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Industrial communication networks – Fieldbus specifications –
Part 4-14: Data-link layer protocol specification – Type 14 elements

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INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-14: Data-link layer protocol specification – Type 14 elements

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NOTE Use of some of the associated protocol types is restricted by their intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a particular data-link layer protocol type to be used with physical layer and application layer protocols in Type combinations as specified explicitly in the IEC 61784 series. Use of the various protocol types in other combinations may require permission from their respective intellectual-property-right holders.

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

Type 14 and possibly other Types:

CN200410088676.7 [SP] Scheduling method with deterministic communication based on Ethernet

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

The holders of these patent rights have assured IEC that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holders of these patent rights are registered with IEC. Information may be obtained from:

[SP] Zhejiang SUPCON Technology Co., Ltd.
Dongqin FENG
Liuhe Road 309, Bingjiang District,
Hangzhou, 310053
CHINA

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International Standard IEC 61158-4-14 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation.

This first edition and its companion parts of the IEC 61158-4 subseries cancel and replace IEC 61158-4:2003. This edition of this part constitutes a technical addition. This part and its Type 14 companion parts also cancel and replace IEC/PAS 62409, published in 2005.

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

a) deletion of the former Type 6 fieldbus, and the placeholder for a Type 5 fieldbus data link layer, for lack of market relevance;

b) addition of new types of fieldbuses;

c) division of this part into multiple parts numbered -4-1, -4-2, …, -4-19.

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

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

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

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

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

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

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

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

INTRODUCTION

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

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

a) as a guide for implementors and designers;

b) for use in the testing and procurement of equipment;

c) as part of an agreement for the admittance of systems into the open systems environment;

d) as a refinement to the understanding of time-critical communications within OSI.

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

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 4-14: Data-link layer protocol specification – Type 14 elements

1 Scope

1.1 General

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

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

a) in a synchronously-starting cyclic manner, according to a pre-established schedule, and

b) in a cyclic or acyclic asynchronous manner, as requested each cycle by each of those data-link entities.

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

1.2 Specifications

This standard specifies

a) procedures for the timely transfer of data and control information from one data-link user entity to a peer user entity, and among the data-link entities forming the distributed data-link service provider;

b) procedures for giving communications opportunities to all participating DL-entities, sequentially and in a cyclic manner for deterministic and synchronized transfer at cyclic intervals up to one millisecond;

c) procedures for giving communication opportunities available for time-critical data transmission together with non-time-critical data transmission without prejudice to the time-critical data transmission;

d) procedures for giving cyclic and acyclic communication opportunities for time-critical data transmission with prioritized access;

e) procedures for giving communication opportunities based on standard ISO/ IEC 8802-3 medium access control, with provisions for nodes to be added or removed during normal operation;

f) the structure of the fieldbus DLPDUs used for the transfer of data and control information by the protocol of this standard, and their representation as physical interface data units.

1.3 Procedures

The procedures are defined in terms of

a) the interactions between peer DL-entities (DLEs) through the exchange of fieldbus DLPDUs;

b) the interactions between a DL-service (DLS) provider and a DLS-user in the same system through the exchange of DLS primitives;

c) the interactions between a DLS-provider and a Ph-service provider in the same system through the exchange of Ph-service primitives.

1.4 Applicability

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

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

1.5 Conformance

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

2 Normative references

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

IEC 61158-3-14, *Industrial communication networks – Fieldbus specifications - Part 3-14: Data-link layer service definition – Type 14 elements*

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

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

ISO/IEC 8802-3, *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 8824-1, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

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

RFC 768, *User Datagram Protocol*

RFC 791, *Internet protocol*

3 Terms, definitions, symbols and abbreviations

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

3.1 Reference model terms and definitions

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

3.1.1 called-DL-address [7498-3]

3.1.2 calling-DL-address [7498-3]

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

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

3.1.5 demultiplexing [7498-1]

3.1.6 DL-address [7498-3]

3.1.7 DL-address-mapping [7498-1]

3.1.8 DL-connection [7498-1]

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

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

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

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

3.1.13 DL-data-sink [7498-1]

3.1.14 DL-data-source [7498-1]

3.1.15 DL-duplex-transmission [7498-1]

3.1.16 DL-facility [7498-1]

3.1.17 DL-local-view [7498-3]

3.1.18 DL-name [7498-3]

3.1.19 DL-protocol [7498-1]

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

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

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

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

3.1.24 DL-relay [7498-1]

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

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

3.1.27 DL-simplex-transmission [7498-1]

3.1.28 DL-subsystem [7498-1]

3.1.29 DL-user-data [7498-1]

3.1.30 flow control [7498-1]

3.1.31 layer-management [7498-1]

3.1.32 multiplexing [7498-3]

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

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

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

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

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

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

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

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

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

3.1.42 peer-entities [7498-1]

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

3.1.44 Ph-interface-data [7498-1]

3.1.45 primitive name [7498-3]

3.1.46 reassembling [7498-1]

3.1.47 recombining [7498-1]

3.1.48 reset [7498-1]

3.1.49 responding-DL-address [7498-3]

3.1.50 routing [7498-1]

3.1.51 segmenting [7498-1]

3.1.52 sequencing [7498-1]

3.1.53 splitting [7498-1]

3.1.54 synonymous name [7498-3]

3.1.55 systems-management [7498-1]

3.2 Service convention terms and definitions

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

3.2.1 acceptor

3.2.2 asymmetrical service

3.2.3 confirm (primitive);
requestor.deliver (primitive)

3.2.4 deliver (primitive)

3.2.5 DL-confirmed-facility

3.2.6 DL-facility

3.2.7 DL-local-view

3.2.8 DL-mandatory-facility

3.2.9 DL-non-confirmed-facility

3.2.10 DL-provider-initiated-facility

3.2.11 DL-provider-optional-facility

3.2.12 DL-service-primitive;
primitive

3.2.13 DL-service-provider

3.2.14 DL-service-user

3.2.15 DL-user-optional-facility

3.2.16 indication (primitive)
acceptor.deliver (primitive)

3.2.17 multi-peer

3.2.18 request (primitive);
requestor.submit (primitive)

3.2.19 requestor

3.2.20 response (primitive);
acceptor.submit (primitive)

3.2.21 submit (primitive)

3.2.22 symmetrical service

3.3 ISO/IEC 8802-3 terms

This standard also makes use of the following terms defined in ISO/IEC 8802-3 as they apply to the data-link layer:

3.3.1 destination address

3.3.2 frame check sequence

3.3.3 length/type

3.3.4 MAC frame

3.3.5 pad

3.3.6 source address

3.4 Common terms and definitions

NOTE Many definitions are common to more than one protocol Type; they are not necessarily used by all protocol Types.

3.4.1
communication macrocycle
set of basic cycles needed for a configured communication activity in a macro network segment

3.4.2
communication phase
elapsed fraction of a cycle, measured from some fixed origin

3.4.3
communication scheduling
algorithms and operation for data transfers occurring in a deterministic and repeatable manner

3.4.4
cyclic
repetitive in a regular manner

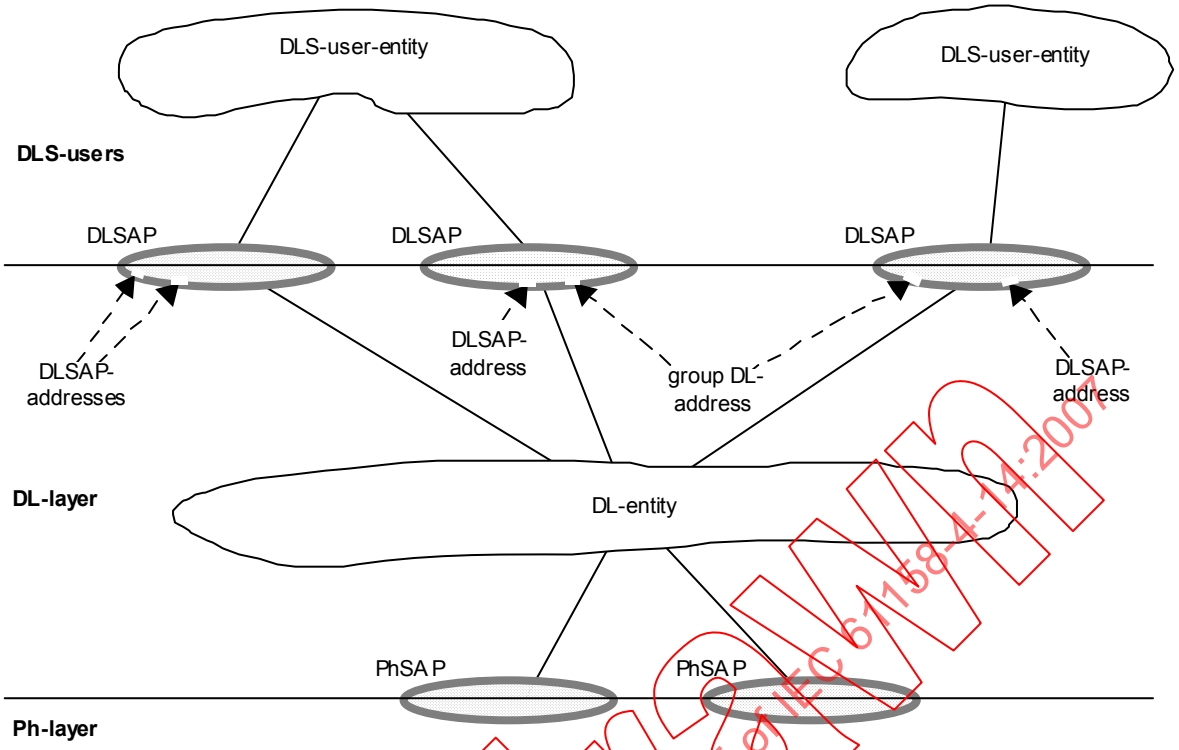
3.4.5
data DLPDU
DLPDU that carries a DLSDU from a local DLS-user to a remote DLS-user

3.4.6
destination FB Instance
FB instance that receives the specified parameters

3.4.7
DL-segment, link, local link
single DL-subnetwork in which any of the connected DLEs may communicate directly, without any intervening DL-relaying, whenever all of those DLEs that are participating in an instance of communication are simultaneously attentive to the DL-subnetwork during the period(s) of attempted communication

3.4.8
DLSAP
distinctive point at which DL-services are provided by a single DL-entity to a single higher-layer entity.

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



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

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

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

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

3.4.9
DL(SAP)-address
either an individual DLSAP-address, designating a single DLSAP of a single DLS-user, or a group DL-address potentially designating multiple DLSAPs, each of a single DLS-user.

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

3.4.10
(individual) DLSAP-address
DL-address that designates only one DLSAP within the extended link

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

3.4.11
extended link
DL-subnetwork, consisting of the maximal set of links interconnected by DL-relays, sharing a single DL-name (DL-address) space, in which any of the connected DL-entities may communicate, one with another, either directly or with the assistance of one or more of those intervening DL-relay entities

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

3.4.12
FCS error
error that occurs when the computed frame check sequence value after reception of all the octets in a DLPDU does not match the expected residual

3.4.13
frame
denigrated synonym for DLPDU

3.4.14
group DL-address
DL-address that potentially designates more than one DLSAP within the extended link. A single DL-entity may have multiple group DL-addresses associated with a single DLSAP. A single DL-entity also may have a single group DL-address associated with more than one DLSAP

3.4.15
micro segment
part of a network, where special scheduling is implemented.

3.4.16
multipoint connection
connection from one node to many nodes.

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

3.4.17
node
single DL-entity as it appears on one local link

3.4.18
offset
number of octets from a specially designated position.

3.4.19
real-time
ability of a system to provide a required result in a bounded time

3.4.20
real-time communication
transfer of data in real-time.

3.4.21
real-time Ethernet (RTE)
ISO/IEC 8802-3-based network that includes real-time communication

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

NOTE 2 This definition is dedicated, but not limited, to ISO/IEC 8802-3. It could be applicable to other IEEE 802 specifications, for example IEEE 802.11.

3.4.22
receiving DLS-user
DL-service user that acts as a recipient of DL-user-data

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

3.4.23
schedule
temporal arrangement of a number of related operations.

3.4.24
scheduling macrocycle
time interval to implement a specific schedule.

3.4.25
sending DLS-user
DL-service user that acts as a source of DL-user-data

3.4.26
time offset
time difference from a specially designated time

3.5 Symbols and abbreviations

3.5.1 ARP	Address resolution protocol
3.5.2 Cnf	Confirmation
3.5.3 CSMA/CD	Carrier sense multiple access with collision detection (protocol)
3.5.4 DHCP	Dynamic host configuration protocol
3.5.5 DL-	(as a prefix) Data-link-
3.5.6 DLCEP	Data-link connection endpoint
3.5.7 DLL	Data-link layer
3.5.8 DLE	Data-link entity
3.5.9 DLM	Data-link-management
3.5.10 DLS	Data-link service
3.5.11 DLSAP	Data-link service access point
3.5.12 DLSDU	DL-service-data-unit
3.5.13 ECSME	Type 14 communication scheduling management entity
3.5.14 EM_	(as a prefix) Type 14 management
3.5.15 Ind	Indication
3.5.16 IP	Internet protocol
3.5.17 LLC	Logical link control
3.5.18 LMP	Link management protocol
3.5.19 MAC	Medium access control
3.5.20 MAU	Medium attachment unit
3.5.21 PAD	Pad (bits)
3.5.22 PDU	Protocol data unit
3.5.23 Req	Request
3.5.24 Rsp	Response

3.5.25 RTE Real-time Ethernet

3.5.26 RT-Ethernet Real-time Ethernet

3.5.27 SAP Service access point

3.5.28 SDU Service data unit

3.5.29 SME System management entity

3.5.30 SNTP Simple network time protocol

3.5.31 TCP Transmission control protocol

3.5.32 UDP User datagram protocol

3.5.33 .cnf Confirm primitive

3.5.34 .ind Indication primitive

3.5.35 .req Request primitive

3.5.36 .rsp Response primitive

4 Overview of the DL-protocol

4.1 General

4.1.1 DLL architecture

According to the basic fieldbus reference model defined in IEC 61158-1, the Type 14 DLL is modeled in Figure 2 as an integrated Data link layer with UDP(TCP), IP, MAC and LLC sublayers defined in ISO/IEC 8802-3 and an extension protocol defined in this part of IEC 61158 standard, where

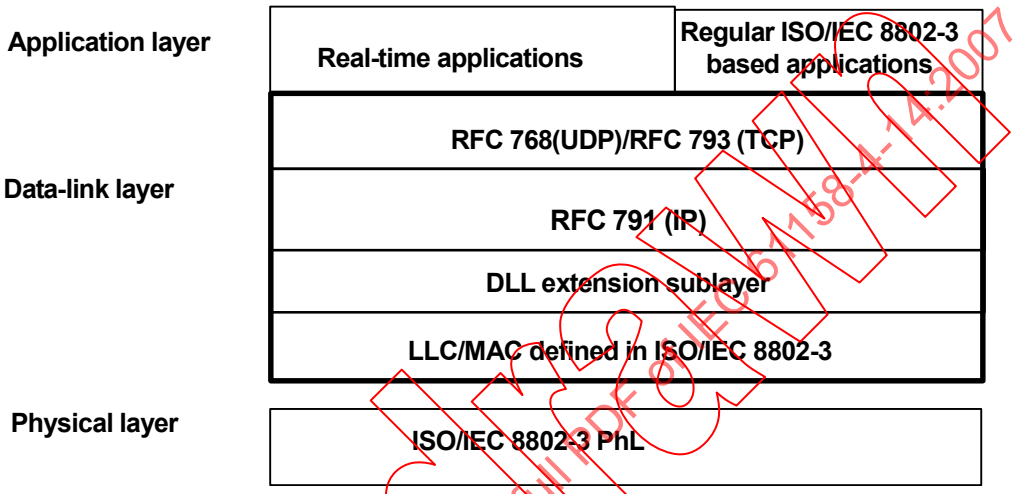


Figure 2 – Communication model

a) the Transfer Control Protocol (TCP) defined in RFC 793 is applied;

b) the User Datagram Protocol (UDP) defined in RFC 768 is applied;

c) the Internet Propocol (IP) defined in RFC 791 is applied;

d) the Logic Link Control (LLC) protocol defined in ISO/IEC 8802-3 is applied;

e) the Medium Access Control (MAC) layer protocol defined in ISO/IEC 8802-3 is applied.

Additionally, a DLL extension sublayer is defined as the Type 14 communication scheduling management entity (ECSME) on ISO/IEC 8802-3 data link protocol to manage the deterministic communication and regular communication.

This ECSME provides the following functions:

f) transparent data transferring between DLE and DLS_User specified in ISO/IEC 8802-3 without modifying the data;

g) receiving DLS_User DATA from DLS_User and buffering them;

h) transferring DLS_User DATA to DLE in configured order and priority. The DLE will send it to Ethernet network using the protocols defined in ISO/IEC8802-3;

i) transferring decoded DLPDU from DLE to DLS_User.

ECSME supports two ways of communication scheduling:

j) free competitive communication scheduling based on the CSMA/CD;

k) deterministic communication based on the time-sharing scheduling policy defined later.

When the former scheduling is used, ECSME shall directly transfer the data between DLE and DLS_User without any buffering or handling.

When the latter k) is used, the ECSME in each Type 14 device shall transfer DLS_User DATA to DLE according to the pre-configured timing order and priority, the DLE shall process the data and send it to PhL, so that the collision is avoided.

4.1.2 Type 14 communication scheduling management entity (ECSME)

ECSME is the extension based on LLC defined in ISO/IEC 8802-3. It transfers data between DLS_User and LLC without any changing.

ECSME does not alter the services provided by DLL to DLS_User defined in ISO/IEC 8802-3 as well as the interface between PhL and MAC. It only provides the transmission management of the DLS_User data.

4.1.3 Transaction between DLL and PhL

The transactions between DLL and PhL defined in ISO/IEC 8802-3 are applied without any changes.

4.1.4 Time synchronization

The time in all Type 14 devices shall be synchronized for the purpose of communication scheduling (see IEC 61158-5-14).

4.2 Services provided by the DL

4.2.1 Overview

The DLL provides connectionless data transfer services and connection-mode data transfer services defined in ISO/IEC 8802-3, RFC 791, RFC 768 and RFC 793 protocols.

4.2.2 Priority

Six levels of priority for packet transmission are defined in this specification, namely 0, 1, 2, 3, 4, 5. These are associated with the services defined in IEC 61158-5-14. The highest priority, that is 0, is used for the cyclic sending of DLSDUs. The execution timing for this fieldbus scheduled service can be accurate and repeatable to better than 1 ms. Services with the highest priority normally are used with UDP/IP protocols.

The low priorities provide for sending of DLSDUs only on an as-available basis. Data on these priorities are sent only when all other higher data priorities have been sent and a sending opportunity is available.

4.2.3 Ethernet type identifier

This specification adopts a registered value of 0x88CB assigned by IEEE for LENGTH/TYPE field in Ethernet frame to identify a Type 14 packet (see Figure 3).

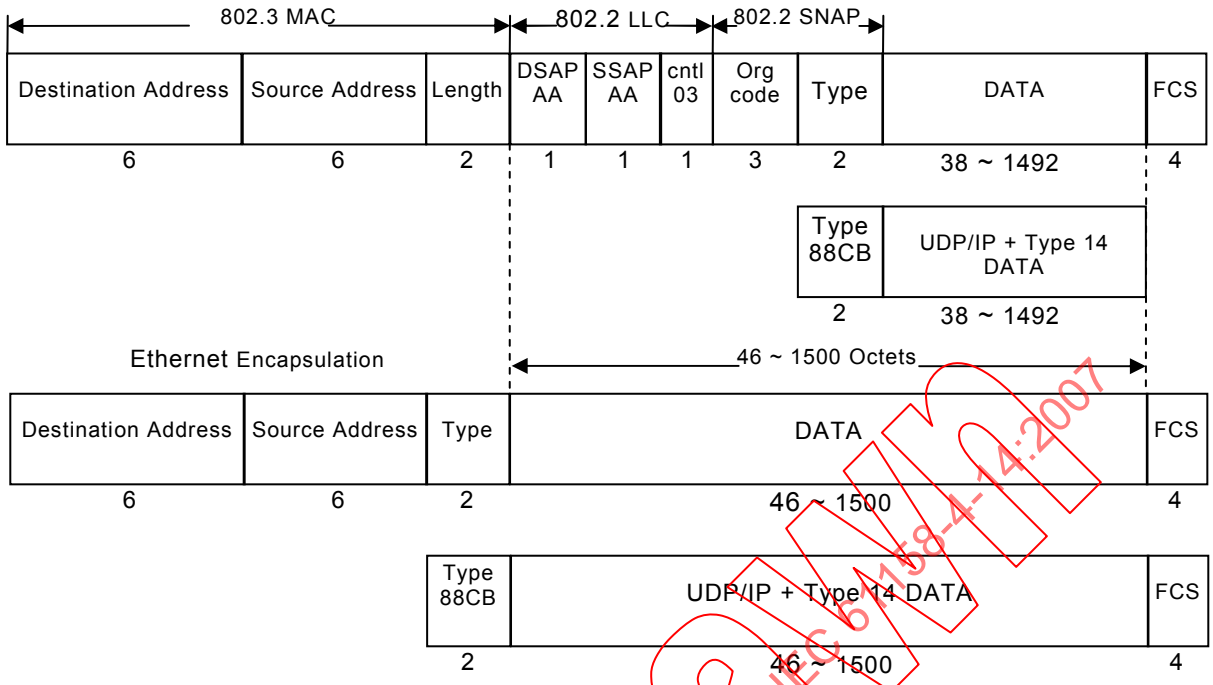


Figure 3 – Type 14 packet identifier

4.2.4 Time synchronization

The time in all Type 14 devices shall be synchronized for the purpose of communication scheduling.

4.3 Structure of deterministic communication scheduling

Within a Type 14 micro-segment, the communication procedure is repeated. The time to complete a communication procedure is called communication macrocycle and marked as T. Each communication macrocycle (T) is divided into two phases, periodic packet transferring phase (Tp) and non-periodic packet transferring phase (Tn) (see

Figure 4).

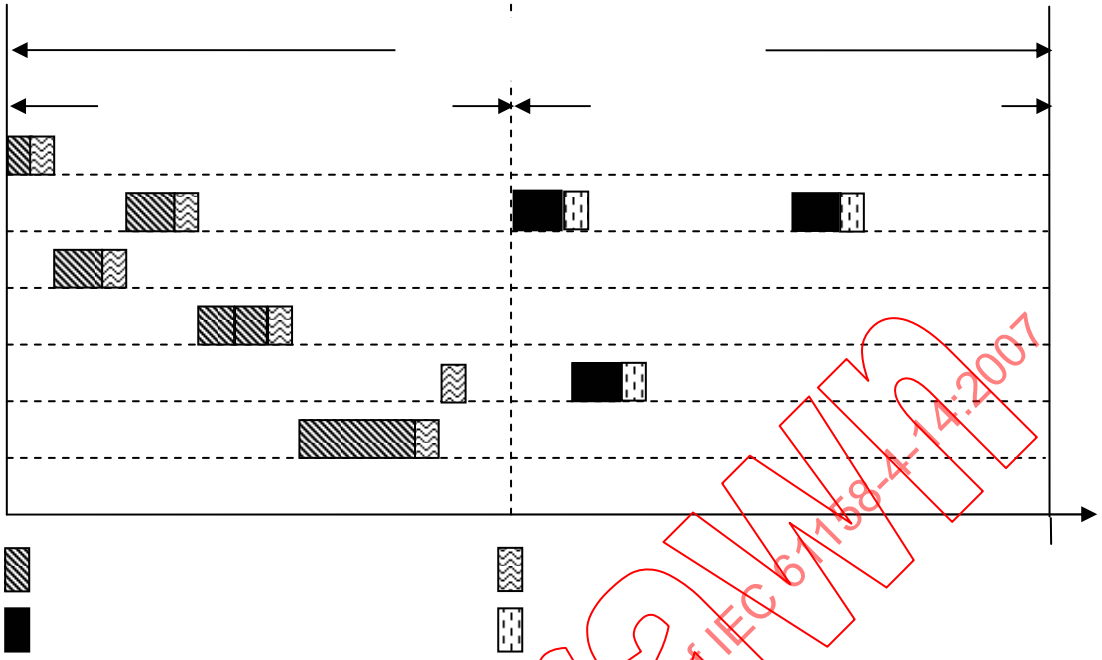


Figure 4 – Time-sharing communication scheduling

In the periodic packet transferring phase (Tp), the ECSME of each Type 14 device delivers periodic DLS_User data to local DLE in a configured order. Local DLE will packet and send the data on the network after it receives them.

Periodic DLS_User data contain the data relevant to process parameters, such as measurement and control data which need to be transmitted periodically in the control loop, or the input/output data which need to be updated cyclically between function blocks. Periodic DLS_User data has the highest priority to be sent.

In non-periodic packet transferring phase (Tn), the ECSME of each Type 14 device delivers non-periodic DLS_User data to local DLE according to their priority and even local IP address. Local DLE will packet and send the data on the network after it receives them.

Non-periodic DLS_User data contain the data which do not need to send out in every macrocycle. That is, non-periodic DLS_User data are not produced cyclically. In Type 14 systems, non-periodic DLS_User data are the primitives of program upload/download, variable read/write, event notification, trend report and RARP, HTTP, FTP, TFTP, ICMP, IGMP application data, etc. In other cases, the primitives of SNTP and DHCP services are regarded as non-periodic DLS_User data.

Non-periodic data are sent out according to their priority, local IP address in time-available way. That is,

a) if time is available, the non-periodic packet with high priority is sent first;

b) if two or more non-periodic packets in local device have identical priority, the one produced first is sent first;

c) if two or more non-periodic packets distributed in different devices, those located in the devices with smaller IP address are sent out first.

5 Procedure of deterministic communication scheduling

5.1 Overview

The mechanism of ECSME can be described in four states: Standby, Ready, PeriodicDataSending and NonPeriodicDataSending. The transitions between these four states are shown in Figure 5 and Table 1.

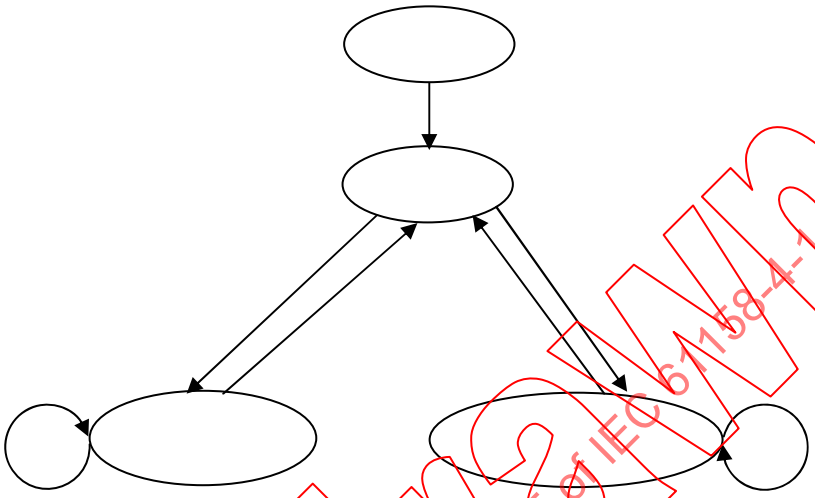


Figure 5 – State transitions of ECSME

5.2 State transitions

5.2.1 Standby

After being powered up, the Type 14 device shall verify all necessary operation parameters. If these parameters have not been configured, the ECSME enters the Standby state until the device is configured.

In *Standby* state, ECSME delivers data between DLS and DLS_User direct without any processing and buffering.

After the configuration of Type 14 Communication Scheduling Management Class of local device is finished, ECSME will enter the *Ready* state automatically, and calculate the time offset from local current time to the starting time of a communication macrocycle (T) according to the following formula:

time offset = MOD (local current time, T)

Then, the starting time of its first communication macrocycle (T) is:

starting time = current time + time offset

5.2.2 Ready

In *Ready* state,

a) When receiving DLS_User data from the DLS_User, ECSME shall put it into the responding unsent message queue according to its transmission priority;

NOTE 1 ECSME shall establish different queues for DLS_User data to be sent with different priorities.

NOTE 2 The queue with priority 0 should be managed according to the value of SendingTimeOffset corresponding to each DLS_User data.

b) When receiving DLPDU from DLE,

1) if the DLPDU is a NonPeriodicDataAnnunciation message, ECSME shall maintain local non-periodic packet transferring management list using the remote IP addresses and transmission priorities from the DLPDUs;

2) otherwise, ECSME shall deliver the DLPDU to DLS_User direct.

5.2.3 PeriodicDataSending

When the following event of

MOD (Current time, T) = SendingTimeOffset of periodic packets

is detected, the state of ECSME shall be changed into *PeriodicDataSending*.

In *PeriodicDataSending* state, ECSME deliver the DLS_User data to DLE in order, and DLE transfer them on the network through PhLE, then it shall transmit the NonPeriodicDataAnnunciation message if there is some non-periodic packet to be sent in local device. After doing the above, the state of ECSME is changed to *Ready*.

5.2.4 NonPeriodicDataSending

When the following event of

MOD (current time, T) = NonPeriodicDataTransferOffset

is detected, or local ECSME receive the EndofNonPeriodDataSending message from remote device, ECSME enters *NonPeriodicDataSending* state.

In this state,

l) if there is no non-periodic DLS_User data – whose priority is not equal to 0 – to be sent in local device, ECSME takes step g), otherwise it takes step b);

m) if the priority of the first non-periodic DLS_User data in local device is lower than those in local non-periodic packet transferring management list for remote devices, ECSME takes step g), otherwise it takes step c);

n) if the priority of the first non-periodic DLS_User data in local device is higher than those in remote devices, ECSME takes step e), otherwise it takes the next step;

o) when the priority of the first non-periodic DLS_User data in local device is equal to at least one of those in remote devices, and this priority is the highest, and if the IP address of local device is larger than that of all other remote devices with the same priority, ECSME takes step g), otherwise it takes the next step;

p) if the remaining time of current communication macrocycle is enough to transmit it, ECSME delivers the non-periodic DLS_User data to DLE for sending to the network, then ECSME goes to the next step, otherwise ECSME reserves the data for the next transmission and goes to step g);

q) if there is more non-periodic packet to be transmitted, ECSME goes to step b);

r) if local device has transmitted at least one non-periodic DLS_User data, ECSME transmits EndofNonPeriodicDataSending annunciation message on the network to notify remote devices;

s) the state of ECSMA is changed into *Ready* state.

5.3 State table

The state transitions of ECSME are illustrated in Table 1.

Table 1 – ECSME state transitions

#	Current state	Event or condition => actions	Next state
S1	PeriodicDataSending	Epnon-periodicDataSendingSuc()=1 => NonPeriodicDataAnnunciation()	Ready
S2	PeriodicDataSending	Epnon-periodicDataSendingSuc()=2 => Epnon-periodicDataSending()	PeriodicDataSending
S3	NonPeriodicDataSending	NonPeriodicDataSendingSuc()=3 ‖ (FirstNonPeriodicDataSending()=TRUE && (NonPeriodicDataPriority()=FALSE ‖ NonPeriodicDataTimeEnough()=FALSE)) => (no actions taken)	Ready
S4	NonPeriodicDataSending	NonPeriodicDataSendingSuc()=1 => EndofNonPeriodicDataSending()	Ready
S5	NonPeriodicDataSending	NonPeriodicDataSendingSuc()=2 && (NonPeriodicDataPriority()=FALSE ‖ (NonPeriodicDataPriority()=TRUE && NonPeriodicDataTimeEnough()=FALSE)) => NonPeriodicDataAnnunciation()	Ready
S6	NonPeriodicDataSending	NonPeriodicDataPriority()=TRUE && NonPeriodicDataTimeEnough()=TRUE => NonPeriodicDataSending()	NonPeriodicDataSending
R1	Standby	IsDeviceConfigured()=TRUE => CountOffsetTime()	Ready
R2	Ready	DataSendingTiming()=1 => Epnon-periodicDataSending()	PeriodicDataSending
R3	Ready	DataSendingTiming()=2 => (no actions taken)	NonPeriodicDataSending
R4	Ready	RecEndofNonPeriodicDataSending() =TRUE => (no actions taken)	NonPeriodicDataSending

5.4 Function descriptions

Table 2 through Table 14 describe the functions referenced by the preceding state transitions table.

5.4.1 NonperiodicDataSendingSuc( )

The description of function NonperiodicDataSendingSuc() is illustrated in Table 2.

Table 2 – NonperiodicDataSendingSuc() description

Name	NonperiodicDataSendingSuc( )	Used in	ECSME
Input		Output	
(none)		data of Unsigned8 data type	
Function			
Checks whether all periodic packets have been transmitted in current Communication Macrocycle: if yes, returns the value of 1; if no, returns the value of 2; otherwise, returns the value of zero			

5.4.2 NonperiodicDataAnnunciation( )

The description of function NonPeriodicDataAnnunciation() is illustrated in Table 3.

Table 3 – NonperiodicDataAnnunciation() description

Name	NonperiodicDataAnnunciation( )	Used in	ECSME
Input		Output	
(none)		(none)	
Function			
Transmits NonPeriodicDataAnnunciation packet.			

5.4.3 NonperiodicDataSending( )

The description of function NonperiodicDataSending() is illustrated in Table 4.

Table 4 – NonperiodicDataSending() description

Name	NonperiodicDataSending( )	Used in	ECSME
Input		Output	
(none)		(none)	
Function			
Transmits periodic packet			

5.4.4 NonperiodicDataSendingSuc( )

The description of function NonperiodicDataSendingSuc() is illustrated in Table 5.

Table 5 – NonperiodicDataSendingSuc() description

Name	NonperiodicDataSendingSuc( )	Used in	ECSME
Input		Output	
(none)		data of Unsigned8 data type	
Function			
Checks whether all non-periodic packets have been transmitted in current Communication Macrocycle: if yes, returns the value of 1; if no, returns the value of 2; if none of non-periodic packet needs to be transmitted, returns the value of 3; otherwise, returns the value of zero			

5.4.5 FirstNonperiodicDataSending( )

The description of function FirstNonperiodicDataSending() is illustrated in Table 6.

Table 6 – FirstNonperiodicDataSending() description

Name	FirstNonperiodicDataSending( )	Used in	ECSME
Input		Output	
(none)		TRUE or FALSE	
Function			
Checks whether it is the first time to transmit non-periodic packet in current Communication Macrocycle: if yes, returns TRUE; otherwise returns FALSE			

5.4.6 NonperiodicDataPriority( )

The description of function NonperiodicDataPriority() is illustrated in Table 7.

Table 7 – NonperiodicDataPriority() description

Name	NonperiodicDataPriority( )	Used in	ECSME
Input		Output	
(none)		TRUE or FALSE	
Function			
Checks whether the priority of non-periodic packet that the local device is ready to transmit is the highest in local non-periodic packet transfer management list. If yes, returns TRUE, otherwise returns FALSE			
NOTE If the priority of non-periodic packet that local device is ready to transmit is equal to that of one remote device or several remote devices, moreover the priority is the highest in the non-periodic packet transfer management list, however the IP address of local device is larger than that of all other remote devices with the same priority, then still returns FALSE			

5.4.7 NonperiodicDataTimeEnough( )

The description of function NonperiodicDataTimeEnough() is illustrated in Table 8.

Table 8 – NonperiodicDataTimeEnough() description

Name	NonperiodicDataTimeEnough( )	Used in	ECSME
Input		Output	
(none)		TRUE or FALSE	
Function			
Checks whether the remaining time in current Communication Macrocycle is enough to transmit the non-periodic packet as well as its annunciation message or not. If yes, returns TRUE; otherwise returns FALSE			

5.4.8 NonperiodicDataSending( )

The description of function NonPeriodicDataSending() is illustrated in Table 9.

Table 9 – NonperiodicDataSending() description

Name	NonPeriodicDataSending( )	Used in	ECSME
Input		Output	
(none)		(none)	
Function			
Transmits non-periodic packet			

5.4.9 EndOfNonperiodicDataSending( )

The description of function EndOfNonperiodicDataSending() is illustrated in Table 10.

Table 10 – EndOfNonperiodicDataSending() description

Name	EndOfNonperiodicDataSending( )	Used in	ECSME
Input		Output	
(none)		(none)	
Function			
Transmits EndofNonPeriodicDataSending annunciation packet.			

5.4.10 IsDeviceConfigured( )

The description of function IsDeviceConfigured() is illustrated in Table 11.

Table 11 – IsDeviceConfigured() description

Name	IsDeviceConfigured( )	Used in	ECSME
Input		Output	
(none)		TRUE or FALSE	
Function			
After the local device is powered up, this function is called to check whether the device has been configurated or not. If yes, returns TRUE, otherwise returns FALSE.			

5.4.11 CountOffsetTime( )

The description of function CountOffsetTime() is illustrated in Table 12.

Table 12 – CountOffsetTime() description

Name	CountOffsetTime( )	Used in	ECSME
Input		Output	
(none)		Data of Unsigned32 type	
Function			
Calculates MOD(local current time ,T), returns the remainder of Unsigned32 data type, its unit is millisecond.			

5.4.12 DataSendingTiming( )

The description of function DataSendingTiming() is illustrated in Table 13.

Table 13 – DataSendingTiming() description

Name	DataSendingTiming( )	Used in	ECSME
Input		Output	
(none)		Data of Unsigned8 type	
Function			
Calls CountOffsetTime() to get the remainder. If the remainder is equal to the value of SendingTimeOffset, returns the value of 1; if the remainder is equal to the value of NonPeriodicDataTransferOffset, returns the value of 2; otherwise, returns the value of zero.			

5.4.13 RecEndofNonPeriodicDataSending( )

The description of function RecEndofNonPeriodicDataSending() is illustrated in Table 14.

Table 14 – RecEndofNonPeriodicDataSending() description

Name	RecEndofNonPeriodicDataSending( )	Used in	ECSME
Input		Output	
(none)		TRUE or FALSE	
Function			
Check whether an EndofNonPeriodicDataSending annunciation packet from the remote device is received or not. If yes, returns TRUE; otherwise returns FALSE.			

6 Structure and encoding of ECSME PDU

6.1 ECSME PDU structure

6.1.1 NonPeriodicDataAnnunciation PDU

The format of NonPeriodicDataAnnunciation PDU is described in Figure 6.

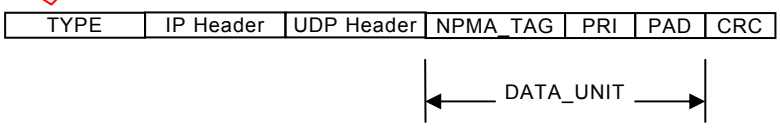


Figure 6 – Format of NonPeriodicDataAnnunciation PDU

TYPE

Protocol type, the length of this field is two octets. Its value is 0x88BC.

IP Header

IP header, the length of this field is 20 octets referring to RFC 791, Internet Protocol (IP).