

INTERNATIONAL STANDARD

**Industrial communication networks – Fieldbus specifications –
Part 4-11: Data-link layer protocol specification – Type 11 elements**

IECNORM.COM : Click to view the full PDF of IEC 61158-4-11:2010



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2010 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

**Industrial communication networks – Fieldbus specifications –
Part 4-11: Data-link layer protocol specification – Type 11 elements**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE

XF

ICS 25.04.40; 35.100.20; 35.110

ISBN 978-2-88912-086-4

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
1.1 General.....	10
1.2 Specifications.....	10
1.3 Procedures.....	10
1.4 Applicability.....	11
1.5 Conformance.....	11
2 Normative references	11
3 Terms, definitions, symbols and abbreviations.....	11
3.1 Reference model terms and definitions.....	11
3.2 Service convention terms and definitions.....	13
3.3 Terms and definitions.....	14
3.4 Symbols and abbreviations.....	18
4 Overview of the DL-protocol	19
4.1 General.....	19
4.2 Overview of the medium access control.....	19
4.3 Service assumed from the PhL.....	21
4.4 DLL architecture.....	21
4.5 Access control machine and schedule support functions	25
4.6 Local parameters, variables, counters, timers and queues.....	26
5 General structure and encoding of PhIDU and DLPDU and related elements of procedure.....	43
5.1 Overview.....	43
5.2 PhIDU structure and encoding.....	43
5.3 Common MAC frame structure, encoding and elements of procedure	44
5.4 Elements of the MAC frame.....	44
5.5 Order of bit transmission.....	49
5.6 Invalid DLPDU.....	49
6 DLPDU-specific structure, encoding and elements of procedure.....	49
6.1 General.....	49
6.2 Synchronization DLPDU (SYN).....	50
6.3 Transmission complete DLPDU (CMP)	55
6.4 In-ring request DLPDU (REQ)	56
6.5 Claim DLPDU (CLM)	57
6.6 Command DLPDU (COM).....	58
6.7 Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP).....	59
6.8 RAS DLPDU (RAS)	60
6.9 Loop repeat request DLPDU (LRR)	61
6.10 Loop diagnosis DLPDU (LPD)	65
7 DLE elements of procedure	66
7.1 DLE elements of procedure for star-architecture.....	66
7.2 DLE elements of procedure for loop-architecture	90
7.3 Serializer and deserializer.....	123
7.4 DLL management protocol.....	123

Bibliography.....	134
Figure 1 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses	15
Figure 2 – Basic principle of medium access control	20
Figure 3 – Interaction of PhS primitives to DLE	21
Figure 4 – Data-link layer internal architecture of star-architecture	23
Figure 5 – Data-link layer internal architecture of loop-architecture	25
Figure 6 – Common MAC frame format for DLPDUs.....	44
Figure 7 – Structure of FC field	45
Figure 8 – Structure of SYN DLPDU	50
Figure 9 – Structure of CMP DLPDU	55
Figure 10 – Structure of REQ DLPDU	56
Figure 11 – Structure of CLM DLPDU	57
Figure 12 – Structure of COM DLPDU.....	59
Figure 13 – Structure of DT DLPDU	59
Figure 14 – Structure of RAS DLPDU.....	60
Figure 15 – Structure of User data of loop-architecture	61
Figure 16 – Structure of LRR DLPDU	62
Figure 17 – Open-ring under control	64
Figure 18 – Structure of LPD DLPDU	65
Figure 19 – Overall structure of DLL	67
Figure 20 – DLE state transition.....	68
Figure 21 – State transition diagram of CTRC.....	70
Figure 22 – State transition diagram of STRC	73
Figure 23 – State transition diagram of ACM.....	77
Figure 24 – State transition diagram of RMC sending and send arbitration.....	85
Figure 25 – State transition diagram of RMC receiving.....	88
Figure 26 – Overall structure of DLL	91
Figure 27 – DLE state transition.....	92
Figure 28 – State transition diagram of CTRC.....	94
Figure 29 – State transition diagram of STRC	98
Figure 30 – State transition diagram of ACM.....	102
Figure 31 – State transition diagram of RMC.....	112
Figure 32 – State transition diagram of DLM	126
Figure 33 – State transition diagram of DLM	130
Table 1 – Data-link layer components of star-architecture.....	22
Table 2 – Data-link layer components of loop-architecture	24
Table 3 – DLE-variables and permissible values of star-architecture.....	27
Table 4 – Observable variables and their value ranges of star-architecture.....	29
Table 5 – DLE variables and permissible values of loop-architecture	30
Table 6 – Observable variables and their value ranges of loop-architecture	32
Table 7 – F-type: DLPDU type	46

Table 8 – FCS length, polynomials and constants	47
Table 9 – PN-parameter: 3rd octet	51
Table 10 – Structure of CW: 4th octet	51
Table 11 – PM parameter	51
Table 12 – RMSEL parameter	52
Table 13 – Structure of CW: 4th octet	52
Table 14 – ST-parameter: 5th octet.....	52
Table 15 – Th-parameter: 6th, 7th and 8th octets.....	53
Table 16 – Tm-parameter: 9th and 10th octets	53
Table 17 – Ts-parameter: 11th and 12th octets	53
Table 18 – TI-parameter: 13th and 14th octets	53
Table 19 – LL parameters: 15th to 46th octets	54
Table 20 – RN parameter.....	56
Table 21 – CLM parameter: 4th octet	57
Table 22 – DT parameter: 3rd and 4th octets	59
Table 23 – RAS parameter: 3rd and 4th octets.....	61
Table 24 – Format of the PS parameter: 3rd octet.....	62
Table 25 – The value of the PP parameter.....	62
Table 26 – The value of the send-enable-A/-B	62
Table 27 – The value of the receive-enable-A/-B.....	63
Table 28 – The value of the forward-enable-A/-B.....	63
Table 29 – RN parameter: 4th octet	63
Table 30 – Operational condition of the node.....	64
Table 31 – Primitives exchanged between DLS-user and CTRC.....	69
Table 32 – Primitives exchanged between CTRC and ACM.....	69
Table 33 – Parameters used with primitives exchanged between DLS-user and CTRC	70
Table 34 – CTRC state table.....	71
Table 35 – CTRC functions table	72
Table 36 – Primitives exchanged between DLS-user and STRC.....	72
Table 37 – Primitives exchanged between STRC and ACM.....	73
Table 38 – Parameters used with primitives exchanged between DLS-user and STRC	73
Table 39 – STRC state table	74
Table 40 – STRC functions table	75
Table 41 – Primitives exchanged between ACM and RMC	76
Table 42 – Parameters used with primitives exchanged between ACM and RMC	76
Table 43 – Primitives exchanged between ACM and CTRC.....	76
Table 44 – Parameters used with primitives exchanged between ACM and CTRC	76
Table 45 – Primitives exchanged between ACM and STRC.....	77
Table 46 – Parameters used with primitives exchanged between ACM and STRC.....	77
Table 47 – ACM state table.....	78
Table 48 – ACM function table	83
Table 49 – Primitives exchanged between ACM and RMC	84
Table 50 – Primitives exchanged between RMC and serializer / deserializer.....	84

Table 51 – Primitives exchanged between RMC and Ph-layer	84
Table 52 – Parameters between RMC and ACM	84
Table 53 – Parameters between RMC and Ph-layer	85
Table 54 – State table of RMC sending	86
Table 55 – State table of RMC send arbitration	87
Table 56 – State table for RMC receiving	88
Table 57 – RMC function table	90
Table 58 – Primitives exchanged between DLS-user and CTRC	93
Table 59 – Primitives exchanged between CTRC and ACM	94
Table 60 – Parameters used with primitives exchanged between DLS-user and CTRC	94
Table 61 – CTRC state table	95
Table 62 – CTRC functions table	96
Table 63 – Primitives exchanged between DLS-user and STRC	97
Table 64 – Primitives exchanged between STRC and ACM	97
Table 65 – Parameters used with primitives exchanged between DLS-user and STRC	97
Table 66 – STRC state table	98
Table 67 – STRC functions table	99
Table 68 – Primitives exchanged between ACM and RMC	100
Table 69 – Parameters used with primitives exchanged between ACM and RMC	100
Table 70 – Primitives exchanged between ACM and CTRC	100
Table 71 – Parameters used with primitives exchanged between ACM and CTRC	100
Table 72 – Primitives exchanged between ACM and STRC	101
Table 73 – Parameters used with primitives exchanged between ACM and STRC	101
Table 74 – ACM state table	103
Table 75 – ACM function table	110
Table 76 – Primitives exchanged between ACM and RMC	111
Table 77 – Primitives exchanged between RMC and Serializer / Deserializer	111
Table 78 – Primitives exchanged between RMS and Ph-layer	111
Table 79 – Parameters between RMC and ACM	112
Table 80 – Parameters between RMC and Serializer / Deserializer, Ph-layer	112
Table 81 – State table of RMC	113
Table 82 – The RMC function table	122
Table 83 – Primitives exchanged between DLMS-user and DLM	123
Table 84 – Parameters used with primitives exchanged between DL-user and DLM	124
Table 85 – Event-related state change variables	125
Table 86 – DLM state table	126
Table 87 – DLM function table	128
Table 88 – Primitives exchanged between DLMS-user and DLM	129
Table 89 – Parameters used with primitives exchanged between DL-user and DLM	129
Table 90 – Event-related state change variables	130
Table 91 – DLM state table	131
Table 92 – DLM function table	133

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-11: Data-link layer protocol specification – Type 11 elements

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 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 61158-4-11 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

- Introduction has been modified to add the patents related to the loop-architecture
- Addition of loop (ring) -architecture
- More details:
 - Subclause 4.4 is extended to cover the loop-architecture as 4.4.3.
 - Subclause 4.6; structure has changed in order to include the loop-architecture, and the data types of variables have been added:

- 4.6.1 Overview;
- 4.6.1.2 Summary of variables of existing star-architecture;
- 4.6.1.3 Summary of variables of additional loop-architecture;
- 4.6.2 Type 11 common variables, parameters, counters, timers and queues;
- 4.6.3 Star-architecture specific variables, parameters, counters, timers and queues;
- 4.6.4 Loop-architecture specific variables, parameters, counters, timers and queues.
- All variables, parameters, counters, timers and queues are rearranged in alphabetical order.
- Subclause 5.4 is modified to cover the loop-architecture.
- Clause 6 is modified to cover the loop-architecture.
- Explanations of symbols referenced in each figure are modified to appear in the form of Key out of each figure object.
- Clause 7 is changed in the structure for inclusion and extension of the loop-architecture as follows:
 - DLE elements of procedure for existing star-architecture are maintained in 7.1 after restructuring with no change to the existing specification;
 - DLE elements of procedure for loop-architecture are added in 7.2;
 - Serializer and deserializer is maintained in 7.3 after restructuring;
 - DLL management protocol is in 7.4 after restructuring, and
 - DLL management protocol for star-architecture is maintained in 7.4.1 without change,
 - DLL management protocol for loop-architecture is added in 7.4.2.

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

FDIS	Report on voting
65C/605/FDIS	65C/619/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 publication has been drafted in accordance with ISO/IEC Directives, Part 2.

A list of all the parts of the IEC 61158 series, published under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

The committee has decided that the contents of this 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.

NOTE The revision of this standard will be synchronized with the other parts of the IEC 61158 series.

INTRODUCTION

This part of IEC 61158 is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the “three-layer” fieldbus reference model described in IEC/TR 61158-1.

The data-link protocol provides the data-link service by making use of the services available from the physical layer. The primary aim of this standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer data-link entities (DLEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

- a) as a guide for implementors and designers;
- b) for use in the testing and procurement of equipment;
- c) as part of an agreement for the admittance of systems into the open systems environment;
- d) as a refinement to the understanding of time-critical communications within OSI.

This standard is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this standard together with other standards positioned within the OSI or fieldbus reference models, otherwise incompatible systems may work together in any combination.

NOTE Use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a particular data-link layer protocol type to be used with physical layer and application layer protocols in Type combinations as specified explicitly in the profile parts. Use of the various protocol types in other combinations may require permission from their respective intellectual-property-right holders.

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 Type 11 elements and possibly other types given in the subclause 4.2, 4.4, 4.5, 5.4, 6.2 to 6.10, 7.1 and 7.2 as follows:

US 4,930,121 [TO] Network system using token-passing bus with multiple priority levels

US 5,414,813 [TO] Direct transfer from a receive buffer to a host in a token-passing type network data transmission system

US 6,711,131 [TO] Data transmitting apparatus, network interface apparatus, and data transmitting system

PCT/JP2007/55292 [TO] Double ring network system, communication control method thereof, transmission station, and communication control program of double ring network system

JP 3,461,954 [TO] Data transmission system

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:

[TO]Toshiba Corporation
1-1, Shibaura 1-Chome
Minato-ku Tokyo 105-8001, Japan
Attention: Intellectual Property Rights Section.

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

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

Withdrawing
IECNORM.COM : Click to view the full PDF of IEC 61158-4-11:2010

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-11: Data-link layer protocol specification – Type 11 elements

1 Scope

1.1 General

The data-link layer provides basic time-critical messaging communications between devices in an automation environment.

This protocol provides communication opportunities to all participating data-link entities

- a) in a synchronously-starting cyclic manner, according to a pre-established schedule, and
- b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

Thus this protocol can be characterized as one which provides cyclic and acyclic access asynchronously but with a synchronous restart of each cycle.

1.2 Specifications

This standard specifies

- a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;
- b) procedures for giving communications opportunities to all participating DL-entities, sequentially and in a cyclic manner for deterministic and synchronized transfer at cyclic intervals up to one millisecond;
- c) procedures for giving communication opportunities available for time-critical data transmission together with non-time-critical data transmission without prejudice to the time-critical data transmission;
- d) procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;
- e) procedures for giving communication opportunities based on standard ISO/IEC 8802-3 medium access control, with provisions for nodes to be added or removed during normal operation;
- f) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this standard, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

- a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;
- b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;
- c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

These procedures are applicable to instances of communication between systems which support time-critical communications services within the data-link layer of the OSI or fieldbus reference models, and which require the ability to interconnect in an open systems interconnection environment.

Profiles provide a simple multi-attribute means of summarizing an implementation's capabilities, and thus its applicability to various time-critical communications needs.

1.5 Conformance

This standard also specifies conformance requirements for systems implementing these procedures. This standard does not contain tests to demonstrate compliance with such requirements.

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 61158-3-11:2007, *Industrial communication networks – Fieldbus specifications – Part 3-11: Data-link layer service definition – Type 11 elements*

IEC 61158-5-11:2007, *Industrial communication networks – Fieldbus specifications – Part 5-11: Application layer service definition – Type 11 elements*

IEC 61158-6-11:2007, *Industrial communication networks – Fieldbus specifications – Part 6-11: Application layer protocol specification – Type 11 elements*

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

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*

ISO/IEC 10731, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the following terms, definitions, symbols and abbreviations apply.

3.1 Reference model terms and definitions

This standard is based in part on the concepts developed in ISO/IEC 7498-1 and ISO/IEC 7498-3, and makes use of the following terms defined therein.

3.1.1	called-DL-address	[ISO/IEC 7498-3]
3.1.2	calling-DL-address	[ISO/IEC 7498-3]
3.1.3	centralized multi-end-point-connection	[ISO/IEC 7498-1]
3.1.4	correspondent (N)-entities correspondent DL-entities (N=2) correspondent Ph-entities (N=1)	[ISO/IEC 7498-1]
3.1.5	demultiplexing	[ISO/IEC 7498-1]
3.1.6	DL-address	[ISO/IEC 7498-3]
3.1.7	DL-address-mapping	[ISO/IEC 7498-1]
3.1.8	DL-connection	[ISO/IEC 7498-1]
3.1.9	DL-connection-end-point	[ISO/IEC 7498-1]
3.1.10	DL-connection-end-point-identifier	[ISO/IEC 7498-1]
3.1.11	DL-connection-mode transmission	[ISO/IEC 7498-1]
3.1.12	DL-connectionless-mode transmission	[ISO/IEC 7498-1]
3.1.13	DL-data-sink	[ISO/IEC 7498-1]
3.1.14	DL-data-source	[ISO/IEC 7498-1]
3.1.15	DL-duplex-transmission	[ISO/IEC 7498-1]
3.1.16	DL-facility	[ISO/IEC 7498-1]
3.1.17	DL-local-view	[ISO/IEC 7498-3]
3.1.18	DL-name	[ISO/IEC 7498-3]
3.1.19	DL-protocol	[ISO/IEC 7498-1]
3.1.20	DL-protocol-connection-identifier	[ISO/IEC 7498-1]
3.1.21	DL-protocol-control-information	[ISO/IEC 7498-1]
3.1.22	DL-protocol-data-unit	[ISO/IEC 7498-1]
3.1.23	DL-protocol-version-identifier	[ISO/IEC 7498-1]
3.1.24	DL-relay	[ISO/IEC 7498-1]
3.1.25	DL-service-connection-identifier	[ISO/IEC 7498-1]
3.1.26	DL-service-data-unit	[ISO/IEC 7498-1]
3.1.27	DL-simplex-transmission	[ISO/IEC 7498-1]
3.1.28	DL-subsystem	[ISO/IEC 7498-1]
3.1.29	DL-user-data	[ISO/IEC 7498-1]
3.1.30	flow control	[ISO/IEC 7498-1]
3.1.31	layer-management	[ISO/IEC 7498-1]
3.1.32	multiplexing	[ISO/IEC 7498-3]

3.1.33	naming-(addressing)-authority	[ISO/IEC 7498-3]
3.1.34	naming-(addressing)-domain	[ISO/IEC 7498-3]
3.1.35	naming-(addressing)-subdomain	[ISO/IEC 7498-3]
3.1.36	(N)-entity DL-entity Ph-entity	[ISO/IEC 7498-1]
3.1.37	(N)-interface-data-unit DL-service-data-unit (N=2) Ph-interface-data-unit (N=1)	[ISO/IEC 7498-1]
3.1.38	(N)-layer DL-layer (N=2) Ph-layer (N=1)	[ISO/IEC 7498-1]
3.1.39	(N)-service DL-service (N=2) Ph-service (N=1)	[ISO/IEC 7498-1]
3.1.40	(N)-service-access-point DL-service-access-point (N=2) Ph-service-access-point (N=1)	[ISO/IEC 7498-1]
3.1.41	(N)-service-access-point-address DL-service-access-point-address (N=2) Ph-service-access-point-address (N=1)	[ISO/IEC 7498-1]
3.1.42	peer-entities	[ISO/IEC 7498-1]
3.1.43	Ph-interface-control-information	[ISO/IEC 7498-1]
3.1.44	Ph-interface-data	[ISO/IEC 7498-1]
3.1.45	primitive name	[ISO/IEC 7498-3]
3.1.46	reassembling	[ISO/IEC 7498-1]
3.1.47	recombining	[ISO/IEC 7498-1]
3.1.48	reset	[ISO/IEC 7498-1]
3.1.49	responding-DL-address	[ISO/IEC 7498-3]
3.1.50	routing	[ISO/IEC 7498-1]
3.1.51	segmenting	[ISO/IEC 7498-1]
3.1.52	sequencing	[ISO/IEC 7498-1]
3.1.53	splitting	[ISO/IEC 7498-1]
3.1.54	synonymous name	[ISO/IEC 7498-3]
3.1.55	systems-management	[ISO/IEC 7498-1]

3.2 Service convention terms and definitions

This standard also makes use of the following terms defined in ISO/IEC 10731 as they apply to the data-link layer:

- 3.2.1 acceptor
- 3.2.2 asymmetrical service
- 3.2.3 confirm (primitive);
requestor.deliver (primitive)
- 3.2.4 deliver (primitive)
- 3.2.5 DL-confirmed-facility
- 3.2.6 DL-facility
- 3.2.7 DL-local-view
- 3.2.8 DL-mandatory-facility
- 3.2.9 DL-non-confirmed-facility
- 3.2.10 DL-provider-initiated-facility
- 3.2.11 DL-provider-optional-facility
- 3.2.12 DL-service-primitive;
primitive
- 3.2.13 DL-service-provider
- 3.2.14 DL-service-user
- 3.2.15 DL-user-optional-facility
- 3.2.16 indication (primitive);
acceptor.deliver (primitive)
- 3.2.17 multi-peer
- 3.2.18 request (primitive);
requestor.submit (primitive)
- 3.2.19 requestor
- 3.2.20 response (primitive);
acceptor.submit (primitive)
- 3.2.21 submit (primitive)
- 3.2.22 symmetrical service

3.3 Terms and definitions

3.3.1

common memory

virtual common memory over Type 11 fieldbus, which is shared by participating Type 11 fieldbus nodes and is primarily used for real-time communications by the time-critical cyclic data service

3.3.2

data DLPDU

DLPDU that carries a DLSDU from a local DLS-user to a remote DLS-user

3.3.3

DLCEP-address

DL-address which designates either

- a) one peer DL-connection-end-point, or
- b) one multi-peer publisher DL-connection-end-point and implicitly the corresponding set of subscriber DL-connection-end-points where each DL-connection-end-point exists within a distinct DLSAP and is associated with a corresponding distinct DLSAP-address

3.3.4

DL-segment, link, local link

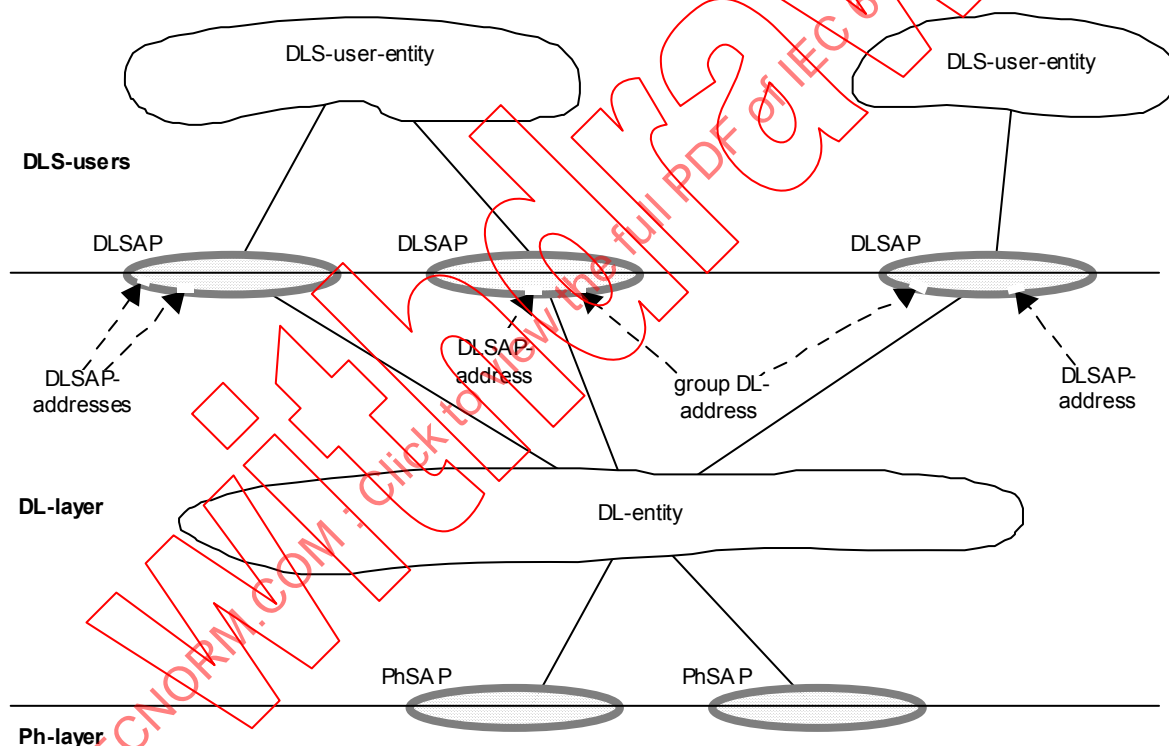
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.3.5

DLSAP

distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity

NOTE This definition, derived from ISO/IEC 7498-1, is repeated here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses. (See Figure 1)



NOTE 1 DLSAPs and PhSAPs are depicted as ovals spanning the boundary between two adjacent layers.

NOTE 2 DL-addresses are depicted as designating small gaps (points of access) in the DLL portion of a DLSAP.

NOTE 3 A single DL-entity may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

Figure 1 – Relationships of DLSAPs, DLSAP-addresses and group DL-addresses

3.3.6

DLSAP

distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity

NOTE This definition, derived from ISO/IEC 7498-1, is repeated here to facilitate understanding of the critical distinction between DLSAPs and their DL-addresses. (See Figure 1)

3.3.7

DL(SAP)-address

either an individual DLSAP-address, designating a single DLSAP of a single DLS-user, or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user

NOTE This terminology is chosen because ISO/IEC 7498-3 does not permit the use of the term DLSAP-address to designate more than a single DLSAP at a single DLS-user.

3.3.8

(individual) DLSAP-address

DL-address that designates only one DLSAP within the extended link

NOTE A single DL-entity may have multiple DLSAP-addresses associated with a single DLSAP.

3.3.9

extended link

DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

NOTE An extended link may be composed of just a single link.

3.3.10

FCS error

error that occurs when the computed frame check sequence value after reception of all the octets in a DLPDU does not match the expected residual

3.3.11

frame

denigrated synonym for DLPDU

3.3.12

group DL-address

DL-address that potentially designates more than one DLSAP within the extended link. A single DL-entity may have multiple group DL-addresses associated with a single DLSAP. A single DL-entity also may have a single group DL-address associated with more than one DLSAP

3.3.13

high-speed cyclic data

data conveyed by means of high-speed cyclic data transmission

3.3.14

high-speed cyclic data transmission

highest priority of time-critical cyclic data service

3.3.15

implicit token

mechanism that governs the right to transmit

NOTE No actual token message is transmitted on the medium. Each node keeps track of the node that it believes currently holds the right to transmit. The right to transmit is passed from node to node by keeping the node that last transmitted. A slot time is used to allow a missing node to be skipped in the rotation.

3.3.16

low-speed cyclic data

data conveyed by means of low-speed cyclic data transmission

3.3.17

low-speed cyclic data transmission

lowest priority of time-critical cyclic data service

3.3.18**medium-speed cyclic data**

data conveyed by means of medium-speed cyclic data transmission

3.3.19**medium-speed cyclic data transmission**

second-highest priority of time-critical cyclic data service

3.3.20**multi-peer DLC**

centralized multi-end-point DL-connection offering DL-duplex-transmission between a single distinguished DLS-user known as the publisher or publishing DLS-user, and a set of peer but undistinguished DLS-users known collectively as the subscribers or subscribing DLS-users. The publishing DLS-user can send to the subscribing DLS-users as a group (but not individually), and the subscribing DLS-users can send to the publishing DLS-user (but not to each other)

3.3.21**multipoint connection**

connection from one node to many nodes

NOTE Multipoint connections allows data transfer from a single publisher to be received by many subscriber nodes.

3.3.22**node**

single DL-entity as it appears on one local link

3.3.23**node DL-address**

DL-address which designates the (single) DL-entity associated with a single node on a specific local link

3.3.24**node-id**

two-octet primary identifier for the DLE on the local link, whose values are constrained

NOTE A permissible value is from 1 to 255. A value 0 is specifically used for SYN node, which emits SYN frame.

3.3.25**receiving DLS-user**

DL-service user that acts as a recipient of DL-user-data

NOTE A DL-service user can be concurrently both a sending and receiving DLS-user.

3.3.26**sending DLS-user**

DL-service user that acts as a source of DL-user-data

3.3.27**slot-time**

512-bit time of the physical signaling symbol specified in the ISO/IEC 8802-3, Clause 29

3.3.28**sporadic message data service**

aperiodic message transfer which sporadically occurs upon DLS-user requesting one or more message to transfer, and regular ISO/IEC 8802-3 Ethernet message frame is transferred by means of this message transfer

3.3.29

SYN node

node transmitting SYN frame

3.3.30

time-critical cyclic data service

cyclic data transfer with three levels of data transmission at the same time, of which each data transmission level is according to the data priority and the data transmission period for real-time delivery, and of which data transmission period and total data volume for each level can be specified in designing phase and on application needs

3.3.31

token

right to transmit on the local link

3.4 Symbols and abbreviations

ACM	Access control machine
CLM	Claim frame
CMP	Transmission complete frame
CTRC	Cyclic-transmission TX/RX control
COM	Command frame
DT	Cyclic data frame
CW	Control word (as parameter of SYN DLPDU)
DT-CMP	DT with transmission complete frame
FC	Frame control field
LL	Live list (as parameter of SYN DLPDU)
PhIDU	Ph-interface-data-unit
PM	Periodic mode (as parameter of SYN DLPDU)
PN	Transmission permits node number (as parameter of SYN DLPDU)
Pri	Priority field
RAS	RAS frame
REC	In-ring request frame
RMC	Redundancy medium control
RMSEL	Redundant medium selection
RN	Recipient node number

SN	Source node number field
ST	Slot time (as parameter of SYN DLPDU)
SYN	Synchronization frame
Th	High-speed transmission period (as transmission period)
Tm	Medium-speed transmission period (as transmission period)
Ts	Sporadic-speed transmission period (as transmission period)
Tl	Low-speed transmission period (as transmission period)

4 Overview of the DL-protocol

4.1 General

This standard meets the industrial automation market objective of providing predictable time deterministic and reliable time-critical data transfer and means, which allow co-existence with non-time-critical data transfer over the ISO/IEC 8802-3 series communications medium, for support of cooperation and synchronization between automation processes on field devices in a real-time application system. The term “time-critical” is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty.

4.1.1 Field of applications

In industrial control systems, several kinds of field devices such as Drives, Sensors and Actuators, Programmable controllers, Distributed Control Systems and Human Machine Interface devices are required to be connected with control networks. The process control data and the state data is transferred among these field devices in the system and the communications between these field devices requires simplicity in application programming and to be executed with adequate response time. In most industrial automation systems such as food, water, sewage, paper and steel, including a rolling mill, the control network is required to provide time-critical response capability for their application, as required in ISO/TR 13283 for time-critical communications architectures.

Plant production may be compromised due to errors, which could be introduced to the control system if the network does not provide a time-critical response. Therefore the following characteristics are required for a time-critical control network:

- deterministic response time between the control device nodes;
- ability to share process data seamlessly across the control system.

This protocol is applicable to such an industrial automation environment, in which time-critical communications is primarily required. The term “time-critical” is used to represent the presence of a time window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time-window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

4.2 Overview of the medium access control

The Type 11 fieldbus has a deterministic medium access control in order to avoid collisions that occur when a number of the nodes send data frames simultaneously, and to provide the opportunity of sending data to each node in a sequential order and within a predetermined

time period. Figure 2 shows the basic principle of medium access control of the Type 11 fieldbus.

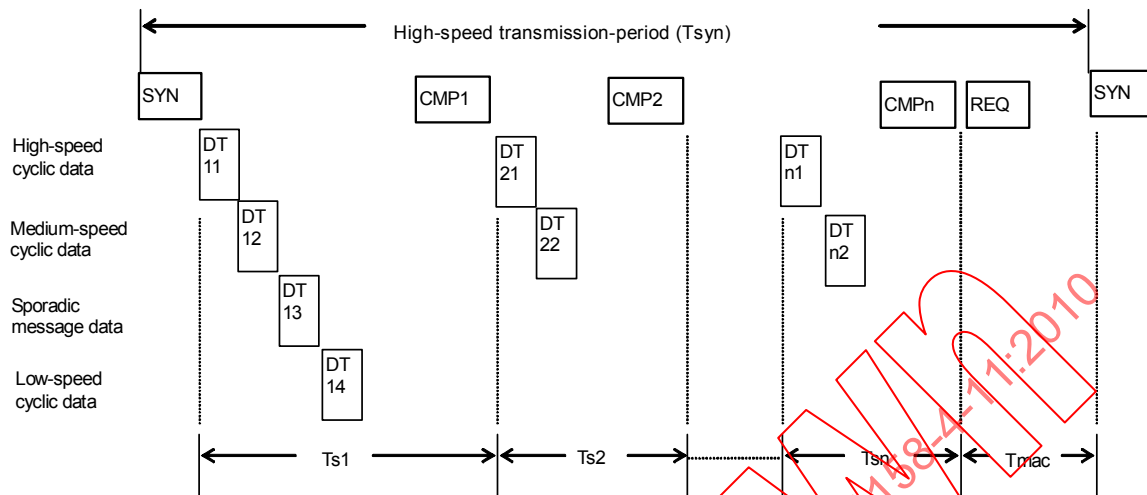


Figure 2 – Basic principle of medium access control

At the start time of every high-speed-transmission-period (T_{syn}), the SYN frame is broadcasted to all nodes. Receiving the SYN frame, the node with sequential number 1 starts sending its data frames, and after that broadcasts its CMP frame in order to indicate the completion of its data frames transmission. The N th node can send out its data frames after receiving the CMP frame from the $(N-1)$ node. After all the nodes send their data frames, the time period to solicit new nodes begins. The REQ frame is used for a new node requesting inclusion to the Type 11 fieldbus network. The sequential number is assigned to a new node at the time approval to join is granted.

Each node can hold the transmission right for a preset time and shall send its CMP frame to transfer the transmission right to the next node within the preset time. The data to be sent and the data to be held over are determined by priority.

Transmission includes Time-critical cyclic data and sporadic Ethernet message transmission. Cyclic data transmission is divided into High-, Medium- and Low-speed data transmission (see Note). Each node sends the High-speed cyclic data frames on each occasion when it obtains the transmission right. The data of lower priorities, that is the Medium-speed cyclic data, the sporadic Ethernet message data and the Low-speed cyclic data (see Note) respectively, is sent or not sent depending on the circumstances. The holding time of the transmission right of each node is determined by the settings of the High-speed cyclic, the Medium-speed cyclic, the sporadic Ethernet message and the Low-speed cyclic data transmission periods and by the volume of transmission data for each node. After sending all the High-speed cyclic data, the node sends the Medium-speed cyclic data. If the holding time of the transmission right ends during sending the Medium-speed cyclic data, the transmission of the Medium-speed cyclic data is interrupted, and the CMP frame is sent. The n^{th} node obtains the transmission right again during the next High-speed data transmission period, during which time all the High-speed cyclic data and the remainder of the previous Medium-speed cyclic data is sent. T_{mac} is the period for a new node sending out REQ frame to enter the network.

NOTE Low-speed data transmission and Low-speed cyclic data are available for star-architecture.

4.3 Service assumed from the PhL

4.3.1 General

This subclause describes the assumed Physical Service (PhS) and the constraints on use by the Type 11 DLE. The Physical Service is assumed to provide the following service primitives specified by ISO/IEC 8802-3, Clause 6.

4.3.2 Assumed primitives of PhS

The PhS is assumed to provide the following two categories of primitives to the Type 11 DL-protocol.

- a) Service primitives for transmitting and receiving frames to / from other peer DLEs.
- b) Service primitives that provide information needed by the local DLE to perform the media access functions.

The assumed primitives of PhS are grouped into these two categories:

- c) Transfer of Data to all other peer DLE
 - 1) PLS_DATA request
 - 2) PLS_DATA indication
- d) Media access management by local DLE
 - 1) PLS_CARRIER indication
 - 2) PLS_SIGNAL indication
 - 3) PLS_DATA_VALID indication

The interaction of the PhS primitives to the DLE is shown in Figure 3.

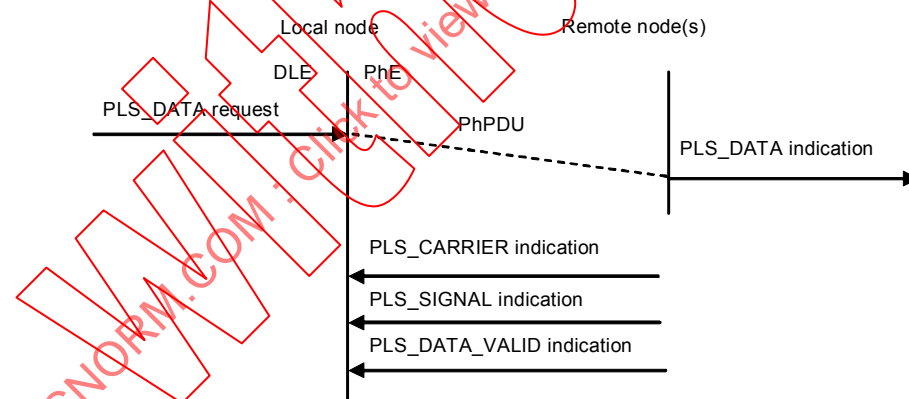


Figure 3 – Interaction of PhS primitives to DLE

4.4 DLL architecture

4.4.1 Overview

The Type 11 fieldbus DLL is modeled as a combination of control components of Access Control Machine (ACM), Cyclic transmission TX/RX Control (CTRC), Sporadic TX/RX Control (STRC), Redundancy Medium Control (RMC), Serializer, Deserializer and DLL management interface.

The Access Control Machine as the primary control component provides the function for deterministic medium access control cooperating with the Cyclic-transmission TX/RX Control, the Sporadic TX/RX Control and the Redundancy Medium Control for reliable and efficient

support of higher-level connection-mode and connectionless data transfer services. Specifically the Access Control Machine has the primary responsibility for

- a) assuring that the local node detects and fully utilizes its assigned access time period;
- b) assuring that the local node does not interfere with the transmissions of other nodes, especially of the node transmitting the SYN frame;
- c) detecting network disruption, and initiating the SYN frame transmission for restoration of the network disruption from after prescribed time duration in which the SYN frame is not heard;
- d) assuring a new node adding to and removing from the network.

The DLL management interface provides DLL management functions. PhL framing and delimiters are managed by DLL functions for serializing and deserializing M_symbol requests and indications.

4.4.2 Star-architecture

The Data-link layer is comprised of the components listed in Table 1. The internal arrangement of these components, and their interfaces, are shown in Figure 4. The arrowheads illustrate the primary direction of flow of data and control.

Table 1 – Data-link layer components of star-architecture

Components	Description
Access control machine (ACM)	Deterministic medium access control and scheduling the opportunities to sending out the DLPDUs, control for adding and removing nodes, restoration from disruption. Assembles and transmits the DLPDUs to the TX framer through the RMC, receives and disassembles the DLPDUs with the control information from the RMC, and determines the timing and duration of the transmissions. Signals the RMC to sending out the DLPDUs for control and diagnosis of the Type 11 fieldbus. Buffers and dispatches in time the DLPDUs received between the DLS-user and the RMC
Cyclic transmission TX/RX control (CTRC)	Buffers and dispatches in time DLSDU received for the time-critical cyclic data transfer between the DLS-user and the ACM
Sporadic TX/RX control (STRC)	Buffers and dispatches in time DLSDU received for the Sporadic message data between DLS-user and the ACM
Redundancy medium control (RMC)	Receives the DLPDUs from the ACM and breaks them down into octet symbol requests to the Octet serializer, assembles received octets from the Octet deserializer into DLPDUs and submits them to the ACM. Selects one of two outputs of the Octet deserializers through the RX framers for medium redundancy
TX/RX framer	Receives the octet symbols from the RMC, detects and indicates the start timing of a DLPDU to the Octet serializer, passes received octets from the Octet deserializer and indicates the start timing of a DLPDU to the RMC
Octet serializer	Receives octet symbols, encodes and serializes them, and sends them as M_symbols to the PhL. It is also responsible for generating the FCS
Octet deserializer	Receives M_symbols from the PhL, converts M_symbols into octets and sends them to the RX framer. It is also responsible for checking the FCS
DLL management interface	Holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters

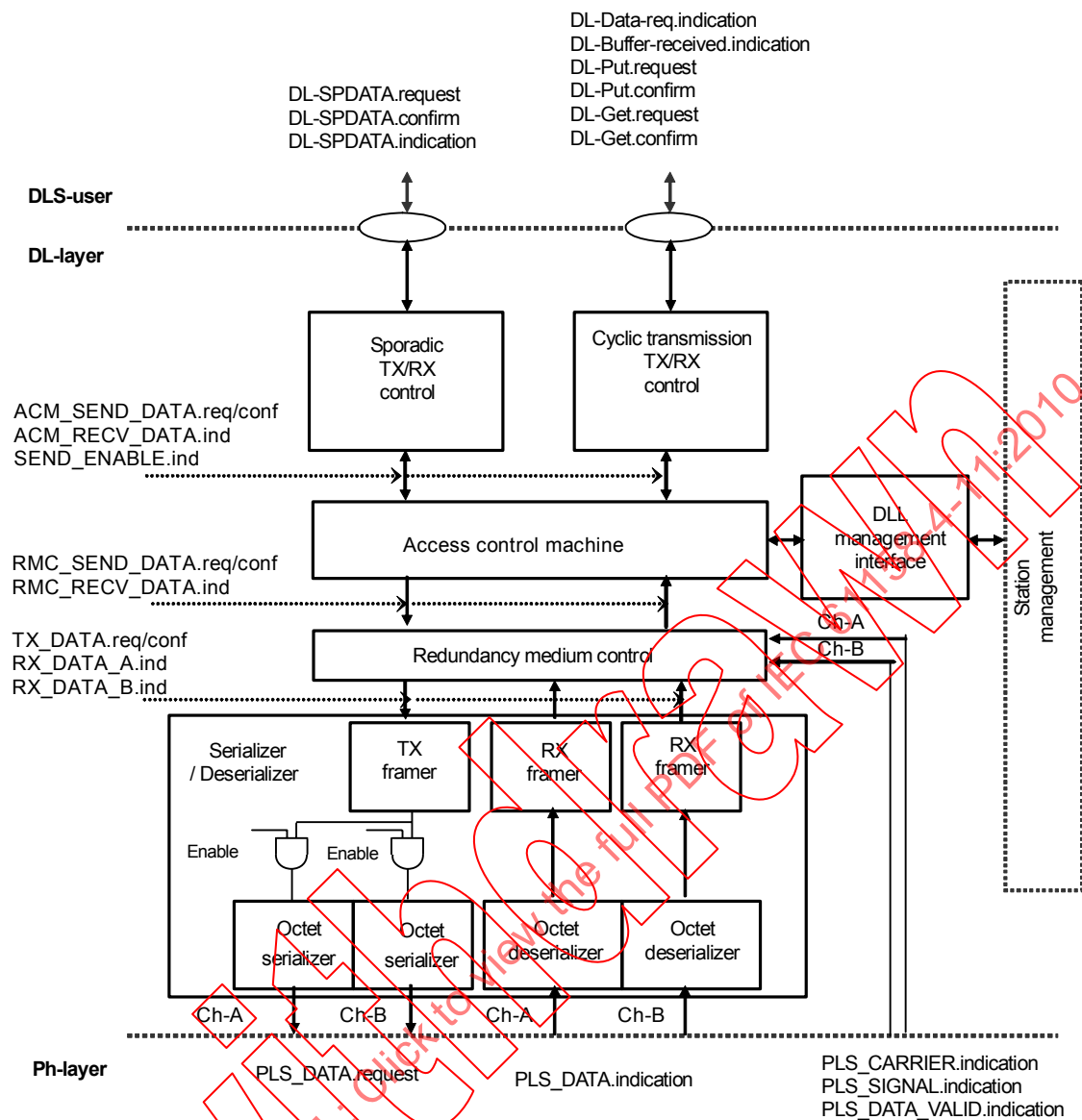


Figure 4 – Data-link layer internal architecture of star-architecture

4.4.3 Loop-architecture

The Data-link layer is comprised of the components listed in Table 2. The internal arrangement of these components, and their interfaces, are shown in Figure 5. The arrowheads illustrate the primary direction of flow of data and control.

Table 2 – Data-link layer components of loop-architecture

Components	Description
Access control machine (ACM)	Deterministic medium access control and scheduling the opportunities to sending out the DLPDUs, control for adding and removing nodes, restoration from disruption. Assembles and transmits the DLPDUs to the TX framer through the RMC, receives and disassembles the DLPDUs with the control information from the RMC, and determines the timing and duration of the transmissions. Signals the RMC to sending out the DLPDUs for control and diagnosis of the Type 11 fieldbus. Buffers and dispatches in time the DLPDUs received between the DLS-user and the RMC
Cyclic transmission TX/RX control (CTRC)	Buffers and dispatches in time DLSDU received for the time-critical cyclic data transfer between the DLS-user and the ACM
Sporadic TX/RX control (STRC)	Buffers and dispatches in time DLSDU received for the Sporadic message data between DLS-user and the ACM
Redundancy medium control (RMC)	Receives the DLPDUs from the ACM and breaks them down into the octet-symbol requests to the TX-framer, assembles received-octets from the RX-framers into the DLPDUs, selects one of two outputs from the RX-framers and submits them to the ACM. Receives the signal from the ACM and activates the transmission of the DLPDU frames for control and diagnosis of the Type 11 fieldbus
TX/RX framer	TX framer receives the octet-symbols from the RMC, detects and indicates the start timing of a DLPDU to the Octet-serializer, forwards received-octets from the Octet-deserializer connected to a Ring-port to other Octet-serializer connected to other Ring-port. RX framer passes received-octets from the Octet-deserializer and indicates the start-delimiter of a DLPDU to the RMC
Octet serializer	Receives octet symbols, encodes and serializes them, and sends them as M_symbols to the PhL. It is also responsible for generating the FCS
Octet deserializer	Receives M_symbols from the PhL, converts M_symbols into octets and sends them to the RX framer and the TX framer. It is also responsible for checking the FCS
DLL management interface	Holds the station management variables that belong to the DLL, and manages synchronized changes of the link parameters

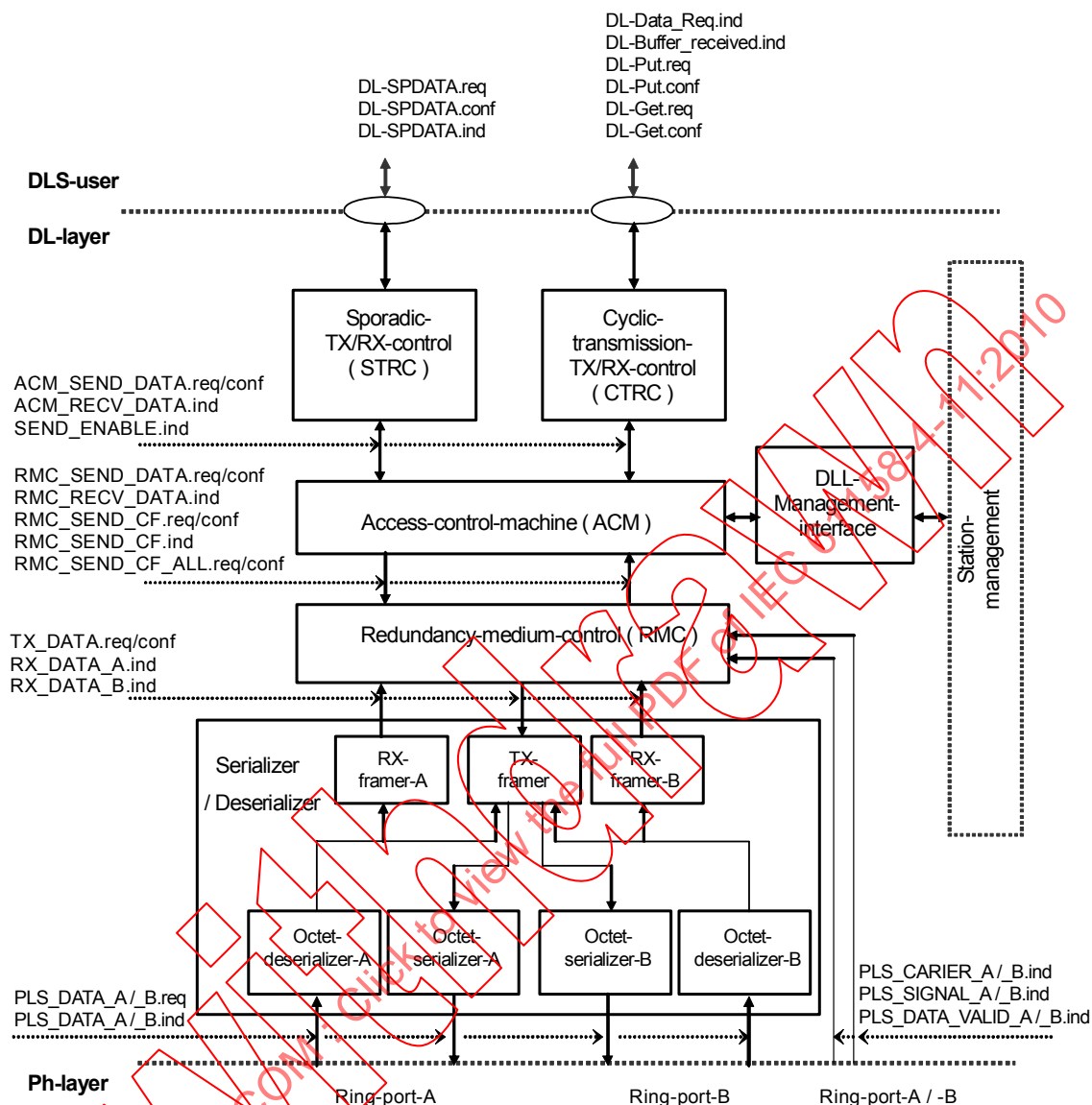


Figure 5 – Data-link layer internal architecture of loop-architecture

4.5 Access control machine and schedule support functions

The ACM functions schedule all communications between the DLEs participating in the Type 11 fieldbus, and the timing of this communications is controlled as to

- fulfill the specific medium access control to give all the DLEs the opportunities to send out two kinds of class of Time-critical cyclic data and Sporadic message data in timely, prioritized and deterministic fashion, and to detect network disruption and to initiate the restoration in appropriate time, further to add and remove nodes on line;
- provide multiple levels of Time-critical data transfer opportunities of sending data to node in sequential order and within each pre-specified time period, and that the data transfer of each level is performed within the pre-specified time duration (token holding time) and whether the data transfer of lower levels to be carried out or to be held over to later cyclic time period depends on the level and the occasion though the top level of the data transfer is always carried out at every occasion; on the other hand the whole volume of the data transfer of lower levels is transferred within each pre-specified time period;

- c) provide sporadic message data transfer opportunities of sending out to node that the request to transfer is happened sporadically by the DLS-user, and the data transfer is performed in pre-specified time period of the corresponding level of priority and is based on regular ISO/IEC 8802-3 applications.

Accurate scheduling timing is very important to support many control and data collection tasks in the applications domain of this protocol.

4.6 Local parameters, variables, counters, timers and queues

4.6.1 Overview

4.6.1.1 General

This specification uses DLS-user request parameters $P(\dots)$ and local variables $V(\dots)$ as a means of clarifying the effect of certain actions and the conditions under which those actions are valid, local timers $T(\dots)$ as a means of monitoring actions of the distributed DLS-provider and of ensuring a local DLE response to the absence of those actions, and local counters $C(\dots)$ for performing rate measurement functions. It also uses local queues $Q(\dots)$ as a means of ordering certain activities, of clarifying the effects of certain actions, and of clarifying the conditions under which those activities are valid.

Unless otherwise specified, at the moment of their creation or of DLE activation:

- a) all variables shall be initialized to their default value, or to their minimum permitted value if no default is specified;
- b) all counters shall be initialized to zero;
- c) all timers shall be initialized to inactive;
- d) all queues shall be initialized to empty.

DL-management may change the values of configuration variables.

4.6.1.2 Summary of variables, parameters, counters, timers for star-architecture

Table 3 and Table 4 summarize the variables and their usage.

NOTE The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5. The most significant bit of the most significant octet is always used as the most significant bit of the binary number. The bits of each octet are numbered 0 to 7, where bit 0 is the least significant bit of the octet. Each octet is transferred to the PH layer low-bit first and multiple octets is transferred low-order octet first (little endian format).

Table 3 – DLE-variables and permissible values of star-architecture

Variable -name	Description	Permissible values	Data type
BW	Length of TCC data word in a DLPDU	The default value is 128 (octets). See 4.6.2.7	UINT
DR	Data-rate	The default value is 100 (Mbps). See 4.6.2.11	UINT
HTh	Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted	2 to $2^{16}-1$ (in unit of 1 ms). The default value is $3 \times V(Th)$. See 4.6.2.12	UDINT
HTI	Maximum observational time period for detecting the continuous low-speed transmission cycle disrupted	2 to $2^{16}-1$ (in unit of 1 ms). The default value is $3 \times V(Th)$. See 4.6.3.5	UDINT
HTm	Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted	2 to $2^{16}-1$ (in unit of 1 ms). The default value is $3 \times V(Th)$. See 4.6.2.14	UDINT
IA	Individual address of this node	Individual 48-bit address identical to ISO/IEC 8802-3. See 4.6.2.16	USINT[6]
IGP	Time interval from the end of a previous frame to the start of the consecutive frame sent by a node	The default value is 24 (0.96 μ s in unit of 0.04 μ s). See 4.6.2.17	UDINT
IP	IP address of this node	32-bit address identical to IPv4. See 4.6.2.18	USINT[4]
MD	Maximum distance on the connection path between any 2 nodes	1 to 100 (km). The default value is 8. See 4.6.2.21	UINT
MDD	Maximum difference of the distance of two redundant physical mediums on the connection path between any 2 nodes	0 to 2 000 (in m). The default value is 500. See 4.6.3.7.	UINT
MGA	Multicast group address	Multicast 48-bit address identical to ISO/IEC 8802-3, for logically associated Type 11 fieldbus nodes. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01. See 4.6.2.22	USINT[6]
MN	Maximum node number	254 (default value). See 4.6.2.23	USINT
MPD	Maximum difference of the signal delay time propagating over two redundant physical mediums on the connection path between any 2 nodes	1 to 0x7c (in units of 0.04 μ s). The default value is 0x7c ($\approx$ 5 μ s). See 4.6.3.8	UDINT
MRT	Maximum number of the repeater units on the connection path between any 2 nodes	0 to 7. The default value is 3. See 4.6.2.24	UINT
MTHt	Maximum-token hold-time for high-speed cyclic data transmission	1 to $2^{16}-1$ (octet times). The default value is 0x30B4 (=900 μ s). See 4.6.2.25	UDINT
PBh	List of up to 2 048 data buffers using for sending out high-speed TCC data	1 to 2048. See 4.6.2.28	UINT
PBl	List of up to 2 048 data buffers using for sending out low-speed TCC data	1 to 2048. See 4.6.3.10	UINT
PBm	List of up to 2 048 data buffers using for sending out medium-speed time-critical cycle data	1 to 2048. See 4.6.2.29	UINT
RCS	Receive-channel switching control for receiving frames. Designates the switching control for receiving frames out of one of two receive-channel A and B corresponding to each of the redundant media A and B	"Automatic", "Force A", "Force B" "Automatic": Automatically switch to the proper receive-channel. "Force A", "Force B": Force to switch Receive-channel A or B respectively. The default is "Automatic". See Table 10, Table 12, 4.6.3.12, 4.6.3.12	BOOL

Variable name	Description	Permissible values	Data type
RMGP	Maximum time-interval for one receive-channel, which has already completed one frame received and has waited for IGP time, to wait for the completion of a frame to be received on the other receive-channel in order to detect the other receive-channel disrupted	250 (in units of 0,04 μ s). The value 250 represents 10 μ s. See 4.6.3.14	UDINT
ST	The slot-time is the fundamentally observational time unit, used in the DLME for observing to initiate action such as re-initialization in sending out the CLM frame, and also used in the DLME for observing the CMP frame sent by the corresponding node, and in case that the node failed to send out, used in the DLME for initiating action just as the CMP frame is received	1 to 255 (in units of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (=100 μ s). See Table 14, 4.6.2.38	USINT
SCMP	Medium-access-control-time for substitute CMP	1 to 255 (in unit of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (=100 μ s). See 4.6.2.31	USINT
SCMPL	Permissible repetitive count within which the node can behave like that the node received the CMP frame even though the corresponding node had failed to send out the CMP frame. The node determines the corresponding node is out of service if the count is over	1 to 16. The default value is 3. See 4.6.2.33	USINT
SEN _A SEN _B	Send enable control for sending frames out of the transmitter-A or –B	"True" / "Enable" or "False" / "Disable" The default value is "True" / "Enable". See 4.6.3.16	BOOL
Th	High-speed transmission period	1 to 160 (in units of 0,1 ms). See Table 15, 4.6.2.39	USINT[3]
Tl	Low-speed transmission period	100 to 10 000 (in unit of 1 ms). See Table 18, 4.6.3.17	UINT
TISPD	Time-interval cyclically processed for Sporadic message data service	1 to 1 000 (in unit of 1 ms). The default value is 100. See Table 17, 4.6.2.40, 4.6.2.41	UINT
Tm	Medium-speed transmission period	10 to 1 000 (in unit of 1 ms). The default value is 100. See Table 16, 4.6.2.42	UINT
TMAC	Maximum observation time period for the SYN node to solicit new nodes into the Type 11 fields	1 to 100 (in units of 0.1 ms). The default value is 100. See 4.6.2.43, 4.6.2.44	USINT
Tsl	DLE number able to send out next slot	1 to 255. See 4.6.2.46	USINT
TSYN	Target-periodic-time from SYN frame arrival to SYN frame arrival	1 to 160 (in units of 0,1 ms). See 4.6.2.47	UDINT
TTRT0	Target-token-rotation-time for access class 0	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.3.18	UDINT
TTRT1	Target-token-rotation-time for access class 1	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.48	UDINT
TTRT2	Target-token-rotation-time for access class 2	1 to 2 ¹⁶ -1 (octet time). The default value is P(TSYN). See 4.6.2.49	UDINT
TN	Node identifier number of the node. The initial value is 0 on power-up or reset	1 to 255. See 4.6.2.45	USINT

Table 4 – Observable variables and their value ranges of star-architecture

Variable -name	Description	Range of value	Data type
AIGP _A AIGP _B	IGP monitor over the receive-channel A and B	0 to 24, continuously decrementing. The value 24 represents 0.96 µs. See 4.6.3.1	UDINT
ARMGP	The observed time period for one receive-channel, which has already completed one frame received and has waited for IGP time (0,96 µs), to wait the completion of a frame received on the other receive-channel in order to detect the other receive-channel disrupted	0 to 250, continuously decrementing. The value 250 represents 10 µs. See 4.6.3.2	UDINT
ASCMP	Collection of counters of total number of nodes. Each counter corresponding to a node indicates observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The node determines the corresponding node is out of service when the count reaches the pre-specified number. The number counted is indicated and is incremented coincidentally at each DLME	1 to 16. The default value is equal to the value of SCMPL, which is 3. See 4.6.2.1	USINT
ATHT	The observed time period of the MHT	0 to MHT, continuously decrementing. See 4.6.2.2	UDINT
ATSYN	The observed time period from SYN frame arrival to SYN frame arrival	1 to 2 ¹⁶ (octet times). See 4.6.2.3	UDINT
ATTRT0	The observed time period of the TTRT0	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.3.3	UDINT
ATTRT1	The observed time period of the TTRT1	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.4	UDINT
ATTRT2	The observed time period of the TTRT2	1 to 2 ¹⁶ -1, continuously decrementing. See 4.6.2.5	UDINT
CDh	Cumulative count of transmitted high-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.8	UDINT
CDH _{blk}	Information data status of the data buffer with the identifier number "blk", indicating the corresponding TCC data being active (healthy) or inactive (unhealthy)	True: active. False: inactive. See 4.6.2.9	BOOL
CDl	Cumulative count of transmitted low-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.3.4	UDINT
CDm	Cumulative count of transmitted medium-speed-cyclic data frames	0 to 2 ³² -1. See 4.6.2.10	UDINT
LL	Live list indicating whether the corresponding node, at this moment, is connected to and running in the Type 11 fieldbus domain in the received SYN frame. The Live list is a set of 256 Booleans, represented in 32 octets, in which each bit corresponds to a node in the Type 11 fieldbus domain and indicates the current status of that node	256-bit set of Booleans True: node is connected and working. False: node is not connected or not working. See 4.6.2.19	USINT[16]
LN	Extracted number from LL at each node and used by each node to decide whether the node is able to send the data frame out over the medium	1 to 255. See 4.6.2.20	USINT
NCD _A , NCD _B	Cumulative count of No-Carrier detected on the receive-channel A or B	0 to 2 ³² -1. See 4.6.3.9	UDINT

Variable -name	Description	Range of value	Data type
NONC	Permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive Tsyn cycles, that is 256 times by SCMP, in order to detect no other node except the SYN node in the Type 11 fieldbus domain	1 to 16. The default value is 3. See 4.6.2.26, 4.6.2.27	USINT
RE _A , RE _B	Cumulative count of DLPDUs received in error on the receive-channel A or B. RE _A is incremented when an error is detected on receive-channel A while receive-channel B is error-free. RE _B corresponds, but with interchanged channel roles.	0 to 2 ³² -1. See 4.6.3.13	UDINT
ROK _A , ROK _B	Cumulative count of DLPDU-received without error on the receive-channel A or B	0 to 2 ³² -1. See 4.6.3.15	UDINT
SL	The observed time period of the SL	0 to V(SL). See 4.6.2.35, 4.6.2.36	USINT
SD	Cumulative count of transmitted sporadic data frames	0 to 2 ³² -1. See 4.6.2.34	UDINT

4.6.1.3 Summary of variables, parameters, counters, timers for loop-architecture

Table 5 and Table 6 summarise the variables and their usage. The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5.

NOTE The data types used in the data link variables, parameters, state machines are specified in IEC 61158-5-11, Clause 5. The most significant bit of the most significant octet is always used as the most significant bit of the binary number. The bits of each octet are numbered 0 to 7, where bit 0 is the least significant bit of the octet. Each octet is transferred to the Ph layer low-bit first and multiple octets is transferred low-order octet first (little endian format).

Table 5 – DLE variables and permissible values of loop-architecture

Variable -name	Description	Permissible values	Data type
BW	Length of TCC data word in a DLPDU	16 to 128. The default value is 64. See 4.6.2.7	UINT
DR	Data-rate	The default value is 100 (Mbps). See 4.6.2.11	UINT
FWE _{AB} , FWE _{BA}	Forwarding control for receiving frame enable to each direction to/from Ring-port-A and -B. FWE _{AB} controls forwarding frames receiving from Ring-port-A to Ring-port-B. On the other hand, FWE _{BA} controls forwarding frames receiving from Ring-port-B to Ring-port-A	“Enable” or “Disable”. “Enable”: permit forwarding frames receiving from one Ring-port to other Ring-port. “Disable”: prohibit forwarding frames between Ring-ports. The default value is “Disable”. See 6.9.3, 4.6.4.3	BOOL
HTh	Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in unit of 1 ms). The default value is 3 x V(Th). See 4.6.2.12	UDINT
HTI	Maximum observational time period for detecting the continuous low-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in unit of 1 ms). The default value is 3 x V(Th). See 4.6.3.5	UDINT
HTm	Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted	2 to 2 ¹⁶ -1 (in unit of 1 ms). The default value is 3 x V(Th). See 4.6.2.14	UDINT
IA	Individual address of this node	Individual 48-bit address identical to ISO/IEC 8802-3. See 4.6.2.16	SWORD[6]
IGP	Time interval from the end of a previous frame to the start of the consecutive frame sent by a node	The default value is 24 (0.96 µs in unit of 0.04µs). See 4.6.2.17	UDINT

Variable -name	Description	Permissible values	Data type
IP	IP address of this node	32-bit address identical to IPv4. See 4.6.2.18	USINT[4]
MD	Maximum distance on the connection path between any 2 nodes	1 to 20 (km). The default value is 4. See 4.6.2.21	UINT
MDAD	Maximum distance between adjacent node	1 to 2 (km). The default value is 1. See 4.6.4.6	UINT
MGA	Multicast group address	Multicast 48-bit address identical to ISO/IEC 8802-3, for logically associated Type 11 fieldbus nodes. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01. See 4.6.2.22	USINT[6]
MN	Maximum node number	254 (default value). See 4.6.2.23	USINT
MRT	Maximum number of the repeater units on the connection path between any 2 nodes	0 to 252. The default value is 30. See 4.6.2.24	USINT
MHT	Maximum-token-hold-time for high-speed cyclic data transmission	1 to $2^{16}-1$ (octet times). The default value is 0x30B4 (=900 µs). See 4.6.2.25	USINT
PBh	List of up to 2 048 data buffers using for sending out high-speed TCC data	1 to 2048. See 4.6.2.28	UINT
PBm	List of up to 2 048 data buffers using for sending out medium-speed time-critical cycle data	1 to 2048. See 4.6.2.29	UINT
PS _A PS _B	Port state control for blocking or non-blocking frame receiving from the Ring-port-A or -B	"Blocked" or "Non-blocked". The default value is "Blocked". See Table 26, 4.6.4.12	BOOL
REN _A REN _B	Receive enable control for receiving frames from the Ring-port-A or -B.	"Enable" or "Disable". The default value is "Enable". See Table 27, 4.6.4.14	BOOL
ST	The slot-time is the fundamentally observational time unit, used in the DLME for observing to initiate action such as re-initialization in sending out the CLM frame, and also used in the DLME for observing the CMP frame sent by the corresponding node, and in case that the node failed to send out, used in the DLME for initiating action just as the CMP frame is received	1 to 255 (in units of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (=100 µs). See Table 14, 4.6.2.38	USINT
SCMP	Medium-access-control-time for substitute CMP	1 to 255 (in unit of physical symbol times for 512 bits, identical to ISO/IEC 8802-3). The default value is 20 (=100 µs). See 4.6.2.31	USINT
SCMPL	Permissible repetitive count within which the node can behave like that the node received the CMP frame even though the corresponding node had failed to send out the CMP frame. The node determines the corresponding node is out of service if the count is over	1 to 16. The default value is 3. See 4.6.2.33	USINT
SEN _A SEN _B	Send enable control for sending frames out of the Ring-port-A or -B	"True" / "Enable" or "False" / "Disable". The default value is "True" / "Enable". See Table 24, 4.6.4.16	BOOL
Th	High-speed transmission period	1 to 160 (in units of 0,1 ms). See Table 15, 4.6.2.39	USINT[3]
TISPD	Time-interval cyclically processed for Sporadic message data service	1 to 1 000 (in unit of 1 ms). The default value is 100. See Table 17, 4.6.2.40, 4.6.2.41	UINT
Tm	Medium-speed transmission period	10 to 1 000 (in unit of 1 ms). The default value is 100. See Table 16, 4.6.2.42	UINT
TMAC	Maximum observation time period for the SYN node to solicit new nodes into the Type 11 fieldbus	1 to 100 (in units of 0.1 ms). The default value is 100. See 4.6.2.43, 4.6.2.44	USINT
Tsl	DLE number able to send out next slot	1 to 255. See 4.6.2.46	USINT

Variable -name	Description	Permissible values	Data type
TSYN	Target-periodic-time from SYN frame arrival to SYN frame arrival	1 to 160 (in units of 0,1 ms). See 4.6.2.47	UDINT
TTRT1	Target-token-rotation-time for access class 1	1 to $2^{16}-1$ (octet time). The default value is P(TSYN). See 4.6.2.48.	UDINT
TTRT2	Target-token-rotation-time for access class 2	1 to $2^{16}-1$ (octet time) The default value is P(TSYN). See 4.6.2.49	UDINT
TN	Node identifier number of the node. The initial value is 0 on power-up or reset	1 to 255. See 4.6.2.45	USINT

Table 6 – Observable variables and their value ranges of loop architecture

Variable -name	Description	Range of value	Data type
AN _A AN _B	Node number of adjacent node neighboring Ring-port-A or -B	1 to 254. See 4.6.4.1	USINT
ASCMP	Collection of counters of total number of nodes. Each counter corresponding to a node indicates observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The node determines the corresponding node is out of service when the count reaches the pre-specified number. The number counted is indicated and is incremented coincidentally at each DLME	1 to 16. The default value is equal to the value of SCMP _L , which is 3. See 4.6.2.1	USINT
ATHT	The observed time period of the MHT	0 to MHT, continuously decrementing. See 4.6.2.2	UDINT
ATSYN	The observed time period from SYN frame arrival to SYN frame arrival	1 to 2^{16} (octet times). See 4.6.2.3	UDINT
ATTRT1	The observed time period of the TTRT1	1 to $2^{16}-1$, continuously decrementing. See 4.6.2.4	UDINT
ATTRT2	The observed time period of the TTRT2	1 to $2^{16}-1$, continuously decrementing. See 4.6.2.5	UDINT
CDh	Cumulative count of transmitted high-speed-cyclic data frames	0 to $2^{32}-1$. See 4.6.2.8	UDINT
CDH _{blk}	Information data status of the data buffer with the identifier number "blk", indicating the corresponding TCC data being active (healthy) or inactive (unhealthy)	True: active. False: inactive. See 4.6.2.9	BOOL
CDm	Cumulative count of transmitted medium-speed-cyclic data frames	0 to $2^{32}-1$. See 4.6.2.10	UDINT
CRE _A CRE _B	Observed repetitive count for the abnormal reception error detected during receiving incoming frame from the Ring-port-A or -B respectively. The count is decreased by each abnormal reception detection repetitively but reset to the initial value when the abnormal reception is cleared. When reached to 0, abnormal reception error is detected	0 to 15. The default value is 2. See 4.6.4.2	USINT
LINK _A LINK _B	Link state indicating the condition of physical link connection at Ring-port-A or -B	"Abnormal" or "Normal". See 4.6.4.4	BOOL
LSYN	Node number of the node in current master state	1 to 254. See 4.6.4.5	USINT

Variable -name	Description	Range of value	Data type
LL	Live list indicating whether the corresponding node, at this moment, is connected to and running in the Type 11 fieldbus domain in the received SYN frame. The Live list is a set of 256 Booleans, represented in 32 octets, in which each bit corresponds to a node in the Type 11 fieldbus domain and indicates the current status of that node	256-bit set of Booleans. True: node is connected and working. False: node is not connected or not working. See 4.6.2.19	USINT[16]
LN	Extracted number from LL at each node and used by each node to decide whether the node is able to send the data frame out over the medium	1 to 255. See 4.6.2.20	USINT
NCD _A , NCD _B	Cumulative count of No-Carrier detected on the Ring-port-A or B	0 to 2 ³² -1. See 4.6.3.9	UDINT
NONC	Permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive Tsyn cycles, that is 256 times by SCmpl, in order to detect no other node except the SYN node in the Type 11 fieldbus domain	1 to 16. The default value is 3. See 4.6.2.26, 4.6.2.27	USINT
NOS	Node operation state indicating the operation condition of a node in normal or open state	"Normal" or "Open". The default value is "Open". See 4.6.4.8	BOOL
NRF _A , NRF _B	Observed time period in which no frame received from Ring-port-A or –B after from other Ring-port-B or –A respectively, a frame has been received	0 to 15 (in unit of T _h time). The default value is 2. See 4.6.4.9	USINT
NS	Node state indicating the node condition operating as master or slave	"Master" or "Slave". The default value is "Slave". See 4.6.4.10	BOOL
PP	Primary port indicating the Ring-port-A or –B through which SYN or CLM received first since this node is power-up, or in the system start-up, or in the system initialization	"Ring-port-A" or "Ring-port-B". The default value is "Ring-port-A". See Table 25, 4.6.4.11	BOOL
RE _A , RE _B	Cumulative count of DLPDUs received in error on the Ring-port-A or –B. RE _A is incremented when an error is detected on the Ring-port-A while the Ring-port-B respectively is error-free. RE _B corresponds, but with interchanged channel roles	0 to 2 ³² -1. See 4.6.4.13	UDINT
ROK _A , ROK _B	Cumulative count of DLPDU-received without error on the Ring-port-A or –B	0 to 2 ³² -1. See 4.6.4.15	UDINT
SL	The observed time period of the SL	0 to V(SL). See 4.6.2.35, 4.6.2.36	USINT
SD	Cumulative count of transmitted sporadic data frames	0 to 2 ³² -1. See 4.6.2.34	UDINT

4.6.2 Type 11 common variables, parameters, counters, timers and queues

4.6.2.1 C(ASCOMP) : ASCMP count

A collection of counters, each of which indicates the number of observed repetitive count that the corresponding node failed to send out the CMP frame and the other node can behave like that the CMP frame received without error. The number of C(ASCOMP) is incremented coincidentally at each node in Type 11 fieldbus. The value is in the range of 1 to V(SCMPL) and the default value is 3.

4.6.2.2 T(ATHT) : MTHT monitor

T(ATHT) is used by the DLE to measure the time elapsed of MTHT. The value is decremented in the range of P(MTHT) to 0.

4.6.2.3 T(ATSYN) : TSYN monitor

T(ATSYN) is used by the DLE to monitor the time period from SYN frame arrival to SYN frame arrival. The value is indicated in octet time by the data signaling rate.

4.6.2.4 T(ATTRT1) : TTRT1 monitor

T(ATTRT1) is used by the DLE to monitor the time period of TTRT1. The value is decremented in the range of $2^{16}-1$ to 1, of which unit is in octet time by the data-signaling rate.

4.6.2.5 T(ATTRT2) : TTRT2 monitor

T(ATTRT2) is used by the DLE to monitor the time period of TTRT2. The value is decremented in the range of $2^{16}-1$ to 1, of which unit is in octet time by the data-signaling rate.

4.6.2.6 Q(BF_{blk}) : Data buffer used for sending and receiving a DLPDU for time-critical cyclic data DLPDU

The total number of buffers is equivalent of the total number of DLCEP. Each buffer with the identifier “blk” number corresponds to a DLCEP with the identifier number “identifier”.

4.6.2.7 V(BW), P(BW) : Length of time-critical cyclic data word in a DLPDU

This variable holds and designates the length of the Time-critical cyclic data word in a DLPDU.

The possible value of the length in octet is as follows:

- a) star-architecture: The default value is 128.
- b) loop-architecture: 16 to 128. The default value is 64.

4.6.2.8 C(CDh) : Cumulative count of high-speed-cyclic data frame sent

C(CDh) indicates the number of cumulative count of high-speed-cyclic data frame sent on the medium. C(CDh) is a roll-over binary counter of 32-bit length.

4.6.2.9 V(CDh_{blk}) Information data status of the data buffer with identifier number “blk”

This variable indicates the status of the corresponding time-critical cyclic data being active (healthy) or inactive (unhealthy). The value “True” indicates active, and the value “False” indicates inactive.

4.6.2.10 C(CDm) : Cumulative count of medium-speed-cyclic data frame sent

C(CDm) indicates the number of cumulative count of medium-speed-cyclic data frame sent on the medium. C(CDm) is a roll-over binary counter of 32 bits length.

4.6.2.11 V(DR) : Data-rate

The value of this variable indicates the data signaling rate in Mbps. The value is 100.

4.6.2.12 V(HTh), P(HTh) : Maximum observational time period for detecting the continuous high-speed transmission cycle disrupted

This variable holds and designates the value of maximum observational time period for detecting the continuous High-speed transmission cycle disrupted. The value of this variable is in the range of 2 to $2^{16}-1$, of which the unit is 1 ms. The default value is $3 \times V(Th)$.

4.6.2.13 T(HTh) : HTh monitor

T(HTh) is used by the DLE to measure the HTh time elapsed to detect the continuous High-speed transmission cycle failed. The value is decremented in the range of V(HTh) to 1.

4.6.2.14 V(HTm), P(HTm) : Maximum observational time period for detecting the continuous medium-speed transmission cycle disrupted

This variable holds and designates the value of maximum observational time period for detecting the continuous Medium-speed transmission cycle disrupted. The value of this variable is in the range of 2 to $2^{16}-1$, of which the unit is 1ms. The default value is $3 \times V(Th)$.

4.6.2.15 T(HTm) : HTm monitor

T(HTm) is used by the DLE to measure the HTm time elapsed to detect the continuous Medium-speed transmission cycle disrupted. The value is decremented in the range of V(HTm) to 1.

4.6.2.16 V(IA) : Individual-address-of-this-node

This variable holds the individual address of this node in the 48-bit length specified by ISO/IEC 8802-3. The value is set by DLMS.

4.6.2.17 V(IGP) : Inter-frame-time-gap

This variable indicates the value of the time interval from the end of a previous frame to the start of the consecutive frame sent by a node. The value is equivalent to $0,96 \mu s$ and is identical to that specified by ISO/IEC 8802-3.

4.6.2.18 V(IP), P(IP) : IP address of this node

This variable holds and designates DLSAP value assigned for Type 11 fieldbus Sporadic message data service.

4.6.2.19 V(LL) : Live-list

This variable indicates the current operational status, whether a corresponding node is connecting to and is running normally in the Type 11 fieldbus. The possible value is "True" or "False", "True" means the node is connecting to and working normally and "False" is not. V(LL) is used by the DLE and is generated from the information conveyed by SYN frame. Live-list is a collection of 8 words of 32-bit length, each bit of which corresponds to the node in the Type 11 fieldbus and indicates the current operational status. Each bit corresponds to the node number V(TN) in a sequential order from 0 to 255 in little endian format.

4.6.2.20 V(LN) : Live-node-number

This variable indicates the TN number of node, extracted from V(LL), which connects to and is running normally in the Type 11 fieldbus at this point. V(LN) is used by the DLE to decide whether the node is able to send the data frame out over the medium. The range of this value is 1 to 255.

4.6.2.21 V(MD), P(MD) : Maximum-distance

The value of this variable holds, and is set by DLMS, the maximum distance in kilometer on the connection path between any 2 nodes.

The range of this value is as follows:

- a) star-architecture: 1 to 100, and the default value is 8.
- b) loop-architecture: 1 to 20, and the default value is 4.

4.6.2.22 V(MGA), P(MGA) : Multicast group address

This variable holds and designates the multicast group address, used by the DLE to build logically associated group of the Type 11 fieldbus nodes, in 48-bit length specified by and identical to ISO/IEC 8802-3. The default value is 0x01-0x00-0x5e-0x50-0x00-0x01.

4.6.2.23 V(MN), P(MN) : Maximum-node-number

This variable holds the maximum node number, and is set by DLMS. The default value of this variable is 254.

4.6.2.24 V(MRT), P(MRT) : Maximum-number-of-the-repeater-unit

This variable holds, and is set by the DLMS, maximum number of the repeater units on the connection path between any 2 nodes.

The possible value is as follows:

- a) star-architecture: 0 to 7, and the default value is 3.
- b) loop-architecture: 0 to 252, and the default value is 30.

4.6.2.25 V(MTHT), P(MTHT) : Maximum-token-hold-time

This variable holds and designates the value of maximum-token-hold-time for high-speed cyclic data transmission. The range of this value is 1 to $2^{16}-1$ of which unit is in octet time by the data signaling rate. The default value is 0x30B4, that is approx. 900 μ s.

4.6.2.26 V(NONC), P(NONC) : Permissible repetitive count of no CMP

This variable holds and designates the value of permissible repetitive count of no CMP frame received by the SYN node within the corresponding consecutive T_{syn} cycles, that is 256 times by V(SCMPL), in order to detect no other node except the SYN node in the Type 11 fieldbus. The range of this value is 1 to 16, and the default value is 3.

4.6.2.27 C(NONC) : NONC count

C(NONC) indicates the number of repetitive count of no CMP frame received by the SYN node within $V(MN) \times V(SCMPL)$ of the consecutive T_{syn} cycles. C(NONC) reached to the number of V(NONC), the SYN node detects and recognizes no other node hooking up to the Type 11 fieldbus.

4.6.2.28 V(PBh), P(PBh) Maximum number of the data buffers used for sending high-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending high-speed time-critical cyclic data. The value is 0 to 2 048.

4.6.2.29 V(PBm), P(PBm) Maximum number of the data buffers used for sending medium-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending medium-speed time-critical cyclic data. The value is 0 to 2 048.

4.6.2.30 Q(QBF_{SPD}) : Queue buffer for sporadic data

The queue buffer for the Sporadic message data service holds the DLPDU by DL-user to be sent. The queue buffer size to transfer as well as to receive the Sporadic message data is implementation matter.

4.6.2.31 V(SCMP), P(SCMP) : Medium-access-control-time for substitute CMP

This variable holds and designates the value of maximum observational time period for the node to initiate the action like that the node received the CPM frame even though the corresponding node failed to send out the CMP frame.

4.6.2.32 T(SCMP) : SCMP monitor

T(SCMP) is used by the DLE of the node to measure the SCMP time elapsed to initiate the action like that the node received the CMP frame even though the corresponding node failed to send out the CMP frame. The value is decremented in the range of V(SCMP) to 0.

4.6.2.33 V(SCMPL), P(SCMPL) : Permissible repetitive count of substitute CMP

This variable holds and designates the value of permissible repetitive count within which the node can behave like that the node received the CMP frame without error even though the corresponding node failed to send out the CMP frame. The range of this value is 1 to 16 and the default value is 3.

4.6.2.34 C(SD) : Cumulative count of sporadic data frame sent

C(SD) indicates the number of cumulative count of sporadic data frames sent on the medium. C(SD) is a roll-over binary counter of 32-bit length.

4.6.2.35 V(SL), P(SL) : Silence time

This variable holds and designates the value of the silence time or inactivity time period for detecting the current SYN node out of order, following to initiate sending the CLM frame out from this node in order to claim new SYN node if this node is designated and permitted to be a SYN node. The value is set by the DLE to the T(SL) timer as follows:

$$T(SL) = V(TSYN) + V(ST) \times V(TN) \times 2$$

4.6.2.36 T(SL) : SL monitor

T(SL) is used by the DLE to measure the time elapsed of SL. The value is decremented in the range of V(SL) to 0.

4.6.2.37 V(SM), P(SM) : Subnet address mask

This variable holds and designates the value of subnet address mask for V(IP) for Type 11 fieldbus Sporadic message data service.

4.6.2.38 V(ST), P(ST), T(ST) : Type 11 fieldbus slot-time

Slot-time is the fundamentally observational time unit, used in the DLME for observation of initiation of the action such as re-initialization in sending out the CLM frame, for observation of initiation of the action that the node behaves like the CMP frame received even though the corresponding node failed to send out the CMP frame.

This variable holds and designates the fundamentally observational time value of slot time. The range of the value is 1 to 255, of which time is in 512-bit physical symbol time specified by and identical to ISO/IEC 8802-3. The default value is 20, which is equivalent to Approx. 100 μs, i.e. $20 \times 512 \times 1/100 \mu s$.

Note The slot time value is calculated from the following mathematics.

$$V(ST) = \text{round up} [2 \times V(MD) + V(MRT)/2 + 2]$$

4.6.2.39 V(Th), P(Th) : High-speed transmission period

This variable holds and designates the cyclic time period of High-speed time-critical data transmission. P(Th) is used by the DLE and the value is set to V(SYN). The range of this value is 1 to 160, of which the unit is 0,1ms. The default value is 100.

4.6.2.40 V(TISPD), P(TISPD) : Time-interval for sporadic-message-data-service

This variable holds and designates the value of time interval cyclically processed for Sporadic-message-data service. The range of this value is 1 to 1 000, of which unit is in 1 ms. The default value is 100.

4.6.2.41 T(TISPD) : TISPD monitor

T(TISPD) is used by the DLE to measure the time interval of TISPD.

4.6.2.42 V(Tm), P(Tm) : Medium-speed transmission period

This variable holds and designates the cyclic time period of Medium-speed time-critical data transmission. P(Tm) is used by the DLE. The range of this value is 10 to 1 000, of which the unit is 1ms. The default value is 100.

4.6.2.43 V(TMAC), P(TMAC) : Medium-access control-time to solicit new nodes

This variable holds and designates the value of maximum observational time period for the SYN node to solicit new nodes into the Type 11 fieldbus. During the time period new nodes attempt to send out the REQ frame to the SYN node. The default value is 100, the unit of which is in 0,1 ms.

4.6.2.44 T(TMAC) : TMAC monitor

T(TMAC) is used by the DLE of the SYN node to measure the time elapsed of TMAC in order to wait for REQ frames sent from node which attempts to enter the Type 11 fieldbus. The value is decremented in the range of V(TMAC) to 0.

4.6.2.45 V(TN), P(TN) : This-node

This variable holds and designates the node identifier number of this node. The initial value is 0 on power-up or reset of this node. The range of this value is 1 to 255.

4.6.2.46 V(Tsl) : DLE number able to send out next slot

This variable is used by the DLE to hold and indicate the node identifier number of V(TN) of which the node can send out its data next in the sequential order in succession to a node currently having completed sending out all its data and CMP or DT-CMP DLPDU. The value of this variable is updated and set to the value of V(TN) of the node next to send out, every time on the reception of CMP or DT-CMP DLPDU. The range of this variable is 1 to 255.

4.6.2.47 V(TSYN) : Target-periodic-time of synchronization

This variable indicates the target time period from SYN frame arrival to SYN frame arrival. The value is equal to V(Th), and the value of P(Th) is used by the DLMS and is set to V(Th). The possible range of this time period is 0,1 to 160 ms. V(SYN) and V(Th) indicate the cyclic time period in which all the node with high-speed cyclic data can obtain the transmission right to send out all of the high-speed cyclic data.

4.6.2.48 V(TTRT1), P(TTRT1) : Target-token-rotation-time for access class 1

This variable holds and designates the value of target-token-rotation-time for access class 1, especially for sporadic message data transmission. The range of this value is 1 to $2^{16}-1$ of

which unit is in octet time by the data signaling rate. The default value is equal to $P(TSYN)$. This value is used by the DLE and should be equal and common to all DLEs of the Type 11 fieldbus.

$P(TTR1)$ is used by the DLME and the value is the time period in which a node with sporadic message data can expect to obtain the transmission right to send out.

4.6.2.49 V(TTRT2), P(TTRT2) : Target-token-rotation-time for access class 2

This variable holds and designates the value of target-token-rotation-time for access class 2, especially for medium-speed cyclic data transmission. The range of this value is 1 to $2^{16}-1$ of which unit is in octet time by the data signaling rate. The default value is equal to $P(TSYN)$. This value is used by the DLE and should be equal and common to all DLEs of the Type 11 fieldbus.

$P(TTR2)$ is used by the DLME, and the value is the expected time period in which all nodes with medium-speed cyclic data can obtain the transmission right and send out all of the medium-speed cyclic data.

4.6.3 Star-architecture specific variables, parameters, counters, timers and queues

4.6.3.1 T(AIGP_A), T(AIGP_B) : IGP monitor over the receive-channel A and B

$T(AIGP_A)$ and $T(AIGP_B)$ are used by the DLE to measure the time elapsed of IGP over the receive-channel A and B respectively. The value is decremented in the range of 24 to 0, and value 24 is equivalent to 0,96 μs .

4.6.3.2 T(ARMGP) : RMGP monitor

$T(ARMGP)$ is used by the DLE to monitor the time elapsed of RMGP. The value is decremented in the range of 250 to 0, and value 250 is equivalent to 10 μs .

4.6.3.3 T(ATTRT0) : TTRT0 monitor

$T(ATTRT0)$ is used by the DLE to monitor the time period of TTRT0. The value is decremented in the range of $2^{16}-1$ to 1, of which unit is in octet time by the data-signaling rate.

4.6.3.4 C(CDI) : Cumulative count of low-speed-cyclic data frame sent

$C(CDI)$ indicates the number of cumulative count of low-speed-cyclic data frames sent on the medium. $C(CDI)$ is a roll-over binary counter of 32-bit length.

4.6.3.5 V(HTI), P(HTI) : Maximum observational time period for detecting the continuous low-speed transmission cycle

This variable holds and designates the value of maximum observational time period for detecting the continuous Low-speed transmission cycle disrupted. The value is in the range of 2 to $2^{16}-1$, of which the unit is 1ms. The default value is $3 \times V(Th)$.

4.6.3.6 T(HTI) : HTI monitor

$T(HTI)$ is used by the DLE to measure the HTI time elapsed to detect the continuous Low-speed transmission cycle disrupted. The value is decremented in the range of $V(HTI)$ to 1.

4.6.3.7 V(MDD), P(MDD) : Maximum-difference-of-the-distance

This variable holds, and is set by DLMS, the maximum difference in meter of the distance of two redundant physical mediums on the connection path between any 2 nodes. The range of this value is 0 to 2 000, and the default value is 500.

4.6.3.8 V(MPD), P(MPD) : Maximum-distance-of-the-signal-propagate-delay

This variable holds, and is set by DLMS, the maximum difference in microsecond of the signal delay time propagating over two redundant physical mediums on the connection path between any 2 nodes. The range of this value is 1 to 0x7c, and the default value is 0x7c which is equivalent to approx. 5 µs, i.e. 0x7c (=124) x 0,04 µs.

4.6.3.9 C(NCD_A), C(NCD_B) : Cumulative count of non-carrier detected on the receive-channel A or B

C(NCD_A) or C(NCD_B) indicates the number of cumulative count of non-carrier detected on one receive-channel while the carrier occurs on the other side of receive-channel. C(NCD_A) and C(NCD_B) are roll-over binary counters of 32-bit length.

4.6.3.10 V(PBI), P(PBI) : Maximum number of the data buffers used for sending low-speed time-critical cyclic data

This variable holds and designates the maximum number of the data buffers used for sending low-speed time-critical cyclic data. The value is 0 to 2 048.

4.6.3.11 V(RCS), P(RCS) : Receive-channel switching control for receiving frames

This variable holds and designates the switching control for receiving frames out of one of two receive-channel A and B corresponding to each of the redundant medium A and B.

The possible value is "Automatic", "Force A" or "Force B". "Automatic" indicates that the switching control for receiving frames is automatically to switch to the proper receive-channel. "Force A" or "Force B" indicates that the switching control is forced to switch to Receive-channel A or B respectively. The default value is "Automatic".

4.6.3.12 V(RCS_A), V(RCS_B) : Receive-channel A or B selected for receiving frames

This variable indicates the corresponding receive-channel is selected for receiving frames from the other node. The value "True" indicates that the corresponding receive-channel is selected, and "False" is not.

4.6.3.13 C(RE_A), C(RE_B) : Cumulative count of DLPDU received with error on the receive-channel A or B

C(RE_A) or C(RE_B) indicates the number of cumulative count of DLPDU received with error while on the other side of the receive-channel no error occurs. C(RE_A) and C(RE_B) are roll-over binary counters of 32-bit length.

4.6.3.14 V(RMGP), P(RMGP) : IGP over other redundant media

This variable holds and designates the value of maximum time-interval for one receive-channel, which has already completed one frame received and has waited for IGP time, to wait the completion of a frame to be received on the other receive-channel in order to detect the other receive-channel disrupted. The default value is 250, of which unit is in 0,04 µs, and is equivalent to 10 µs.

4.6.3.15 C(ROK_A), C(ROK_B) : Cumulative count of DLPDU received without error on the receive-channel A or B

C(ROK_A) or C(ROK_B) indicates the number of the cumulative count of DLPDU received without error on the receive-channel A or B respectively. C(ROK_A) and C(ROK_B) are roll-over binary counters of 32-bit length.

4.6.3.16 **V(SEN_A), P(SEN_A); V(SEN_B), P(SEN_B) : Transmitter A or B enabled to send out frames**

This variable designates the transmitter A or B enable to send out frames from, and indicates the state of the transmitter A or B being enabled or disabled. The value “True” is to be enabled and “False” is not for the corresponding Transmitter A or B. The default value is “True”.

4.6.3.17 **V(TI), P(TI) : Low-speed transmission period**

This variable holds and designates the cyclic time period of Low-speed time-critical data transmission. P(TI) is used by the DLE. The range of this value is 100 to 1 000, of which the unit is 1 ms, and the default value is 100.

4.6.3.18 **V(TTRT0), P(TTRT0) : Target-token-rotation-time for access class 0**

This variable holds and designates the value of target-token-rotation-time for access class 0, especially for low-speed cyclic data transmission. The range of this value is 1 to $2^{16}-1$ of which unit is in octet time by the data signaling rate. The default value is equal to P(TSYN). This value is used by the DLE and should be equal and common to all DLEs of the Type 11 fieldbus.

P(TTR0) is used by the DLME, and the value is the expected time period in which all nodes with low-speed cyclic data can obtain the transmission right and send out all of the low-speed cyclic data.

4.6.4 **Loop-architecture specific variables, parameters, counters, timers and queues**

4.6.4.1 **V(AN_A), V(AN_B) : Node-number of adjacent node-A, -B**

This variable holds the node-number of adjacent node. The V(AN_A) and V(AN_B) indicate the node-number of the adjacent node in the neighbourhood of the Ring-port-A and -B of this node respectively. The initial value on power-up or reset of this node is 0.

4.6.4.2 **V(CRE_A), P(CRE_A), C(CRE_A); V(CRE_B), P(CRE_B), C(CRE_B): Maximum permissible repetitive count for abnormal-reception error-A, -B**

This variable holds, is set by the DLE and indicates the number of observed repetitive count of the abnormal-reception error detected during receiving the incoming frames from the Ring-port-A and -B respectively. The abnormal-reception is happened under the condition of the reception-abnormal and the long-silence of reception. The range of this variable is 15 to 0. The default value is 2. The count is decremented by each abnormal-reception detected repetitively, and is set to the default value when the abnormal-reception is cleared. When reached to 0, the RMC recognizes the failure happened.

4.6.4.3 **V(FWE_{AB}), P(FWE_{AB}), V(FWE_{BA}), P(FWE_{BA}) : Forwarding state-AB, -BA**

This variable holds and designates the Ring-port-A or -B enable to forward frames received from the Ring-port-A to -B or from the Ring-port-B to -A respectively.

The value “Enable” is to be enabled and “Disable” is not for corresponding Ring-port-A or -B. the default value is “Disable”.

4.6.4.4 **V(LINK_A), V(LINK_B) : Link state-A, -B**

This variable indicates the link state of the Ring-port-A and -B of this node. The value of this variable is “normal” or “abnormal” according to the physical link connection to the trunk specified by the ISO/IEC 8802-3 standard.

4.6.4.5 V(LSYN) : Node number in the master-state

This variable indicates the node number of the node in the current master-state.

4.6.4.6 V(MDAD), P(MDAD) : Maximum-distance between adjacent node

The value of this variable holds, and is set by DLE, the maximum-distance in kilometer between the adjacent nodes. The range of this value is 1 to 2, and the default value is 1.

4.6.4.7 C(NCD_A), C(NCD_B) : Cumulative count of no-carrier detected -A, -B

C(NCD_A) or C(NCD_B) indicates the number of cumulative count of no-carrier detected on the Ring-port-A or -B respectively while the carrier occurs on the other port. The C(NCD_A) and the C(NCD_B) are roll-over binary counters of 32-bit length.

4.6.4.8 V(NOS) : Node-operation state

This variable holds and indicates the operation state of the node which is in the normal- or the open-state. The value of this variable is either "Normal" or "Open" according the normal-state or the open-state respectively. The initial value on power-up or reset of this node is "Open".

4.6.4.9 V(NRF_A), P(NRF_A), T(NRF_A); V(NRF_B), P(NRF_B), T(NRF_B) : Maximum observational time period for no frame received -A, -B

This variable holds, is set, and is used by the DLE to monitor the time period in which no frame received from the Ring-port -A or -B after from the other port, that is the Ring-port-B or -A respectively, a frame has been received. The range of this value is 15 to 0. The default value is 2, of which the unit is equal to V(TSYN). The timer is set to 2 and starts to clock every time when any frame has been received from the other port, and is decremented during no frame received from the port.

4.6.4.10 V(NS) : Node state

This variable holds and indicates the node state which is the master- or slave-state. The value of this variable is "Master" if in the master-state, or "Slave" in the slave-state. The initial value on power-up or reset of this node is "Slave".

4.6.4.11 V(PP) : Primary-port

This variable holds and indicates the port through which the SYN-frame first received since this node is power-up, or in the system start-up, or in the system initialization. The value of this variable is "Ring-port-A" or "Ring-port-B".

4.6.4.12 V(PS_A), P(PS_A); V(PS_B), P(PS_B) : Ring-port state-A, -B

These variables hold and designate the port state of this node. The V(PS_A), P(PS_A) and the V(PS_B), P(PS_B) holds, and is set by the DLE, the port state of the Ring-port-A and -B respectively. The value is either "Blocked" or "Non-blocked". Each initial value on power-up or reset of this node is "Blocked".

4.6.4.13 C(RE_A), C(RE_B) : Cumulative count of frame received with error -A, -B

C(RE_A) or C(RE_B) indicates the number of cumulative count of the frame received with error from the Ring-port-A or -B respectively while no error occurs on the other port. The C(RE_A) and the C(RE_B) are roll-over binary counters of 32-bit length.

4.6.4.14 $V(REN_A)$, $P(REN_A)$; $V(REN_B)$, $P(REN_B)$: Receive enable -A, -B

These variables hold and designate the receive enable from the Ring-port-A or -B of this node. The $V(REN_A)$, $P(REN_A)$ and the $V(REN_B)$, $P(REN_B)$ holds, and is set by the DLME, the state of receive frame enable from the Ring-port-A and -B respectively.

The value of this variable is "Enable" or "Disable". The default value is "Enable".

4.6.4.15 $C(ROK_A)$, $C(ROK_B)$: Cumulative count of frame received without error-A, -B

$C(ROK_A)$ or $C(ROK_B)$ indicates the number of the cumulative count of the frame received without error from the Ring-port-A or -B respectively. The $C(ROK_A)$ and the $C(ROK_B)$ are roll-over binary counters of 32-bit length.

4.6.4.16 $V(SEN_A)$, $P(SEN_A)$; $V(SEN_B)$, $P(SEN_B)$: Send enable -A, -B

These variables hold and designate the send enable out of the Ring-port-A or -B of this node. The $V(SEN_A)$, $P(SEN_A)$ and the $V(SEN_B)$, $P(SEN_B)$ holds, and is set by the DLME, the state of send-frame-enable out of the Ring-port-A and -B respectively.

The value of this variable is "Enable" or "Disable". The default value is "Enable".

5 General structure and encoding of PhIDU and DLPDU and related elements of procedure

5.1 Overview

The DLL and its procedures are those necessary to provide the services offered to the DLS user by using the services available from the PhL. This clause describes the structure and semantics of PhIDU, MA_PDU, DLPDU and the procedure, commonly used in this specification nevertheless this portion is identical to and fully compliant with the ISO/IEC 8802-3 standard.

NOTE Within this clause, any reference to bit k of an octet is a reference to the bit whose weight in a one-octet unsigned is 2^k , and this is sometimes referred to as "little endian" bit numbering.

5.2 PhIDU structure and encoding

The local MAC sublayer uses the service primitives provided by the PLS sublayer specified by ISO/IEC 8802-3 Clause 6. All of the service primitives provided by the PLS sublayer are as follows and are considered mandatory:

- a) PLS_DATA request;
- b) PLS_DATA indication;
- c) PLS_CARRIER indication;
- d) PLS_SIGNAL indication;
- e) PLS_DATA_VALID indication.

NOTE In the case where a 100BASE-X specification is applied, the reconciliation sublayer maps the signals provided at the MII to the PLS service primitives as specified by ISO/IEC 8802-3, Clause 22. The PLS service primitives provided by the reconciliation sublayer behave in exactly same manner as defined in Clause 6.

5.3 Common MAC frame structure, encoding and elements of procedure

5.3.1 MAC frame structure

5.3.1.1 Common MAC frame format for the Type 11 fieldbus DLPDU

The structure of the MAC frame for the Type 11 fieldbus DLPDU is encapsulated in the frame format of Ethernet V2.0 specified by ISO/IEC 8802-3, Clause 3. The value of the Length/Type field is designated to 0x888B, which is authorized and registered as the protocol identification number by the IEEE Registration Authority, to be identified as the Type 11 fieldbus frame. Figure 6 shows the MAC frame format used common to the Type 11 fieldbus DLPDU except for sporadic data transmission of the Type 11 fieldbus.

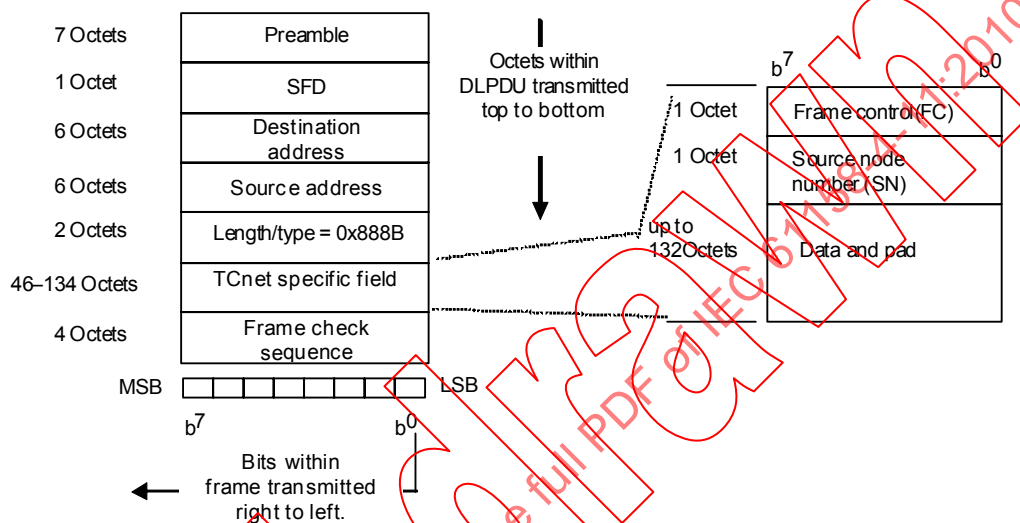


Figure 6 – Common MAC frame format for DLPDUs

5.3.1.2 MAC frame format for Type 11 fieldbus sporadic DLPDU

The MAC frame format used for sporadic data transmission of the Type 11 fieldbus shall be according to ISO/IEC 8802-3:2000, Figure 3-1.

5.4 Elements of the MAC frame

5.4.1 General

The elements of the MAC frame are the preamble, the start frame delimiter, the destination address, the source address, the length/type code, and the frame check sequence, all as specified by ISO/IEC 8802-3, Clause 3.

5.4.2 Preamble field

The preamble of the MAC frame is identical to ISO/IEC 8802-3, Clause 3. The preamble field is a 7-octet field that is used to allow the physical signaling part circuitry to reach its steady-state synchronization with the receiving frame timing.

The preamble pattern is:

“10101010 10101010 10101010 10101010 10101010 10101010 10101010”

5.4.3 Start frame delimiter (SFD)

The Start Frame Delimiter (SFD) is identical to ISO/IEC 8802-3, Clause 3. The SFD field is the sequence of bit pattern “10101011”. It immediately follows the preamble pattern and indicates the start of a frame.

5.4.4 Address field

5.4.4.1 General

The address fields (both Destination Address and Source Address) are identical in structure and semantics to the address field of the basic MAC frame, described in ISO/IEC 8802-3, Clause 3. Each address field shall be 48-bit in length.

5.4.4.2 Destination address field (DA)

The Destination Address (DA) field is identical to ISO/IEC 8802-3, Clause 3. The Destination Address field specifies the station(s) for which the frame is intended. It may be an individual or multicast (including broadcast) address. The value of DA for the Type 11 fieldbus DLPDU except for the Type 11 fieldbus sporadic data transmission is always set to V(MGA).

5.4.4.3 Source address field (SA)

The Source Address (SA) field is identical to ISO/IEC 8802-3, Clause 3. The Source Address field specifies the station sending the frame. The Source Address field is not interpreted by the DLE as well as the CSMA/CD MAC sublayer. The value of SA is always set to V(IA).

5.4.5 Length/type field

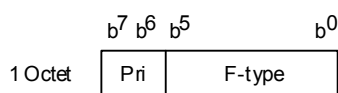
The Length/type field is identical to ISO/IEC 8802-3, Clause 3. In order to be identified as a Type 11 fieldbus frame, the value of the length/type field is set to 0x888B, which is authorized and registered as protocol identification number for Type 11 fieldbus by the IEEE Registration Authority. Every frame with the value all but 0x888B is identical to the frame according to ISO/IEC 8802-3, Clause 3 and is processed as a Type 11 fieldbus sporadic data frame.

5.4.6 Frame control field (FC)

5.4.6.1 Structure of FC field

The structure of the Frame control field is shown in Figure 7.

The F-type field is used by the DLE to identify and designate the frame type of the Type 11 fieldbus for medium access control. The Pri field is used by the DLE to designate and identify the service class of time-critical cyclic data frame.



Key

Pri = Priority

F-type = Frame type

Figure 7 – Structure of FC field

5.4.6.2 Frame type (F-type) field

Table 7 shows the list of F-types, the values and the corresponding Type 11 fieldbus frames.

Table 7 – F-type: DLPDU type

F-type value	Frame type	Frame name
0x00	CLM	Claim frame
0x01	SYN	Synchronization frame
0x02, 0x22	REQ	In-ring request frame -Star-architecture: the value is 0x02 -Loop-architecture: the value is 0x22
0x04	COM	Command frame
0x05	RAS	RAS frame
0x07	DT	Cyclic data frame
0x08	CMP	Transmission complete frame
0x0F	DT-CMP	DT with transmission complete frame
0x23	LPD	Loop diagnosis frame
0x26	LRR	Loop repeat request frame
NOTE All but the above are reserved for future use		

5.4.6.3 Priority field (Pri)

The priority field is used by the DLE to designate and identify the service class of time-critical cyclic data frame, which is applied to both DT and DT-CMP. 3 levels of service class for star-architecture and 2 levels of service class for loop-architecture are provided, and the top to lowest level is level 3 to 0. High-speed time critical data transmission is assigned to level 3 of the service class, Medium-speed time-critical data transmission to level 2 and Low-speed time-critical data transmission to level 0. The Low-speed time-critical data transmission assigned to level 0 is provided only for star-architecture. Other type of frame except for DT and DT-CMP is assigned to level 3 of the service class.

5.4.7 Source node number field (SN)

The value of SN is the node identifier number and is equal to the value of V(TN) of the node which has sent the Type 11 fieldbus DLPDU.

5.4.8 Data and pad field

The data field contains a sequence of N octets which provides full data transparency in the sense that any arbitrary sequence of octet values may appear in the data field up to a maximum number specified by ISO/IEC 8802-3. A minimum frame size is required, that is `mimFrameSize` by ISO/IEC 8802-3, and if a frame size is less than `mimFrameSize`, then the data field is extended by appending extra bits in units of octets. The frame, from the DA field through the FCS field inclusive, is at least `mimFrameSize` bits.

The structure of this field for the Type 11 fieldbus DLPDU is described in Clause 6.

5.4.9 Frame check sequence (FCS)

5.4.9.1 General

The frame check sequence (FCS) construction, polynomial and expected residual are identical to ISO/IEC 8802-3, Clause 3.

Within this clause, any reference to bit K of an octet is a reference to the bit whose weight in a one-octet unsigned integer is 2^K .

NOTE This is sometimes referred to as "little endian" bit numbering.

For most of the protocol Types in this standard, as in other International Standards (for example, ISO/IEC 3309, ISO/IEC 8802 and ISO/IEC 9314-2), DLPDU-level error detection is provided by calculating and appending a multi-bit frame check sequence (FCS) to the other DLPDU fields during transmission to form a "systematic code word"¹⁾ of length n consisting of k DLPDU message bits followed by $n - k$ (equal 32) redundant bits, and by calculating during reception that the message and concatenated FCS form a legal (n,k) code word. The mechanism for this checking is as follows:

The generic form of the generator polynomial for this FCS construction is specified in equation (6) and the polynomial for the receiver's expected residue is specified in Equation (11). The specific polynomials for each DL-protocol type are specified in Table 8.

Table 8 – FCS length, polynomials and constants

Item	Value
$n-k$	32
$G(X)$	$X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + 1$ (notes 1, 2 and 3)
$R(X)$	$X^{31} + X^{30} + X^{26} + X^{25} + X^{24} + X^{18} + X^{15} + X^{14} + X^{12} + X^{11} + X^{10} + X^8 + X^6 + X^5 + X^4 + X^3 + X + 1$ (notes 3 and 4)
NOTE 1 Code words $D(X)$ constructed from this $G(X)$ polynomial have Hamming distance 4 for lengths ≤ 22 901 octets, Hamming distance 5 for lengths ≤ 371 octets, Hamming distance 6 for lengths ≤ 33 octets, Hamming distance 7 for lengths ≤ 21 octets, and Hamming distance 8 for lengths ≤ 11 octets. NOTE 2 This $G(X)$ polynomial is relatively prime to all, and is thus not compromised by any, of the polynomials commonly used in DCEs (modems): the differential encoding polynomial $1 + X^{-1}$ and all primitive scrambling polynomials of the form $1 + X^{-j} + X^{-k}$. NOTE 3 These are the same polynomials and method as specified in ISO/IEC 8802-3 (Ethernet). NOTE 4 The remainder $R(x)$ should be 1100 0111 0000 0100 1101 1101 0111 1011 (X^{31} to X^0, respectively) in the absence of errors.	

5.4.9.2 At the sending DLE

The original message (that is, the DLPDU without an FCS), the FCS, and the composite message code word (the concatenated DLPDU and FCS) are regarded as vectors $M(X)$, $F(X)$, and $D(X)$, of dimension k , $n - k$, and n , respectively, in an extension field over $GF(2)$. If the message bits are $m_1 \dots m_k$ and the FCS bits are $f_{n-k-1} \dots f_0$, where

$m_1 \dots m_8$ form the first octet sent,

$m_{8N-7} \dots m_{8N}$ form the N th octet sent,

$f_7 \dots f_0$ form the last octet sent, and

m_1 is sent by the first PhL symbol(s) of the message and f_0 is sent by the last PhL symbol(s) of the message (not counting PhL framing information),

NOTE This "as transmitted" ordering is critical to the error detection properties of the FCS.

then the message vector $M(X)$ is

$$M(X) = m_1 X^{k-1} + m_2 X^{k-2} + \dots + m_{k-1} X^1 + m_k \quad (1)$$

and the FCS vector $F(X)$ is

¹⁾ W. W. Peterson and E. J. Weldon, Jr., *Error Correcting Codes* (2nd edition), MIT Press, Cambridge, 1972.

$$\begin{aligned} F(X) &= f_{n-k-1}X^{n-k-1} + \dots + f_0 \\ &= f_{31}X^{31} + \dots + f_0 \end{aligned} \quad (\text{for the case of } k = 32) \quad (2)$$

The composite vector $D(X)$, for the complete DLPDU, is constructed as the concatenation of the message and FCS vectors

$$\begin{aligned} D(X) &= M(X) X^{n-k} + F(X) \\ &= m_1X^{n-1} + m_2X^{n-2} + \dots + m_kX^{n-k} + f_{n-k-1}X^{n-k-1} + \dots + f_0 \\ &= m_1X^{n-1} + m_2X^{n-2} + \dots + m_kX^{32} + f_{31}X^{31} + \dots + f_0 \quad (\text{for the case of } k = 32) \end{aligned} \quad (3)$$

The DLPDU presented to the PhL shall consist of an octet sequence in the specified order.

The redundant check bits $f_{n-k-1} \dots f_0$ of the FCS are the coefficients of the remainder $F(X)$, after division by $G(X)$, of $L(X) (X^k + 1) + M(X) X^{n-k}$

where $G(X)$ is the degree $n-k$ generator polynomial for the code words

$$G(X) = X^{n-k} + g_{n-k-1}X^{n-k-1} + \dots + 1 \quad (4)$$

and $L(X)$ is the maximal weight (all ones) polynomial of degree $n-k-1$

$$\begin{aligned} L(X) &= \frac{X^{n-k} + 1}{X + 1} = X^{n-k-1} + X^{n-k-2} + \dots + X + 1 \\ &= X^{31} + X^{14} + X^{13} + X^{12} + \dots + X^2 + X + 1 \quad (\text{for the case of } k = 32) \end{aligned} \quad (5)$$

That is,

$$F(X) = L(X) (X^k + 1) + M(X) X^{n-k} \quad (\text{modulo } G(X)) \quad (6)$$

NOTE 1 The $L(X)$ terms are included in the computation to detect initial or terminal message truncation or extension by adding a length dependent factor to the FCS.

NOTE 2 As a typical implementation when $n-k = 32$, the initial remainder of the division is preset to all ones. The transmitted message bit stream is multiplied by X^{n-k} and divided (modulo 2) by the generator polynomial $G(X)$, specified in equation (7). The ones complement of the resulting remainder is transmitted as the $(n-k)$ -bit FCS, with the coefficient of X^{n-k-1} transmitted first.

5.4.9.3 At the receiving DLE

The octet sequence indicated by the PhE is concatenated into the received DLPDU and FCS, and regarded as a vector $V(X)$ of dimension u

$$V(X) = v_1X^{u-1} + v_2X^{u-2} + \dots + v_{u-1}X + v_u \quad (7)$$

NOTE 1 Because of errors u can be different than n , the dimension of the transmitted code vector.

A remainder $R(X)$ is computed for $V(X)$, the received DLPDU and FCS, by a method similar to that used by the sending DLE (see 5.4.9.2) in computing $F(X)$

$$\begin{aligned} R(X) &= L(X) X^u + V(X) X^{n-k} \quad (\text{modulo } G(X)) \\ &= r_{n-k-1}X^{n-k-1} + \dots + r_0 \end{aligned} \quad (8)$$

Define $E(X)$ to be the error code vector of the additive (modulo-2) differences between the transmitted code vector $D(X)$ and the received vector $V(X)$ resulting from errors encountered (in the PhS provider) between sending and receiving DLEs.

$$E(X) = D(X) + V(X) \quad (9)$$

If no error has occurred, so that $E(X) = 0$, then $R(X)$ will equal a non-zero constant remainder polynomial

$$R_{0k}(X) = L(X) X^{n-k} \text{ (modulo } G(X)) \quad (10)$$

whose value is independent of $D(X)$. Unfortunately $R(X)$ will also equal $R_{0k}(X)$ in those cases where $E(X)$ is an exact non-zero multiple of $G(X)$, in which case there are “undetectable” errors. In all other cases, $R(X)$ will not equal $R_{0k}(X)$; such DLPDUs are erroneous and can be discarded without further analysis.

NOTE 2 As a typical implementation, the initial remainder of the division is preset to all ones. The received bit stream is multiplied by X^{n-k} and divided (modulo 2) by the generator polynomial $G(X)$, specified in equation (8).

5.5 Order of bit transmission

The order of bit transmission is identical to ISO/IEC 8802-3, Clause 3. Each octet of the DLPDU, with the exception of the FCS, shall be transmitted low-order bit first; the FCS shall be transmitted in the order specified in 5.4.9.2.

5.6 Invalid DLPDU

An invalid DLPDU shall be defined as one that meets at least one of the following conditions, and is almost identical to ISO/IEC 8802-3, Clause 3:

- The frame length is inconsistent with a length value specified in the Length/Type field. If the Length/Type field contains a type value as defined by ISO/IEC 8802-3, 3.2.6, then the frame length is assumed consistent with this field and should not be considered an invalid DLPDU on this basis.
- It is not an integral number of octets in length.
- The bits of the incoming DLPDU (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.
- It is inconsistent with a F-type value of Type 11 fieldbus DLPDU.

The contents of invalid DLPDU shall not be passed to the DL-user or DLE. The occurrence of invalid DLPDU may be communicated to network management.

NOTE Invalid DLPDU may be ignored, discard, or used in private manner by DL-user other than RTE DL-user. The use of such DLPDUs is beyond the scope of this specification.

6 DLPDU-specific structure, encoding and elements of procedure

6.1 General

This clause defines the structure, contents and encoding of each type and format of the DLPDU except for the Sporadic DLPDU of the Type 11 fieldbus, and specifies elements of procedure for the DLPDU.

Within each subclause, the structure, contents, parameters and encoding of the DLPDU are described, and the Type 11 fieldbus specific part of the DLPDU structure, which is shown in 5.3.1.1, is specified. The aspects relating to the sending and receiving of DLS-users and their DLEs are further described. All data format and encoding is described in little endian format throughout this clause.

NOTE Within this clause, any reference to bit K of an octet is a reference to the bit whose weight in a one-octet unsigned is 2^K , and this is sometimes referred to as “little endian” bit numbering.

Whenever a conditional action is specified and the specific enabling condition does not occur, then the corresponding action also does not occur. The effect eventually is that events which do not meet any of the enabling conditions specified in a service procedure will have no consequential actions with respect to that specific service procedure.

6.2 Synchronization DLPDU (SYN)

6.2.1 General

A DLE which is as the SYN node or operating currently in master state sends the SYN DLPDU periodically at the specific time intervals of $V(T_h)$ for the synchronization of time-critical cyclic data transmission by all related DLEs in the Type 11 fieldbus.

A DLE which attempts to be on line, sends REQ DLPDU for claiming to the SYN node to be added in the Type 11 fieldbus under the condition when the DLE has received a SYN DLPDU with the value of PN filed equal to the $V(T_N)$. The time frame, which REQ DLPDU is sent, is during the MAC control period of T_{mac} . The MAC control period of T_{mac} starts immediately after the DLE has completely received a CMP DLPDU or DT-CMP DLPDU by the node with the biggest number of the value of $V(T_N)$.

A DLE which is on line and is functioning as a SYN node, controls the time-critical cyclic data transmission of the Type 11 fieldbus DLPDUs, solicits new node to join and manages node drop-out, controls and manages all of the parameters related to keep cyclic and stable data transmission. A DLE not operating as a SYN node shall attempt to become a new SYN node to keep cyclic and stable data transmission in succession to the current SYN node when the current SYN node happens to malfunction. A DLE not operating as a SYN node decides the order and the timing to send out its time-critical cyclic data transmission using the value of $V(LL)$ in the SYN DLPDU received.

6.2.2 Structure of SYN DLPDU

The structure of SYN DLPDU is shown in Figure 8.

The T_s and T_l are available for star-architecture, otherwise the values are set to 0x0.

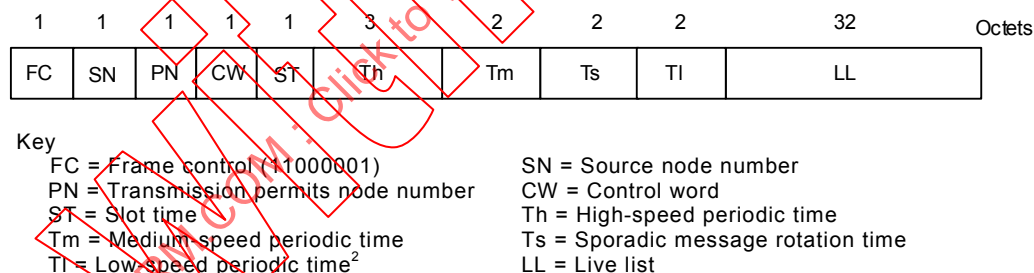


Figure 8 – Structure of SYN DLPDU

6.2.3 Parameters of SYN DLPDU

6.2.3.1 Transmission permits node number (PN)

A DLE attempting to be on line is permitted to send REQ DLPDU out for claiming to enter into the Type 11 fieldbus to the SYN node when the value of PN in the SYN DLPDU becomes equal to the value of $V(T_N)$. The DLE can send REQ DLPDU out to the SYN node in the time frame of the MAC control period during the time slot of $V(T_{SYN})$ in which the DLE has received the SYN DLPDU with equal value of PN to that of the $V(T_N)$.

The range of this value is 0x1 to 0xFF. The value is incremented by each SYN DLPDU and rolled over from 0xFF to 0x1.

Table 9 shows the structure of the PN parameter.

Table 9 – PN-parameter: 3rd octet

Transmission permits node number							
PN (1 to 255)							
7	6	5	4	3	2	1	0

6.2.3.2 Control word (CW)**6.2.3.2.1 CW for star-architecture****6.2.3.2.1.1 Structure of CW**

The structure of Control word (CW) is shown in Table 10.

Table 10 – Structure of CW: 4th octet

Control word							
Periodic mode	Reserved					Redundant medium selection	
PM	0					RMSEL	
7	6	5	4	3	2	1	0

6.2.3.2.1.2 Periodic mode (PM) parameter

The “PM” parameter indicates the mode of synchronization for the Time-critical cyclic data transmission.

“Free-run” mode is based on simple periodic data transmission, that is, the SYN node sends out the SYN frame immediately after the SYN node detects that all nodes have sent their time-critical cyclic data within the time period of $V(TSYN)$. On the other hand, “Constant period” mode is based on time-synchronized data transmission with a signal from a clock source of constant time-period.

Table 11 shows the mode of PM parameter.

Table 11 – PM parameter

PM mode	Value	Description
Free-run	0	Cyclic data transmission based on free run
Constant period	1	Cyclic data transmission based on time-synchronization

6.2.3.2.1.3 Redundant medium selection (RMSEL)

This parameter indicates and designates the mode of redundant medium selection to all nodes. The value of RMSEL is used and set to $V(RCS)$ by the DLE for switching control to the receive frames out of one of two receive-channel A and B corresponding to each of the redundant medium A and B. The possible value is “Automatic”, “Force A” and “Force B”.

“Automatic” designates that the switching control for receiving frames is automatically to switch to the proper receive-channel. “Force A” or “Force B” designates that the switching control is forced to switch to Receive-channel A or B respectively. The initial value is “Automatic”.

The mode of RMSEL parameter is summarized in Table 12.

Table 12 – RMSEL parameter

RMSEL mode	Value	Description
Automatic	00	Automatically switch to the proper receive-channel
–	01	Reserved for future use
Force A	10	Force to switch receive-channel A
Force B	11	Force to switch receive-channel B

6.2.3.2.2 CW for loop-architecture

6.2.3.2.2.1 Structure of CW

The structure of CW is shown in Table 13.

Table 13 – Structure of CW: 4th octet

Control word							
Reserved (0x0)				PM	Reserved (0x0)		
7	6	5	4	3	2	1	0

6.2.3.2.2.2 Periodic mode (PM) parameter

The “PM” parameter indicates the mode of synchronization for the Time-critical cyclic data transmission. The PM parameter is equal to that of star-architecture specified in 6.2.3.2.1.2.

6.2.3.3 Slot time (ST)

This parameter is the fundamentally observational time unit, using in the DLE for the observation of initiating action such as re-initialization in sending out CLM frame, for sending out the CMP frame specifically by the current SYN node in substitute for the node failed to send out the CMP frame.

V(ST) holds the value of ST. The rage of this value is 1 to 255, of which time is in 512-bit physical symbol time specified by and identical to ISO/IEC 8802-3. The default value is 20, which is equivalent to approximately 100 μ s, that means $20 \times 512 \times 1/100 \mu$ s.

Table 14 shows the structure of ST parameter.

Table 14 – ST-parameter: 5th octet

V(ST) : Slot time							
7	6	5	4	3	2	1	0

6.2.3.4 High-speed transmission period (Th)

This parameter designates the cyclic time period of High-speed time-critical data transmission. The value of Th is used by the DLE, and ultimately set to V(Th), V(TSYN) equally for each node on-line. The range of this value is 1 250 to 2 500 000, of which the unit is in 80 ns.

Table 15 shows the structure of Th parameter.

Table 15 – Th-parameter: 6th, 7th and 8th octets

High-speed transmission period																							
$T_h (2^7 - 2^0)$								$T_h (2^8 - 2^{15})$								$T_h (2^{16} - 2^{23})$							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.2.3.5 Medium-speed transmission period (T_m)

This parameter designates the cyclic time period of Medium-speed time-critical data transmission. The value of T_m is used by the DLE, and is set to $V(T_m)$ equally for each node on-line. The range of this value is 10 to 1 000, of which the unit is in 1 ms.

Table 16 shows the structure of T_m parameter.

Table 16 – T_m -parameter: 9th and 10th octets

Medium-speed transmission period															
$T_m (2^7 - 2^0)$								$T_m (2^8 - 2^{15})$							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.2.3.6 Sporadic message transmission target-token-rotation-time period (T_s)

This parameter designates the value of target-token-rotation-time for sporadic message data transmission for star-architecture and is not used for loop-architecture. This value is used by the DLE, and is set to $V(TTRT1)$ equally for each node on-line. The range of this value is 1 to 1 000, of which the unit is in 1 ms.

Table 17 shows the structure of T_s parameter.

Table 17 – T_s -parameter: 11th and 12th octets

Sporadic message transmission target-rotation-time period															
$T_s (2^7 - 2^0)$								$T_s (2^8 - 2^{15})$							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.2.3.7 Low-speed transmission period (T_l)

This parameter designates the cyclic time period of Low-speed time-critical data transmission for star-architecture and is not used for loop-architecture. The value of T_l is used by the DLE for star-architecture, and is set to $V(T_l)$ equally for each node on-line. The range of this value is 10 to 10 000, of which the unit is in 1 ms.

Table 18 shows the structure of T_l parameter for star-architecture. The T_l field is reserved and the value is set to 0x0 for loop-architecture.

Table 18 – T_l -parameter: 13th and 14th octets

Low-speed transmission period															
$T_l (2^7 - 2^0)$								$T_l (2^8 - 2^{15})$							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.2.3.8 Live list (LL)

This parameter indicates the current operational status, whether a corresponding node is on line and is running normal in the Type 11 fieldbus. Each bit of value “1” indicates the corresponding node on-line and normal, and a node of value “0” is off-line.

V(LL) is used by the DLE and is generated from the information conveyed by the SYN frame. Live list is a collection of 8 words of 32-bit length, each of which corresponds to each node in the Type 11 fieldbus and indicates the current operational status. Each bit in the LL word corresponds to the node number V(TN) in a sequential order from 0 to 255 in little endian format.

Table 19 shows the structure of LL parameter.

Table 19 – LL parameters: 15th to 46th octets

Live-list																	
LL ($2^7 - 2^0$)									LL ($2^8 - 2^{15}$)								
15 th	7	6	5	4	3	2	1	0	15	14	13	12	11	10	9	8	16 th
17 th	23	22	21	20	19	18	17	16	31	30	29	28	27	26	25	24	18 th
19 th	39	38	37	36	35	34	33	32	47	46	45	44	43	42	41	40	20 th
21 th	55	54	53	52	51	50	49	48	63	62	61	60	59	58	57	56	22 th
23 th	71	70	69	68	67	66	65	64	79	78	77	76	75	74	73	72	24 th
⋮																	⋮
41 th	215	214	213	212	211	210	209	208	223	222	221	220	219	218	217	216	42 th
43 th	231	230	229	228	227	226	225	224	239	238	237	236	235	234	233	232	44 th
45 th	247	246	245	244	243	242	241	240	255	254	253	252	251	250	249	248	46 th

6.2.4 User data

No user data is conveyed by the SYN DLPDU.

6.2.5 Sending SYN DLPDU

A DLE of current SYN node sends out SYN DLPDU with a set of parameters, as stated above, which are managed, maintained and set to SYN DLPDU by the DLE of current SYN node.

6.2.6 Receiving SYN DLPDU

Each DLE of the node, which is on line or is to be on line, except SYN node takes the following actions on reception of SYN DLPDU.

- As for star-architecture, the value of RMSEL is used to determine the switching control for receiving frames out of one of two receive-channel A and B corresponding to each of the redundant medium A and B, and is reflected in V(RCS).
- Each value of ST, Th, Ts and TI, however the TI is not used with loop-architecture, received in SYN DLPDU and the corresponding value of V(ST), V(Th), V(Tm) and V(TI) in a node is compared respectively. If the value is different, then each value of ST, Th, Ts and TI is to be a new value of each variable V(ST), V(Th), V(Tm) and V(TI) respectively.
- The value of LL is to be a new value of V(LL).
- The DLE, which has sent REQ DLPDU out, shall confirm that the corresponding bit to the V(TN) in LL becomes “true”. If the value of the corresponding bit of LL is “true”, then the node of the V(TN) is on line. The DLE of the V(TN) shall start to send out its Time-critical Cyclic data every time immediately after the DLE has received CMP or DT-CMP DLPDU

from a node that is on line and of which the node identifier number can be obtained from the LL and is lower in sequential order in the LL.

6.3 Transmission complete DLPDU (CMP)

6.3.1 General

CMP DLPDU is sent to indicate all of the time-critical cyclic data transmission completed at the end of data transmission. Two types of DLPDU for indicating the data transmission completed is specified, one is CMP DLPDU and the other is DT DLPDU.

6.3.2 Structure of CMP DLPDU

Figure 9 shows the structure of the CMP DLPDU.

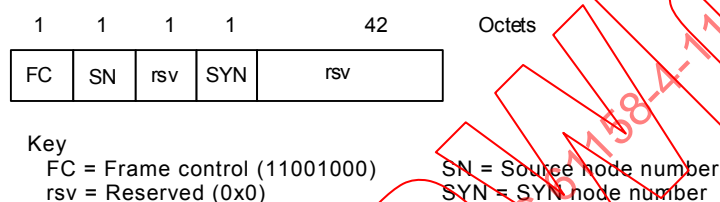


Figure 9 – Structure of CMP DLPDU

6.3.3 SYN node number (SYN) parameter

This parameter indicates the number of the V(TN) of the current SYN node.

6.3.4 User data of CMP DLPDU

No user data is conveyed by the CMP DLPDU.

6.3.5 Sending CMP DLPDU

CMP DLPDU is sent by the DLE at the timing and condition specified as follows.

- a) The DLE which is in the assigned time frame to send out its data and is just sending out its data in the V(TSYN) time period, shall send out CMP DLPDU at the time when the DLE has completed sending out all of the data both of Time-critical Cyclic data and Sporadic message data. The CMP DLPDU is sent by the last frame out of the node to notify its data transmission completed to all Type 11 fieldbus nodes.

NOTE When a DLE sends out time-critical cyclic data as the last DLPDU, the DLE shall send out DT-CMP DLPDU in substitution of CMP DLPDU.

- b) A DLE of SYN node shall wait for CMP or DT-CMP DLPDU from the DLE, which is sending its data out, in the duration of V(SCMP). When the DLE of SYN node has failed to receive CMP or DT-CMP DLPDU, the DLE of SYN node shall initiate sending out CMP DLPDU in substitution for the DLE which has not send out its CMP or DT-CMP DLPDU.

6.3.6 Receiving CMP DLPDU

Each DLE of the node, which is on line, shall activate the followings on reception of CMP or DT-CMP DLPDU:

- a) The value of V(Tsl) is updated to the number of V(TN) of which node is to send out its date, after searched next node out of V(LL), translated into and get actual node identifier number of V(TN). In searching the next node, the DLE checks and extracts the first bit of V(LL) being “true” in the greater order than the corresponding bit position of the node which has finished sending out. When the first bit of being “true” is found, and according to the bit position found in the V(LL), the DLE shall translate the bit position into the actual node identifier number of V(TN),

- b) On condition that the value of the node identifier number, which is translated from the bit position in the V(LL), is equal to the number of V(TN) of this node, the DLE shall begin to send out data of every high-speed time-critical cyclic data, Medium-speed time-critical cyclic data, Sporadic message data and Low-speed time-critical cyclic data, however the Low-speed time-critical cyclic data is used only with star-architecture, in this order.

The Medium-speed Time-critical cyclic data, the Sporadic message data and the low-speed time-critical cyclic data is able to send out from the node if the condition is met respectively, and each data transmission shall terminate when one of the following conditions met:

- All the data with each priority level has finished sending out,
- The corresponding observational timer has expired,
- The T(MTHT) for High-speed time-critical cyclic data transmission has been expired.

6.4 In-ring request DLPDU (REQ)

6.4.1 General

REQ DLPDU is sent by the DLE to the SYN node to claim to be added in Type 11 fieldbus.

6.4.2 Structure of REQ DLPDU

Figure 10 shows the structure of the REQ DLPDU.

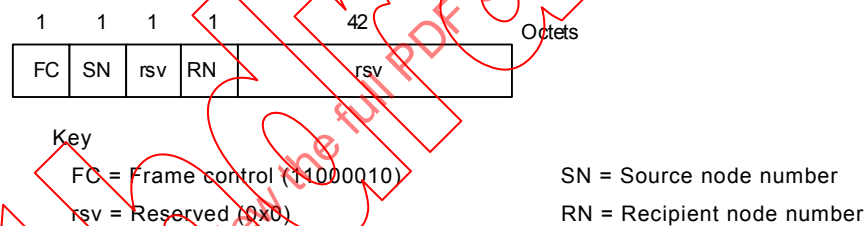


Figure 10 – Structure of REQ DLPDU

6.4.3 Recipient node number (RN) parameter

This parameter designates the recipient node number of which the node is to receive the REQ DLPDU. The RN is used for loop-architecture, otherwise the value is set to 0x0.

Table 20 shows the format of the RN parameter.

Table 20 – RN parameter

RN: Recipient node number							
V(RN) (1 to 254)							
7	6	5	4	3	2	1	0

6.4.4 User data of REQ DLPDU

No user data is conveyed by the REQ DLPDU.

6.4.5 Sending REQ DLPDU

REQ DLPDU is sent by the DLE of a node which attempts to be a member in the Type 11 fieldbus, claiming to be added and to be on-line, on condition that the DLE has received a SYN DLPDU with the value of PN field equal to the V(TN) and further in the time frame of the MAC control period of Tmac. The start of the MAC control period of Tmac is immediately after the DLE has completely received a CMP DLPDU or a DT-CMP DLPDU out of a node with the biggest number of the value of V(TN) in Type 11 fieldbus.

6.4.6 Receiving REQ DLPDU

REQ DLPDU is received by the DLE of the current SYN node in operation. Received REQ DLPDU, the DLE extracts the number of V(TN) of sending DLE out of the value of SN field in the REQ DLPDU, and sets to “1” (being on-line or live) the corresponding bit of the V(TN) in V(LL). Immediately after the MAC control period of Tmac during which the DLE received a REQ DLPDU, the DLE sends out SYN DLPDU with the value of extracted number of V(TN) in the LL field.

6.5 Claim DLPDU (CLM)

6.5.1 General

CLM DLPDU is sent by the DLE claiming for re-synchronization of the Type 11 fieldbus on condition that the current SYN node malfunctions and the T(SL) timer to monitor SYN node inactive has expired. CLM DLPDU can be sent from the node which is designated and permitted to be the SYN node. The value of T(SL) of each node is different and depends on the value of the V(ST) and the V(TN).

6.5.2 Structure of CLM DLPDU

Figure 11 shows the structure of the CLM DLPDU.

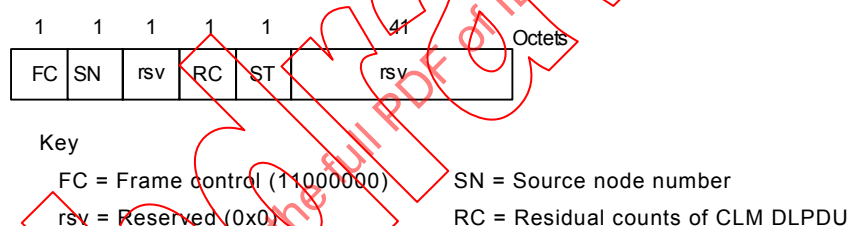


Figure 11 – Structure of CLM DLPDU

6.5.3 Parameter of CLM DLPDU

6.5.3.1 Residual counts of CLM DLPDU parameter (RC)

This parameter indicates the residual counts for the DLE to send out CLM DLPDU. The value is decremented in the range of V(ST) to 0. The default value is 20. Reached to count “0”, the DLE becomes a SYN DLE.

Table 21 shows the structure of the CLM parameter.

Table 21 – CLM parameter: 4th octet

Residual Counts of CLM DLPDU							
V(RC) ($2^7 - 2^0$)							
7	6	5	4	3	2	1	0

6.5.3.2 Slot time (ST) parameter

The value of this parameter is set to that defined in 6.2.3.3.

6.5.4 User data of CLM DLPDU

No user data is conveyed by the CLM DLPDU.

6.5.5 Sending and receiving CLM DLPDU

CLM DLPDU is sent by the DLE, which is provided with the SYN node function, claiming for re-synchronization of the Type 11 fieldbus.

After the DLE has been powered and initialized, once the T(SL) timer has expired, the T(ST) timer is successively triggered. When the T(ST) timer has expired, CLM DLPDU is sent by the DLE.

The DLE shall send out CLM DLPDU in a predefined number of times, which depends on the value of V(ST). The number of times is calculated by the following equation, in which “N” is the number of times.

$$N = \text{round up} [2 \times V(\text{MD}) + V(\text{MRT}) / 2 + 2]$$

When a CLM DLPDU is being sent, and when the collision has happened, the DLE immediately stops sending out CLM DLPDU and starts to monitor and check the condition over the common medium.

When the DLE has successfully received a CLM DLPDU from other DLE, the DLE shall extract the value of SN within the CLM DLPDU and compare the value of SN with its V(TN). When the value of SN is lower than the V(TN), the DLE shall not persist in sending out another CLM DLPDU. On the contrary when the V(TN) is lower, the DLE shall again attempt to send out CLM DLPDU after both of T(SL) and consecutive T(ST) expired.

When the DLE has successfully sent CLM DLPDU in total counts of V(ST), the DLE becomes SYNM DLE. On the other hand SYN DLPDU received from other DLE, the DLE shall cease to send out CLM DLPDU for re-synchronization.

The DLE that is not provided with the SYN node function or is not designated to be a SYN node, shall not send out CLM DLPDU, and furthermore shall not respond to CLM DLPDU received from another node.

6.6 Command DLPDU (COM)

6.6.1 General

COM DLPDU is sent by the DLE to ask the DLE of the SYN node to equalize and change the value of the Type 11 fieldbus parameters of all member nodes, and the change shall be reflected in the SYN DLPDU to be sent in the next V(Th) time period. The Type 11 fieldbus parameters to be equalized are as follows:

- V(ST): Slot time(ST).
- V(Th), V(Tm), V(Ts), V(Tl): The cyclic time periods, the target-token-rotation time period,
- CW: Node control word.

NOTE V(Ts), V(Tl) are not used for loop-architecture.

6.6.2 Structure of COM DLPDU

Figure 12 shows the structure of the COM DLPDU. The Ts and Tl are available for star-architecture, otherwise the values are set to 0x0.

1	1	1	1	1	3	2	2	2	32	Octets
FC	SN	PN	CW	ST	Th	Tm	Ts	Tl	rsv	

Key

FC = Frame control (11000100)	SN = Source node number
PN = Transmission permits node number	CW = Control word
ST = Slot time	Th = High-speed periodic time
Tm = Medium-speed periodic time	Ts = Sporadic message rotation time
Tl = Low-speed periodic time	rsv = Reserved (0x0)

Figure 12 – Structure of COM DLPDU**6.6.3 Parameters of COM DLPDU**

The parameters of COM DLPDU are equal to that of the SYN DLPDU specified in 6.2.3.

6.6.4 User data of COM DLPDU

No user data is conveyed by the COM DLPDU.

6.6.5 Sending and receiving COM DLPDU

The DLE is activated to send COM DLPDU by receiving DLM_SET_Value primitive, especially requiring change of each value of V(ST), V(Th), V(Tm), V(Ts), V(Tl) and CW.

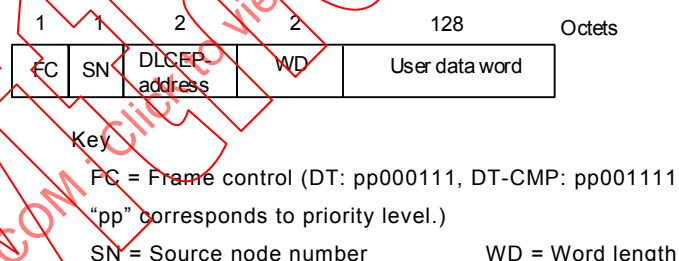
When the DLE of the SYN node has successfully received COM DLPDU from the DLE of another node, the DLE reflects the requirement by COM DLPDU to SYN DLPDU to be sent in the next V(Th) time period.

6.7 Cyclic data and cyclic data with transmission complete DLPDU (DT) and (DT-CMP)**6.7.1 General**

Either DT DLPDU or DT-CMP DLPDU is used to convey the Time-critical cyclic data to all Type 11 fieldbus member nodes. The difference of DT DLPDU and DT-CMP DLPDU is indication of transmit completion or not.

6.7.2 Structure of DT DLPDU

Figure 13 shows the structure of the DT DLPDU.

**Figure 13 – Structure of DT DLPDU****6.7.3 Parameters of DT DLPDU****6.7.3.1 DLCEP-address parameter**

This parameter indicates DLCEP for predefined multi-point publisher DL-connection.

Table 22 shows the structure of the DT parameter.

Table 22 – DT parameter: 3rd and 4th octets

DLCEP-address															
DLCEP-address ($2^7 - 2^0$)								DLCEP-address ($2^8 - 2^{15}$)							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.7.3.2 Word length parameter (WD)

6.7.3.2.1 WD for star-architecture

This parameter indicates the length of the User-data-word. The value is 0x40, and the value is held into V(BW).

6.7.3.2.2 WD for loop-architecture

This parameter indicates the length of the User-data-word. The value is one of 0x8, 0x0c, 0x10, 0x14, 0x18, 0x24, 0x30 and 0x40 selectable, and the value is held into V(BW).

6.7.4 Sending DT or DT-CMP DLPDU

The CTRC(Cyclic-transmission TX/RC control) manages to send out DT DLPDU or DT-CMP DLPDU on receipt of DL-PUT primitive from the DL-user.

The type of High-speed cyclic data transmission or Medium-speed cyclic data transmission or Low-speed cyclic data transmission shall be designated to the pp subfield of FC of the DT DLPDU and the DT-CMP DLPDU. The Low-speed cyclic data transmission is not used for loop-architecture.

6.7.5 Receiving DT or DT-CMP DLPDU

The DLE that has received DT DLPDU or DT-CMP DLPDU shall update the corresponding Receive_buffer associated with DLCEP address field in the DT DLPDU or the DT-CMP DLPDU, and notify the DLS-user using DL-Buffer-Received indication primitive that the data in the specified receive-buffer is updated and is available to read out.

6.8 RAS DLPDU (RAS)

6.8.1 General

RAS DLPDU is used for transfer the RAS(Reliability, Availability, Serviceability) related information to all member node.

6.8.2 Structure of RAS DLPDU

Figure 14 shows the structure of the RAS DLPDU.

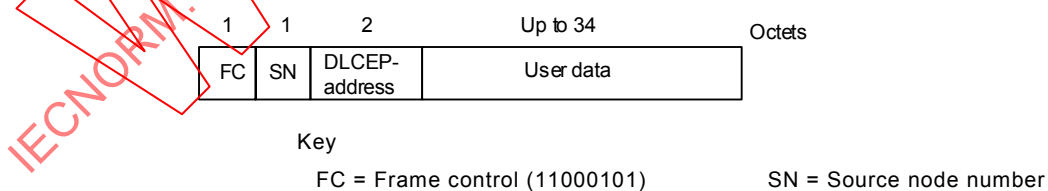


Figure 14 – Structure of RAS DLPDU

6.8.3 DCEP-address parameters

This parameter indicates the DLCEP for predefined multi-point publisher DL-connection.

Table 23 shows the structure of the RAS parameter.

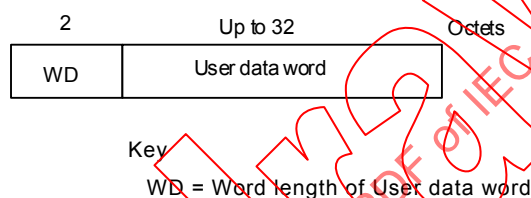
Table 23 – RAS parameter: 3rd and 4th octets

DLCEP-address															
DLCEP-address ($2^7 - 2^0$)								DLCEP-address ($2^8 - 2^{15}$)							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.8.4 User data

RAS DLPDU conveys the user data, which is specifically associated with the RAS related information of the local DLE, up to 34 octets one time, however in which WD parameter of 2 octet length is included and used for loop-architecture so that user data is conveyed up to 32 octet. Figure 15 shows the structure of user data of loop-architecture.

The DLE of each local node may handle the RAS related information over 34 octets, and then the total number of the RAS related information of each node is broken down into several fragments and each fragment is conveyed on the RAS DLPDU.

**Figure 15 – Structure of User data of loop-architecture**

6.8.5 Sending and receiving RAS DLPDU

The DLE of local node can broadcast the RAS related information to all Type 11 fieldbus member nodes using the RAS DLPDU. The RAS DLPDU is sent during TMAC time duration by the DLE of each local node each by each in order of V(TN), therefore the transmission of the RAS DLPDU or broadcasting of the RAS related information of local node is carried out on background basis.

When the RAS DLPDU has been received, the DLE shall update the corresponding Receive_buffer associated with the DLCEP address field in the RAS DLPDU and notify the DLS-user using the DL-Buffer-Receive indication primitive that the data in specific receive-buffer is updated and is available to read out.

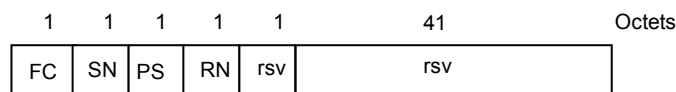
6.9 Loop repeat request DLPDU (LRR)

6.9.1 General

LRR DLPDU is specific use for loop-architecture and is sent for recovering the open-ring upon failure.

6.9.2 Structure of LRR DLPDU

Figure 16 shows the structure of the LRR DLPDU.



Key

FC = Frame control (11100110)

SN = Source node number

PS = Port status

RN = Recipient node number

rsv = Reserved (0x0)

Figure 16 – Structure of LRR DLPDU

6.9.3 Parameters of LRR DLPDU

6.9.3.1 Structure of Port status (PS)

6.9.3.1.1 General

This parameter indicates the status of the node. Table 24 shows the structure of the port status.

Table 24 – Format of the PS parameter: 3rd octet

PP: Port status							
Reserved	Primary Port (PP)	Send-enable-A/-B		Receive-enable-A/B		Forward-enable-A/-B	
7	6	5	4	3	2	1	0

6.9.3.1.2 Primary port (PP)

This parameter indicates the ring-port through which the SYN-frame first received since this node is power-up, or in the system start-up, or in the system initialization.

Table 25 shows the value of the primary port parameter.

Table 25 – The value of the PP parameter

Primary port (PP)	Value	Description
Ring-port-A	0	The Ring-port-A is as the primary port.
Ring-port-B	1	The Ring-port-B is as the primary port.

6.9.3.1.3 Send- Receive- and Forward-enable parameters

These parameters indicate the operational status of the ring-port whether the ring-port is in the send-, the receive- and the forward-enabled or not.

Table 26, Table 27 and Table 28 show the value of the send-, the receive-, the forward-enable-A / -B parameters.

Table 26 – The value of the send-enable-A/-B

Send enable-A/-B	Value	Description
Send-disable	00	Both the Ring-port-A and -B are in disabled
Send-enable-A	01	The Ring-port-A is in enabled
Send-enable-B	10	The Ring-port-B is in enabled
Send-enable-A and -B	11	Both the Ring-port-A and -B is in enabled

Table 27 – The value of the receive-enable-A/-B

Receive enable-A/-B	Value	Description
Receive-disable	00	Both the port-A and -B is in disabled
Receive-enable-A	01	The port-A is in enabled
Receive-enable-B	10	The port-B is in enabled
Receive-enable- A and -B	11	Both the port-A and -B is in enabled

Table 28 – The value of the forward-enable-A/-B

Forward enable-A/-B	Value	Description
Forward-disable	00	The forwarding between the port-A and B is in disabled. Both Ring-port -A and -B are in Blocked
Forward-enable-A	01	The forwarding from the port-A to -B is in enabled. Ring-port-A is in Non-blocked and Ring-port-B is in Blocked
Forward-enable-B	10	The forwarding from the port-B to -A is in enabled. Ring-port-B is in Non-blocked and Ring-port-A is in Blocked
Forward-enable-A to -B	11	The forwarding between the port-A and B is in enabled. Both Ring-port-A and -B are in Non-blocked

6.9.3.2 Recipient node number (RN)

This parameter designates the recipient node number of which the node is to receive the LRR DLPDU. The format is shown in Table 29.

Table 29 – RN parameter: 4th octet

RN: Recipient node number							
V(RN) (1 to 254)							
7	6	5	4	3	2	1	0

6.9.4 Sending and receiving LRR DLPDU

The type 11 fieldbus of loop-architecture is in a ring structure, in which each node is connected in series to two other nodes. The DLPDU is sent in both directions out of the node at a time so that the DLPDU is passed through sequentially between the nodes. In order to circumvent the DLPDU being circulated for ever in the ring, there exist open-points purposely under control over the type 11 fieldbus so that a DLPDU is not returned any more to the source node along through the circular path.

Figure 17 shows an open-ring structure under control as an example, and Table 30 summarizes the operation condition of each node.

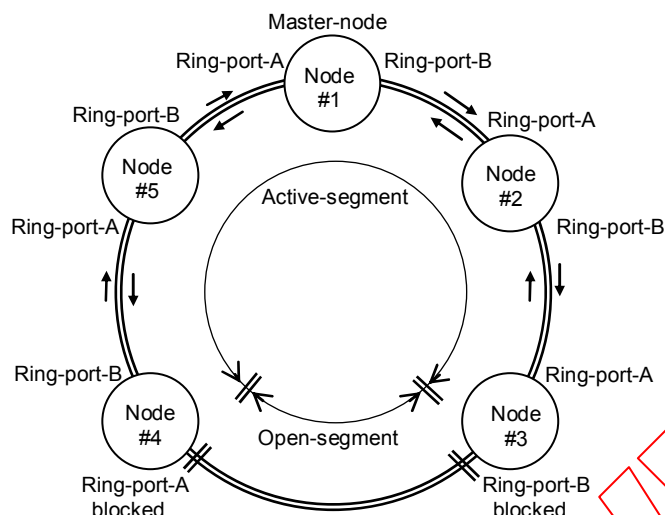


Figure 17 – Open-ring under control

Table 30 – Operational condition of the node

Node #	Node condition			
	Master/Slave -node state	Normal/Open state	Ring-port-A/-B state	
			Ring-port-A	Ring-port-B
1	Master	Normal	Non-blocked	Non-blocked
2	Slave	Normal	Non-blocked	Non-blocked
3	Slave	Open	Non-blocked	Blocked
4	Slave	Open	Blocked	Non-blocked
5	Slave	Normal	Non-blocked	Non-blocked

The DLE provides function to manage the remedy action in cooperation with the DLE in other nodes upon a single point of failure in order to maintain the communications between the nodes in healthy operation.

The sending and receiving LRR DLPDU to compensate a single point of failure are as follows:

- A DLE in the open-state (hereafter DLE1) which is at one end of current active-segment and suffers a single point of failure over the path to the node in the master-state, shall detect long-silence of reception;
- The DLE1 in the open-state, detecting the long-silence of reception, shall send out LRR DLPDU with the RN equal to the node-identifier-number of the adjacent node, that is another node (or DLE, hereafter DLE2) in open-state at the edge of the current active-segment, in both direction at a time at the timing given by the ACM;
- The DLE1 :
 - shall wait to receive LRR DLPDU with the RN equal to V(TN);
 - shall enter into normal-state if receiving within a specified time period a LRR DLPDU with the RN equal to V(TN) out of the DLE2;
 - shall change the port status “Blocked” of the Ring-port to the current active-segment and further the port state “Non-blocked” of the Ring-port on the current open-segment if not receiving the LRR DLPDU with the RN equal to V(TN) within the specified time period out of the DLE which is the adjacent node on the current active-segment;

- d) The DLE2 which is receiving LRR DLPDU with the RN equal to V(TN), shall enter into normal-state;
- e) The DLE (hereafter DLE3) which is in normal-state and is over the path between the single point of failure and the node in open-state (DLE1), shall send out LRR DLPDU with the RN equal to the node-identifier-number of the adjacent node at the side of the Ring-port through which a LRR DLPDU is receiving, in both direction at a time;
- f) The DLE3 :
- shall wait during a specified time period, to receive LRR DLPDU with the RN equal to V(TN);
 - shall maintain in the normal-state if receiving within a specified time period a LRR DLPDU with the RN equal to V(TN) from the opposite side of the Ring-port through which the DLE3 first received a LRR DLPDU;
 - shall change the port status “Blocked” of a Ring-port at the opposite side of a Ring-port through which the DLE3 first received a LRR DLPDU if not receiving a LRR DLPDU with the RN equal to V(TN) from the Ring-port within the specific time period, and shall enter into open-state.

6.10 Loop diagnosis DLPDU (LPD)

6.10.1 General

The LPD DLPDU is sent to diagnose the condition of the links between the adjacent nodes.

6.10.2 Structure of LPD DLPDU

Figure 18 shows the structure of the LPD DLPDU.

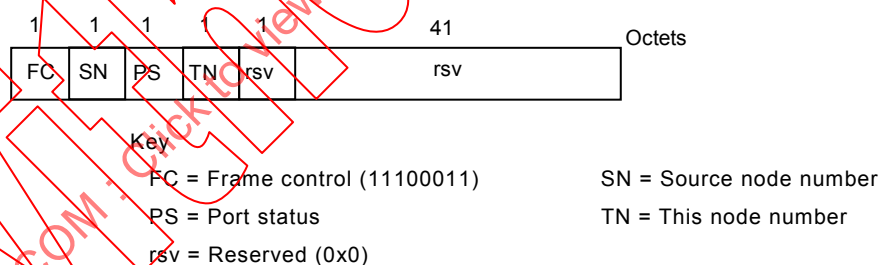


Figure 18 – Structure of LPD DLPDU

6.10.3 Parameters of LPD DLPDU

6.10.3.1 Port status (PS)

This parameter is equivalent to the PS in 6.9.3.1.

6.10.3.2 This node number (TN)

This parameter indicates the node-identifier-number of V(TN), of which the node sent out the LPD DLPDU.

6.10.4 Sending and receiving LPD DLPDU

Each DLE periodically sends out LPD DLPDU with the node identifier number V(TN) of the node and the port status in operation so that the neighboring nodes are able to collect these information.

- a) Each DLE shall send out the LPD DLPDU in both direction at a time at the specific instant which is given periodically by the ACM of loop-architecture;
- b) The LPD DLPDU shall be sent out of each node all together at the same instant;
- c) Each DLE on receiving LPD DLPDU shall not forward the LPD DLPDU receiving from one Ring-port to the other Ring-port.

7 DLE elements of procedure

7.1 DLE elements of procedure for star-architecture

7.1.1 Overall structure

The DLL is composed of control elements of Cyclic transmission TX/RX Control (CTRC), Sporadic TX/RX Control (STRC), Access Control Machine(ACM), Redundancy Medium Control(RMC), TX/RX Framer, Octet Serializer, Octet Deserializer and DLL Management Interface.

The ACM as the primary control element provides the function for deterministic medium access control cooperating with the CTRC, the STRC and the RMC for reliable and efficient support both of higher-level connection-mode and connection-less mode data transfer services.

The DLL management interface provides DLL management functions.

Figure 19 depicts the overall structure of the DLL.

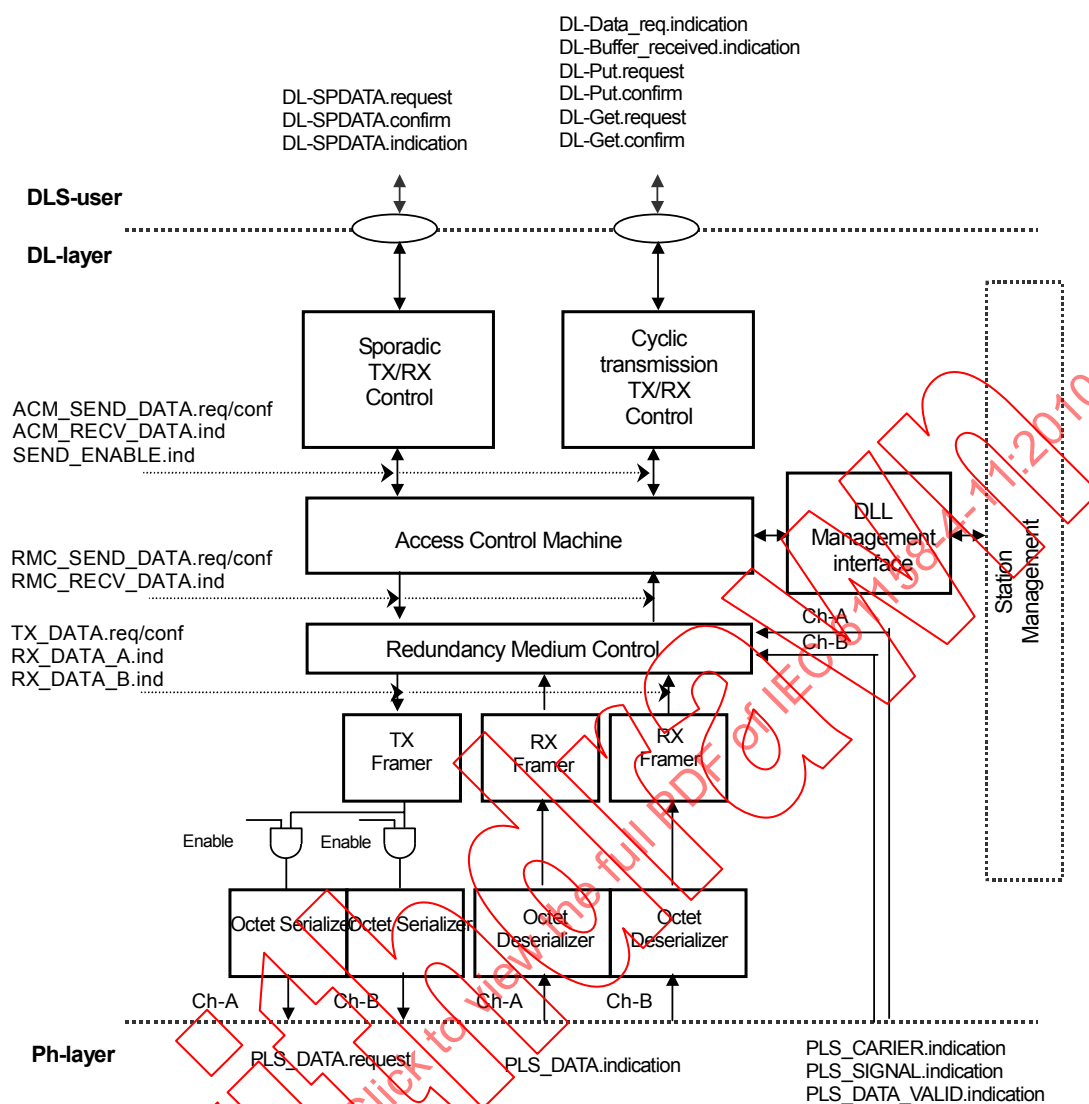


Figure 19 – Overall structure of DLL

7.1.2 Initialization

Upon power-up or after the reception of the DLM-RESET request primitive, the DLE shall go into the OFF-LINE state. When in OFF-LINE, the DLE shall not transmit and shall ignore any DLPDU received.

When all the variables for normal DLE operation are set up by the DLM-Set-Value request primitive, the state is changed from OFF-LINE to STATION MODE CONTROL in which the DLE shall start normal DL operation.

Figure 20 depicts the DLE state transition.

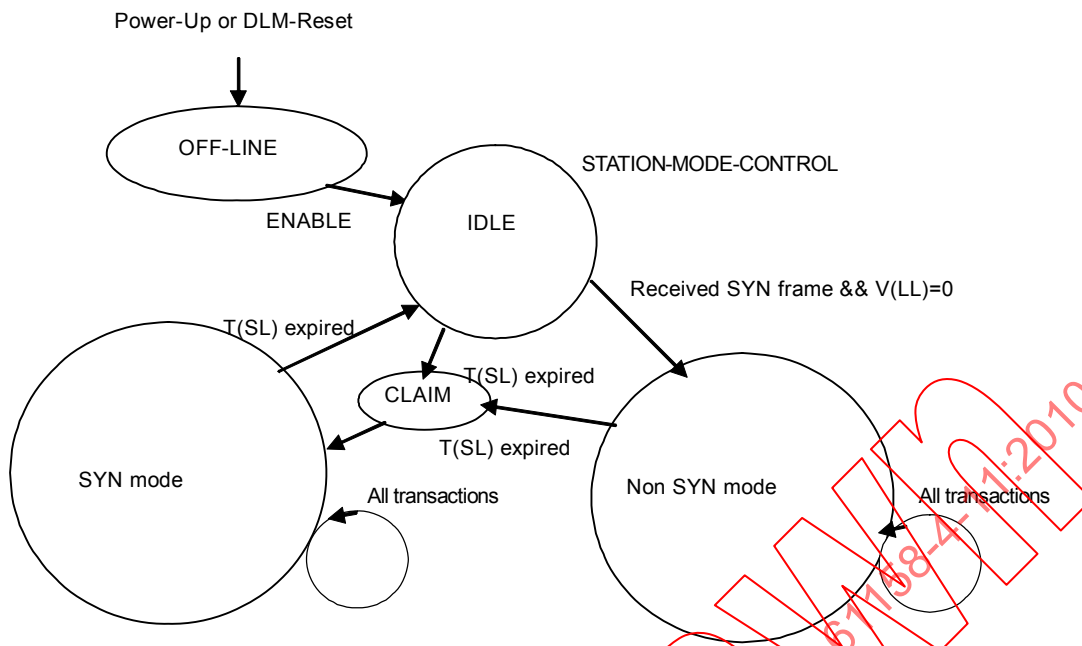


Figure 20 – DLE state transition

7.1.3 Cyclic transmission TX/RX control (CTRC)

7.1.3.1 Overview

The Cyclic transmission TX/RX control (CTRC) is responsible for buffering and dispatching the DLSDU received for the Time-critical cyclic data transfer between the DLS-user and the ACM.

DL-Data-Req indication primitive by the CTRC informs the DLS-user to initiate the data transfer from each DLS-user buffer to the send buffer of the DLE using DL-Put request primitive. The DLS-user buffer is addressed with the DLCEP-identifier parameter in the DL-Data-req indication primitive from the CTRC.

Each DLS-user buffer contains data for Time-critical cyclic data transmission. After the DLS-user data received, the CTRC issues ACM_SEND_DATA request primitive to initiate ACM sending out the DLS-user data as DT or DT-CMP DLPDU.

DL-Data-Req indication primitive is issued by the CTRC in response to SEND_ENABLE indication primitive from the ACM. The SPEED Class parameter in SEND_ENABLE indication primitive allows the CTRC to activate transfer of corresponding class of data-buffer by the DLS-user. The classes designated by the speed-class parameter correspond to the classes of High-speed cyclic data, Medium-speed cyclic data and Low-speed cyclic data transfer.

The data transfer of each Speed-class designated is dependant on the level of transfer priority:

- As for Priority class 3, which corresponds to the High-speed cyclic data transfer, when received SEND_ENABLE indication primitive, the CTRC shall handle all of the data of every DLS-user buffer corresponding to the High-speed Cyclic data transfer or the High-speed class is to be delivered to the ACM and to be sent on the transmission medium all at once on each occasion;
- As for Priority class 2 and 0, which corresponds to the Medium-speed cyclic data transfer or the Medium-speed class and the Low-speed cyclic data transfer or the Low-speed class respectively, the CTRC shall handle on each occasion the data of every DLS-user buffer corresponding to the Medium-speed and the Low-speed class is sent or not depending on the condition. The token-holding time of each class 2 and 0 governs the condition. After

sending out all the High-speed cyclic data, the Medium-speed cyclic data is sent. If the token-holding time ends during sending the Medium-speed cyclic data, the data transfer is interrupted and the CMP DLPDU or the DT-CMP DLPDU is sent at the this occasion. On the next occasion, the remainder of the previous Medium-speed cyclic data is to be sent depending on the same condition. As for the Low-speed cyclic data, the same control as for the Medium-speed cyclic data transfer is to be done. The occasion happens every V(TSYN) time period.

When the ACM_RECV_DATA indication primitive has been received from the ACM, the CTRC stores the DLPDU by the ACM into each receive-buffer, which is addressed with the DLCEP-identifier parameter in ACM_RECV_DATA indication primitive. Furthermore, the CTRC issues DL-Buffer-received indication primitive to inform the DLS-user the receive-buffer of the DLE is updated and is available to read out. The DLS-user can read out the data in the receive-buffer using DL-Get request primitive in response to DL-Buffer-received indication primitive from the CTRC.

7.1.3.2 Primitive definitions

7.1.3.2.1 Primitives exchanged between DLS-user and CTRC

The primitives exchanged between DLS-user and CTRC is shown in Table 31 and the primitives exchanged between the CTRC and the ACM is summarized in Table 32.

Table 31 – Primitives exchanged between DLS-user and CTRC

Primitive name	Source	Associated parameters
DL-Data-req.indication	CTRC	DLCEP-identifier
DL-Put.request	DL-user	DLCEP-identifier, DLSDU-length, DLSDU
DL-Put.confirm	CTRC	DLCEP-identifier, Status
DL-Buffer-received.indication	CTRC	DLCEP-identifier
DL-Get.request	DL-user	DLCEP-identifier
DL-Get.confirm	CTRC	DLCEP-identifier, DLSDU-length, DLSDU, Status

Table 32 – Primitives exchanged between CTRC and ACM

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	CTRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_RECV_DATA.ind	ACM	DLPDU

7.1.3.2.2 Parameters used with primitives exchanged between DLS-user and CTRC

The parameters used for interaction between the DLS-user and the CTRC are summarized in Table 33.

Table 33 – Parameters used with primitives exchanged between DLS-user and CTRC

Parameter name	Description
DLCEP-identifier	Identifier to designate Send-Buffer or Receive-Buffer
DLSDU	The contents of Send-Buffer or Receive-Buffer, which is Time-critical Cyclic data processed by CTRC
DLSDU-length	The length of DLSDU
Speed-class	Speed-class to designate the class of Time-critical Cyclic data transfer, that is for High-speed Cyclic data, Medium-speed Cyclic data and Low-speed Cyclic data
Status	Status report whether the requested service is successfully provided or failed for the reason specified

7.1.3.3 CTRC state table

The state transition diagram of the CTRC is depicted in Figure 21, and the CTRC state table is shown in Table 34.

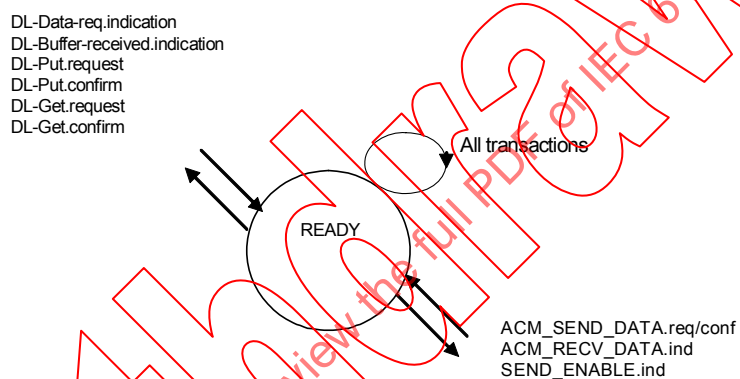


Figure 21 – State transition diagram of CTRC

Table 34 – CTRC state table

#	Current state	Event /condition ⇒actions	Next state
1	READY	DL-Put.request {DLCEP-identifier, DLSDU-length, DLSDU} / CHECK_PAR_PUT (DLCEP-identifier, DLSDU) = "True" ⇒ PUT_BUFFER (DLCEP-identifier, DLSDU) DL-Put.confirm { DLCEP-identifier, DLSDU-length, Status := "success" }	READY
2	READY	DL-Put.request {DLCEP-identifier, DLSDU-length, DLSDU} / CHECK_PAR_PUT (DLCEP-identifier, DLSDU) = "False" ⇒ DL-Put.confirm { DLCEP-identifier, DLSDU-length, Status := "failure" }	READY
3	READY	DL-Get.request {DLCEP-identifier } / CHECK_PAR_GET (DLCEP-identifier) = "True" ⇒ DL-Get.confirm { DLCEP-identifier, DLSDU-length, DLSDU := GET_BUFFER(DLCEP-identifier), Status := "success" }	READY
4	READY	DL-Get.request {DLCEP-identifier} / CHECK_PAR_GET (DLCEP-identifier) = "False" ⇒ DL-Get.confirm { DLCEP-identifier, DLSDU-length, DLSDU := null, Status := "failure" }	READY
5	READY	SEND_ENABLE.ind {Speed-class} / Speed-class <> "SPORADIC" && CHECK_NEXT_SEND(Speed-class) = "True" ⇒ DL-Data-req.indication { DLCEP-identifier := GET_NEXT_ID(Speed-class) } DLSDU := GET_BUFFER (DLCEP-identifier) DLPDU := BUILD_DT (Speed-class, DLCEP-identifier, DLSDU) ACM_DATA.req { DLPDU } ACM_DATA.conf { } -- immediate ⇒ NEXT(Speed-class)	READY
6	READY	SEND_ENABLE.ind {Speed-class} / Speed-class <> "SPORADIC" && CHECK_NEXT_SEND(Speed-class) = "False" ⇒ ACM_DATA.req { null -- no data } ACM_DATA.conf { } -- immediate ⇒ NEXT(Speed-class)	READY
7	READY	ACM_DATA.ind {DLPDU} / Class <> "SCOPRADIC" && CHECK_PAR_DT (DLPDU) ⇒ DL-Buffer-received.indication { DLPDU.DLCEP-address }	READY

7.1.3.4 Functions of CTRC

All functions of the CTRC are summarized in Table 35.

Table 35 – CTRC functions table

Function Name	Input	Output	Operation
CHECK_PAR_PUT	DLCEP-identifier, DLSDU	True/False	Check that all parameters of DLCEP-identifier and DLSDU of DL-put.request primitive are valid. If valid, "True" is returned, otherwise "False" is returned
PUT_BUFFER	DLCEP-identifier, DLSDU	(none)	Store DLSDU into the Send-Buffer associated with the DLCEP-identifier
CHECK_PAR_GET	DLCEP-identifier	True/False	Check that that DLCEP-identifier of DL-get.request primitive is valid. If valid, "True" is returned
GET_BUFFER	DLCEP-identifier	DLSDU	Get DLSDU in the Receive-Buffer associated with DLCEP-identifier
CHECK_NEXT_SEND	Speed-class	True/False	Check that the DLSDU specified by Speed-class exists. If it exists, "True" is returned, otherwise "False" is returned
GET_NEXT_ID	Speed-class	DLCEP-identifier	Get next DLCEP-identifier of the DLS User-Buffer specified by Speed-class
BUILD_DT	Speed-class, DLCEP-identifier, DLSDU	DLPDU	Build into DLPDU of Time-critical Cyclic data out of the data in the Send-Buffer. DLPDU is assembled as follows. DLPDU.DA := V(MGA) DLPDU.SA := V(IA) DLPDU.Len/Type := 0x888b DLPDU.FC := Speed-class + "DT" DLPDU.SN := V(TN) DLPDU.DLCEP.address := DLCEP-identifier DLPDU.DLSDU := DLSDU
CHECK_PAR_DT	DLPDU	True/False	Check that the specified DLPDU is valid. If valid, "True" is returned
NEXT	Speed-class		Check that additional DLSDU specified by the Speed-class is remained. If remained, the control is returned to the top of current state

7.1.4 Sporadic TX/RX control (STRC)

7.1.4.1 Overview

The Sporadic TX/RX control (STRC) is responsible for buffering and dispatching in time DLSDU received for the Sporadic message data between DLS-user and the ACM.

7.1.4.2 Primitive definitions

7.1.4.2.1 Primitives exchanged between DLS-user and STRC

Table 36 shows all primitives exchanged between DLS-user and STRC and Table 37 shows all primitives exchanged between the STRC and the ACM.

Table 36 – Primitives exchanged between DLS-user and STRC

Primitive name	Source	Associated parameters
DL-SPDATA.request	DLS-user	DA, MSDU
DL-SPDATA.confirm	DLS-user	DA, Status
DL-SPDATA.indication	STRC	DA, SA, MSDU, Rec-Status

Table 37 – Primitives exchanged between STRC and ACM

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	STRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_SEND_DATA.ind	ACM	DLPDU

7.1.4.2.2 Parameters used with primitives exchanged between DLS-user and STRC

All parameters used with primitives exchanged between the DLS-user and the STRC is shown in Table 38.

Table 38 – Parameters used with primitives exchanged between DLS-user and STRC

Parameter name	Description
DA	Destination Address
SA	Source Address
MSDU	MAC service data unit
Status	Indicate whether the requested service of DL-SPDATA.request is successfully provided or failed for the reason specified
Rec-Status	Indicates whether the DLPDU had received without error or not
DLPDU	DLPDU for Sporadic message transfer
Speed-class	Speed-class requested by DLS-user. In Sporadic message transfer service, Speed-class is specified as "Sporadic" or Class 1.

7.1.4.3 STRC state table

The state transition diagram of the STRC is depicted in Figure 22, and the STC state table is shown in Table 39.

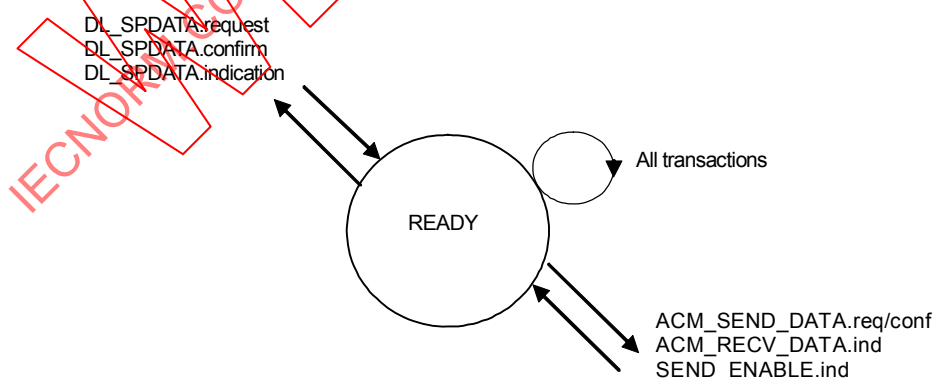
**Figure 22 – State transition diagram of STRC**

Table 39 – STRC state table

#	Current state	Event /condition ⇒actions	Next state
1	READY	DL-SPDATA.request {DA, MSDU} / CHECK_PAR_SPDATA (DA, MSDU) = "True" && CHECK_SPDATAQ () <> "Full" ⇒ QUEUE_SPDATA (DA, MSDU) DL-SPDATA.confirm { DA, MSDU, Status := "success" }	READY
2	READY	DL-SPDATA.request {DA, MSDU} / CHECK_PAR_SPDATA (DA, MSDU) = "True" && CHECK_SPDATAQ () = "Full" ⇒ DL-SPDATA.confirm { DA, MSDU, Status := "failure - The SPDATA Queue is full" }	READY
3	READY	DL-SPDATA.request {DA, MSDU} / CHECK_PAR_SPDATA (DA, MSDU) = "False" ⇒ DL-SPDATA.confirm { DA, MSDU, Status := "Failure - Invalid parameter" }	READY
4	READY	SEND_ENABLE.ind {Speed-class} / Speed-class = "SPORADIC" && CHECK_SPDATAQ() <> "Empty" ⇒ DLPDU := BUILD_SPDATA (DA, MSDU := DEQUEUE_SPDATA ()) ACM_SEND_DATA.req { DLPDU } ACM_SEND_DATA.conf { } -- immediate response ⇒ (no action taken)	READY
5	READY	ACM_SEND_DATA.ind {DLPDU} / Speed-class = "SPORADIC" && CHECK_SPDATA (DLPDU) ⇒ DL-Buffer-received.indication { DLPDU.DLCEP-address }	READY

7.1.4.4 Functions of STRC

All functions of the STRC are summarized in Table 40.

Table 40 – STRC functions table

Function name	Input	Output	Operation
CHECK_PAR_SPDATA	DA, MSDU	True/False	Check that all of parameters, DA and DSDU provided with DL-SPDATA.request are valid. If valid, "True" is returned
CHECK_SPDATAQ	(none)	status	Check that the Queue condition for SPDATA is fully queued. The returned status is any one of "Full", "Empty" and "Queued"
QUEUE_SPDATA	DA, MSDU	(none)	Queues the input data into the SPDATA Queue on a FIFO basis
DEQUEUE_SPDATA	(none)	DA, MSDU	Dequeue from the SPDATA queue on a FIFO basis
BUILD_SPDATA	DA, MSDU	DLPDU	Build into DLPDU of Sporadic message data. DLPDU is assembled as follows: DLPDU.DA := MSDU.DA DLPDU.SA := V(IA) DLPDU.Len/Type := MSDU.LEN/Type DLPDU.MSDU := MSDU.DLSDU
CHECK_RCV_SPDATA	DLPDU	True/False	Check that the specified DLPDU is valid. If valid, "True" is returned

7.1.5 Access control machine (ACM)

7.1.5.1 Overview

The access control machine (ACM) is responsible for deterministic medium access control and scheduling opportunities to send out the DLPDUs, for control to add and remove nodes and for restoration from network disruption to be system down.

The ACM has the primary responsibility for

- assuring that the local node detects and fully utilizes its assigned access time period;
- assuring that the local node does not interfere with the transmissions of other nodes, especially of the node transmitting the SYN DLPDU;
- detecting network disruption, and initiating the SYN DLPDU transmit for restoration of the network disruption from after prescribed time duration in which the SYN DLPDU is not heard;
- assuring a new node adding to and removing from the network.

7.1.5.2 ACM and the schedule support functions

The ACM functions schedule all communications between the DLEs participating in the Type 11 fieldbus, and the timing of this communications is controlled as to:

- fulfill the specific medium access control to give all the DLEs the opportunities to send out 2 kinds of class of the Time-critical cyclic data and Sporadic message data in timely, prioritized and deterministic fashion, and to detect the network disruption and to initiate the restoration in appropriate time, further to add and remove the nodes on line;
- provide 3 levels of the Time-critical data transfer opportunities of sending data to the node in sequential order and within each pre-specified time period, and that the data transfer of each level is performed within the pre-specified time duration (token holding time) and whether the data transfer of lower levels to be carried out or to be held over to the later cyclic time period depends on the level and the occasion though the top level of the data transfer is always carried out at every occasion, on the other hand, the whole volume of the data transfer of lower levels is transferred within each pre-specified time period;
- provides the sporadic message data transfer opportunities of sending out to the node that the request to transfer is happened sporadically by the DLS-user, and the data transfer is

performed within a pre-specified time period of the corresponding level of priority and is based on the regular ISO/IEC 8802-3 applications.

7.1.5.3 Primitive definitions

7.1.5.3.1 Primitives exchanged between ACM and RMC

Table 41 summarizes all primitives exchanged between the ACM and the RMC.

Table 41 – Primitives exchanged between ACM and RMC

Primitive name	Source	Associated parameters
RMC_SEND_DATA.req	ACM	RMSDU
RMC_SEND_DATA.conf	RMC	RMC-status
RMC_RECV_DATA.ind	RMC	RMSDU

The parameters used with the primitives exchange between the ACM and the RMC are described in Table 42.

Table 42 – Parameters used with primitives exchanged between ACM and RMC

Parameter name	Description
RMSDU	SDU of RMC
RMC-status	Status indicating the results of the request to RMC

7.1.5.3.2 Primitives exchanged between ACM and CTCR

Table 43 summarizes all primitives exchanged between the ACM and the CTCR.

Table 43 – Primitives exchanged between ACM and CTCR

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	CTCR	DLPDU
ACM_SEND_DATA.conf	ACM	ACM_status
ACM_RECV_DATA.ind	ACM	DLPDU

The parameters used with the primitives exchange between the ACM and the CTCR are described in Table 44.

Table 44 – Parameters used with primitives exchanged between ACM and CTCR

Parameter name	Description
ACM_Status	Status indicating the results
DLPDU	SDU of AMC
Speed-class	Speed class indicating Time-critical Cyclic data transmission

7.1.5.3.3 Primitives exchanged between ACM and STRC

Table 45 lists all primitives exchanged between the ACM and the STRC.

Table 45 – Primitives exchanged between ACM and STRC

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	STRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_SEND_DATA.ind	ACM	DLPDU

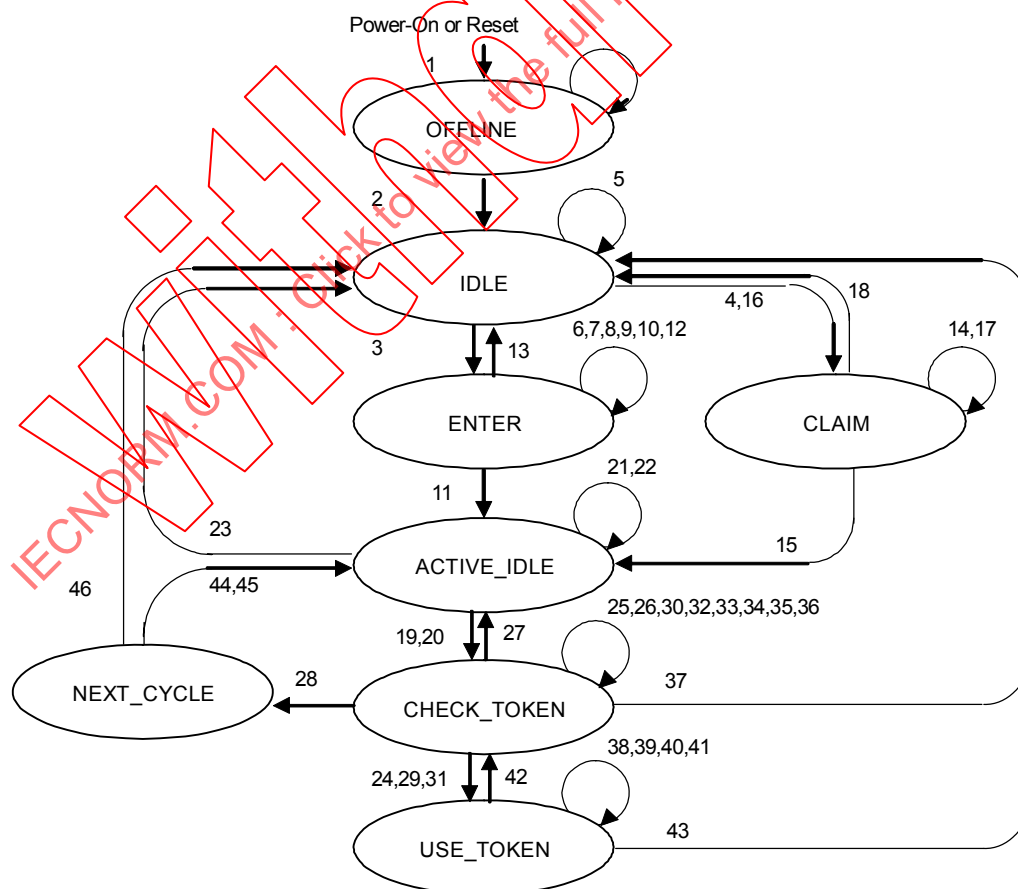
The parameters used with the primitives exchange between the ACM and the CTRC are described Table 46.

Table 46 – Parameters used with primitives exchanged between ACM and STRC

Parameter name	Description
ACM_Status	Status indicating the results
DLPDU	SDU of AMC
Speed-class	Speed class indicating Time-critical Cyclic data transmission

7.1.5.4 ACM state table

The state transition diagram is shown in Figure 23.

**Figure 23 – State transition diagram of ACM**

The state "OFFLINE" is entered on power-up or when DLM-Reset.request primitive is issued. In this state, all of the variables, parameters and configuration information are set up by the DLE. When "In_Ring_Desire" becomes true, the state changes to "IDLE".

The state "IDLE" is to wait and be ready to join the Type 11 fieldbus membership. When a SYN DLPDU has been received from another SYN node, the state change to "ENTER" in which the REQ DLPDU is sent to claim adding into the Type 11 fieldbus membership to the current SYN node. Moreover, in "IDLE" state, when the signals over the transmission media continues to be inactive during a specified time period, the state becomes "CLAIM", in which the node attempts to be a new SYN node.

The state "ACTIVE_IDLE" is in the Type 11 fieldbus membership, and the node manages to obtain the transmission right by the Type 11 fieldbus medium access control, either when the node is operating as the SYN mode by transmitting the SYN DLPDU or as the non-SYN mode receiving the SYN DLPDU by other SYN node, the state is in "CHECK_TOKEN".

The state "CHECK_TOKEN" waits until $V(Tsl)$ becomes equal to $V(TN)$ in order to send out the data over the transmission media. When $V(Tsl)$ becomes equal to $V(TN)$, the state changes to "USE_TOKEN".

The state "USE_TOKEN" is that the node is able to send out the Time-critical cyclic transmission data and the Sporadic transmission data. When all data has been sent or the token holding time is expired, the state changes to "NEXT_CYCLE".

The state "NEXT_CYCLE" is for solicit new node as a primary function.

The ACM state table is shown in Table 47.

Table 47 – ACM state table

#	Current state	Event /condition ⇒actions	Next State
1	Any states	POWER-ON or RESET ⇒	OFFLINE
2	OFFLINE	In_Ring_Desired = "True" ⇒ START_TIMER (T(SL), V(SL))	IDLE
3	IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && RMSDU.PN = V(TN) && $V(LL) < V(TN) > = 0$ ⇒ -- receiving SYN frame and LL this node not live -- SYN_frame := RMSDU $V(LN) := 1$ START_TIMER (T(SL), V(SL))	ENTER
4	IDLE	EXPIRED_TIMER (T(SL)) = "True" ⇒ RMSDU := BUILD_PDU (CLM) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	CLAIM
5	IDLE	RMC_RECV_DATA.ind { RMSDU } / ⇒ -- receiving a frame except the above -- START_TIMER (T(SL), V(SL))	IDLE
6	ENTER	$V(LL) < V(LN) > = 1$ && $V(LN) < > V(TN)$ ⇒ START_TIMER (T(SCMP), V(Tsl))	ENTER

#	Current state	Event /condition ⇒actions	Next State
7	ENTER	V(LL)<V(LN)> = 0 && V(LN) <> V(MN) => V(LN)++	ENTER
8	ENTER	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CMP && V(LN) = V(MN) => -- Live Node = Maximum Node No. -- RMSDU := BUILD_PDU (REQ) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	ENTER
9	ENTER	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CMP && V(LN) <> V(MN) => -- Live Node less than Maximum Node No. -- V(LN)++ START_TIMER (T(SL), V(SL))	ENTER
10	ENTER	RMC_SEND_DATA.conf { } => (none)	ENTER
11	ENTER	RMC_RECV_DATA.ind { RMSDU } && FC = SYN / V (LL)<V(TN)> = 1 => SYN_frame := RMSDU V(LN) := 1 START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
12	ENTER	EXPIRED_TIMER (T(SCMP)) = "True" => V(LN)++	ENTER
13	ENTER	EXPIRED_TIMER (T(SL)) = "True" => -- Expired Silence Timer -- START_TIMER (T(SL), V(SL))	IDLE
14	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "False" && All_Slot_Time <= V(MN) => All_Slot_Time++ START_TIMER (T(SL), V(SL))	CLAIM
15	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "False" && All_Slot_Time = V(MN) => V(LL) = 0 V(LL)<V(TN)> := 1 RMSDU := BUILD_PDU (SYN) SYN_frame := RMSDU RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
16	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "True" => START_TIMER (T(SL), V(SL))	IDLE
17	CLAIM	RMC_RECV_DATA.ind { RMSDU } => -- receiving a frame except the above -- START_TIMER (T(SL), V(SL))	CLAIM
18	CLAIM	EXPIRED_TIMER (T(SL)) = "True" => -- Expired Silence Timer -- START_TIMER (T(SL), V(SL))	IDLE

#	Current state	Event /condition ⇒actions	Next State
19	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN => -- receiving SYN frame-- SYN_frame := RMSDU V(LL) := SYN_frame.LL V(LN) := 1	CHECK_TOKEN
20	ACTIVE_IDLE	RMC_RECV_DATA.conf { RMSDU } / RMSDU.FC = SYN => -- sent SYN frame-- SYN_mode := "True" V(LN) := 1	CHECK_TOKEN
21	ACTIVE_IDLE	RMC_RECV_DATA.conf { RMSDU } / RMSDU.FC = DT => -- sending DT frame-- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
22	ACTIVE_IDLE	RMC_RECV_DATA.conf { RMSDU } / RMSDU.FC <> Type 11 fieldbus FRAME => -- Receiving SPORADIC Frame -- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
23	ACTIVE_IDLE	EXPIRED_TIMER (T(SL)) = "True" / => -- expired Silence Timer -- SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE
24	CHECK_TOKEN	/ V(LL)<V(TN)> = 1 && V(LN) = V(TN) => -- Get token -- Speed-class := 3 – High Priority START_TOKEN_HOLD_TIMER () SEND_ENABLE.ind { Speed-class } START_TIMER (T(MAC), V(MAC))	USE_TOKEN
25	CHECK_TOKEN	V(LL)<V(LN)> = 1 && V(LN) <> V(TN) => START_TIMER (T(SCMP), V(Tsl))	CHECK_TOKEN
26	CHECK_TOKEN	V(LL)<V(LN)> = 0 && V(LN) <> V(MN) => V(LN)++	CHECK_TOKEN
27	CHECK_TOKEN	/V(LN) = V(MN) && SYN_frame .PN = V(TN) && SYN_mode = "False" => -- Non-SYN mode, on MAC control time -- IF Required COM frame THEN RMSDU := BUILD_PDU (COM) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL)) ENDIF	ACTIVE_IDLE
28	CHECK_TOKEN	/V(LN) = V(MN) && SYN_frame .PN <> V(TN) && SYN_mode = "True" => -- in SYN mode, on MAC control time -- START_TIMER (T(MAC), V(MAC))	NEXT_CYCLE

#	Current state	Event /condition ⇒actions	Next State
29	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CMP && V(LN)++ = V(TN) => -- Get token -- -- matching V(LN) and on receiving CMP frame -- STOP_TIMER (T(SCMP)) Speed-class := 3 -- High Priority START_TOKEN_HOLD_TIMER () SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
30	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CMP && V(LN)++ <> V(TN) => -- not matching V(LN) and on receiving CMP frame -- START_TIMER (T(SCMP), V(Tsl))	CHECK_TOKEN
31	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = DT-CMP && V(LN)++ = V(TN) => -- matching V(LN) and on receiving DT-CMP frame -- Speed-class := 3 -- High Priority START_TOKEN_HOLD_TIMER () SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
32	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = DT-CMP && V(LN)++ <> V(TN) => -- not matching V(LN) and on receiving DT-CMP frame -- START_TIMER (T(SCMP), V(Tsn))	CHECK_TOKEN
33	CHECK_TOKEN	RMC_RECV_DATA.conf { RMSDU } / RMSDU.FC = DT => -- sending DT frame -- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
34	CHECK_TOKEN	RMC_RECV_DATA.conf { RMSDU } / RMSDU.FC <> Type-11 fieldbus FRAME => -- Receiving SPORADIC Frame -- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
35	CHECK_TOKEN	EXPIRED_TIMER (T(SCMP)) / => V(LN)++ if SYN_mode = "True" then MAINT_LL(V(LN)) endif START_TIMER (T(SL), V(SL))	CHECK_TOKEN
36	CHECK_TOKEN	RMC_SEND_DATA.conf { RMSDU } / RMSDU.FC = CMP => -- sending CMP frame-- V(LN)++	CHECK_TOKEN
37	CHECK_TOKEN	EXPIRED_TIMER (T(SL)) = "True" / => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE
38	USE_TOKEN	ACM_SEND_DATA.req { DLPDU } / => -- send DT or Sporadic frame -- RMPDU := BUILD_PDU (DLPDU) RMC_SEND_DATA.req { DLPDU } START_TIMER (T(SL), V(SL))	USE_TOKEN

#	Current state	Event /condition ⇒actions	Next State
39	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / (DLPDU.FC = DT) (DLPDU.FC <> Type-11 fieldbus && EXPIRED_TIMER (T(ATHT)) = "False" => ACM_SEND_DATA.conf { RMC-status } SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
40	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / (DLPDU.FC = DT) (DLPDU.FC <> Type-11 fieldbus) && EXPIRED_TIMER (T(ATHT)) = "True" && Speed-class <> 0 => -- Expired THT, Next Speed class -- ACM_SEND_DATA.conf { RMC-status } Speed-class := Speed-class -1 START_THT (Speed-class) START_TTRT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
41	USE_TOKEN	ACM_SEND_DATA.req { NIL } / Speed-class <> 0 => -- Next Speed-class -- Speed-class := Speed-class -1 START_THT (Speed-class) START_TTRT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
42	USE_TOKEN	ACM_SEND_DATA.req { NIL } / Speed-class = 0 => -- All sent -- RMSDU := BUILD_PDU (CMP) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
43	USE_TOKEN	EXPIRED_TIMER (T(SL)) = "True" / => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE
44	NEXT_CYCLE	EXPIRED_TIMER (T(MAC)) = "True" =>	ACTIVE_IDLE
45	NEXT_CYCLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = REQ => -- receiving REQ from non-SYN node -- V(LL)<RMSDU.SN> := 1 RMSDU := BUILD_PDU (SYN) RMC_SEND_DATA.req { RMSDU } SYN_frame := RMSDU START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
46	NEXT_CYCLE	EXPIRED_TIMER (T(SL)) = "True" / => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE

7.1.5.5 Functions used by ACM

All the functions used by the ACM are summarized in Table 48.

Table 48 – ACM function table

Function name	Input	Output	Operation
BUILD_PDU	FC	RMSDU	According to requested FC(Frame Control), assemble the Type-11 fieldbus frame
EXPIRED_TIMER	T(x)	True/False	When requested timer x has expired, "True" is returned, otherwise False is returned
MAINT_LL	V(LN)	(none)	The node specified V(LN) is read when T(SCMP) expired. When T(SCMP) expires all at number-of-times continuation of C(ASCMP) in the past, the corresponding bit of V(LL) is cleared
START_TIMER	T(x), V(y)	(none)	Timer x is set by value of y, and is activated
START_THT	Speed-class	(none)	T(ATHT) is activated according to the V(TTRT) remaining value of Access-class specified by Speed-class
START_TTRT	Speed-class	(none)	T(ATTRT) is activated according to the V(TTRT) value of Access-class specified by Speed-class
STOP_TIMER	T(x)	(none)	Timer x is deactivated

7.1.6 Redundancy medium control (RMC)

7.1.6.1 Overview

The redundancy medium control (RMC) manages the selection of two inputs from two RX framers, and moreover of two outputs to two Octet serializers for reliable support, without interruption of higher-level data transfer services. The function of RMC is as follows:

- When the DLPDUs are received from the ACM, the RMC breaks them down into octet symbol requests to both Octet serializers so that the DLPDUs are send out over both of the transmission media A and B simultaneously;
- If a collision has happened during the sending-out of the DLPDUs over one of two transmission media, the data transmission over which the collision happened is stopped immediately and the JAM signal specified by ISO/IEC 8802-3 is sent for the next DLPDU ready to be sent. Nevertheless, if on another transmission medium, no collision happens, the data transmission over the transmission medium is continued without interruption;
- The RMC selects one of two outputs from the Octet deserializers. The selection is on first-come basis to a frame without error, and the RMC submits octets of frame to the ACM;
- The RMC provides a function purposely to select and designate one of two inputs from two RX framers. This function is managed according to the value of the RMSEL parameter in the CW field of the received SYN DLPDU. The relationship between the redundant medium selection and the value of the RMSEL parameter is specified in 6.2.3.2.1.3. In the case of a single medium system the control command by RMSEL is ignored.

7.1.6.2 Primitive definitions

7.1.6.2.1 Primitives exchanged between ACM and RMC

Table 49 shows all of the primitives exchanged between the ACM and the RMC. Table 50 shows the primitives between the RMC and the Serializer /Deserializer; furthermore, the primitives between the RMC and the Ph-layer are shown in Table 51.

Table 49 – Primitives exchanged between ACM and RMC

Primitive name	Source	Associated parameters
RMC_SEND_DATA.req	ACM	RMSDU
RMC_SEND_DATA.conf	RMC	RMC-status
RMC_RECV_DATA.ind	RMC	RMSDU

Table 50 – Primitives exchanged between RMC and serializer / deserializer

Primitive name	Source	Associated parameters
TX_DATA_A.req	RMC	RMPDU
TX_DATA_B.req	RMC	RMPDU
TX_DATA_A.conf	Serializer_A	Status
TX_DATA_B.conf	Serializer_B	Status
RX_DATA_A.ind	Deserializer_A	RMPDU, Status
RX_DATA_B.ind	Deserializer_B	RMPDU, Status

Table 51 – Primitives exchanged between RMC and Ph-layer

Primitive name	Source	Associated parameters
PLS_CARRIER_A.indication	Ph-layer_A	CARRIER_STATUS(ON/ OFF)
PLS_SIGNAL_A.indication	Ph-layer_A	SIGNAL_STATUS(ERROR/NO _ERROR)
PLS_DATA_VALID_A.indication	Ph-layer_A	DATA_VALID_STATUS(DATA_VALID/DATA_NOT_VALID)
PLS_CARRIER_B.indication	Ph-layer_B	CARRIER_STATUS(CARRIER_ON/CARRIER_OFF)
PLS_SIGNAL_B.indication	Ph-layer_B	SIGNAL_STATUS(SIGNAL_ERROR/NO_SIGNAL_ERROR)
PLS_DATA_VALID_B.indication	Ph-layer_B	DATA_VALID_STATUS(DATA_VALID/DATA_NOT_VALID)

7.1.6.2.2 Parameters used between RMC and ACM, Ph-layer

Table 52 and Table 53 show the parameters used for interaction between the RMC and the ACM or the Ph-layer respectively.

Table 52 – Parameters between RMC and ACM

Parameter name	Description
RMSDU	Service data unit used between RMC and ACM
RMC-status	Status for result of request, condition of receiving etc
TX_ENABLE	Enable/Disable control for data transmission

Table 53 – Parameters between RMC and Ph-layer

Parameter name	Description
CARRIER_STATUS	Status for condition of carrier signal on or not over medium
SIGNAL_STATUS	Status for collision happened
DATA_VALID_STATUS	Status for received data available

7.1.6.3 RMC state table

7.1.6.3.1 State table for sending and send arbitration

Figure 24 shows the state transition diagram of the RMC sending and send arbitration. The state table of the RMC sending is shown in Table 54, and furthermore the state table of the RMC send arbitration is shown in Table 55.

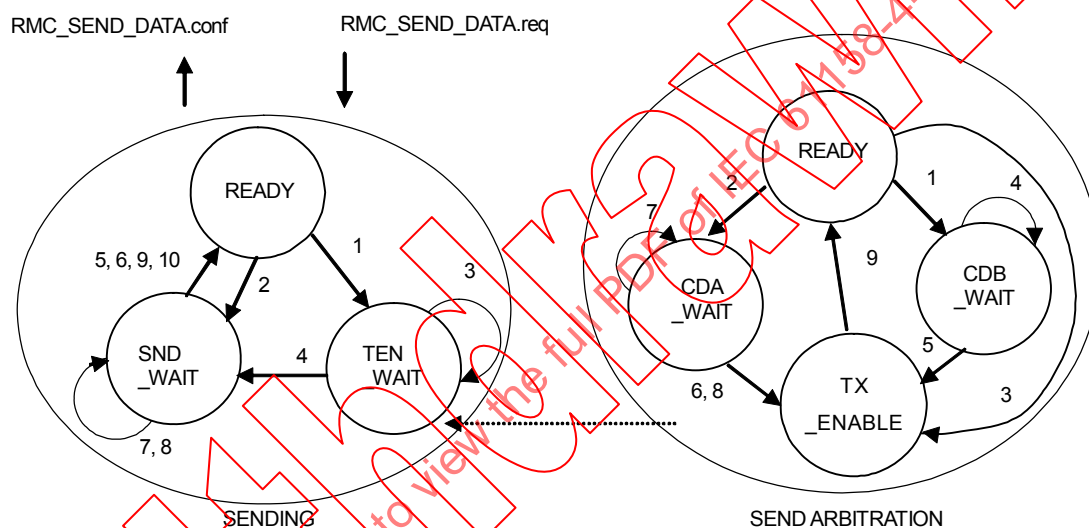
**Figure 24 – State transition diagram of RMC sending and send arbitration**

Table 54 – State table of RMC sending

#	Current state	Event /condition ⇒actions	Next state
1	READY	RMC_SEND_DATA.req { RMSDU } / RMC_STATE <> "TX_ENABLE" ⇒ (no action)	TEN_WAIT
2	READY	RMC_SEND_DATA.req { RMSDU } / RMC_STATE = "TX_ENABLE" ⇒ ----- Under transmission enable SNDC = TX_DATA_AB (RMSDU)	SND_WAIT
3	TEN_WAIT	/ RMC-STATE <> "TX_ENABLE" ⇒ (no action)	TEN_WAIT
4	TEN_WAIT	/ RMC_STATE = "TX_ENABLE" ⇒ ----- Channel A into transmission enable SNDC = TX_DATA_AB (RMSDU)	SND_WAIT
5	SND_WAIT	TX_DATA_A.conf { } / SNDC = 1 ⇒ -----Transmission completed through Channel A RMC_SEND_DATA.conf { RMC-status := "success"}	READY
6	SND_WAIT	TX_DATA_B.conf { } / SNDC = 1 ⇒ -----Transmission completed through Channel B RMC_SEND_DATA.conf { RMC-status := "success"}	READY
7	SND_WAIT	TX_DATA_A.conf { } / SNDC = 2 ⇒ ---- Transmission completed on Channel A but B incomplete SNDC := SNDC - 1	SND_WAIT
8	SND_WAIT	TX_DATA_B.conf { } / SNDC = 2 ⇒ --- Transmission completed on Channel B but A incomplete SNDC := SNDC - 1	SND_WAIT
9	SND_WAIT	TX_DATA_A.conf { } / SNDC = 0 ⇒ -----Transmission completed through Channel A RMC_SEND_DATA.conf { RMC-status := "fail"}	READY
10	SND_WAIT	TX_DATA_B.conf { } / SNDC = 0 ⇒ -----Transmission completed through Channel B RMC_SEND_DATA.conf { RMC-status := "fail"}	READY

Table 55 – State table of RMC send arbitration

#	Current state	Event /condition ⇒actions	Next state
1	READY	PLS_CARRIER_A.indication { CARRIER_STATUS (OFF) } / ⇒ ----- Carrier Off over medium A START_TIMER (T(AIGP _A)) START_TIMER (T(ARMGP))	CDB_WAIT
2	READY	PLS_CARRIER_B.indication { CARRIER_STATUS (OFF) } / ⇒ ----- Carrier Off over medium B START_TIMER (T(AIGP _B)) START_TIMER (T(ARMGP))	CDA_WAIT
3	CDB_WAIT	EXPIRED_TIMER (T(AIGPT)) = "True" / ⇒ ----- No transmission from Channel A	TX_ENABLE
4	CDB_WAIT	PLS_CARRIER_B.indication { CARRIER_STATUS (OFF) } / ⇒ ----- No transmission from both Channel A and B START_TIMER (T(AIGP _B)) STOP_TIMER (T(ARMGP))	CDB_WAIT
5	CDB_WAIT	EXPIRED_TIMER (T(AIGP _B)) = "True" / ⇒ ----- Inter-packet-gap time elapsed over channel B	TX_ENABLE
6	CDA_WAIT	EXPIRED_TIMER (T(ARMGP)) = "True" / ⇒ ----- No transmission from Channel A	TX_ENABLE
7	CDA_WAIT	PLS_CARRIER_A.indication { CARRIER_STATUS (OFF) } / ⇒ ----- Carrier Off over both medium A and B START_TIMER (T(AIGP _A)) STOP_TIMER (T(ARMGP))	CDB_WAIT
8	CDB_WAIT	EXPIRED_TIMER (T(AIGP _A)) = "True" / ⇒ ----- Inter-packet-gap time elapsed over channel A	TX_ENABLE
9	TX_ENABLE	⇒ ----- Signal TX_ENABLE to Sending state machine	READY

NOTE 1 When DLPDUs are received from the ACM, the RMC breaks them down into octet symbol requests to both Octet Serializers so that the DLPDUs are send-out over both of the transmission media A and B simultaneously.

NOTE 2 If a collision has happened while sending-the DLPDUs over one of two transmission media, the data transmission over which the collision happened is stopped immediately and the JAM signal specified by ISO/IEC 8802-3 is sent for the next DLPDU ready to be sent. Nevertheless if on another transmission medium, no collision happens, the data transmission over the transmission medium is continued without interruption.

NOTE 3 If a collision has happened over both transmission media, the JAM signal is sent over both transmission media. In that case, there happens no re-transmission.

NOTE 4 Both cases of Note 2 and Note 3 are carried out on the basis of DLPDU by the DLE.

NOTE 5 TX_ENABLE signal is actually activated by the later of the expired timing of T(GPA) and T(GPB).

NOTE 6 After one of T(AIGP*) expires and a further wait for T(ARMGP) expires, if not received when the other T(AIGP*) is expired, the RMC decides the corresponding channel enters into abnormal condition. The reestablishment from abnormal state is by the expiration signal of the T(AIGP*) received.

7.1.6.3.2 State table for RMC receiving

Figure 25 depicts the state transition diagram of the RMC receiving, and the state table of the RMC receiving is shown in Table 56.

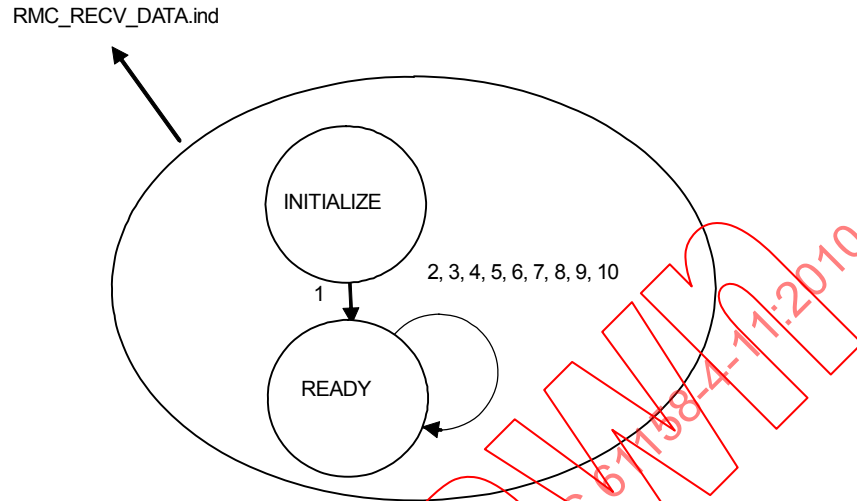


Figure 25 – State transition diagram of RMC receiving

Table 56 – State table for RMC receiving

#	Current state	Event /condition ⇒actions	Next state
1	INITIALIZE	POWER-ON or RESET / ⇒ RCVM := DECIDE_RCVM () ----- Determine Receive channel	READY
2	READY	FORCE_RCVM(RCS) / ⇒ RCVM := DECIDE_RCVM ()	READY
3	READY	RX_DATA_A.ind { RMPDU } / RCVM = MEDIA-A && Status := NORMAL && RMPDU = "SYN" frame ⇒ LAST_RMA := NORMAL RMSDU := RMPDU RMC_RECV_DATA.ind { RMSDU } RCVM := DECIDE_RCVM ()	READY
4	READY	RX_DATA_A.ind { RMPDU } / RCVM = MEDIA-A && Status := "NORMAL" ⇒ LAST_RMA := "NORMAL" RMSDU := RMPDU RMC_RECV_DATA.ind { RMSDU }	READY
5	READY	RX_DATA_A.ind { RMPDU } / RCVM <> MEDIA-A && Status := "NORMAL" ⇒ LAST_RMA := "NORMAL"	READY

#	Current state	Event /condition ⇒actions	Next state
6	READY	RX_DATA_A.ind { RMPDU } / Status := "ERROR" ⇒ LAST_RMA := ERROR RCVM := DECIDE_RCVM ()	READY
7	READY	RX_DATA_B.ind { RMPDU } / RCVM = MEDIA-B && Status := "NORMAL" && RMPDU = "SYN" frame ⇒ LAST_RMB := "NORMAL" RMSDU := RMPDU RMC_RECV_DATA.ind { RMSDU } RCVM := DECIDE_RCVM ()	READY
8	READY	RX_DATA_B.ind { RMPDU } / RCVM = MEDIA-B && Status := "NORMAL" ⇒ LAST_RMB := "NORMAL" RMSDU := RMPDU RMC_RECV_DATA.ind { RMSDU }	READY
9	READY	RX_DATA_B.ind { RMPDU } / RCVM <> MEDIA-B && Status := "NORMAL" ⇒ LAST_RMB := "NORMAL"	READY
10	READY	RX_DATA_A.ind { RMPDU } / Status := "ERROR" ⇒ LAST_RMB := "ERROR" RCVM := DECIDE_RCVM ()	READY
NOTE 1 At initial stage the Receive-Media A is selected. NOTE 2 Switching control by "FORCE_RCV()" is executed immediately after receiving the command. NOTE 3 Switching policy is as follows: — Receive-Media A or B is selected according to "Manual-select"; — Receive-Media A or B is selected according to the mode specified by the RMSEL in the SYN DLPDU received; — Once selected and without any error happening, the selected Receive-Media is maintained; — If any error happens, the other Receive-Media is selected.			

7.1.6.4 Functions used by RMC

The functions used by the RMC are summarized in Table 57.

Table 57 – RMC function table

Function name	Description and operation
EXPIRED_TIMER (T(X))	When the requested timer x has expired, "True" is returned; otherwise, "False" is returned
FORCE_RCV (RCS)	if RCS:= Force_A then RCV := MEDIA-A endif if RCS := Force_B then RCV = MEDIA-B if RCS := Automatic then RCV := DECIDE_RCV()
START_TIMER (v(t))	Activate the timer specified . STOP_TIMER() forces to stop the timer specified and running. "Expired Timer" event happens at the time that a designated timer expired
STOPT_TIMER(v(t))	Forcibly stop the timer specified
DECIDE_RCV ()	Receive-media is selected by "FORCE_RECV", "Manual-select", "RMSEL in SYN DLPDU" and is switched on a condition basis of previous DLPDU received under "Automatic" mode Switching control is executed in the order of descending priority of "FORCE_RCV", "Manual-select", "RMSEL in SYN DLPDU" and a condition basis under "Automatic" mode. If FORCE_RCV(RCS := MEDIA-A or := MEDIA-B) then return MEDIA-A or MEDIA-B else if "Manual-select" := MEDIA-A then return MEDIA-A endif else if "Manual-select" := MEDIA-B then return MEDIA-B endif else if RMSEL of SYN DLPDU := MEDIA-A then return MEDIA-A endif else if RMSEL of SYN DLPDU := MEDIA-B then return MEDIA-B endif else if RCV := MEDIA-A && LAST_RMA <> NORMAL then return MEDIA-B endif else if RCV := MEDIA-B && LAST_RMB <> NORMAL then return MEDIA-A endif endif
TX_DATA_AB (PDU)	Send the PDU out over both Media-A and B at the same time, however it is prohibited to send out over the Media banned. The requested counts of TX_DATA_A or B. request is returned. sndc:= 0; if Media-A is permitted to send out then TX_DATA_A.req { PDU } sndc := sndc + 1 endif if Media-B is permitted to send out then TX_DATA_B.req { PDU } sndc := sndc + 1 endif return sndc

7.2 DLE elements of procedure for loop-architecture

7.2.1 Overall structure

Figure 26 depicts the overall structure of the DLL. The DLL is composed of control elements of Cyclic-transmission-TX/RX-control (CTRC), Sporadic-TX/RX-control (STRC), Access-control-machine (ACM), Redundancy-medium-control (RMC), TX/RX-framer, Octet-serializer /-deserializer and DLL-management-interface.

The ACM as the primary control element provides the function for deterministic medium access control cooperating with the CTRC, the STRC and the RMC for reliable and efficient support both of higher-level connection-mode and connection-less mode data transfer services.

The DLL management interface provides DLL management functions.

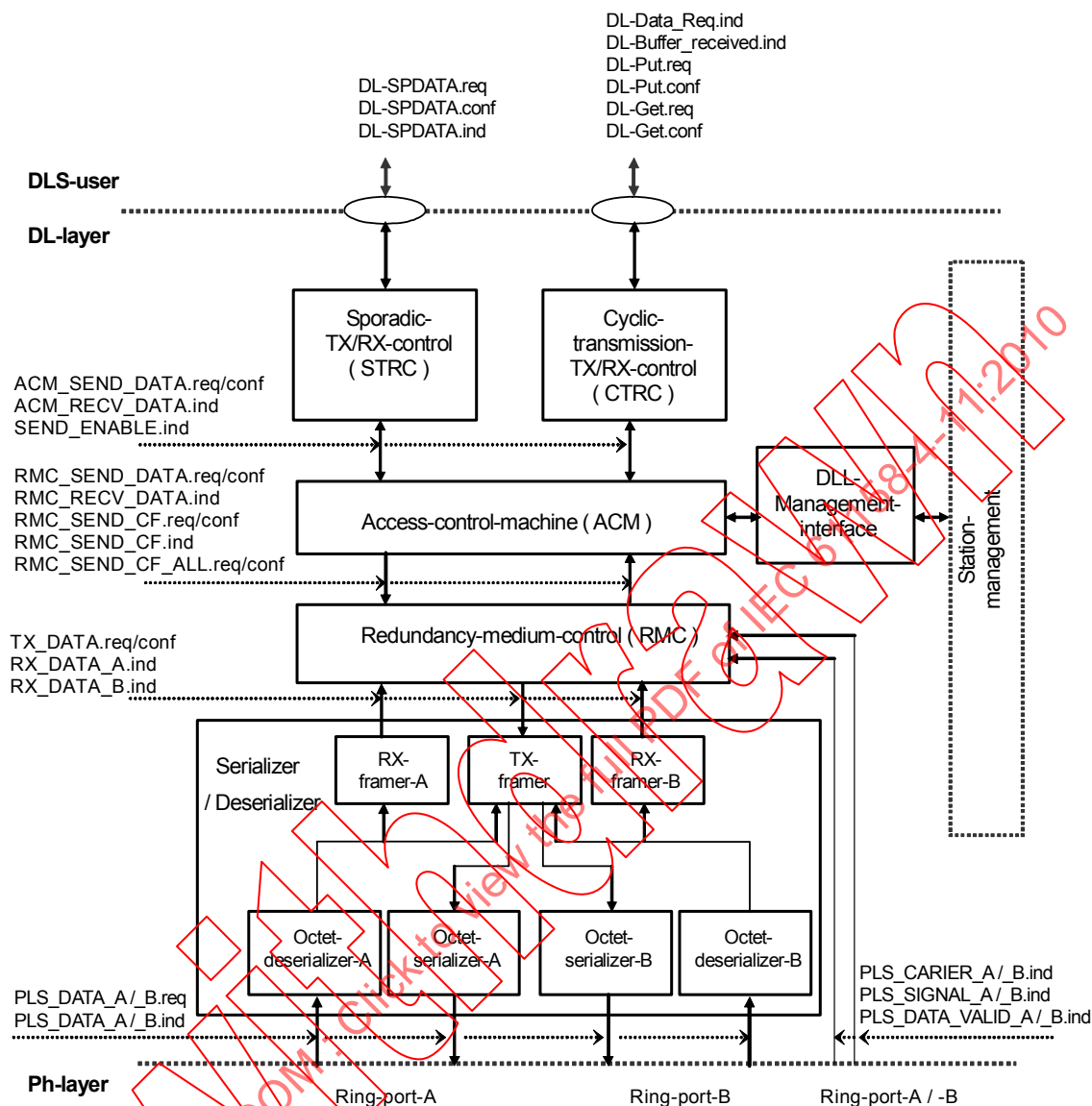


Figure 26 – Overall structure of DLL

7.2.2 Initialization

Upon power-up or after the reception of the DLM-RESET request primitive, the DLE shall go into the OFF-LINE state. When in OFF-LINE, the DLE shall not transmit and shall ignore any DLPDU received.

When all the variables for normal DLE operation are set up by the DLM-Set-Value request primitive, the state is changed from OFF-LINE to STATION MODE CONTROL in which the DLE shall start normal DL operation.

Figure 27 depicts the DLE state transition.

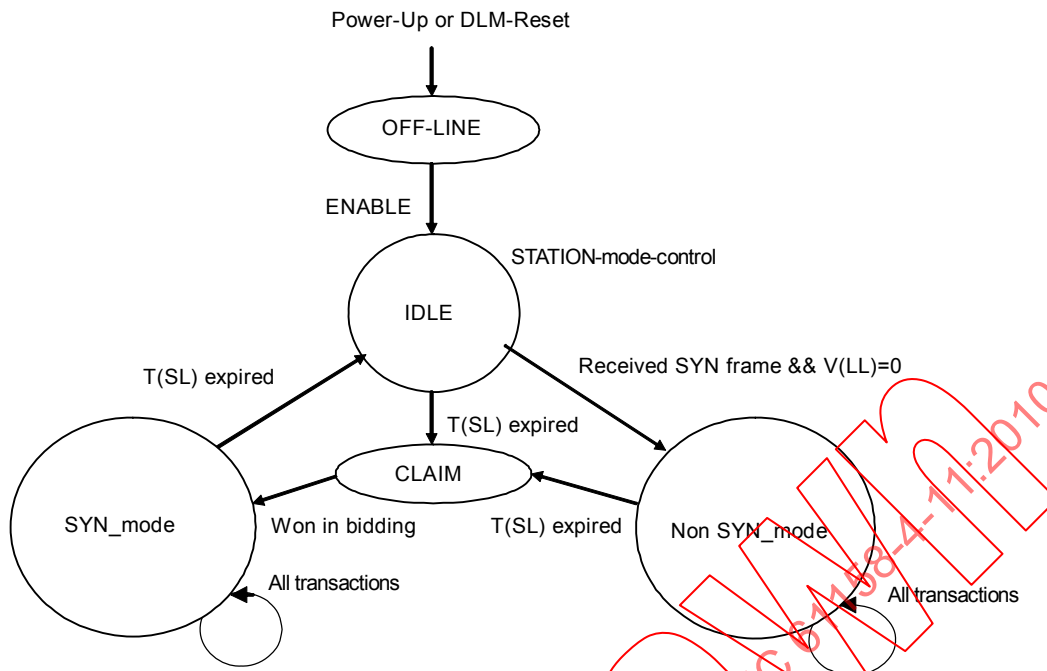


Figure 27 – DLE state transition

7.2.3 Cyclic transmission TX/RX control (CTRC)

7.2.3.1 Overview

The Cyclic-transmission-TX/RX-control(CTRC) is responsible for buffering and dispatching the DLSDU received for the Time-critical-cyclic-data-transfer between the DLS-user and the ACM.

DL-Data-Req.indication primitive by the CTRC informs the DLS-user to initiate the data transfer from each DLS-user buffer to the send buffer of the DLE using DL-Put request primitive. The DLS-user buffer is addressed with the DLCEP-identifier parameter in the DL-Data-Req indication primitive from the CTRC.

Each DLS-user buffer contains data for Time-critical-cyclic-data-transmission. After the DLS-user data received, the CTRC issues ACM_SEND_DATA request primitive to initiate ACM sending out the DLS-user data as DT or DT-CMP DLPDU.

DL-Data-Req indication primitive is issued by the CTRC in response to SEND_ENABLE indication primitive from the ACM. The Speed-class parameter in SEND_ENABLE indication primitive allows the CTRC to activate transfer of corresponding class of data-buffer by the DLS-user. The classes designated by the Speed-class parameter correspond to the classes of High-speed-cyclic-data and Medium-speed-cyclic-data transfer.

The data transfer of each Speed-class designated is dependant on the level of transfer priority:

- As for priority-class 3, which corresponds to the High-speed-cyclic-data transfer, when received SEND_ENABLE indication primitive, the CTRC shall handle all of the data of every DLS-user buffer corresponding to the High-speed-cyclic-data transfer or the High-speed-class is to be delivered to the ACM and to be sent on the transmission medium all at once on each occasion;
- As for the priority-class 2, which corresponds to the Medium-speed-cyclic-data transfer or the Medium-speed-class respectively, the CTRC shall handle on each occasion the data of every DLS-user buffer corresponding to the Medium-speed-class is sent or not depending on the condition. The token-holding-time of priority-class 2 governs the condition. After sending out all the High-speed-cyclic-data, the Medium-speed-cyclic-data

is sent. If the token-holding- time ends during sending the Medium-speed-cyclic-data, the data transfer is interrupted and the CMP DLPDU or the DT-CMP DLPDU is sent at the occasion. On the next occasion, the remainder of the previous Medium-speed-cyclic-data is to be sent depending on the same condition. As for the Lower priority-class 1, the same control as for the Medium-speed-cyclic- data transfer is to be done. The occasion happens every V(TSYN) time period.

NOTE CP 11/2 shall support 3 classes of the Speed-class. The Speed-class 3 is for the High-speed-cyclic-data transfer, the Speed-class 2 is for the Medium-speed-cyclic-data transfer and the Speed-class 1 is for the Sporadic-message-data transfer.

When the ACM_RECV_DATA indication primitive has been received from the ACM, the CTRC stores the DLPDU by the ACM into each receive-buffer, which is addressed with the DLCEP-identifier parameter in ACM_RECV_DATA indication primitive. Furthermore, the CTRC issues DL-Buffer-received indication primitive to inform the DLS-user the receive-buffer of the DLE is updated and is available to read out. The DLS-user can read out the data in the receive-buffer using DL-Get request primitive in response to DL-Buffer-received indication primitive from the CTRC.

7.2.3.2 Primitive definitions

7.2.3.2.1 Primitives exchanged between DLS-user and CTRC

The primitives exchanged between the DLS-user and the CTRC, and the primitives exchanged between the CTRC and the ACM are same as of star-architecture, and are summarized in Table 58 and Table 59 respectively.

Table 58 – Primitives exchanged between DLS-user and CTRC

Primitive name	Source	Associated parameters
DL-Data-Req.ind	CTRC	DLCEP-identifier
DL-Put.req	DL-user	DLCEP-identifier, DLSDU-length, DLSDU
DL-Put.conf	CTRC	DLCEP-identifier, Status
DL-Buffer-received.ind	CTRC	DLCEP-identifier
DL-Get.req	DL-user	DLCEP-identifier
DL-Get.conf	CTRC	DLCEP-identifier, DLSDU-length, DLSDU, Status

Table 59 – Primitives exchanged between CTRC and ACM

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	CTRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_RECV_DATA.ind	ACM	DLPDU

7.2.3.2.2 Parameters used with primitives exchanged between DLS-user and CTRC

The parameters used for interaction between the DLS-user and the CTRC are summarized in Table 60.

Table 60 – Parameters used with primitives exchanged between DLS-user and CTRC

Parameter name	Description
DLCEP-identifier	Identifier to designate the Send-Buffer or the Receive-Buffer
DLSDU	The contents of the Send-Buffer or the Receive-Buffer, which is the Time-critical- cyclic-data processed by the CTRC
DLSDU-length	The length of DLSDU
Speed-class	Speed-class to designate the class of the Time-critical-cyclic-data transfer, that is for the High-speed-cyclic-data, the Medium-speed-cyclic-data. The value of the Speed-class for the High-speed-cyclic-data is 3, and is 2 for the Medium-speed-cyclic-data
Status	Status report whether the requested service is successfully provided or failed for the reason specified

7.2.3.3 CTRC state table

The state transition diagram of the CTRC is depicted in Figure 28, and the CTRC state table is shown in Table 61.

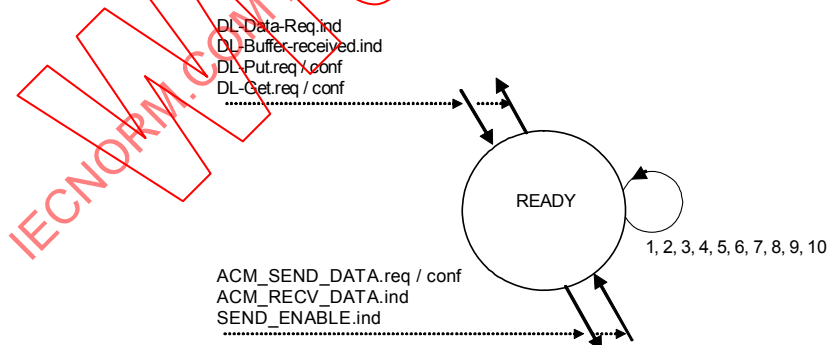


Figure 28 – State transition diagram of CTRC

Table 61 – CTRC state table

#	Current state	Event /condition =>actions	Next state
1	READY	DL-Put.req { DLCEP-identifier, DLSDU-length, DLSDU } / CHECK_PAR_PUT (DLCEP-identifier, DLSDU) = "True" => Status := "success" PUT_BUFFER (DLCEP-identifier, DLSDU) DL-Put.conf { DLCEP-identifier, DLSDU-length, Status }	READY
2	READY	DL-Put.req { DLCEP-identifier, DLSDU-length, DLSDU } / CHECK_PAR_PUT (DLCEP-identifier, DLSDU) = "False" => Status := "failure" DL-Put.conf { DLCEP-identifier, DLSDU-length, Status }	READY
3	READY	DL-Get.req { DLCEP-identifier } / CHECK_PAR_GET (DLCEP-identifier) = "True" => Status := "success" DLSDU := GET_BUFFER (DLCEP-identifier) DL-Get.conf { DLCEP-identifier, DLSDU-length, DLSDU, Status }	READY
4	READY	DL-Get.req { DLCEP-identifier } / CHECK_PAR_GET (DLCEP-identifier) = "False" => Status := "failure" DLSDU := "null" DL-Get.conf { DLCEP-identifier, DLSDU-length, DLSDU, Status }	READY
5	READY	SEND_ENABLE.ind { Speed-class } / Speed-class <> "SPORADIC" && CHECK_NEXT_SEND (Speed-class) = "True" => DLCEP-identifier := GET_NEXT_ID (Speed-class) DL-Data.req ind { DLCEP-identifier } DLSDU := GET_BUFFER (DLCEP-identifier) DLPDU := BUILD_DT (Speed-class, DLCEP-identifier, DLSDU) ACM_SEND_DATA.req { DLPDU }	READY
6	READY	SEND_ENABLE.ind { Speed-class } / Speed-class <> "SPORADIC" && CHECK_NEXT_SEND (Speed-class) = "False" => ACM_SEND_DATA.req { null } ----- no data remained to send out	READY
7	READY	ACM_RECV_DATA.ind { DLPDU } / Speed-class <> "SPORADIC" && CHECK_PAR_DT (DLPDU) = "True" => DLCEP-identifier := DLPDU.DLCEP-address DL-Buffer-received.ind { DLCEP-identifier }	READY
8	READY	ACM_RECV_DATA.ind { DLPDU } / Speed-class <> "SPORADIC" && CHECK_PAR_DT (DLPDU) = "False" => none	READY
9	READY	ACM_SEND_DATA.conf { } / DLPDU <> "null" => none	READY
10	READY	ACM_SEND_DATA.conf { } / DLPDU = "null" => NEXT (Speed-class)	READY

7.2.3.4 Functions used by CTRC

All functions of the CTRC are summarized in Table 62.

Table 62 – CTRC functions table

Function Name	Input	Output	Operation
CHECK_PAR_PUT	DLCEP-identifier, DLSDU	True/False	Check that all the parameters of DL-Put.req primitive are valid. If valid, "True" is returned, otherwise "False" is returned
PUT_BUFFER	DLCEP-identifier, DLSDU	(none)	Store DLSDU into the Send-buffer associated with the DLCEP-identifier
CHECK_PAR_GET	DLCEP-identifier	True/False	Check that DLCEP-identifier of DL-Get.req primitive is valid. If valid, "True" is returned
GET_BUFFER	DLCEP-identifier	DLSDU	Get DLSDU in the buffer associated with DLCEP-identifier
CHECK_NEXT_SEND	Speed-class	True/False	Check that the DLSDU specified by Speed-class exists. If exists, "True" is returned, otherwise "False" is returned
GET_NEXT_ID	Speed-class	DLCEP-identifier	Get next DLCEP-identifier of the DLS User-buffer specified by the Speed-class
BUILD_DT	Speed-class, DLCEP-identifier, DLSDU	DLPDU	Build into a DLPDU out of the data in the Send-buffer. DLPDU is assembled as follows: DLPDU.DA := V(MCA) DLPDU.SA := V(MA) DLPDU.Len/Type := 0x888b DLPDU.FC := Speed-class + "DT" DLPDU.SN := V(TN) DLPDU.DLCEPaddress := DLCEP-identifier DLPDU.DLSDU := DLSDU
CHECK_PAR_DT	DLPDU	True/False	Check that the DLPDU is valid. If valid, "True" is returned, otherwise "False" is returned
NEXT	Speed-class		Check that DLSDUs specified by the Speed-class exist in the Send-buffer. If exist, get the DLCEP-identifier of a DLSDU on the Send-buffer, issue DL_Data_Req.ind primitive with the obtained DLCEP-identifier to the DLS-user, and after that, repeat same sequence with new DLCEP-identifier of a DLSDU next to the DLSDU designated in the previous sequence. The process shall go in cycles to all the DLSDUs specified by the Speed-class on the Send-buffer

7.2.4 Sporadic TX/RX control (STRC)

7.2.4.1 Overview

The Sporadic-TX/RX-control (STRC) is responsible for buffering and dispatching in time DLSDU received for the Sporadic-message-data between the DLS-user and the ACM.

7.2.4.2 Primitive definitions

7.2.4.2.1 Primitives exchanged between DLS-user and STRC

Table 63 shows all primitives exchanged between the DLS-user and the STRC, and Table 64 shows all primitives exchanged between the STRC and the ACM. These primitives are same as of star-architecture.

Table 63 – Primitives exchanged between DLS-user and STRC

Primitive name	Source	Associated parameters
DL-SPDATA.req	DLS-user	DA, MSDU
DL-SPDATA.conf	DLS-user	DA, Status
DL-SPDATA.ind	STRC	DA, SA, MSDU, Rec-status

Table 64 – Primitives exchanged between STRC and ACM

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	STRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_RECV_DATA.ind	ACM	DLPDU

7.2.4.2.2 Parameters used with primitives exchanged between DLS-user and STRC

All parameters used with primitives exchanged between the DLS-user and the STRC is shown in Table 65. The parameters are same as of star-architecture.

Table 65 – Parameters used with primitives exchanged between DLS-user and STRC

Parameter name	Description
DA	Destination-address
SA	Source-address
MSDU	MAC-service-data-unit
Status	Indicate whether the requested service of DL-SPDATA.req is successfully provided or failed for the reason specified
Rec-status	Indicates whether the DLPDU had received without error or not
DLPDU	DLPDU for Sporadic-message-transfer
Speed-class	Speed-class requested by DLS-user. In Sporadic-message-transfer service, Speed-class is specified as "Sporadic" or "Class 1"

7.2.4.3 STRC state table

The state transition diagram of the STRC is depicted in Figure 29, and the STC state table is shown in Table 66.

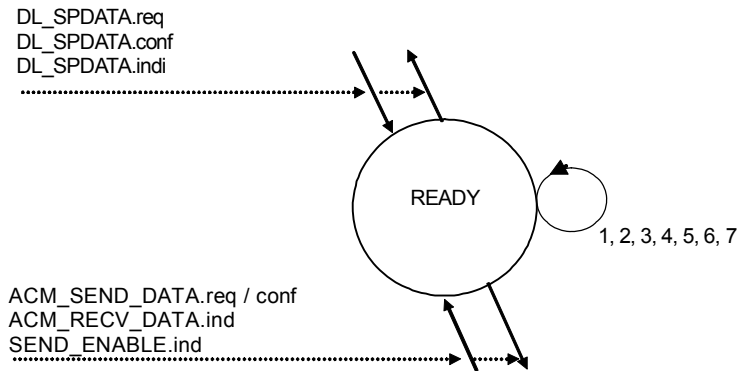


Figure 29 – State transition diagram of STRC

Table 66 – STRC state table

#	Current state	Event /condition =>actions	Next state
1	READY	DL-SPDATA.req { DA, MSDU } / CHECK_PAR_SPDATA (DA, MSDU) = "True" && CHECK_SPDATAQ () <> "Full" => QUEUE_SPDATA (DA, MSDU) DL-SPDATA.confirm { DA, MSDU, Status := "success" }	READY
2	READY	DL-SPDATA.req { DA, MSDU } / CHECK_PAR_SPDATA (DA, MSDU) = "True" && CHECK_SPDATAQ () = "Full" => Status := "Failure – The SPDATA queue is full" DL-SPDATA.conf { DA, MSDU, Status }	READY
3	READY	DL-SPDATA.req { DA, MSDU } / CHECK_PAR_SPDATA (DA, MSDU) = "False" => Status := "Failure – Invalid parameter" DL-SPDATA.confirm { DA, MSDU, Status }	READY
4	READY	SEND_ENABLE.ind {Speed-class} / Speed-class = "SPORADIC" && CHECK_SPDATAQ () <> "Empty" => MSDU := DEQUEUE_SPDATA () DLPDU := BUILD_SPDATA (DA, MSDU) ACM_SEND_DATA.req { DLPDU }	READY
5	READY	ACM_SEND_DATA.conf { } / => none	READY
6	READY	ACM_RECV_DATA.ind { DLPDU } / Speed-class = "SPORADIC" && CHECK_RECV_SPDATA (DLPDU) = "True" => DL-SPDATA.ind { DLPDU }	READY
7	READY	ACM_RECV_DATA.ind { DLPDU } / Speed-class = "SPORADIC" && CHECK_RECV_SPDATA (DLPDU) = "False" => none	READY

7.2.4.4 Functions used by STRC

All functions of the STRC are summarized in Table 67.

Table 67 – STRC functions table

Function name	Input	Output	Operation
CHECK_PAR_SPDATA	DA, MSDU	True/False	Check that all the parameters of DL-SPDATA.req are valid. If valid, "True" is returned, otherwise "False" is returned
CHECK_SPDATAQ	(none)	Status	Check that the queue condition for SPDATA is full. The returned status is any one of "Full", "Empty" and "Queued"
QUEUE_SPDATA	DA, MSDU	(none)	Queues the input data into the SPDATA-queue on First-In-First-Out basis
DEQUEUE_SPDATA	(none)	DA, MSDU	Dequeue from the SPDATA-queue on First-In-First-Out basis
BUILD_SPDATA	DA, MSDU	DLPDU	Build into a DLPDU of Sporadic-message-data. The DLPDU is assembled as follows: DLPDU.DA := MSDU.DA DLPDU.SA := V(IA) DLPDU.Len/Type := MSDU.Len/Type DLPDU.MSDU := MSDU.DLSDU
CHECK_RCV_SPDATA	DLPDU	True/False	Check that the specified DLPDU is valid. If valid, "True" is returned, otherwise "False" is returned

7.2.5 Access control machine (ACM)

7.2.5.1 Overview

The access-control-machine (ACM) is responsible for deterministic medium-access-control and scheduling opportunities to send out the DLPDUs, for control to add and remove nodes and for restoration from network disruption to be system down.

The ACM has the primary responsibility for

- assuring that the local node detects and fully utilizes its assigned access time period;
- assuring that the local node does not interfere with the transmissions of other nodes, especially of the node transmitting the SYN DLPDU;
- detecting network disruption, and initiating the SYN DLPDU transmit for restoration of the network disruption from after prescribed time duration in which the SYN DLPDU is not heard;
- assuring a new node adding to and removing from the network.

7.2.5.2 ACM and the schedule support functions

The ACM functions schedule all communications between the DLEs participating in the Type 11/2 fieldbus, and the timing of this communications is controlled as to:

- fulfill the specific medium-access-control to give all the DLEs the opportunities to send out two kinds of class of the Time-critical-cyclic data and Sporadic-message data in timely, prioritized and deterministic fashion, and to detect the network disruption, and to initiate the restoration in appropriate time, and further to add and remove the nodes on line;
- provide 2 levels of the Time-critical-data-transfer opportunities of sending data to the node in sequential order and within each pre-specified time period, and that the data transfer of each level is performed within the pre-specified time duration (token holding time) and whether the data transfer of lower levels to be carried out or to be held over to the later cyclic time period depends on the level and the occasion though the top level of the data transfer is always carried out at every occasion, on the other hand, the whole volume of the data transfer of lower levels is transferred within each pre-specified time period;
- provide the sporadic-message-data-transfer opportunities of sending out to the node that the request to transfer is happened sporadically by the DLS-user, and the data transfer is

performed within a pre-specified time period of the corresponding level of priority and is based on the regular ISO/IEC 8802-3 applications.

7.2.5.3 Primitive definitions

7.2.5.3.1 Primitives exchanged between ACM and RMC

Table 68 lists all primitives and Table 69 shows the parameters used with the primitives exchanged between the ACM and the RMC.

Table 68 – Primitives exchanged between ACM and RMC

Primitive name	Source	Associated parameters
RMC_SEND_DATA.req	ACM	RMSDU
RMC_SEND_DATA.conf	RMC	RMC-status
RMC_RECV_DATA.ind	RMC	RMSDU
RMC_SEND_CF.req	ACM	RMSDU
RMC_SEND_CF.conf	RMC	RMC-status
RMC_SEND_CF.ind	RMC	RMC-status
RMC_SEND_CF_ALL.req	ACM	RMSDU
RMC_SEND_CF_ALL.conf	RMC	RMC-status

Table 69 – Parameters used with primitives exchanged between ACM and RMC

Parameter name	Description
RMSDU	SDU of RMC
RMC-status	Status indicating the results of the request to RMC

7.2.5.3.2 Primitives exchanged between ACM and CTRC

Table 70 lists all primitives and Table 71 shows the parameters used with the primitives exchanged between the ACM and the CTRC.

Table 70 – Primitives exchanged between ACM and CTRC

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	CTRC	DLPDU
ACM_SEND_DATA.conf	ACM	ACM-status
ACM_RECV_DATA.ind	ACM	DLPDU

Table 71 – Parameters used with primitives exchanged between ACM and CTRC

Parameter name	Description
ACM-status	Status indicating the results of the request to ACM
DLPDU	SDU of ACM
Speed-class	Speed-class indicating Time-critical Cyclic-data-transmission

7.2.5.3.3 Primitives exchanged between ACM and STRC

Table 72 lists all primitives and Table 73 shows the parameters used with the primitives exchanged between the ACM and the STRC.

Table 72 – Primitives exchanged between ACM and STRC

Primitive name	Source	Associated parameters
SEND_ENABLE.ind	ACM	Speed-class
ACM_SEND_DATA.req	STRC	DLPDU
ACM_SEND_DATA.conf	ACM	Status
ACM_SEND_DATA.ind	ACM	DLPDU

Table 73 – Parameters used with primitives exchanged between ACM and STRC

Parameter name	Description
ACM-Status	Status indicating the results of the request to ACM
DLPDU	SDU of AMC
Speed-class	Speed class indicating Time-critical Cyclic data transmission

7.2.5.4 ACM state table

The state transition diagram is shown in Figure 30.

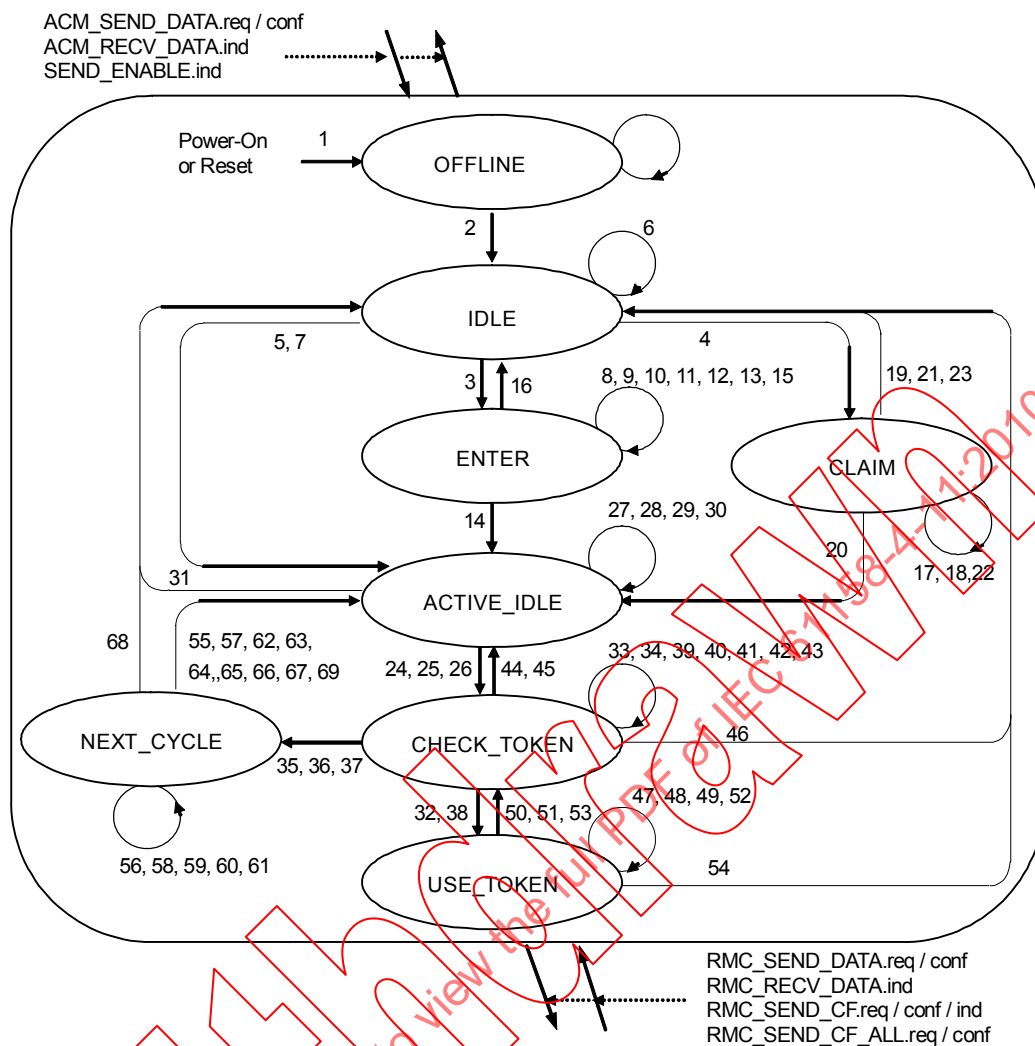


Figure 30 – State transition diagram of ACM

The state "OFFLINE" is entered on power-up or when DLM-Reset.request primitive is issued. In this state, all of the variables, parameters and configuration information are set up by the DLE. When "In_Ring_Desire" becomes true, the state changes to "IDLE".

The state "IDLE" is to wait and be ready to join the type 11 fieldbus membership. When a SYN DLPDU has been received from another SYN-node, the state change to "ENTER" in which the REQ DLPDU is sent to claim adding into the type 11 fieldbus membership to the current SYN-node. Moreover, in "IDLE" state, when the signals over the transmission-media continues to be inactive during a specified time period, the state becomes "CLAIM", in which the node attempts to be a new SYN-node.

The state "ACTIVE_IDLE" is in the type 11 fieldbus membership, and the node manages to obtain the transmission-right by the type 11 fieldbus medium-access-control, either when the node is operating as the SYN-mode by transmitting the SYN DLPDU or as the non-SYN-mode receiving the SYN DLPDU by other SYN-node, the state is in "CHECK_TOKEN".

The state "CHECK_TOKEN" waits until $V(LN)$ becomes equal to $V(TN)$ in order to send out the data over the transmission media. When $V(LN)$ becomes equal to $V(TN)$, the state changes to "USE_TOKEN".

The state “USE_TOKEN” is that the node is able to send out the Time-critical cyclic-transmission data and the Sporadic-transmission data. When all data has been sent or the token-holding-time is expired, the state changes to “NEXT_CYCLE”.

The state “NEXT_CYCLE” is for solicit new node as a primary function.

The ACM state table is shown in Table 74.

Table 74 – ACM state table

#	Current state	Event /condition =>actions	Next State
1	Any states	/ POWER-ON or RESET =>	OFFLINE
2	OFFLINE	/ In_Ring_Desired = "True" => START_TIMER (T(SL), V(SL))	IDLE
3	IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && V(LL) = 0 => -- receiving SYN and LL is not alive -- SYN_frame := RMSDU V(LL) := SYN_frame.LL V(LN) := 1 START_TIMER (T(SL), V(SL))	ENTER
4	IDLE	/ EXPIRED_TIMER (T(SL)) = "True" && V(LL) = 0 => ----sending out CLM All_Slot_Time := V(ST) RMSDU := BUILD_PDU (CLM) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	CLAIM
5	IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && V(LL) <> 0 && V(LL)<V(TN)> = "True" => -- receiving SYN and this node is alive -- SYN_frame := RMSDU V(LL) := SYN_frame.LL V(LN) := 1 START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
6	IDLE	RMC_SEND_CF.ind { } / V(LL) <> 0 && V(LL)<V(TN)> = "True" && V(LN) = V(TN) => -----activate sending out LRR RMSDU := BUILD_PDU (LRR) RMS_SEND_CF.req { RMSDU } START_TIMER (T(SL), V(SL))	IDLE
7	IDLE	RMS_SEND_CF.conf { } / RMSDU.FC = LRR => none	ACTIVE_IDLE
8	ENTER	/ V(LL)<V(LN)> = 1 && V(LN) <> V(TN) => START_TIMER (T(SCMP), V(SCMP))	ENTER
9	ENTER	/ V(LL)<V(LN)> = 0 && V(LN) <> V(MN) => V(LN)++	ENTER

#	Current state	Event /condition =>actions	Next State
10	ENTER	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = (CMP DT-CMP) && V(LN) = V(MN) && V(LL)<V(TN)> = "False" && SYN_frame.PN = V(TN) => RMSDU := BUILD_PDU (REQ) -----send REQ RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	ENTER
11	ENTER	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = (CMP DT-CMP) && V(LN) <> V(MN) => -- Live Node less than Maximum Node No. -- V(LN)++	ENTER
12	ENTER	/ V(LN) = V(MN) && V(LL)<V(TN)> = "False" && SYN_frame.PN = V(TN) => RMSDU := BUILD_PDU (REQ) -----send REQ RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	ENTER
13	ENTER	RMC_SEND_DATA.conf { } => none	ENTER
14	ENTER	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && V(LL)<V(TN)> = "True" => SYN_frame := RMSDU V(LL) := SYN_frame.LL V(LN) := 1 START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
15	ENTER	/ EXPIRED_TIMER (T(SCMP)) = "True" => V(LN)++	ENTER
16	ENTER	/ EXPIRED_TIMER (T(SL)) = "True" => -- Expired Silence Timer -- START_TIMER (T(SL), V(SL))	IDLE
17	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "False" && All_Slot_Time > 0 => All_Slot_Time-- START_TIMER (T(SL), V(SL)) START_TIMER (T(IGP), V(IGP))	CLAIM
18	CLAIM	/ EXPIRED_TIMER (T(IGP)) = "True" => RMSDU:=BUILD_PDU (CLM) RMC_SEND_DATA.req { RMSD } START_TIMER (T(SL), V(SL))	CLAIM
19	CLAIM	RMC_SEND_DATA.ind {RMSDU} / RMSDU.FC = (SYN CLM) => START_TIMER (T(SL), V(SL)) STOP_TIMER (T(IGP))	IDLE
20	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "False" && All_Slot_Time = 0 => All_Slot_Time := V(ST) V(LL) = 0 V(LL)<V(TN)> := 1 RMSDU := BUILD_PDU (SYN) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE

#	Current state	Event /condition =>actions	Next State
21	CLAIM	RMC_SEND_DATA.conf { } / CHECK_COL () = "True" => All_Slot_Time := V(ST) START_TIMER (T(SL), V(SL))	IDLE
22	CLAIM	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC <> (SYN CLM) => -- receiving a frame except SYN, CLM -- START_TIMER (T(SL), V(SL))	CLAIM
23	CLAIM	EXPIRED_TIMER (T(SL)) = "True" => -- Expired Silence Timer -- V(LL) := 0 START_TIMER (T(SL), V(SL))	IDLE
24	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && SYN_mode = "False" => --- receiving SYN in non-SYN_mode---- SYN_frame := RMSDU V(LL) := SYN_frame.LL V(LN) := 1	CHECK_TOKEN
25	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = SYN && SYN_mode = "True" => ---Receiving SYN in SYN_mode----- SYN_Frame := RMSDU if SYN_frame.SN < V(TN) then SYN_mode := 0 V(LL) := SYN_frame.LL V(LN) := 1 endif	CHECK_TOKEN
26	ACTIVE_IDLE	RMC_SEND_DATA.conf { } / RMSDU.FC = SYN && CHECK_COL () = "False" => -- sent SYN ---- SYN_mode := 1 V(LN) := 1	CHECK_TOKEN
27	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CLM && SYN_mode = "True" => SYN_mode := 0 START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
28	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CLM && SYN_mode = "False" => none	ACTIVE_IDLE
29	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = (DT DT-CMP) => -- receiving DT frame-- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
30	ACTIVE_IDLE	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC <> Type-11 fieldbus FRAME => -- Receiving SPORADIC Frame -- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
31	ACTIVE_IDLE	/ EXPIRED_TIMER (T(SL)) = "True" => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE

#	Current state	Event /condition =>actions	Next State
32	CHECK_TOKEN	/ V(LL)<V(TN)> = 1 && V(LN) = V(TN) => ----- Get token ----- STOP_TIMER (T(SCMP)) Speed-class := 3 -----Highest-priority-class START_THT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
33	CHECK_TOKEN	/ V(LL)<V(LN)> = 1 && V(LN) <> V(TN) => START_TIMER (T(SCMP), V(SCMP))	CHECK_TOKEN
34	CHECK_TOKEN	/ V(LL)<V(LN)> = 0 && V(LN) <> V(MN) => V(LN)++	CHECK_TOKEN
35	CHECK_TOKEN	/ V(LN) = V(MN) && SYN_frame.PN <> V(TN) && SYN_mode = "True" => ---- in SYN-mode, on MAC-control-time-period ---- START_TIMER (T(TMAC), V(TMAC))	NEXT_CYCLE
36	CHECK_TOKEN	/ V(LN) = V(MN) && SYN_frame.PN = 255 && V(LL)<V(TN)> = "True" => RMSDU := BUILD_PDU (LPD) -----send LPD RMC_SEND_CF_ALL.req { RMSDU } START_TIMER (T(TMAC), V(TMAC)) START_TIMER (T(SL), V(SL))	NEXT_CYCLE
37	CHECK_TOKEN	/ V(LN) = V(MN) && SYN_frame.PN = V(TN) && V(LL)<V(TN)> = "True" => RMSDU := BUILD_PDU (RAS) -----send RAS RMC_SEND_DATA.req { RMSDU } START_TIMER (T(TMAC), V(TMAC)) START_TIMER (T(SL), V(SL))	NEXT_CYCLE
38	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = (CMP DT-CMP) && V(LN)++ = V(TN) => -- Get token -- ----- matching V(LN), on receiving CMP or DT-CMP STOP_TIMER (T(SCMP)) C(ASCMP)<RMSDU.SN> := 0 Speed-class := 3 -- Highest Priority START_THT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL)) if RMSDU.FC = DT-CMP then ACM_RECV_DATA.ind { RMSDU } endif	USE_TOKEN
39	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = (CMP DT-CMP) && V(LN)++ <> V(TN) =>--not matching V(LN).on receiving CMP or DT-CMP START_TIMER (T(SCMP), V(SCMP)) C(ASCMP)<RMSDU.SN>:=0 if RMSDU.FC = DT-CMP then ACM_RECV_DATA.ind { RMSDU } endif	CHECK_TOKEN
40	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = DT => ---- receiving DT ---- C(ASCMP)<RMSDU.SN> := 0 ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN

#	Current state	Event /condition =>actions	Next State
41	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC <> Type-11 fieldbus FRAME => -- Receiving SPORADIC Frame -- ACM_RECV_DATA.ind { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
42	CHECK_TOKEN	/ EXPIRED_TIMER (T(SCMP)) => C(ASCMP)<V(LN)>++ V(ANONC)++ if SYN_mode = "True" then MAINT_LL(V(LN)) endif V(LN)++	CHECK_TOKEN
43	CHECK_TOKEN	RMC_SEND_DATA.conf { } / RMSDU.FC = (CMP DT-CMP) => -- sending CMP frame-- V(LN)++	CHECK_TOKEN
44	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CLM && SYN_mode = "True" => SYN_mode := 0 START_TIMER (T(SL), V(SL))	ACTIVE_IDLE
45	CHECK_TOKEN	RMC_RECV_DATA.ind { RMSDU } / RMSDU.FC = CLM && SYN_mode = "False" => none	ACTIVE_IDLE
46	CHECK_TOKEN	/ EXPIRED_TIMER (T(SL)) = "True" => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE
47	USE_TOKEN	ACM_SEND_DATA.req { DLPDU } / => -- send out DT or Sporadic frame -- RMSDU := BUILD_PDU (DLPDU) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	USE_TOKEN
48	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / (RMSDU.FC = DT RMSDU.FC <> Type 11 fieldbus) && EXPIRED_TIMER (T(ATHT)) = "False" => ACM_SEND_DATA.conf { RMC-status } SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
49	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / (RMSDU.FC = DT RMSDU.FC <> Type 11 fieldbus) && EXPIRED_TIMER (T(ATHT)) = "True" && Speed-class <> 1 => -- Expired THT, Next Speed class -- ACM_SEND_DATA.conf { RMC-status } Speed-class := Speed-class - 1 START_THT (Speed-class) START_TTRT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN

#	Current state	Event /condition =>actions	Next State
50	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / (RMSDU.FC = DT RMSDU.FC <> Type 11 fieldbus) && EXPIRED_TIMER (T(ATHT)) = "True" && Speed-class = 1 => ---Expired THT and Speed-class =1 ---- ACM_SEND_DATA.conf { RMC-status } RMSDU := BUILD_PDU (CMP) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
51	USE_TOKEN	RMC_SEND_DATA.conf { RMC-status } / RMSDU.FC = DT-CMP => ACM_SEND_DATA.conf { RMC-status } STOP_TIMER (T(ATHT)) Speed-class := Speed-class – 1 if Speed-class = 2 then START_TTRT (Speed-class) START_TTRT (Speed-class – 1) else if Speed-class = 1 then START_TTRT (Speed-class) endif	CHECK_TOKEN
52	USE_TOKEN	ACM_SEND_DATA.req { null } / Speed-class <> 1 => -- Next Speed-class -- Speed-class := Speed-class -1 START_THT (Speed-class) START_TTRT (Speed-class) SEND_ENABLE.ind { Speed-class } START_TIMER (T(SL), V(SL))	USE_TOKEN
53	USE_TOKEN	ACM_SEND_DATA.req { null } / Speed-class = 1 => -- All sent -- RMSDU := BUILD_PDU (CMP) RMC_SEND_DATA.req { RMSDU } START_TIMER (T(SL), V(SL))	CHECK_TOKEN
54	USE_TOKEN	EXPIRED_TIMER (T(SL)) = "True" / => -- expired Silence Timer - SYN_mode := "False" START_TIMER (T(SL), V(SL))	IDLE
55	NEXT_CYCLE	RMC_SEND_CF_ALL.conf { } / RMSDU.FC = LPD => none	ACTIVE_CYCLE
56	NEXT_CYCLE	RMC_SEND_DATA.conf { } / RMSDU.FC = RAS && SYN_frame.PN = V(TN) && SYN_mode = "True" => START_TIMER (T(IGP), V(IGP))	NEXT_CYCLE
57	NEXT_CYCLE	RMC_SEND_DATA.conf { } / RMSDU.FC = RAS && SYN_frame.PN = V(TN) && SYN_mode = "False" => if ACM_SEND_DATA.req { COM } then START_TIMER (T(IGP), V(IGP)) else none endif	ACTIVE_CYCLE
58	NEXT_CYCLE	/EXPIRED_TIMER (T(IGP)) = "True" && SYN_mode = "False" => RMSDU := BUILD_PDU (COM) ----send COM RMC_SEND_DATA.req { RMSDU }	NEXT_CYCLE