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**Real-time Ethernet – EtherNet/IP™
with time synchronization**



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CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope	7
2 Normative references	7
3 Terms, definitions, symbols, abbreviated terms and conventions	7
3.1 Terms and definitions	7
3.2 Symbols and abbreviated terms	8
3.3 Terms and definitions of conventions	8
4 Application layer service definition – Data type ASE	8
4.1 General.....	8
4.2 FAL defined data types	8
4.2.1 Fixed length types.....	8
5 Application layer service definition – Type 2 communication model specification	8
5.1 Concepts.....	8
5.2 ASEs.....	9
5.2.1 Object management ASE	9
6 Application layer protocol definition – Type 2.....	12
6.1 Abstract syntax.....	12
6.1.1 FAL PDU abstract syntax	12
6.1.2 Data abstract syntax specification	21

TABLES

Table 1 – Management_Message service parameters	11
Table 2 – Time Sync object instance attributes	12
Table 3 – Structure of Management_Message _RequestPDU body	13
Table 4 – Structure of Management_Message _ResponsePDU body.....	13
Table 5 – Management Message Command values.....	13
Table 6 – ObtainIdentity response parameters.....	14
Table 7 – InitializeClock request parameters	14
Table 8 – SetSubdomain request parameters	14
Table 9 – GetDefaultDataSet response parameters	15
Table 10 – UpdateDefaultDataSet request parameters.....	16
Table 11 – GetCurrentDataSet response parameters	16
Table 12 – GetParentDataSet response parameters	17
Table 13 – GetPortDataSet request parameters.....	17
Table 14 – GetPortDataSet response parameters	18
Table 15 – GetGlobalDataSet response parameters	18
Table 16 – UpdateGlobalTimeProperties request parameters.....	19
Table 17 – GoToFaultyState request parameters	19
Table 18 – GetForeignDataSet response parameters.....	19

Table 19 – SetSyncInterval request parameters.....	20
Table 20 – DisablePort request parameters	20
Table 21 – EnablePort request parameters.....	20
Table 22 – DisableBurst request parameters	20
Table 23 – EnableBurst request parameters	21
Table 24 – SetTime request parameters	21

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Real-time Ethernet – EtherNet/IP^{TM1} with time synchronization

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IEC-PAS 62413 has been processed by subcommittee 65C: Digital communications, of IEC technical committee 65: Industrial-process measurement and control.

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

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

Draft PAS	Report on voting
65C/361/NP	65C/377/RVN

Following publication of this PAS, the technical committee or subcommittee concerned will transform it into an International Standard.

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It is intended that the content of this PAS will be incorporated in the futures new editions of the various parts of IEC 61158 series and/or IEC 61784 series according to the structure of these series.

This PAS shall remain valid for an initial maximum period of three years starting from 2005-07. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

INTRODUCTION

The EtherNet/IP™ communication technology, standardized in IEC 61784-1 as Communication Profile 2/2 (using Type 2 specifications in IEC 61158), already provides ISO/IEC 8802-3 based real time communication, through the use of frame prioritization. The addition of time synchronization services and protocols allows using it also for the most demanding applications.

Real-time Ethernet – EtherNet/IP™ with time synchronization

1 Scope

This PAS defines additional mechanisms to provide accurate time synchronization between nodes using the ISO/IEC 8802-3 based real time communication technology EtherNet/IP.

It contains specifications for Application layer service definition and application layer protocol specification.

2 Normative references

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

IEC 61158 (all parts), *Digital data communications for measurement and control — Fieldbus for use in industrial control systems*

IEC 61158-5:2003, *Digital data communications for measurement and control – Fieldbus for use in industrial control systems - Part 5: Application layer service definition*

IEC 61158-6:2003, *Digital data communications for measurement and control – Fieldbus for use in industrial control systems - Part 6: Application layer protocol specification*

IEC 61588:2004, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61784-1:2003, *Digital data communications for measurement and control — Part 1: Profile sets for continuous and discrete manufacturing relative to fieldbus use in industrial control systems*

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

3 Terms, definitions, symbols, abbreviated terms and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61158 (general and Type 2 specific ones) and the following apply.

3.1.1

current data set

data set which defines members whose values characterize the current properties of the local clock that describe the source and quality of the local time
[IEC 61588]

3.1.2

default data set

data set which defines inherent or assumed properties of the local clock
[IEC 61588]

3.1.3

epoch

reference time defining the origin of a time scale
[IEC 61588]

3.2 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in IEC 61158 and IEC 61784-1 (general and Type 2 specific ones) and the following apply.

PTP Precision Time Protocol

[IEC 61588]

3.3 Terms and definitions of conventions

For the purposes of this document, the conventions given in IEC 61158 apply (general and Type 2 specific ones).

4 Application layer service definition – Data type ASE

4.1 General

This PAS uses the following data types as defined in IEC 61158-5:
BOOL, BYTE, USINT, UINT, UDINT, SINT, INT, DINT, LINT,
and the additional STIME data type specified in 4.2.1.1.1 and 6.1.2.1, according to the format defined in IEC 61158-5.

4.2 FAL defined data types

4.2.1 Fixed length types

4.2.1.1 Date types

4.2.1.1.1 STIME

1	Data Type Numeric Identifier	=	not used
2	Data Type Name	=	STIME
3	Format	=	FIXED LENGTH
4.1	Octet Length	=	8

This data type expresses the Synchronized Time in nanoseconds.

The range of values for variables of type STIME is the same as for variables of type LINT, representing the absolute time in nanoseconds since the epoch. The epoch is not defined by STIME.

5 Application layer service definition – Type 2 communication model specification

5.1 Concepts

Time synchronization for CP 2/2 of IEC 61784-1 is specified as an extension of the Type 2 Object management ASE defined in IEC 61158-5.

5.2 ASEs

5.2.1 Object management ASE

5.2.1.1 FAL management model class specification

5.2.1.1.1 General formal model

The Time Sync formal model is defined based on the general formal model of the Object management ASE.

5.2.1.1.2 Time Sync formal model

5.2.1.1.2.1 Class definition

The Time Sync ASE (Object) shall provide an IEC 61158 Type 2 interface to the IEC 61588 Precision clock synchronization protocol for networked measurement and control systems, commonly referred to as the Precision Time Protocol (PTP). Any device supporting Type 2 Time Synchronization shall provide a single instance (Instance 1) of the Time Sync Object.

NOTE Additional details may be found in the IEC 61588 standard.

(*) in front of an attribute or a service means that this attribute/service is either mandatory or optional, based on some constraints defined in the attribute/service description.

FAL ASE:	FAL Management ASE
CLASS:	Time_Sync_Object
CLASS ID:	<tdb>
PARENT CLASS:	Base_Object
ACCESS ATTRIBUTES:	
1 (m) Key Attribute:	Object Instance number
2 (o) Key Attribute:	Symbolic name
SYSTEM MANAGEMENT ATTRIBUTES (CLASS ATTRIBUTES) :	
1 (o) Attribute:	Revision = 1
2 (o) Attribute:	Max Instance
3 (o) Attribute:	Number of Instances
4 (o) Attribute:	Optional attribute list
4.1 (m) Attribute:	Number of attributes
4.2 (m) Attribute:	Optional attributes
5 (o) Attribute:	Optional service list
5.1 (m) Attribute:	Number services
5.2 (m) Attribute:	Optional services
6 (o) Attribute:	Maximum ID Number Class Attributes
7 (o) Attribute:	Maximum ID Number Instance Attributes
OBJECT MANAGEMENT ATTRIBUTES (INSTANCE ATTRIBUTES) :	
1 (m) Attribute:	CurrentTime
2 (m) Attribute:	PTPTime
SYSTEM MANAGEMENT SERVICES:	
10 (*) Mgt Service:	Get_Attribute_Single
OBJECT MANAGEMENT SERVICES:	
10 (m) Ops Service:	Get_Attribute_Single
11 (m) Ops Service:	Set_Attribute_Single
OBJECT SPECIFIC SERVICES:	
1 (m) OpsService:	Management_Message

5.2.1.1.2.2 System management attributes (class attributes)

No specific requirement for this object.

5.2.1.1.2.3 Object management attributes

CurrentTime

Current value of local time.

This instance attribute has an access rule of Set.

PTPTime

Current value of local time, according to IEC 61588 format.

This instance attribute has an access rule of Set.

5.2.1.1.2.4 System management (class level) services

Get_Attribute_Single

This service is **mandatory** if any attributes are implemented, else it is **optional**.

5.2.1.1.2.5 Object management (instance level) services

No specific requirement for this object.

5.2.1.1.2.6 Object specific services

Management_Message

The Management_Message service shall be used to initiate a Type 2 management command to the PTP Clock. Each management command shall be identified by a dedicated Management Message Command parameter within the service request and response.

5.2.1.2 FAL management model ASE service specification

5.2.1.2.1 Supported services

The object specific services defined for this ASE are:

Management_Message (Time Sync Object)

5.2.1.2.2 Management_Message

5.2.1.2.2.1 Service overview

The Management_Message service shall be used to initiate a Type 2 management command to the PTP Clock. Each management command shall be identified by a dedicated Management Message Command parameter.

5.2.1.2.2.2 Service primitives

The service parameters for this service are shown in Table 1.

Table 1 – Management_Message service parameters

Parameter name	Req	Ind	Rsp	Cnf
Argument	M			
AREP	M			
Local	S			
UCMM Record identifier	S			
Transport identifier	S			
Receiver/Server Local ID		M		
Path	M	C		
Routing Path	M			
Additional Path	U	U(=)		
Port ID		M		
Management Message Command	C	C(=)		
Command specific request parameters	C	C(=)		
Result (+)			S	S(=)
AREP				M
Receiver/Server Local ID			M	
Service status			M	M(=)
Management Message Command			C	C(=)
Command specific response parameters			C	C(=)
Result (-)			S	S(=)
AREP				M
Receiver/Server Local ID			M	
Service status			M	M(=)

Argument

The argument contains the parameters of the service request.

Management Message Command

This parameter identifies the management command to be initiated to the PTP Clock. It provides a correspondence with the relevant IEC 61588 Management Message Key.

Command specific request parameters

This parameter contains request parameters specific to the selected management command. These are further detailed in IEC 61588 for each command.

Result(+)

This selection type parameter indicates that the service request succeeded.

Service status

This parameter shall indicate success.

Management Message Command

This parameter identifies the management command initiated to the PTP Clock.

Command specific response parameters

This parameter contains response parameters specific to the selected management command. These are further detailed in IEC 61588 for each command.

Result(-)

This selection type parameter indicates that the service request failed.

Service status

This parameter shall indicate an error.

5.2.1.2.2.3 Service procedure

No specific service procedure.

6 Application layer protocol definition – Type 2

6.1 Abstract syntax

6.1.1 FAL PDU abstract syntax

6.1.1.1 General

Time synchronization for CP 2/2 of IEC 61784-1 uses the same abstract syntax as specified in IEC 61158-6, with the extensions specified in 6.1.1.2 and 6.1.2.

6.1.1.2 OM_Service_PDU

6.1.1.2.1 Time Sync object specific syntax elements

6.1.1.2.1.1 Attributes

Instance attributes

The format of the Time Sync Object instance attributes shall be as specified in Table 2.

Table 2 – Time Sync object instance attributes

Attribute ID	Name	Data Type	Semantics of values
1	CurrentTime	STIME	According to data type
2	PTPTime	STRUCT of	Synchronized Time based on the IEC 61588 Precision Time Protocol (PTP)
	epochNumber	UDINT	Number of times the 32-bit seconds clock (seconds field) has rolled over since the beginning of the epoch
	seconds	UDINT	Number of seconds since the beginning of the epoch. When the epoch is defined as the PTP epoch the epoch began at 0 hours on 1 January 1970.
	nanoseconds	DINT	The range of the absolute value of the nanoseconds field shall be restricted to $0 \leq \text{nanoseconds} \leq 10^9 - 1$. The sign of the nanoseconds field shall be interpreted as the sign of the entire representation. A negative timestamp shall indicate time prior to the epoch.

6.1.1.2.1.2 Management_Message service

The Management_Message_RequestPDU body shall be as specified in Table 3.

Table 3 – Structure of Management_Message_RequestPDU body

Name	Data Type	Semantics of values
Management Message Command	UINT	See Table 5
Management Message Parameters	Command specific	See Table 6 to Table 24 and specific Management Message Key sections in IEC 61588.

The Management_Message_ResponsePDU body shall be as specified in Table 4.

Table 4 – Structure of Management_Message_ResponsePDU body

Name	Data Type	Semantics of values
Management Message Command	UINT	Identical to request parameter. See Table 5
Management Message Parameters	Command specific	See Table 6 to Table 24 and specific Management Message Key sections in IEC 61588.

Table 5 – Management Message Command values

Management Message Command	Value
ObtainIdentity	1
InitializeClock	3
SetSubDomain	4
ClearDesignatedPreferredMaster	5
SetDesignatedPreferredMaster	6
GetDefaultDataSet	7
UpdateDefaultDataSet	9
GetCurrentDataSet	10
GetParentDataSet	12
GetPortDataSet	14
GetGlobalTimeDataSet	16
UpdateGlobalTimeProperties	18
GoToFaultyState	19
GetForeignDataSet	20
SetSyncInterval	22
DisablePort	23
EnablePort	24
DisableBurst	25
EnableBurst	26
SetTime	27

ObtainIdentity

The ObtainIdentity command shall return the clock identity of the PTP Clock.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 6.

Table 6 – ObtainIdentity response parameters

Name	Data Type	Description of Parameter	Semantics of values
ClockCommunicationTechnology	USINT	clock_communication_ technology	See IEC 61588
ClockUuidField	ARRAY [0..5] of BYTE	clock_uuid_field	
ClockPortField	UINT	clock_port_field	
ManufacturerIdentity	ARRAY [0..47] of BYTE	manufacturer_identity	

InitializeClock

The InitializeClock command shall be used to initialize the PTP clock. If the “Initializable” attribute of the PTP clock is set, the receipt of this message shall cause the clock to execute the behaviour normally executed on a reboot or power cycle of the node containing the clock. Otherwise, the receipt of this message shall have no effect.

Command-specific parameters for the service request are specified in Table 7.

Table 7 – InitializeClock request parameters

Name	Data Type	Description of Parameter	Semantics of values
InitializationKey	UINT	Initialization key	See IEC 61588

There are no command-specific parameters for the service response.

SetSubdomain

The SetSubdomain command shall be used to update the value of the subdomain name in the default data set with the new value sent in the service request.

Command-specific parameters for the service request are specified in Table 8.

Table 8 – SetSubdomain request parameters

Name	Data Type	Description of Parameter	Semantics of values
SubdomainName	ARRAY [0..15] of BYTE	subdomainName	See IEC 61588

There are no command-specific parameters for the service response.

ClearDesignatedPreferredMaster

The ClearDesignatedPeferredMaster command shall be used to set the value of preferred in the default data set to FALSE.

There are no command-specific parameters for the service request.

There are no command-specific parameters for the service response.

SetDesignatedPreferredMaster

The SetDesignatedPreferredMaster command shall be used to set the value of preferred in the default data set to TRUE.

There are no command-specific parameters for the service request.

There are no command-specific parameters for the service response.

GetDefaultDataSet

The GetDefaultDataSet command shall be used to get the default data set.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 9.

Table 9 – GetDefaultDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
ClockCommunicationTechnology	USINT	clock_communication_technology	See IEC 61588
ClockUuidField	ARRAY [0..5] of BYTE	clock_uuid_field	
ClockPortField	UINT	clock_port_field	
ClockStratum	USINT	clock_stratum	
ClockIdentifier	ARRAY [0..3] of BYTE	clock_identifier	
ClockVariance	INT	clock_variance	
ClockFollowupCapable	BOOL	clock_followup_capable	
Preferred	BOOL	preferred	
Initializable	BOOL	initializable	
ExternalTiming	BOOL	external_timing	
IsBoundaryClock	BOOL	is_boundary_clock	
SyncInterval	SINT	sync_interval	
SubdomainName	ARRAY [0..15] of BYTE	subdomain_name	
NumberPorts	UINT	number_ports	
NumberForeignRecords	UINT	number_foreign_records	

UpdateDefaultDataSet

The UpdateDefaultDataSet command shall be used to update the default data set with the new values sent in the service request.

Command-specific parameters for the service request are specified in Table 10.

Table 10 – UpdateDefaultDataSet request parameters

Name	Data Type	Description of Parameter	Semantics of values
ClockStratum	USINT	clock_stratum	See IEC 61588
ClockIdentifier	ARRAY [0..3] of BYTE	clock_identifier	
Clock Variance	INT	clock_variance	
Preferred	BOOL	preferred	
SyncInterval	USINT	sync_interval	
SubDomain Name	ARRAY [0..15] of BYTE	subdomain_name	

There are no command-specific parameters for the service response.

GetCurrentDataSet

The GetCurrentDataSet command shall be used to get the current data set.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 11.

Table 11 – GetCurrentDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
StepsRemoved	UINT	steps_removed	See IEC 61588
OffsetFromMasterSeconds	UDINT	offset_from_master (sec)	
OffsetFromMasterNanoseconds	DINT	offset_from_master(nsec)	
OneWayDelaySeconds	UDINT	one_way_delay (sec)	
OneWayDelayNanoseconds	DINT	one_way_delay (nsec)	

GetParentDataSet

The GetParentDataSet command shall be used to get the parent data set.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 12.

Table 12 – GetParentDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
ParentCommunicationTechnology	USINT	parent_communication_technology	See IEC 61588
ParentUuid	ARRAY [0..5] of BYTE	parent_uuid	
ParentPortId	UINT	parent_port_id	
ParentLastSyncSequenceNumber	UINT	parent_last_sync_sequence_number	
ParentFollowupCapable	BOOL	Parent_followup_capable	
parentExternalTiming	BOOL	Parent_external_timing	
ParentVariance	INT	Parent_variance	
ParentStats	BOOL	Parent_stats	
ObservedVariance	INT	observed_variance	
ObservedDrift	DINT	observed_drift	
UtcReasonable	BOOL	utc_reasonable	
GrandmasterCommunicationTechnology	USINT	grandmaster_communication_technology	
GrandmasterUuidField	ARRAY [0..5] of BYTE	grandmaster_uuid_field	
GrandmasterPortIdField	UINT	grandmaster_port_id_field	
GrandmasterStratum	USINT	grandmaster_stratum	
GrandmasterIdentifier	ARRAY [0..3] of BYTE	grandmaster_identifier	
GrandmasterVariance	INT	grandmaster_variance	
GrandmasterPreferred	BOOL	grandmaster_preferred	
GrandmasterIsBoundaryClock	BOOL	grandmaster_boundary_clock	
GrandmasterSequenceNumber	UINT	grandmaster_sequence_number	

GetPortDataSet

The GetPortDataSet command shall be used to get the port data set of the port whose port_id_field of the port configuration data set matches the TargetPortId field of the service request.

Command-specific parameters for the service request are specified in Table 13.

Table 13 – GetPortDataSet request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

Command-specific parameters for the service response are specified in Table 14.

Table 14 – GetPortDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
ReturnedPortNumber	UINT	returned_port_number	See IEC 61588
PortState	USINT	port_state	
LastSyncEventSequenceNumber	UINT	last_sync_event_sequence_number	
LastGeneralEventSequenceNumber	UINT	last_general_event_sequence_number	
PortCommunicationTechnology	USINT	port_communication_technology	
PortUuidField	ARRAY [0..5] of BYTE	port_uuid_field	
PortIdField	UINT	port_id_field	
BurstEnabled	BOOL	burst_enabled	
SubdomainAddressOctets	USINT	subdomain_address_octets	
EventPortAddressOctets	USINT	event_port_address_octets	
GeneralPortAddressOctets	USINT	general_port_address_octets	
SubdomainAddress	ARRAY of BYTE	subdomain_address	
EventPortAddress	ARRAY of BYTE	event_port_address	
GeneralPortAddress	ARRAY of BYTE	general_port_address	

GetGlobalTimeDataSet

The GetGlobalDataSet command shall be used to get the global data set.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 15.

Table 15 – GetGlobalDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
LocalTimeSeconds	UDINT	local_time (sec)	See IEC 61588
LocalTimeNanoseconds	DINT	local_time (nsec)	
CurrentUtcOffset	INT	current_uct_offset	
Leap59	BOOL	leap_59	
Leap61	BOOL	leap_61	
EpochNumber	UINT	epoch_number	

UpdateGlobalTimeProperties

The UpdateGlobalTimeProperties command shall be used to update the global time data set with the new values sent in the service request.

Command-specific parameters for the service request are specified in Table 16.

Table 16 – UpdateGlobalTimeProperties request parameters

Name	Data Type	Description of Parameter	Semantics of values
CurrentUtcOffset	INT	current_uct_offset	See IEC 61588
Leap59	BOOL	leap_59	
Leap61	BOOL	leap_61	
EpochNumber	UINT	epoch_number	

There are no command-specific parameters for the service response.

GoToFaultyState

The GoToFaultyState command shall be used to set the port whose port_id_field of the port configuration data set matches the TargetPortId field of the service request to the faulty state.

Command-specific parameters for the service request are specified in Table 17.

Table 17 – GoToFaultyState request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

There are no command-specific parameters for the service response.

GetForeignDataSet

The GetForeignDataSet command shall be used to get the foreign data set.

There are no command-specific parameters for the service request.

Command-specific parameters for the service response are specified in Table 18.

Table 18 – GetForeignDataSet response parameters

Name	Data Type	Description of Parameter	Semantics of values
ReturnedPortNumber	UINT	returned_port_number	See IEC 61588
ReturnedRecordNumber	UINT	returned_record_number	
ForeignMasterCommunication Technology	USINT	foreign_master_communication_technology	
ForeignMasterUuidField	ARRAY [0..5] of BYTE	foreign_master_uuid_field	
ForeignMasterPortIdField	UINT	foreign_master_port_id_field	
ForeignMasterSyncs	UINT	foreign_master_syncs	

SetSyncInterval

The SetSyncInterval command shall be used to set the sync_interval in the default data set to the new value in the service request.

Command-specific parameters for the service request are specified in Table 19.

Table 19 – SetSyncInterval request parameters

Name	Data Type	Description of Parameter	Semantics of values
SyncInterval	SINT	Sync_interval	See IEC 61588

There are no command-specific parameters for the service response.

DisablePort

The DisablePort command shall be used to set the port whose port_id_field of the port configuration data set matches the TargetPortId field of the service request to the disabled state.

Command-specific parameters for the service request are specified in Table 20.

Table 20 – DisablePort request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

There are no command-specific parameters for the service response.

EnablePort

The EnablePort command shall be used to set the port whose port_id_field of the port configuration data set matches the TargetPortId field of the service request to the enabled state.

Command-specific parameters for the service request are specified in Table 21.

Table 21 – EnablePort request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

There are no command-specific parameters for the service response.

DisableBurst

The DisableBurst command shall be used to set the burst_enable whose port_id_field of the port configuration data set matches the TargetPortId field of the service request to FALSE.

Command-specific parameters for the service request are specified in Table 22.

Table 22 – DisableBurst request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

There are no command-specific parameters for the service response.

EnableBurst

The EnableBurst command shall be used to set the burst_enable whose port_id_field of the port configuration data set matches the TargetPortId field of the service request to FALSE.

Command-specific parameters for the service request are specified in Table 23.

Table 23 – EnableBurst request parameters

Name	Data Type	Description of Parameter	Semantics of values
TargetPortId	UINT	Target port Id	See IEC 61588

There are no command-specific parameters for the service response.

SetTime

The SetTime command shall be used to set the value of the clock.

Command-specific parameters for the service request are specified in Table 24.

Table 24 – SetTime request parameters

Name	Data Type	Description of Parameter	Semantics of values
localTimeSeconds	UDINT	local_time (sec)	See IEC 61588
localTimeNanoseconds	DINT	local_time (nsec)	

There are no command-specific parameters for the service response.

6.1.1.3 Class, attribute and service codes

6.1.1.3.1 Code definitions

6.1.1.3.1.1 OM_Service codes

The code for the object specific Management_Message service of the Time Sync object is 0x4B.

6.1.2 Data abstract syntax specification

6.1.2.1 Control network data specification

The definition of AnyTime is modified as follows:

AnyTime ::= CHOICE {ITIME, TIME, FTIME, LTIME, STIME}

The following data specification is added to the existing ones:

STIME:= [PRIVATE 12] IMPLICIT LINT



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