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Industrial communication networks – Fieldbus specifications

Part 6-26: Application layer protocol specification – Type 26 elements (IEC 61158-6-26:2019)

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National foreword

This British Standard is the UK implementation of EN IEC 61158-6-26:2019. It is identical to IEC 61158-6-26:2019.

The UK participation in its preparation was entrusted to Technical Committee GEL/65/3, Industrial communications: process measurement and control, including fieldbus.

A list of organizations represented on this committee can be obtained on request to its secretary.

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EN IEC 61158-6-26

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Réseaux de communication industriels - Spécifications des bus de terrain - Partie 6-26: Spécification du protocole de la couche application - Eléments de type 26 (IEC 61158-6-26:2019)

Industrielle Kommunikationsnetze - Feldbusse - Teil 6-26: Protokollspezifikation des Application Layer (Anwendungsschicht) - Typ 26-Elemente (IEC 61158-6-26:2019)

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European foreword

The text of document 65C/948/FDIS, future edition 1 of IEC 61158-6-26, prepared by SC 65C "Industrial networks" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61158-6-26:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-04-25
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-07-25

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 61158-1	2019	Industrial communication networks - Fieldbus specifications - Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series	EN IEC 61158-1	2019
IEC 61158-5-26	2019	Industrial communication networks - Fieldbus specifications - Part 5-26: Application layer service definition - Type 26 elements	EN IEC 61158-5-26	2019
IEC 61784-2	2019	Industrial communication networks - Profiles - Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC/IEEE 8802-3	EN IEC 61784-2	2019
ISO/IEC 7498-1	-	Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model	-	-
ISO/IEC/IEEE 8802-3	-	Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Standard for Ethernet	-	-
ISO/IEC 8822	-	Information technology - Open Systems Interconnection - Presentation service definition	-	-
ISO/IEC 8824-1	-	Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation	-	-
ISO/IEC 8825-1	-	Information technology - ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)	-	-
ISO/IEC 9545	-	Information technology - Open Systems Interconnection - Application Layer structure	-	-
ISO/IEC 9899	-	Information technology - Programming languages - C	-	-
IETF RFC 768	-	User Datagram Protocol	-	-
IETF RFC 791	-	Internet Protocol - DARPA Internet Program Protocol Specification	-	-

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IETF RFC 792	-	Internet Control Message Protocol	-	-
IETF RFC 793	-	Transmission Control Protocol - DARPA Internet Program Protocol Specification	-	-
IETF RFC 796	-	Address mappings	-	-
IETF RFC 826	-	Ethernet Address Resolution Protocol: Or Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware	-	-
IETF RFC 894	-	Standard for the Transmission of IP Datagrams over Ethernet Networks	-	-
IETF RFC 919	-	Broadcasting Internet Datagrams	-	-
IETF RFC 922	-	Broadcasting Internet datagrams in the presence of subnets	-	-
IETF RFC 950	-	Internet Standard Subnetting Procedure	-	-

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 6-26: Application layer protocol specification – Type 26 elements

FOREWORD

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International standard IEC 61158-6-26 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement and control.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
65C/948/FDIS	65C/956/RVD

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

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

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

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

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

A bilingual version of this publication may be issued at a later date.

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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 61158-1.

The application protocol provides the application service by making use of the services available from the data-link or other immediately lower layer. The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer application entities (AEs) 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:

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

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

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 6-26: Application layer protocol specification – Type 26 elements

1 Scope

1.1 General

The fieldbus Application Layer (FAL) provides user programs with a means to access the fieldbus communication environment. In this respect, the FAL can be viewed as a “window between corresponding application programs”.

This part of IEC 61158 provides common elements for basic time-critical and non-time-critical messaging communications between application programs in an automation environment and material specific to Type 26 fieldbus. 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.

This International Standard defines in an abstract way the externally visible behavior provided by the Type 26 of the fieldbus Application Layer in terms of:

a) the abstract syntax defining the application layer protocol data units conveyed between communicating application entities;

b) the transfer syntax defining the application layer protocol data units conveyed between communicating application entities;

c) the application context state machine defining the application service behavior visible between communicating application entities; and

d) the application relationship state machines defining the communication behavior visible between communicating application entities.

The purpose of this document is to define the protocol provided to:

a) define the wire-representation of the service primitives defined in IEC 61158-5-26, and

b) define the externally visible behavior associated with their transfer.

This document specifies the protocol of the Type 26 fieldbus Application Layer, in conformance with the OSI Basic Reference Model (see ISO/IEC 7498-1) and the OSI Application Layer Structure (see ISO/IEC 9545).

FAL services and protocols are provided by FAL application-entities (AE) contained within the application processes. The FAL AE is composed of a set of object-oriented Application Service Elements (ASEs) and a Layer Management Entity (LME) that manages the AE. The ASEs provide communication services that operate on a set of related application process object (APO) classes. One of the FAL ASEs is a management ASE that provides a common set of services for the management of the instances of FAL classes.

Although these services specify, from the perspective of applications, how request and responses are issued and delivered, they do not include a specification of what the requesting and responding applications are to do with them. That is, the behavioral aspects of the applications are not specified; only a definition of what requests and responses they can

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send/receive is specified. This permits greater flexibility to the FAL users in standardizing such object behavior. In addition to these services, some supporting services are also defined in this document to provide access to the FAL to control certain aspects of its operation.

1.2 Specifications

The principal objective of this document is to specify the syntax and behavior of the application layer protocol that conveys the application layer services defined in IEC 61158-5-26.

A secondary objective is to provide migration paths from previously-existing industrial communications protocols. It is this latter objective which gives rise to the diversity of protocols standardized in subparts of the IEC 61158-6.

1.3 Conformance

This document does not specify individual implementations or products, nor does it constrain the implementations of application layer entities within industrial automation systems.

There is no conformance of equipment to the application layer service definition standard. Instead, conformance is achieved through implementation of this application layer protocol specification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE All parts of the IEC 61158 series, as well as IEC 61784-1 and IEC 61784-2 are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 61158-1:2019, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-5-26:2019, *Industrial communication networks – Fieldbus specification – Part 5-26: Application layer service definition – Type 26 elements*

IEC 61784-2:2019, *Industrial communication networks – Profiles – Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC/IEEE 8802-3*

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

ISO/IEC/IEEE 8802-3, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

ISO/IEC 8822, *Information technology – Open Systems Interconnection – Presentation service definition*

ISO/IEC 8824-1, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

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ISO/IEC 8825-1, *Information technology – ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*

ISO/IEC 9545, *Information technology – Open Systems Interconnection – Application Layer structure*

ISO/IEC 9899, *Information technology – Programming languages – C*

IETF RFC 768, *User Datagram Protocol*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 791, *Internet Protocol*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 792, *Internet Control Message Protocol*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 793, *Transmission Control Protocol*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 796, *Address mappings,* available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 826, *An Ethernet Address Resolution Protocol*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 894, *A Standard for the Transmission of IP Datagrams over Ethernet Networks*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 919, *Broadcasting Internet Datagrams*, available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 922, *Broadcasting Internet Datagrams in the presence of subnets,* available at http://www.ietf.org [viewed 2018-09-20]

IETF RFC 950, *Internet Standard Subnetting Procedure*, available at http://www.ietf.org [viewed 2018-09-20]

3 Terms, definitions, symbols, abbreviations and conventions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions from other ISO/IEC standards

3.1.1 Terms and definitions from ISO/IEC 7498-1

For the purposes of this document, the following terms and definitions given in ISO/IEC 7498-1 apply.

a) application entity

b) application process

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c) application protocol data unit
d) application service element
e) application entity invocation
f) application process invocation
g) application transaction
h) real open system
i) transfer syntax

3.1.2 Terms and definitions from ISO/IEC 8822

For the purposes of this document, the following terms and definitions given in ISO/IEC 8822 apply:

a) abstract syntax
b) presentation context

3.1.3 Terms and definitions from ISO/IEC 9545

For the purposes of this document, the following terms and definitions given in ISO/IEC 9545 apply:

a) application-association
b) application-context
c) application context name
d) application-entity-invocation
e) application-entity-type
f) application-process-invocation
g) application-process-type
h) application-service-element
i) application control service element

3.1.4 Terms and definitions from ISO/IEC 8824-1

For the purposes of this document, the following terms and definitions given in ISO/IEC 8824-1 apply:

a) object identifier
b) type
c) value
d) simple type
e) structured type
f) component type
g) tag
h) Boolean type
i) true
j) false
k) integer type
l) bitstring type
m) octetstring type
n) null type

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o) sequence type

p) sequence of type

q) choice type

r) tagged type

s) any type

t) module

u) production

3.1.5 Terms and definitions from ISO/IEC 8825-1

For the purposes of this document, the following terms and definitions given in ISO/IEC 8825-1 apply:

a) encoding (of a data value)

b) data value

c) identifier octets (the singular form is used in this document)

d) length octet(s) (both singular and plural forms are used in this document)

e) contents octets

3.2 Type 26 specific terms and definitions

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

3.2.1
application relationship
cooperative association between two or more application-entity-invocations for the purpose of exchange of information and coordination of their joint operation.

Note 1 to entry: This relationship is activated either by the exchange of application-protocol-data-units or as a result of preconfiguration activities.

3.2.2
application process object
component of an application process that is identifiable and accessible through an FAL application relationship

3.2.3
application relationship endpoint
context and behavior of an application relationship as seen and maintained by one of the application processes involved in the application relationship

Note 1 to entry: Each application process involved in the application relationship maintains its own application relationship endpoint.

3.2.4
client
<object view> object which uses the services of another (server) object to perform a task

3.2.5
client
<communication view> initiator of a message to which a server react

3.2.6
common memory
virtual memory accessible with logically unique address used for the cyclic-data transmission

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Note 1 to entry: It is composed of the memory-area-1 and -2 of the memory size 512 words and 8 192 words respectively and is shared with the Type 26 nodes in a Type 26 fieldbus network.

3.2.7
connection
logical binding between application objects that are within the same or different devices

Note 1 to entry: Connections can be either point-to-point or multipoint.

3.2.8
cyclic-data frame
frame used for the Type 26 cyclic-data transmission

3.2.9
cyclic-data transmission
data transmission with which a Type 26 node sends out data on a pre-assigned area for the node on the common-memory, in broadcasting to all other Type 26 nodes every time the node obtains a token

3.2.10
device
physical hardware connected to the link

Note 1 to entry: A device can contain one or more than one node.

3.2.11
device profile
collection of device dependent information and functionality providing consistency between similar devices of the same device type

3.2.12
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.2.13
event
instance of a change of conditions

3.2.14
FA-link header
header part of the APDU used for Type 26 data transmission

3.2.15
FA-link protocol
communication protocol for Type 26 fieldbus

Note 1 to entry: It defines the token management, the cyclic data transmission and the message data transmission, with which each Type 26 node can perform data transmission on an equal basis.

3.2.16
final-cyclic-data frame
cyclic-data frame sent out immediately before sending a token-frame out of a Type 26 node

3.2.17
frame
synonym for DLPDU

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3.2.18
invocation
act of using a service or other resource of an application process

Note 1 to entry: Each invocation represents a separate thread of control that can be described by its context. Once the service completes, or use of the resource is released, the invocation ceases to exist. For service invocations, a service that has been initiated but not yet completed is referred to as an outstanding service invocation.

3.2.19
in-ring-startup state
state of a node attempting to participate in Type 26 fieldbus network in the valid-linking state

3.2.20
major-version
indication of the major-version number of the FA-link protocol

Note 1 to entry: The version number of the FA-link protocol is given as a combination of a major- and a minor-version number. The value of the major-version number is in the range of 1 to 15 (encoded with four bits) and corresponds to the digits before the decimal point (for example, the major-version number is 3 for the FA-link protocol Version 3.01.).

3.2.21
management information
network-accessible information that supports managing the operation of the fieldbus system, including the application layer

Note 1 to entry: Managing includes functions such as controlling, monitoring, and diagnosing.

3.2.22
message-data frame
frame used for the Type 26 message-data transmission

3.2.23
message-data transmission
sporadic data transmission with which a Type 26 node sends out the message data of request, response, information report, and notification upon event happened at the node and so forth, to other Type 26 nodes

3.2.24
minor-version
indication of the minor-version number of the FA-link protocol

Note 1 to entry: The version number of the FA-link protocol is given as a combination of a major- and a minor-version number. The value of the minor-version number is in the range of 1 to 15 (encoded with four bits) and corresponds to the digits after the decimal point (for example, the minor-version number is 1 for the FA-link protocol Version 3.01.).

3.2.25
network load measurement function
provision for monitoring and measurement of the communication load over a Type 26 fiedbus with a Type 26 node

3.2.26
network-startup state
state of a node attempting to participate in Type 26 fieldbus network not yet in the valid-linking state

3.2.27
participation-request-frame
frame used for a Type 26 node notifying of its participation-request in a Type 26 fieldbus network

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3.2.28
protocol type
identification of communication protocol

3.2.29
publisher
role of an AR endpoint that transmits APDUs onto the fieldbus for consumption by one or more subscribers

3.2.30
resource
processing or information capability of a subsystem

3.2.31
subscriber
role of an AREP in which it receives APDUs produced by a publisher

3.2.32
sequence number
consecutive number used to determine whether a receiving message-data from other nodes has been previously received and is redundant

Note 1 to entry: The value is set to 0 (zero) at the time of the network-startup and is increased by 1 (one) every time on a message-data transmission completed.

3.2.33
server
<communication view> role of an AREP in which it returns a confirmed service response APDU to the client that initiated the request

3.2.34
server
<object view> object which provides services to another (client) object

3.2.35
token-frame
frame used for hand-over the token between Type 26 nodes

3.2.36
transaction code
code used to discriminate and identify each data transmission frame, and which represents the transaction of a receiving frame

3.2.37
trigger-frame
frame used in the network-startup state for a Type 26 node notifying of its entrance into a new participation-request over a Type 26 fieldbus network

3.2.38
valid-linking state
state in which a token is consecutively circulated among nodes over Type 26 fieldbus network

3.2.39
version of sequence number
version number of the sequence number in a receiving message-data from other nodes used to determine whether the receiving message-data is valid and is not overdue

Note 1 to entry: The value is set at the time when a Type 26 node completes to participate in a Type 26 fieldbus network, and is maintained until the node drops out of the Type 26 fieldbus network.

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3.2.40
virtual-address-space
virtual memory space with pseudo logical address, used for the message-transmission

3.3 Abbreviations and symbols

3CWT	Waiting time period for 3 laps of token circulation
AE	Application Entity
AL	Application Layer
ALME	Application layer management entity
ALP	Application layer protocol
AP	Application Process
APDU	Application Protocol Data Unit
APO	Application Process Object
AR	Application Relationship
AREP	Application Relationship End Point
ASCII	American Standard Code for Information Interchange
ASE	Application Service Element
AWT	Waiting time period for receiving message-acknowledge
ASN.1	Abstract Syntax Notation One
BCD	Binary Coded Decimal
BCT	Broadcast transmission
BER	Basic Encoding Rule
BSIZE	Current-fragment-block-size
CBN	Current-fragment-block-number
C_AD1	Data-head-address on common-memory-area-1
C_AD2	Data-head-address on common-memory-area-2
CM	Common Memory
cnf	confirmation primitive
C_SZI	Data-size on common-memory-area-1
C_SZ2	Data-size on common-memory-area-2
DA	Destination-address
DCS	Distributed Control system
DL	Data-link
DLC	Data-link Connection
DLCEP	Data-link Connection End Point
DLL	Data-link layer
DLPDU	Data-link Protocol Data Unit
DLSAP	Data-link Service Access Point
DLSDU	Data-link Service Data Unit
DNA	Destination-node-number
DNS	Domain name service
FA	Factory Automation
FAL	Fieldbus Application Layer
FIFO	First In First Out
HMI	Human-machine interface
H_TYPE	Header-type
ID	Identifier

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IEC	International Electrotechnical Commission
ind	indication primitive
IP	Internet protocol
ISO	International Organization for Standardization
LME	Layer management entity
LSB	least significant bit
MAC	Media Access Control
M_ADD	Message-offset-address in the virtual-address-space
MAJ_VER	FA-link protocol version: major-version
M_CTL	Message-control
MFT	Allowable-minimum-frame-interval-time
MIN_VER	FA-link protocol version: minor-version
MSB	most significant bit
MSN	Manufacturer's model name of a Type 26 node
M_SZ	Message-data-size in the virtual-address-space
M_RLT	Message result
NC	Numerical Controller
NDN	Node name of Type 26 node
OSI	Open Systems Interconnection
PAT	Participation-request-frame-acceptance-time
PC	Personal Computer
PDU	Protocol Data Unit
PhL	Ph-layer
PLC	Programmable Logic Controller
PPT	Peer-to-peer transmission
P_TYPE	Protocol-type
PWT	Participation-request-frame-transmission-waiting-time
RCT	Allowable-refresh-cycle-time
req	request primitive
RMT	Refresh-cycle-measurement-timer
rsp	response primitive
RC	Robot Controller
RT	Real Time
SA	Source-address
SAP	Service Access Point
SDU	Service Data Unit
SEQ	Sequence-number
SNA	Source-node-number
TBN	Total-fragment-block-number
TCD	Transaction code
TCP	Transmission Control Protocol
TDT	Joining-token-detection-time
TBN	Total-fragment-block-number
TFL	Total frame length in octet including both of header and data
THT	Token-holding-time
TrWT	Waiting time period before sending out a trigger-frame

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TW	Token-watchdog
UDP	User Datagram protocol
ULS	Upper layer status
VDN	Vender code of Type 26 node
V_SEQ	Version of sequence number

3.4 Conventions

3.4.1 Conventions used in state machines

Protocol sequences are described by means of state machines.

The state machine description and the meaning of the elements of a state machine description are defined in tabular form as shown in Table 1.

Each row of the state table represents a state transition. The first column shows the state transition name or number. The second column shows the current state. The third column shows the events, conditions and actions. The fourth column shows the next state. When an event or condition is fulfilled, the action is performed and the state machine transitions to the next state.

Table 1 – Conventions used for state machines

#	Current state	Event / condition => action	Next state
Name or number of this state transition	The current state to which this state transition applies	Events or conditions that trigger this state transaction. => The actions that are taken when the above events or conditions are met. The actions are always indented below events or conditions	The next state after the actions in this transition is taken

The conventions used in the state machines are shown in Table 2.

Table 2 – Conventions used in state machine

Notation	Description
:=	Value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event. xxx is a parameter name. Example: Identifier:= reason means value of a 'reason' parameter is assigned to a parameter called 'Identifier'. "xxx" Indicates fixed value Example: Identifier:= "abc" means value "abc" is assigned to a parameter named 'Identifier'.
=	A logical condition to indicate an item on the left is equal to an item on the right
<	A logical condition to indicate an item on the left is less than the item on the right
>	A logical condition to indicate an item on the left is greater than the item on the right
<>	A logical condition to indicate an item on the left is not equal to an item on the right
&&	Logical "AND"
||	Logical "OR"
!	Negation operator

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Notation	Description
+, -, x, /	Arithmetic operator
;	Breakpoint
- – “comment” or /* “comment” */	Comments out conditions and actions. The “- – “comment” " type notation is used in one-line comments, and the “/* “comment text */ “ type notation is used in one or multiple-line comments.

Further the following conventions apply.

- The construct described below as an example allows the execution of a sequence of actions in a loop within one transition. The loop is executed for all values from start_value to end_value.

  Example:

  ```
  for (Identifier:= start_value to end_value)
      actions
  endfor
  ```

- The construct described below as an example allows the execution of alternative actions depending on some condition (which might be the value of some identifier or the outcome of a previous action) within one transition.

  Example:

  ```
  If (condition)
  then
      actions
  else
      actions
  endif
  ```

- Notations as defined in C language according to ISO/IEC 9899 is used to describe conditions and actions.

3.4.2 Convention for abstract syntax description

This document uses a subset of ASN.1 according to ISO/IEC 8824-1 for the description.

The description is provided by means of a combination of SEQUENCE type, CHOICE type, basic types and subtype elements defined in ASN.1.

3.4.3 Convention for reserved bits and octets

The term "reserved" is used to describe bits in octets or whole octets for indicating that certain values within the range of a parameter are reserved for future extensions. All the bits or the octets shall be set to zero at the sending side and is not validated intentionally at the receiving side except it is explicitly stated that a state machine shall validate the bits or octets reserved.

3.4.4 Conventions for bit description in octets

Each bit in an octet is identified by a number and is described as Bit n. Figure 1 shows the bit identification in an octet.

When specifying bit identification in multiple octets, the LSB of the lowest octet is identified as Bit 0, and the bit identification numbers are assigned in an ascending order. Figure 2 shows the bit identification in four octets as an example.

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Bits are grouped as group of bits. Each bit or group of bits shall be addressed by its Bit Identification. When specifying multiple bits sequentially located, the range separator ".." is used. A group of bits of Bit 0 through Bit 4 denotes Bit 0..4.

Alias names are used for each bit or group of bits. The grouping of individual bits is in ascending order without gaps. The values for a group of bits are provided as binary, decimal or hexadecimal values, and the value is only valid for the group bits.

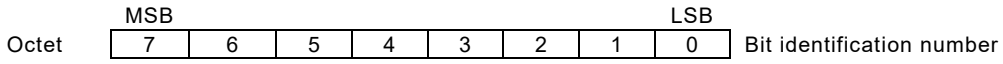

Figure 1 – Bit identification in an octet

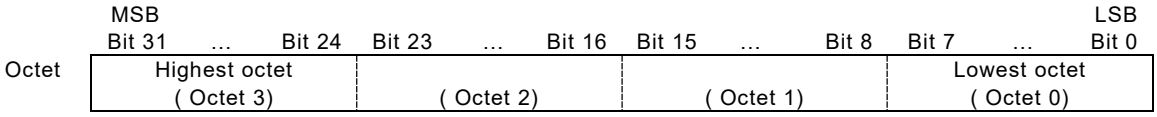

Figure 2 – Bit identification in multiple octets (four-octet case)

4 FAL syntax description

4.1 General

This document specifies the Application layer protocol of Type 26 fieldbus that is essential for the ISO/IEC/IEEE 8802-3 based FA Link network (FL-net[1]) which will be incorporated as one of the communication networks for the Real-time Ethernet (RTE) defined in IEC 61784-2.

The Type 26 fieldbus 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/IEEE 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.

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:

– A deterministic response time between the control device nodes.
– Ability to share process data seamlessly across the control system.

The Type 26 fieldbus is applicable to such an industrial automation environment, in which time-critical communications are primarily required.

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1 FL-net is the trade name of JEMA/FL-net: The Japan Electrical Manufacturers' Association / the Factory Automation Link network. This information is given for the convenience of users of this document and does not constitute an endorsement by IEC of the trademark holder or any of its products. Compliance does not require use of the trade name. Use of the trade name requires permission of the trade name holder.

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4.2 Overview of Type 26 fieldbus

4.2.1 Application field and Common-memory

The Type 26 fieldbus is applicable to a controller level network for efficiently executing the control and state data exchange between various kinds of field devices such as Programmable Logic Controllers (PLC), Robot Controllers (RC), Numerical Controllers (NC), Factory Automation (FA) controllers, Distributed Control systems (DCS), Personal Computers (PC) for the control purpose and the human-machine interfaces and so forth, in industrial automation control systems in which a time-criticality for their data exchanges is required.

The communications between these field devices also require simplicity in actual application programming as well as the time-critical transfer of the control and state data required among these field devices. To meet such requirement the Type 26 fieldbus provides so-called Common-memory (CM) which provides a function to share the control and state data seamlessly across an industrial control network system.

The CM is a virtual common memory accessible with logically unique address across the Type 26 nodes in a Type 26 fieldbus network, and the APs running over each Type 26 node can handle the CM as a global common memory shared among the Type 26 nodes over the Type 26 fieldbus network.

Cyclic-data transmission is used for refreshing and equalizing the contents of the CM among the Type 26 nodes by means of a cyclic broadcasting performed at a constant rate after a Type 26 node writes a data peace on a pre-allocated memory area of the CM for the Type 26 node.

The data distribution/refreshing function to all Type 26 nodes provided by the CM by means of the cyclic-data transmission enables each node to share the same data with each other, and to make good use of the data; i.e. a memory space allocated to each node is a container for application data in general use and provides flexibility to apply in a variety of industrial application processes.

In operational view of the CM, the memory area in the CM allocated to a certain node is used as the transmission area of the node by a cyclic-data transmission as a sender. On the other hand as receiving nodes of the cyclic-data transmission, the memory area of the sender node is used as a receiving area for the sender nodes.

Figure 3 shows the data sharing with the CM.

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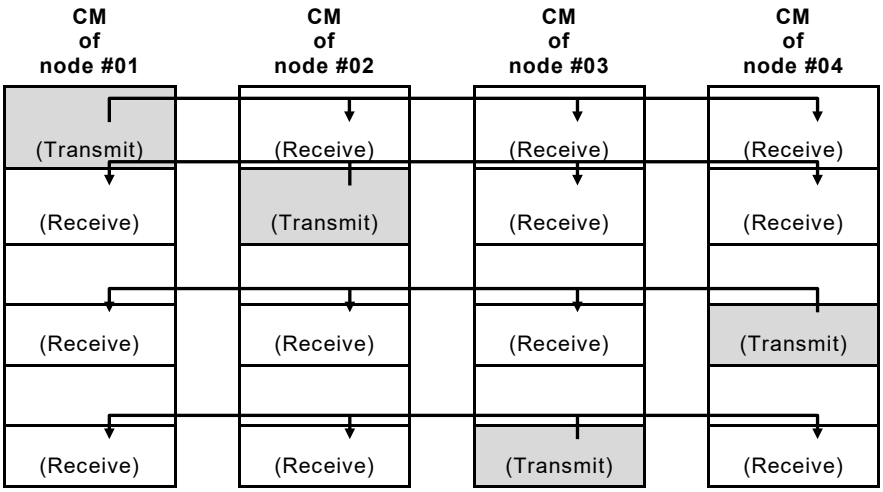

Figure 3 – Data sharing with the CM

4.2.2 Structure of Type 26 protocol

The application layer exploits the services of the data-link layer immediately below, in terms of the “three-layer” Fieldbus Reference Model which is based in part on the OSI Basic Reference Model. The OSI reference model provides a layered approach to communications standards, whereby the layers can be developed and modified independently. IEC 61158 specifies functionality from top to bottom of a full OSI stack and, potentially, some functions for the users of the stack.

Figure 4 shows the protocol stack for a Type 26 fieldbus, the OSI layers and the equivalent layers in the IEC 61158 basic fieldbus reference model.

Functions of the intermediate OSI layers, layers 3 through 6, are consolidated into the IEC 61158 data-link layer for a Type 26 fieldbus as the lower layer of the FA Link protocol. The data-link layer is that of a general-purpose Ethernet with UDP (see RFC 768), TCP (see RFC 793), IP (see RFC 791) and Ethernet layer (see RFC 894, ISO/IEC/IEEE 8802-3) as the main components. Type 26 fieldbus utilizes that of the services provided with a general-purpose Ethernet protocol suite.

The application layer for Type 26 fieldbus is the main component of the FA Link protocol stack, and is specified as the upper layer of the FA Link protocol. The application layer is mapped directly on the data-link layer as the lower layer of the FA Link protocol.

Two kinds of data transmissions are defined; i.e. Cyclic-data transmission and Message-data transmission. The cyclic-data and the message-data transmissions are the data transmission of UDP connectionless based. Data transmission based on connection-oriented TCP is only for the General-purpose-command-server transmission.

This document defines the protocol specification, and the service elements and services are defined in IEC 61158-5-26.

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OSI layer			IEC 61158 layer
7	Application		**Application** IEC 61158-5-26 IEC 61158-6-26
6	Presentation	null	
5	Session	null	
4	Transport		**Data-link** RFC 768, (RFC 793)
3	Network		RFC 791 RFC 919, RFC 922 (RFC 792, RFC 950)
2	Data-link		RFC 894/ ISO/IEC/IEEE 8802-3 MAC (RFC 826)
1	Physical		**Physical** ISO/IEC/IEEE 8802-3 Phy

Figure 4 – Protocol stack for Type 26 fieldbus

4.2.3 Structure of Type 26 FAL

The FAL is defined as a set of object-oriented ASEs. Each ASE specification is composed of three parts: the class definitions, the services and the protocol specification. The first two are contained and defined in IEC 61158-5-26.

The FAL ASEs and their architectural relationships for Type 26 FAL are shown in Figure 5.

Each ASE provides the services as follows:

a) The cyclic-data ASE provides the cyclic data communication service with Type 26 specific common-memory defined in 6.4 of IEC 61158-5-26, and the cyclic-data transmission is performed at a constant rate for updating the common-memory;

b) Message data ASE provides the message-data communication service between nodes and the message-data transmission is performed on demand by the ALS-user in order to intercommunicate between the APs running on remote nodes;

c) The load measurement ASE provides services to conduct the start and the termination of the communication load measurement on the target node, and provides the measurement result containing the token holding time related and the general purpose communication load related statistical information on that node available for analyzing the total communication load condition over the Type 26 fieldbus network;

d) The General purpose command server ASE provides the general purpose command server communication service, and provides the facilities for setting and reading the values of various network visible APOs of other nodes, and for requesting the start and the stop of the communication load measurement to other nodes;

e) The Network management ASE provides services to access Type 26 APO attributes; modify the APO instances; configure the nodes; inform the status report on the unexpected events, the errors and the status changes of the nodes; manage network visible APOs accessed through the FAL.

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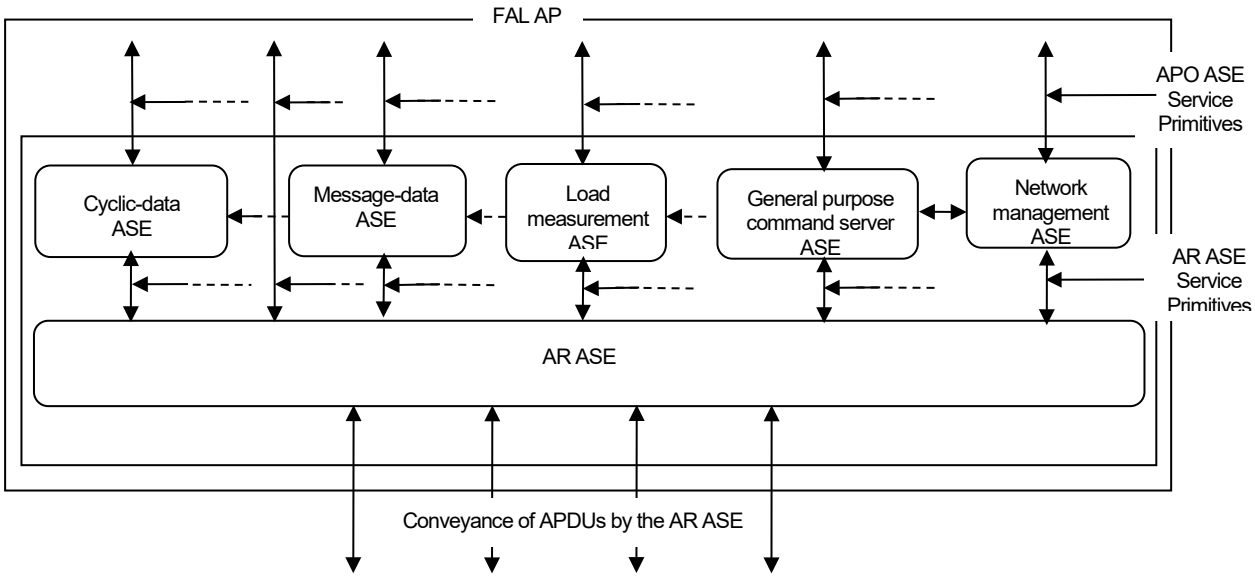

Figure 5 – The structure of ASEs for Type 26 FAL

4.2.4 Data link layer

Two types of addressing exist for DL-addressing in terms of the Fieldbus three layer reference model, one is over UDP and other is over TCP protocol channels which are represented as the T- profile in terms of the OSI reference model.

The cyclic-data and the message-data transmissions are the data transmission of UDP connectionless based. The message-data transmission based on connection-oriented TCP is only for the General-purpose-command-server transmission.

The cyclic-data and the message-data transmissions utilize the local broadcast medium/mechanism over the UDP and the TCP protocols, and are restricted generally to the local link. Requirement for the Data link layer as the FAL lower layer shall specify the broadcast communication function as the mandatory fundamental function.

With respect to the Ethernet MAC address, the default set to the Ethernet MAC interface by the device vendor is used as the MAC address, and for the IP address, class C of IP address defined in RFC 796 is assigned and used. The default value of the IP address is specified as 192.168.250.N with the value of 255.255.255.0 as the subnet mask, and the value of N shall be identical to the Node number of 1 to 254.

4.3 Operating principle

4.3.1 Overview

A token controls the right to send the data out of a Type 26 node to a Type 26 fieldbus network. The node which holds (possesses) the token can primarily perform the data transmission over the Type 26 fieldbus network.

The token is passed by Type 26 nodes, and as the token is passed from node to node a logical ring is formed. Logical ring maintenance functions within the Type 26 nodes are provided for ring initialization, lost token recovery, multiple tokens, new node addition, node drop-out, entering and exiting ring, monitoring and detection fault and so forth.

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Operation in normal, steady state on the node consists of a data transmission phase and a token transmission phase. The two kinds of data transmissions for Type 26 nodes are the cyclic-data transmission and the message-data transmission.

The cyclic-data transmission is primarily carried out by the node every time the node obtains the token; on the other hand the message-data transmission is dependent on request and the communication load condition at that time. After the node has completed transmitting any data, the node passes the token to the successor by sending out a token frame.

4.3.2 Logical ring maintenance

4.3.2.1 Token passing

A token is passed by the nodes, and as the token is passed from node to node a logical ring is formed. Figure 6 shows a token circulation on a logical ring.

The token transfer is performed by sending a token frame out of a node (predecessor) to its successor after the predecessor has completed sending any data frames. The token frame contains a destination node number (DNA) and a source node number (SNA). The DNA indicates the node number of successor, and the SNA indicates the node number of predecessor.

Type 26 fieldbus is in general a broadcast type, and every Type 26 node receives the token frame. The node has the right to send out the data by recognizing and accepting the token frame of which the DNA number is identical with the node number.

The token passing is always sequential in a logical sense. During normal, steady-state operation, a data transmission phase and a token transmission phase are performed. After the node has completed transmitting any data, the node passes the token to the successor by sending out a token frame.

The token or the right to send out data passes from node to node in a logically circular fashion. The token or the right to send out data is circulated from node to node in ascending numerical order of the node number.

The node which holds the token and has the largest node number in a Type 26 fieldbus network shall pass the token to the node which has the smallest node number. Figure 6 shows a Type 26 fieldbus network which is consisting of Node #1 to Node #N. Each node number of the Node #1 to the Node #N is 1 to N respectively in ascending numerical order. In that configuration, the Node #N which holds the token and has the largest node number shall pass the token to the Node #1 which has the smallest node number in order to maintain the logical ring of the Type 26 fieldbus network.

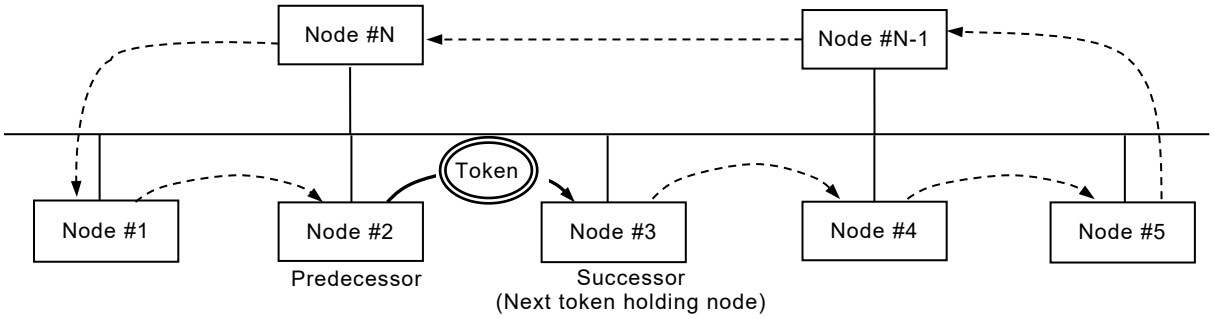

Figure 6 – A token circulation on a logical ring

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4.3.2.2 Right to transmit

A node can hold the right to transmit data over the Type 26 fieldbus network after obtaining the token until the time that the node shall hand over the token to the next node or the successor.

Operation in normal, steady state on the node consists of a data transmission phase and a token transmission phase. In the data transmission phase, two kinds of data transmissions exist; i.e. the cyclic-data transmission and the message-data transmission. The cyclic-data transmission is primarily carried out by the node every time the node obtains the token; on the other hand the message-data transmission is dependent on request and the communication load condition at that time.

During the above process, the data transmission is performed as follows:

a) The token-holding-time (THT) controls and limits the time period within which every node is able to be holding the token. The time period of holding the token by the nodes shall not exceed the time period of the THT;

b) While holding the token, the node can send out one or more cyclic-data frames every time and further can send out at most one message-data frame;

c) After the node has completed transmitting any data within the time period of the THT, the node shall pass the token to the successor by sending out a token frame;

d) The token frame is never sent out upon failure that the time period of holding the token exceeds the time period of the THT.

NOTE Nodes which do not holde the token are exceptionally able to send out Type 26 specific control frames. A new node can send out these frames during the entering state in order to join in an operating Type 26 fieldbus network or the logical ring in operation. In addition, a node can send out a new token frame in order to reform and recover the logical ring, after it has been disrupted by one of the following events: token lost, node dropped out of the logical ring, failure happening within nodes, and so forth.

4.3.2.3 Logical ring recovery

When a node recognizes and determines the logical ring is disrupted whether or not it holds the token, sends out a token frame in order to reform and recover the logical ring.

Each node is monitoring the state of a token circulation on the logical ring by means of two observational timers that are the refresh-cycle-measurement-timer (RMT) and the token-watchdog-timer (TW).

The RMT is provided with each node and is an observational timer to measure the refresh-cycle-time which is the elapsed time period from the time after obtaining the token by a node until the time the node obtains the token once again. When the RMT overruns the limit of allowable-refresh-cycle-time (RCT) set to each node and common to all nodes, the RMT is considered to be time out.

The TW-timer is provided with each node and is used as an observational timer to measure the elapsed time period from the time a node obtains the token until the time the node sends out a token frame over the fieldbus network.

Each node has the maximum observational time limit to the TW-timer. Each node has the knowledge on the TW values of other nodes, for instance by means of checking the APDU header received from other nodes, and the node can utilize these TW values of other nodes to detect some kind of failure by means of checking the elapsed time period during which a node holds the token.

When the TW-sum-time in the case of using the maximum observational time limit to the TW-timer of each node overruns the limit of the sum total of the maximum observational time limit to the TW-timer of each node which resides sequentially on the logical ring from a token

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holding node to this node in ascending numerical order of the node number, the TW-timer of some node is considered to be time out.

A token frame shall be sent out of a node upon time out both of the RMT and the TW-timer at a time. Both timers out at the same time results from the logical ring disrupted, so that the token frame shall be sent out to reform and recover the logical ring.

Figure 7 shows the sequential process for the logical ring recovery in the case that the node #3 dropped out from the logical ring of five nodes. The sequential process is as follows:

a) The node #1 passes the token to the node #2,

b) The node #2 passes the token to the node #3,

c) Since the node #3 has not responded, a token frame shall be sent out from the node #4 to the node #5 after the TW-timer and the RMT out of the node #4,

d) The node #5 passes the token to the node #1,

e) The node #1 passes the token to the node #2,

f) Since the node #3 has dropped out of the logical ring, the node #2 shall pass the token to the node #4,

g) The token is passed to the node #5 from the node #4. The token circulates on new logical ring of node #1, #2, #4 and #5.

NOTE When the nodes receive a token frame from the node which is identified not as a member node in the logical ring and then is identified as a new node, the TW value for the node is set to the maximum time value of 255 ms.

When the nodes receive a token frame from the node which is once a member node of the logical ring, the TW value for the node is set to the same value which is used and set to as the TW value of the node at that time.

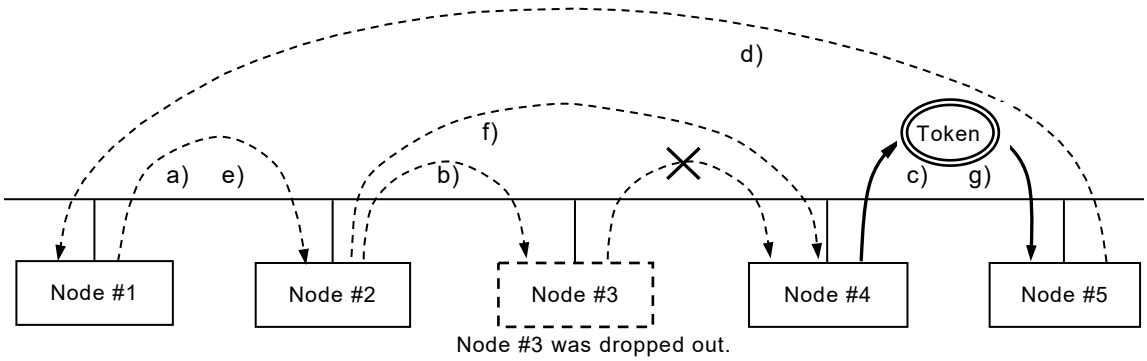

Figure 7 – Logical ring recovery

4.3.2.4 Multiple tokens

There are two types of conditions for a node to handle the problem of multiple tokens:

a) When a node is holding the token and receives a token frame of which the DNA number is not identical to the node number and is smaller than that of the node, the node shall abandon the right to send out the data; shall give priority to the node with the DNA number and shall enter into the waiting for the token state;

b) On the other hand, when a node with the token receives a token frame with the DNA number which addresses to other node and is not smaller than that of the node, the node shall discard the token frame received and shall maintain the state in which the node is holding the token and is holding the right to send out the data.

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4.3.3 Node addition

4.3.3.1 Overview

A new node in the entering state into a logical ring shall monitor the activity on the Type 26 fieldbus network until the joining-token-detection-time timer (TDT-timer) is timed out. The default observational time period is 3 000 ms and the value is set to the TDT-timer.

There are two kinds of conditions to start the process for node addition; one is under the condition in the network start-up and the other is under the condition in the in-ring start-up state:

a) During the time period when the node does not detect any token frames, the node recognizes and determines that the logical ring over the Type 26 fieldbus network is not yet formed and is in the network start-up state;

b) On the other hand, when the node detects any token frames, the node determines that the logical ring over the network has already formed and is in operation, and then the node shall enter into the in-ring start-up state.

4.3.3.2 Node addition in the network start-up state

This process and the procedures are identical to form a new logical ring or to start up a new Type 26 fieldbus network.

There are two types of conditions for a new node to enter into this process; i.e. another node is simultaneously entering and the new node alone enters into this process under the condition in the network start-up state.

Figure 8 shows an example of the sequential timing diagram in the case that a node enters into this process simultaneously with another node under the condition in the network start-up state. Figure 9 shows the sequential timing diagram in the case that a node is alone and enters into this process under the condition in the network start-up state.

The process and the procedures are as follows:

a) A new node shall start the Trigger-frame-transmission-waiting-time timer (TrWT-timer) after the TDT-timer out without any token frames received. In case of no reception of any trigger frames from another node until the TrWT-timer out, a trigger frame shall be sent out of the new node as shown in Figure 9;

b) On the contrary, the new node has received any trigger frames from another node during the time period of the TrWT. In this case the trigger frame shall not be sent out of the new node, and the new node shall start both of the Participation-request-frame-transmission-waiting-time timer (PWT-timer) and the participation-request-frame-acceptance-time timer (PAT-timer) upon reception of a trigger frame from another node as shown in Figure 8;

c) After the TrWT-timer out, the new node shall start both of the Participation-request-frame-transmission-waiting-time timer (PWT-timer) and the participation-request-frame-acceptance-time timer (PAT-timer) in case of no reception of any trigger frames during the time period of the TrWT as shown in Figure 9;

d) Each node has different values of the time period of the TrWT and the PWT, and the values are set as follows:

   – TrWT = R x 4 (ms):

     R is the remainder of the node number divided by 8;

   – PWT = (the node number) x 4 (ms).

   The new node shall send out a participation-request frame upon the PWT-timer out;

e) The new node shall wait for reception of any participation-request frames from another node until the PAT-timer out. The default observational time period is 1 200 ms and the value is set to the PAT-timer;

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f) During the PAT time period upon reception of any participation-request frames, each node shall check and validate the contents of receiving participation-request frames; i.e. shall check the overlap of each common-memory-area claiming for its own use by each node and the duplication of the node number of other nodes; and further shall enrol the sender node related information with the validated common-memory area information and so on into the participating-node-management information table. The participating-node-management-information is updated upon reception of any participation-request frames;

g) Upon the PWT-timer out, the new node shall send out the participation-request frame;

h) Upon the PAT-timer out, according to the contents of the participating-node-management-information table new logical ring shall be formed; and then the node with the minimum node number shall send out a token frame first as shown in Figure 8;

i) On the contrary, in the case of no reception from other nodes until the PAT-timer out, the TDT-timer shall be started again and the above mentioned process and procedures shall be followed and repeated until any trigger frames, any participation-request frames or any token frames from other nodes is received as shown in Figure 9. After repeating three cycle times or sending out the participation-request frame three times, upon the PAT-timer out, the node shall recognize and determine that only the node exists and attempts alone to form a new logical ring; and then shall notify the FAL-user of the node status with a flag of waiting for any receptions from other nodes;

j) The node which detects and identifies the overlap of the node number with other nodes by means of validating the participation-request frame received from another node shall not enter and participate in the new logical ring; and shall not send out any data and shall discard any receiving frames. Error information with the duplicated node number shall be notified to the FAL-user;

k) The node which detects and identifies the overlap of the common-memory area with other nodes by means of validating the participation-request frame received from another node shall enter and participate in the new logical ring; shall set the common-memory area unavailable: i.e. set to zero (0) the head-address and the size of the common memory area for own use of the node; and shall not send out any cyclic-data. Error information with the overlap of the common-memory area shall be notified to the FAL-user; the validity of the contents of the common-memory shall be flagged as invalid and unavailable.

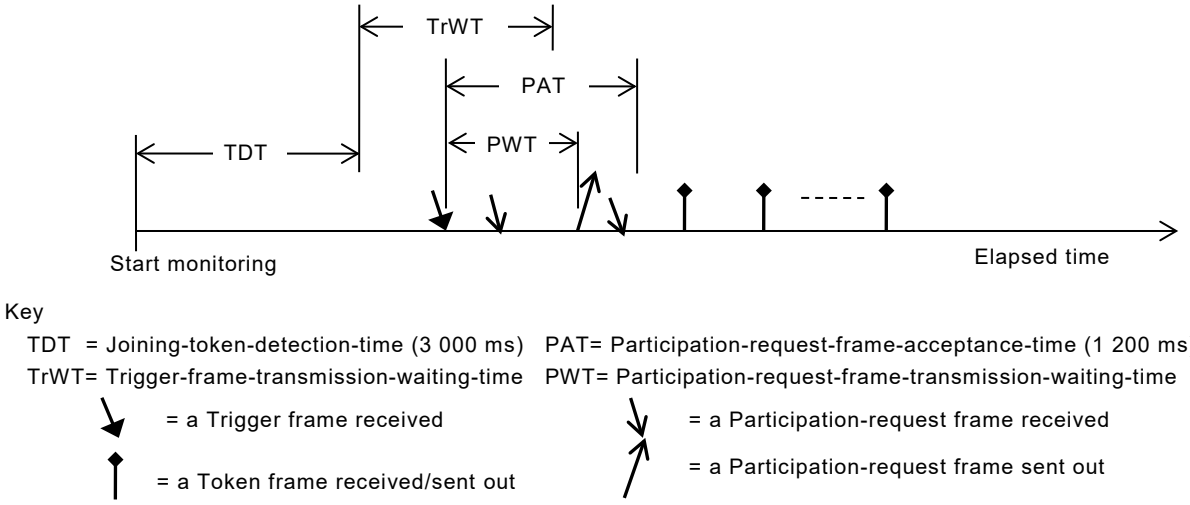

Figure 8 – An example in case of start simultaneously with another node

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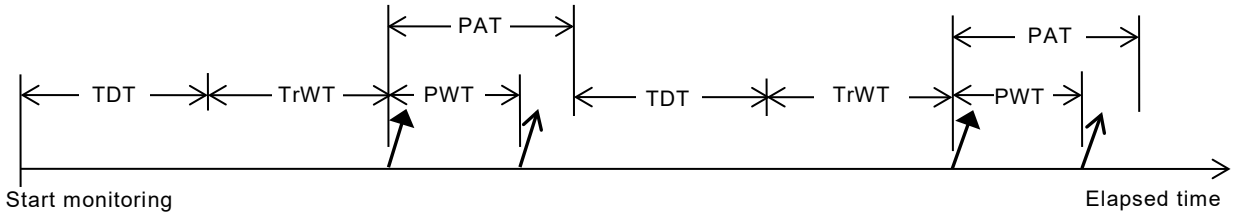

Key

TDT = Joining-token-detection-time (3 000 ms) PAT= Participation-request-frame-acceptance-time (1 200 ms)

TrWT = Trigger-frame-transmission-waiting-time PWT= Participation-request-frame-transmission-waiting-time

= a Trigger frame sent out

= a Participation-request frame sent out

Figure 9 – Start alone case

4.3.3.3 New node addition in the in-ring star-up state

A new node in the entering state into a logical ring shall monitor the activity on the Type 26 fieldbus network until the TDT-timer out. During the TDT time period when the node detects any token frames, the node determines that the logical ring over the network has already formed and is in operation, and then the node enters into the in-ring start-up state.

Figure 10 shows an example of the sequential timing diagram for a new node of node #5 in the in-ring start-up state into 4-node logical ring in operation.

The process and the procedures are as follows:

a) The node shall keep the monitoring until the token circulates on the logical ring three times after receiving the token frame with the minimum node number in the logical ring;

b) During the three-lap time period of the token circulation on the logical ring, the node shall check and detect the overlap of the common-memory-area claiming for its own use with the area used by other nodes and the duplication of the node number to other nodes by means of the validation of any receiving frames containing these information; and after the validation of any receiving frames, the node shall enrol the sender node related information with the validated common-memory area information and so on into the participating-node-management information table. The participating-node-management-information is updated during this time period;

c) After the three-lap time period of the token circulation (3CWT time period) with no duplicated node number, the node shall start the PWT-timer to send out a participation-request frame to enter into the logical ring;

d) Upon the PWT-timer out, the node shall send out a participation-request frame even though the node is not holding the token;

e) The node which detects and identifies the duplication of the node number to other nodes shall not send out any participation-request frames; and shall not enter into the logical ring. The node shall notify the FAL-user of the error information with the duplicated node number and the node-status with a flag of node number duplication;

f) The node which detects and identifies the overlap of the common-memory area with other nodes shall enter and participate in the new logical ring; shall set the common-memory area unavailable: i.e. set to zero (0) the head-address and the size of the common memory area for own use of the node; and shall not send out any cyclic-data. Error information with the overlap of the common-memory area shall be notified to the FAL-user; and the validity of the contents of the common-memory shall be flagged as invalid and unavailable;

g) After sending out a participation-request frame, in case of no reception of any token frames addressed to this node until the 3CWT-timer out, the node shall attempt and follow again the above mentioned process and the procedures to enter into the logical ring;

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h) After sending out a participation-request frame, in case of no reception of any token frames until the 3CWT-timer out, the node shall attempt and follow again the above mentioned process and the procedures to enter into the logical ring;

i) When a node on a logical ring receives any participation-request frames, the node shall update and enrol the receiving node related information into the participating-node-management-information after validation without the overlapping of the common-memory address space and further the duplication of the node number. Detected error information shall be notified to the FAL-user.

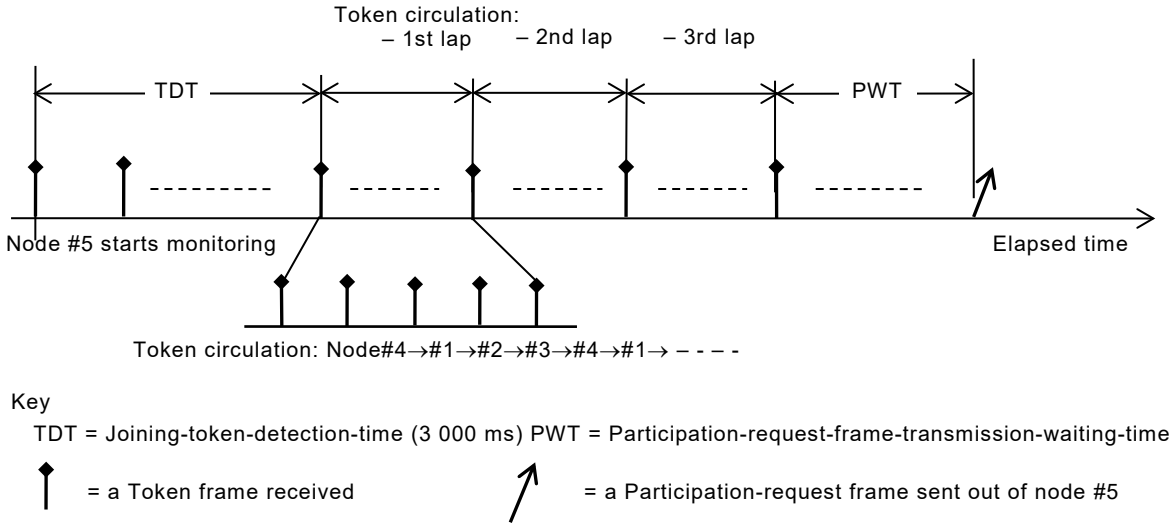

Figure 10 – Node addition: in-ring start-up state

4.3.4 Node in a logical ring

When a node on a logical ring in normal, steady state receives any participation-request frames and/or any final cyclic-data frames which contain the fragmented cyclic-data and are sent out last by the nodes, the node shall update and enrol the receiving node related information into the participating-node-management-information even though the sender node number is not identified after validation without the overlapping of the common-memory address space and further the duplication of the node number. Detected error information shall be notified to the FAL-user.

4.3.5 Node drop-out

Node drop-out or node exiting out of the logical ring is as follows:

a) Each node on a logical ring in normal, steady state shall check the sender node number of any token frames every time on the reception; and shall detect whether no reception of the token frame from a certain node continues for three consecutive token circulation periods; and shall recognize and determine the corresponding certain node is removed and dropped out of the logical ring;

b) When the node determines the corresponding certain node is dropped out of the logical ring, the node shall update the corresponding certain node related information within the participating-node-management information to change the status as the corresponding certain node removed.

c) When the node recognizes and determines all other nodes are removed during the token circulation periods and only the node itself exists, the node shall move into the initial state and take the procedures specified in 4.3.3.2 and 4.3.3.3.

d) Each node on a logical ring in normal, steady state shall monitor and check any token frames addressed to the node. In the case that no reception of the token frame addressed

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to the node from other nodes continues for three consecutive token circulation periods, the node shall recognize and determine the node is dropped out of the logical ring. The node shall move into the initial state and take the procedures specified in 4.3.3.2 and 4.3.3.3.

4.3.6 Data transmission

4.3.6.1 Overview

Operation in normal, steady state on the node consists of a data transmission phase and a token transmission phase.

In the data transmission phase, two kinds of data transmissions are performed:

– Cyclic-data transmission;
– Message-data transmission.

4.3.6.2 Cyclic-data transmission

4.3.6.2.1 Overview

The Type 26 fieldbus is applicable to a controller level network for efficiently executing the control and state data exchange between various kinds of field devices in industrial automation control systems.

The communications between field devices requires simplicity in actual application programming as well as the time-critical transfer of the control and state data among field devices. To meet such a requirement, the CM provides a function to share the control and state data seamlessly across an industrial control network system.

The CM is a virtual common memory accessible with logically unique address across the Type 26 nodes, and the APs running over each node can handle the CM as a global common memory shared among the nodes over the Type 26 fieldbus network.

Cyclic-data transmission is used for refreshing and equalizing the contents of the CM among the nodes by means of a cyclic broadcasting performed at a constant rate after a node writes a data peace on a pre-allocated memory area of the CM for each node.

The data distribution/refreshing function to all nodes in temporal and spatial coherency provided with the CM by means of the cyclic-data transmission performed at a constant rate enables each node to share the same data with each other and to make good use of the data; i.e. a memory space allocated to each node is a container for application data in general use and provides flexibility to apply in a variety of industrial application processes.

Figure 11 shows the data sharing with the CM.

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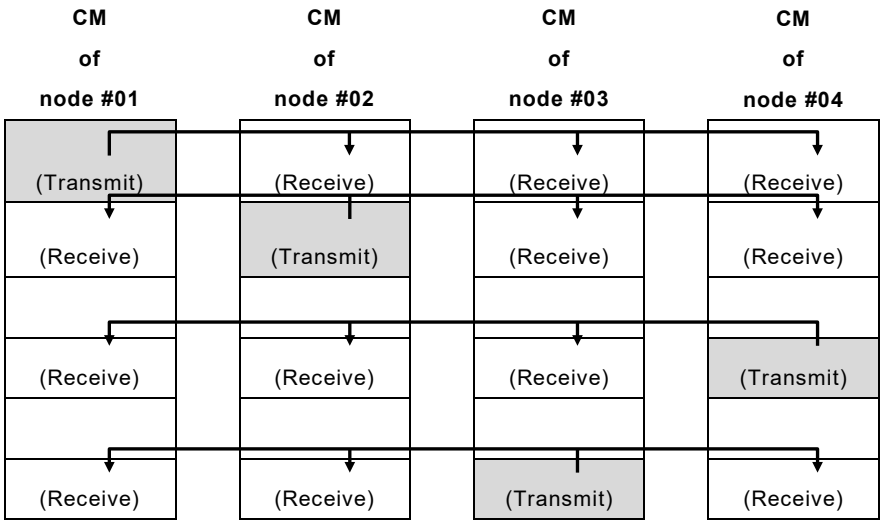

Figure 11 – Data sharing with the CM

4.3.6.2.2 Configuration of Common-memory

Figure 12 shows the configuration of the CM which is composed of two memory areas; i.e. the memory-area-1 and -2 with the memory size of 512 words and 8 192 words respectively. The total memory size of the CM is up to 8 704 words.

The memory area allocated to each node as the output/write area on one or both of the memory-area-1 and -2 is dependent on the implementation. Any memory size in word boundary is allocable from 0 (zero) to the maximum space size of the memory-area-1 and/or -2 to each node, and the memory space allocation is designated with the memory size and the head-address. The memory space allocated to each node shall not overlap with each other. And the allocated memory space is identical to the cyclic-data transmission area by the node.

In case of total zero memory space allocated to a node, it means no cyclic-data transmission to be carried out by the node. It is applicable to a mixture system of the nodes with and without the CM.

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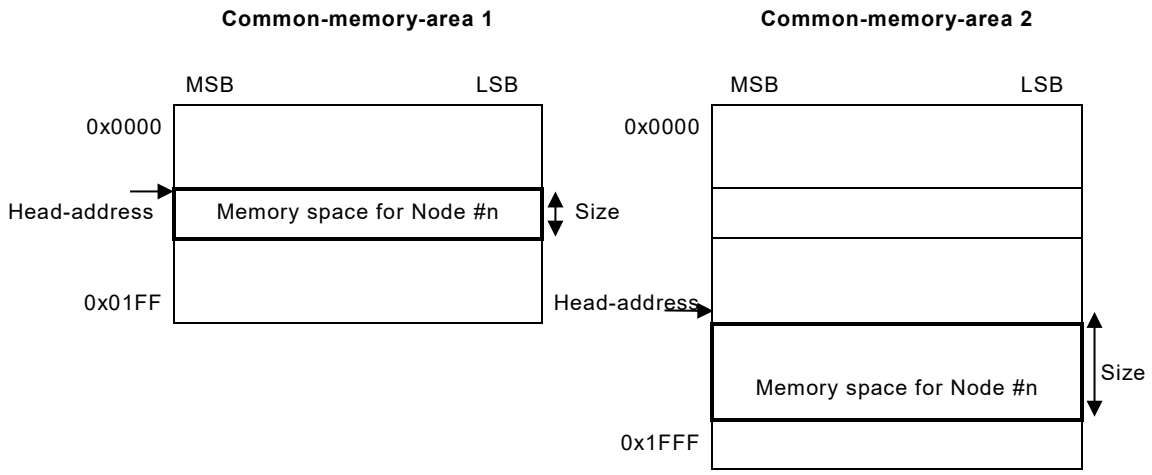

Figure 12 – Configuration of the Common-memory

4.3.6.2.3 Cyclic-data transfer

Cyclic-data is transferred by means of the cyclic-data transmission.

The memory area on the CM allocated to a certain node is used as the transmission area of the node by the cyclic-data transmission as a sender. On the other hand as receiving nodes of the cyclic-data transmission, the memory area of the sender node is used as a receiving area for the data from the sender node.

Cyclic-data transmission shall be performed each time the node obtains the token, and all the data on the CM area allocated to the node shall be sent out of the node.

Dependent on the total amount of data to be transferred, one or more cyclic-data frames are sent out each time the node obtains the token. In the case that the total amount of data is less than or equal to 1 024 octets, data resided in the memory space allocated for the node on the CM-area-1 and -2 shall be packed into a single cyclic-data frame and shall be sent out at a time. On the other hand in the case that the total amount of data is over 1 024 octets, the data shall be fragmented into multiple packets and shall be sent out by means of consecutive multiple cyclic-data frames while holding the token.

The total amount of data over 1 024 octets which resides in the memory space riding both on the CM-area-1 and -2 shall be fragmented into two or more packets for multiple cyclic-data frames to be sent out. The first cyclic-data frame shall contain all the data resided in the memory space on the CM-area-1 and all or part of the data resided in the memory space on the CM-area-2 but the total volume of data contained in the cyclic-data frame shall not exceed 1 024 octets. The following cyclic-data frames shall be sent out with the data by 1 024 octets until all the data is packed into multiple cyclic-data frames. The last cyclic-data frame, so-called “final-cyclic-data frame” shall contain the data of 1 024 octets or less size.

Figure 13 shows an example of the APDUs for multiple cyclic-data frames containing fragmented data. In this case since the total amount of data is over 1 024 octets, the data are fragmented and packed into three cyclic-data frames.

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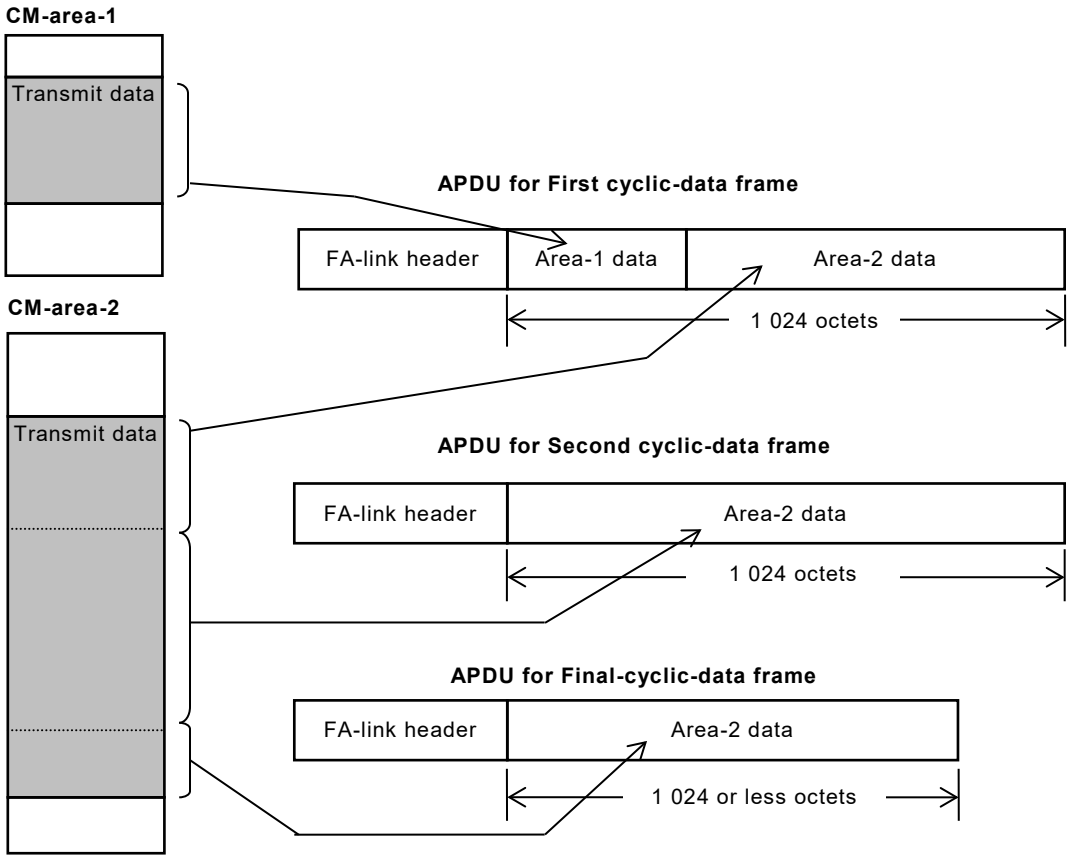

Figure 13 – APDUs of cyclic-data frames containing fragmented data

Each cyclic-data frame shall contain the information in the FA-link header to disassemble/assemble the cyclic-data APDU as follows:

- TBN: total-fragment-block-number;
- CBN: current-fragment-block-number;
- BSIZE: current-fragment-block-size;
- C_AD1: data-head-address on common-memory-area-1;
- C_AD2: data-head-address on common-memory-area-2;
- C_SZ1: data-size on common-memory-area-1;
- C_SZ2: data-size on common-memory-area-2.

Each node receiving a cyclic-data frame shall check the value of TBN in the FA-link header and determine whether the cyclic-data frame is fragmented or not. In the case of the cyclic-data frame fragmented, the receiving node shall store each received block into the receive buffer one by one upon reception of the fragmented cyclic-data frames; and after receiving the final-cyclic-data frame without error, all data received from other nodes shall be written into the corresponding memory address space on the common-memory-area-1 and -2.

In the case that each node fails to receive a series of the cyclic-data frames from other nodes without error, the node shall discard all the received data stored in the receive buffer without writing into the corresponding memory address space on the common-memory-area-1 and -2.

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4.3.6.3 Message-data transmission

4.3.6.3.1 Overview

Message-data transmission is used by the message-data transfer service which is based on aperiodic data transfer and is sporadically occurred upon FAL-user request to transfer one or more messages to other nodes. Message-data transfer is performed by means of message-data transmission on the communication channel provided by the DL service of UDP (see RFC 768) or TCP (see RFC 793) as the lower layer of Type 26 FAL.

NOTE Message-data transmission in general is performed by means of connectionless UDP communication channels. The message-data transmission based on connection-oriented TCP channels is only for the General-purpose-command-server-communication which is utilized for intercommunication between the nodes and the general-purpose Human-Machine-Interface tool.

4.3.6.3.2 Message-data transfer

Message-data is transferred by means of the message-data transmission.

Message -data transmission shall be performed as follows:

a) When a node obtains the token and the message-data transfer is requested by the FAL-user, the node shall send out at a maximum one message-data frame before sending out the cyclic-data frames;

b) The maximum size of the message-data contained in one message-data frame shall be restricted to 1 024 octets excluding the FA-link header;

c) Two types of the message-data transmission are applicable: i.e. one-to-one transfer type and one-to-N broadcasting type. The destination node number (DNA) contained in the message-data frame of one-to-one type message-data transmission shall be specified from 1 to 254 as the receiver node number, on the other hand the DNA shall be set to 255 for one-to-N broadcasting type message-data transmission; and the node receiving the message-data frame shall check the received DNA and determines whether the message-data frame is one-to-one type or one-to-N type message-data transmission.

The one-to-one type message-data transmission is based on confirmed type data transmission; on the other hand the one-to-N type message-data transmission is of unconfirmed type.

The one-to-one type message-data transmission provides the functions for automatic retransmission and sequence number management. The automatic retransmission is performed, for instance upon no acknowledgement from the receiver node after sending out a message-data frame addressed to a receiver node. The sequence number management is utilized to check and determine whether a receiving message-data frame has been previously received and is redundant.

Table 3 summarizes the functions available to each type of message-data transmission.

Delivery confirmation and automatic retransmission is performed explicitly by means of the message-data transmission on connectionless UDP channels. On the other hand, delivery confirmation and automatic retransmission by means of the message-data transmission on connection-oriented TCP channels is performed implicitly. The TCP protocol provides these functions.

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Table 3 – Available functions to message-data transfer on UDP channel

Message-data transmission	Delivery confirmation	Automatic retransmission	Sequence number management
One-to-one type	Available	Available	Available
One-to-N type	–	–	Available

4.3.6.3.3 Traffic control of message-data transmission

The traffic control function is performed primarily for the message-data transfer on connectionless UDP channels.

When a node obtains the token, the node shall send out at a maximum one message-data frame before sending out the cyclic-data frames and it shall be performed on the basis of the condition of communication load at that time. The condition of the communication load for the node possible to send out one message-data frame is as follows:

- The value of the RMT shall be less than or equal to 90 % value of the RCT, or
- The value of the RMT is greater than 90 % value of the RCT and is less than the value of the RCT and no message-data frame was sent out last time when the node obtained the token.

When the value of the RMT is equal to or greater than the value of the RCT, no message-data frame shall be sent out of the node.

4.3.6.3.4 Delivery confirmation

Delivery confirmation for the message-data transfer shall be performed explicitly by means of a series of the message-data transmission on connectionless UDP channels. On the other hand, delivery confirmation by means of the message-data transmission on connection-oriented TCP communication channels is performed implicitly and the TCP protocol provides the function.

- Delivery confirmation is performed by Acknowledge response from the node receiving a confirm type message-data frame. Acknowledge response is the confirmation responded to the sending node by the receiving node upon reception of a confirm type message-data frame without error. Each node shall provide the function for Acknowledge response.
- The acknowledge response or ACK shall be conveyed by means of cyclic-data transmission; i.e. a cyclic-data frame to be sent out of the receiving node shall contain the ACK to the sending node.
- The cyclic-data frame is sent out of the receiving node when the receiving node obtains the token, so that the cyclic-data frame can convey one or more ACKs which corresponds to the confirm type message-data frames received until the receiving node obtains the token and/or the receiving node sends out the cyclic-data frame with these ACKs.

NOTE The ACKs are conveyed by the final-cyclic-data frame in which at a maximum eight ACKs can be contained.

Figure 14 shows an example of a sequential diagram of exchanging ACKs for message-data transmissions on connectionless UDP channels among node #1, node #2 and node #3.

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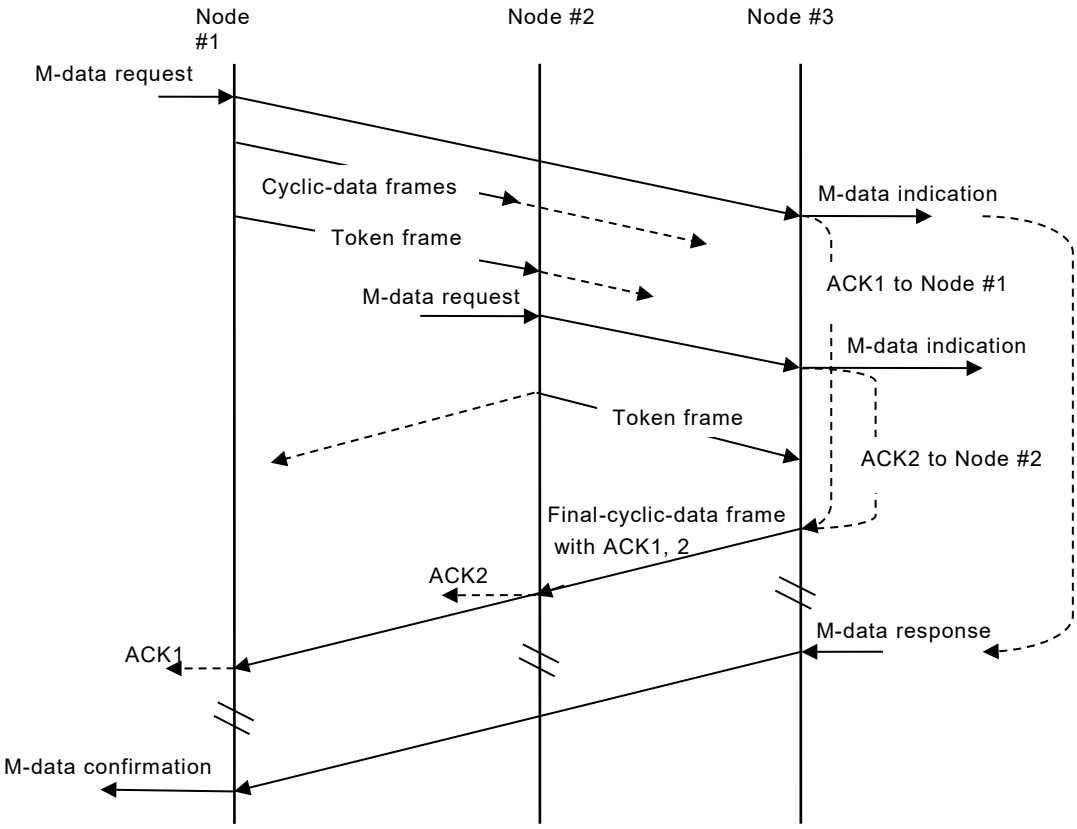

Figure 14 – Example of sequential diagram of ACK over UDP channel

Figure 15 shows the delivery confirmation or ACK sequence for a message-data transmission implicitly checked by TCP protocol on a connection-oriented TCP channel between node #1 and node #2.

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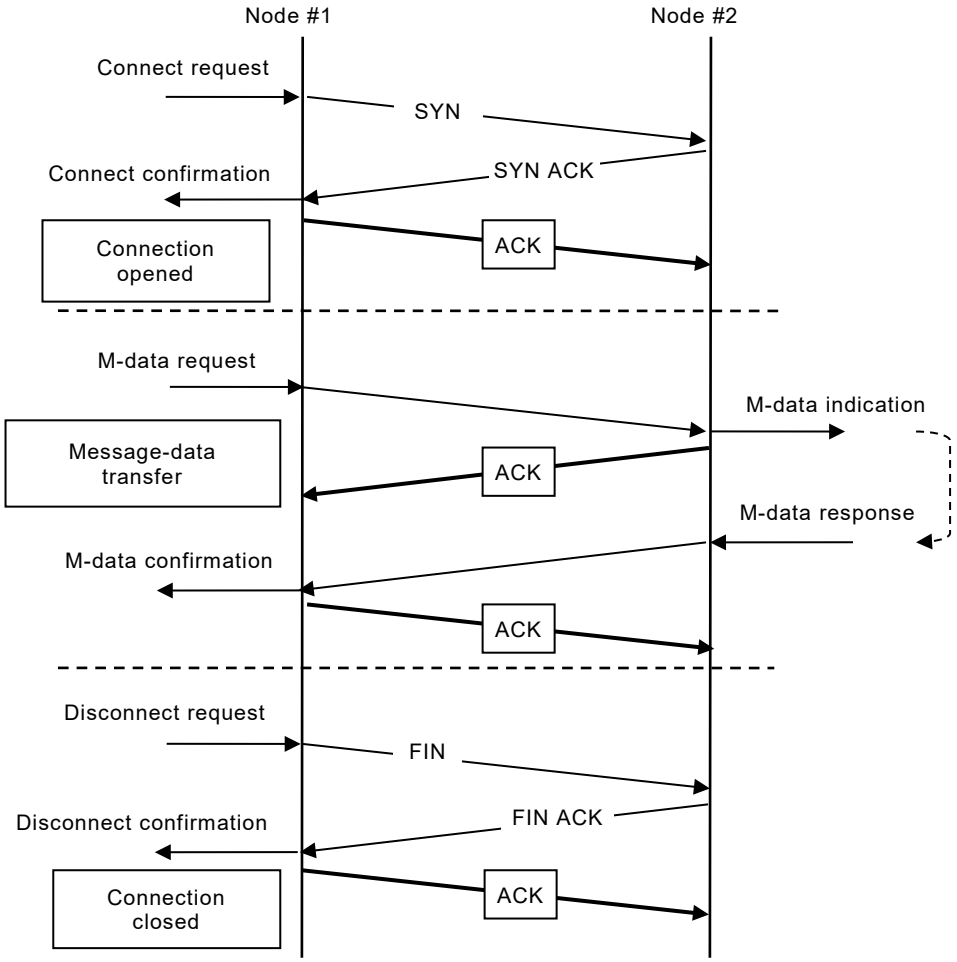

Figure 15 – Delivery confirmation checked by TCP protocol

4.3.6.3.5 Automatic retransmission

The automatic retransmission shall be performed by the nodes upon no ACK from the destination node of a message-data frame sent out and upon receiving ACK with error from the destination node, after sending out a message-data frame to the destination node.

Each node shall be provided with the automatic retransmission function as follows:

a) Upon reception of an ACK with error, the node shall perform the retransmission of the message-data transmission;

b) Upon the waiting-time-period-for-receiving-message-acknowledge timer (AWT-timer) out under no reception of any ACK from the destination node during the three-lap time period of the token circulation (3CWT time period) to the node after sending out a message-data frame, the node shall perform the retransmission of the message-data transmission;

c) Retransmission by the node shall be carried out at a maximum three times;

d) Upon no reception of any ACK from the destination node after retransmissions three times, the node shall cancel the message-data transmission and shall notify of the error result with error information to the FAL-user.

4.3.6.3.6 Sequence Number Management

The sequence number management is utilized to check and determine whether a receiving message-data frame has been previously received and is redundant.

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The sequence number management by each node is as follows:

a) The sequence number management by each node shall be performed by means of both of the version of sequence number and the sequence number;

b) The value of the version of sequence number shall be set at the time when a node enters into the logical ring as a new node and shall be maintained until the node drops out of the logical ring, and is used for other nodes to determine whether a receiving message-data from the node is valid and not overdue;

c) The value of the version of sequence number shall be a unique number and is supposed to be generated by each node, for instance from current time data, random number data or random data and so forth. However the method to generate the unique number is implementation matter and is intentionally excluded in this document;

d) The value of the sequence number is used for other nodes to determine whether a receiving message-data from the node has been previously received and is redundant, and shall be set to zero (0) at the time of the network start-up, and shall be increased by one (1) every time on a message-data transmission completed; i.e. the sequence number shall be increased by one upon completion of a message-data transmission with ACK reception without error or completion with retransmission over due to error and then cancelling the message-data transmission; the value of the sequence number shall be a roll-over binary counter value of 32-bit length in the range of 0x1 to 0xFFFF FFFF;

e) The version of sequence number and the sequence number shall be set in the FA-link header and shall be conveyed by means of the cyclic-data and the message-data transmission to other nodes;

f) The values of the version of sequence number and the sequence number which are conveyed by a message-data transmission from other nodes shall be put into the corresponding entry area to each node in the message-sequence-number-management-information on one node to node basis upon reception of a message-data frame from a node;

g) When the value of the version of sequence number in the FA-link header of received message-data frame differs from the value of the corresponding node in the message-sequence-number-management-information, the value in the message-sequence-number-management-information shall be updated to the value in the FA-link header; and the received message-data frame shall be discarded; and ACK with error status of the version of sequence number different shall be sent back to the initiator node or the source node of the message-data frame;

h) The contents of the message-sequence-number-management-information shall be cleared in advance of each node entering into the logical ring;

i) When the value of the version of the sequence number of the corresponding node in the message-sequence-number-management-information is zero (0) as its initial value, the receiving message-data frame shall be valid without check; and the value of the version of the sequence number in the FA-link header of a received message-data frame shall be put into the corresponding entry area to that node in the message-sequence-number-management-information;

j) When the value of the sequence number in the FA-link header of the receiving message-data frame is equal to the value of the sequence number of the corresponding node in the message-sequence-number-management-information, the node receiving the message-data frame shall recognize that the receiving message-data frame is being retransmitted by the corresponding node; and the received message-data is already processed and then the receiving message-data frame shall be discarded; and the ACK without error status shall be sent back to the corresponding node;

k) When the value of the sequence number in the FA-link header of the receiving message-data frame differs from the value of the sequence number of the corresponding node in the message-sequence-number-management-information, the node receiving the message-data frame shall recognize the receiving message-data as a new one and shall put the value of received sequence number into the corresponding entry area to that node in the message-sequence-number-management-information.

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