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

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

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IEC draws attention to the fact that it is claimed that compliance with this standard may involve the use of patents as follows, where the [xx] notation indicates the holder of the patent right:

Type 11 and possibly other Types:

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

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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 first edition and its companion parts of the IEC 61158-4 subseries cancel and replace IEC 61158-4:2003. This edition of this part constitutes a technical addition. This part and its Type 11 companion parts also cancel and replace IEC/PAS 62406, published in 2005.

This edition of IEC 61158-4 includes the following significant changes from the previous edition:

a) deletion of the former Type 6 fieldbus, and the placeholder for a Type 5 fieldbus data link layer, for lack of market relevance;
b) addition of new types of fieldbuses;
c) division of this part into multiple parts numbered -4-1, -4-2, ..., -4-19.

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

FDIS	Report on voting
65C/474/FDIS	65C/485/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.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn;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.

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

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.

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

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

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Basic Reference Model – 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 standard, 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 [7498-3]

3.1.2 calling-DL-address [7498-3]

3.1.3 centralized multi-end-point-connection [7498-1]

3.1.4 correspondent (N)-entities [7498-1]
correspondent DL-entities (N=2)
correspondent Ph-entities (N=1)

3.1.5 demultiplexing [7498-1]

3.1.6 DL-address [7498-3]

3.1.7 DL-address-mapping [7498-1]

3.1.8 DL-connection [7498-1]

3.1.9 DL-connection-end-point [7498-1]

3.1.10 DL-connection-end-point-identifier [7498-1]

3.1.11 DL-connection-mode transmission [7498-1]

3.1.12 DL-connectionless-mode transmission [7498-1]

3.1.13 DL-data-sink [7498-1]

3.1.14 DL-data-source [7498-1]

3.1.15 DL-duplex-transmission [7498-1]

3.1.16 DL-facility [7498-1]

3.1.17 DL-local-view [7498-3]

3.1.18 DL-name [7498-3]

3.1.19 DL-protocol [7498-1]

3.1.20 DL-protocol-connection-identifier [7498-1]

3.1.21 DL-protocol-control-information [7498-1]

3.1.22 DL-protocol-data-unit [7498-1]

3.1.23 DL-protocol-version-identifier [7498-1]

3.1.24 DL-relay [7498-1]

3.1.25 DL-service-connection-identifier [7498-1]

3.1.26 DL-service-data-unit [7498-1]

3.1.27 DL-simplex-transmission [7498-1]

3.1.28 DL-subsystem [7498-1]

3.1.29 DL-user-data [7498-1]

3.1.30 flow control [7498-1]

3.1.31 layer-management [7498-1]

3.1.32 multiplexing [7498-3]

3.1.33 naming-(addressing)-authority [7498-3]

3.1.34 naming-(addressing)-domain [7498-3]

3.1.35 naming-(addressing)-subdomain [7498-3]

3.1.36 (N)-entity [7498-1]
DL-entity
Ph-entity

3.1.37 (N)-interface-data-unit [7498-1]
DL-service-data-unit (N=2)
Ph-interface-data-unit (N=1)

3.1.38 (N)-layer [7498-1]
DL-layer (N=2)
Ph-layer (N=1)

3.1.39 (N)-service [7498-1]
DL-service (N=2)
Ph-service (N=1)

3.1.40 (N)-service-access-point [7498-1]
DL-service-access-point (N=2)
Ph-service-access-point (N=1)

3.1.41 (N)-service-access-point-address [7498-1]
DL-service-access-point-address (N=2)
Ph-service-access-point-address (N=1)

3.1.42 peer-entities [7498-1]

3.1.43 Ph-interface-control-information [7498-1]

3.1.44 Ph-interface-data [7498-1]

3.1.45 primitive name [7498-3]

3.1.46 reassembling [7498-1]

3.1.47 recombining [7498-1]

3.1.48 reset [7498-1]

3.1.49 responding-DL-address [7498-3]

3.1.50 routing [7498-1]

3.1.51 segmenting [7498-1]

3.1.52 sequencing [7498-1]

3.1.53 splitting [7498-1]

3.1.54 synonymous name [7498-3]

3.1.55 systems-management [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

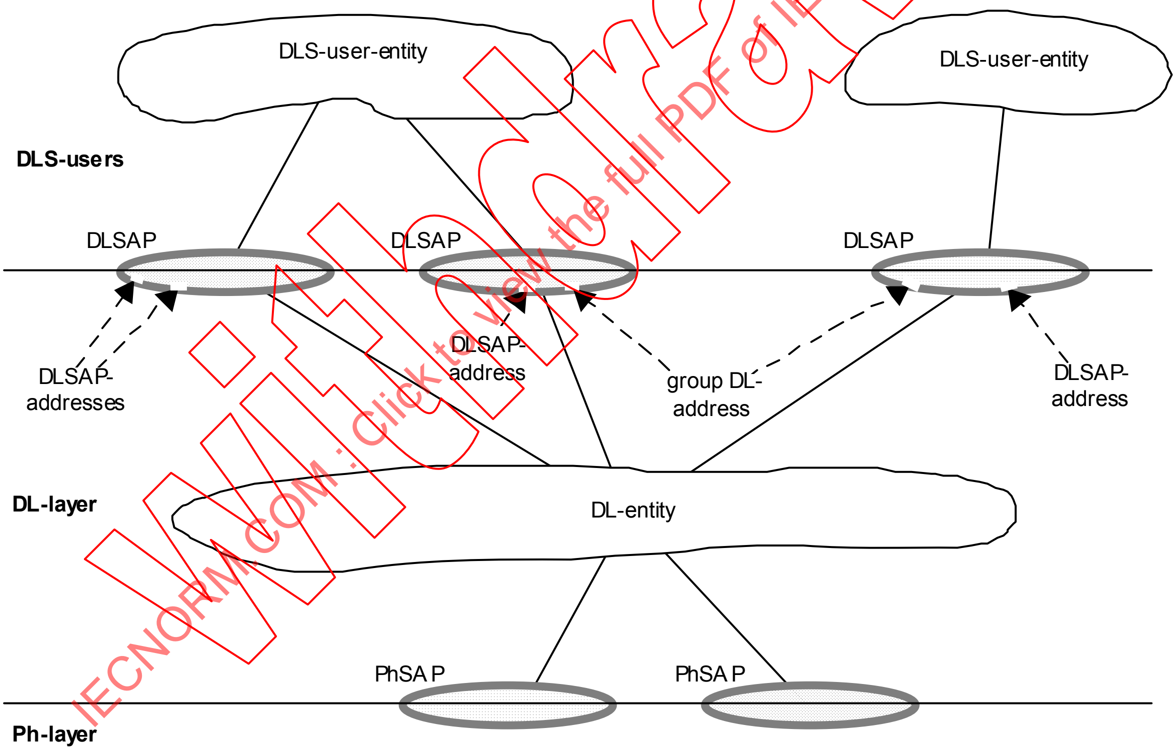
a) one peer DL-connection-end-point, or

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
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.

3.3.7
(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.

3.3.8
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.

3.3.9
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

3.3.10
frame
denigrated synonym for DLPDU

3.3.11
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

3.3.12
high-speed cyclic data
data conveyed by means of high-speed cyclic data transmission

3.3.13
high-speed cyclic data transmission
highest priority of time-critical cyclic data service

3.3.14
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.

3.3.15
low-speed cyclic data
data conveyed by means of low-speed cyclic data transmission

3.3.16
low-speed cyclic data transmission
lowest priority of time-critical cyclic data service

3.3.17
medium-speed cyclic data
data conveyed by means of medium-speed cyclic data transmission

3.3.18
medium-speed cyclic data transmission
second-highest priority of time-critical cyclic data service

3.3.19
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)

3.3.20
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.

3.3.21
node
single DL-entity as it appears on one local link

3.3.22
node DL-address
DL-address which designates the (single) DL-entity associated with a single node on a specific local link

3.3.23
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.

3.3.24
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.

3.3.25
sending DLS-user
DL-service user that acts as a source of DL-user-data

3.3.26
slot-time
512-bit time of the physical signaling symbol specified in the ISO/IEC 8802-3, Clause 29

3.3.27
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

3.3.28
SYN node
node transmitting SYN frame

3.3.29
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

3.3.30
token
right to transmit on the local link

3.4 Symbols and abbreviations

3.4.1 ACM	Access control machine
3.4.2 CLM	Claim frame
3.4.3 CMP	Transmission complete frame
3.4.4 CTRC	Cyclic-transmission TX/RX control
3.4.5 COM	Command frame
3.4.6 DT	Cyclic data frame
3.4.7 CW	Control word (as parameter of SYN DLPDU)
3.4.8 DT-CMP	DT with transmission complete frame
3.4.9 FC	Frame control field
3.4.10 LL	Live list (as parameter of SYN DLPDU)
3.4.11 PM	Periodic mode (as parameter of SYN DLPDU)
3.4.12 PN	Transmission permits node number (as parameter of SYN DLPDU)
3.4.13 Pri	Priority field
3.4.14 RAS	RAS frame
3.4.15 REC	In-ring request frame
3.4.16 RMC	Redundancy medium control
3.4.17 RMSEL	Redundant medium selection
3.4.18 SN	Source node number field
3.4.19 ST	Slot time (as parameter of SYN DLPDU)
3.4.20 SYN	Synchronization frame
3.4.21 Th	High-speed transmission period (as transmission period)
3.4.22 Tm	Medium-speed transmission period (as transmission period)
3.4.23 Ts	Sporadic-speed transmission period (as transmission period)
3.4.24 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.

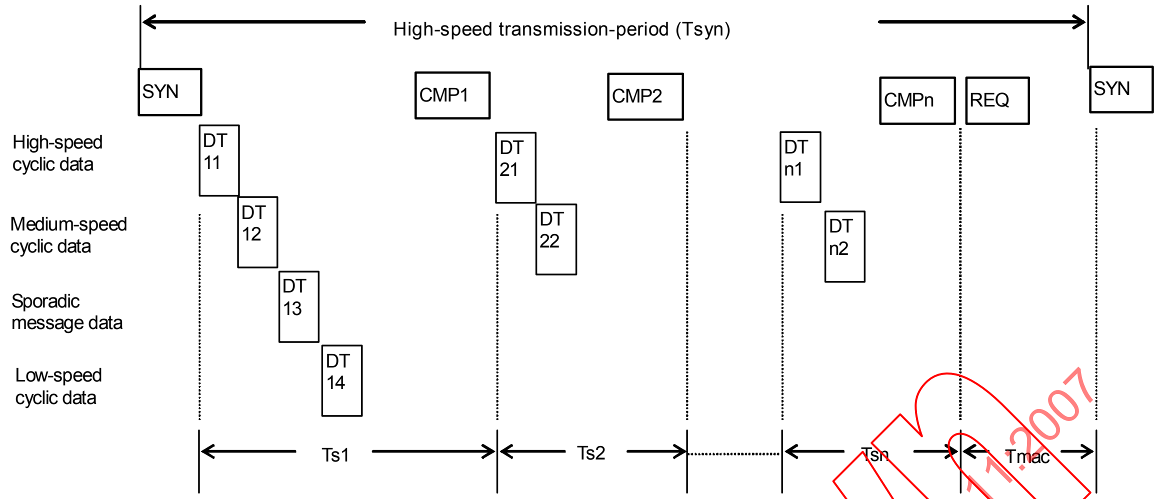


Figure 2 – Basic principle of medium access control

At the start time of every high-speed-transmission-period (Tsyn), 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 Nth 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 must 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. 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 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. Tmac is the period for a new node sending out REQ frame to enter the network.

4.3 Service assumed from the PhL

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.

4.3.1 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.

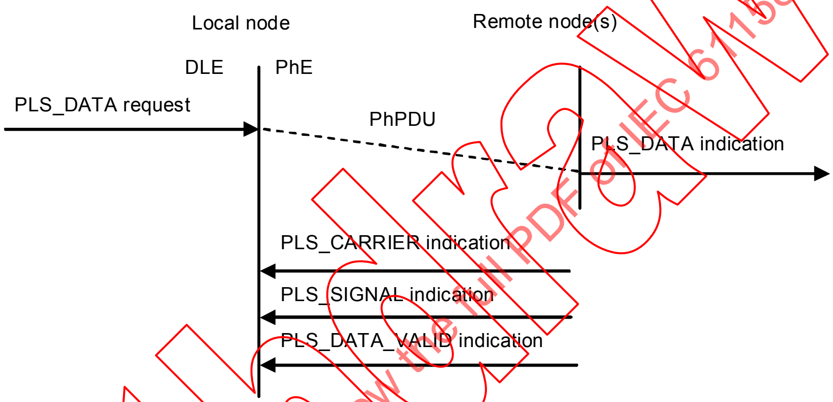


Figure 3 – Interaction of PhS primitives to DLE

4.4 DLL architecture

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.

The Data-link layer is comprised of the components listed in Table 1.

Table 1 – Data-link layer components

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 in the RMC, receives and disassembles the DLPDUs with the control information from the RX framer in the RMC, and determines the timing and duration of the transmissions
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 seserializers for medium redundancy
TX/RX framer	Receives the octet symbols from RMC, detects and indicates the start timing of a DLPDU to octet serializer, passes received octets from octet seserializer and indicates the start timing of a DLPDU to 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 receive machine. 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

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.

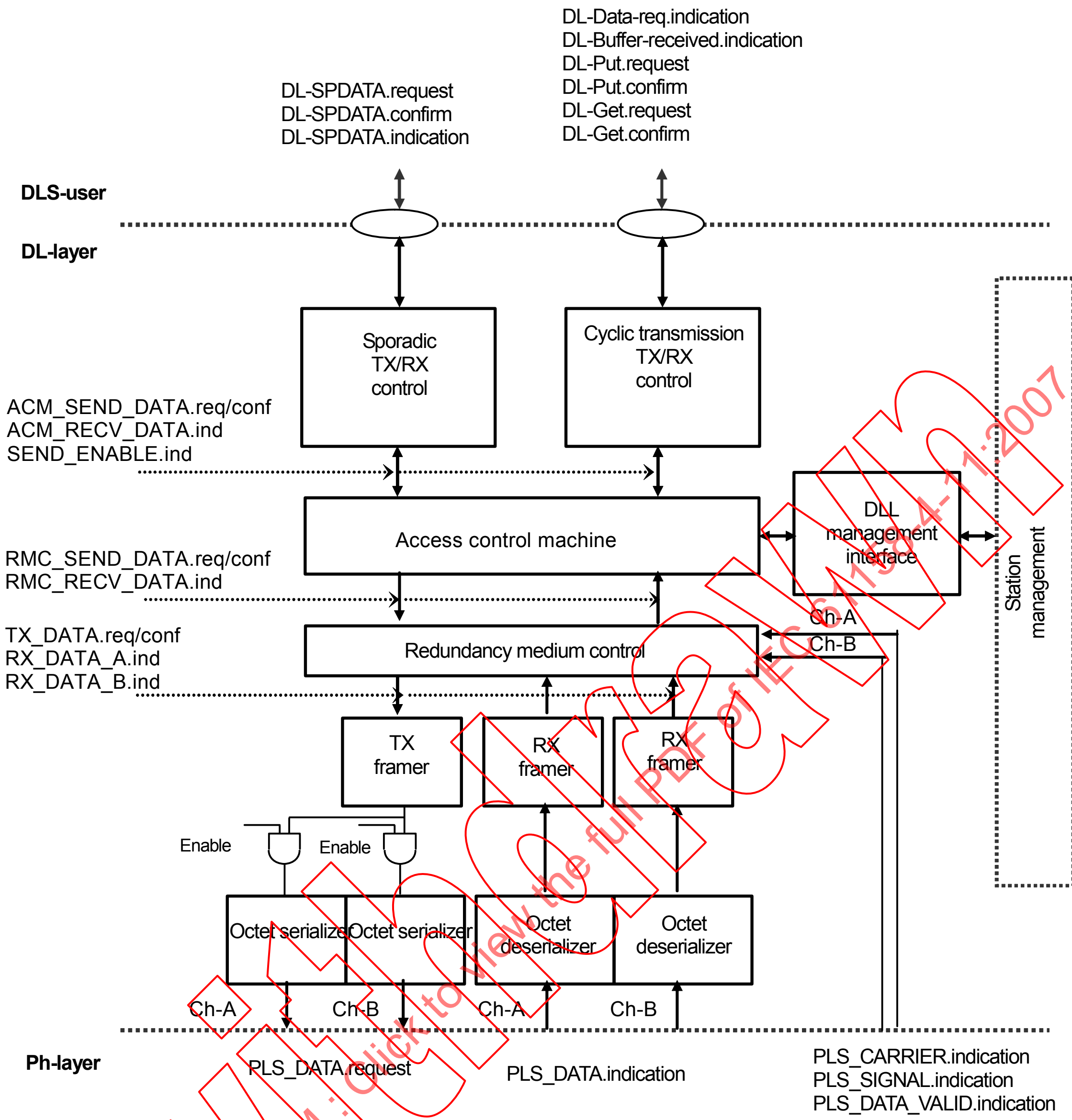


Figure 4 – Data-link layer internal architecture

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

a) 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;

b) provide three 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, variable, counters, timers

This specification uses DLS-user request parameters P(…) and local variables V(…) as a means of clarifying the effect of certain actions and the conditions under which those actions are valid, local timers T(…) 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(…) for performing rate measurement functions. It also uses local queues Q(…) 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.

Table 2 and Table 3 summarize many of these variables and their usage.

Table 2 – Mandatory DLE-variables and permissible values

Operating parameters		
Variable-name	**Description**	**Permissible values**
Th	High-speed transmission period	1 to 160 (in units of 0,1 ms)
Tm	Medium-speed transmission period	10 to 1 000 (ms)
Tl	Low-speed transmission period	100 to 10 000 (ms)
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 packet, and also used in the DLME for observing the CMP packet 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 packet 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).
MTHT	Maximum-token-hold-time for high-speed cyclic data transmission	1 to 2^{16}-1 (octet times). The default value is 0x30B4 (=900 μs).
TISPD	Time-interval cyclically processed for Sporadic message data service	1 to 1 000 (ms) The default value is 100.
MD	Maximum distance on the connection path between any 2 nodes	1 to 100 (km). The default value is 8.
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.
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 μs). The default value is 0x7c (≈5 μs).

Operating parameters		
Variable-name	**Description**	**Permissible values**
MN	Maximum node number	254 (default value)
IA	Individual address of this node	Individual 48-bit address identical to ISO/IEC 8802-3.
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.
MRT	Maximum number of the repeater units on the connection path between any 2 nodes	0 to N. The default value is 3.
BW	Length of TCC data word in a DLPDU	32 to 128 (octets). The default value is 128.
SCMPL	Permissible repetitive count within which the node can behave like that the node received the CMP packet even though the corresponding node had failed to send out the CMP packet. The node determines the corresponding node is out of service if the count is over	1 to 16. The default value is 3.
RCS	Receive-channel switching control for receiving packets. Designates the switching control for receiving packets 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"
RMGP	Maximum time-interval for one receive-channel, which has already completed one packet received and has waited for IGP time, to wait for the completion of a packet to be received on the other receive-channel in order to detect the other receive-channel disrupted	250 (in units of 0,04 μs). The value 250 represents 10 μs
PBh	List of up to 2 048 data buffers using for sending out high-speed TCC data	
PBm	List of up to 2 048 data buffers using for sending out medium-speed time-critical cycle data	
PBl	List of up to 2 048 data buffers using for sending out low-speed TCC data	

Table 3 – Observable variables and their value ranges

Operating parameter		
Variable-name	**Description**	**Range of value**
ATSYN	The observed time period from SYN packet arrival to SYN packet arrival	1 to 2^{16} (octet times)
ATTRT2	The observed time period of the TTRT2	1 to 2^{16}-1, continuously decrementing
ATTRT1	The observed time period of the TTRT1	1 to 2^{16}-1, continuously decrementing
ATTRT0	The observed time period of the TTRT0	1 to 2^{16}-1, continuously decrementing
ATHT	The observed time period of the MTHT	0 to MTHT, continuously decrementing
ASL	The observed time period of the SL	0 to V(SL) (Note)

Operating parameter		
Variable-name	**Description**	**Range of value**
ARMGP	The observed time period for one receive-channel, which has already completed one packet received and has waited for IGP time (0,96 μs), to wait the completion of a packet 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
ASCMP	Observed repetitive count that the corresponding node failed to send out the CMP packet and the other node can behave like that the CMP packet 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
NONC	Permissible repetitive count of no CMP packet 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
ROK_A, ROK_B	Cumulative count of DLPDU-received without error on the receive-channel A or B	0 to 2^{32}-1
NCD_A, NCD_B	Cumulative count of Non-Carrier detected on the receive-channel A or B. NCD_A is incremented when Non-Carrier happens on receive-channel A while Carrier occurs on the receive-channel B. NCD_B corresponds, but with interchanged channel roles	0 to 2^{32}-1
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
CDh	Cumulative count of transmitted high-speed-cyclic data packets	0 to 2^{32}-1
CDm	Cumulative count of transmitted medium-speed-cyclic data packets	0 to 2^{32}-1
CDl	Cumulative count of transmitted low-speed-cyclic data packets	0 to 2^{32}-1
SD	Cumulative count of transmitted sporadic data packets	0 to 2^{32}-1
LL	Live list indicating whether or not 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.
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
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
NOTE SL (Silence time) for detecting failure of the current SYN node. Timeout triggers those nodes that are designated as SYN nodes to send a CLM packet.		

4.6.1 Variables, parameter, counter, timer and queues to support DLE function

4.6.1.1 V(DR) : Data-rate

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

4.6.1.2 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.

4.6.1.3 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.

4.6.1.4 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.

4.6.1.5 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.

4.6.1.6 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 1 to 100, and the default value is 8.

4.6.1.7 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.

4.6.1.8 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.

4.6.1.9 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 0 to 7, and the default vale is 3.

4.6.1.10 V(RCS), P(RCS) : Receive- channel switching control for receiving packets

This variable holds and designates the switching control for receiving packets 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 packets 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".

4.6.1.11 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 32 to 128, and the default value is 128.

4.6.1.12 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.

4.6.1.13 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.

4.6.1.14 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 packet, for observation of initiation of the action that the node behaves like the CMP packet received even though the corresponding node failed to send out the CMP packet.

This variable holds and designates the fundamentally observational time value of slot time. The rage 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 x 512 x 1/100 µs.

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

V(ST)= round up [2 x V(MD) + V(MRT)/2 + 2]

4.6.1.15 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.

4.6.1.16 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.

4.6.1.17 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.

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

This variable indicates the target time period from SYN packet arrival to SYN packet 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.

4.6.1.19 T(ATSYN) : TSYN monitor

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

4.6.1.20 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.

4.6.1.21 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.

4.6.1.22 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.

4.6.1.23 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 μs.

4.6.1.24 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.

4.6.1.25 V(IGP) : Inter-packet-time-gap

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

4.6.1.26 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.

4.6.1.27 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 packet 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) x V(TN) x 2

4.6.1.28 T(ASL) : SL monitor

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

4.6.1.29 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 packet received and has waited for IGP time, to wait the completion of a packet 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.

4.6.1.30 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.

4.6.1.31 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.

4.6.1.32 T(TISPD) : TISPD monitor

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

4.6.1.33 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.

4.6.1.34 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.

4.6.1.35 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 packet to the SYN node. The default value is 100, the unit of which is in 0,1 ms.

4.6.1.36 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 packets sent from node which attempts to enter the Type-11 fieldbus. The value is decremented in the range of V(TMAC) to 0.

4.6.1.37 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 packet even though the corresponding node failed to send out the CMP packet.

4.6.1.38 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 packet even though the corresponding node failed to send out the CMP packet. The value is decremented in the range of V(SCMP) to 0.

4.6.2 Variables, counter, timer and queues to support time-critical cyclic data service

4.6.2.1 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.

4.6.2.2 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.

4.6.2.3 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.

4.6.2.4 V(Tl), P(Tl) : Low-speed transmission period

This variable holds and designates the cyclic time period of Low-speed time-critical data transmission. P(Tl) 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.

4.6.2.5 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 1ms. The default value is 3 x V(Th).

4.6.2.6 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.

4.6.2.7 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 x V(Th).

4.6.2.8 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.

4.6.2.9 V(HTl), P(HTl) : 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 x V(Th).

4.6.2.10 T(HTl) : HTl monitor

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

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

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

4.6.2.12 V(SEN_A), P(SEN_A); V(SEN_B), P(SEN_B) : Transmitter A or B enabled to send out packets

This variable designates the transmitter A or B enable to send out packets 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".

4.6.2.13 V(SCMPL), P(SCMP) : 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 packet without error even though the corresponding node failed to send out the CMP packet. The range of this value is 1 to 16 and the default value is 3.

4.6.2.14 C(ASCMP) : ASCMP count

C(ASCMP) indicates the number of observed repetitive count that the corresponding node failed to send out the CMP packet and the other node can behave like that the CMP packet received without error. The number of C(ASCMP) 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.

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

This variable holds and designates the value of permissible repetitive count of no CMP packet received by the SYN node within the corresponding consecutive Tsyn 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.

4.6.2.16 C(NONC) : NONC count

C(NONC) indicates the number of repetitive count of no CMP packet received by the SYN node within 256 x V(SCMPL) of the consecutive Tsyn 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.

4.6.2.17 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.

4.6.2.18 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.

4.6.2.19 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.

4.6.2.20 C(CDh) : Cumulative count of high-speed-cyclic data packet sent

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

4.6.2.21 C(CDm) : Cumulative count of medium-speed-cyclic data packet sent

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

4.6.2.22 C(CDl) : Cumulative count of low-speed-cyclic data packet sent

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

4.6.2.23 C(SD) : Cumulative count of sporadic data packet sent

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

4.6.2.24 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.

4.6.2.25 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”.

4.6.2.26 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.

4.6.2.27 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.

4.6.2.28 V(PBl), P(PBl) 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.

4.6.2.29 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.

5 General structure and encoding of PhIDUs 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 5 shows the MAC frame format used common to the Type-11 fieldbus DLPDU except for sporadic data transmission of the Type-11 fieldbus.

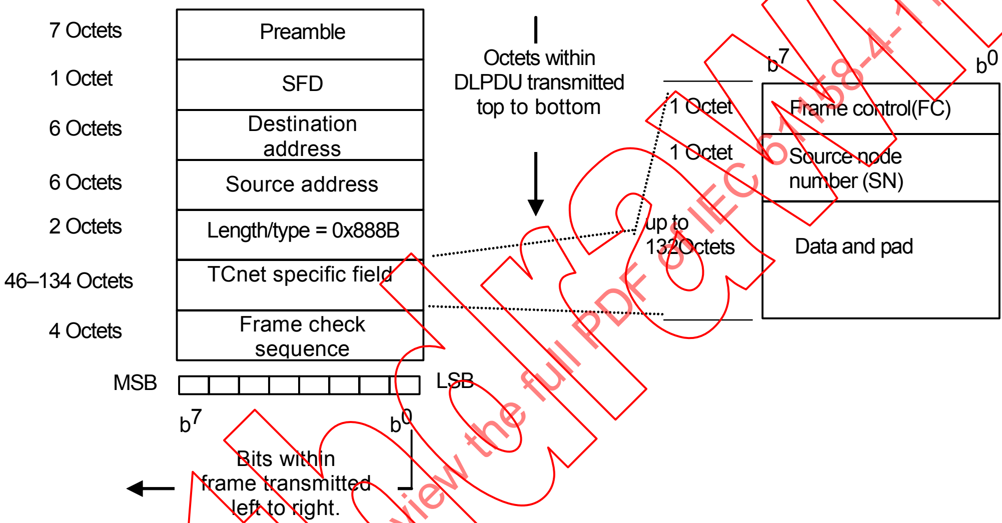


Figure 5 – Common MAC frame format for DLPDUs

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 is fully identical to the frame format of Ethernet V2.0 specified by ISO/IEC 8802.3, Clause 3 "Media access control frame structure", and the value of the Length/Type field is all but 0x888B. Figure 6 shows the frame format for sporadic DLPDU of the Type-11 fieldbus.

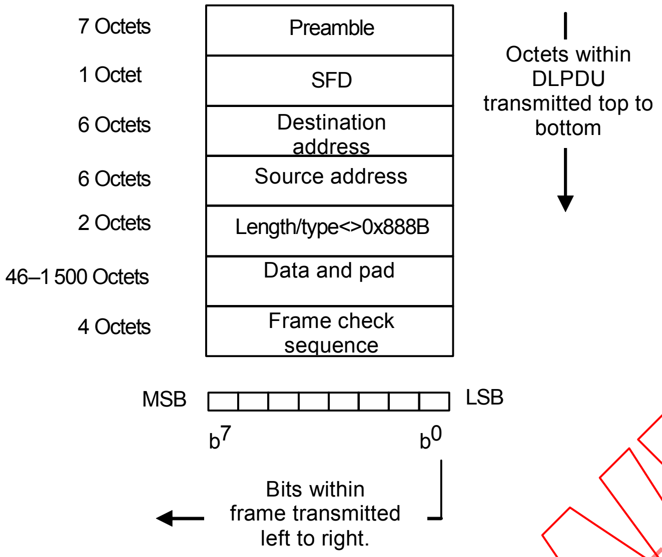


Figure 6 – Sporadic DLPDU format

5.4 Elements of the MAC frame

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.

5.4.1 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”

5.4.2 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.

5.4.3 Address field

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.

5.4.3.1 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).

5.4.3.2 Source address field (SA)

The Source Address (SA) filed 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).

5.4.4 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 an Type-11 fieldbus sporadic data frame.

5.4.5 Frame control field (FC)

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

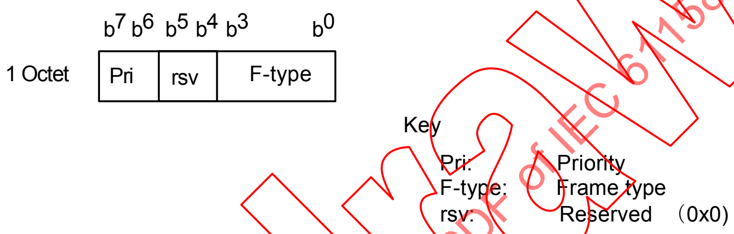


Figure 7 – Structure of FC field

5.4.5.1 Frame type (F-type) field

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. Table 4 shows the list of F-type and the corresponding the Type-11 fieldbus frame.

Table 4 – F-type: DLPDU type

F-type value	Frame type	Frame name
0x00	CLM	Claim frame
0x01	SYN	Synchronization frame
0x02	REQ	In-ring request frame
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
NOTE All but the above are reserved for future use.		

5.4.5.2 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 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. Other type of frame except for DT and DT-CMP is assigned to level 3 of the service class.

5.4.6 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.

5.4.7 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.

5.4.8 Frame check sequence (FCS)

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 $\boldsymbol{n}$ consisting of $\boldsymbol{k}$ DLPDU message bits followed by $\boldsymbol{n - k}$ (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 5.

Table 5 – 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.

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

5.4.8.1 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 $m_1 \ldots m_k$ and the FCS bits are $f_{n-k-1} \ldots f_0$, where

$m_1 \ldots m_8$	form the first octet sent,
$m_{8N-7} \ldots m_{8N}$	form the *N*th octet sent,
$f_7 \ldots f_0$	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

$$M(X) = m_1X^{k-1} + m_2X^{k-2} + \ldots + m_{k-1}X^1 + m_k \tag{1}$$

and the FCS vector F(X) is

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

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

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

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

The redundant check bits $f_{n-k-1} \ldots f_0$ 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

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

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

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

That is,

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

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.

5.4.8.2 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***

$$V(X) \quad = \quad v_1 X^{u-1} + v_2 X^{u-2} + \ldots + v_{u-1} X + v_u \qquad (7)$$

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 5.4.8.1) in computing F(X)

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

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.

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

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

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

whose value is independent of D(X). Unfortunately R(X) will also equal $R_{ok}(X)$ 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 $R_{ok}(X)$; 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 5.4.8.1.

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.

a) 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.

b) It is not an integral number of octets in length.

c) The bits of the incoming DLPDU (exclusive of the FCS field itself) do not generate a CRC value identical to the one received.

d) 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 Figure 5, 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)

A DLE which is as the SYN node sends the SYN DLPDU periodically at the specific time intervals of V(Th) 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(TN). The time frame, which REQ DLPDU is sent, is during the MAC control period of Tmac. The MAC control period of Tmac 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(TN).

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.

6.2.1 Structure of SYN DLPDU

The structure of SYN DLPDU is shown in Figure 8.

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

Where
FC: Frame control (11000001)
PN: Transmission permits node number
CW: Control word
Th: High-speed periodic time
Ts: Sporadic message rotation time
Tl: Low-speed periodic time
SN: Source node number
ST: Slot time
Tm: Medium-speed periodic time
LL: Live list

Figure 8 – Structure of SYN DLPDU

6.2.1.1 Parameters of SYN DLPDU

6.2.1.1.1 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(TN). 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(SYN) in which the DLE has received the SYN DLPDU with equal value of PN to that of the V(TN).

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 6 shows the structure of the PN parameter.

Table 6 – PN -parameter: 3rd octet

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

6.2.1.1.2 Control word (CW)

The structure of CW is shown in Table 7.

Table 7 – CW -parameters: 4th octet

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

6.2.1.1.2.1 Periodic mode (PM)

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 nods have sent their time-critical cyclic data within the time period of V(SYN). 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 8 shows the mode of PM parameter.

Table 8 – 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

6.2.1.1.2.2 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 packets 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 packets 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 9.

Table 9 – 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

6.2.1.1.3 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 packet, for sending out the CMP packet specifically by the current SYN node in substitute for the node failed to send out the CMP packet.

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 approx.100 ms, i.e. 20 x 512 x 1/100 µs.

Table 10 shows the structure of ST parameter.

Table 10 – ST-parameter: 5th octet

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

6.2.1.1.4 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(SYN) 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 11 shows the structure of Th parameter.

Table 11 – Th-parameter: 6th, 7th and 8th octets

High-speed transmission period																							
Th (2^7 - 2^0)								Th (2^8 - 2^{15})								Th (2^{16} - 2^{31})							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

6.2.1.2 Medium-speed transmission period (Tm)

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

Table 12 shows the structure of Tm parameter.

Table 12 – Tm-parameter: 9th and 10th octets

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

6.2.1.2.1 Sporadic message transmission target-token-rotation-time period (Ts)

This parameter designates the value of target-token-rotation-time for sporadic message data transmission. 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 10 to 10 000, of which the unit is in 1 ms.

Table 13 shows the structure of Ts parameter.

Table 13 – Ts-parameter: 11th and 12th octets

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

6.2.1.2.2 Low-speed transmission period (Tl)

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

Table 14 shows the structure of Tl parameter.

Table 14 – Tl-parameter: 13th and 14th octets

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

6.2.1.2.3 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 15 shows the structure of LL parameter.

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

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

6.2.1.3 User data

No user data is conveyed by the SYN DLPDU.

6.2.2 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.

6.2.3 Receiving the 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.

a) The value of RMSEL is used to determine the switching control for receiving packets 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).

b) Each value of ST, Th, Ts and Tl received in SYN DLPDU and the corresponding value of V(ST),V(Th),V(Tm) and V(Tl) in a node is compared respectively. If the value is different, then each value of ST, Th, Ts and Tl is to be a new value of each variable V(ST), V(Th), V(Tm) and V(TL) respectively.

c) The value of LL is to be a new value of V(LL).

d) 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)

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.

6.3.1 Structure of CMP DLPDU

Figure 9 shows the structure of the CMP DLPDU.

1	1	1	1	Octet
FC	SN	rsv	SYN	

Where
FC: Frame Control (11001000)
rsv: Reserved (0x0)
SYN: SYN node number
SN: Source Node number

Figure 9 – Structure of CMP DLPDU

6.3.1.1 Parameters of the CMP DLPDU

6.3.1.1.1 SYN node number (SYN)

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

6.3.1.2 User data of CMP DLPDU

No user data is conveyed by the CMP DLPDU.

6.3.2 Sending the 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.

6.3.3 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 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;

1) All the data with each priority level has finished sending out,

2) The corresponding observational timer has expired,

3) The T(MTHT) for High-speed time-critical cyclic data transmission has been expired.

6.4 In-ring request DLPDU (REQ)

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

6.4.1 Structure of REQ DLPDU

Figure 10 shows the structure of the REQ DLPDU.

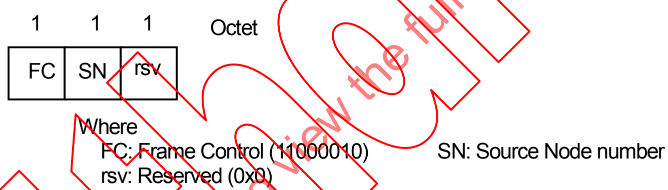


Figure 10 – Structure of the REQ DLPDU

6.4.1.1 Parameter of REQ DLPDU

No user parameter is conveyed by the REQ DLPDU.

6.4.1.2 User data of REQ DLPDU

No user data is conveyed by the REQ DLPDU.

6.4.2 Sending the 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.

6.4.3 Receiving the 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)

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).

6.5.1 Structure of CLM DLPDU

Figure 11 shows the structure of the CLM DLPDU.

1	1	1	1	1	Octet
FC	SN	rsv	RC	ST	

Where
FC: Frame Control(11000000)
SN: Source Node number
rsv: Reserved (0x0)
RC: Residual Counts of CLM DLPDU able to send out

Figure 11 – Structure of CLM DLPDU

6.5.1.1 Parameter of the CLM DLPDU

6.5.1.1.1 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 16 shows the structure of the CLM parameter.

Table 16 – CLM parameter: 4th octet

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

6.5.1.1.2 Slot time (ST) parameter

The value of this parameter is set to that defined in 6.2.1.1.3.

6.5.1.2 User data of the CLM DLPDU

No user data is conveyed by the CLM DLPDU.

6.5.2 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 = (2 x V(MD))+(1/2 x V(MRT))

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 (COM) DLPDU

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:

a) V(ST): Slot time(ST),

b) V(Th), V(Tm), V(Ts), V(Tl): The cyclic time periods, the target-token-rotation time period,

c) V(RCS): Redundant medium selection for receiving data packets

6.6.1 Structure of the COM DLPDU

Figure 12 shows the structure of the COM DLPDU.

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

where

FC: Frame control(11000100)
SN: Source node number
rsv: Reserved (00000000)
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

Figure 12 – Structure of COM DLPDU

6.6.1.1 Parameters of COM DLPDU

The parameters of COM DLPDU are equal to that of the SYN DLPDU specified in 6.2.1.1.

6.6.1.2 User data of the COM DLPDU

No user data is conveyed by the COM DLPDU.

6.6.2 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 V(RCS).

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)

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.

6.7.1 Structure of the DT DLPDU

Figure 13 shows the structure of the DT DLPDU.

1	1	2	Up to 130	Octet
FC	SN	DLCEP-address	User data	

where
FC: Frame Control (DT: pp000111, DT-CMP: pp001111)
SN: Source node number

Figure 13 – Structure of DT DLPDU

6.7.1.1 Parameters of DT DLPDU

6.7.1.1.1 DLCEP-address parameter

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

Table 17 shows the structure of the DT parameter.

Table 17 – 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

6.7.1.2 User data

DT DLPDU can send user data up to 132 octets.

6.7.2 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.

6.7.3 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)

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

6.8.1 Structure of RAS DLPDU

Figure 14 shows the structure of the RAS DLPDU.

1	1	2	Up to 34	Octet
FC	SN	DLCEP-address	User data	

where
FC: Frame control(11000101) SN: Source Node number

Figure 14 – Structure of RAS DLPDU

6.8.2 Parameters of RAS DLPDU

6.8.2.1 DCEP-address parameter

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

Table 18 shows the structure of the RAS parameter.

Table 18 – 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

6.8.2.2 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. 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.

6.8.2.3 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.

7 DLE elements of procedure

7.1 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 15 depicts the overall structure of the DLL.

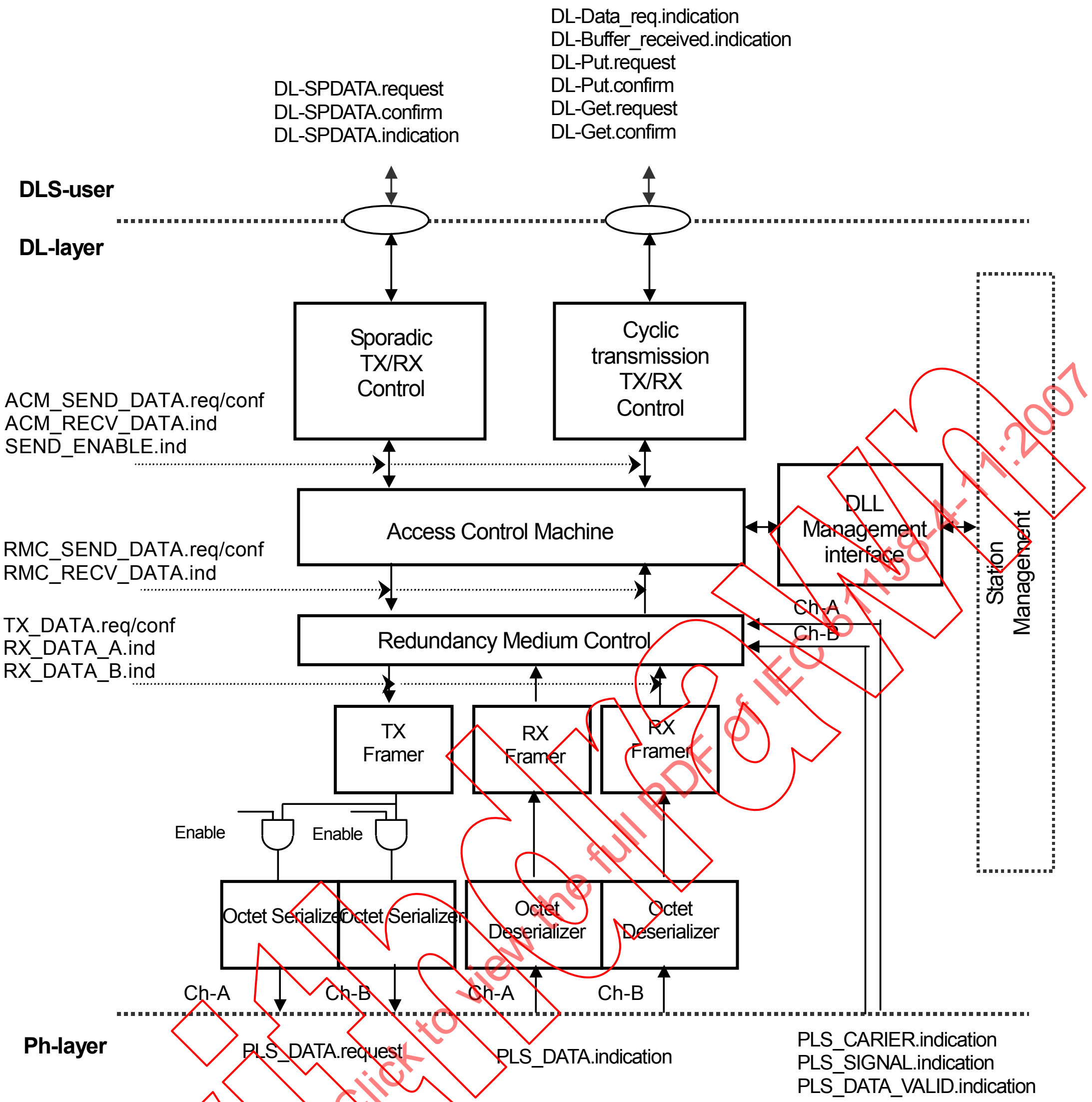


Figure 15 – Overall structure of DLL

7.2 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 16 depicts the DLE state transition.

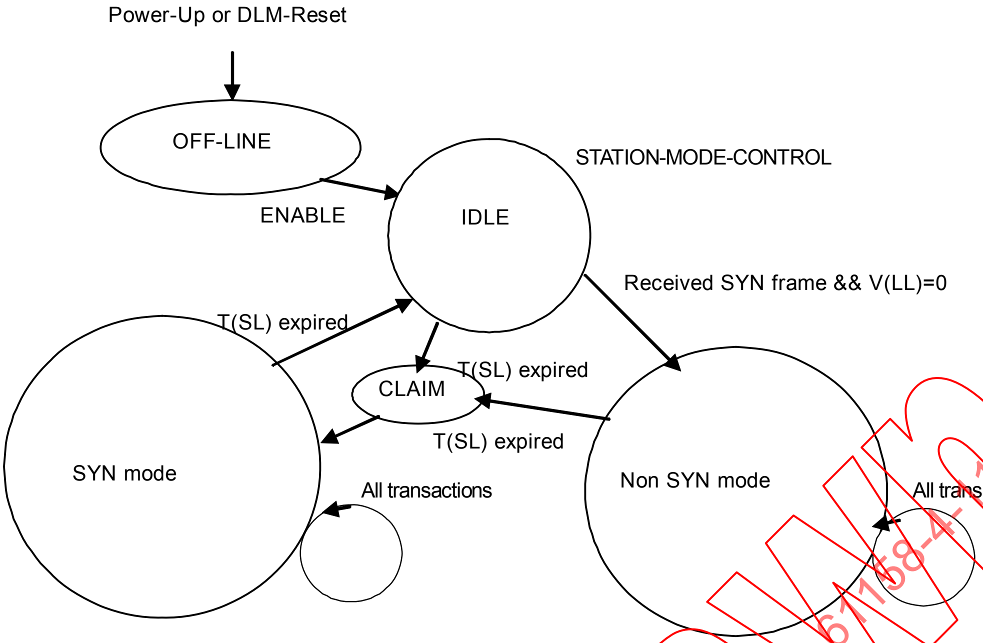


Figure 16 – DLE state transition

7.3 Cyclic transmission TX/RX control (CTRC)

7.3.1 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:

a) 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;

b) 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.

7.3.2 Primitive definitions

7.3.2.1 Primitives exchanged between DLS-user and CTRC

The primitives exchanged between DLS-user and CTRC is shown in Table 19 and the primitives exchanged between the CTRC and the ACM is summarized in Table 20.

Table 19 – 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 20 – 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

7.3.2.2 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 21.

Table 21 – 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

7.3.3 CTRC state table

The state transition diagram of the CTRC is depicted in Figure 17, and the CTRC state table is shown in Table 22.

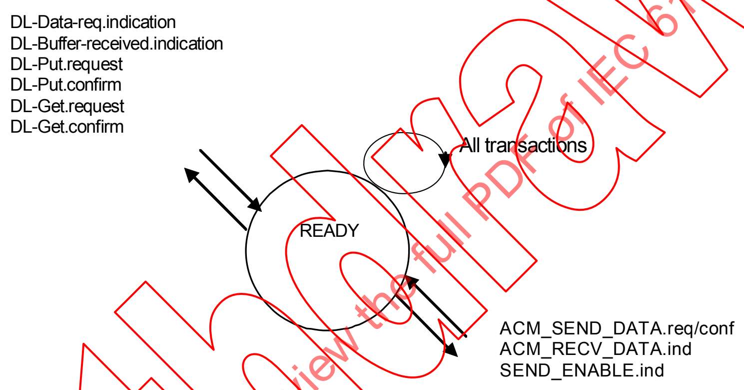


Figure 17 – State transition diagram of CTRC

Table 22 – 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

7.3.4 Functions of CTRC

All functions of the CTRC are summarized in Table 23.

Table 23 – 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

7.4 Sporadic TX/RX control (STRC)

7.4.1 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.

7.4.2 Primitive definitions

7.4.2.1 Primitives exchanged between DLS-user and STRC

Table 24 shows all primitives exchanged between DLS-user and STRC and Table 25 shows all primitives exchanged between the STRC and the ACM.

Table 24 – 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 25 – 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

7.4.2.2 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 26.

Table 26 – 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

7.4.3 STRC state table

The state transition diagram of the STRC is depicted in Figure 18, and the STC state table is shown in Table 27.

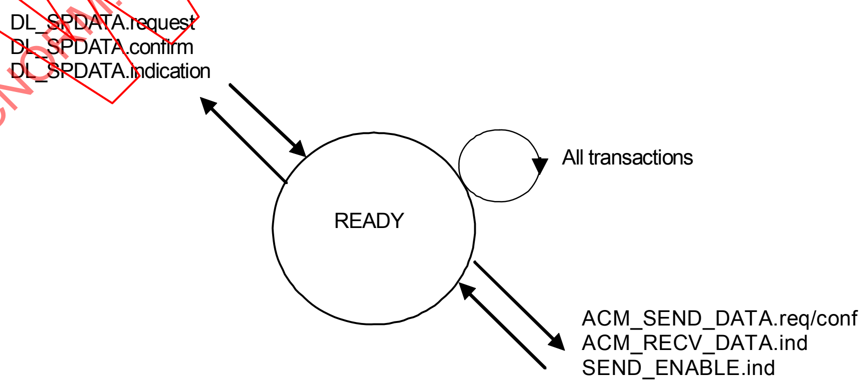


Figure 18 – State transition diagram of STRC

Table 27 – 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

7.4.4 Functions of STRC

All functions of the STRC are summarized in Table 28.

Table 28 – 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

7.5 Access control machine (ACM)

7.5.1 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

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 DLPDU;

c) 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;

d) assuring a new node adding to and removing from the network.

7.5.2 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

a) 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;

b) 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;

c) 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.

7.5.3 Primitive definitions

7.5.3.1 Primitives exchanged between ACM and RMC

Table 29 summarizes all primitives exchanged between the ACM and the RMC.

Table 29 – 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 30.

Table 30 – 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

7.5.3.2 Primitives exchanged between ACM and CTRC

Table 31 summarizes all primitives exchanged between the ACM and the CTRC.

Table 31 – 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

The parameters used with the primitives exchange between the ACM and the CTRC are described in Table 32.

Table 32 – Parameters used with primitives exchanged between ACM and CTRC

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

7.5.3.3 Primitives exchanged between ACM and STRC

Table 33 lists all primitives exchanged between the ACM and the STRC.

Table 33 – 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 34.

Table 34 – 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

7.5.4 ACM state table

The state transition diagram is shown in Figure 19.

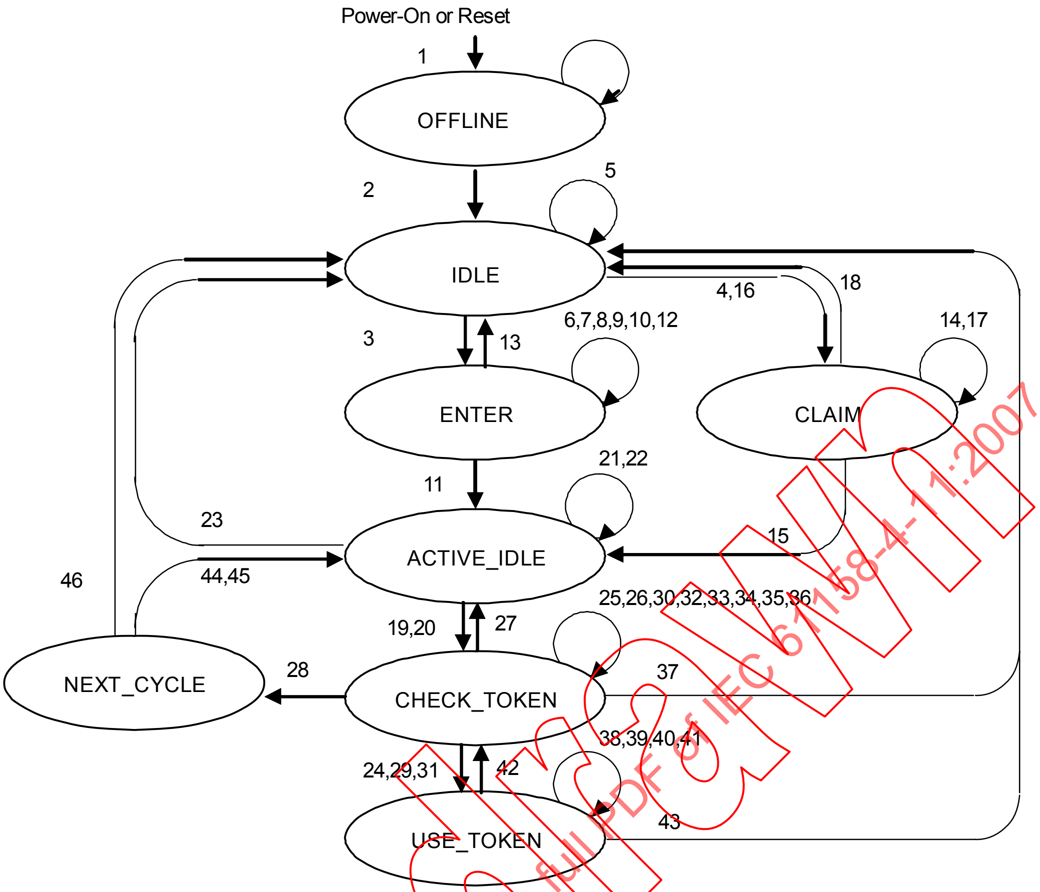


Figure 19 – State transition diagram of ACM

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 35.

Table 35 – 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
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

#	Current state	Event /condition ⇒actions	Next State
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
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

#	Current state	Event /condition ⇒actions	Next State
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
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(Tsl))	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