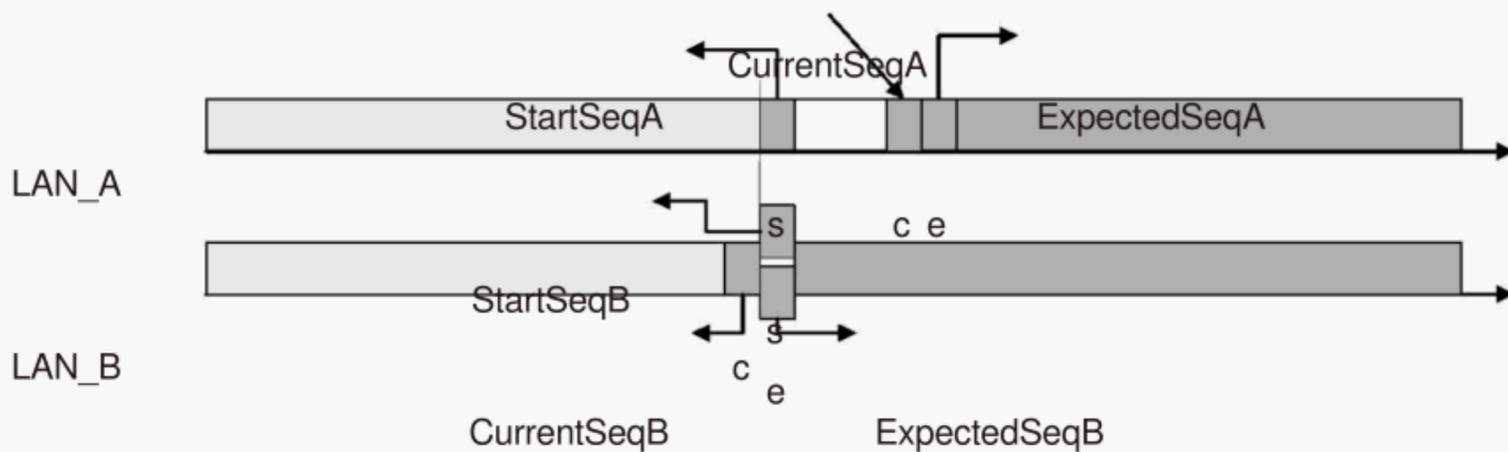


IEC 364/10

**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.

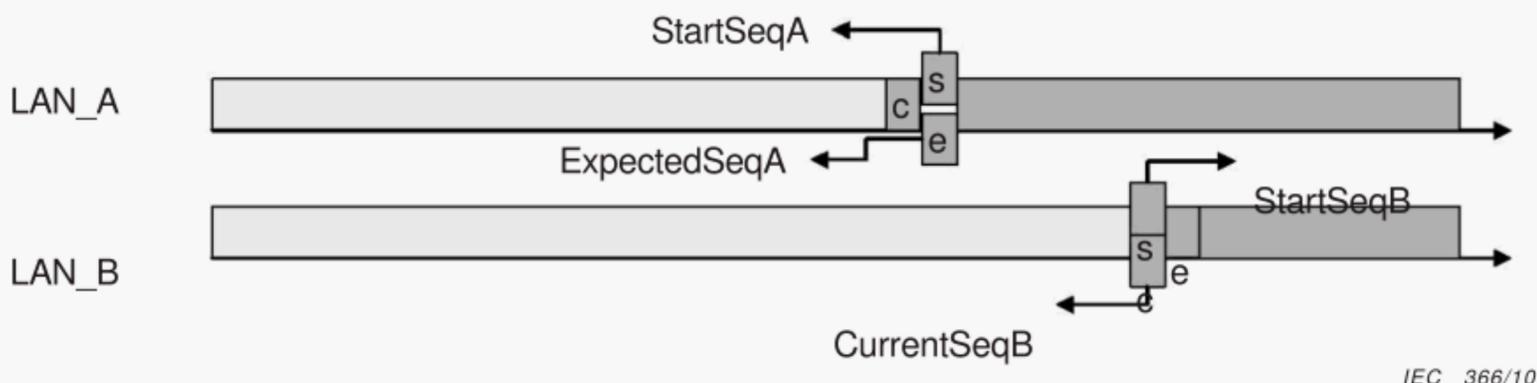


IEC 365/10

**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 or 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.





#### 4.2.7.4.4 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 4 – PRP arguments**

Argument	Definition	Data Type
MacAddressA	MAC address of the source node (6 octets)	OctetString6
MacAddressB <sup>a</sup>	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

<sup>a</sup> MacAddressB is not a key attribute.

### 4.3.3 PRP write

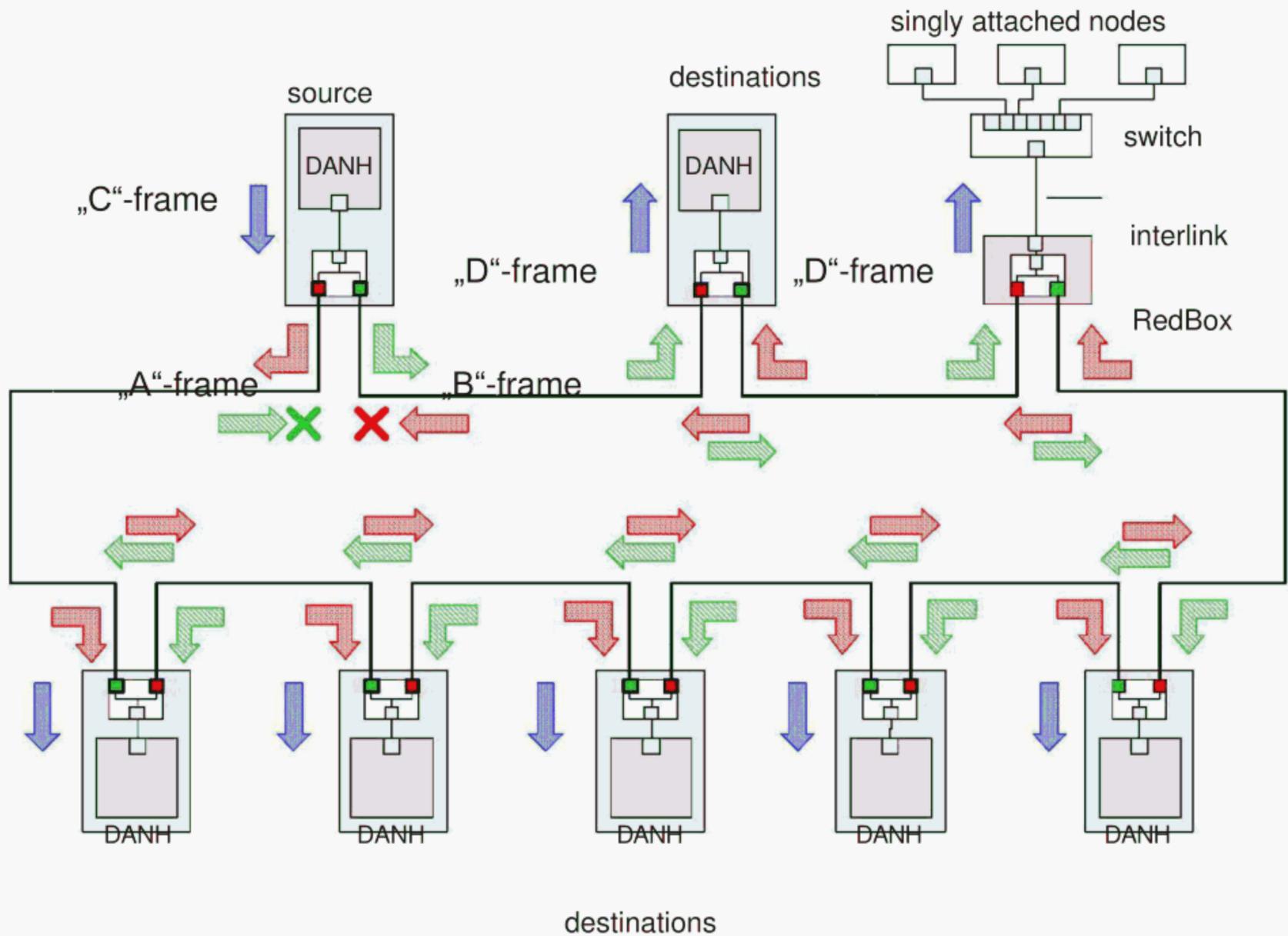
This service shall be used to write values to the LRE of a DANP to control the PRP. Table 5 shows the parameters of this service.

**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(=)		







**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

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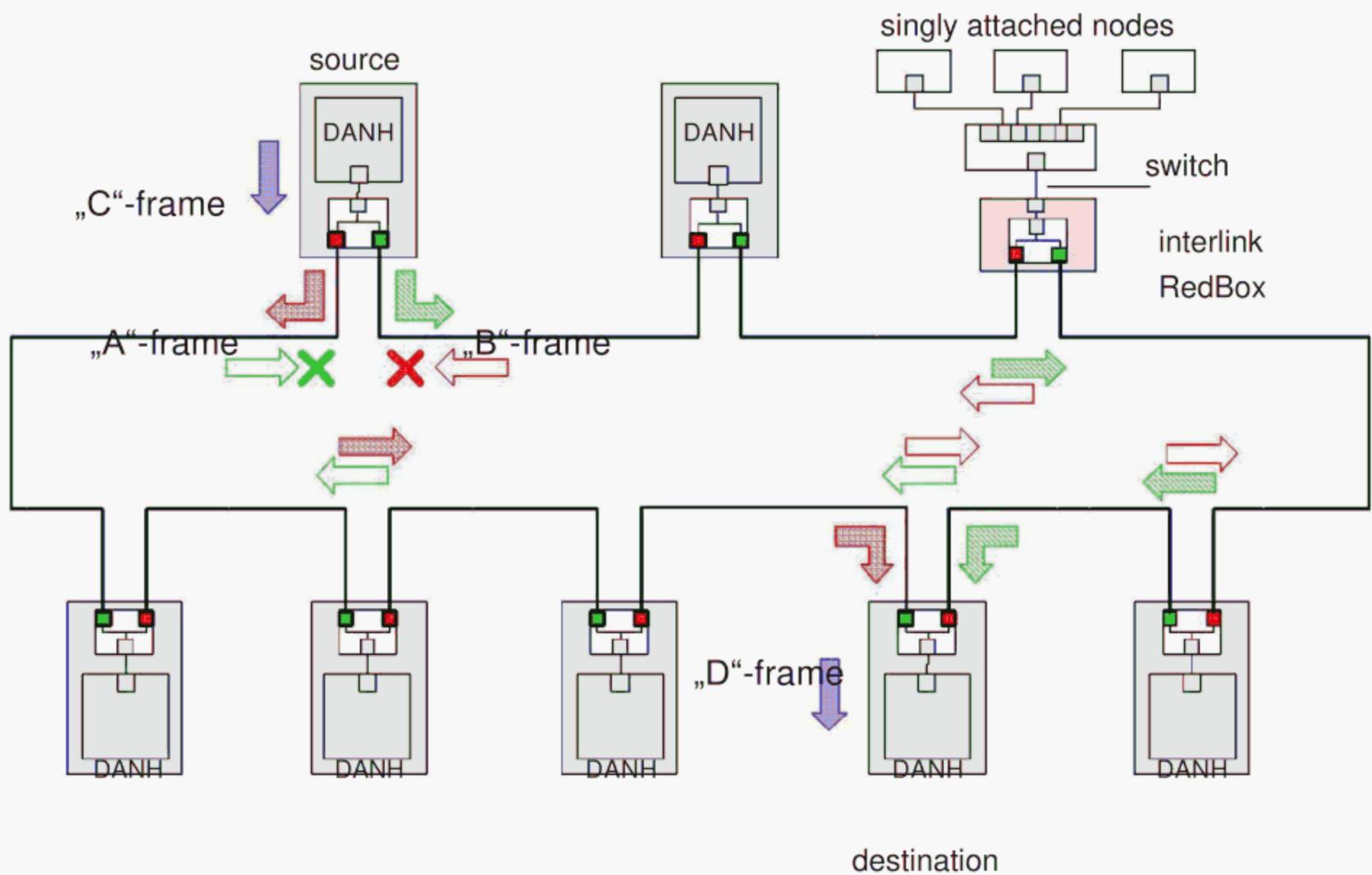
**Figure 13 – HSR example of ring configuration for multicast traffic**

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.



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**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.

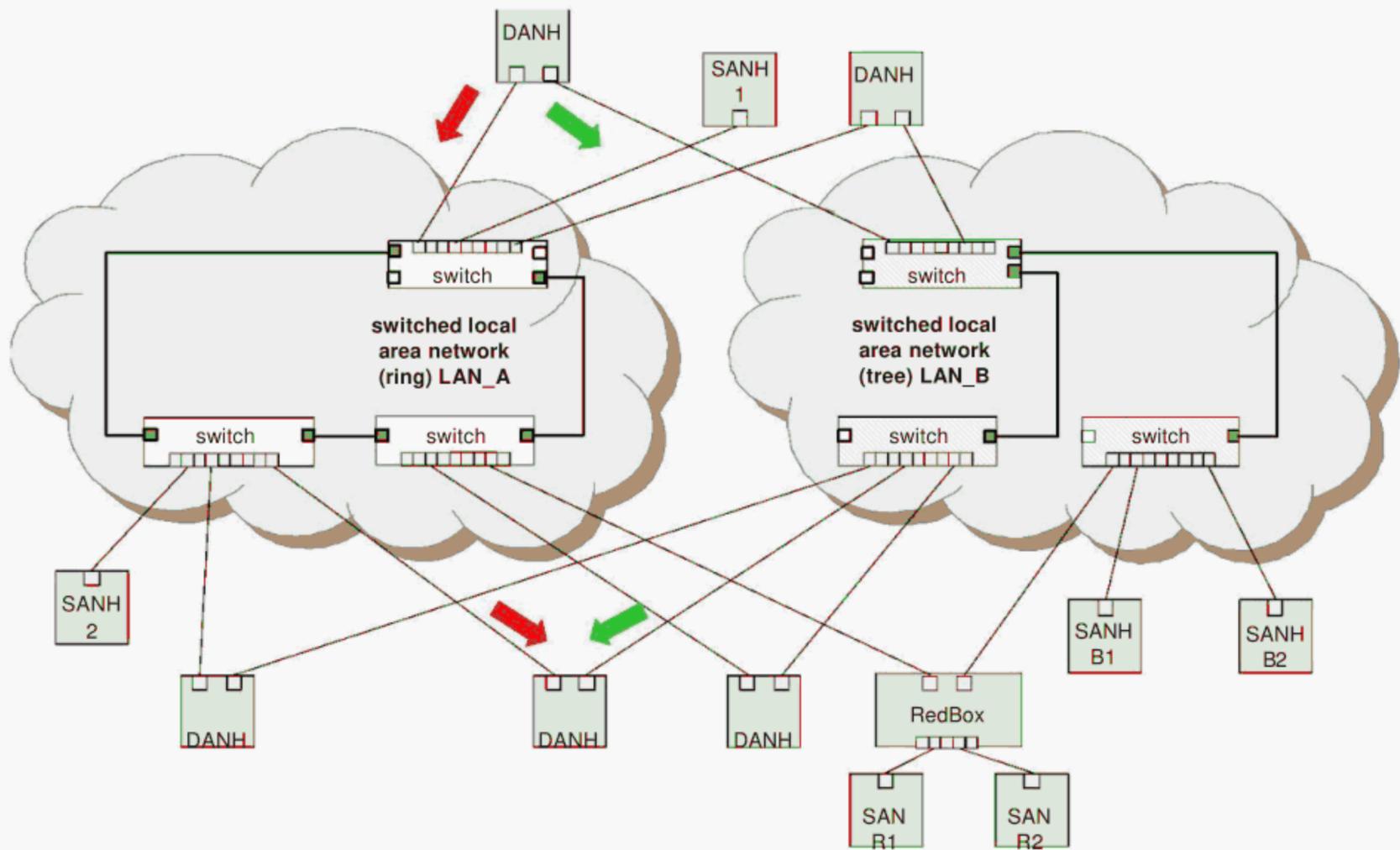
NOTE The time skew between two frames of a pair depends on the relative position of the receiving node and of the sending node. Assuming a worst case in which each node in the ring is transmitting at the same time its own frame with the largest size of 1 536 octets (maximum length supported by the Ethertype 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.





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Figure 16 – HSR example of topology using two independent networks

### 5.2.3.3 Peer coupling of rings

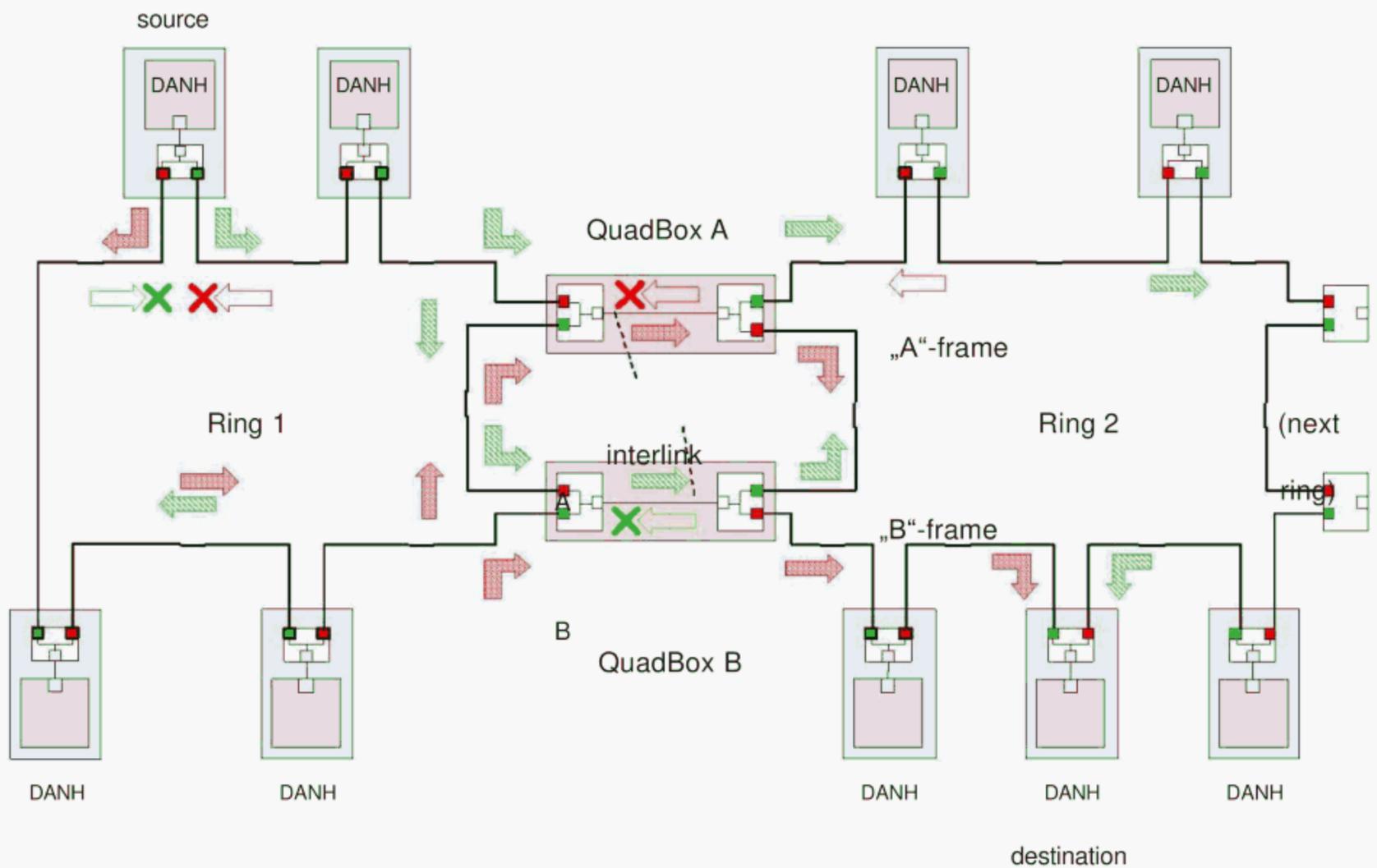
Two HSR rings may be connected by quadruple port devices with forwarding capabilities, called QuadBoxes, as Figure 17 shows. This is advantageous when the traffic flow exceeds the capabilities of a single ring. However, transmission delays from end to end are not improved.

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.



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**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.

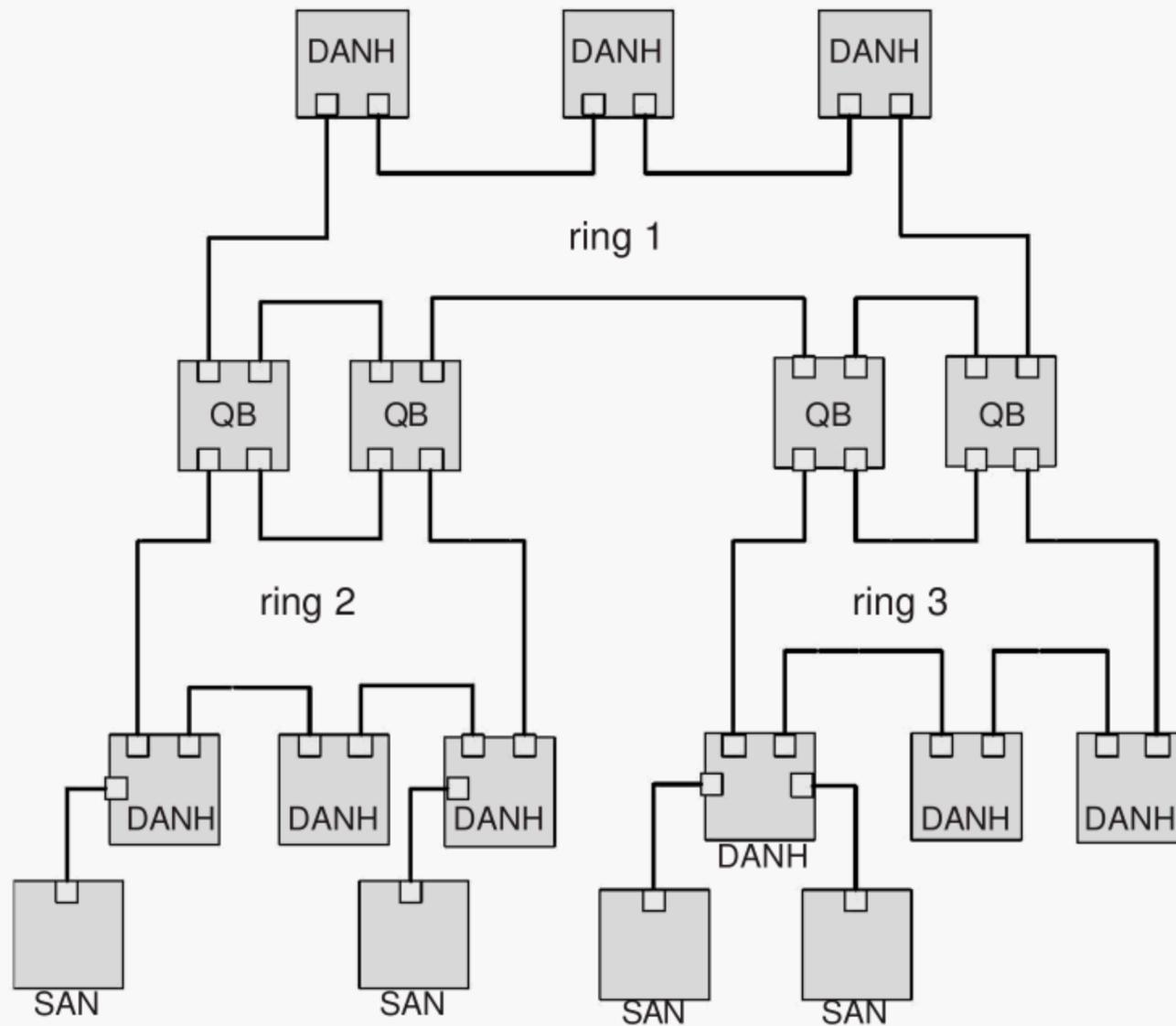
This does not cause four frames to circulate on the second ring, since, when a copy from a first QuadBox reaches the second QuadBox on the same second ring, the second QuadBox will not forward it if it already sent a copy that came from its interlink. Conversely, if the second QuadBox did not yet receive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



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**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.

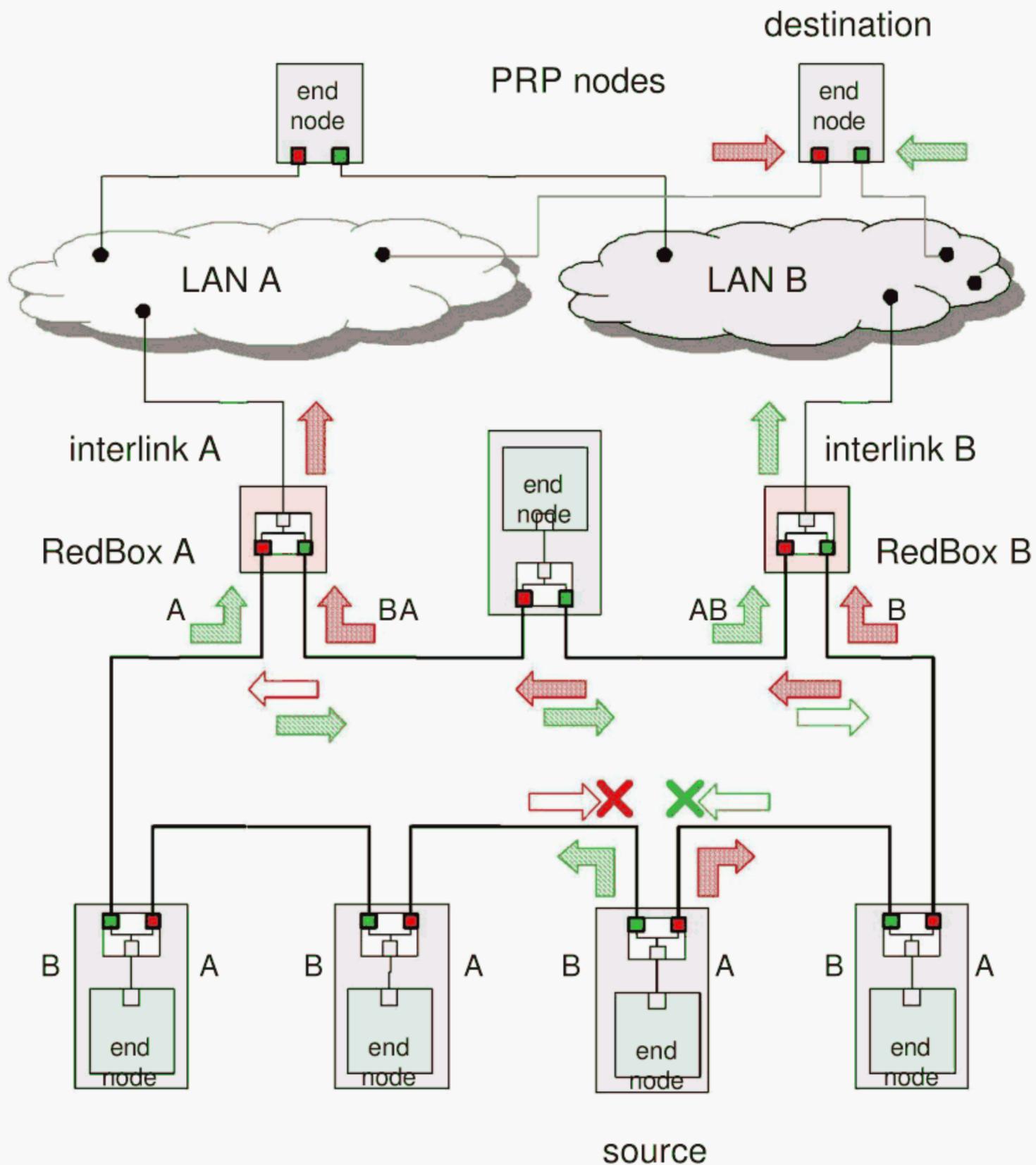
Some SANs are connected directly to the DANH that performs the duty of a simplified RedBox.

### 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.





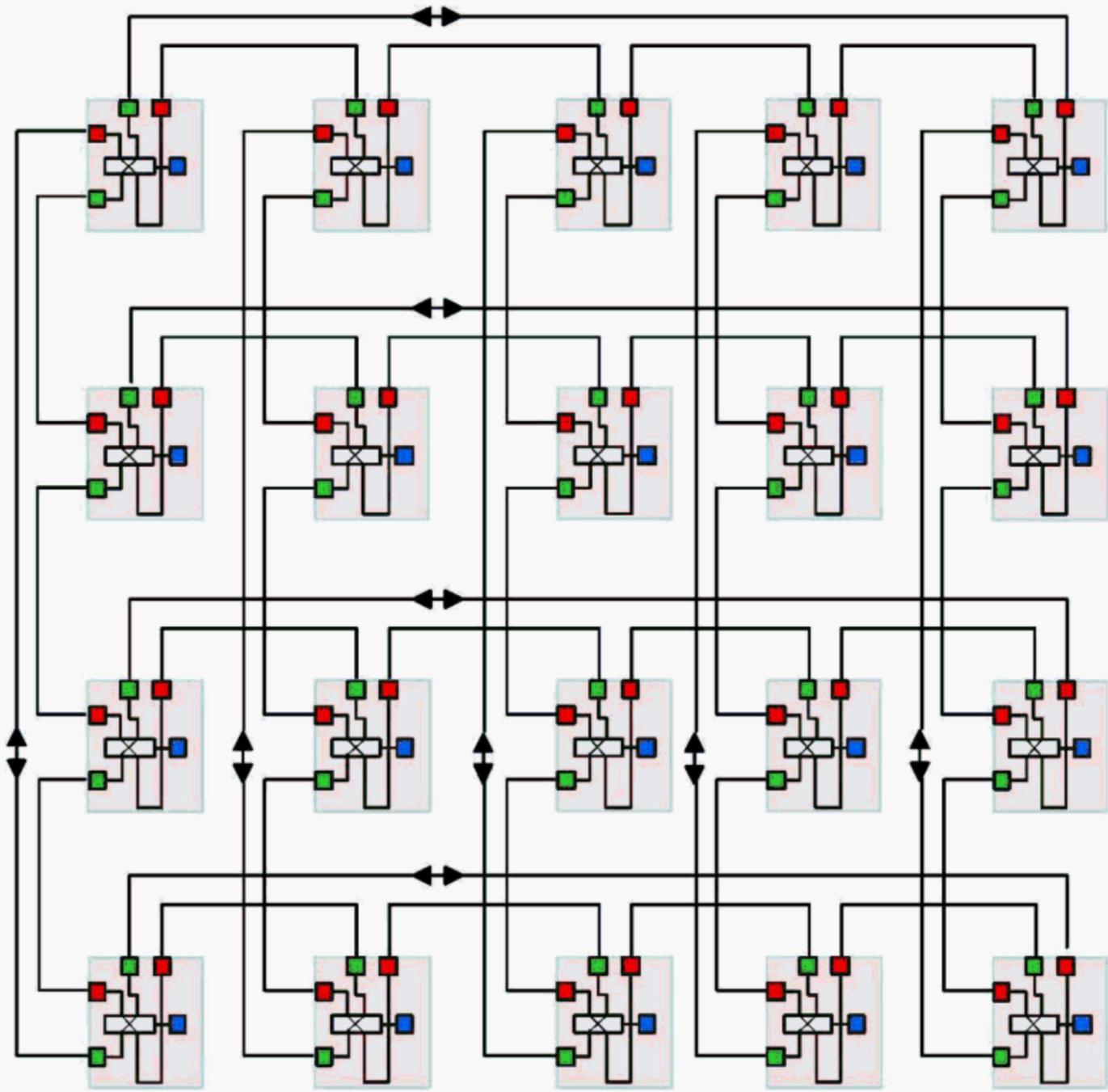
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**Figure 20 – HSR example of coupling from a ring node to redundant PRP LANs**

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.

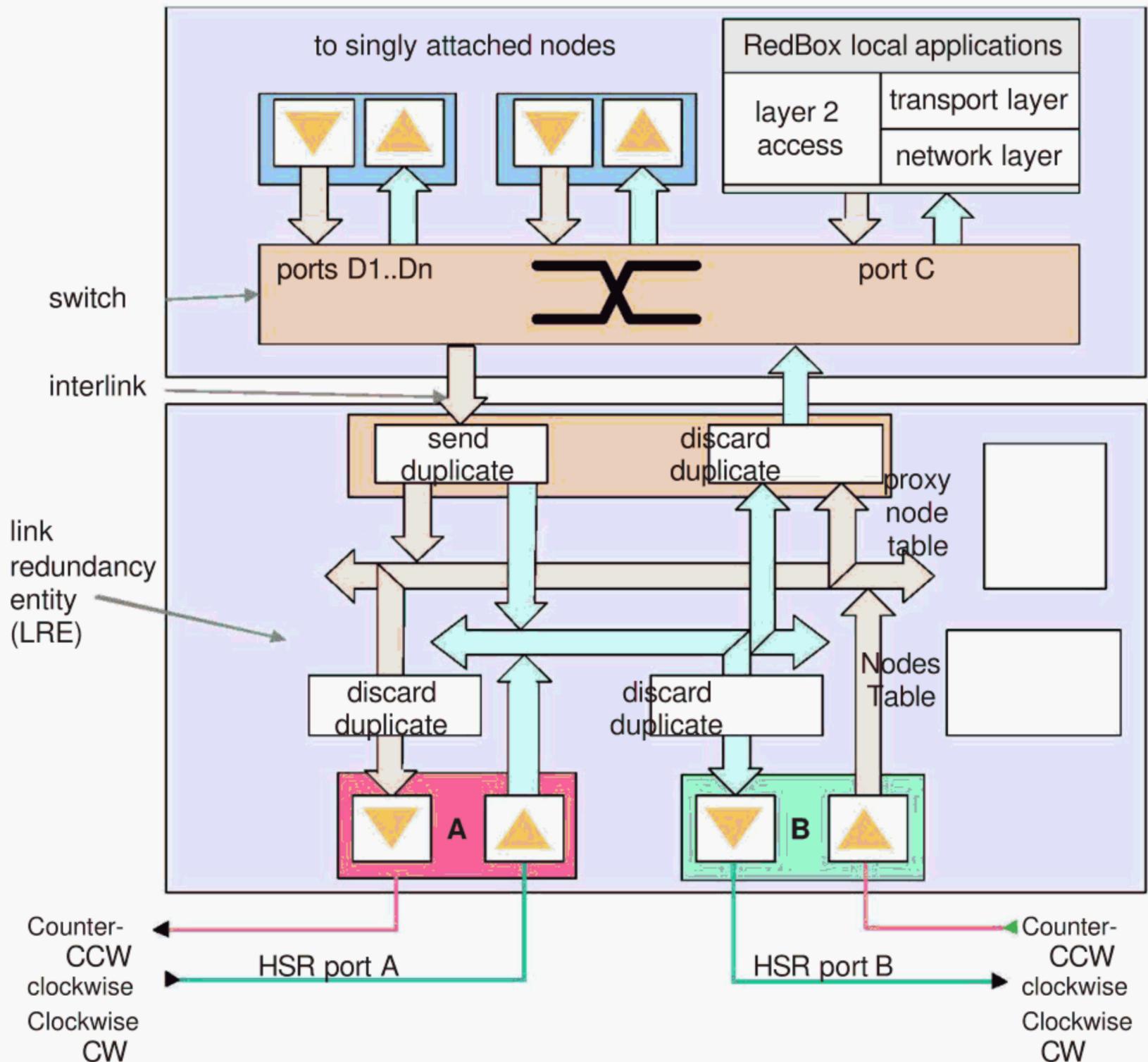


IEC 376/10

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.



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)







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**

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

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



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  lsd                // payload, not used in algorithm
}
```

##### 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
```

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