

PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

Real-time Ethernet – Real-time Automation Protocol for Industrial Ethernet
(RAPIEnet)

Withdrawn



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Real-time Ethernet – Real-time Automation Protocol for Industrial Ethernet (RAPIEnet)

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IEC-PAS 62573 has been processed by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
65C/488/NP	65C/496/RVN

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INTRODUCTION

This Publicly Available Specification (PAS) describes a set of specifications essential for the ISO/IEC 8802-3-based “Real-time Automation Protocol for Industrial Ethernet (RAPIEnet),” Each specification in this PAS is to be classified into a separate part of the IEC 61158 series.

This specification meets the industrial automation market objective of identifying the RTE communication networks co-existing with the ISO/IEC 8802 series, providing more predictable, time-deterministic, and reliable real-time data transfer.

More specifically, these profiles help correctly state the compliance with the ISO/IEC 8802 series, and avoid the spread of divergent implementations that would limit its use, clarity, and understanding.

Additional profiles to address specific market concerns, such as functional safety or information security, may be addressed by future parts of the IEC 61784 series. This is not within the scope of this document. This PAS specifies the RAPIEnet communication profile portion of the protocol set.

This PAS specifies the essential part of the RAPIEnet profile, which is an extension of the ISO/IEC 8802-3-based data link layer, and the application layer exploiting the services of the data link layer immediately below. This document describes the specifications essential for the RAPIEnet profile, specifically for the data link layer and the application layer, in terms of the three-layer fieldbus Reference Model, which is based in part on the OSI Basic Reference Model. Other parts of RAPIEnet are outside the scope of this document.

Withhold

Real-time Ethernet – Real-time Automation Protocol for Industrial Ethernet (RAPIEnet)

1 Scope

In industrial control systems, several types of field devices may be connected to control networks. These include drives, sensors and actuators, programmable controllers, distributed control systems, and human-machine interface devices. The process control data and the state data are transferred among these field devices in the system, and the communications between these field devices requires simplicity in application programming to be executed with adequate response time. In most industrial automation systems, the control network is required to provide time-deterministic and predictable response capability for applications. Plant production may be compromised due to errors that could be introduced into the control system if the network does not provide a time-deterministic response. Therefore, the following characteristics are required for a real-time Ethernet-based control network:

- a) a time-deterministic response time between the control devices;
- b) the ability to share process data seamlessly across the control system.

RAPIEnet is applicable to such an industrial automation environment in which time-deterministic real-time communications are a fundamental requirement.

This PAS specifies the protocol set necessary for RAPIEnet, specifically for the data link layer and the application layer, which is mapped on top of the data link layer, to exploit the services in accordance with the three-layer fieldbus reference model, which is based in part on the OSI Basic Reference Model. Both reference models subdivide the area of standardization for interconnection into a series of layers of manageable size. Throughout this PAS, the term "service" refers to the abstract capability provided by one layer of the OSI Basic Reference model to the layer immediately above.

This PAS consists of

- a) physical layer specification;
- b) data link layer service definitions;
- c) data link layer protocol specification;
- d) application layer service definitions;
- e) application layer protocol specification.

The service of both the data link and the application layer in this PAS is a conceptual architectural service, independent of administrative and implementation details.

The data link layer describes the extension of the ISO/IEC 8802-3 data link layer for RAPIEnet, and the application layer describes the utilization of the upper layer functions over the RAPIEnet data link layer protocol.

2 Normative references

The following documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the document (including any amendments) applies.

IEC 61158-3 (all parts), *Industrial communication networks – Fieldbus specifications – Part 3: Data-link layer service definition*

IEC 61158-4 (all parts), *Industrial communication networks – Fieldbus specifications – Part 4: Data link layer protocol specification*

IEC 61158-5 (all parts), *Industrial communication networks – Fieldbus specifications – Part 5: Application layer service definition*

IEC 61158-6 (all parts), *Industrial communication networks – Fieldbus specifications – Part 6: Application layer protocol specification*

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

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

ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

ISO/IEC 8822:1994, *Information technology – Open Systems Interconnection – Presentation service definition*

ISO/IEC 8824-1:2002, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

ISO/IEC 8825-1:2002, *Information technology – ASN.1 encoding rules: Specifications of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*

ISO/IEC 8886:1996, *Information technology – Open Systems Interconnection – Data link service definition*

ISO/IEC 9545:1994, *Information technology – Open Systems Interconnection – Application Layer structure*

ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

3 Terms, definitions, and abbreviations

For the purposes of this document, some of the following terms and definitions have been compiled from the referenced documents. The terms and definitions of the ISO/IEC 7498-1, ISO/IEC 8802-3, and IEC 61588 series shall be fully valid, unless otherwise stated.

3.1 IEC 61158 definitions

For the purposes of this document, the following definitions of IEC 61158 apply.

3.1.1

application

function or data structure for which data are consumed or produced

[IEC 61158-5:2007]

3.1.2

application objects

multiple object classes that manage and provide a run-time exchange of messages across the network and within the network device

[IEC 61158-5:2007]

3.1.3

bit

unit of information consisting of a 1 or a 0. This is the smallest data unit that can be transmitted

[IEC 61158-4:2007]

3.1.4

client

- 1) object that uses the services of another (server) object to perform a task.
- 2) initiator of a message to which a server reacts

[IEC 61158-4:2007]

3.1.5

communication objects

components that manage and provide a run-time exchange of messages across the network

[IEC 61158-5:2007]

3.1.6

connection

logical binding between two application objects within the same or different devices

[IEC 61158-4:2007]

3.1.7

connector

coupling device employed to connect the medium of one circuit or communication element with that of another circuit or communication element

[IEC 61158-2:2007]

3.1.8

cyclic

term used to describe events that repeat in a regular and repetitive manner

[IEC 61158-3:2007]

3.1.9

Cyclic Redundancy Check (CRC)

residual value computed from an array of data and used as a representative signature for the array

[IEC 61158-4:2007]

3.1.10

data

generic term used to refer to any information carried over a fieldbus

[IEC 61158-3:2007]

3.1.11**data consistency**

means for coherent transmission and access of the input or output data object between and within client and server

[IEC 61158-5:2007]

3.1.12**device**

physical entity connected to the fieldbus composed of at least one communication element (the network element) and which may have a control element and/or a final element (transducer, actuator, etc.)

[IEC 61158-2:2007]

3.1.13**device profile**

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

[IEC 61158-5:2007]

3.1.14**diagnosis information**

all data available at the server for maintenance purposes

[IEC 61158-5:2007]

3.1.15**error**

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

[IEC 61158-4:2007]

3.1.16**error class**

general grouping for related error definitions and corresponding error codes

[IEC 61158-5:2007]

3.1.17**error code**

identification of a specific type of error within an error class

[IEC 61158-5:2007]

3.1.18**event**

an instance of a change of conditions

[IEC 61158-5:2007]

3.1.19**frame**

denigrated synonym for data link protocol data unit

[IEC 61158-3:2007]

3.1.20

index

address of an object within an application process

[IEC 61158-5:2007]

3.1.21

interface

shared boundary between two functional units, defined by functional characteristics, signal characteristics, or other characteristics as appropriate

[IEC 61158-5:2007]

3.1.22

master

device that controls the data transfer on the network and initiates the media access of the slaves by sending messages, and that constitutes the interface to the control system

[IEC 61158-2:2007]

3.1.23

medium

cable, optical fibre, or other means by which communication signals are transmitted between two or more points

[IEC 61158-2:2007]

3.1.24

network

set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers, and lower-layer gateways

[IEC 61158-6:2007]

3.1.25

node

endpoint of a link in a network, or a point at which two or more links meet

[IEC 61158-2, modified]

3.1.26

object

abstract representation of a particular component within a device

[IEC 61158-4:2007]

NOTE An object can be

- a) an abstract representation of the capabilities of a device. Objects can be composed of any or all of the following components:
 - 1) data (information which changes with time);
 - 2) configuration (parameters for behaviour);
 - 3) methods (things that can be done using data and configuration);
- b) a collection of related data (in the form of variables) and methods (procedures) for operating on that data that have clearly defined interface and behaviour.

3.1.27

server

object that provides services to another (client) object

[IEC 61158-4:2007]

3.1.28**service**

operation or function that an object and/or object class performs upon request from another object and/or object class

[IEC 61158-5:2007]

3.1.29**slave**

data link entity accessing the medium only after being initiated by the preceding slave or master

[IEC 61158-3:2007]

3.2 Definitions from other standards

The following definitions apply.

3.2.1**frame**

unit of data transmission for ISO/IEC 8802-3 media access control that conveys a protocol data unit between media access control service users

[IEEE Std. 802.1Q:1998]

3.2.2**message**

ordered series of octets intended to convey information

[derived from ISO 2382:16.02.01]

NOTE A message is normally used to convey information between peers at the application layer.

3.2.3**switch**

media access control bridge as defined in IEEE 802.1D:1998

3.3 RAPIEnet terms and definitions

Terms and definitions of this PAS are described separately in 7.4 for the data link layer service definitions and protocol specifications, in 9.4 for the application layer service definition, and in 10.4 for the application layer protocol specification.

3.4 Symbols and abbreviations

Symbols and abbreviations of this PAS are described separately in 7.4 for the data link layer service definitions and protocol specifications, in 9.4 for the application layer service definition, and in 10.4 for the application layer protocol specification.

4 Technology overview**4.1 General Information**

This section describes the basic operating principles and technical features of RAPIEnet. The aim of RAPIEnet is to maximize the use of full-duplex Ethernet bandwidth through the use of an internal hardware Ethernet switch. Therefore, RAPIEnet provides a collision-free transmission mechanism between two nodes. Every RAPIEnet device detects link failure and link establishment using media sensing technologies and shares the link information with each other so that fast connectivity recovery time is also guaranteed in a line or ring network.

4.2 Operating principles

From an Ethernet point of view, a RAPIEnet device is a dual-port switching device that receives and transmits standard ISO/IEC 8802-3 Ethernet frames. It is intelligent and can control directional frame forwarding between its dual ports according to the network status and device status.

4.2.1 Frame forwarding and receiving control

By using the internal full-duplex hardware switch, RAPIEnet provides a very efficient transmission mechanism that allows each RAPIEnet device on a network to transmit frames at any time without collision. Therefore, a RAPIEnet device transmits frames without restriction of medium access as soon as a frame appears in the transmit queue. Figure 1 shows the forwarding and receiving control of the RAPIEnet device

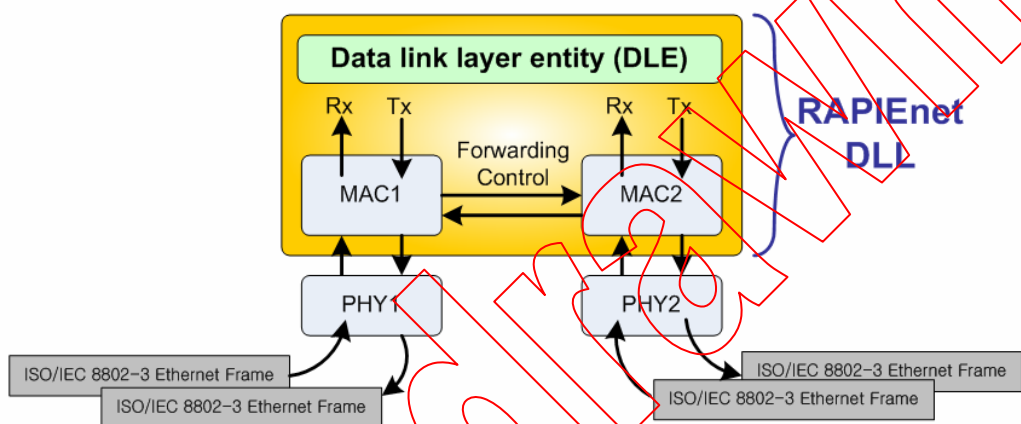


Figure 1 – Forwarding and receiving Ethernet frames

When an Ethernet frame is received at the media access control (MAC) layer through the physical interface transceiver (PHY), a RAPIEnet general device (GD, see 8.6.3.3) other than the ring network manager (RNM, see 8.6.3.3) or the line network manager (LNM, see 8.6.3.3), handles the received frame by taking one of the following actions depending on the destination MAC address in the received frame.

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

This frame forwarding procedure is processed by the internal hardware switch so that it has little impact on the performance of the RAPIEnet protocol. In Figure 1, when the DLE has two concurrent frames to be transmitted through a common MAC port, such as a frame from the upper layer and a frame to be forwarded from the other port, the “round-robin” method is used to determine their transmission order.

As shown in Figure 2, the LNM disables both directional frame forward functions so that frames are not forwarded to the other port.

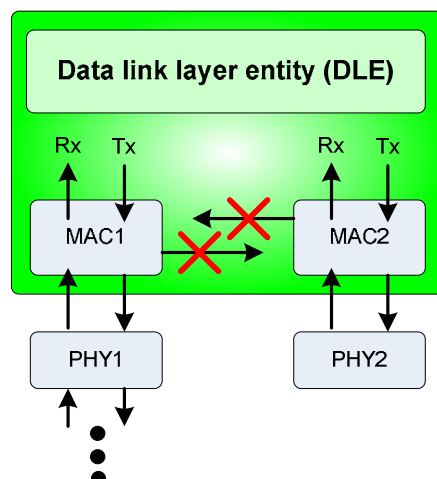


Figure 2 – Forward control of LNM

In a ring network, a frame can be continuously circulated when the designated device is not found or when the frame is broadcast on the network. In a RAPIEnet ring network, two RNMs are automatically selected, and, as shown in Figure 3, each RNM disables only one directional frame forward function to prevent infinite frame circulation. A primary RNM (RNMP) is selected first and then one of its neighbouring nodes is selected as a secondary RNM (RNMS).

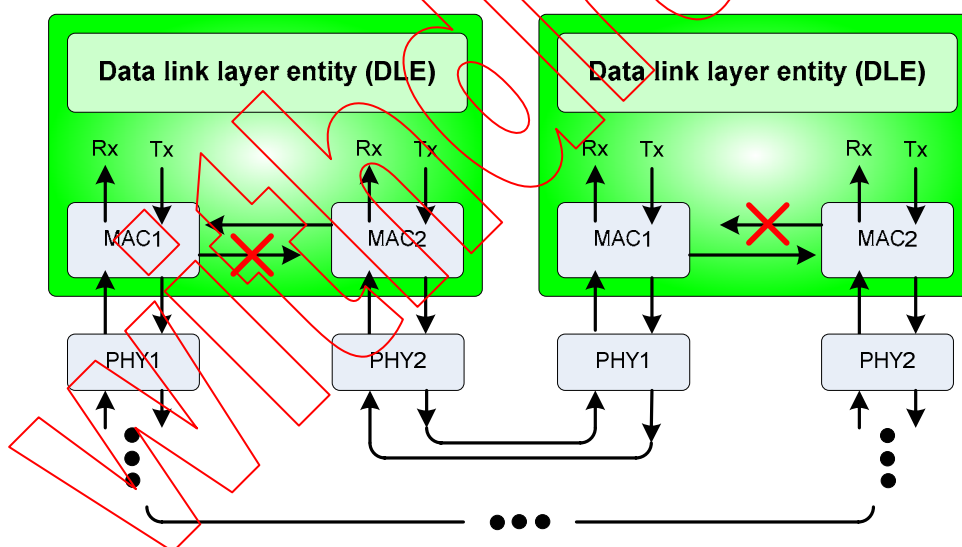


Figure 3 – Forward control of RNM

4.2.2 Link status monitoring

RAPIEnet provides an efficient mechanism for dynamic network topology management. When a link between two devices is established or released, it is automatically detected by both devices. This link status information is distributed and shared with every device on the network so that the network topology can be dynamically managed. The link status information is either “link active” or “link inactive” and the link status detection process is initiated by the hardware-triggered signal event (see 7.8.4.3). A status of “link active” means a RAPIEnet communication link is established between two devices and it is possible to send frames through the link. A status of “link inactive” means a RAPIEnet communication link is not established through an Ethernet MAC port and it is not possible to send frames through the port. By sharing all the link information on the network, every RAPIEnet device on the network knows the online network connectivity status (see 8.5.5). Figure 4 shows the intrinsic link status monitoring procedure of the RAPIEnet data link layer (DLL).

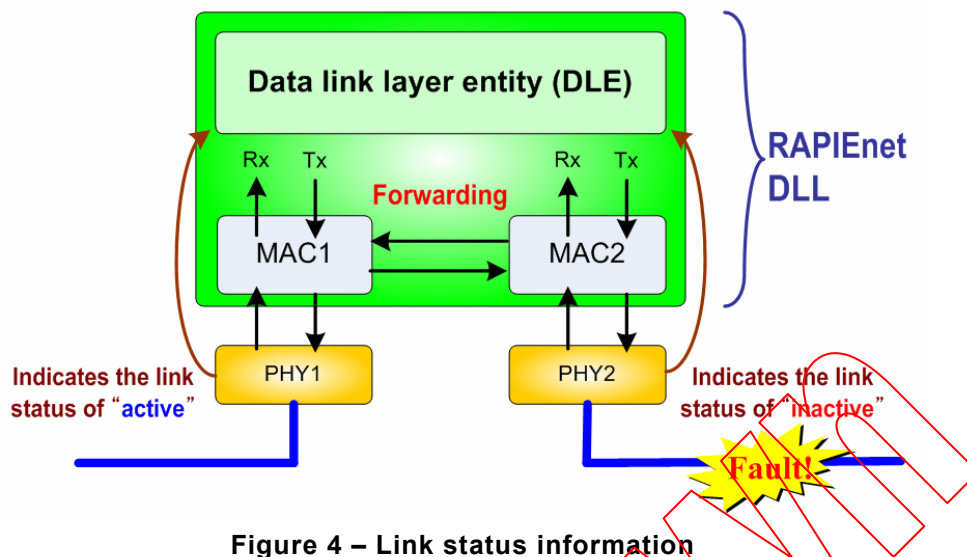


Figure 4 – Link status information

4.2.3 Error detection

A RAPIEnet device examines the frame check sequence (FCS) to determine whether the received frame is valid. When an invalid frame is received or an error is detected during the FCS, the RAPIEnet device discards the received frame, and the frame is not forwarded to the next device.

4.3 Topology

Network topology is one of the key features of automated control systems.

A line topology is more flexible, easier to configure, and more cost-effective than a star topology using Ethernet switches. In a RAPIEnet line topology, every device controls its dual Ethernet MAC port to form a daisy-chain line network. The link information between two nodes is shared with every device on the network, and thus every device updates its own path table with the link information it receives.

In a ring network, two paths are possible between two nodes: the clockwise path and the counter-clockwise path. Therefore, a RAPIEnet ring topology can maintain the network connectivity even in the case of cable break or link failure. To provide reliable and redundant network connectivity, RAPIEnet supports an online auto-configuration mechanism to form a network topology. When a link failure is detected in a ring network, the network is automatically reconfigured as a line network. RAPIEnet supports both line and ring network topologies, and also provides extremely fast recovery time from line-to-ring or from ring-to-line networks.

Figure 5 shows a basic example of RAPIEnet line network. A basic RAPIEnet line topology can be configured between two nodes with a single connection. A large-scale RAPIEnet line network can be expanded by extending the daisy-chained connection. Conversely, a large-scale RAPIEnet line network can be divided into two or more smaller scale line networks.

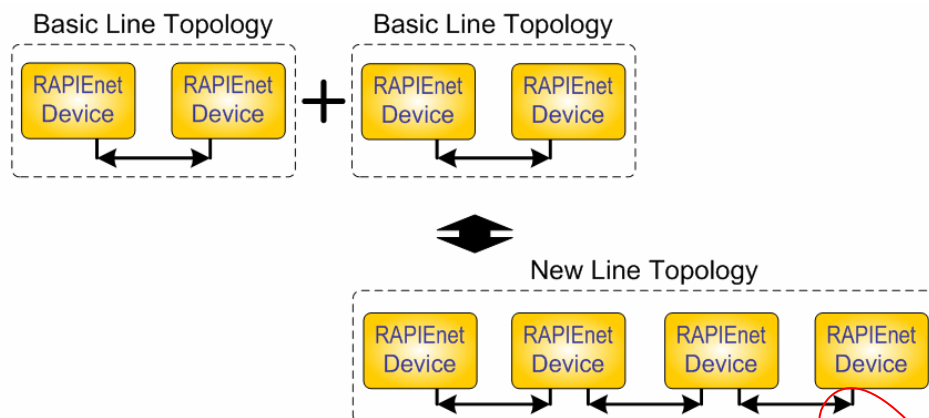


Figure 5 – Line topology

Figure 6 shows a basic example of a RAPIEnet ring network. When a new link is connected between two end nodes in a line network, the network is automatically reconfigured as a ring network. On the other hand, the network is automatically reconfigured as a line network when any link failure is detected in a ring network. Two RNMs are automatically selected to block the infinite circulation of any frame in a RAPIEnet ring network.

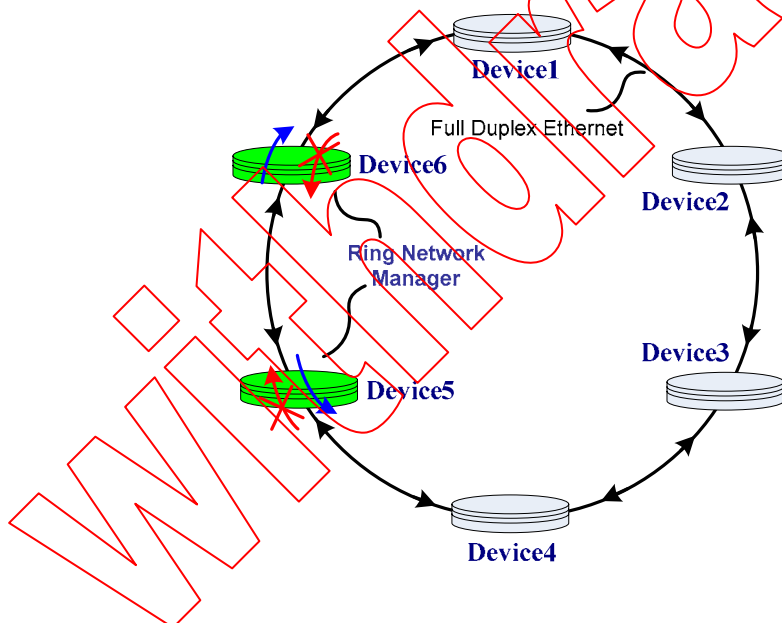


Figure 6 – Ring topology

4.4 Device reference model

This section describes the RAPIEnet device reference model using the principles, methodology, and model of ISO/IEC 7498-1. The OSI model provides a layered approach to communications standards, in which the layers can be developed and modified independently. This PAS defines functionality from the top to bottom of a full OSI stack and, potentially, some functions for the users of the stack. Functions of intermediate OSI layers 3 through 6 are consolidated into either the RAPIEnet data link layer or the RAPIEnet application layer. Likewise, features common to users of the fieldbus application layer may be provided by the RAPIEnet application layer to simplify user operation as shown in Figure 7.

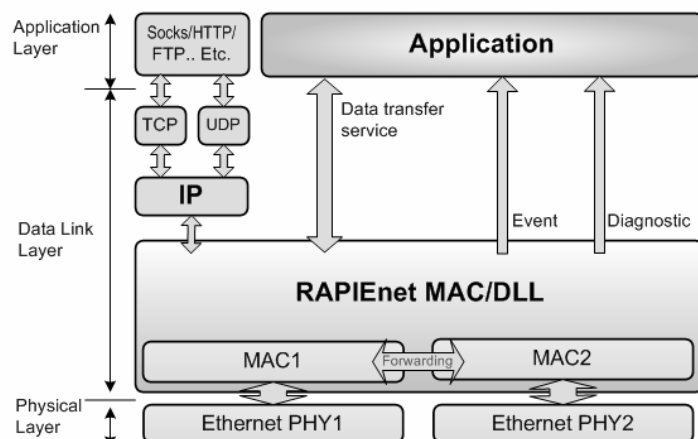


Figure 7 – OSI basic reference model

4.4.1 Physical layer

The RAPIenet physical layer corresponds to the ISO/IEC 8802-3:2002 access method and physical layer specifications. The physical layer receives data from the upper data link layer, encodes the bits into signals, and transmits the resulting physical signals to the connected transmission medium. Signals are then received and decoded by the next device, and the data units are passed to the data link layer of the recipient device.

4.4.2 Data link layer (DLL)

The RAPIenet DLL provides basic time-deterministic support for data communications among communication devices connected via RAPIenet. The data link layer supports the timing demands typically required for high-performance automation applications. These do not change the basic principles of ISO/IEC 8802-3 but extend it towards RTE. Thus, it is possible to continue to use standard Ethernet hardware, infrastructure components, or test and measurement equipment, such as network analysers.

4.4.3 Application layer

The RAPIenet application layer is designed to support the transfer of time-deterministic application requests and responses among communication devices in an automation environment. RAPIenet allows for several optional services and protocol families to co-exist within the same communication device. In this way, generic Ethernet communication, such as TCP/UDP/IP-based protocols, may be implemented alongside real-time communications, file access protocols, and other generic protocols and services.

4.5 Data link layer overview

The RAPIenet DLL has some unique technical features, such as extremely fast network recovery, plug and play, network management information base management, and automatic network configuration.

4.5.1 Extremely fast network recovery (EFR)

EFR is one of the most outstanding technical features of the RAPIenet protocol. When a link fault is detected in a RAPIenet ring network, the fault link information is broadcast to every device on the network. Every device updates its own path table and tries to find a new path around the fault. RAPIenet provides extremely fast recovery time from topology changes to provide redundant network connectivity. The link status information is monitored by the hardware-triggered signal event (see 7.8.4), and the link status change information is broadcast to every device on the network.

4.5.2 Plug and play (PnP)

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

4.5.3 Network management information base (NMIB) management

A RAPIEnet device automatically collects and maintains its network management information base (NMIB), including network information and path table (see 8.3.6).

Every device on the same network shares and gathers link information on the network to update its network information and path table. Every device updates its network information and path table when it receives link status change information.

4.5.4 Automatic network configuration (ANC)

To support EFR functions in both ring and line networks, RAPIEnet does not restrict the dynamic change in network topology. RAPIEnet also supports automatic network configuration. When the network topology is changed, the changed network information is shared with every device on the network, and then every device updates its own network information and path table. RNMs or LNMs are automatically selected on the network according to the MAC address and data link address (see Annex A).

4.6 Application layer overview

Industrial automation and process control systems consist of primary automation devices (for example, sensors, actuators, local display devices, annunciators, programmable logic controllers, small single-loop controllers, and stand-alone field controls) as well as control and monitoring equipment.

The data transfer between these devices takes place in a peer-to-peer or multicast communication manner.

Figure 8 illustrates the interaction between the RAPIEnet fieldbus application layer (FAL) and the DLL. RAPIEnet supports cyclic and acyclic data transfer for its own application processes. RAPIEnet can also be used in parallel with TCP/IP or UDP communication. The use of other standard communication protocols is outside the scope of this PAS.

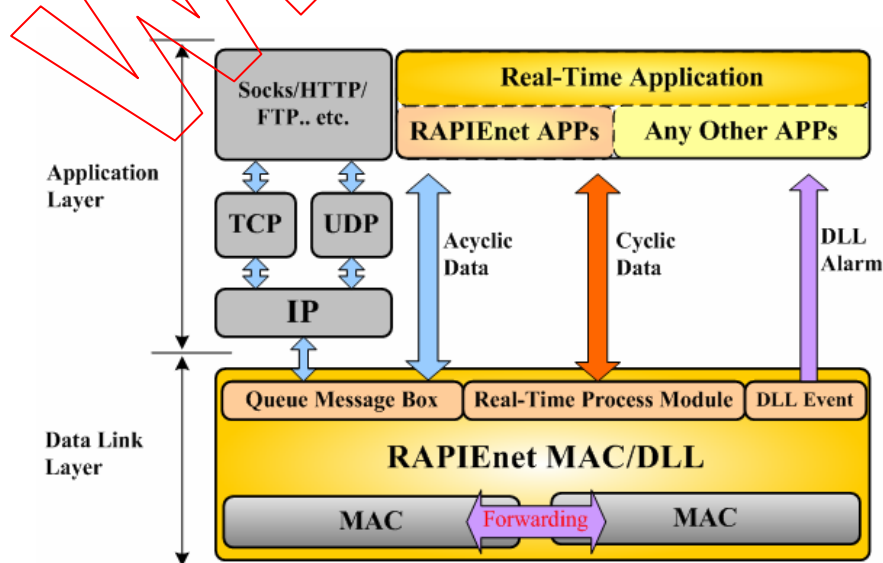


Figure 8 – Interaction between FAL and DLL

RAPIEnet supports the publisher-subscriber communication model for cyclic data sharing as shown in Figure 9. The publisher periodically multicasts preconfigured data, and subscribers receive that data. This cyclic data sharing is the most widely used model in industrial applications.

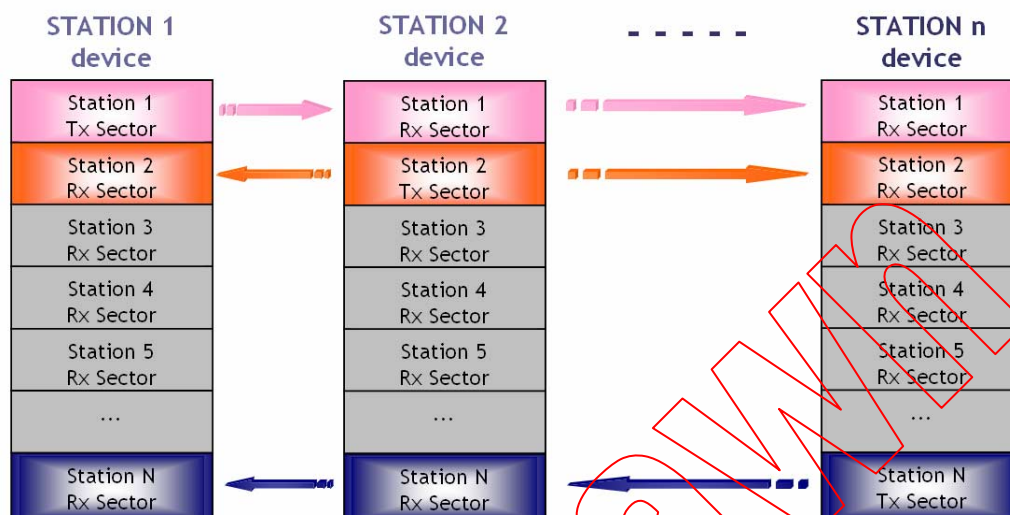


Figure 9 – Publisher-subscriber communication model

RAPIEnet supports the client-server communication model for event-triggered data transfer as shown in Figure 10. The client requests data invoked by the internal or external events. The server replies with the data requested. This can be used for event-triggered or user-triggered application processes.

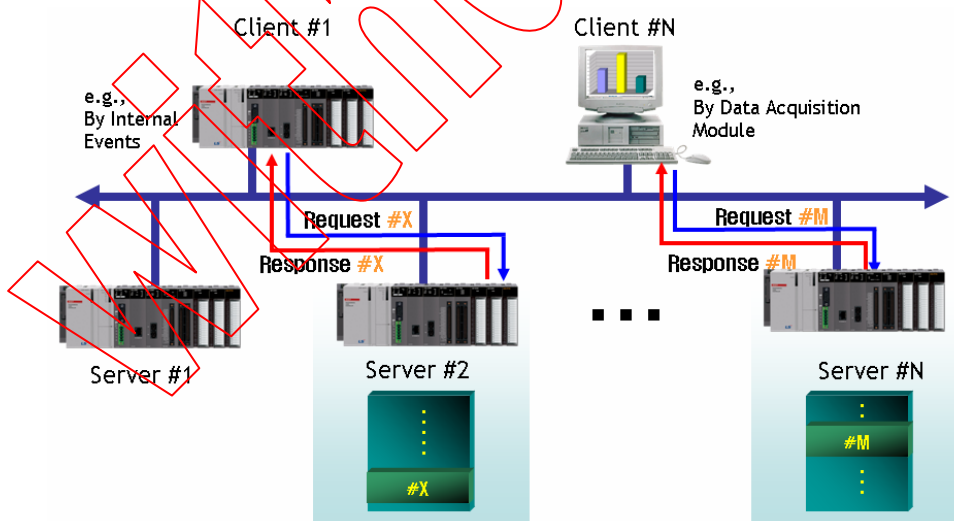


Figure 10 – Client-server communication model

5 Physical layer

5.1 Overview

The RAPIEnet physical layer corresponds to the ISO/IEC 8802-3:2002 access method and physical layer PASSs. For RAPIEnet network systems, the following full-duplex physical layer technologies are used.

- a) 100BASE-TX;

- b) 100BASE-FX;
- c) 1000BASE-T (IEEE 802.3:2005);
- d) 1000BASE-X (IEEE 802.3:2005).

NOTE Recently proposed physical layer technologies, such as 10 Gigabit Ethernet or 100 Gigabit Ethernet, can also be used for the RAPIEnet physical layer because RAPIEnet is designed to be independent of the physical layer technology.

In a RAPIEnet network, any combination of these physical layer technologies may be used. Changeovers from one physical layer to another are supported.

5.2 100BASE-TX

100BASE-TX is an electrical physical layer system specified in ISO/IEC 8802-3. It uses two pairs of Category 5 balanced cabling as specified by ISO/IEC 11801.

5.3 100BASE-FX

100BASE-FX is an optical fibre physical layer system specified in ISO/IEC 8802-3. It uses two transmission technologies over fibre.

5.4 1000BASE-T

1000BASE-T is an electrical physical layer system specified in IEEE 802.3-2005. It uses four pairs of Category 5 balanced cabling as specified by ISO/IEC 11801. Category 6 cable may also be used.

5.5 1000BASE-X

1000BASE-X is an optical fibre physical layer system specified in IEEE 802.3-2005. It uses four transmission technologies over fibre.

6 Data link layer service definitions

6.1 Introduction

This section defines the RAPIEnet data link layer (DLL) services. This is to be one of the real-time Ethernet (RTE) specifications to facilitate the interconnection of automation system components. RAPIEnet data link services provide reliable and transparent data communication among RAPIEnet data link users through the logical interface between the ISO/IEC 8802-3 physical layer and the DLL.

The Data link Service is provided by the Data link Protocol that uses the services available from the physical layer. This section defines the Data link Service characteristics that the higher level protocol may use immediately. The Data link Protocol defines some procedures for sharing and maintaining the network information in a RAPIEnet network.

6.2 Scope

6.2.1 Overview

This subclause provides the common elements for basic time-critical messaging communications between devices in an automation environment. The term “time-critical” in this context means the prioritized full-duplex collision-free time-deterministic communication, of which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the required time risks the failure of the applications requesting the actions, with attendant risk to equipment, plant, and possibly human life.

This PAS defines in an abstract way the externally visible service provided by the RAPIEnet DLL in terms of

- a) primitive actions and events of the service;
- b) parameters associated with each primitive action and event, and the form that they take;
- c) interrelationships between these actions and events, and their valid sequences.

The purpose of this PAS is to define the services provided to

- a) the RAPIEnet application layer at the boundary between the application and DLLs of the fieldbus reference model;
- b) systems management at the boundary between the DLL and the systems management of the Fieldbus reference model.

6.2.2 Specifications

The principal objective of this PAS is to specify the characteristics of conceptual DLL services suitable for time-critical communications, and to supplement the OSI Basic Reference Model in guiding the development of data link protocols for time-critical communications. A secondary objective is to provide migration paths from previously existing industrial communications protocols.

This PAS may be used as the basis for formal data link programming interfaces. Nevertheless, it is not a formal programming interface, and any such interface will need to address implementation issues not covered by this PAS, including

- a) the sizes and octet ordering of various multi-octet service parameters;
- b) the correlation of paired primitives for request and confirm, or indication and response.

6.2.3 Conformance

This PAS neither describes individual implementations of products, nor does it constrain the implementations of data link entities in industrial automation systems.

There is no conformance of equipment to this data link layer service definition specification. Instead, conformance is achieved through implementation of the corresponding data link protocol that fulfils the RAPIEnet DLL services defined in this PAS .

6.3 Normative references

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

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

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

ISO/IEC 8802-3, *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 PASs*

ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

6.4 Terms, definitions, symbols, abbreviations, and conventions

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

6.4.1 Reference model terms and definitions

This PAS 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.

DL-address	[7498-3]
DL-address-mapping	[7498-1]
called-DL-address	[7498-3]
calling-DL-address	[7498-3]
centralized multi-end-point-connection	[7498-1]
DL-connection	[7498-1]
DL-connection-end-point	[7498-1]
DL-connection-end-point-identifier	[7498-1]
DL-connection-mode transmission	[7498-1]
DL-connectionless-mode transmission	[7498-1]
correspondent (N)-entities	[7498-1]
correspondent DL-entities (N=2)	
correspondent Ph-entities (N=1)	
DL-duplex-transmission	[7498-1]
(N)-entity	[7498-1]
DL-entity (N=2)	
Ph-entity (N=1)	
DL-facility	[7498-1]
flow control	[7498-1]
(N)-layer	[7498-1]
DL-layer (N=2)	
Ph-layer (N=1)	
layer-management	[7498-1]
DL-local-view	[7498-3]
DL-name	[7498-3]
naming-(addressing)-domain	[7498-3]
peer-entities	[7498-1]
primitive name	[7498-3]
DL-protocol	[7498-1]
DL-protocol-connection-identifier	[7498-1]
DL-protocol-data-unit	[7498-1]
DL-relay	[7498-1]
Reset	[7498-1]
responding-DL-address	[7498-3]

Routing	[7498-1]
Segmenting	[7498-1]
(N)-service	[7498-1]
DL-service (N=2)	
Ph-service (N=1)	
(N)-service-access-point	[7498-1]
DL-service-access-point (N=2)	
Ph-service-access-point (N=1)	
DL-service-access-point-address	[7498-3]
DL-service-connection-identifier	[7498-1]
DL-service-data-unit	[7498-1]
DL-simplex-transmission	[7498-1]
DL-subsystem	[7498-1]
systems-management	[7498-1]
DLS-user-data	[7498-1]

6.4.2 Service convention terms and definitions

This PAS also makes use of the following terms defined in ISO/IEC 10731 as they apply to the DLL.

acceptor

asymmetrical service

confirm (primitive);
requestor.deliver (primitive)

deliver (primitive)

DL-confirmed-facility

DL-facility

DL-local-view

DL-mandatory-facility

DL-non-confirmed-facility

DL-protocol-machine

DL-provider-initiated-facility

DL-provider-optional-facility

DL-service-primitive;
primitive

DL-service-provider

DL-service-user

DLS-user-optional-facility

indication (primitive);
acceptor.deliver (primitive)

multi-peer

request (primitive);
requestor.submit (primitive)

requestor

response (primitive);
acceptor.submit (primitive)

submit (primitive)

symmetrical service

6.4.3 Data link service terms and definitions

DL-segment, link, local link

Single data link (DL) subnetwork in which any of the connected data link entities (DLEs) may communicate direct, without any intervening data link 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.

Data link service access point (DLSAP)

Distinctive point at which DL-services are provided by a single DLE 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.

DLSAP address

Either an individual DLSAP address designating a single DLSAP of a single data link service (DLS) user (DLS-user), or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user.

NOTE This terminology was 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.

(individual) DLSAP-address

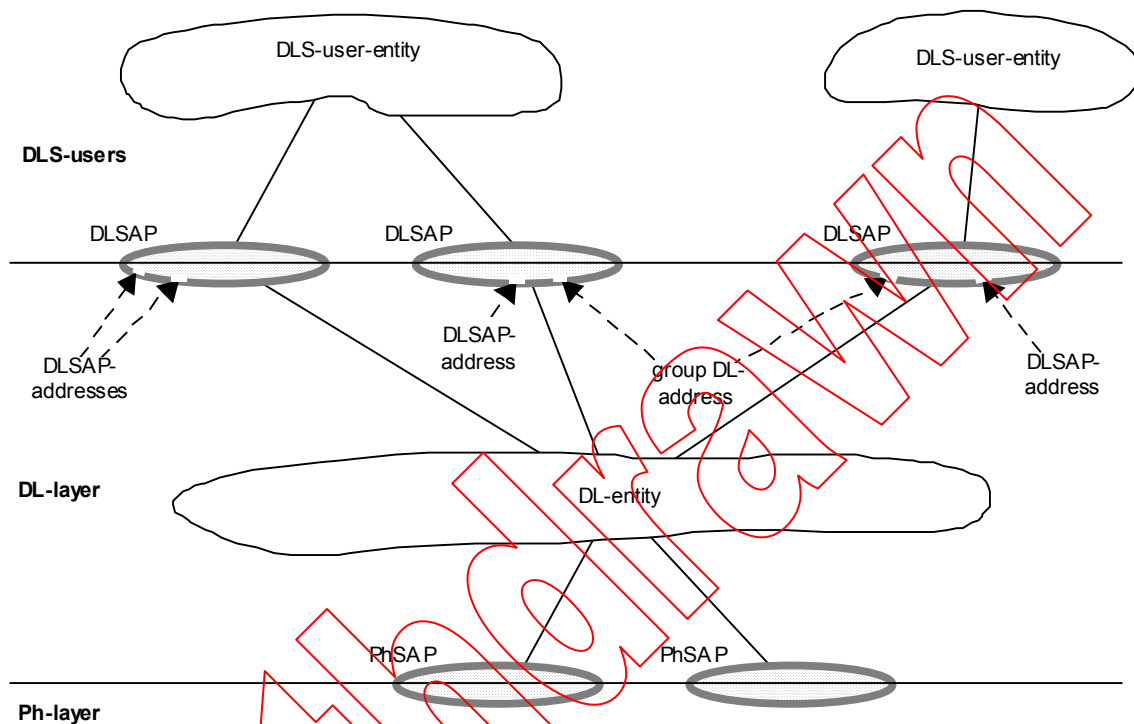
DL-address that designates only one DLSAP within the extended link

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

Data link connection endpoint address (DLCEP-address)

DL-address that designates either

- a) one peer DL-connection-end-point;
- 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.



NOTE 1 DLSAPs and physical layer service access points (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 DLE may have multiple DLSAP-addresses and group DL-addresses associated with a single DLSAP.

Figure 11 – Relationships of DLSAPs, DLSAP-addresses, and group DL-addresses

Frame check sequence (FCS) error

Error that occurs when the computed frame check sequence value after reception of all the octets in a data link protocol data unit (DLPDU) does not match the expected residual.

frame

Synonym for DLPDU

network management

Management functions and services that perform network initialization, configuration, and error handling

protocol

Convention on the data formats, time sequences, and error correction for data exchange in communication systems.

receiving DLS-user

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

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

sending DLS-user

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

device

single DLE as it appears on one local link.

DL-address

address that designates the (single) DLE associated with a single device on a specific local link. DL-address values are in the range 0-255. DL-addresses may be provided by hardware settings (for example, rotary switch) or set by software

device unique identification

unique 8-byte identification to identify a RAPIEnet device in a network. This ID is a combination of a 6-byte ISO/IEC 8802-3 MAC address and 2-byte DL-address

ring

active network where each node is connected in series to two other devices

NOTE A ring may also be referred to as a loop.

linear topology

topology where the devices are connected in series, with two devices each connected to only one other device, and all others each connected to two other devices, i.e., connected in a line

R-port

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

real-time

ability of a system to provide a required result in a bounded time

real-time communication

transfer of data in real-time

real-time Ethernet (RTE)

ISO/IEC 8802-3 based network that includes real-time communication

NOTE 1 Other communications can be supported, providing that the real-time communication is not compromised.

NOTE 2 This definition is based on, but not limited to, ISO/IEC 8802-3. It could be applicable to other IEEE 802 PASs, for example, IEEE802.11.

RTE end device

device with at least one active RTE port

RTE port

media access control (MAC) sublayer point where an RTE is attached to a local area network (LAN)

NOTE This definition is derived from that of bridge port in ISO/IEC 10038:1993, as applied to local MAC bridges.

switched network

network also containing switches.

NOTE Switched network means that the network is based on IEEE 802.1D and IEEE 802.1Q with MAC bridges and priority operations.

link

transmission path between two adjacent nodes [derived from ISO/IEC 11801].

6.4.4 Symbols and abbreviations

6.4.4.1 Common symbols and abbreviations

Term or abbreviation	Definition or meaning
DL	data link (used as a prefix or adjective)
DLC	data link connection
DLCEP	data link connection endpoint
DLE	data link entity (the local active instance of the DLL)
DLL	data link layer
DLPDU	data link protocol data unit
DLPM	data link protocol machine
DLM	data link management
DLME	data link management entity (the local active instance of DLM)
DLMS	data link management service
DLS	data link service
DLSAP	data link service-access-point
DLSDU	data link service-data-unit
FIFO	first-in, first-out (queuing method)
NMT	network management
OSI	Open Systems Interconnection
Ph-	physical layer (as a prefix)
PHY	physical interface transceiver
PhL	physical layer
RTE	Real-time Ethernet
IEC	International Electrotechnical Commission
IP	Internet protocol (see RFC 791)

ISO	International Organization for Standardization
MAC	media access control
NRT	non-real-time
PDU	protocol data unit
SAP	service access point
RT	real-time
TCP	Transmission Control Protocol (see RFC 793)
UDP	User Datagram Protocol (see RFC 768)

6.4.4.2 RAPIEnet: Additional symbols and abbreviations

Term or abbreviation	Definition or meaning
EFR	extremely fast recovery
GD	general device
LNM	line network manager
PO	power on
PnP	plug and play
RNM	ring network manager
RNMP	primary ring network manager
RNMS	secondary ring network manager
RNAC	ring network auto configuration
UID	device unique identification
RAPIEnet NMIB	RAPIEnet network management information base

6.4.5 Conventions

6.4.5.1 Common conventions

This PAS uses the descriptive conventions given in ISO/IEC 10731. The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation. Service primitives, used to represent service user/provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interaction.

This PAS uses a tabular format to describe the component parameters of the DLS primitives. The parameters that apply to each group of DLS primitives are set out in tables throughout the remainder of this specification. Each table consists of up to six columns, containing the name of the service parameter, and a column for each of those primitives and parameter-transfer directions used by the DLS, including

- the request primitive's input parameters;
- the request primitive's output parameters;
- the indication primitive's output parameters;
- the response primitive's input parameters;
- the confirmation primitive's output parameters.

NOTE The request, indication, response and confirmation primitives are also known as requestor.submit, acceptor.deliver, acceptor.submit, and requestor.deliver primitives, respectively (see ISO/IEC 10731).

One parameter, or a portion of it, is listed in each row of each table. Under the appropriate service primitive columns, the following code is used to specify how the parameter is used, and its direction.

- M parameter: mandatory for the primitive
- U parameter: a user option that may or may not be provided depending on the dynamic use of the DLS-user. When not provided, a default value for the parameter is assumed
- C parameter is conditional upon other parameters or upon the environment of the DLS-user
- (Blank) parameter is never present.

Some entries are further qualified by items in parentheses. These may be one of

- a) (=) a parameter-specific constraint indicating that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table;
- b) (n) an indication that following note n contains additional information pertaining to the parameter and its use.

In any particular interface, not all parameters shall be stated explicitly. Some may be implicitly associated with the DLSAP at which the primitive is issued.

In the diagrams illustrating these interfaces, dashed lines indicate cause and effect or time sequence relationships, and wavy lines indicate that events occur at approximately the same time.

6.4.5.2 Additional conventions

In the diagrams illustrating the DLS and DLM interfaces, dashed lines indicate cause and effect or time sequence relationships between actions at different stations, while solid lines with arrows indicate cause and effect time sequence relationships that occur within the DLE provider at a single station.

The following notation, a shortened form of the primitive classes defined in 6.4.5.1, is used in the figures and tables.

req: request primitive

ind: indication primitive

cnf: confirmation primitive (confirmation)

res: response primitive

6.5 Data link service and concept

6.5.1 Overview

This PAS specifies the RAPIEnet data link services for an ISO/IEC 8802-3 based time-deterministic control network, which is one of the communication networks for RTE. The communication services support timing demands typical of high-performance automation.

applications. They do not change the basic principles of ISO/IEC 8802-3, but extend it toward RTE. Thus, it is possible to continue to use standard Ethernet hardware, infrastructure components, or test and measurement equipment, such as network analysers.

The RAPIenet DLL provides reliable and transparent data communication between two RAPIenet end devices. The RAPIenet DLL also guarantees abstract transparent data transfer between DL-users so that DLL provides flexible and convenient network connectivity to network users.

6.5.1.1 Overview of full duplex flow control

A RAPIenet device is based on an integrated switch with two ports (ring ports) connected to the ring. Therefore, a RAPIenet network system is made up of full-duplex, collision-free switching devices configured as a ring or a line network. Figure 12 shows the full-duplex flow control procedure in a RAPIenet network system. RAPIenet guarantees collision-free data transmission between two devices linked by a full-duplex Ethernet connection so that the RAPIenet DLL provides reliable, transparent, and collision-free data transmission to the DLS-users.

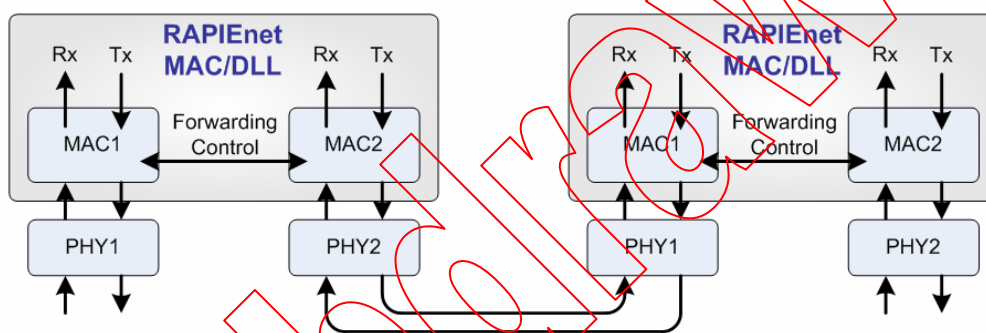


Figure 12 – Full-duplex flow control

6.5.1.2 Types and classes of DL-layer service

The DLS provides transparent and reliable data transmission between DLS-users over RAPIenet. The DLS is based on services provided by the physical layer of ISO/IEC 8802-3 to the conceptual interface between the physical and data link layers.

Three types of data transmission services are provided.

Data service (DL-DATA)

Data service is used to transmit a RAPIenet frame to a destination device or devices using the priority option. DL-DATA service is a queued service using the RT-queue.

Sporadic data service (DL-SPDATA)

Sporadic data service is used to transmit a common protocol frame, such as TCP/IP or UDP. RAPIenet data link layer transmits without modification any received DLSDUs generated by a DLS-user. In this case, DLSDU is assumed to include DLPDU. DL-SPDATA is a queued service using the NRT-queue.

Network control message

Network-control-message service is used by the DL-management entity to share network-related information with the other devices in a RAPIenet network segment.

6.5.1.2.1 Primitives of the data service`

The sequence of primitives for the data service is shown in Figure 13.

DL-DATA request and DL-DATA indication correspond to the MA-DATA request and MA-DATA indication defined by ISO/IEC8802-3, respectively.

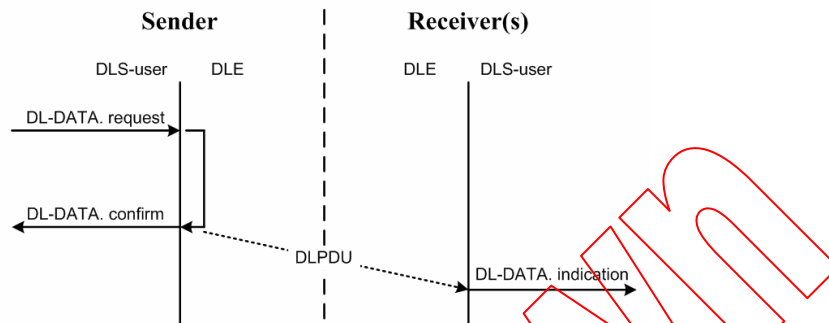


Figure 13 – Sequence diagram of DL-DATA service

The sender DLS-user prepares a DLSDU for a single receiver-side DLS-user, or for multiple DLS-users. The DLSDU is passed to the local DLE via the DLS interface by means of a DL-DATA request primitive. The DLE queues the service request, and the queued service request is transmitted by the DLPM to the receiver DLE or to multiple DLEs.

The receiving DLE(s) attempt to deliver the received DLSDU to the specified DLS-user(s).

There is no confirmation of correct receipt at the remote DLEs or of delivery to the intended DLS-user(s); acknowledgements do not occur. When the DLSDU is transmitted, it reaches all receiver-side DLEs at about the same time, ignoring signal propagation delays. Each DLE addressed by the DLSDU that has received the data error-free, passes the DLSDU and associated addressing information to the local DLS-user by means of a DL-DATA indication primitive.

6.5.1.2.2 Primitives of the sporadic data service

The sequence of primitives for the sporadic data service is shown in Figure 14. DL-SPDATA request and DL-SPDATA indication correspond to the MA-DATA request and MA-DATA indication defined by ISO/IEC8802-3, respectively.

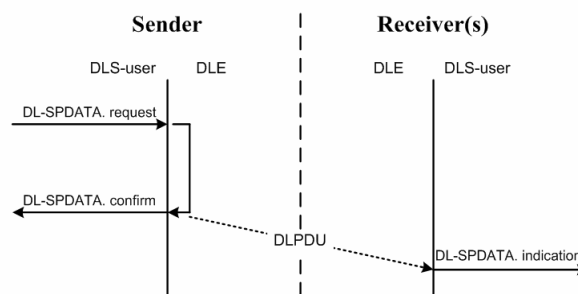


Figure 14 – Sequence diagram of DL-SPDATA service

DL-SPDATA service is used to transmit other protocol frames, such as TCP/IP or UDP. DL-SPDATA service is transmitted through both R-ports using the non-real-time (NRT) queue without referring to the path table and without modification of the received DLSDU.

6.5.1.2.3 Primitives of the network control message service

The sequence of primitives for the network control message service is shown in Figure 15. DL-NCM_SND request and DL-NCM_SND indication correspond to the MA-DATA request and MA-DATA indication defined by ISO/IEC 8802-3, respectively.

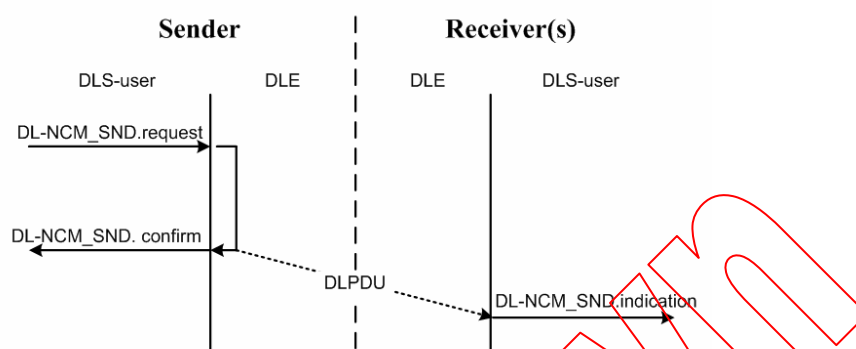


Figure 15 – Sequence diagram of NCM service primitive

The DL-NCM_SND service is used to transmit a network control message. The DL-NCM_SND service is transmitted to one or both R-ports through the real-time (RT) queue.

6.5.1.3 Addressing

Each DLE on the link is designated by a DL-address. The range of individual DL-addresses is limited, from 0 to a maximum of 255. Table 1 shows the DL-address assignment (see 8.4.3.3.2).

The DL-address 0xFFFF is used for broadcast message. This DL-address is either configured by the application process or is set on the device (for example, using address switches).

Table 1 – Destination DL-address

Field Name	Position	Value/Description
Destination DL-address	b15 – b0	0xFFFF: broadcast address 0xFFFFE: network control address (C_NCM_ADDR) 0xFFFFD – 0xFFFE: user-defined multicast address 0xFFFD: invalid address 0x0100 – 0xFFDC: reserved 0x0000 – 0x00FF: regular RAPIEnet address

6.5.1.3.1 Broadcast address

If the destination DL-address is 0xFFFF, the destination MAC address field contains the ISO/IEC 8802-3 broadcast MAC address (see 8.4.3.3.2.1).

6.5.1.3.2 Network control address

If the destination DL-address is C_NCM_ADDR, the destination MAC address field contains C_NCM_MAC_ADDR. (see 8.4.3.3.2.2) However, NCM_LINK_ACTV and NCM_ADV_THIS messages are transmitted using C_NCM_ADDR as destination address (see 8.4.3.3.2.2).

NOTE C_NCM_ADDR cannot be accessed by the DLS-user.

6.5.1.3.3 User-defined multicast address

A user-defined multicast address may be used to indicate multiple recipients. This PAS does not restrict the use of the user-defined multicast address and it is not a mandatory feature in RAPIEnet (see 8.4.3.3.2.3).

6.5.2 Detailed description of the data service

6.5.2.1 General

DL-DATA request and DL-DATA indication correspond to the MA-DATA request and MA-DATA indication defined by ISO/IEC8802-3, respectively.

DL-DATA service provides 1:1 or 1:N data transmission in a RAPIEnet segment. DL-DATA service is used by the DLS-user to send a DLSDU to a single peer-end device or multiple peer-end devices. The DL-DATA service is processed by the priority option indicated in the DL-DATA request primitive. Figure 16 shows the DL-DATA service procedure.

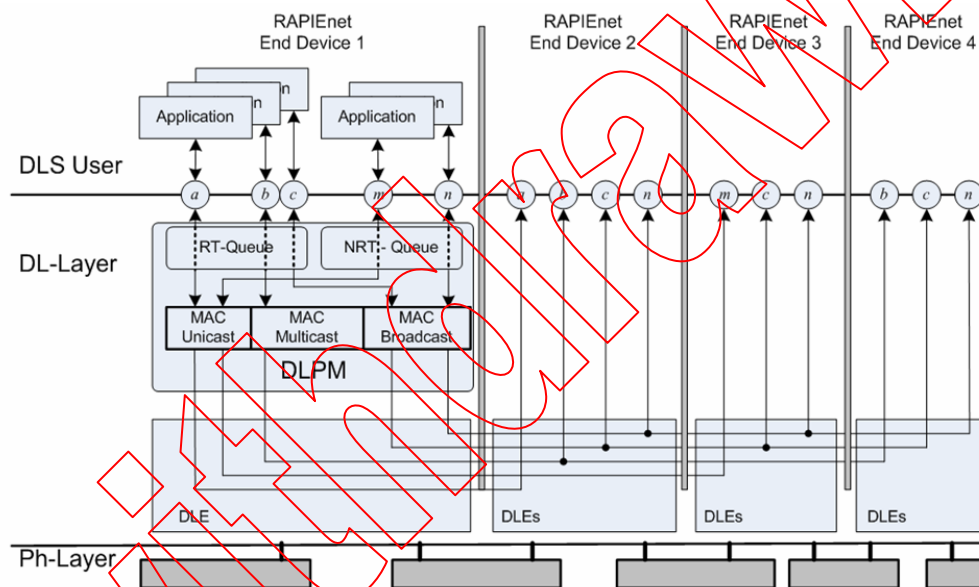


Figure 16 – DL-DATA service

6.5.2.2 Sequence of primitives

The data service primitives and their associated parameters are summarized in Table 2 and the primitive sequence is shown in Figure 13.

Table 2 – Primitives and parameters used in DL-DATA service

Function	Location	Primitive	Direction	Parameters
Send data	Sender	DL-DATA request	To DLE	DST_addr Priority DSAP SSAP Group mask Group mask length DLSDU DLSDU length

Function	Location	Primitive	Direction	Parameters
Send data confirmation to calling DLS-user	Sender	DL-DATA confirm	From DLE	Status
Receive data	Receiver(s)	DL-DATA indication	From DLE	DST_addr SRC_addr SSAP DLSDU DLSDU length

6.5.2.3 Transmit/receive data

6.5.2.3.1 Function

DL-DATA service primitives allow the DLS-user to transfer message data to a single peer DLS-user or multiple peer DLS-users at remote devices.

6.5.2.3.2 Types of primitives and the parameters

Table 3 indicates the parameters of DL-DATA service.

Table 3 – DL-DATA primitives and parameters

DL-DATA	Request	Indication	Confirm
Parameter	Input	Output	Output
DST_addr	M	M(=)	-
SRC_addr		M	-
Priority	M	M(=)	-
DSAP	M	-	-
SSAP	U	U(=)	-
Group mask	U	-	-
Group mask length	U	-	-
DLSDU	M	M(=)	-
DLSDU length	M	M(=)	-
Status	-	-	M

6.5.2.3.2.1 DST_addr

This parameter indicates the destination DL-address of the DLE(s) for which the DLPDU is intended. It may be an individual or multicast (including broadcast) DL-address. It should be noted that this is the DL-address, not the MAC address (see Table 1).

6.5.2.3.2.2 SRC_addr

This parameter indicates the source DL-address of an individual DLE, which sends the DLPDU.

6.5.2.3.2.3 Destination service access point (DSAP)

This parameter indicates the destination service access point of the DLE for which the DLPDU is intended. The DSAP address is not reserved for any particular application.

6.5.2.3.2.4 Priority

This parameter indicates the message priority of the DL-DATA service request and the priority of the frame in the RT-queue. A DLS-user can indicate the message priority of a DL-DATA service request according to the application.

6.5.2.3.2.5 Source service access point (SSAP)

This parameter indicates the source service access point of the DLE from which the DLPDU is being sent. The source SAP address is not reserved for any particular application.

6.5.2.3.2.6 Data link service data unit (DLSDU)

This parameter specifies the information that is transferred from local DLS-user to the remote DLS-user.

6.5.2.3.2.7 DLSDU length

This parameter indicates the length of DLSDU in bytes.

6.5.2.3.2.8 Status

This parameter allows the DLS-user to determine whether the requested service was provided successfully. If it failed, the reason is specified. The value of this parameter can be one of

- a) "success – successfully completed";
- b) "failure – invalid requested parameter";
- c) "failure – RT-queue is full";
- d) "failure – unavailable destination"

6.5.3 Detailed description of the sporadic data service

6.5.3.1 General

This DLS provides unacknowledged data transmission between single DLSAPs or unacknowledged data transmission from a single DLSAP to a group of DLSAPs on the extended link. DL-SPDATA request and DL-SPDATA indication correspond to the MA-DATA request and MA-DATA indication defined by ISO/IEC 8802-3, respectively. The DL-SPDATA service allows the DLS-user to transfer non-RAPIenet message data to a single-peer DLS-user or multiple-peer DLS-users at remote devices. The DL-SPDATA service is processed through the NRT-queue. A DLSDU from a DLS-user is not modified and is transmitted to both R-ports without referring to the path table.

6.5.3.2 Sequence of primitive

The sporadic message data service primitives and the parameters are summarized in Table 4 and the primitive sequence is shown in Figure 14.

Table 4 – Primitives and parameters used in DL-SPDATA service

Function	Location	Primitive	Direction	Parameters
Send Sporadic Data	Sender	DL-SPDATA request	To DLE	DLSDU DLSDU length
Confirmation to calling DLS-user	Sender	DL-SPDATA confirm	From DLE	Status
Receive Sporadic Data	Receiver(s)	DL-SPDATA indication	From DLE	DLSDU DLSDU length

6.5.3.3 Transmit/receive sporadic data

6.5.3.3.1 Function

DL-SPDATA service primitives allow the DLS-user to transfer message data to a single-peer DLS-user or multiple-peer DLS-users at remote nodes through the two R-ports.

6.5.3.3.2 Type of primitives and the parameters

Table 5 indicates the parameters of sporadic data service.

Table 5 – DL-SPDATA primitives and parameters

DL-SPDATA	Request	Indication	Confirm
Parameter	Input	Output	Output
DLSDU	M	M(=)	-
DLSDU length	M	M(=)	-
Status	-	-	M

6.5.3.3.2.1 Data link service data unit (DLSDU)

This parameter indicates the DLSDU generated by the DLS-user.

6.5.3.3.2.2 DLSDU length

This parameter indicates the length of the DLSDU.

6.5.3.3.2.3 Status

This parameter allows the DLS-user to determine whether or not the requested service was provided successfully. If it failed, the reason is specified. The value of this parameter can be one of

- “success – successfully completed”;
- “failure – invalid requested parameter”;
- “failure – the NRT-queue is full”.

6.5.4 Detailed description of network control message service

6.5.4.1 General

The network control message service is used by the DLM to share network-related information with the other devices in a RAPIEnet network segment. The network control message service is a local device information transfer service initiated by the DLM.

6.5.4.2 Sequence of primitives

The network control message data service primitives and the parameters are summarized in Table 6, and the primitive sequence is shown in Figure 15.

Table 6 – Primitives and parameters used on DL-NCM_SND service

Function	Location	Primitive	Direction	Parameters
Send Network Control Message	DLM	DL-NCM_SND request	To DLPM	DST_addr NCMT DLMDU

				DLMDU length R-port
Confirmation to calling DLM	DLPM	DL-NCM_SND confirm	To DLM	Status
Receive Network Control Message	DLPM	DL-NCM_SND indication	To DLM	DST_addr SRC_addr NCMT DLMDU DLMDU length R-port

6.5.4.3 Transmit/receive network control message

6.5.4.3.1 Function

DL-NCM_SND service primitives allow the DLS-user to transfer network control messages to a single peer DLS-user or multiple peer DLS-users at remote nodes through the R-port.

6.5.4.3.2 Type of primitives and parameters

Table 7 indicates the parameters of the network control message service.

Table 7 – DL-NCM_SND primitives and parameters

DL-NCM_SND	Request	Indication	Confirm
Parameter	input	output	output
DST_addr	M	M(=)	-
SRC_addr		M	-
NCMT	M	M(=)	-
DLMDU	M	M(=)	-
DLMDU length	M	M(=)	-
R-port	M	M	-
Status	-		M

6.5.4.3.2.1 DST_addr

This parameter indicates the destination DL-address of the DLE(s) for which the DLPDU is intended. When the network control message (NCM) type is NCM_LINK_ACTV or NCM_ADV_THIS, the destination DL-address is set to C_NCM_ADDR (see 8.4.3.3.2.2). When the network control message type is NCM_LINE_START or NCM_RING_START, the destination DL-address is set to the broadcast address (see 8.4.3.3.2.1).

6.5.4.3.2.2 SRC_addr

This parameter indicates the source DL-address of an individual DLE from which the data link management data unit (DLMDU) is being sent.

6.5.4.3.2.3 Network control message type (NCMT)

This parameter indicates the type of network control message. Table 8 describes the NCMT.

Table 8 – Summary of Network Control Message Type

Network Control Message Type	Description
NCM_LINK_ACTV	This message type indicates that a new RAPIEnet link has been established through an R-port. This network control message is transmitted through the newly activated R-port DLM detects the status of each R-port using the Ph-LINK_STATUS_CHANGE and Ph-GET_LINK_STATUS services. When an R-port's status is changed from link inactive to link active, local device information is transmitted through the newly activated R-port
NCM_ADV_THIS	NCM_ADV_THIS message is used to transmit the recipient's local device information when the recipient receives the NCM_LINK_ACTV message from the newly linked device. This message is transmitted through the R-port, which is used to receive the NCM_LINK_ACTV message
NCM_LINE_START	This message is used to broadcast that the network topology has been automatically configured as a line network. This message is initiated by the DLM whose state has changed to LNM when the existing line network is divided into two line networks or when a link failure is detected in a ring network, and the network is reconfigured as a line network
NCM_RING_START	This message is used to broadcast that the network topology has been automatically configured as a ring network. This message is initiated and transmitted through both R-ports by the DLM whose state has changed to RNMP
NCM_ACK_RNMS	This message is used by the RNMS device to advise that the RNMS has been successfully selected. NCM_ACK_RNMS message is unicast from the RNMS to the RNMP

6.5.4.3.2.4 R-port

This parameter indicates the RAPIEnet MAC port to send or receive a frame.

6.5.4.3.2.5 Data link Management Data Unit (DLMDU)

This parameter indicates the DLMDU. Local device information is used as the DLMDU in network control messages.

6.5.4.3.2.6 DLMDU length

This parameter indicates the length of the DLMDU in bytes.

6.5.4.3.2.7 Status

This parameter allows the DLMS-user to determine whether the requested service was provided successfully. If it failed, the reason is specified. The value of this parameter can be one of

- “ok – success – network control message is successfully completed”;
- “failure – invalid parameters in the request”.

6.6 Data link management services**6.6.1 General**

This section describes the interface between a DLE and a data link management system user (DLMS-user). The services of this interface are required for the protocol that implements the DLS specified in 7.5

6.6.2 Data link management service (DLMS) facilities

The DLMS provides the facilities for the initialization, configuration, event and error handling between the DLMS-user and the logical functions in the DLE. The following functions are provided to the DLMS-user.

- a) Reset the local DLE.
- b) Request for and modification of the actual operating parameters and of the counters of the local DLE.
- c) Notification of unexpected events, errors, and status changes, both local and remote.
- d) Request for identification of the local DLE, and its DLSAP configuration.

6.6.3 Data link management service (DLMS)

6.6.3.1 Overview

The DLMS provides the following services to the DLMS-user.

- a) Reset
- b) Set-value
- c) Get-value
- d) SAP-allocation
- e) SAP-deallocation
- f) Get-SAP-information
- g) Get-diagnostic-information
- h) Event
- i) Get-path

The services Reset, Set-value, Get-value, SAP-allocation, SAP-deallocation, Get-diagnostic-information, Event, and Get-path are considered mandatory. The others are optional.

6.6.3.2 Reset

The DLMS-user uses this service to cause the DLM to reset the DLE. Reset is equivalent to power on. The DLMS-user receives a confirmation of the reset.

6.6.3.3 Set-value

The DLMS-user uses this service to assign new values to the DLE variables. The DLMS-user receives a confirmation of whether or not the specified variables have been set to the new values.

6.6.3.4 Get-value

This service enables the DLM to read DLE variables. The response includes the actual value of the specified variables.

6.6.3.5 SAP-allocation

The SAP-allocation service is used by the DLMS-user to obtain a SAP assignment from the DLM. To receive a service request from the peer device and deliver the received DLSDU to the corresponding DLS-user, the destination DLS-user should obtain a SAP assignment before the service transaction. However, the SSAP does not have to be assigned beforehand because the default SSAP value of 0 is used for normal DL services. An SSAP might be assigned for special application functions.

6.6.3.6 SAP-deallocation

The SAP-deallocation service is used by the DLMS-user to release and return the allocated SAP to DLM. The deallocated SAP can be used again using the SAP-allocation service.

6.6.3.7 Get-SAP information

The Get-SAP information service is used by the DLMS-user to obtain information from the DLM about the allocated SAP.

6.6.3.8 Get-diagnostic-information

The Get-diagnostic information service is used by the DLMS-user to obtain current diagnostic information about the local device, remote devices, and the network.

6.6.3.9 Event

DLM employs this service to inform the DLMS-user about certain events or errors in the DLL.

6.6.3.10 Get-path

The Get-path service is used by the DLS-user to obtain path information from the DLM to determine which is the preferred R-port.

6.6.4 Overview of interactions

The DLMS and their primitives are summarized in Table 9.

Table 9 – Summary of DL-management primitives and parameters

Service	Primitive	Parameter
Reset	DLM-RESET request	<none>
	DLM-RESET confirm	Status
Set-value	DLM-SET_VALUE request	Variable name Desired value
	DLM-SET_VALUE confirm	Status
Get-value	DLM-GET_VALUE request	Variable name
	DLM-GET_VALUE confirm	Status Current value
SAP-allocation	DLM-SAP_ALLOC request	SAP DLS-user ID
	DLM-SAP_ALLOC confirm	Status
SAP-deallocation	DLM-SAP_DEALLOC request	SAP
	DLM-SAP_DEALLOC confirm	Status
Get-SAP-information	DLM-GET_SAP_INFO request	SAP
	DLM-GET_SAP_INFO confirm	Status DLS-user ID
Get-diagnostic-information	DLM-GET_DIAG request	Diag-type
	DLM-GET_DIAG confirm	Status, Diagnostic information
Event	DLM-EVENT indication	DLM event ID

Service	Primitive	Parameter
Get-path	DLM-GET_PATH request	DST_addr
	DLM-GET_PATH confirm	status R-port MAC-address

The sequences of the DLM primitives are shown in Figures 17 and 18.

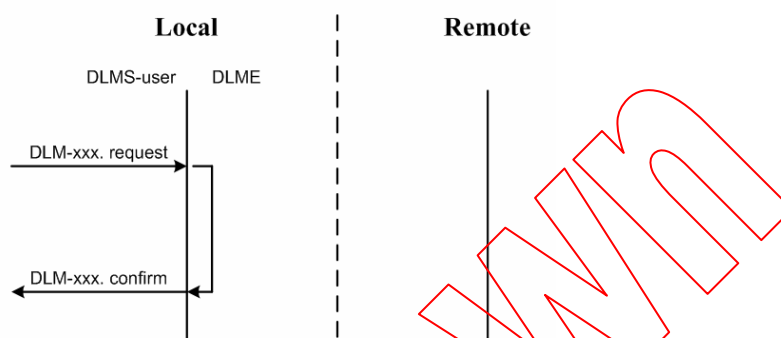


Figure 17 – Sequence diagram of Reset, Set-value, Get-value, SAP-allocation, SAP-deallocation, Get-SAP information and Get-diagnostic information service primitives

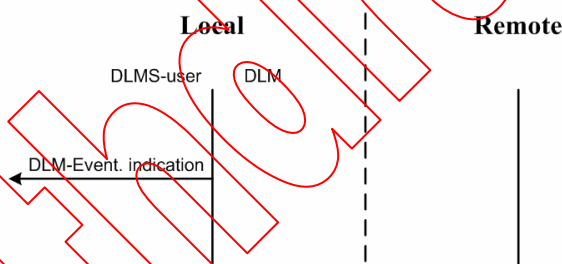


Figure 18 – Sequence diagram of event service primitive

6.6.5 Detailed specification of service and interactions

6.6.5.1 Reset

6.6.5.1.1 Function

The DLM-Reset request primitive allows the DLM to reset the DLE. Reset is equivalent to power on. When the DLE receives a reset request from the DLM, the DLE sets its status to “offline” and all DLE variables are cleared. The DLMS-user receives the DLM-Reset confirmation primitive with the success or failure status of the result.

6.6.5.1.2 Types of primitives and the parameters

6.6.5.1.2.1 General

Table 10 indicates the primitives and parameters of the Reset service.