

DIN EN 62439-7

ICS 35.110

**Industrielle Kommunikationsnetze –
Hochverfügbare Automatisierungsnetze –
Teil 7: Protokoll für ringbasierte Redundanz (RRP)
(IEC 62439-7:2011);
Englische Fassung EN 62439-7:2012**

Industrial communication networks –
High availability automation networks –
Part 7: Ring-based Redundancy Protocol (RRP)
(IEC 62439-7:2011);
English version EN 62439-7:2012

Réseaux de communication industriels –
Réseau de haute disponibilité pour l'automatisation –
Partie 7: Protocole de redondance pour réseau en anneau (RRP)
(CEI 62439-7:2011);
Version anglaise EN 62439-7:2012

Gesamtumfang 82 Seiten

DKE Deutsche Kommission Elektrotechnik Elektronik Informationstechnik im DIN und VDE

Anwendungsbeginn

Anwendungsbeginn für die von CENELEC am 2012-01-20 angenommene Europäische Norm als DIN-Norm ist 2012-08-01.

Nationales Vorwort

Vorausgegangener Norm-Entwurf: E DIN EN 62439-7:2011-08.

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

Die enthaltene IEC-Publikation wurde vom SC 65C „Industrial networks“ erarbeitet.

Das IEC-Komitee hat entschieden, dass der Inhalt dieser Publikation bis zu dem Datum (stability date) unverändert bleiben soll, das auf der IEC-Website unter „<http://webstore.iec.ch>“ zu dieser Publikation angegeben ist. Zu diesem Zeitpunkt wird entsprechend der Entscheidung des Komitees die Publikation

- bestätigt,
- zurückgezogen,
- durch eine Folgeausgabe ersetzt oder
- geändert.

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

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

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

Das Präsidium des DIN hat mit Präsidialbeschluss 1/2004 festgelegt, dass DIN-Normen, deren Inhalt sich auf internationale Arbeitsergebnisse der Informationsverarbeitung gründet, unter bestimmten Bedingungen allein in englischer Sprache veröffentlicht werden dürfen. Diese Bedingungen sind für die vorliegende Norm erfüllt.

Da sich die Benutzer der vorliegenden Norm der englischen Sprache als Fachsprache bedienen, wird die englische Fassung der EN 62439-7 veröffentlicht. Zu deren Abschnitt 3, der die Begriffe festlegt, wurde eine Übersetzung angefertigt und als informativer Nationaler Anhang NA der vorliegenden Norm hinzugefügt. Für viele der verwendeten Begriffe existieren keine gebräuchlichen deutschen Benennungen, da sich die deutschen Anwender in der Regel ebenfalls der englischen Benennungen bedienen. Diese Norm steht nicht in unmittelbarem Zusammenhang mit Rechtsvorschriften und ist nicht als Sicherheitsnorm anzusehen.

Erklärung zu Schutzrechten

Die Internationale Elektrotechnische Kommission macht darauf aufmerksam, dass ihr gegenüber erklärt wurde, dass die Übereinstimmung mit dem vorgesehenen Norm-Inhalt die Anwendung von Patenten erforderlich machen könnte. Nähere Informationen hierzu befinden sich im Vorwort der Europäischen und Internationalen Norm.

Es wird darauf aufmerksam gemacht, dass Bestandteile der vorliegenden Norm Gegenstand von weiteren Patentrechten sein können. Es liegt nicht im Verantwortungsbereich der DKE, einige oder alle dieser Patentrechte zu benennen.

Der Leser der vorliegenden Norm wird jedoch gebeten, ihm bekannte derartige Patentrechte der Geschäftsstelle mitzuteilen und entsprechende Informationen zur Verfügung zu stellen.

Nationaler Anhang NA (informativ)

3 Begriffe, Abkürzungen, Akronyme und Vereinbarungen

3.1 Begriffe

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

3.1.1

R-port

(en: R-port)

ein Port in einem Kommunikationsgerät, das Teil einer linien- oder ringförmigen Struktur ist

3.1.2

Geräteadresse

(en: device address)

eine Zwei-Oktettadresse, die das Gerät, das einem einzelnen Gerät an einem spezifischen lokalen Link zugeordnet ist, kennzeichnet

3.1.3

Gateway-Gerät

GWD

(en: Gateway Device

GWD)

ein RRP-Gerät, das mehr als drei Ethernet-Ports hat; mindestens zwei Ports müssen das RRP-Protokoll unterstützen

3.1.4

normales Gerät

ND

(en: Normal Device

ND)

normales RRP-Gerät, das zwei RRP-Ports hat

3.1.5

Unique Identification

UID

(en: Unique Identification

UID)

eindeutige Acht-Oktett-Kennung, die verwendet wird, um ein RRP-Gerät innerhalb eines Netzwerksegments zu kennzeichnen. Eine UID ist aus einer Zwei-Oktett-Geräte-Adresse und einer Sechs-Oktett-Mac-Adresse zusammengesetzt, so dass sie innerhalb eines Netzwerkes einen eindeutigen Wert darstellt.

3.2 Abkürzungen und Akronyme

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

Abkürzung	Deutsche Benennung	Englische Benennung
ASE	Anwendungs-Dienstelement	Application Service Element
DLE	Data Link Layer-Entity	Data Link layer Entity
FC	Rahmensteuerung	Frame Control
FCS	Rahmenprüfungssequenz	Frame Check Sequence

Abkürzung	Deutsche Benennung	Englische Benennung
GD	allgemeines Gerät	General Device
GWD	Gateway-Gerät	Gateway Device
LNМ	Netzwerkmanager der Linie	Line Network Manager
MAC	Medienzugriffssteuerung	Media Access Control
MIB	Datenbank für Management-Information	Management Information Base
NCM	Netzwerksteuerungsnachricht	Network Control Message
NCMT	Nachrichtentyp zur Netzwerksteuerung	Network Control Message Type
ND	normales Gerät	Normal Device
NMIB	Netzwerkmanagement-Informationsbasis	Network Management Information Base
PHY	Transceiver an der physikalischen Schnittstelle	Physical Interface Transceiver
PO	eingeschaltet	Power On
PRI	Priorität	Priority
RES	reserviert	Reserved
RNM	Netzwerkmanager des Rings	Ring Network Manager
RRP	Ring-basiertes Redundanzprotokoll	Ring based Redundancy Protocol
SA	Alleinbetrieb	Stand Alone
ToS	Dienststart	Type of Service
VoE	Validierung des Extension Code	Validation of Extension code

3.3 Vereinbarungen

Dieser Teil der Reihe IEC 62439 folgt den Vereinbarungen nach IEC 62439-1.

**Industrial communication networks -
High availability automation networks -
Part 7: Ring-based Redundancy Protocol (RRP)
(IEC 62439-7:2011)**

Réseaux de communication industriels -
Réseau de haute disponibilité pour
l'automation -
Partie 7: Protocole de redondance pour
réseau en anneau (RRP)
(CEI 62439-7:2011)

Industrielle Kommunikationsnetze -
Hochverfügbare Automatisierungsnetze -
Teil 7: Protokoll für ringbasierte
Redundanz (RRP)
(IEC 62439-7:2011)

This European Standard was approved by CENELEC on 2012-01-20. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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

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

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

CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 65C/668/FDIS, future edition 1 of IEC 62439-7, 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 62439-7:2012.

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) 2012-10-20
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2015-01-20

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

Endorsement notice

The text of the International Standard IEC 62439-7:2011 was approved by CENELEC as a European Standard without any modification.

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

IEC 61158 series NOTE Harmonized in EN 61158 series.

CONTENTS

INTRODUCTION	7
1 Scope	8
2 Normative references	8
3 Terms, definitions, abbreviations, acronyms, and conventions	8
3.1 Terms and definitions	8
3.2 Abbreviations and acronyms	9
3.3 Conventions	9
4 RRP overview	9
4.1 General	9
4.2 Frame forwarding and receiving control	10
4.2.1 General	10
4.2.2 Normal Device (ND) and Gateway Device (GWD)	10
4.2.3 Behaviours of the General Device (GD)	11
4.2.4 Behaviours of the Line Network Manager (LNM)	11
4.2.5 Behaviours of the Ring Network Managers (RNMs)	12
4.3 Link status monitoring	12
4.4 Error detection	13
4.5 Plug and play	13
4.6 Network management information base (NMIB) management	13
4.7 Network recovery	13
4.8 Automatic network configuration	13
4.9 RRP basic operating principle	14
5 RRP redundancy behaviours	16
5.1 Network topology	16
5.2 Network recovery in ring network	16
5.2.1 General	16
5.2.2 Link fault between neighbouring devices	19
5.2.3 Link fault of remote device	19
5.2.4 Device fault on a RNM	20
5.3 Automatic Ring Network Manager (RNM) election procedure	21
5.3.1 General	21
5.3.2 Primary RNM (RNMP)	21
5.3.3 Secondary RNM (RNMS)	21
5.4 Path management	22
5.4.1 General	22
5.4.2 Path in a line topology network	22
5.4.3 Path in a ring topology network	22
5.5 Device address collision	24
6 RRP class specification	25
6.1 General	25
6.2 Template	25
6.3 Attributes	26
7 RRP services specification	32
7.1 Set device information	32

7.2	Get device information	33
7.3	Get network information	35
7.4	Get path table information	37
8	RRP protocol specification	40
8.1	General	40
8.2	Ethernet header	40
8.2.1	Preamble	40
8.2.2	Start frame delimiter	40
8.2.3	Destination MAC address	40
8.2.4	Source MAC address	40
8.2.5	Length/Type	40
8.3	Encoding of RRP_FrameHDR	41
8.3.1	Version and length	41
8.3.2	DST_addr	41
8.3.3	SRC_addr	42
8.3.4	Frame Control (FC)	42
8.4	Encoding of data and pad	44
8.4.1	General	44
8.4.2	Encoding of FamilyReq	44
8.4.3	Encoding of FamilyRes	45
8.4.4	Encoding of MediaLinked	46
8.4.5	Encoding of AdvThis	46
8.4.6	Encoding of LineStart	47
8.4.7	Encoding of RingStart	47
8.4.8	Encoding of AckRNMS	48
8.4.9	Encoding of CheckRNMS	49
8.5	Frame Check Sequence (FCS)	49
9	RRP protocol machine	50
9.1	Protocol state machine description	50
9.2	Local parameters and variables for protocol state	51
9.2.1	General	51
9.2.2	Variables to support local device information management	51
9.2.3	Variables to support network information management	52
9.2.4	Variables to support device path information management	52
9.2.5	Variables of Received RRP Frame	52
9.2.6	Local variables for protocol state	53
9.2.7	Constants for protocol state	53
9.3	State transitions	54
9.4	Function descriptions	66
10	RRP Management Information Base (MIB)	71
	Bibliography	77
	Annex ZA (normative) Normative references to international publications with their corresponding European publications	78
	Figure 1 – Forwarding and receiving Ethernet frames	10
	Figure 2 – Structures of ND and GWD	11
	Figure 3 – LNM forwarding control	12
	Figure 4 – RNM forwarding control	12
	Figure 5 – Link status information	13

Figure 6 – A device operation in initialization phase	14
Figure 7 – Devices operation in line network establishing phase	14
Figure 8 – Extension of line network operation	15
Figure 9 – Ring network establishment operation	15
Figure 10 – Ring to line network change operation	16
Figure 11 – Ring topology	16
Figure 12 – Link fault between neighbouring devices	19
Figure 13 – Link fault of remote device	20
Figure 14 – Device fault on a RNM	20
Figure 15 – Path management in a line topology network	22
Figure 16 – Path management in a ring topology network	23
Figure 17 – RRP device address collision in a ring network	24
Figure 18 – Common MAC frame format for RRP DLPDU	40
Figure 19 – RRP protocol state machine	50
Table 1 – RRP network recovery parameter	17
Table 2 – Parameters for calculation	17
Table 3 – Path table of Device1 in a line topology network	22
Table 4 – Path table of Device4 in a line topology network	22
Table 5 – Path table of Device1 in a ring topology network	23
Table 6 – Path table of Device3 in a ring topology network	23
Table 7 – Device address collision information	24
Table 8 – Parameters of set device information service	32
Table 9 – Parameters of get device information service	34
Table 10 – Parameters of get network information service	36
Table 11 – Parameters of get path table information service	37
Table 12 – RRP Length/Type field	40
Table 13 – Version	41
Table 14 – DST_addr	41
Table 15 – SRC_addr	42
Table 16 – Network control message type	42
Table 17 – Type of service	43
Table 18 – Priority	43
Table 19 – Validation of extension code	43
Table 20 – Encoding of FamilyReq frame	45
Table 21 – Encoding of FamilyRes frame	45
Table 22 – Encoding of MediaLinked frame	46
Table 23 – Encoding of AdvThis frame	46
Table 24 – Encoding of LineStart frame	47
Table 25 – Encoding of RingStart frame	48
Table 26 – Encoding of AckRNMS frame	48
Table 27 – Encoding of CheckRNMS frame	49
Table 28 – Variables to support device information management	51

Table 29 – Variables to support managing network information 52

Table 30 – Variables to support device path information management 52

Table 31 – Variables of Received RRP Frame..... 52

Table 32 – Local variables for protocol state 53

Table 33 – Constants for protocol state..... 53

Table 34 – RRP State transitions 54

Table 35 – RRP Function descriptions 66

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 8802-3:2000 (IEEE 802.3) with compatible, reliable data communications, and preserve determinism in real-time data communications. In cases of fault, removal, and insertion of a component, they provide deterministic recovery times.

These protocols retain fully the Ethernet communication capabilities typically used in the office world, to ensure that software that relies on these protocols will remain applicable.

The market is in need of several network solutions, each with different performance characteristics and functional capabilities, meeting diverse application requirements. These solutions support different redundancy topologies and mechanisms, which are introduced in IEC 62439-1 and specified in the companion International Standards. IEC 62439-1 also distinguishes between these different solutions, providing guidance for 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 patents concerning IEC 61158-4-21 given in Clause 4 and Clause 5.

Patent Number KR 0789444 "COMMUNICATION PACKET PROCESSING APPARATUS AND METHOD FOR RING TOPOLOGY ETHERNET NETWORK CAPABLE OF PREVENTING PERMANENT PACKET LOOPING," owned by LS INDUSTRIAL SYSTEMS CO., LTD., Anyang, Korea

Patent Number KR 0732510 "NETWORK SYSTEM" owned by LS INDUSTRIAL SYSTEMS CO., LTD., Anyang, Korea

Patent Number KR 0870670 "Method For Determining a Ring Manager Node", owned by LS INDUSTRIAL SYSTEMS CO., LTD., Anyang, Korea

IEC takes no position concerning the evidence, validity and scope of these patent rights.

The holder of these patent rights has assured the IEC that he/she is willing to negotiate licences either free of charge or under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of these patent rights is registered with IEC. Information may be obtained from:

LSIS Co Ltd
LS Tower
1026-6, Hoggie-Dong
Dongan-Gu
Anyang, Gyeonggi-Do, 431-848
South Korea
Phone +82 2 2034 4917
Fax +82 2 2034 4648

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

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

INDUSTRIAL COMMUNICATION NETWORKS – HIGH AVAILABILITY AUTOMATION NETWORKS –

Part 7: Ring-based Redundancy Protocol (RRP)

1 Scope

The IEC 62439 series of standards is applicable to high-availability automation networks based on the ISO/IEC 8802-3:2000 (Ethernet) technology.

This part of the IEC 62439 series specifies a redundancy protocol that is based on a ring topology, in which the redundancy protocol is executed at the end nodes, as opposed to being built into the switches. Each node detects link failure and link establishment using media-sensing technologies, and shares the link information with the other nodes, to guarantee fast connectivity recovery times. The nodes have equal RRP network management functions.

2 Normative references

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

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

IEC 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, and the following apply.

3.1.1

R-port

port in a communication device that is part of a line or ring structure

3.1.2

device address

2 octet address that designates the device associated with a single device on a specific local link

3.1.3

Gateway Device

GWD

RRP device that has more than 3 Ethernet ports on it. At least 2 ports have to support RRP protocol

3.1.4

Normal Device

ND

normal RRP device which has two RRP ports on it

3.1.5

Unique Identification

UID

Unique 8 octet identification used to identify a RRP device within a network segment. UID is combines a 2 octet device address and a 6 octet MAC address, so that it has a unique value in a network

3.2 Abbreviations and acronyms

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

ASE	Application Service Element
DLE	Data Link layer Entity
FC	Frame Control
FCS	Frame Check Sequence
GD	General Device
GWD	Gateway Device
LNМ	Line Network Manager
MAC	Media Access Control
MIB	Management Information Base
NCM	Network Control Message
NCMT	Network Control Message Type
ND	Normal Device
NMIB	Network Management Information Base
PHY	Physical Interface Transceiver
PO	Power On
PRI	Priority
RES	Reserved
RNM	Ring Network Manager
RRP	Ring based Redundancy Protocol
SA	Stand Alone
ToS	Type of Service
VoE	Validation of Extension code

3.3 Conventions

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

4 RRP overview

4.1 General

The RRP specifies a recovery protocol, based on a ring topology. All links in an RRP network shall be full duplex through the use of an internal hardware Ethernet switch. Thus, RRP provides a collision-free transmission mechanism between two nodes. Every RRP device detects link failure and link establishment

using the rules specified in ISO/IEC 8802-3:2000 and shares this information with other RRP devices so that fast connectivity recovery time is also guaranteed in the ring network.

A RRP device is a dual-port switching device that receives and transmits standard ISO/IEC 8802-3:2000 Ethernet frames. It is intelligent and can control directional frame forwarding between its dual ports according to the network status and device status. RRP uses a special network management scheme specified in this standard. RRP also uses a network control based on device address and MAC address, and thus general bridge hub or switch might not be suitable for RRP network. However, when connecting a general Ethernet device to RRP network, Gateway Device (GWD) should be used.

4.2 Frame forwarding and receiving control

4.2.1 General

RRP provides a collision-free transmission mechanism with an internal full-duplex hardware switch with switching queue and dual MACs in a device. The switching priority method between Tx and Forwarding can be Round-Robin, Tx-First or Forwarding-First scheme. However RRP does not specify the switching method.

Thus, a RRP device transmits frames without the restriction of medium access, as soon as they appear in the transmit queue for each MAC. Figure 1 shows the forwarding and receiving control of the RRP device.

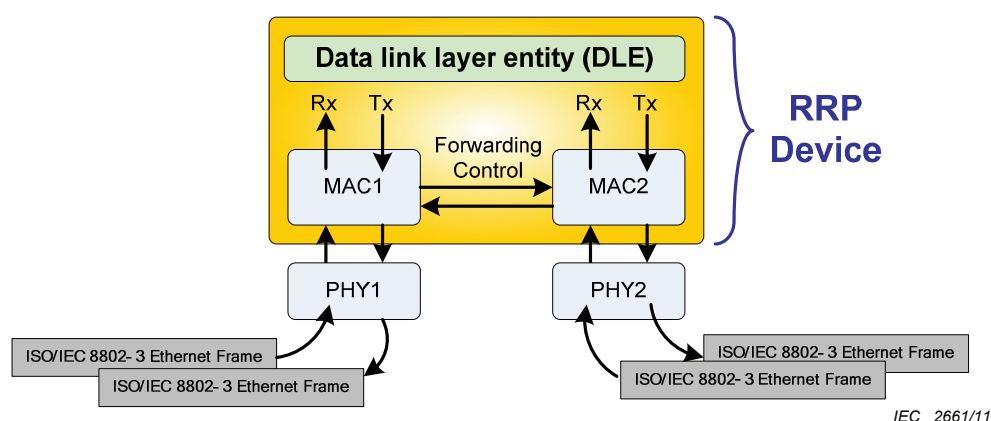


Figure 1 – Forwarding and receiving Ethernet frames

4.2.2 Normal Device (ND) and Gateway Device (GWD)

RRP is operated in a dual-port ring topology. A general Ethernet device can send standard Ethernet frames through RRP ring network with GWD. Multi-ring network can also be established using GWD.

GWD is responsible for switching Ethernet frames between RRP network and external Ethernet networks through application layer using a dynamic table. The dynamic table maps addresses to external Ethernet ports automatically. The dynamic table is automatically made by learning frame movements in the network. The GWD inspects both the destination and the source addresses. The destination address is used for the forwarding decision; the source address is used for adding entries to the table and for updating purposes. When an Ethernet frame is received at the media access control (MAC) layer through the physical interface transceiver (PHY), a GWD handles the received frame by taking one of the following actions, depending on the destination MAC address and the source MAC addresses in the received frame:

- for a broadcast or multicast frame, accept and deliver the frame to the data link layer entity (DLE), and forward the frame to the other RRP port and external Ethernet ports;
- for a frame designated for the device itself, accept and deliver the frame to the DLE without forwarding;
- for a frame designated for another device, accept the frame to its application layer and inspect both the destination and the source addresses. When the destination address of the frame is in the dynamic table, the GWD delivers the frame to the corresponding port in the dynamic table without forwarding to other

ports. Otherwise, the GWD delivers the frame to all other ports. The GWD adds this entry to the dynamic table with source MAC address and port number information.

NOTE Dynamic table entries are automatically removed after the Ageing Time which is specified in IEEE 802.1D.

Figure 2 shows different structures of ND and GWD. In GWD, external Ethernet connection is connected to RRP ring network through MAC_E and PHY_E.

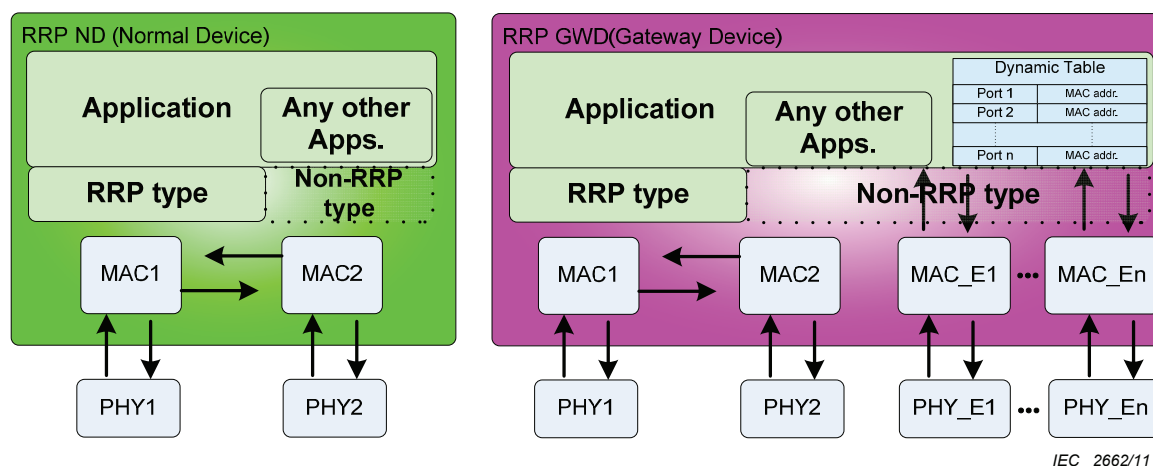


Figure 2 – Structures of ND and GWD

4.2.3 Behaviours of the General Device (GD)

When an Ethernet frame is received at the MAC layer through the PHY, a RRP general device other than the ring network manager (RNM) or the line network manager (LNM), handles the received frame by taking one of the following actions, depending on the destination MAC address and the device address in the received frame:

- for a broadcast or multicast frame, accept and deliver the frame to the DLE, and forward the frame to the other port;
- for a frame designated for the device itself, accept and deliver the frame to the DLE without forwarding;
- for a frame designated for another device, do not accept the received frame, but forward the frame to the other port.

This frame forwarding procedure is processed by the internal hardware switch, so that it has little impact on the performance of the RRP protocol.

4.2.4 Behaviours of the Line Network Manager (LNM)

As shown in Figure 3, the LNM disables the frame forward functions in both directions, so that frames are not forwarded to another port. In RRP networks, a LNM is automatically configured. When a device senses that only one port is connected, the device takes this to indicate that it is at the end of the line network. The LNM also becomes a control point of the hop count to other devices in a line network.

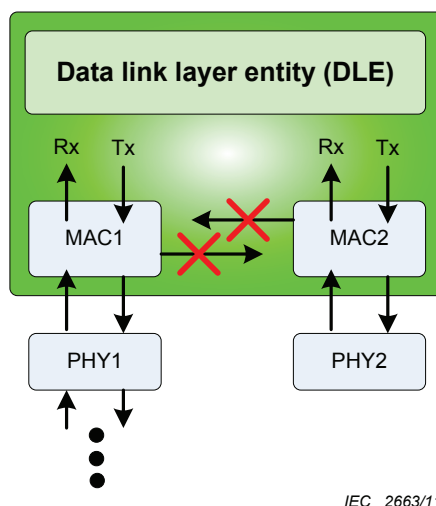


Figure 3 – LNM forwarding control

4.2.5 Behaviours of the Ring Network Managers (RNMs)

A frame in a ring network can be continuously circulated when the designated device is not found or when the frame is broadcast on the network. In a RRP ring network, two RNMs are automatically selected, and each RNM enables only one directional frame forward function to prevent infinite frame circulation, as shown in Figure 4.

The dual RNM structure is used to avoid message duplication. A primary RNM (RNMP) is selected with the highest UID device first, and then one of its neighbouring nodes is selected as a secondary RNM (RNMS). The RNMP and RNMS send Network Control Message Type (NCMT) messages to each other, to monitor network integrity.

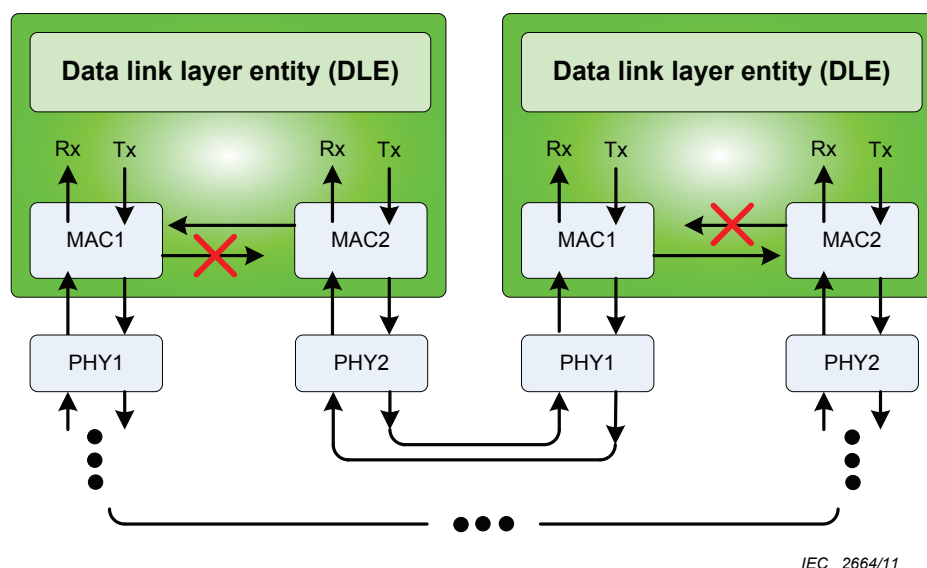


Figure 4 – RNM forwarding control

4.3 Link status monitoring

The RRP manages the network dynamically. When a link between two devices is established or released, it is automatically detected in the physical layer, as specified in ISO/IEC 8802-3:2000, Clause 24. This link status information is distributed and shared with every device on the network using NCMT messages, so that the network topology can be managed dynamically. The link status information is either “PHY_LINK_UP” or “PHY_LINK_DOWN” and the link status detection process is initiated by the sublayer of PHY service. A status of “PHY_LINK_UP” means that a RRP communication link is connected between two devices and it is possible to send frames through the link. A status of “PHY_LINK_DOWN” means that a RRP communication

link is not established through an Ethernet MAC port and it is not possible to send frames through the port. By sharing all the link information on the network, all RRP devices on the network can determine the online network connectivity status. Figure 5 shows the intrinsic link status monitoring procedure of the RRP device.

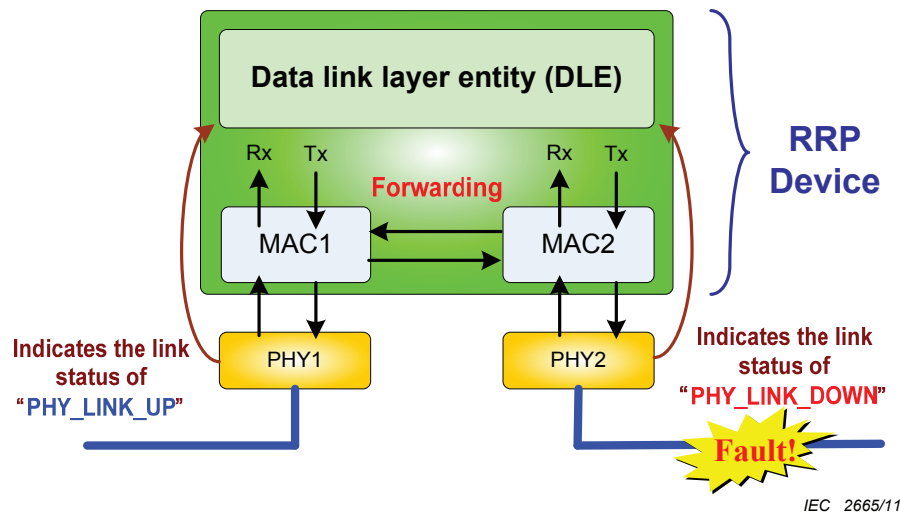


Figure 5 – Link status information

4.4 Error detection

A RRP device examines both frame validation and physical link status. Frame validation is examined using the frame check sequence (FCS) of ISO/IEC 8802-3:2000, Clause 3. The physical link status can be validated by a PHY link monitoring function. RRP uses a service of PHY sublayer to monitor link status.

4.5 Plug and play

When a new device joins an existing network, the new link information is broadcast via a NCMT message to every device on the network. The new device also collects existing link information from each device so that it can communicate to the other nodes on the network without manual configuration.

4.6 Network management information base (NMIB) management

A RRP device automatically manages network information and a path table. Network information and the path table are stored in the device's NMIB. All RRP devices in a network share link information via NCMT messages. Every device updates its network information and path table when it receives a NCMT message containing network information. Every device on the same network shares and gathers link information on the network to update its own network information and path table. Every device updates its network information and path table when it receives link status change information.

4.7 Network recovery

When link failure or device failure is detected in a RRP ring network, the topology changes and the link status information is automatically broadcast to every device on the network. After broadcasting topology change information, every device on a network starts to update its own path table and tries to find new paths to other devices on the network. This process is operated in protocol machine and changing the blocking point of the network. Thus, devices can transmit messages to their destinations, while they are updating their NMIB.

4.8 Automatic network configuration

RRP supports automatic network configuration. When the network topology changes, the RRP protocol machine of every device shares the changed network information, and then every device updates its own NMIB. RNMs or LNMs are automatically selected on the network according to the device UID and connection status.

When a device joins to a RRP network, the device broadcasts a NCMT message with its network information. Other devices in a RRP network receive the NCMT message then update their NMIB and reply to a new device. Thus NMIB is updated automatically through a joining process.

Similarly when a device detects any fault conditions, the device broadcasts a NCMT message to other devices in the network. So that network information is managed automatically by NCMT messages.

4.9 RRP basic operating principle

The RRP network is established by following steps:

- power On (Initialization);
- establishment of line network;
- extension of line network;
- establishment of ring network;
- change topology from ring network to line network.

In the initialization phase, a RRP device becomes a stand-alone device. The device tries to find valid RRP connections on its ports. Figure 6 shows that Device1 is initialized and remained stand-alone device. In this phase, the device is in SA state.

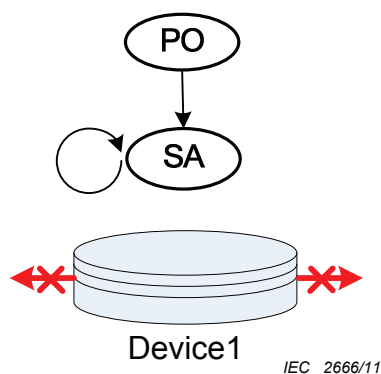


Figure 6 – A device operation in initialization phase

When the device detects a valid RRP connection on any port, it changes its state from SA to LNM and broadcast a NCMT message to the network. Figure 7 shows the device connection and its state.

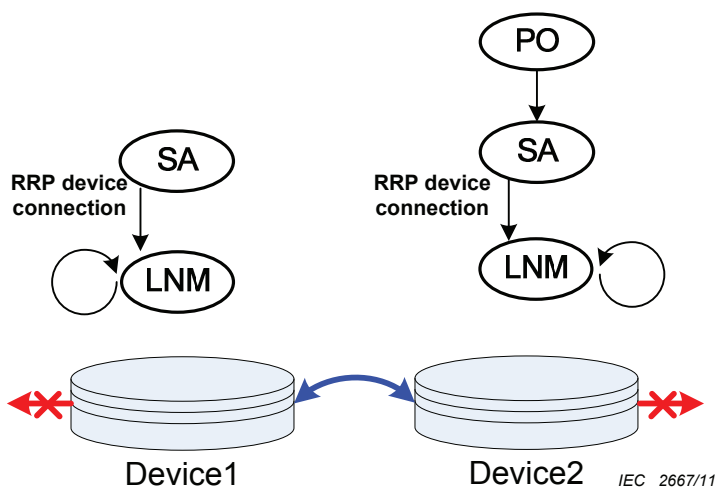


Figure 7 – Devices operation in line network establishing phase

If one or more devices added to the line network, the network is extended and two devices at both ends of the line network remain LNMs. This process is operated by RRP protocol machine in each device with NMIB. Figure 8 shows extension of line network operation.

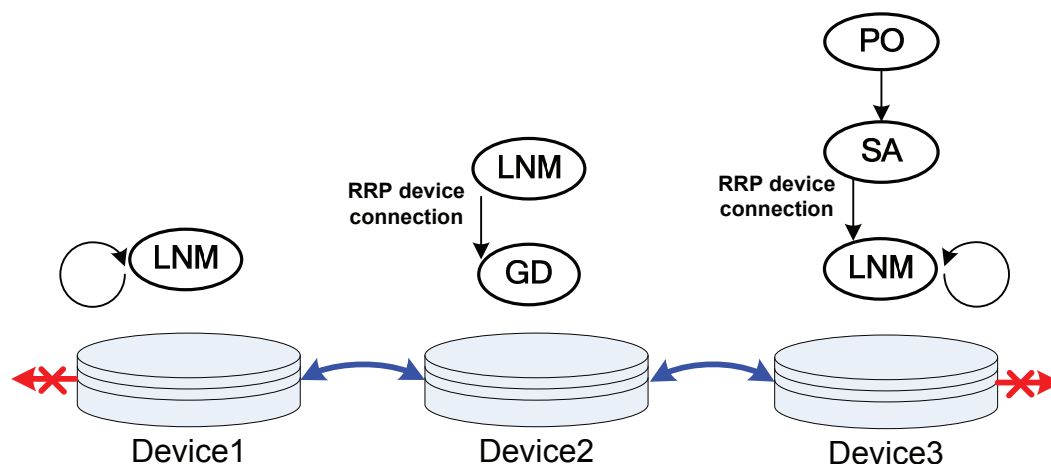


Figure 8 – Extension of line network operation

When both ends of the line network are connected, the line network is changing to ring network. Then the highest UID device sends a NCMT message as a RNMP. RNMP chooses R-port1 side neighbouring device as RNMS. Figure 9 shows a ring network establishment operation.

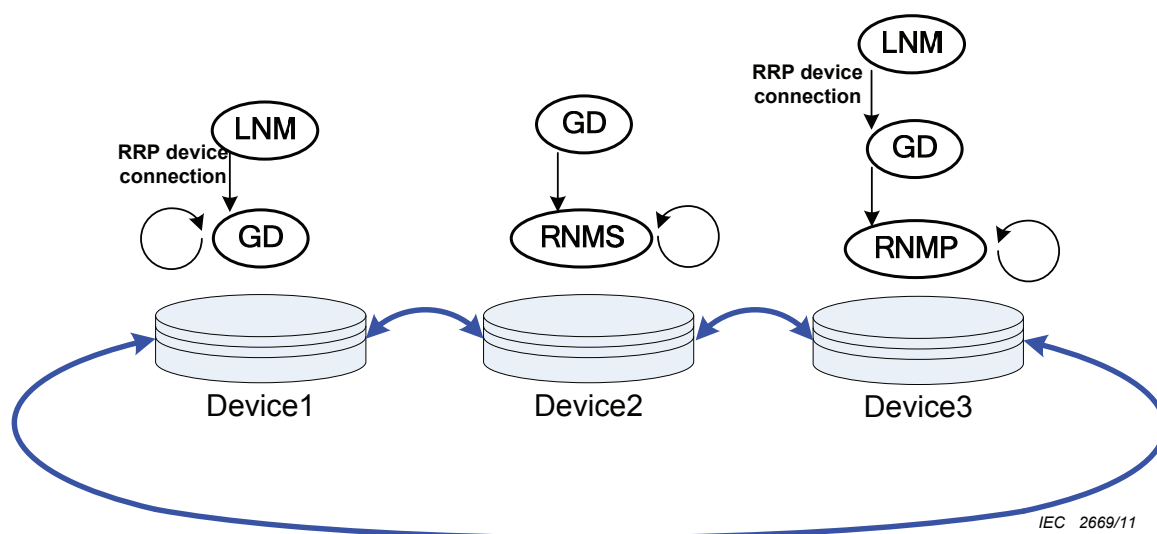


Figure 9 – Ring network establishment operation

If any fault condition is detected, neighbouring devices of the fault point broadcast NCMT message and change their state to LNM. Then the ring network is changed to line network. Figure 10 shows topology changing operation from ring network to line network. If the loss of valid connection is recovered, the network will be changed to ring network automatically as shown Figure 9.

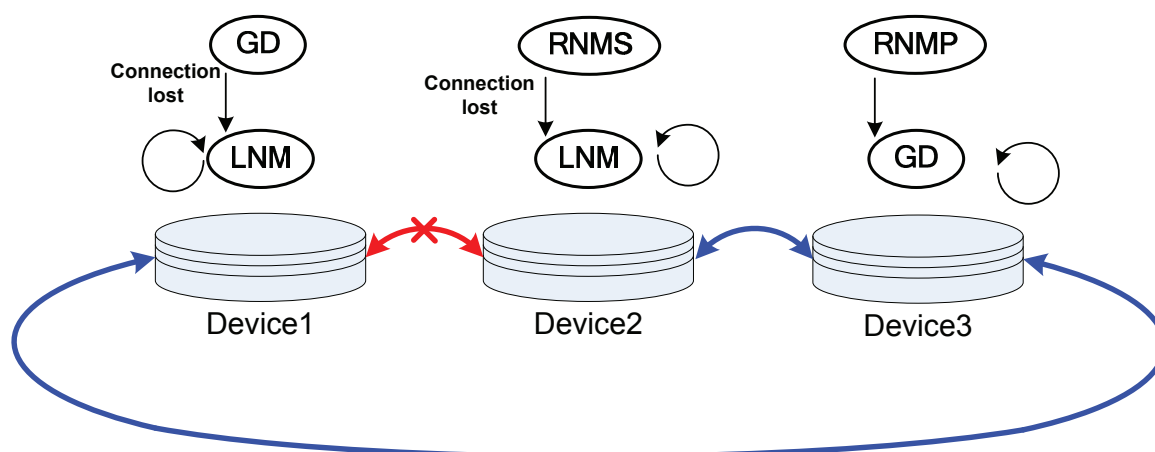


Figure 10 – Ring to line network change operation

5 RRP redundancy behaviours

5.1 Network topology

Figure 11 shows a basic example of a RRP ring network.

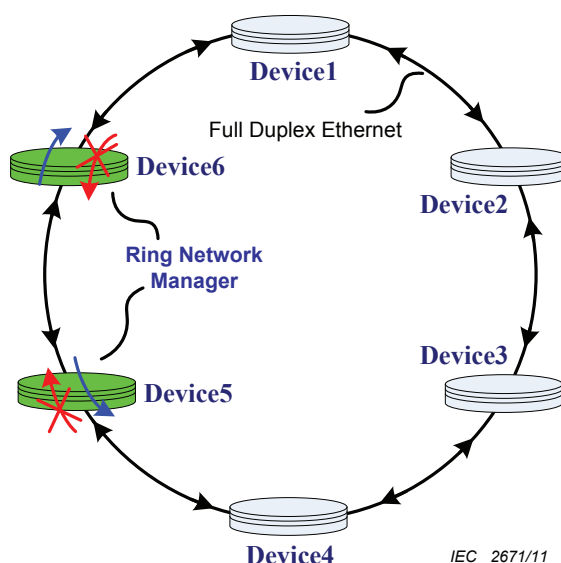


Figure 11 – Ring topology

When a new link is established between two end nodes in a line network, the network is automatically reconfigured as a ring network. Two RNMs are automatically selected to prevent the infinite circulation of any frame in a ring network. However, when a link failure is detected in the ring network, the ring network managers (RNMs) change their internal state to convert network topology from a ring to a line network. RNM could send NCMT message periodically to other RNM though the network to examine of the network integrity.

5.2 Network recovery in ring network

5.2.1 General

The RRP network recovery process is simple and is handled within the protocol machine to provide fast recovery time upon network topology changes. When a link failure is detected in a ring network, the network

is reconfigured automatically as a line network. A topology change from a ring to a line network occurs in the following three cases:

- link fault with the neighbouring device;
- link fault of the remote device;
- local device fault.

If a link failure occurs, the two devices nearest the fault point enter the LNM state and broadcast the NCMT message NCM_LINE_START. When a device receives NCM_LINE_START, it checks its connection status and changes its state to GD or LNM.

A cable break or power failure is treated in the same way as a link fault. A device fault also takes the same time to recover. Redundancy recovery time is determined from the time when a link fault occurs to the time when the path is recovered in a new direction.

The RRP specifies recovery times for the transition from a ring to a line network. Table 1 shows the parameter set for worst case RRP recovery times when the network parameter is set as Table 2.

Table 1 – RRP network recovery parameter

Parameter	100BASE-X	1000BASE-X	Meaning
T_fault_sense	350 us	2 ms	the network fault sense time in PHY specified in ISO/IEC 8802-3:2000, Clause 24, Clause 25, Clause 26 and Clause 36 100BASE-TX: ANSI X3.263-1995, Clause 10 100BASE-FX: ISO/IEC 9314-3:1990, Clause 9 1000BASE-X: ANSI X3.230-1994, Annex I
T_state_transient	1 ms	1 ms	the time spent switching the protocol machine from RNM or GD to LNM, in the RRP device
T_message_propagation	6 ms	700 µs	the message delivery time of NCM_LINE_START from a new LNM to the farthest device in a segment
T_recovery (max.)	≤ 8 ms	≤ 4 ms	the total network recovery time in ms

Table 2 – Parameters for calculation

Parameter	Value		Meaning
	100BASE-X	1000BASE-X	
N	50	50	the number of nodes between sending and receiving devices
T_{PKT}	24 µs	2,4 µs	the packet transmit time
NCMsize	112 octets	112 octets	the message length of NCM_LINE_START message
POsize	40 octets	40 octets	the size of protocol overhead
LDR	100	1 000	the link speed in Mbit/s
T_{CPD}	0,5 µs	0,05 µs	the cable propagation time of node for 100 m
T_{SND}	50 µs	50 µs	the sender stack traversal time including PHY and MAC
T_{RCV}	50 µs	50 µs	the receiver stack traversal time including PHY and MAC
T_{NLD}	120 µs	12 µs	the node latency delay time for worst case
	3 µs	0,3 µs	the node latency delay time for best case

The network recovery time can be calculated by Equation (1)

$$T_{\text{RECOVER}} = T_{\text{FS}} + T_{\text{RtoL}} + T_{\text{MSG}} \quad (1)$$

where

- T_{RECOVER} is the network recovery time in ms;
- T_{FS} is the link fault sense time in ms;
- T_{RtoL} is the device state transition delay time in μs ;
- T_{MSG} is the message propagation time to the farthest device of NCM_LINE_START message in ms, see Equation (2).

The NCMT message, NCM_LINE_START, propagation time to the farthest device T_{MSG} can be calculated by Equation (2).

$$T_{\text{MSG}} = T_{\text{SND}} + T_{\text{PKT}} + T_{\text{CPD}} + \sum_{i=0}^N T_{\text{NLD}_i} + T_{\text{RCV}} \quad (2)$$

where

- T_{MSG} is the message propagation time in μs ;
- T_{SND} is the sender stack traversal time including PHY and MAC in μs ;
- T_{PKT} is the packet transmit time in microseconds, see Equation (3);
- T_{CPD} is the cable propagation time for a node, in μs ;
- T_{NLD_i} is the node latency time for node i in micro seconds, see Equation (4);
- T_{RCV} is the receiver stack traversal time including PHY and MAC in μs ;
- N is the number of nodes between sending and receiving devices.

The packet transmit time T_{PKT} can be calculated by Equation (3)

$$T_{\text{PKT}} = \frac{(\text{NCMsize} + \text{POsize}) \times 8}{\text{LDR}} \quad (3)$$

where

- T_{PKT} is the packet transmit time on the medium, in μs ;
- NCMsize is the size of the NCM data unit in octets;
- LDR is the link data rate in bits per second;
- POsize is the size of the protocol overhead in octets.

The node latency time of node i T_{NLD_i} can be calculated by Equation (4)

$$T_{\text{NLD}_i} = T_{\text{NPD}_i} + T_{\text{PKT}_i} + \sum_{j=0}^M T_{\text{TX_PKT}_{ij}} \quad (4)$$

where

- T_{NLD_i} is the node latency delay time for node i in μs ;
- T_{NPD_i} is the node propagation delay time for node i in μs ;

T_{PKT_i}	is the packet transmit time for node i in μs ;
$T_{TX_PKT_ij}$	is the packet transmit time for packet j in ms within the port transmit queue of node i in front of this packet;
M	is the number of packets in the port transmit queue of node i in front of this packet.

5.2.2 Link fault between neighbouring devices

Figure 12 shows an example of a link fault between neighbouring devices in a ring network.

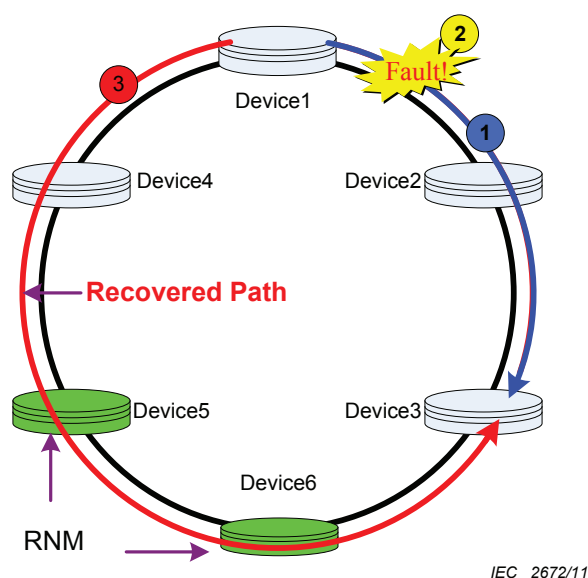


Figure 12 – Link fault between neighbouring devices

If the link between Device1 and Device2 is disconnected when Device1 tries to send a frame to Device3, the link fault event is triggered spontaneously by a hardware signal, and it is detected by the RRP protocol machine in Device1. Device1 then decides that the link is not available for data transmission, and so the ring network should be reconfigured as a line network, by changing the state of Device1 to LNM. Device1 broadcasts a NCM_LINE_START message and modifies the destination R-port to Device3. Device1 transmits the frame to the new destination R-port. Device2 also broadcasts a NCM_LINE_START message, to announce the link fault, and changes its own state to LNM.

In case that Device2 could not detect the link fault, Device5 receives NCM_LINE_START message from Device1 and change its state from RNM to GD. Then, Device5 relays NCM_LINE_START message to Device6. Thus, other devices of the network recognize topology changing.

5.2.3 Link fault of remote device

Figure 13 shows an example of a link fault of the remote device in a ring network.

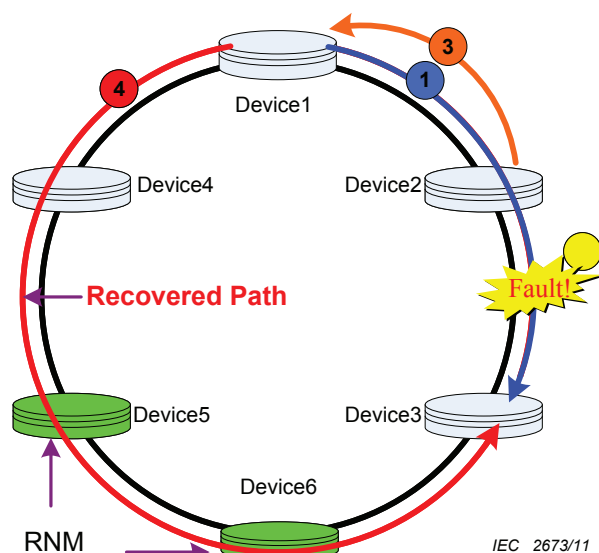


Figure 13 – Link fault of remote device

If the link between Device2 and Device3 is disconnected when Device1 tries to send a frame to Device3, the link fault event is triggered spontaneously by the hardware signal and is detected by the RRP protocol machine in Device2. At this point, Device2 broadcasts an NCM_LINE_START message indicating that the link is not available and that the ring network should be reconfigured as a line network. Device1 modifies the destination R-port to Device3 as the other R-port and transmits the frame through the new R-port. Device3 also broadcasts a NCM_LINE_START message, to announce the link fault, and changes its own state to LNM.

5.2.4 Device fault on a RNM

Figure 14 shows an example of a device fault on a RNM in a ring network.

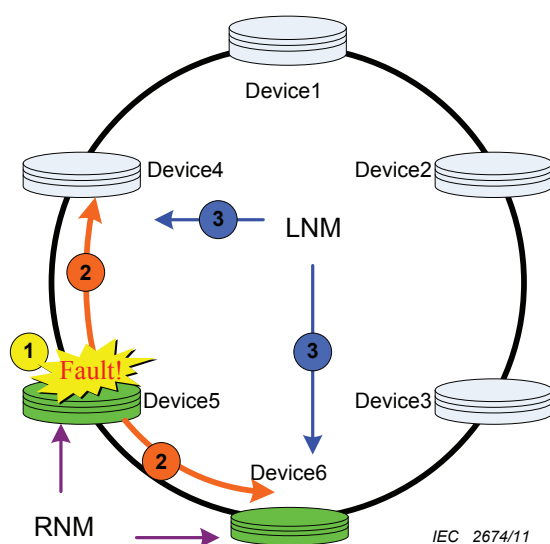


Figure 14 – Device fault on a RNM

If a fault occurs on Device5, Device6 and Device4 sense link failure on their respective Device5 side R-ports. Device6 and Device4 both broadcast NCM_LINE_START messages to other devices and change their state of to LNM. A GD fault is treated in same way as a RNM fault.

5.3 Automatic Ring Network Manager (RNM) election procedure

5.3.1 General

To prevent infinite frame circulation in a RRP ring network, the primary RNM (RNMP) and the secondary RNM (RNMS) are selected automatically using their device unique IDs (UID), via the following steps:

- when two LNMs are connected, each LNM sends NCMT message as multicast or broadcast;
- every device which receives NCMT message responds with its UID as multicast or broadcast;
- when a device receives its own responded NCMT message, the device detects the network is a ring network and does not forward the message;
- the device with the highest device UID value in the ring network is selected automatically as the RNMP;
- the RNMP sends an NCM_RING_START message including the RNMS assignment request to the neighbouring device connected through its both of R-port1 and R-port2;
- the RNMS replies with an NCM_ACK_RNMS message to the RNMP;
- automatic ring network configuration is completed with RNMP and RNMS;
- the RNMP blocks frame forwarding to RNMS side R-port and RNMS also blocks frame forwarding to RNMP side R-port to prevent looping on the ring.

5.3.2 Primary RNM (RNMP)

A RRP device realizes that the network is configured as a ring topology when the NCMT message generated by the device itself is received through the other port. In a ring network, the device with the highest device UID value is selected as the RNMP. When a RRP device detects that the network is configured as a ring network, each device tries to find the device in the path table that has the highest device UID value. Thus, competition to select the RNMP is not necessary in RRP. If a remote device has the highest UID on the network, the other devices wait for the NCM_RING_START message from it. If a local device has the highest UID on the network, then it is selected as the RNMP, the RRP protocol machine disables both frame forwarding functions to prevent looping on the network, and generates an NCM_RING_START message, including the RNMS information of the device connected through both of R-port1 and R-port2 of the RNMP.

When the RNMP receives the NCM_ACK_RNMS message from the RNMS, it disables the frame forwarding function in the RNMS direction, but keeps the opposite direction enabled. The RNMS disables the frame forwarding function in the RNMP direction and enables it in the opposite direction.

RNMP could send NCM_CHECK_RNMS message to RNMS as a network integrity check frame periodically. If the response of NCM_CHECK_RNMS message is not arrived within the timer RRP_ChkRNMST from RNMS and exceed the number of network integrity retry count, the RNMP figures out the network has an error.

NOTE 1 The device UID has a unique value on the network. The RNMP and RNMS are therefore selected automatically even in the case of a device address collision (See 5.5).

NOTE 2 NCM_CHECK_RNMS and NCM_ACK_RNMS messages are using to choose RNMS and to confirm RNMS by RNMP. But RRP supports these messages could be used to check network integrity by user. The timer and the retry count are specified as local variables (See Table 32).

5.3.3 Secondary RNM (RNMS)

The RNMS is assigned by the RNMP. When a GD device receives an NCM_RING_START message from the RNMP, the RRP protocol machine compares the local device UID to the RNMS device UID in the received NCM_RING_START message. If the device is not designated as the RNMS, the RRP protocol machine enables both frame forwarding functions in the GD state device. If the device is designated as the RNMS, the RRP protocol machine enters the RNMS state and transmits NCM_ACK_RNMS to the RNMP through the received R-port of the NCM_RING_START message and NCM_CHECK_RNMS message from the RNMP. Additionally, the RNMS device disables the frame forwarding function in the RNMP direction, but enables it in the opposite direction.