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Industrial communication networks – Broadband fieldbus specification – Autbus

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This Published Document is the UK implementation of IEC PAS 63256:2020.

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

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

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Published by BSI Standards Limited 2020

ISBN 978 0 539 05718 8

ICS 33.040.40; 35.240.50

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 January 2020.

Amendments/corrigenda issued since publication

Date	Text affected

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IEC PAS 63256

Edition 1.0 2020-01

PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

Industrial communication networks – Broadband fieldbus specification – Autbus

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 00.000

ISBN 978-2-8322-7749-2

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1 Scope

This document defines the broadband fieldbus specification AUTBUS. AUTBUS implements real-time, high reliability and deterministic transmission and application for both industrial fieldbus data and ISO/IEC/IEEE 8802-3 Ethernet data by shared medium bus.

This document explains the structure and content of AUTBUS, and describes the definition and specification of Physical Layer (PhL) protocol / service, Data-link Layer (DLL) protocol / service and Application Layer (AL) protocol / service of AUTBUS.

2 Normative references

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

ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 7498-3:1997, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

ISO/IEC/IEEE 8802-3:2017, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Standard for Ethernet*

3 Terms and definitions, abbreviated terms and symbols

3.1 Terms and definitions

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

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

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

3.1.1
cyclic
a term used to describe recurring events in a regular manner

3.1.2
control device
refers to the physical entity with logical operation, timing, calculation and other functions to control all kinds of field device

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3.1.3
field device
a physical entity connected to a process or factory device, and at least one signal element communicates with other device over cable

3.1.4
management node
a device that allocates and manages AUTBUS PhL communication resources

3.1.5
terminal node
a device that receives the AUTBUS PhL communication resources allocated by the management node and communicates through the allocated resources

3.1.6
clock synchronization
clock calibration of the Terminal Node device

3.1.7
clock query
Get clock information from the Management Node or Terminal Node device

3.1.8
cyclic time
the time of cyclic processing of a device or module

3.1.9
RT data
data sensitive to time deterministic requirements

3.1.10
non-RT data
Data insensitive to time deterministic requirements

3.1.11
OFDM Symbol
a symbol contains all subcarriers in the frequency domain, the minimum data transmission unit in time domain in Orthogonal Frequency Division Multiplexing (OFDM) technology

3.1.12
upper-side band
a set of subcarriers with a frequency of 16,896 ~ 32,256 MHz on an OFDM symbol

3.1.13
lower-side band
a set of subcarriers with a frequency of 1,536 ~ 16,896 MHz on an OFDM symbol

3.1.14
half-side band
the upper-side band or lower-side band of an OFDM symbol

3.1.15
carrier mode
data transfer mode over data subframe made up of OFDM symbols

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3.1.16
working mode
OFDM operation in a specific transmission mode, Reed-Solomon coding, convolutional coding, and modulation mode

3.1.17
two-wire non-bridged
the devices are connected by physical media with two wires, without being connected through a bridge device

3.1.18
cyclic frame
the physical layer signal frame is processed in a cyclic way, and the user should configure the number of continuous cyclic signal frames

3.1.19
cyclic symbol
the method for physical layer processing of OFDM symbols in signal frames, user should configure the number of symbols for continuous cyclic processing

3.1.20
code block
an octet sequence consisting of a certain number of octets is the basic data unit for data exchange between the PhL entity and the data-link layer entity

3.1.21
data transmission channel
a logical channel of the data-link layer mapped by the determined physical communication resource for transmitting data-link layer data frames

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

AL	Application layer
ALCE	Application layer clock entity
ALDE	Application layer data entity
ALME	Application layer management entity
ALS	Application layer service
AE	Application entity
AP	Application process
APO	AP object
AR	Application relationship
ASE	Application service elements
BPSK	Binary phase shift keying
CB	Code block
C/S	Client/Server
CLMDTA	Connection-less Mode Data Transmission with Acknowledge
CLMDTNA	Connection-less Mode Data Transmission with No Acknowledge
CLMDTRA	Connection-less Mode Data Transmission with Request and Acknowledge
CLMDTRRNA	Connection-less Mode Data Transmission with Request and Response but No Acknowledge
CMDTA	Connection Mode Data Transmission with Acknowledge

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CMDTNA	Connection Mode Data Transmission with No Acknowledge
DCE	Data communication equipment
DIS	DCE independent sublayer
DL-	Data-link layer (as a prefix)
DLCSS	Data-link clock synchronization service
DLCE	Data-link clock entity
DLDE	Data-link data entity
DLE	Data-link entity
DLL	Data-linkL layer
DLM	Data-link management
DLME	Data-link managemnent entity
DLMS	Data-link management service
DLMS-user	Data-link managemet service user
DLS	Data-link service
DLP	Data-link protocol
DLS-user	Data-link service user
DLSDU	Data-link service data unit
DLPDU	Data-link protocol data unit
DTC	Data transmission channel
DTE	Data terminal equipment
DTS	Data transmission service
SynS	Synchronize signal
MAC	Medium access control
MCS	Modulation coding scheme
MN	Management node
NodeID	Node identification
nRT	non-Real-Time
OFDM	Orthogonal Frequency Division Multiplexing
PhL	Physical layer
PhL-	Physical layer (as a prefix)
PhLDE	Physical layer Data Entity
PhLME	Physical layer management entity
PhPCI	Physical layer protocol control information
PhPDU	Physical layer protocol data unit
PhS	Physical layer service
PhSAP	Physical layer service access point
PhSDU	Physical layer service data unit
QAM	Quadrature amplitude modulation
RF	Radio frequency
RMS	Root mean square
RS	Reed-Solomon
RT	Real-Time
RTA	Real-Time acyclic

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RTC Real-Time ayclic
SAP Service access point
SynS Synchronization signal
TM Transmit mode
TN Terminal node

3.3 Symbols

T_S Sampling interval

N_{CBL} Bit interleaving block length

N_{COL} Column number of bits interleaving

N_{BPS} Bit interleaving symbol bit number

N_{SD} Number of subcarriers of an OFDM symbol

N_{SYM} Number of OFDM symbols of a signal frame

4 Data type

4.1 Overview

AUTBUS data coding specifies the machine independent syntax for the data conveyed by each layer services. AUTBUS supports the definition and transmission of basic and complex data types.

The basic type cannot be divided into smaller elemental types. Complex data types are composed of several basic types and other structured types, and the complexity and depth of nesting are not constrained by this document.

4.2 Basic data type

4.2.1 Unsigned type coding (UINT)

The value of AUTBUS unsigned type data is an unsigned integer, Table 1 shows the coding.

Table 1 – Unsigned type data coding

Type name	Value range	length
UINT8	0 ~ (2^8-1)	one octet
UINT16	0 ~ (2^{16}-1)	two octets
UINT32	0 ~ (2^{32}-1)	four octets
UINT64	0 ~ (2^{64}-1)	eight octets
UINT128	0 ~ (2^{128}-1)	sixteen octets

Table 2 shows the coding of each bit of the octet for UINT16. When data is transferred, the MSB of the highest valid octet of this type of data is transmitted at first.

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Table 2 – UINT16 type data coding

octet	bit							
	7	6	5	4	3	2	1	0
1	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
2	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

4.2.2 Time type coding (TIMEV)

The time data type is an unsigned integer of 64 bits, which represents the time incremented with 1 ns. Table 3 shows the coding.

Table 3 – TIMEV type data coding

octet	bit							
	7	6	5	4	3	2	1	0
1	2^{63}	2^{62}	2^{61}	2^{60}	2^{59}	258	2^{57}	2^{56}
2	2^{55}	2^{54}	2^{53}	2^{52}	2^{51}	2^{50}	2^{49}	2^{48}
3	2^{47}	2^{46}	2^{45}	2^{44}	2^{43}	2^{42}	2^{41}	2^{40}
4	2^{39}	2^{38}	2^{37}	2^{36}	2^{35}	2^{34}	2^{33}	2^{32}
5	2^{31}	2^{30}	2^{29}	2^{28}	2^{27}	2^{26}	2^{25}	2^{24}
6	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}
7	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
8	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

4.2.3 Date type coding (DATE2000)

The DATE2000 data type length is seven octets, indicating date and time. Table 4 shows the meaning of each octet.

Table 4 – DATE2000 type coding

octet	bit								description
	7	6	5	4	3	2	1	0	
1	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	Indicates the millisecond value less than a minute
2	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	
3	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	Indicates the minute value less than a hour
4	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	Indicates the hour values less than a day
5	2^{2}	2^{1}	2^{0}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	The first 3 bits means the day of the week, the last 5 bits is the day of the current month
6	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	Indicates the month
7	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	Indicates the year. The value 0 ~ 50 correspond to 2000 – 2050, the values 51 ~ 99 correspond to 1951 – 1999.

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4.2.4 Time of day type coding (TIMEOFDAY)

TIMEOFDAY data type length is six octets and indicates the time of day. Table 5 shows the meaning of each octet.

Table 5 – TIMEOFDAY type coding

octet	bit								description
	7	6	5	4	3	2	1	0	
1	2^{31}	2^{30}	2^{29}	2^{28}	2^{27}	2^{26}	2^{25}	2^{24}	Indicates the nanosecond count starting at 0:00 midnight
2	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	
3	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	
4	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	
5	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	Indicates the number of days that have been counted since 1 January 1984
6	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	

4.2.5 Time difference type coding (TIMEDIFFER)

TIMEDIFFER data type length is six octets and indicates time difference. Table 6 shows the meaning of each octet.

Table 6 – TIMEDIFFER type coding

octet	bit								description
	7	6	5	4	3	2	1	0	
1	2^{31}	2^{30}	2^{29}	2^{28}	2^{27}	2^{26}	2^{25}	2^{24}	Indicates the deviation of nanosecond values less than a day.
2	2^{23}	2^{22}	2^{21}	2^{20}	2^{19}	2^{18}	2^{17}	2^{16}	
3	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	
4	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	
5	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}	Indicates number of days of deviation
6	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	

4.2.6 String type coding (STRING)

STRING type is a set of octet in order. The length is not fixed, it is 1~ n octet. Table 7 shows the string coding. For strings of N octets, the MSB of the highest valid octet of this type of data is transmitted at first.

Table 7 – STRING type data coding

octet	bit							
	7	6	5	4	3	2	1	0
1	2^{8N-1}	2^{8N-2}	2^{8N-3}	2^{8N-4}	2^{8N-5}	2^{8N-6}	2^{8N-7}	2^{8N-8}
2	2^{8N-9}	2^{8N-10}	2^{8N-11}	2^{8N-12}	2^{8N-13}	2^{8N-14}	2^{8N-15}	2^{8N-16}
…	…	…	…	…	…	…	…	…
N	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

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4.2.7 Bitmap tpye coding (BITMAP)

BITMAP type length is 2~256 octets, includes Width and Mask_Info information. Figure 1 shows the bitmap type coding.

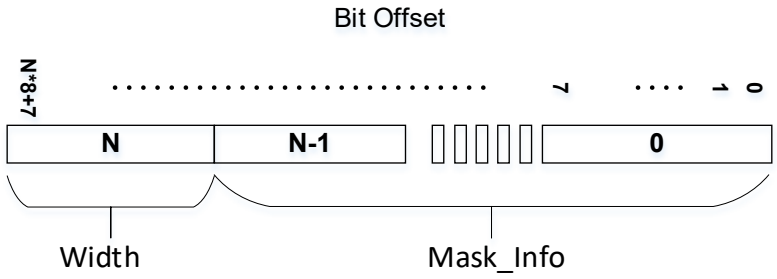

Figure 1 – BITMAP data type

Description:

Width: One octet, its value indicates the number of the octets of Mask_Info.

Mask_Info: The information represented by bit, the octet length is Width value and the bit length is Width×8.

4.3 Complex type

4.3.1 Struct type coding (STRUCT)

STRUCT type is an ordered set of different basic data types or structured data.The data of these basic data types or structured data types is called a member of the struct. The struct type data may be accessed as a whole, or a member of the struct data may be accessed only by specifying the list of members.

4.3.2 Array type coding (ARRAY)

ARRAY type is an ordered set of elements of the same type. The data type of array elements is not limited in this specification, but each element belong to the same type. Once an array is defined, the number of elements in this array cannot be changed.

5 AUTBUS overview

5.1 Overview

AUTBUS is an industrial fieldbus with two-wire medium and 100 Mbps bandwidth, which is used for process control and distributed control applications and is compatible with ISO/IEC/IEEE 8802-3, IPv4 and IPv6. The AUTBUS provides fixed-bandwidth data service and variable-bandwidth data service for periodic real-time process data, burst real-time control, alarm data and non-real-time data through pre-configuration or dynamic application of physical communication resource. It supports network slicing technology and it implements the transmission and application of the existing fieldbus based on the AUTBUS network. AUTBUS adopts Orthogonal Frequency Division Multiplexing (OFDM) technology, and has feature. It is a deterministic fieldbus communication network based on high-precision clock synchronization. It uses a time-triggered mechanism and the optimal time for data delivery is 8 μs.

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5.2 AUTBUS protocol stack architecture

The AUTBUS protocol follows the ISO/IEC 7498-1 OSI reference model. The AUTBUS defines the Physical Layer (PhL), Data-link Layer (DLL) and Application Layer (AL). The AUTBUS AL covers the basic functions of layer 3 to layer 7 of OSI, it also meets the requirements of compatible application services based on other fieldbuses and Ethernet, and AUTUBS AL provides related common features to simplify user operation. Figure 2 shows the corresponding relationship between AUTBUS protocol stack and OSI reference mode.

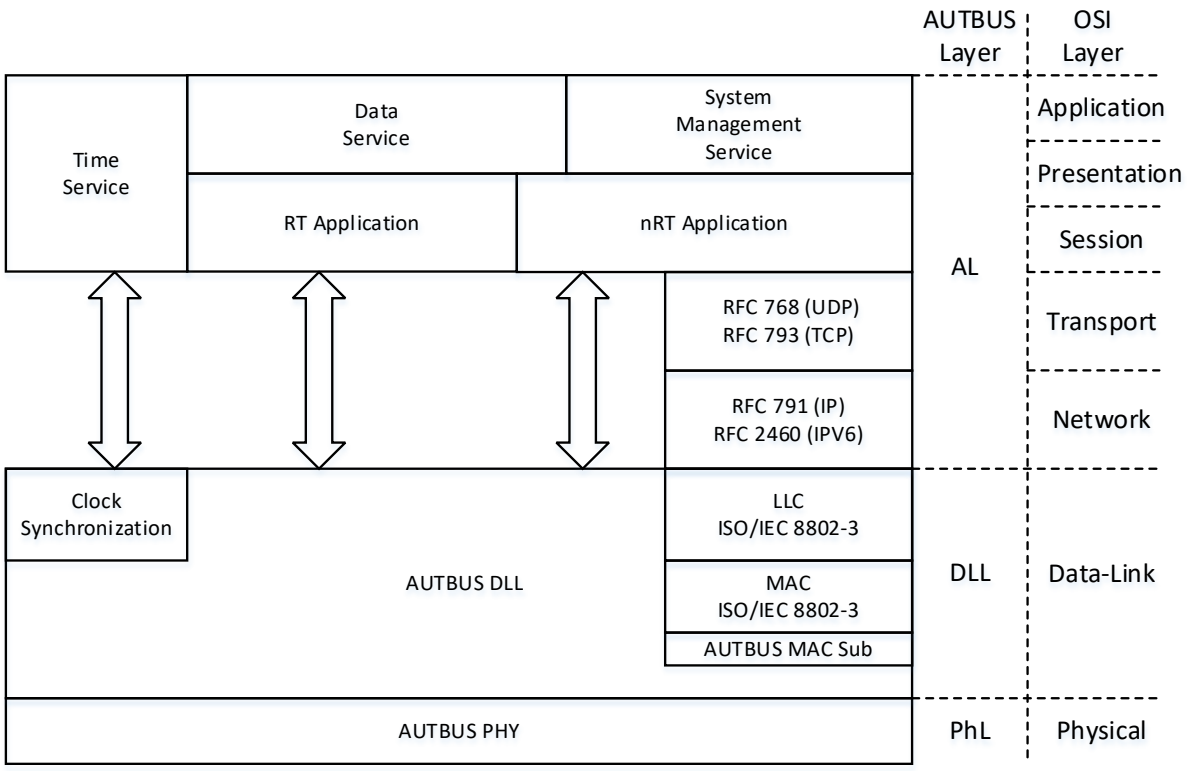

Figure 2 – Corresponding relationship between AUTBUS protocol stack and OSI reference model

AUTBUS PhL is based on OFDM technology, adopts two-wire medium transmission, supports full duplex mode. AUTBUS PhL implements physical signal encoding and decoding through RS code, convolutional code and interleaving technology. The communication resources allocated in time domain and frequency domain are used to provide highly reliable synchronous transmission service. AUTBUS PhL provides system management service interface to meet the flexible configuration requirements of system management users.

AUTBUS DLL uses the service interface provided by PhL to implement connection and connection-less data transmission services between AUTBUS devices. AUTBUS DLL provides clock synchronization, data transmission and system management services to users. Based on AUTBUS DLL system management service, it provides the configuration, discovery and maintenance of AUTBUS device, as well as the allocation and management of physical communication resources. AUTBUS DLL provides an interface compatible with ISO/IEC/IEEE 8802-3.

The AUTBUS AL uses the service interface provided by the DLL, defines a communication model meeting the requirement of industrial automation application, provides real-time cyclic process data, real-time acyclic alarm data, non-real-time data transmission service, and AL time synchronization and network configuration, diagnostics and logging features. The AUTBUS AL

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also provides network slicing to realize the integration of the AUTBUS network and other heterogeneous fieldbus networks.

The PhL, DLL and AL in the AUTBUS protocol stack have corresponding data entity and management entity, each layer provides a corresponding service access point to the upper layer user, and each layer in the AUTBUS protocol stack provides a service access point facing the system management. The DLL and the AL in the AUTBUS protocol stack both have clock entity, which respectively provide a clock entity service access point for the upper layer user. The gray parts in Figure 3 denote the AUTBUS protocol stack content.

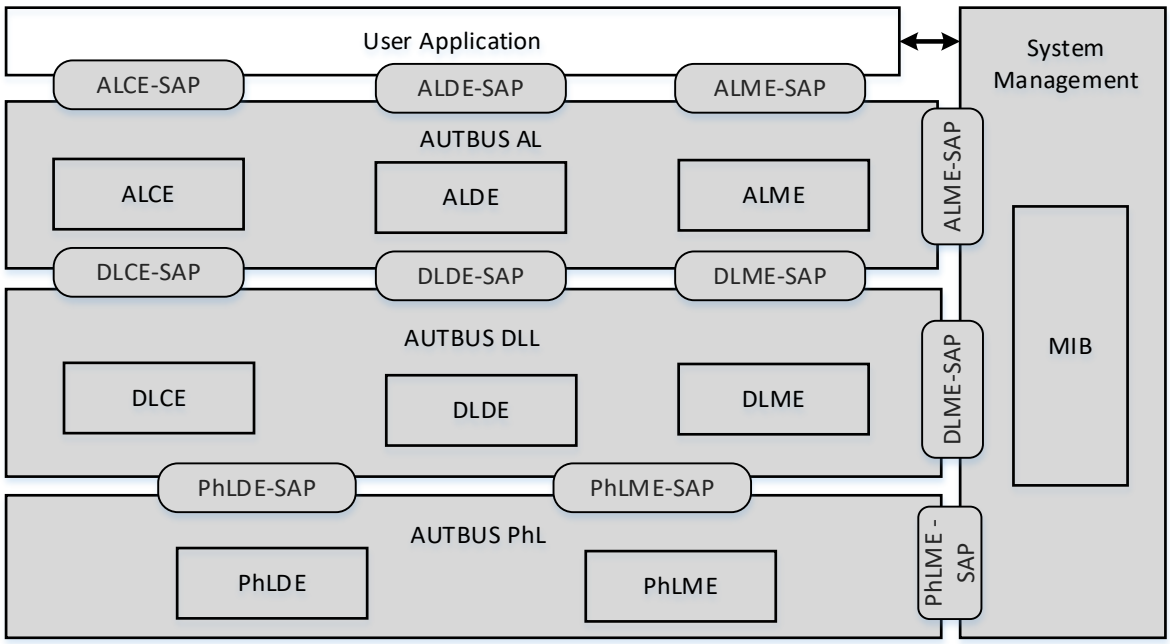

Figure 3 – AUTBUS protocol stack architecture

Description:

- PhLDE: The PhL Data Entity, processing interface data and converting them into physical signals that should be transmitted by the medium.
- PhLME: PhL Management Entity, performing PhL system management including synchronization.
- PhLDE-SAP: The PhLDE Service Access Point, the PhLDE implements the interaction processing with the data unit of the DLL through this service access point, including the interactive processing of the DLL clock synchronization data.
- PhLME-SAP: The PhLME Service Access Point, the PhLME provides system management services to the system management or DLL through this service access point.
- DLDE: DLL Data Entity, processing DLL data, encapsulate and parsing the DLPDU.
- DLME: DLL Management Entity, performing DLL system management.
- DLCE: DLL Clock Entity, performing DLL clock synchronization processing.
- DLDE-SAP: DLDE Service Access Point, the DLDE provides data transmission service to the AL through this service access point.
- DLME-SAP: DLME Service Access Point, the DLME provides system management service to system management or AL through this service access point.
- DLCE-SAP: DLCE Service Access Point, the DLCE provides clock synchronization service to AL through this service access point.
- ALDE: AL Data Entity, process the AL data, encapsulate and parsing the AL message.

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– ALME: AL Management Entity, performing AL system management
– ALCE: AL Clock Entity, performing AL time synchronization service processing
– ALDE-SAP: The ALDE Service Access Point, the ALDE provides the data transmission service to the user layer through this service access point.
– ALME-SAP: The ALME Service Access Point, the ALME provides system management services to the system management or user layer through this service access point.
– ALCE-SAP: The ALCE Service Access Point, the ALCE provides the time synchronization service to the user layer through this service access point.

5.3 Device type

5.3.1 Overview

AUTBUS devices distinguish between control device and field device according to the control role of device in industrial automation applications. AUTBUS devices distinguish management node and terminal node according to the management role of the device in the process of AUTBUS physical communication resource allocation.

5.3.2 Control Device

It refers to the physical entity that has the functions of logic operation, timing, calculation and so on, and controls all kinds of field device. The common device is programmable logic controller.

5.3.3 Field Device

It refers to the physical entity connected to the process or factory device, and at least one signal element communicates with other device over cable. The field devices distinguish input device and output device.

Input device: All kinds of transmitters and sensors, such as temperature transmitters, pressure sensors, etc.

Output device: All kinds of actuators and driving unit, such as switches, valves.

5.3.4 Management Node

The AUTBUS Management Node (MN) is responsible for the unified allocation, recycling and scheduling of physical communication resources in the network. The AUTBUS MN may be the control device or the field device, or the device that is only used for physical communication resource allocation and scheduling and not involved in the industrial automation application. There is one and only one active MN in an AUTBUS network.

5.3.5 Terminal Node

The Terminal Node (TN) should only receive physical communication resources allocated by MN and communicate with other devices through the allocated resources. The TN may be the control device or the field device.

5.4 Network topology

AUTBUS supports bus and ring topologies. Figure 4 shows the network topology. An AUTBUS network supports 254 nodes.

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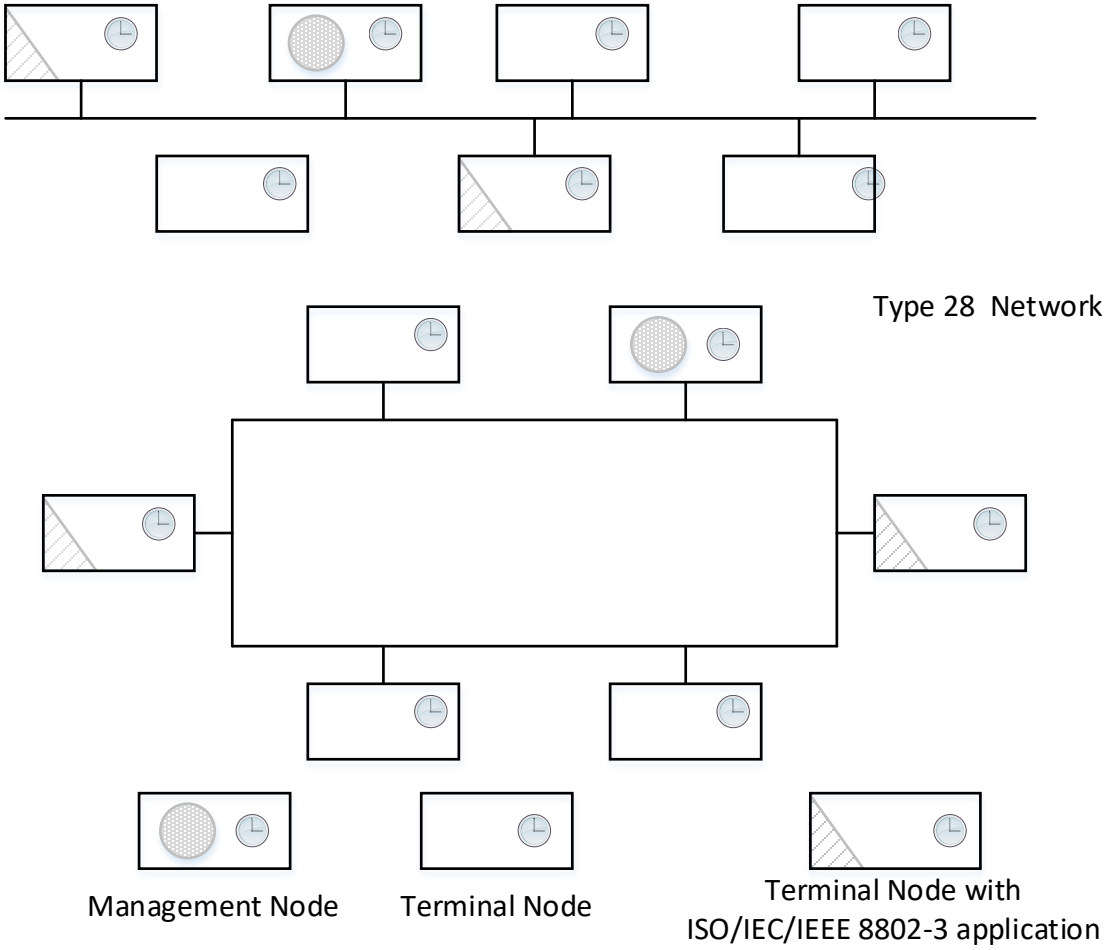

Figure 4 – AUTBUS network topology

6 System management

6.1 Overview

AUTBUS defines the management service access point in the PhL, the DLL and the AL (refer to Figure 3). AUTBUS defines the corresponding management information table for each layer (see 6.3.1 to 6.3.3). The AUTBUS network adopts a centralized and distributed management architecture. The MN is used for unified configuration, discovery and maintenance of the network, and allows the TN to be found and accessed to the network, and response to the configuration and maintenance request of the MN. The deployment of the network should be completed through these interactions. AUTBUS network PhL communication resources are centrally allocated and scheduled by the MN, the TN can identify and process the communication resources of the whole network and be responsible for the management of its related communication resources. The TN should also interact with the MN to implement the application, release and reset of new communication resources.

6.2 System management process

The AUTBUS implement management of management entities at the corresponding layer based on the management service interface provided by the AL, DLL and the PhL. The remote peer entity is managed through the corresponding management message and the management protocol frame. Figure 5 shows the AUTBUS system management process.

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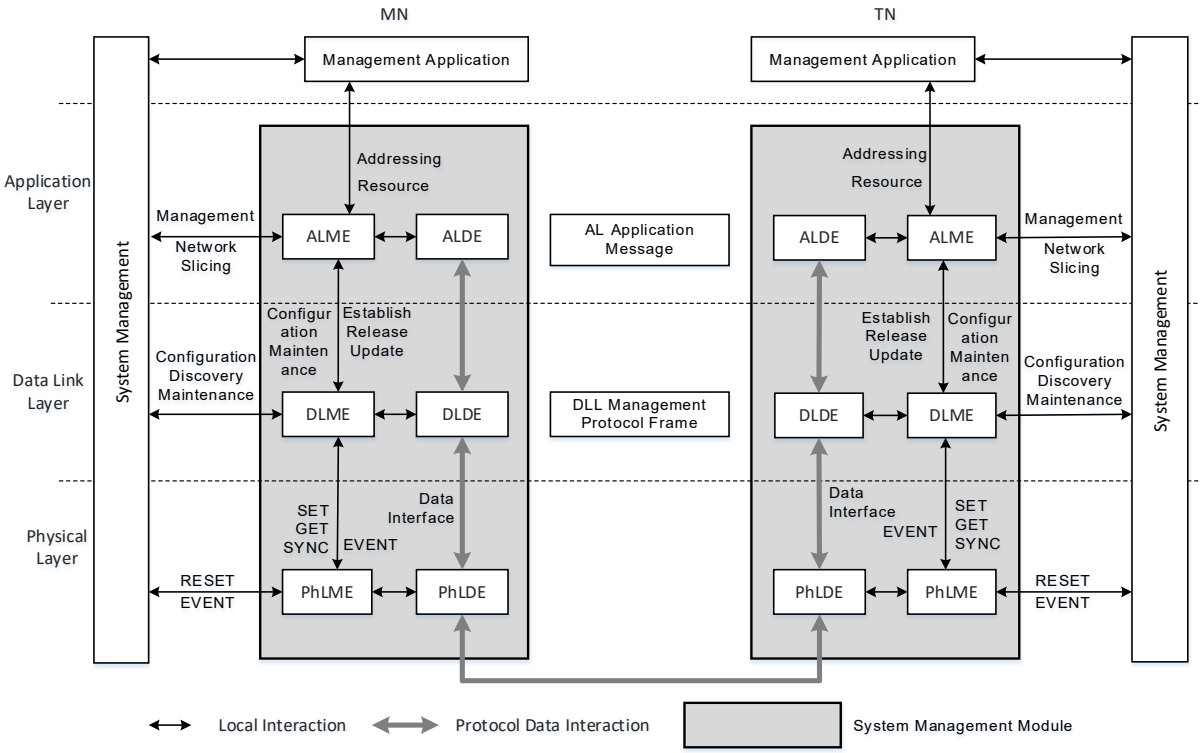

Figure 5 – AUTBUS system management process

The AUTBUS PhLME provides basic operations for reset, set, get and synchronization of the local PhL entity. The local PhL entity should convert and encode the corresponding DLL protocol data based on the management service request of the local DLL, and send the protocol data to the remote physical entity that connected to the medium. The remote physical entity should receive the protocol data and decode them for futher processing. The AUTBUS DLME provides network configuration, discovery and maintenance of the link layer. The AUTBUS DLME implements the service function of establishing, releasing and maintaining the DTC resources based on the system management services provided by the PhL, to meet the configuration management of communication resources by AL users. The system management information table related to the PhL、DLL and AL interact with the corresponding layer entity of the local device to implement the corresponding system management function. The corresponding layer entity should request or response the remote peer entity through the message and DLPDU.

6.3 System management information table

6.3.1 PhL related management information table

6.3.1.1 General

The PhL management information includes physical device configuration information, system configuration information, PhL synchronization management information, system diagnosis and maintenance information and physical communication resource management information. The system management user or data-link management user should access the corresponding information table through the service interface provided by the PhL.

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6.3.1.2 Physical device configuration information table

Table 8 – Physical device configuration information table

Parameter index	Parameter name	RW	Data Type	Description
0x0000	node_id	R/W	UINT16	Device node NodeID number High 8bit is reserved, low 8bit is vaild Number valid range: 0~255 See addressing in 8.1.2.2. 0: AUTBUS management node 1~253: AUTBUS terminal node or multicast group NodeID. Multicast group NodeID decreases from 253 in turn., max support 16 groups 254: Reserve to nodes that are not assigned NodeID 255: Broadcast address number
0x0001	mcn_bmp	RW	UINT16	The multicast group to which the node belongs bit 0 ~ bit 15: Corresponding broadcast group 238~253 The corresponding bit set to 0 indicates that the node device does not belong to the multicast group, and set to 1 indicates that the node device belongs to the multicast group.
0x0002	device_role	R/W	UINT8	Device type node role represented by bit bit 0 indicates whether it is management node bit 1 indicates whether it is terminal node The corresponding bit set to 1 indicates it is corresponding role, and set to 0 indicates it is not corresponding role The values of bit 0 and bit 1 on the working node should be different bit 2 ~ bit 7: reserved
0x0003	device_state	RO	UINT8	The state of the node at different phases represented by bit bit 0: Initialization state bit 1: configuration state bit 2: running state bit 3: synchronization state The corresponding bit set to 0 indicates state is normal, set to 1 indicates state is abnormal. bit 5 ~ bit 7: reserved
0x0004 ~ 0x008F	Reserved			Protocol reserved
0x0090 ~ 0x00FF	Reserved			Reserved for equipment manufacturer

6.3.1.3 System configuration related information table

Table 9 defines system configuration related information.

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Table 9 – System configuration related information table

Parameter Index	Parameter name	RW	Data Type	Description
0x0100	trans_mode	R/W	UINT8	Transmit mode Value range: 0 ~ 255, see Table 18 for valid value 0: Corresponding transmit mode 0 1: Corresponding transmit mode 1 2: Corresponding transmit mode 2 3: Corresponding transmit mode 3 The default value is 0 Other values are reserved
0x0101	work_mode_up	R/W	UINT8	Upper-side band working mode Value range: 0 ~ 255, valid value range: 0 ~ 21, see 7.2.6 working mode. 0 ~ 9: corresponding working mode A0 ~ A9; 10 ~ 21: corresponding working mode B0 ~ B11; Default value is 0 Other values are reserved
0x0102	work_mode_down	R/W	UINT8	Lower-side band working mode value range and value description are same with work_mode_up
0x0103	cb_up	RO	UINT8	Upper-side band coding mode Value range: 0 ~ 255 High 5bit value corresponds to RS coding Mode, see Table 34, valid value rang 0 ~ 11. Other values are reserved. Low 3bit value corresponds to convolutional code coding mode, see table 23, valid value range 0 ~ 2. Other values are reserved.
0x0104	cb_down	RO	UINT8	Lower-side band coding mode Value range and value description are same with cb_up.
0x0105	inter_mode	RO	UINT8	Interleaving mode Value range 0 ~ 255 High 4 bits indicate the upper side-band interleaving mode , low 4 bits indicate the lower-side band interleaving mode, the valid value range of every 4 bits is 0 ~ 4, and other values are reserved, see Table 35 for valid value.
0x0106	power_ratio	R/W	UINT8	Side-band power ratio Value range 0 ~ 255 0: Indicates upper and lower-side band power average distribution, other values are reserved.
0x0107	band_flag	R/W	UINT8	Side-band occupation flag represented by bit bit 0: lower-side band occupation flag. bit 1: upper-side band occupation flag. The corresponding bit set to 0 indicates that it is not occupied, set to 1 indicates it is occupied bit 2 ~ bit 7: reserved

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Parameter Index	Parameter name	RW	Data Type	Description
0x0108	net_state	RO	UINT8	AUTBUS network state Value range: 0 ~ 255 0: Initialization state 1: Normal working state Other values are reserved
0x0109	reset_en	WO	UINT8	Reset flag bit represented by bit bit 0: PhL reset flag The corresponding bit set to 0 indicates disable, set to 1 indicates enable. bit 1 ~ bit 7: reserved
0x010A	lb_mode	R/W	UINT8	Loopback mode setting indicated by bit. bit 0: Loopback at the DCE and DTE interfaces bit 1: Loopback at MAU near the cable side. The corresponding bit set to 0 indicates disable, set to 1 indicates enable. bit 2 ~ bit 7: reserved
0x010B ~ 0x018F	reserved			Protocol reserved
0x0190 ~ 0x01FF	reserved			Reserved for equipment manufacturer

6.3.1.4 PhL synchronization management information table

Table 10 defines PhL synchronization management information.

Table 10 – PhL synchronization management information table

Parameter Index	Parameter name	RW	Data Type	Description
0x0200	sync_delay	RW	UINT8	Synchronization delay information Value range: 0 ~ 255 0: Indicates that the synchronization is normal or it is synchronizing Other values N: should wait for N signal frames to start synchronous processing
0x0201	cycle_id	RO	UINT16	Cycle ID value Value range: 0 ~ 65 536 Valid value range is 0 ~ 16 383 Other values are reserved
0x0202	symbol_id	RO	UINT8	OFDM symbol ID Value range: 0 ~ 255 Valid value range is 0 ~ 63 Other values are reserved
0x0203	frame_id	RO	UINT64	Signal frame ID Value range: 0 ~ (2^{44}-1) Other values are reserved

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Parameter Index	Parameter name	RW	Data Type	Description
0x0204	time_mode	R/W	UINT8	The time information mode currently supported by the node. Value range: 0 ~ 255 0: TAI mode 1: UTC mode Other values are reserved
0x0205	time_high	RO	UINT64	Time information of the current above second level of the node. Value range: 0 ~ (2^{48}-1) 0: Information is not available Other values are reserved
0x0206	time_low	RO	UINT64	Time information of the current below second level of the node. Value range: 0 ~ (2^{48}-1) Other values are reserved
0x0207 ~ 0x028F	Reserved			Protocol reserved
0x0290 ~ 0x02FF	Reserved			Reserved for equipment manufacturer
0x0300 ~ 0x03FD	delay_cn	RO	UINT32	Transmission delay (calculated by the management node) between the manmagement node and the terminal node and the unit is ns. 254 Table items correspond to the delay of node id 0 to node id 253. Value range: 0 ~ (2^{32}-1)
0x03FE ~ 0x03FF	reserved			Protocol reserved

6.3.1.5 System diagnosis and maintenance related information table

Table 11 defines system diagnosis and maintenance related information.

Table 11 – System diagnosis and maintenance related information table

Parameter Index	Parameter name	RW	Data Type	Description
0x0400	fm_sync_err	RO	UINT8	Synchronization error state Value range: 0 ~ 255 0: No error 1: Frame synchronization error Other values are reserved
0x0401	symbol_err	RO	UINT64	Current OFDM symbol error of node (Frame ID and Symbol ID should be recorded when OFDM symbol error occurs). Value range: 0 ~ (2^{64}-1) 0: no OFDM symbol error Other values: Frame ID and Symbol ID

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Parameter Index	Parameter name	RW	Data Type	Description
0x0402	band_err	RO	UINT64	The current side-band error of the node (Frame ID, Symbol ID and upper or lower side-band should be recorded when the error occurs). Value range: 0 ~ (2^{64}-1) 0: No side-band error Others: Frame ID and Symbol ID
0x0403	data_err	RO	UINT64	The current node has a data transmission error and records the Frame ID, Symbol ID and side-band information. Value range: 0 ~ (2^{64}-1) 0: No transmitting error Others: Frame ID and Symbol ID and side-band information.
0x0404 ~ 0x048F	reserved			Protocol reserved
0x0490 ~ 0x04FF	reserved			Reserve for equipment manufacturer

6.3.1.6 Physical communication resource management information table

Table 12 defines Physical communication resource management information.

Table 12 – Physical communication resource management information table

Parameter Index	Parameter name	RW	Data Type	Description
0x0500	sym_down_num	R/W	UINT8	Symbol number of downlink subframe Value range: 2 ~ 62 Other values are invalid
0x0501	cycle_frame_num	R/W	UINT8	Cycle frame length Value range: 0 ~ 16 Other values are reserved
0x0502 ~ 0x05FF	reserved			Protocol reserved
0x0600	res_blcok_id	R/W	UINT16	The resource block [1] number used by the node. Value range: 0 ~ 65 535
0x0601	sequence_id	R/W	UINT8	Resource sub-block[1] Sequence Number. Value range: 0 ~ 255
0x0602	tx_node_id	R/W	UINT8	The device node NodeID for transmitting data based on symbolic Resources. Value range: 0 ~ 255
0x0603	res_rt_attr	R/W	UINT16	Real-time attribute of the resource Value range: 0 ~ 512 0: Static resources, always occupied 1 ~ 512: Number of times of corresponding resource blocks are occupted by circulation Other values are reserved.

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Parameter Index	Parameter name	RW	Data Type	Description
0x0604	sym_reserved	R/W	UINT8	Reserved field
0x0605	bd_flag	R/W	UINT8	Side-band occupation flag indicated by bit. bit 0: The upper-side band occupation flag bit 1: The lower-side band occupation flag The corresponding bit set to 0 indicates that the half-side band is not occupied, and set to 1 indicates that the half-side band is occupied. bit 2 ~ bit 7: reserved
0x0606	bd_mode	R/W	UINT8	Corresponding side-band coding mode represented by bit. The high 5 bit value corresponds to RS coding mode, see Table 34, the valid value range is 0 ~ 11. Other values are reserved. The low 3 bit value corresponds to the convolutional code coding mode, see Table 35, the valid value range is 0 ~ 2. Other values are reserved.
0x0607	sym_pos	R/W	UINT16	Symbol resource starting position Value range: 0 ~ 511 Other values are reserved.
0x0608	sym_len	R/W	UINT16	Symbol resource length Value range: 1 ~ 512 Value 0 is invalid Other values are reserved.
0x0609[2]	sym_cycle_num	R/W	UINT16	Number of times symbol resources are recycled Value range: 1 ~ 512 Value 0 is invalid. Other values are reserved.
0x060A ~ 0x060F	reserved			Protocol reserved
0x0610 ~ 0x09FF	[2]	[2]	[2]	[2]
0x0A00 ~ 0x0FFF	reserved			Protocol reserved

Explaination:

[1] See 7.2.1 signal frame. Node device processes the data based on the continuous half-side band or side-band symbol in the specified signal frame, the continuous symbol is a resource subblock, the device implements deterministic data communication through one or multiple resource subblocks. Multiple resource sub-blocks form a resource block.

[2] The index from 0x0600 to 0x609 corresponds to a resource block information.Figure 6 shows the resource block information structure, and the index 0x060A ~ 0x060F are reserved index for the corresponding resource block. 64 resource blocks information is allowed on each physical device, that is, the corresponding valid index range of resource information management is 0x0600 to 0x09FF.

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<table>
<tr><td colspan="16">Bit offset</td><td rowspan="2">Octet offset</td></tr>
<tr><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="16">res_block_id</td><td>0</td></tr>
<tr><td colspan="8">tx_node_id</td><td colspan="8">sequence_id</td><td>2</td></tr>
<tr><td colspan="3">reserved</td><td colspan="13">res_rt_attr</td><td>4</td></tr>
<tr><td colspan="3">sym_pos</td><td colspan="5">bd_mode</td><td colspan="8">bd_flag</td><td>6</td></tr>
<tr><td colspan="8">sym_len</td><td colspan="8">sym_pos</td><td>8</td></tr>
<tr><td colspan="12">sym_cycle_num</td><td colspan="4">sym_len</td><td>10</td></tr>
<tr><td colspan="16">reserved</td><td>12~15</td></tr>
</table>

Figure 6 – Resource block information structure

6.3.2 DLL related management information table

6.3.2.1 General

The DLL management information usually exists in the storage area as software variable and should be accessed by the system management user or the AL user.The important information should be placed in the non-volatile storage area or hardware table item. The DLL related management information includes protocol stack version management information, link node management information and link timeout management information, the system management user or the AL management user should access the corresponding information table through the service interface provided by the DLL.

6.3.2.2 Protocol stack version management Information table

Table 13 – Protocol stack version management information table

Parameter index	Parameter name	RW	Data Type	Description
0x1000	ps_version	RO	UINT32	The protocol version number indicated by dotted decimal notation: XX.XXXX.XX bit 31 ~ bit 24: major version number. Value range: 0 ~ 255. bit 23 ~ bit 8: secondary version number. Value range: 0 ~ 65 535. bit 7 ~ bit 0: protocol version number. Value range: 0 ~ 255. The protocol version number should be notified to all nodes to ensure that the protocol version is consistent, and the other two version numbers are used as the software version properties of the management node protocol stack for the reference of the user program verification.
0x1001	reserved			Reserved for equipment manufacturer.

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6.3.2.3 Link node management information table

Table 14 – Link node management information table

Parameter index	Parameter name	RW	Data Type	Description
0x1002	node_role	R/W	UINT8	The role attributes of a link node represented according to bit. bit 0: whether it is management node bit 1: whether it is terminal node The corresponding bit set to 1 indicates it is the corresponding role, and set to 0 indicates that it is not the corresponding role bit 2 ~ bit 7: reserved
0x1003	acc_status	R/W	UINT8	Access status Value range: 0 ~ 3 0: initialization 1: runing 2: pause 3: offline Other values are reserved.
0x1004	start_nodeID	R/W	UINT16	The start node NodeID for configuration, that is, the start NodeID value corresponding to the MAC address mapping table. The high 8 bits are reserved and the low 8 bits are valid. Value range: 0 ~ 255 See Table 8
0x1005	uc_num	R/W	UINT16	Number of valid nodes accessing the network. Valid value range: 0 ~ 255 Other values are reserved.
0x1006	mc_num	R/W	UINT8	The number of valid multicast group configured by the network Value range: 0 ~ 16 Other values are reserved.
0x1007 ~ 0x107F	reserved			Protocol reserved
0x1080 ~ 0x10FF	reserved			Reserved for equipment manufacturer

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6.3.2.4 Link timeout management information table

Table 15 – Link timeout management information table

Parameter index	Parameter name	RW	Data Type	Description
0x1100	T1	R/W	UINT16	Configure timeout, unit is μs Value range: 0 ~ 65 535 Value 0 indicates that timeout check is not performed.
0x1101	T2	R/W	UINT16	Configure cycle, unit is μs. This value should be an integer multiple of the physical signal frame period time. Value range: 0 ~ 65 535 Value 0 indicates that configuration cycle check is not performed.
0x1102	T3	R/W	UINT16	Heartbeat detection cycle, unit is μs, this value should be an integer multiple of the physical signal frame period time Value range: 0 ~ 65 535 Value 0 indicates no heartbeat detection.
0x1103	Max_Discovery_timeout	R/W	UINT32	Discovery timeout, unit is μs Value range: 0 ~ (2^{32}-1) Value 0 indicates that the discovery timeout check is not performed.
0x1104	Max_Heartbeat_timeout	R/W	UINT8	Number of heartbeat detection timeout frame period Value range: 0 ~ 255 Value 0 indicates no heartbeat detection.
0x1105	Max_Retry_ReqCnt	R/W	UINT8	Maximum number of retry requests Value range: 0 ~ 255 Value 0 indicates no retry request
0x1106	Max_Retry_ResCnt	R/W	UINT8	Maximum number of retry responses Value range: 0 ~ 255 Value 0 indicates no retry response
0x1107	Max_Retry_Cnt	R/W	UINT8	Maximum number of retry Value range: 0 ~ 255 Value 0 indicates no retry
0x1108	Max_ReqIn_Cnt	R/W	UINT8	Maximum number of random access requests. Value range: 0 ~ 255 Value 0 indicates that the number of random access requests is not limited
0x1109	Max_Establish_Req_Retry_Cnt	R/W	UINT8	Maximum number of establish requests Value range: 0 ~ 255 Value 0 indicates that the maximum number of establish request is not limited
0x110A	Max_Update_Req_Retry_Cnt	R/W	UINT8	Maximum number of update requests Value range: 0 ~ 255 Value 0 indicates that the maximum number of update request is not limited

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Parameter index	Parameter name	RW	Data Type	Description
0x110B ~ 0x18FF	reserved			Protocol reserved
0x1900 ~ 0x1FFF	reserved			Reserved for equipment manufacturer

6.3.3 AL related management information table

6.3.3.1 General

The AL management information is consistent with the corresponding items in the system management configuration file, and exists in the form of software variables in the device. AL management information includes time management information and network management information. The AL system management user or the AL user should access the corresponding information table through the AL management service interface.

6.3.3.2 Time management information table

Table 16 – Time management information table

Parameter index	Parameter name	RW	Data Type	Description
0x2000	time_fmt	R/W	UINT8	Different time formats represented by bit bit 0: indicates that time format is based on hour, minute and second. bit 1: indicates that time format is based on milliseconds and microseconds. bit 2: indicates that the time format is based on second pulse. The corresponding bit set to 0 is invalid, set to 1 is valid bit 3 ~ bit 7: reserved
0x2001	time_ns	R/W	TIMEV	Time count based on nanosecond
0x2002	date2000	R/W	DATE2000	Convert to date value of year, month, day, minute and second, accurate to milliseconds
0x2003	timeofday	R/W	TIMEOFDAY	The number of days based on ns
0x2004	timediffer	R/W	TIMEOFDIFF	The time difference based on nanosecond
0x2005	tid_cnt	R/W	UINT8	Number of clocks on the device or module Value range: 1 ~ 8 Value 0 is invalid. Other values are reserved
0x2006	tid_val	R/W	UINT8	Clock ID Value range: 0 ~ 7 Other values are reserved
0x2007	tid_attr	R/W	UINT8	Control-field attribute of clock Value range: 0 ~ 1 0: control clock 1: field clock Other values are reserved

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Parameter index	Parameter name	RW	Data Type	Description
0x2008	tcd_lst	R/W	ARRAY	ARRAY of type UINT8 TCD command for the corresponding clock Value range see 9.3.2.3
0x2009 ~ 0x208F	reserved			Protocol reserved
0x2090 ~ 0x20FF	reserved			Reserve for equipment manufacturer

6.3.3.3 Network management information table

Table 17 – Network management information table

Parameter index	Parameter name	RW	Data Type	Description
0x2100	network_id	R/W	UINT32	Indicate NETWORKID of node or module See 9.2.2.5.1.1.
0x2101	ip_switch	R/W	UINT8	Whether supporting the IPV4 or the IPV6 represented by bit bit 0: Whether supporting IPV4 bit 1: Whether supporting IPV6 The corresponding bit set to 0 indicates that not support, set to 1 indicates that support. bit 2 ~ bit 7: reserved
0x2102	multicast_id0 ~ 15	R/W	UINT32	NETWORKID with group type indicates the multicast group to which the device or module belongs to. Each device or module belongs to a maximum of 16 multicast groups. See Table 93
0x2103	mac_addr	RW	UINT64	Unique MAC address of the device or module Value range: 0 ~ (2^{48}-1) Other values are reserved.
0x2104	nodeid	RW	UINT8	Node ID address of the device Value range: 0 ~ 255 See Table 44
0x2105	dctime	RW	UINT16	Data calculation cycle time, unit is μs Value range: 0 ~ 65 535
0x2106	bctime	RW	UINT16	Bus service cycle timec, unit is μs Value range: 0 ~ 65 535
0x2107	wctime	RW	UINT16	Bus service data writing cycle time, unit is μs Value range: 0 ~ 65 535
0x2108	rctime	RW	UINT16	Bus service data reading cycle time, unit is μs Value range: 0 ~ 65 535
0x2109	cctime	RW	UINT16	Bus service competition cycle time, unit is μs Value range: 0 ~ 65 535

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Parameter index	Parameter name	RW	Data Type	Description
0x210A	totcnt	RW	UINT16	Number of timeout allowed by device or module Value range: 0 ~ 65 535
0x210B	rt_data_addr	RO	UINT32	Real-time data buffer start address Value range: 0 ~ (2^{32}-1)
0x210C	rt_data_size	RW	UINT32	Real-time data buffer size Value range: 0 ~ (2^{32}-1)
0x210D	nrt_data_addr	RW	UINT32	Non-real-time data buffer start address Value range: 0 ~ (2^{32}-1)
0x210E	nrt_data_size	RW	UINT32	Non-real-time data buffer size Value range: 0 ~ (2^{32}-1)
0x210F ~ 0x28FF	reserved			Protocol reserved
0x2900 ~ 0x2FFF	reserved			Reserved for equipment manufacturer

7 Physical layer

7.1 Physical Layer overview

Figure 7 shows AUTBUS Physical Layer model.

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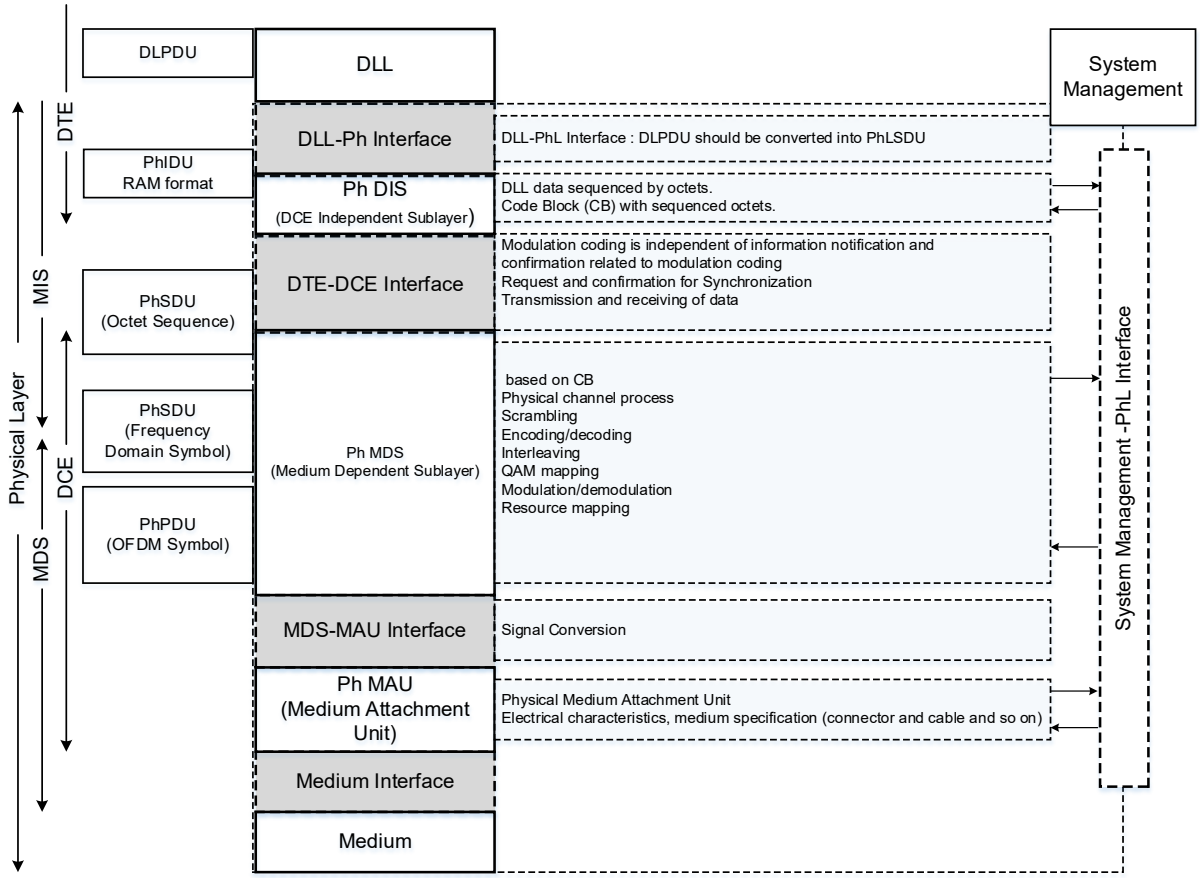

Figure 7 – AUTBUS Physical Layer model

The AUTBUS PhL receives the data unit from the DLL, converts them into service data unit that can be processed by PhL, adds the required check control information, and then generates OFDM symbols by scrambling, encoding, and mapping, then the physical signal is transmitted to the corresponding physical medium after D/A conversion. The physical signal is transmitted to one or more devices on the AUTBUS network through the medium. The physical signal is received, then A/D conversion, demodulation and decoding, and the control information is removed to recovery to the data unit which can be processed by the DLL entity.

The AUTBUS PhL entity is partitioned into a Data Terminal Equipment (DTE) and a Data Communication Equipment (DCE). DTE implements the conversion between the DLL Protocol Data Unit (DLPDU) and the PhL Service Data Unit (PhLSDU). DCE does the OFDM processing to the PhLSDU, generates the OFDM symbols and converts them into the physical signals which shall be processed by the medium.

7.2 PhL resource

7.2.1 Signal frame

In AUTBUS network, the DLPDU sent by DLL are converted into Code Block (CB) that should be processed by the PhL through DLL-PhL interface. The CB should be encoded by Reed-Solomon (RS) coding and convolution coding, QAM mapping in PhL, then corresponds to the physical resource defined by OFDM symbol and subcarrier, and modulated by IFFT. Then the PhL signal frame (SF) is formed and transmitted to the cable. The receiver recovers the digital signal and stream through the reverse process.

The sampling interval of AUTBUS in time domain is T_s :

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$$T_s = 1 / (24000 \times 4096) s \quad (1)$$

That is 10,17 ns. The sampling interval is fixed in different TMs.

The basic unit of PhL signal in AUTBUS is SF, and 64 OFDM symbols form one SF. Each OFDM symbol is divided into upper-side band and lower-side band in the frequency domain subcarrier. The high frequency subcarrier (16,896 ~ 32,256 MHz) is named upper-side band and the low frequency subcarrier (1,536 ~ 16,896 MHz) is named lower-side band. The upper-side band and lower-side band can be allocated to different MN or TNs when AUTBUS allocates its channel resources to users.

Figure 8 shows the structure of the SF and OFDM symbol.

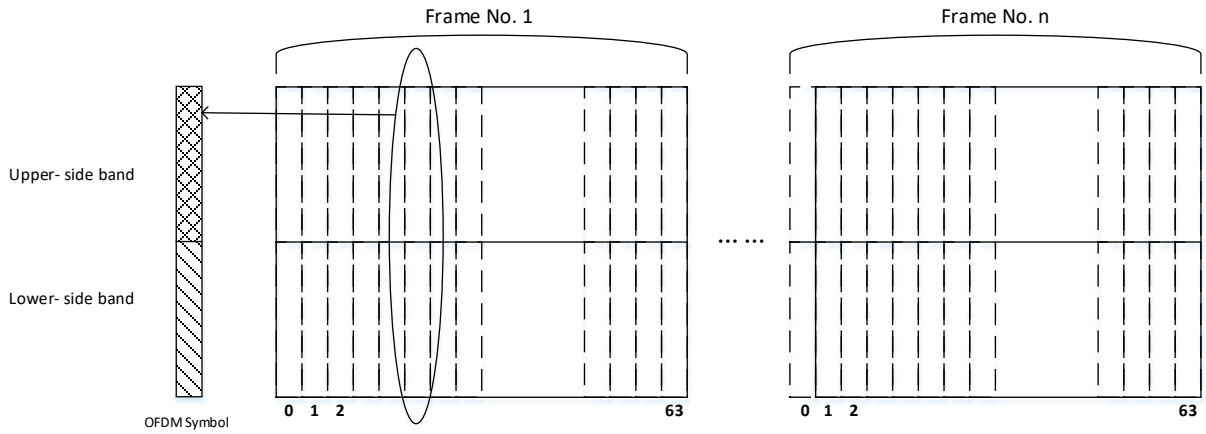

Figure 8 – AUTBUS SF and OFDM symbol

Figure 9 shows the block diagram of the SF. The AUTBUS signal frame should be decomposed by the following elements: Synchronization Signal (SynS), downlink subframe and data subframe, in which:

– **Synchronization Signal (SynS)** is used to identify the start of a SF. SysS has the function of SF synchronization and SF header positioning. The SynS is fixed to the lower-side band of the first and the second OFDM symbol of each SF (see Figure 9).
– **Downlink subframe** is used to send data and information from MN to TNs. It should include channel information, bandwidth allocation result, system maintenance status and other content. Downlink subframe contains the lower-side band of greater than or equal to 2 OFDM Symbols (see Figure 9).
– **Data subframe** is the allocable PhL communication resources. The minimum allocation unit is half-side band of one OFDM symbol (see 7.2.2 Carrier mode A) or half-side band of two OFDM symbols (see 7.2.2 Carrier mode B). In Figure 9, all blank parts are data subframe. The MN and TNs should request or config the corresponding data subframe according to their requirment for data transmission.

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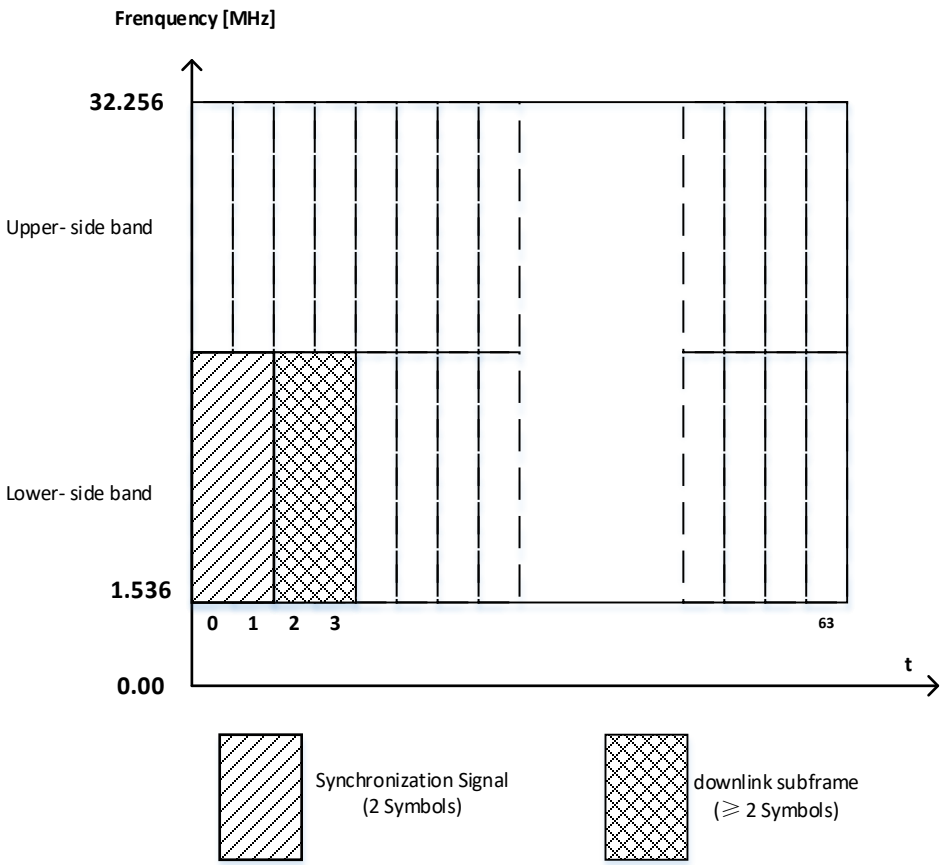

Figure 9 – SF structure

7.2.2 Data subframe

After AUTBUS allocates the data subframe to the MN or each TN, in order to enable the receiver to decode the corresponding information quickly and accurately, pilot signals need to be inserted according to a specific form in the data subframe, this pilot is called symbol pilot, AUTBUS supports discrete pilot and continuous pilot.

According to the difference of inserting symbol pilot mode and the data carrier structure of data subframe, the data subframe supports two kinds of carrier modes: carrier mode A and carrier mode B. They are defined as follows:

– **Carrier mode A** Using continuous pilot, a single OFDM half-side band should transmit both the data signal and the symbol pilot signal, in which the ratio of the symbol pilot signal to the number of subcarriers occupied by the data signal is 1:8.

– **Carrier mode B** Using discrete pilot, the first OFDM half-side band of the applied data subframe should transmit the symbol pilot signal, and the subsequent OFDM symbols should transmit the data signal.

Figure 10 shows the difference between carrier mode A and carrier mode B.

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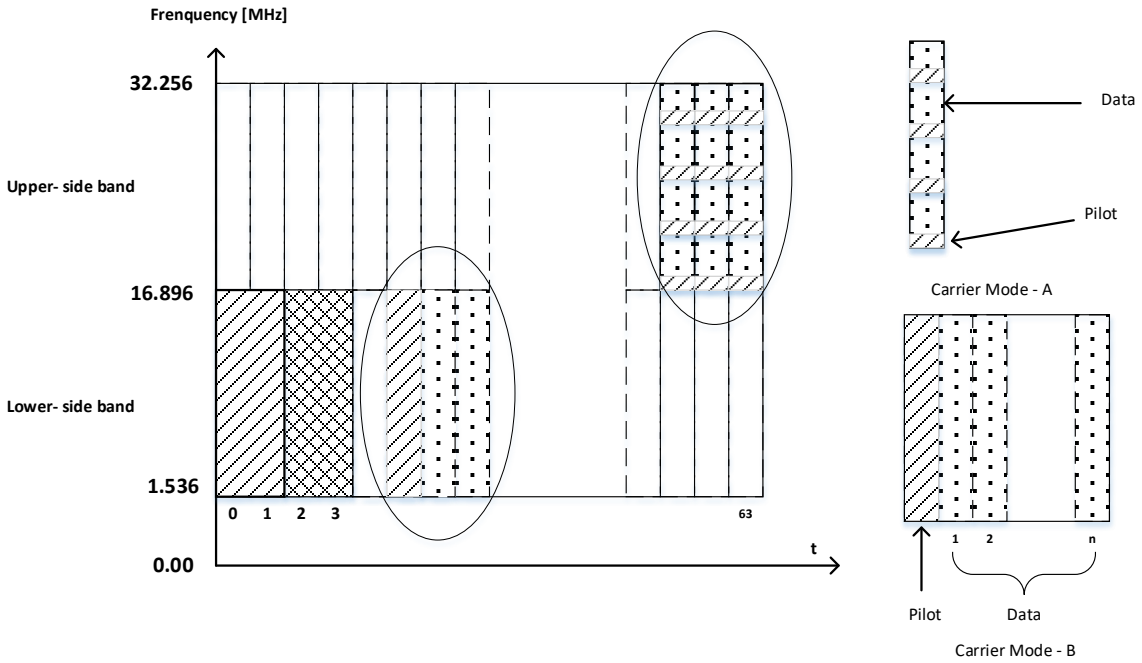

Figure 10 – Carrier mode A and carrier mode B of data subframe

Carrier mode A is generally used for periodic cyclic data transmission. AUTBUS supports up to 8 users intervals if the carrier mode A is used. Carrier mode A also supports the application and use of equal allocation of interval resources for multi-users.

Carrier mode B is used both for cyclic fixed rate data transmission and variable rate data transmission.

NOTE Fixed rate data transmission means that the transmitted data is transmitted on the bus in a fixed cycle, and the data size transmitted per cycle is fixed. Variable rate data transmission means that the transmitted data is not processed on the bus in a fixed cycle, and the size of the data being processed is not fixed.

See Annex A for the distinction and choice of carrier mode A or carrier mode B.

7.2.3 OFDM symbol

Each OFDM symbol in the AUTBUS PhL has the maintenance information as shown in Figure 11 to maintain the availability of OFDM symbols.

DV-H (2 bits)	DV-L (2 bits)	RVD (2 bits)	Symbol_Length (10-bits)	OFDM timing (64-bits)	Symb_Contents (14-812 octets)

Figure 11 – OFDM symbol structure of PhL

– **DV-H** is the availability of the upper-side band and carrier mode of the OFDM symbol, 0b00 is unable, 0b01 is carrier mode A, 0b10 is carrier mode B, 0b11 is reserved.

– **DV-L** is the availability of the lower-side band and carrier mode of the OFDM symbol, 0b00 is unable, 0b01 is carrier mode A, 0b10 is carrier mode B, 0b11 is reserved.

– **RVD** is reserved bits.

– **Symbol_Length** is the number of valid data octets loaded by this OFDM symbol.

– **OFDM_timing** is the time information contained in this OFDM symbol.

– **Symb_Contents** is the data loaded by this OFDM symbol and consists of 1 or 2 CBs (see 7.2.4).

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Figure 12 shows OFDM timing structure. The structure has 64 bits and is the basis for AUTBUS clock synchronization between nodes.

Figure 12 – OFDM timing structure

- **Frame Index** is the SF number of the current OFDM symbol, which counts from 0 when the MN is working normally. The valid value range is 0 ~ (2^{44} -1). When the count equal to (2^{44}-1), it starts from 0 again.
- **Symbol Index** indicates the position of the current OFDM symbol in a SF. The valid value range is 0 ~ 63 and start counting from received the SynS of a SF.
- **Cycle Index** is the current sampling subcarrier number. The valid value range is 0 ~ 4 095 and start counting from the start of the received OFDM symbol.

7.2.4 Code Block

The basic unit of data interaction between AUTBUS PhL and DLL is Code Block (CB). The CB is composed of a certain number of octet sequences, which have the following characteristics:

- The number of octets of one CB is fixed corresponding to the different working modes of PhL (see 7.2.6). 1 ~ 2 CBs can be processed on each OFDM symbol half side-band.
- A DLPDU may be placed in one or more CBs after being serialized by octets. A CB may be store octet sequence information for more than one DLPDU. Figure 13 shows the relationship between DLPDU and CB.
- The PhL entity automatically adds CRC check codes with the length of four octets for each CB before starting to process the CB.
- If the CB contains invalid octet sequence, the value of octets are set to 0 by default.
- The MSB in the code block stores the octet sequence information corresponding to the MSB data of DLPDU, and the LSB stores the octet sequence information corresponding to the LSB data of DLPDU.

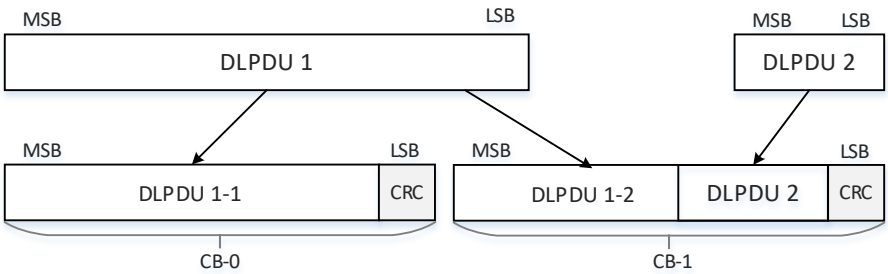

Figure 13 – DLPDU and CB

7.2.5 Resource element

The transmission signal of each SF is defined as the resource grid with N_{SD} subcarriers and N_{SYM} OFDM symbols, N_{SD} is determined by the transmit mode, the configuration value is shown in Table 18, and N_{SYM} is 64. Figure 14 shows resource grid structure, each element in the resource grid is called a resource element, and each resource element is uniquely defined by (k,l), where $k = 0, \ldots, N_{SD} - 1$ and $l = 0, \ldots, N_{SYM} - 1$. k represents the frequency domain and l reprents the time domain. Resource element (k,l) corresponds to complex value

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$a_{k,l}$. The corresponding resource $a_{k,l}$ is set to 0 if it is not used for the transmission of physical signals.

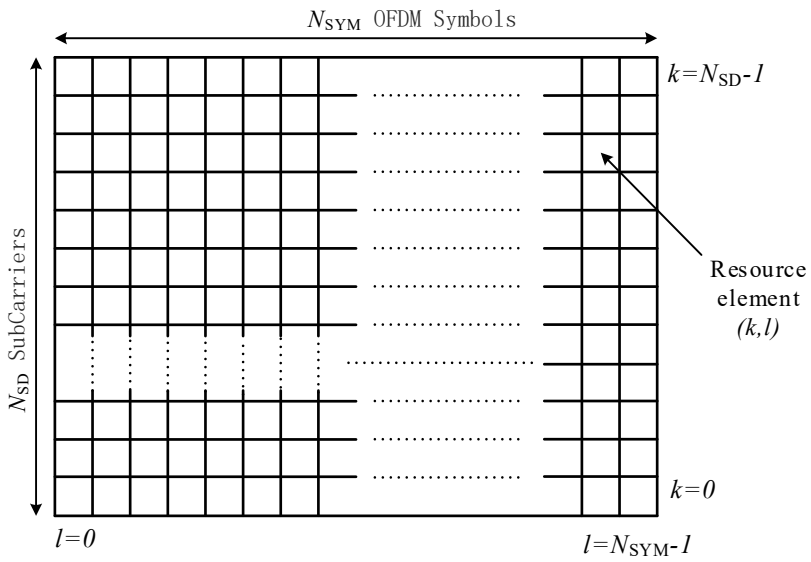

Figure 14 – Resource element schematic diagram

7.2.6 Working mode

The AUTBUS PhL adopts OFDM technology and supports both time division multiplexing (TDM) and frequency division multiplexing (FDM). The AUTBUS PhL provides four different Transmit Modes (TM 0 / 1 / 2 / 3) in frequency domain. AUTBUS users can select the TM according to the actual signal-to-noise ratio (SNR) of the application environment. An OFDM symbol time length should be configured as 64 us, 32 us, 16 us or 8 us corresponding to different TMs, The SF period varies from 500 µs to 4,0 ms. Table 18 shows the corresponding parameters in different TMs of the AUTBUS PhL.

Table 18 – AUTBUS TMs and corresponding parameters

Parameters	Transmit Mode			
	0	1	2	3
Frequency Range [MHz]	1,536 – 32,256	1,536 – 32,256	1,536 – 32,256	1,536 – 32,256
Lower-Side Band Frequency Range [MHz]	1,536 – 16,896	1,536 – 16,896	1,536 – 16,896	1,536 – 16,896
Upper-Side Band Frequency Range [MHz]	16,896 – 32,256	16,896 – 32,256	16,896 – 32,256	16,896 – 32,256
Frequency Bandwidth [Mhz]	30,72	30,72	30,72	30,72
Sub-carrier Spacing, *B* [KHz]	24	48	96	192
Number of Sub-carriers N_{SD}	1 280	640	320	160
FFT Size [K=1 024]	4K	2K	1K	0,5K
Sub-carrier modulation scheme	16QAM, 64QAM, 256QAM	16QAM, 64QAM, 256QAM	16QAM, 64QAM, 256QAM	16QAM, 64QAM, 256QAM

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Parameters	Transmit Mode			
	0	1	2	3
Useful Symbol length [us]	41,666 7	20,833 3	10,416 7	5,208 3
Cyclic Prefix length [us]	20,833 3	10,416 7	5,208 3	2,604 2
Symbol length [us]	62,5	31,25	15,625	7,812 5
Sampling Interval [ns]	10,17	10,17	10,17	10,17
Frame length [ms]	4,0	2,0	1,0	0,5
OFDM Symbols per frame N_{SYM}	64	64	64	64
Available Channel per Symbol	1 or 2	1 or 2	1 or 2	1 or 2

AUTBUS PhL has multiple working modes to carry DLL data. Different working modes adapt to different channel environments and data transmission requirements. In each working mode, the allocation of physical resources and the efficiency of data carry are varied based on the selection of TM, frame format and modulation coding strategy (MCS).

After the configuration is complete, the MN should broadcast the working mode to each TN of the whole network. If the network configuration is successful, the AUTBUS network should work according to this mode and implement the communication between nodes until the MN reconfigures the working mode next time.

The CB is the basic unit of data processing in the PhL. The valid octet number carried by an OFDM symbol is an integer multiple of the number of valid octets of a CB. AUTBUS supports a total of 22 working modes, of which carrier mode A supports 10 working modes, carrier mode B supports 12 working modes. The parameter configuration and the equivalent available bandwidth in each mode are shown in Table 19 and Table 20.

Table 19 – Working mode under carrier mode A

Working mode	Transmit mode	FFT Points	Valid data in CB (octets)	Valid data of a OFDM symbol (octets)	Valid N_{SD} of OFDM symbol	Equivalent available bandwidth (Mbps)
A0	0	1 024	173	346	1 280	44,288
A1	0	1 024	103	412	1 280	52,736
A2	0	1 024	173	692	1 280	88,576
A3	1	512	84	168	640	43,008
A4	1	512	103	206	640	52,736
A5	1	512	173	346	640	88,576
A6	2	256	57	114	320	58,368
A7	2	256	84	168	320	86,016
A8	3	128	22	44	160	45,056
A9	3	128	39	78	160	79,872

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Table 20 – Working mode under carrier mode B

Working mode	Transmit mode	FFT Points	Valid data in CB (octets)	Valid data of a OFDM symbol (octets)	Valid N_{SD} of OFDM symbol	Equivalent available bandwidth (Mbps)
B0	0	1 024	123	246	1 280	31,488
B1	0	1 024	203	406	1 280	51,968
B2	0	1 024	123	492	1 280	62,976
B3	0	1 024	203	812	1 280	103,936
B4	1	512	59	118	640	30,208
B5	1	512	99	198	640	50,688
B6	1	512	123	246	640	62,976
B7	1	512	203	406	640	103,936
B8	2	256	59	118	320	60,416
B9	2	256	99	198	320	101,376
B10	3	128	27	54	160	55,296
B11	3	128	47	94	160	96,256

7.3 DLL–PhL interface

7.3.1 General

Subclause 7.3 defines the required Physical Service (PhS) primitive and constraints on their use.

PhIDU shall be transferred between the DLL and the PhL in accordance with the requirements of ISO/IEC 7498-1 as shown in Figure 15.

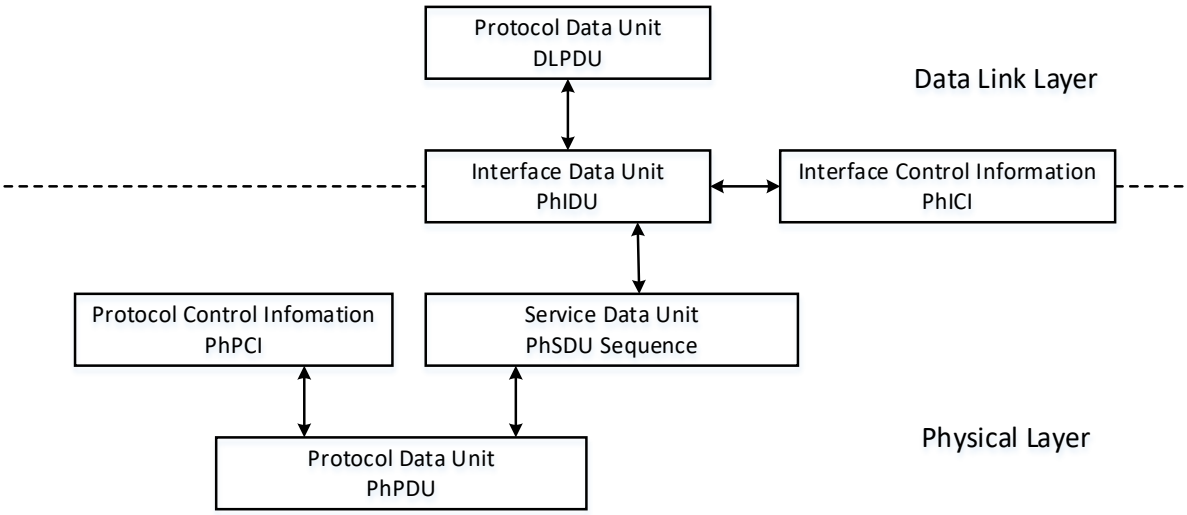

Figure 15 – Mapping between data units across the DLL-PhL interface

These services provide for the interchange of information data units between a DLL entity and its associated PhL entity. They also provide methods for data interaction between data entities,

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allows cooperative work DLL entities to coordinate transmission and data exchange on shared medium, and ensures the deterministic and synchronous of data exchange.

7.3.2 Service primitive

7.3.2.1 Ph-Param (para, value)

The PhL informs the current working mode, coding and modulation related parameters to DLL. The DLL shall implement the encapsulation and processing of the PhLSDU according to the parameters. Table 21 shows the primitives and parameters of the Ph-Param service. The primitive parameters are described in Table 22.

Table 21 – Ph-Param service primitives and parameters

Parameter name	Indication
para	M
value	M

Table 22 – Ph-Param service primitive parameter description

para		value
para index	para description	
0	Transmit_mode	0 ~ 3, see Table 18, current system transmitting mode
1	Work_mode	0 ~ 21, see Table 19 and Table 20, current working mode parameter 0 ~ 9 corresponding to working mode A0 ~ A9, 10 ~ 21 corresponding to working mode B0 ~ B11
2	Rs_code	0 ~ 11, see Table 34, RS code mode
3	Con_code	0 ~ 2, see Table 35, Convolutional code mode
4	Qam_mode	0 ~ 2, respectively corresponding to three mapping mode of 16QAM, 64QAM and 64QAM

7.3.2.2 Ph-Data (length, data, status)

AUTBUS PhL provides the ability of the DLL to transmit and receive data based on the service. Table 23 shows the service primitives and parameters. Primitive parameter length is the octet length, data is DLPDU and status is the processing result of the corresponding service primitive. The primitive parameters are described in Table 24.

Table 23 – Ph-Data service primitives and parameters

Parameter name	Request	Indication	Comfirm
length	M	M	M
data	M	M	—
status	—	M	M

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Table 24 – Ph-Data service primitive parameter description

Parameter name	Description
length	Specify the octet length of data
data	Transmitting or receiving DLPDU, data is invalid when the flag is the transmitting confirmation
status	This parameter is a 16-bit length value Status information indicated by bit bit 0 indicates transmitting or receiving status bit 1 indicates data status bit 2 indicates CRC check status The corresponding bit set to 0 indicates that the status is correct, and set to 1 indicates status error bit 3 ~ bit 15 reserved

The DLL Data Entity (DLDE) requests the PhL entity to tranmit the data based on the service request primitive. When the PhL receives the DLL Ph-Data request primitive, the PhLDE shall convert DLPDU to PhSDU according to the PhICI information and add the required PhPCI information, and the PhPDU in the form of physical signal shall be transmitted to the physical medium by encoding and modulation. The transmitting result is notified to the DLL through the Ph-Data.Confirm primitive.

The PhL Data Entity (PhLDE) informs the DLDE to receive data based on the service indication primitive. When the PhL receives the PhPDU in the form of physical signal through the medium, after demodulation and decoding, the PhLDE should resolve the PhSDU transmitted by the peer PhLDE and convert them into DLPDU according to the PhICI information, and transmit to DLL through the Ph-Data.Indicaton primitive.

7.3.2.3 Ph-Clock-Sync (command, data, ofdmtiming)

The AUTBUS PhL provides clock synchronization service to the DLL. The DLL should implement the function of clock synchronization and delay measurement based on this service. Table 25 shows the service primitives and parameters. The primitive parameters are described in Table 26.

Table 25 – Ph-Clock-Sync service primitives and parameters

Parameter name	Request	Indication
command	M	M
data	M	M
ofdmtiming	-	M

Table 26 – Ph-Clock-Sync service primitive parameter description

Parameter name	Description
command	DLL requests PhL clock synchronization command 0 Clock synchronization 1 Delay measurement
data	Clock synchronous DLPDU, fixed length
ofdmtiming	PhL OFDM timing information Only the indication primitive is valid

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When the DLL requests the PhL to transmit clock synchronization information (command=0 or 1) through the Ph-Clock-Sync.Request primitive, the PhLDE should fill the current OFDM timing information into the clock information field (see 8.3.2.12) of the clock synchronization DLPDU, convert the clock synchronization DLPDU to PhSDU according to the PhICI information and add the required PhPCI information. The PhLDE shoud encode and modulate the PhPDU to form physical signals, and then transmit them to the physical medium. When the PhL receives a PhPDU with clock information in the form of a physical signal through the medium, after demodulation and decoding, the PhLDE should resolve the PhSDU transmitted by the peer entity and convert it into a clock synchronous DLPDU according to the PhICI information. PhLDE should transmit the PhSDU to DLL through Ph-Clock-Sync.Indicaton primitive.

When the PhLDE receives the Ph-Clock-Sync.Request (Command=1) primitive, the PhLDE should notify the PhL Management Entity (PhLME) to perform delay measurement processing in addition to transmitting clock synchronization DLPDUs (see 7.4.2.5).

7.3.3 Primitive process

Figure 16 shows DLL-PhL interface service primitive process.

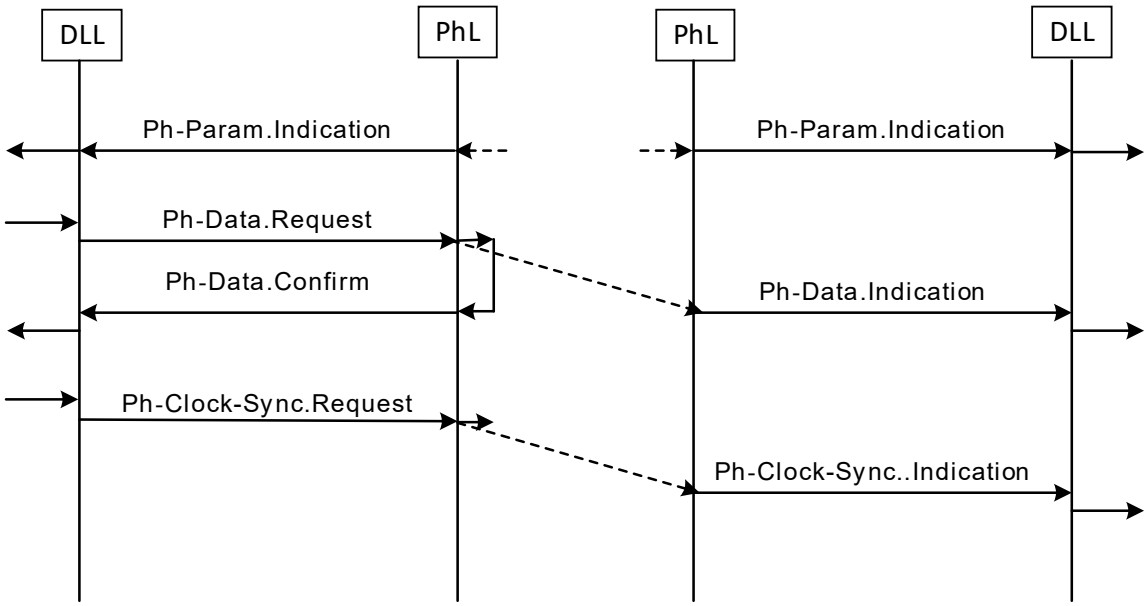

Figure 16 – DLL-PhL interface service primitive process

7.4 System management-PhL interface

7.4.1 General

This interface provides services to the PhL, which are required for initialization and selection of options.

The system management user implements the processing of the related content of the PhLME based on this interface. The service interface parameter parameter_index should be consistent with the actual content of the PhLME. See 6.3.1 for related information about PhL entity and system management information. Subclause 7.4 does not require this interface to be exposed. Each device in the network can use a subset of the described primitives in this document.

7.4.2 Service primitive

7.4.2.1 Ph-RESET (flag)

The PhL system management user informs the PhL to reset based on the service primitive. Table 27 shows the service primitives and parameters.

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Table 27 – Ph-RESET primitives and parameters

	Request	Confirm
flag	M	—

The PhL confirms whether it needs to be reset through the parameter flag, as described in Table 28. For reset operations with flag = 1, system management users should receive confirmation information.

Table 28 – Ph-RESET service primitive parameter description

Parameter name	Parameter value
flag	Reset flag: 0: Do not reset the PhL 1: Reset all functions of the PhL and the PhL entity parameters should be initialized to the default values.

7.4.2.2 Ph-SET-VALUE (parameter_index, value, status)

The PhL system management user uses the service to set the related parameters of PhLME. Table 29 shows the service primitives and parameters. See 6.3.1 for the specific description of the parameters parameter_index and value. The parameter status identifies the confirmation status of the requested service. Table 30 shows the service primitive parameter status.

Table 29 – Ph-SET-VALUE primitives and parameters

	Request	Confirm
parameter_index	M	—
value	M	—
status	—	M

Table 30 – Ph-SET-VALUE primitive parameter status description

Parameter name	Parameter value
status	Service returns status value 0: success 1: failure

7.4.2.3 Ph-GET-VALUE (parameter_index, value, status)

The PhL system management user uses the service to get the related parameters of the PhLME. Table 31 shows the service primitives and parameters. See 6.3.1 for the parameter parameter_index description. The parameter status as shown in Table 30 indicates the confirmation status of the corresponding request service.

Table 31 – Ph-GET-VALUE service primitives and parameters

	Request	Confirm
parameter_index	M	—
value	—	M
status	—	M

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