IEC TR 61850-90-13

Edition 1.0 2021-02

TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 90-13: Deterministic networking technologies

IEC TR 61850-90-13:2021-02(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TR 61850-90-13

Edition 1.0 2021-02

TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 90-13: Deterministic networking technologies

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.200

ISBN 978-2-8322-9283-9

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD 5
INTRODUCTION 7
1 Scope 8
2 Normative references 8
3 Terms and definitions, abbreviated terms and acronyms 9
3.1 Terms and definitions 9
3.2 Abbreviated terms and acronyms 11
4 Characteristics of determinism 13
4.1 Deterministic latency 13
4.2 Deterministic jitter 14
5 Problem Statement 15
5.1 Overview 15
5.2 Problems with existing technologies 16
5.3 Improvements in networking communication from using the capabilities of deterministic communication technologies 17
5.4 Drawbacks of deterministic networking 17
5.4.1 General 17
5.4.2 Change in network design 18
5.4.3 Changes to the network infrastructure 18
5.4.4 Change to the network tools 18
5.4.5 Hardware changes to the IEDs 18
5.4.6 Change to the IED applications 18
5.4.7 Change to the standard 18
5.4.8 Backward compatibility and transition phase 19
5.5 Survey about problem statement 19
6 Deterministic networking – support and improvements for existing use cases 19
6.1 Use cases for the LAN 19
6.1.1 Requirements 19
6.1.2 Substation automation 20
6.1.3 WAN-based use cases 23
6.1.4 Protection and control for Distributed Energy Resources (DER) 26
6.1.5 Use cases in which determinism supports non-functional requirements 28
6.2 New use cases (in substation automation and over the WAN) 29
6.2.1 Large control loops 29
6.2.2 Multi-service networks 30
7 Deterministic networking 31
7.1 Capabilities and improvements 31
7.1.1 General 31
7.1.2 Time synchronization 31
7.1.3 Quality of service (QoS) 31
7.1.4 Network configuration and management 32
7.2 Deterministic networking technologies 32
7.2.1 Deterministic HSR 32
7.2.2 IEEE 802.1 Time-sensitive networking (TSN) 34
7.2.3 IETF DetNet 41
7.2.4 Other technologies 42

8 Co-existence and interoperability with existing and emerging technologies (and how to address technology changes) 47
8.1 Relation of TSN to technologies such as SDN (Software Defined Networking) and NFV (Network Function Virtualization) 47
8.2 Relation and interoperability to existing architectures for high-availability and redundancy based on PRP/HSR 48
8.3 Relation and interoperability to existing WAN-architectures based on MPLS (IP/MPLS, MPLS-TP) 48
8.4 Brownfield deployment options 48
8.5 Migration path 49
9 Design consideration for a future utility profile using deterministic networking technologies 50
9.1 IEC 61850 traffic patterns and protocols 50
9.2 Non-IEC 61850 traffic patterns and protocols 52
9.3 High-availability and reliability 53
9.4 Deterministic traffic classification 53
9.5 Conceptual model 53
9.5.1 General 53
9.5.2 Utility profile considerations using 802.1 TSN technologies 54
9.5.3 Specific IEEE 802.1Q-2018 clauses and related amendments 54
9.5.4 Time synchronization 54
10 Harmonization of deterministic networking requirements 54
10.1 IEC 61850-5 54
10.2 IEC 61850-9-2 54
10.3 IEC/IEEE 61850-9-3 54
10.4 IEC TR 61850-90-1 55
10.5 IEC/TR 61850-90-2 55
10.6 IEC TR 61850-90-4 55
10.7 IEC TR 61850-90-12 55
11 Impact on application operation 55
11.1 Scope and dependencies 55
11.2 Impact on existing applications 56
11.3 Impact for new applications and application evolution 56
Annex A (informative) Related work and liaisons 57
A.1 IEC/IEEE 60802 TSN-Profile for industrial automation 57
A.2 IEEE 802.24.1 Smart Grid TG 58
A.3 IEC SEG8 58
A.4 Power utility automation and control applications using 5G technology 58
Bibliography 59

Figure 1 – Delay probability for hard- and soft-real-time system 14
Figure 2 – Low jitter – jitter deterministic delay 15
Figure 3 – Substation station bus, process bus and traffic example (IEC TR 61850-90-4, Figure 11) 20
Figure 4 – Substation with Deterministic Ethernet 21
Figure 5 – Current differential tele-protection system (IEC TR 61850-90-12:2015) 24
Figure 6 – Microgrid with renewable generation, storage and grid infeed 26
Figure 7 – Multi-Service Networks 30

Figure 8 – Precise sending in HSR 33
Figure 9 – TSN Components 34
Figure 10 – Fully Distributed Model 38
Figure 11 – Hybrid Model 39
Figure 12 – Central Model 40
Figure 13 – Topology of a WAN network using VSN 44
Figure 14 – Frame Structure 45
Figure 15 – Mapping data in a single EtherCAT DLPDU 46
Figure 16 – Brownfield configuration options 49
Figure 17 – GOOSE protocol time/space chart (Source IEC TR 61850-90-4) 52

Table 1 – Transfer time requirements of IEC 61850-5 19
Table 2 – Station bus communication specifics in today's substations and possible benefits / improvements with TSN 23
Table 3 – Process bus communication specifics in today's substations and possible benefits / improvements with TSN 23
Table 4 – Latency requirements for protection schemes 25
Table 5 – IEEE 802.1 Qcc Configuration Models 36
Table 6 – DetNet documents 42
Table 7 – Traffic type characteristics of IEC 61850 protocols 51
Table 8 – Traffic type characteristics of non-IEC 61850 protocols 53

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-13: Deterministic networking technologies

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a Technical Report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 61850-90-13, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
57/2236/DTR	57/2301/RVDTR

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

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

A list of all parts in the IEC 61850 series, published under the general title *Communication networks and systems for power utility automation*, can be found on the IEC website.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Deterministic networking technologies enable applications that require bounded communication delays regardless of network load or reconfiguration. They allow traffic of different time-criticality to share the same physical medium. Deterministic network technologies are based on the pre-allocation of resources using for example scheduling, traffic shaping and the pre-emption of low priority messages to guarantee the timely delivery of high-priority traffic.

Power automation and control is an industry domain where deterministic networking is needed to support existing use cases and applications (requiring real-time communication), and to enable new developments. This networking is currently being provided by SDH networks or dedicated (for protection communications) Ethernet networks; however significant drives (economic and political) are now emerging to use "converged" Ethernet networks.

In this document the term WAN is used for the inter-substation communication networks, with the driving force usually being the desire of a utility to use the same network infrastructure for IT as well as for operational tasks such as inter-substation protection communications.

The term LAN is used for the intra-substation communication networks. Converged networks are those supporting mixed traffic (e.g. process data, configuration management, voice and video surveillance data) in the same network being used for critical power automation applications. In the same way that using public transportation to get from A to B in a timely (deterministic) manner requires the ability to be guaranteed a seat at a particular time, using a communication network for the deterministic delivery of data also requires the guarantee of access at a particular time. This document identifies, describes, and discusses the known technologies to address this determinism issue.

Summary:

Clause 5 describes the problem (with non-deterministic networks);

Clause 6 provides use cases;

Clause 7 lists deterministic networking technologies;

Clause 8 discusses interoperability issues;

Clause 9 suggests changes to the IEC 61850 standards needed to support determinism;

Annex A lists some related works and liaisons.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-13: Deterministic Networking Technologies

1 Scope

This part of IEC 61850, which is a Technical Report, provides information, use cases, and guidance on whether and how to use deterministic networking technologies. Furthermore, this document comprises technology descriptions, provides guidance how to achieve compatibility and interoperability with existing technologies, and lays out migration paths. It will separate the problem statement from the possible solutions.

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.

IEC 60834-1:1999, *Teleprotection equipment of power systems – Performance and testing – Part 1: Command systems*

IEC 60870-5-104:2006, *Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles*

IEC/IEEE 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC 61850-5:2013, *Communication networks and systems for power utility automation – Part 5: Communication requirements for functions and device models*

IEC 61850-6:2009, *Communication networks and systems for power utility automation – Part 6: Configuration description language for communication in electrical substations related to IEDs*

IEC 61850-8-1:2011, *Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3*

IEC 61850-9-2, *Communication networks and systems for power utility automation – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3*

IEC/IEEE 60802, *Time-sensitive networking profile for industrial automation*

IEC/IEEE 61850-9-3-2016, *IEC/IEEE International Standard – Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation*

IEC TR 61850-90-1:2010, *Communication networks and systems for power utility automation – Part 90-1: Use of IEC 61850 for the communication between substations*

IEC TR 61850-90-2:2016, *Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for communication between substations and control centres*

IEC TR 61850-90-4:2020, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC TR 61850-90-5:2012, *Communication networks and systems for power utility automation – Part 90-5: Use of* IEC 6*1850 to transmit synchrophasor information according to* IEEE *C37.118*

IEC TR 61850-90-12:2020, *Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines*

IEC 62351-7:2017, *Power systems management and associated information exchange – Data and communications security – Part 7: Network and System Management (NSM) data object models*

IEC 62439-3:2016, *Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)*

IEEE 802.1AS, *IEEE Standard for Local and Metropolitan Area Networks – Timing and Synchronization for Time-Sensitive Applications*, available at http://www.ieee.org

IEEE 802.1Q, *IEEE Standard for Local and metropolitan area networks – Bridges and Bridged Networks;* available at <http://www.ieee.org>

IEEE 802.1Qcc-2018, *IEEE Standard for Local and Metropolitan Area Networks – Bridges and Bridged Networks – Amendment 31: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements*

IEEE 802.3-2018, *IEEE Standard for Ethernet*

IEEE C37.94-2017, *IEEE Standard for N times 64 kbps Optical Fiber Interfaces between Teleprotection and Multiplexer Equipment*

IEEE C37.118.1-2011, *IEEE Standard for Synchrophasor Measurements for Power Systems*

3 Terms and definitions, abbreviated terms and acronyms

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
Centralized Network Configuration
CNC
logical component that configures network resources on behalf of TSN applications (users)

3.1.2
Centralized User Configuration
CUC
logical component that discovers and configures application (user) resources in end stations; the CUC exchanges information with the CNC in order to configure TSN features on behalf of its end stations

3.1.3
convergence
heterogeneous applications running on devices connected to the same physical network (LAN, WAN, or combination of both) which are able to exchange data, within the defined QoS parameters derived from application requirements

3.1.4
deterministic jitter
property of a system to change its output in response to a change of its input after a guaranteed minimum delay and before a guaranteed maximum delay, under error-free conditions

3.1.5
deterministic latency
property of a system to change its output in response to a change of its input within a guaranteed maximum delay, under error-free conditions

3.1.6
deterministic networking
predictable network behaviour which can be characterized by bounded latency, nearly zero jitter and extremely low data loss rates

3.1.7
DetNet
IETF Deterministic Networking (DetNet) Working Group

3.1.8
end station
device attached to a local area network (LAN) or wide area network (WAN), which acts as a source of, and/or destination for, traffic carried on the LAN or WAN

Note 1 to entry: The term end-station is used in relation to time-sensitive networking.

3.1.9
EtherCAT
Ethernet fieldbus system according to the type 12 specifications of IEC 61158 (all parts)

3.1.10
hard real time
property of a system with a deterministic latency

3.1.11
jitter
time variation of an expected occurrence with respect to a defined period

3.1.12
Listener
end station that is the destination, the receiver of a Stream

3.1.13
Pdelay
measure of the time from when a message is transmitted from one device to when the same part of the same message is received by the other device and vice versa as defined in IEC/IEEE 61588 and IEEE 802.1AS-2020

3.1.14
pre-emption
suspension of the transmission of a pre-emptible frame to allow one or more express frames to be transmitted before transmission of the pre-emptible frame is resumed

3.1.15
process data
data object containing application objects designated to be transferred cyclically or acyclically for the purpose of processing

3.1.16
project
system part with ownership of a set of IEDs, typically those located in one substation, and handled by one system configuration tool

3.1.17
soft real-time
property of a system whose latency is a probabilistic function with a low probability to exceed defined upper and lower bounds under error-free conditions

3.1.18
Stream
unidirectional flow of time-sensitive application data between from one source (Talker) to one or more destinations (Listeners)

3.1.19
Talker
end station that is the source or producer of a Stream

3.1.20
traffic shaping
queue management technique in packet-based networks to administrate data rates and bandwidth

3.1.21
TSN
series of Ethernet standards which is developed by the Time-Sensitive Networking task group in the scope of IEEE 802.1

3.2 Abbreviated terms and acronyms

The following abbreviated terms and acronyms apply to this document.

ARP	Address Resolution Protocol
CIP	Critical Infrastructure Protection
CNC	Centralized Network Configuration
CUC	Centralized User Configuration
DC	Distributed Clocks
DDoS	Distributed Denial of Service
DoS	Denial of Service
DER	Distributed Energy Resources
DL-	Data-link layer (as a prefix)
DLL	DL-layer
DLPDU	DL-protocol-data-unit
ENI	EtherCAT Network Information
ESI	EtherCAT Slave Information
ESP	Electronic Security Perimeter
FQTSS	Forwarding and Queueing for Time-Sensitive Streams
GNSS	Global Navigation Satellite System
GOOSE	Generic Object Oriented Substation Event
HMI	Human Machine Interface
HSR	High-availability Seamless Redundancy
ID	Identification
IED	Intelligent Electronic Device – any programmable or configurable device in the system
IERS	International Earth Rotation and Reference Systems Service
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IS-IS	Intermediate System to Intermediate System
IT	Information Technology
LAN	Local area network
LD	Logical Device (IEC 61850)
MAC	Media Access Control
MPLS	Multiprotocol Label Switching
MSRP	Multiple Stream Registration Protocol (MSRP)
NERC	North American Electric Reliability Corporation
NFV	Network Function Virtualization
OSI	Open System Interconnect
PDF	Portable Document Format
PMU	Phasor Measurement Unit
PRP	Parallel Redundancy Protocol
PTP	Precision Time Protocol
QoS	Quality of Service
RAS	Remedial Action Scheme

RSTP	Rapid Spanning Tree Protocol
SA	Substation Automation
SCD	System Configuration Description in the sense of 61850-6. Output of a system tool of a project to configure the IEDs belonging to the project (imported by IED tools).
SCL	Substation Configuration description Language according to IEC 61850
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Networking
SNMP	Simple Network Management Protocol
SONET	Synchronous Optical NETwork
SRP	Stream Reservation Protocol
SP	Synchrophasor
SPS	Special Protection Schemes
SS	Substation System
SV	Sampled Values
SW	Software
TAI	International Atomic Time
TDM	Time-division Multiplexing
TCP	Transmission Control Protocol
TP	Tele-Protection
TSN	Time Sensitive Networking
UDP	User Datagram Protocol
UNI	User Network Interface
VLAN	Virtual LAN
WAN	Wide area network
XML	eXtensible Markup Language
YANG	Yet Another Next Generation, a modeling language for network management

NOTE Abbreviated terms used for the identification of the common data classes and as names of the attributes are specified in the specific clauses of this document and are not repeated here.

4 Characteristics of determinism

4.1 Deterministic latency

A system with a deterministic latency is characterized by a guaranteed maximum delay between a change at its input and the reaction at its output, under error-free conditions.

Mathematically, the input to output delay of a system with a deterministic latency presents a probability distribution function (pdf) that has an upper bound smaller than a given deadline, in contrast to a non-deterministic system whose delay has a low, but non-zero probability, to exceed the deadline under error-free conditions, see Figure 1.