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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Réseaux de communication industriels – Réseaux d'automatisation à haute disponibilité – Partie 4: Protocole de redondance inter-réseau (CRP)

IEC 62439-4:2010

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

Part 4: Cross-network Redundancy Protocol (CRP)

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

International Standard IEC 62439-4 has been prepared by subcommittee 65C: Industrial Networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This standard cancels and replaces IEC 62439 published in 2008. This first edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC 62439 (2008):

– adding a calculation method for RSTP (rapid spanning tree protocol, IEEE 802.1Q),
– adding two new redundancy protocols: HSR (High-availability Seamless Redundancy) and DRP (Distributed Redundancy Protocol),
– moving former Clauses 1 to 4 (introduction, definitions, general aspects) and the Annexes (taxonomy, availability calculation) to IEC 62439-1, which serves now as a base for the other documents,
– moving Clause 5 (MRP) to IEC 62439-2 with minor editorial changes,
– moving Clause 6 (PRP) was to IEC 62439-3 with minor editorial changes,

– moving Clause 7 (CRP) was to IEC 62439-4 with minor editorial changes, and
– moving Clause 8 (BRP) was to IEC 62439-5 with minor editorial changes,
– adding a method to calculate the maximum recovery time of RSTP in a restricted configuration (ring) to IEC 62439-1 as Clause 8,
– adding specifications of the HSR (High-availability Seamless Redundancy) protocol, which shares the principles of PRP to IEC 62439-3 as Clause 5, and
– introducing the DRP protocol as IEC 62439-6.

This bilingual version (2012-12) corresponds to the monolingual English version, published in 2010-02.

The text of this standard is based on the following documents:

FDIS	Report on voting
65C/583/FDIS	65C/589/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This International Standard is to be read in conjunction with IEC 62439-1:2010, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods*.

A list of the IEC 62439 series can be found, under the general title *Industrial communication networks – High availability automation networks*, on the IEC website.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with ISO/IEC Directives, Part 2.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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 a full-duplex Ethernet in which each device periodically transmits a message representing its connectivity to the other devices , allowing them to choose a redundant path in case of failure, given in 7.1 and 7.3.

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

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Austin, TX 78759

USA

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INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

Part 4: Cross-network Redundancy Protocol (CRP)

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 a redundancy protocol that is based on the duplication of the network, the redundancy protocol being executed within the end nodes, as opposed to a redundancy protocol built in the switches. The switchover decision is taken in each node individually. The cross-network connection capability enables single attached end nodes to be connected on either of the two networks.

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, *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*

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.

3.2 Abbreviations and acronyms

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

DANC Doubly attached node implementing CRP

SANC Singly attached node implementing CRP

3.3 Conventions

This document follows the conventions defined in IEC 62439-1.

4 CRP overview

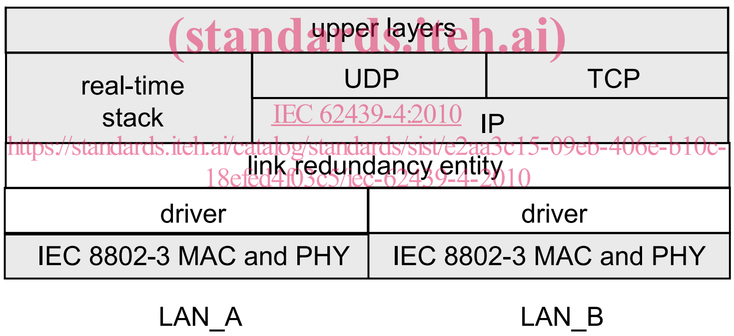
This International Standard specifies a redundancy protocol that is based on the duplication of the network, the redundancy protocol being executed within the end nodes, as opposed to a redundancy protocol built in the switches. There is no central “redundancy manager”; instead each node operates autonomously. The cross-network connection capability enables single attached end nodes to be connected on either of the two networks.

5 CRP nodes

There exists different classes of nodes that may interoperate on the same network:

- DANCs (Doubly Attached Nodes) able to execute the CRP protocol, and having two ports for the purpose of redundancy.
- SANCs (Singly Attached Nodes) able to execute the CRP protocol, and having only one port.
- SAN (Singly Attached Nodes), such as commercially available laptops or file servers that are not aware of the CRP protocol. Even though not aware, SANs can also have access to the redundancy management data for the purpose of monitoring and network management.

In DANCs, these two ports are referred to as port A and port B. They are managed by the Link Redundancy Entity (LRE), whose implementation is not prescribed, and which is conceptually located in the communication stack below the network layer, as illustrated in Figure 1.



IEC 380/10

Figure 1 – CRP stack architecture

This arrangement provides application-level transparency. The LRE hides redundancy from the upper layers and manages the ports. A node can therefore operate with only one IP address.

6 CRP LAN topology

Implementing the redundancy protocol within the DANCs allows a variety of topologies, using switches that are not aware of the redundancy protocol and could implement another redundancy protocol such as RSTP.

This International Standard does not dictate the topology, but does allow for configuration of node behaviour to accommodate the characteristics of the specific LAN being used.

Nodes may be attached to the same or to different switches of a single LAN, which may or may not include redundant links, as Figure 2 shows. Attaching both links to the same switch only provides leaf link failure resilience.

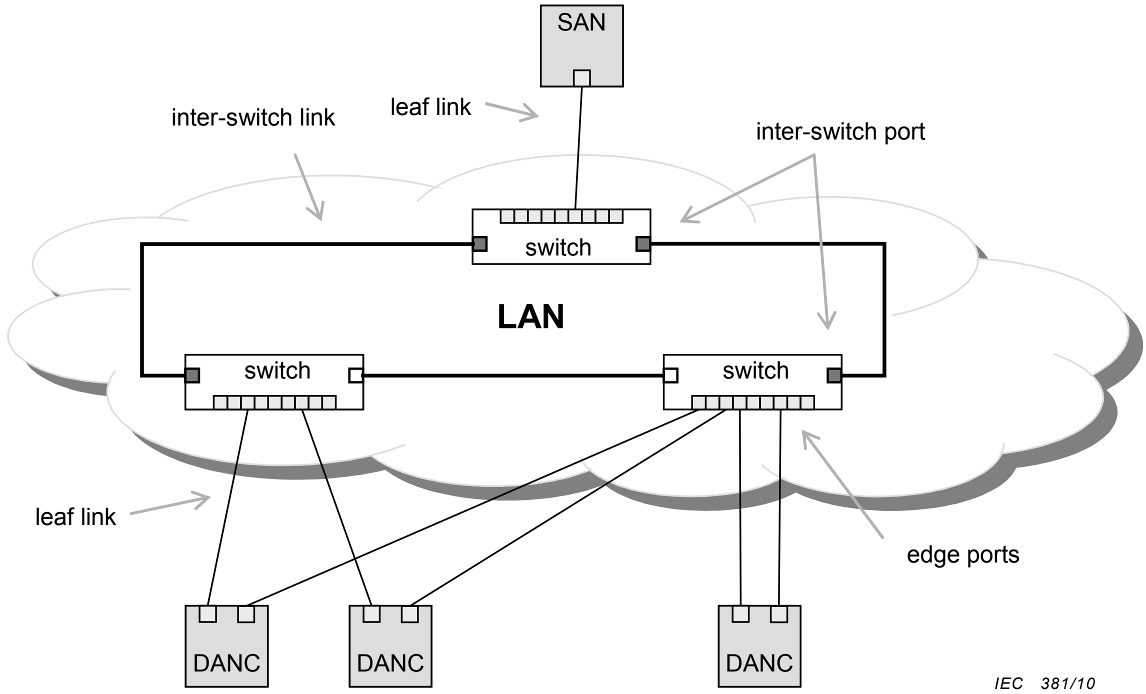


Figure 2 – CRP single LAN topography

Nodes may be attached to separate LANs, which are basically failure-independent, but may be connected by an inter-LAN link, as Figure 3 shows.

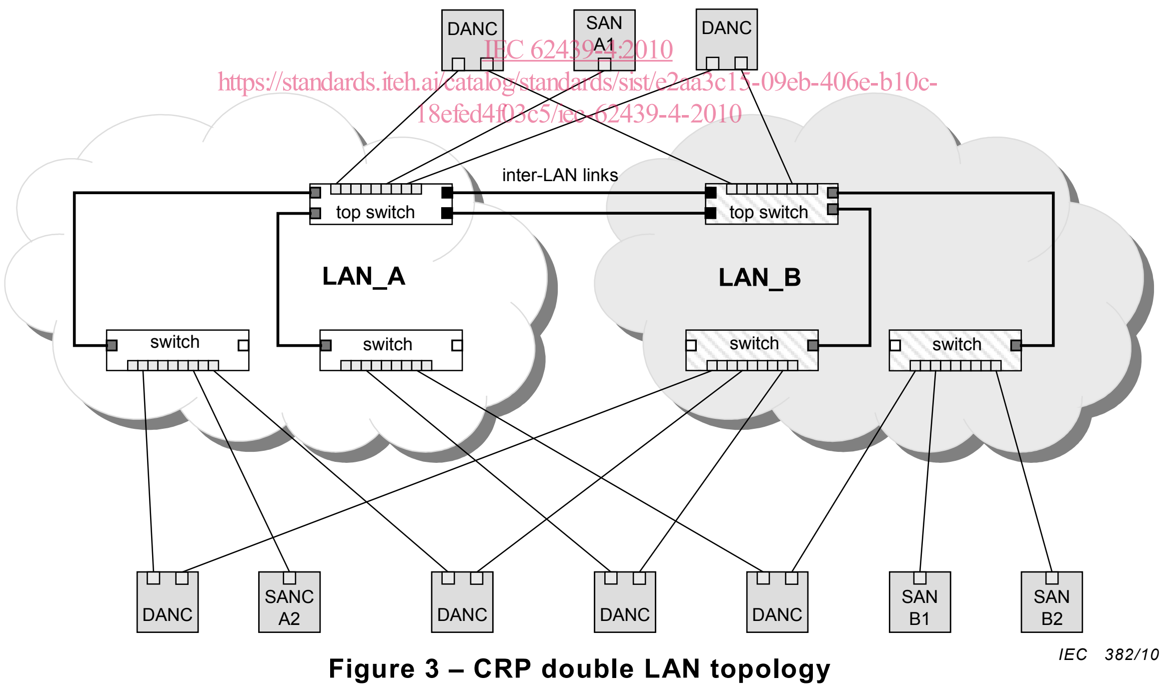


Figure 3 – CRP double LAN topology

When there is only one LAN, a node is attached through both its ports to that LAN. In double LAN configurations, port A is normally connected to LAN_A and port B to LAN_B. Connecting a node twice to the same network tree or connecting port A to LAN_B and vice-versa may be a configuration error called “crossed cables”.

7 CRP key components

7.1 CRP general protocol operation

7.1.1 Doubly-attached nodes (DANCs)

DiagnosticFrames are used to exercise communication paths and to assess the network health. A DiagnosticFrame contains a summary of the reporting node's view of the network health and status, including its own port.

Annunciation frames are sent to announce the existence of the node. These frames are described in 8.7.1

Each DANC sends a pair of DiagnosticFrames periodically, every T_{dmi}, on both of its ports, as Figure 4 shows. Each DANC that receives one DiagnosticFrame on one port expects the other message of the pair on the other port. (On a single LAN, the node receives both messages on both ports.) If a node receives no message or if it does not receive the second DiagnosticFrame on the other port before receiving several more DiagnosticFrames on the same port, it records a fault in the row of the Network_Status_Table for the corresponding node.

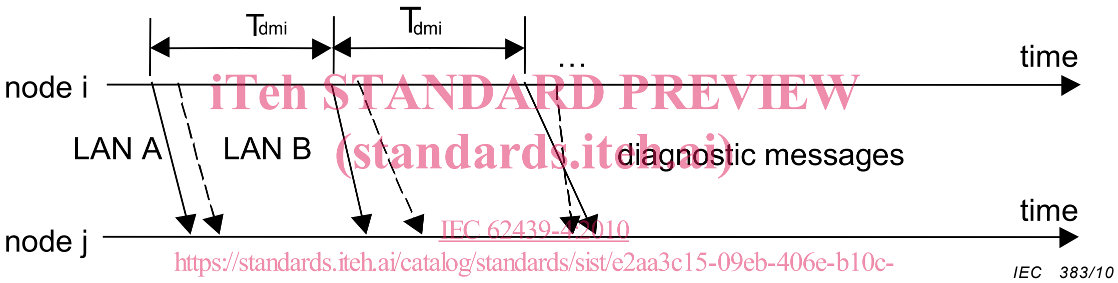


Figure 4 – CRP DiagnosticFrame pair approach

In practice the receiving node compares the Sequence_Number of the last message received on the other port with that just received. If the difference in Sequence_Number is more than the configured Max_Sequence_Number_Difference, a fault is recorded.

Based upon the diagnostic frames it receives from all other nodes, each node can select which port to use to send messages to a particular node, on a node-per-node basis.

EXAMPLE Figure 5 shows four nodes connected to two redundant LANs which are not connected with each other. Node 3 and node 4 have link failures. The diagnostic frame handling on node 3 is detailed.

Each node broadcasts its view on the port status of all nodes it detected in addition to other status information (source MAC address, Node_Index, etc.).

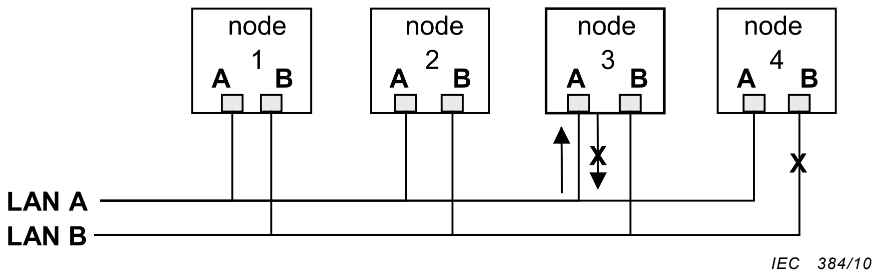
Node 3 maintains a Network_Status_Table populated by the DiagnosticFrames from nodes 1, 2, and 4, as shown in Table 1.

The port status values are OK to indicate a working condition, and X for a don't know or bad condition.

According to the first three columns of the Network_Status_Table in Table 1, node 3 sends out its Received_DiagnosticFrame for port A as [OK, OK, OK, OK] and for port B as [OK, OK, OK, X].

Similarly, node 1 sends out its view on nodes 2, 3, and 4 as [OK, OK, X, OK] for port A and [OK, OK, OK, X] for port B. Node 3's adapter A and adapter B status is populated as shown in Table 1.

The row for node 3 is set based on its own testing, but in this example there is no testing, so all appears to be OK.



Node 3: Interface A partial failure; can receive, but not transmit
Node 4: Interface B complete failure.

Figure 5 – CRP example system

Table 1 – CRP example Network_Status_Table for node 3

Node_Index Number	Received_DiagnosticFrame		Reported status extracted from DiagnosticFrame	
	Received on adapter A	Received on adapter B	Node 3 Received on adapter A	Node 3 Received on adapter B
	Received from adapter A/B [a]	Received from adapter A [a]/B	Received from adapter A/B [a]	Received from adapter A [a]/B
1	OK/X	X/OK	X/X	X/OK
2	OK/X	X/OK	X/X	X/OK
3 (this node)	OK/X	X/OK	OK/X	X/OK
4	OK/X	X/X	X/X	X/X

[a] The cross statuses are all “X” for a dual LAN without inter-LAN link. That is, messages originating from a port A are never heard on a port B and vice versa.

The DiagnosticFrames provide therefore:

- minimal assurance of a working path. With each message received, the receiving node can assume that its own receiver, the reporting node’s transmitter, and the path through the network are all working;
- assurance that the reverse path is working. With each message received, the receiving node can extract the reporting node’s view of the receiving node and thus determine whether its own transmitter, the reporting node’s receiver, and the path through the network are all working.

This allows the system administrator to construct a variety of coverage strategies such as:

- ensure that all paths between all nodes are tested;
- send to a single node. This node may be a “diagnostic node” that only provides detection of faults between each node and the diagnostic node.

7.1.2 Singly attached nodes

Singly attached nodes (SANCs) also can send and receive DiagnosticFrames. If they choose to transmit them, the DANCs and SANCs are aware of their presence and attempt to ensure that messages reach them. The Network_Status_Table built by the SANC allows it to build DiagnosticFrames and also, in a single LAN, to select a path to a node with a failed port.

7.2 CRP statistics

Statistics should be gathered and presented for each port, by a system management application. Examples of presentation methods are a graphical user interface for visual reporting of network errors or via SNMP.

7.3 CRP Network_Status_Table

Each node maintains a Network_Status_Table that holds the node's view of the network.

This table is used to assist with selection of which port(s) to use for transmission to a destination address and which port(s) to use for reception of multicast transmissions.

The Network_Status_Table is constructed from received DiagnosticFrames as well as from other locally acquired and sometimes vendor-specific diagnostic information, for example built-in tests, link integrity pulse, etc.

This table is conceptual and is described to assist with understanding of the concepts in this specification and no specific implementation is prescribed or implied. It is therefore not visible to network management; however, the contents of the table are reflected in the DiagnosticFrames.

The Network_Status_Table in each node keeps for each node, and in some cases for each port of each node the following information:

a) for each remote reporting node,
   - remote node identification (name, index in a table, etc.);
   - diagnosis message interval;
   - apparent number of ports (1..N);
   - for each port, in nominal order (e.g., port to LAN_A before port to LAN_B) the MAC address of the remote port.

b) for each pairing of local and remote ports (e.g., A/B, B/A, A/A or B/B)
   - time of latest message receipt;
   - sequence number of latest received message;
   - receipt of DiagnosticFrame from remote port within time;
   - remote port's link status from last received DiagnosticFrame.

c) for assessment of remote connectivity
   - inferred status of set of ports (functioning properly, cross-connected, ...);
   - preferred port pairing.

EXAMPLE Table 2 shows a Network_Status_Table for a SANC and Table 3 a Network_Status_Table for a DANC.

Table 2 – CRP Network_Status_Table for singly connected nodes

Reporting node information			Messages received here sent from reporting node's adapter A				Messages received here sent from reporting node's adapter B			
Node_Index and Node_Name	Number of adapters	Interval (ms)	Time	Sequence_ number of last message received	Diagnostic Frame received	Reported status extracted from DiagnosticFrame for AA	Time	Sequence_ number of Last message received	Diagnostic Frame received	Reported status extracted from Diagnostic Frame for BA
1 FD001	1	2 000	Time	Number	OK	OK				
2 FD002	1	2 000	Time	Number	OK	OK				
3 LD001	1	1 000					Time	Number	OK	OK
4										
5 LD003	1	5 000	Time	Number	OK	OK				
6	2	5 000	Time	Number	OK	OK	Time	Number	OK	OK
7	1	5 000	Time	Number	OK	OK				