PD IEC TR 61850-90-12:2020



BSI Standards Publication

Communication networks and systems for power utility automation

Part 90-12: Wide area network engineering guidelines

bsi.

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

National foreword

This Published Document is the UK implementation of IEC TR 61850-90-12:2020. It supersedes PD IEC/TR 61850-90-12:2015, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/57, Power systems management and associated information exchange.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 02142 4

ICS 33.200

Compliance with a British Standard cannot confer immunity from legal obligations.

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

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

IEC TR 61850-90-12

Edition 2.0 2020-07

TECHNICAL REPORT

colour inside

Communication networks and systems for power utility automation – Part 90-12: Wide area network engineering guidelines

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.200

ISBN 978-2-8322-8657-9

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

® Registered trademark of the International Electrotechnical Commission

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

CONTENTS

FOREWORD 12
INTRODUCTION 14
1 Scope 16
2 Normative references 16
3 Terms, definitions, abbreviated terms, acronyms, and symbols 21
3.1 Terms and definitions 21
3.2 Abbreviated terms and acronyms 25
3.3 Network diagram symbols 34
4 Wide area communication in electrical utilities 36
4.1 Executive summary 36
4.2 Network and application example: ENDESA, Andalusia (Spain) 38
4.3 Typical interface between a substation and the WAN 40
4.4 WAN characteristics and actors 41
4.5 Smart Grid Architecture Model (SGAM) Mapping 42
4.6 Network elements and voltage level 44
4.7 WAN interfaces in substation automation (IEC 61850-5) 45
4.8 Logical interfaces and protocols in the architecture in IEC TR 62357-200 46
4.9 Network traffic and ownership 47
5 WAN metrics 48
5.1 Traffic types 48
5.2 Quality of Service (QoS) of TDM and PSN 48
5.3 Latency calculation 48
5.3.1 Latency components 48
5.3.2 Propagation delay 49
5.3.3 Residence delay 49
5.3.4 Latency accumulation 49
5.3.5 Example: latency of a microwave system 49
5.3.6 Latency and determinism 50
5.3.7 Latency classes in IEC 61850-5 50
5.4 Jitter 52
5.4.1 Jitter definition 52
5.4.2 Jitter classes in IEC 61850 53
5.5 Latency symmetry and path congruency 53
5.6 Medium asymmetry 53
5.7 Communication speed symmetry 54
5.8 Recovery delay 54
5.9 Time accuracy 54
5.9.1 Time accuracy definition 54
5.9.2 Time accuracy classes 55
5.10 Tolerance against failures 56
5.10.1 Failure 56
5.10.2 Reliability 57
5.10.3 Redundancy principles 57
5.10.4 Redundancy and reliability 58
5.10.5 Redundancy checking 59
5.10.6 Redundant layout: single point of failure 59

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

5.10.7 Redundant layout: cross-redundancy 60
5.10.8 Maintainability 61
5.10.9 Availability 61
5.10.10 Integrity 63
5.10.11 Dependability 64
5.10.12 Example: Dependability of GOOSE transmission 64
6 Use cases and WAN communication requirements 65
6.1 List of generic use cases 65
6.2 Teleprotection (IF2 & IF11) 66
6.2.1 Teleprotection schemes 66
6.2.2 Teleprotection data kinds 66
6.2.3 Current differential teleprotection for multi-terminal transmission line 66
6.2.4 Teleprotection communication requirements 67
6.3 Wide area monitoring system (IF13) 69
6.3.1 WAMS overview 69
6.3.2 WAMS topology 70
6.3.3 WAMS communication requirements 72
6.4 Wide area monitoring, protection, and control (WAMPAC) IF13 74
6.4.1 Functional description 74
6.4.2 WAMPAC communication requirements 76
6.5 Fault Location 76
6.5.1 Functional description 76
6.5.2 Fault location communication requirements 78
6.6 Distribution Automation 78
6.6.1 Functional description 78
6.6.2 Distribution automation communication requirements 79
6.7 Condition monitoring and diagnostics (CMD) and asset management (IF7) 80
6.7.1 Functional description 80
6.7.2 CMD communication requirements 80
6.8 Telecontrol (SCADA) 81
6.8.1 Functional description 81
6.8.2 Telecontrol communication requirements 81
6.9 Control centre to control centre (IF12) 82
6.9.1 Functional description 82
6.9.2 Inter control centre communication requirements 83
6.10 Smart metering / advanced metering infrastructure 84
6.10.1 Functional description 84
6.10.2 Smart metering communication requirements 84
6.11 WAN communication requirements summary 85
7 Wide-area and real-time network technologies 86
7.1 General 86
7.2 Topology 86
7.3 Overview 87
7.4 Layer 1 (physical) transmission media 89
7.4.1 Summary 89
7.4.2 Installation guidelines 89
7.4.3 Metallic lines 89
7.4.4 Power line carrier (PLC) 91
7.4.5 Radio transmission 101

AVA Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

7.4.6 Fibre optics 112
7.4.7 Layer 1 redundancy 118
7.4.8 Application example: diverse redundancy against extreme contingencies (Hydro-Quebec) 119
7.4.9 Layer 1 security 120
7.5 Layer 1,5 (physical) multiplexing 120
7.6 Layer 2 (link) technologies 121
7.6.1 Telephony technologies 121
7.6.2 SDH/SONET 123
7.6.3 Optical Transport Network 133
7.6.4 Ethernet 135
7.6.5 Ethernet over TDM 144
7.6.6 Carrier Ethernet 146
7.6.7 Audio-video bridging 147
7.6.8 Provider Backbone Bridge (PBB) 147
7.6.9 Multiprotocol Label Switching (MPLS) 149
7.7 Layer 3 (network) technologies 157
7.7.1 Internet Protocol (IP) 157
7.7.2 IP QoS 167
7.7.3 IP multicast 170
7.7.4 IP redundancy 171
7.7.5 IP security 171
7.7.6 IP communication for utilities 173
7.7.7 IP summary 175
7.8 Layer 4 (transport) protocols 176
7.8.1 Transport layer encapsulation 176
7.8.2 UDP 176
7.8.3 TCP 177
7.8.4 Layer 4 redundancy 178
7.8.5 Layer 4 security 178
7.9 Layer 5 (session) and higher 178
7.9.1 Session layer 178
7.9.2 Routable GOOSE and SMV 179
7.9.3 Example: C37.118 transmission 179
7.9.4 Session protocol for voice and video transmission 180
7.9.5 Application interface redundancy 180
7.9.6 Application device redundancy 181
7.10 Protocol overlay – tunnelling 181
7.10.1 Definitions 181
7.10.2 Tunnelling principle 182
7.10.3 Tunnelling Layer 2 over Layer 3 182
7.10.4 Application Example: Tunnelling GOOSE and SMV in IEC 61850 183
7.11 Virtual private networks (VPNs) 184
7.11.1 VPN principles 184
7.11.2 L2VPNs 184
7.11.3 L2VPN multicast on MPLS 186
7.11.4 L3VPN 186
7.11.5 VPN mapping to application 188
7.12 Cyber security 192

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

7.12.1 Security circles 192
7.12.2 Network security 193
7.12.3 Access control 195
7.12.4 Threat detection and mitigation 195
7.12.5 Security architecture 199
7.12.6 Application (end-to-end) communication security 200
7.12.7 Security for synchrophasor (PMU) networks (IEC TR 61850-90-5) 201
7.12.8 Additional recommendations 202
7.13 QoS and application-specific engineering 202
7.13.1 General 202
7.13.2 SDH/SONET QoS and SLA 202
7.13.3 PSN QoS and SLA 202
7.13.4 Application and priority 203
7.13.5 QoS chain between networks 203
7.13.6 QoS mapping between networks 204
7.13.7 QoS engineering 205
7.13.8 Customer restrictions 206
7.13.9 Clock services 206
7.14 Configuration and OAM 206
7.14.1 Network configuration 206
7.14.2 OAM 206
7.15 Time synchronization 208
7.15.1 Oscillator stability 208
7.15.2 Mutual synchronization 209
7.15.3 Direct synchronization 209
7.15.4 Radio synchronization 210
7.15.5 GNSS synchronization 210
7.15.6 Frequency distribution 210
7.15.7 Time distribution 212
7.15.8 PTP telecommunication profiles 218
7.15.9 PTP over MPLS 219
7.15.10 Comparison of time distribution profiles based on IEC 61588 219
7.15.11 Application example: synchrophasor time synchronization 220
7.15.12 Application example: Atomic clock hierarchy 221
8 Technology mapping to applications 222
8.1 Overview 222
8.2 Current differential teleprotection for multi-terminal transmission lines 222
8.2.1 General 222
8.2.2 Deterministic fibre-optic PDH loop network 223
8.2.3 Dedicated Gigabit Ethernet network 223
8.2.4 Carrier Ethernet with wide-area time synchronization 224
8.2.5 MPLS based wide area network 225
8.3 Wide area monitoring, protection, and control (WAMPAC) 227
8.3.1 General 227
8.3.2 Wide area stabilizing control using legacy network 227
8.3.3 PMU-based WAMPAC using time-synchronized Layer 2 and Layer 3 network 229
8.4 Fault location 231
8.5 SCADA and facility maintenance 233

AVA Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

8.6 Distribution automation 234
8.7 Smart metering 234
9 Network migration 237
9.1 TDM to packet switched network 237
9.1.1 General 237
9.1.2 Overview 237
9.1.3 Drivers for network migration 237
9.1.4 Considerations for network migration 238
9.1.5 Migration concepts 240
9.1.6 Implementation details 246
9.2 From IPv4 to IPv6 250
9.2.1 IPv4 to IPv6 evolution 250
9.2.2 IPv4 to IPv6 migration 250
9.2.3 IEC 61850 stack with IPv4 and IPv6 251
Annex A (informative) Future promising or upcoming technologies 252
A.1 5G 252
A.1.1 General 252
A.1.2 Different performance requirements 253
A.2 Deterministic networking technologies 256
Bibliography 257

Figure 1 – Symbols 35
Figure 2 – Substation locations in Andalusia 38
Figure 3 – Topology of the Andalusia network 39
Figure 4 – Cabinet of a substation edge node 40
Figure 5 – Communication interfaces in a SEN 41
Figure 6 – Communicating entities 42
Figure 7 – SGAM communication model 43
Figure 8 – Principle of grid voltage level and network technology 44
Figure 9 – Communication paths and interfaces 45
Figure 10 – IEC TR 62357 Interfaces, protocols, and applications 46
Figure 11 – Composition of end-to-end latency in a microwave relay 49
Figure 12 – Example of latency in function of traffic 50
Figure 13 – Jitter for two communication delay types 52
Figure 14 – Precision and accuracy definitions 55
Figure 15 – Redundancy of redundant systems 58
Figure 16 – Redundancy calculation 59
Figure 17 – Redundancy layout with single point of failure 59
Figure 18 – Redundancy layout with cross-coupling 60
Figure 19 – Availability definitions 61
Figure 20 – Residual error rate as a function of BER 63
Figure 21 – Network configurations for multi-terminal line protection 67
Figure 22 – Principle of synchrophasor transmission 71
Figure 23 – PMUs and data flow between TSO and regional data hubs 72
Figure 24 – Target phenomena for WAMPAC 74

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Figure 25 – Example of main function and general information flow 75
Figure 26 – Network configuration for a fault locator system 77
Figure 27 – System configuration for distribution automation 79
Figure 28 – Network configurations for CMD and asset management 80
Figure 29 – Logical network configuration for telecontrol (SCADA) 81
Figure 30 – Network configurations for inter-control centre 83
Figure 31 – System configuration for smart metering 84
Figure 32 – Network ring topology example 87
Figure 33 – Narrowband channel plans for LV PLC Europe vs. North America 93
Figure 34 – HF allocated frequency spectrum plans for LV BPL 93
Figure 35 – Narrowband spectrum usage vs. standards and regulation areas [57] 94
Figure 36 – HV PLC link building blocks 96
Figure 37 – Phase-to-ground coupling for PLC 97
Figure 38 – HV PLC coupling with suspended line traps 97
Figure 39 – Phase-to-phase signal coupling for PLC 98
Figure 40 – Phase-to-phase signal coupling 98
Figure 41 – Power line carrier, line traps 99
Figure 42 – Terrestrial microwave link 102
Figure 43 – Layer 2 transport on microwave radio systems 103
Figure 44 – DMR (Digital Mobile Radio) 106
Figure 45 – LoRaWAN™ Protocol Stack 108
Figure 46 – ADSS fibre cable 113
Figure 47 – ADSS installation with splicing box 113
Figure 48 – OPGW in ground cable 114
Figure 49 – OPGW with two "C"-tubes each with 32 fibers 114
Figure 50 – OPGW fibers 115
Figure 51 – Splicing box 116
Figure 52 – WDM over one fibre 117
Figure 53 – OCh optical components 117
Figure 54 – Optical link with microwave back-up 119
Figure 55 – Photograph of a partially destroyed 735 kV line 120
Figure 56 – E1 and E2 channels 122
Figure 57 – Digital transmission hierarchy (T-standards) 122
Figure 58 – Digital transmission hierarchy (E-standard) 123
Figure 59 – Example of an SDH network for utilities 124
Figure 60– SONET multiplexing hierarchy 125
Figure 61 – SDH multiplexing hierarchy 125
Figure 62 – SDH/SONET with point-to-point topology 127
Figure 63 – SDH/SONET with linear topology 127
Figure 64 – BLSR/BSHR topology in normal conditions (from A to D) 129
Figure 65 – BLSR/BSHR topology in failure conditions 129
Figure 66 – SNCP/UPSR topology in normal conditions 130
Figure 67 – SNCP/UPSR topology in failure conditions 131

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Figure 68 – Example of information flow relationship in OTN 134
Figure 69 – IEEE 802.3 (Ethernet) frame format 135
Figure 70 – IEEE 802.3 (Ethernet) topology with RSTP switches 136
Figure 71 – IEEE 802.1Q-tagged Ethernet frame format 137
Figure 72 – Direct Ethernet with VLAN in substation-to-substation transmission 138
Figure 73 – Substation-to-substation Layer 2 transmission tunnelled over IP 139
Figure 74 – PRP structure (within and outside a substation) 140
Figure 75 – HSR ring connecting substations and control centre 141
Figure 76 – MACsec frame format 142
Figure 77 – IEEE 802.1X principle 143
Figure 78 – Ethernet for substation-to-substation communication 144
Figure 79 – Packets over TDM 145
Figure 80 – IEEE 802.1Q/ad/ah network configuration 148
Figure 81 – Basic MPLS architecture 150
Figure 82 – Example of MPLS frame format with IPv4 payload 150
Figure 83 – MPLS building blocks 151
Figure 84 – MPLS network architecture for utilities 153
Figure 85 – IP/MPLS and MPLS-TP features 154
Figure 86 – MPLS-TP redundant routing 156
Figure 87 – Ethernet frame with IP network header 157
Figure 88 – Mapping of IPv4 to Ethernet frames 158
Figure 89 – Mapping of IPv6 to Ethernet frames 161
Figure 90 – IPv6 unicast address structure 162
Figure 91 – IPv6 ULA address structure 163
Figure 92 – IPv6 link local address structure 163
Figure 93 – Mapping of IPv4 to IPv6 addresses 166
Figure 94 – DiffServ codepoint field 169
Figure 95 – Unidirectional protocol independent multicast 170
Figure 96 – Bidirectional protocol independent multicast 171
Figure 97 – Frame format for IPsec (authenticated) 172
Figure 98 – Frame format for IPsec (encrypted) 172
Figure 99 – Layer 3 direct connection within same address space 173
Figure 100 – Connecting substations to SCADA by a NAT 174
Figure 101 – Substation to SCADA connection over ALG 175
Figure 102 – Ethernet frame with UDP transport layer 176
Figure 103 – UDP header 177
Figure 104 – TCP header 177
Figure 105 – Session and presentation layers for MMS 179
Figure 106 – Session and presentation layers for R-GOOSE 179
Figure 107 – IEEE C37.118 frame over UDP 180
Figure 108 – Redundant network transmission handled by the application layer 180
Figure 109 – Tunnelling in IEC TR 61850-90-1 182
Figure 110 – L2TP transporting Layer 2 frames over IP 183

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Figure 111 – Tunneling SMV over IP in IEC TR 61850-90-5 184
Figure 112 – L2VPNs VPWS and VPLS 185
Figure 113 – L3VPN 186
Figure 114 – Emulation of L3VPN by L2VPN and global router 188
Figure 115 – Tele-protection over VPWS 190
Figure 116 – WAMS over VPLS 190
Figure 117 – VPN for IP-based SCADA/EMS traffic 191
Figure 118 – VPN deployment options 194
Figure 119 – IP network separator 196
Figure 120 – Security architecture (using segmentation and perimeter security) 200
Figure 121 – QoS chain 204
Figure 122 – Timing pulse transmission methods of legacy teleprotection devices 209
Figure 123 – SyncE application 211
Figure 124 – Synchronous Ethernet architecture 211
Figure 125 – SNTP clock synchronization and network delay measurement 213
Figure 126 – Model of GMC, two BCs in series and SC over Layer 3 216
Figure 127 – Timing diagram of PTP (end-to-end, 2-step, TC and BC) 216
Figure 128 – Timing diagram of PTP (peer-to-peer, 2-step TCs) 217
Figure 129 – Substations synchronization over WAN 221
Figure 130 – Example of synchronization network 222
Figure 131 – Distributed loop configuration for HV multi-terminal line protection 223
Figure 132 – Current differential teleprotection for HV multi-terminal transmission line using Layer 2 network 224
Figure 133 – Configuration of wide area current differential primary and backup teleprotection system employing Carrier Ethernet and IEC 61588 time synchronization 225
Figure 134 – Current differential protection communication via MPLS network 226
Figure 135 – System configuration for wide area stabilizing control system 228
Figure 136 – Appearance of typical CCE cubicle 228
Figure 138 – IEEE 802.1Q/ad utility network 232
Figure 139 – Mixed SDH/MPLS network for SCADA and facility maintenance services 233
Figure 140 – Wired technology solutions for distribution automation 234
Figure 141 – Wireless technology solutions for distribution automation (Radio network in feeder automation) 234
Figure 142 – Multi-hop wireless system 235
Figure 143 – NB-PLC system 235
Figure 144 – Cellular services used for a low-density residential area 235
Figure 145 – WAN communication protocols for smart metering 236
Figure 146 – Migration path from TDM to Packet in the Power Utility Operational Network 243
Figure 147 – Ethernet or MPLS beside SDH over separate fibre or wavelength 244
Figure 148 – Ethernet or MPLS-TP and SDH in a Hybrid platform 244
Figure 149 – Pseudo-wire principle 247
Figure 150 – Non-IP voice communication over PSN 248
Figure 151 – Circuit emulation over PSN 249

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Figure 152 – IPv6 evolution 250
Figure 153 – IEC 61850 stack with IPv4 and IPv6 (doubly attached) 251
Figure A.1 – Software network technologies in 5G overall architecture 253
Figure A.2 – 5G Conceptual Diagram – NGMN 254
Figure A.3 – NB-IOT deployment models 255

Table 1 – Latency classes in IEC 61850-5 51
Table 2 – Latency classes in IEC TR 61850-90-1 51
Table 3 – Latency classes for WANs 52
Table 4 – Jitter classes in IEC TR 61850-90-1 53
Table 5 – Jitter classes for WAN 53
Table 6 – Recovery delay classes for WAN 54
Table 7 – IEC TR 61850-90-1 time accuracy classes 55
Table 8 – IEC 61850-5 time accuracy classes for IED synchronization 56
Table 9 – WAN time synchronization classes 56
Table 10 – Latency for line protection 68
Table 11 – Summary of operational requirements of line protection 68
Table 12 – Summary of communication requirements for teleprotection 69
Table 13 – Summary of synchrophasor requirements 73
Table 14 – Summary of communication requirements for wide area monitoring 74
Table 15 – Typical communication requirements for WAMPAC 76
Table 16 – Requirements for fault location 78
Table 17 – Requirements for distribution automation communication 79
Table 18 – Communication requirements for CMD 80
Table 19 – Communication requirements for CC to SS/PS 82
Table 20 – Latency and timing requirements from IEC TR 61850-90-2 82
Table 21 – Communication requirements for inter-control centre communications 83
Table 22 – Requirements for smart metering communication 84
Table 23 – Classification of communication requirements 85
Table 24 – Communication requirements of wide-area applications 86
Table 25 – Communication technologies 88
Table 26 – Physical communication media 89
Table 27 – DSL communication over twisted pairs 90
Table 28 – Trade-offs in copper cable communication 90
Table 29 – Power Line Telecommunication advantages and disadvantages 91
Table 30 – HF spectrum allocated for HV/MV PLC systems 92
Table 31 – HF spectrum used for narrowband LV PLC and associated standards 92
Table 32 – Characteristics of common NB-PLC standards 95
Table 33 – HV/MV APLC/DPLC/BPL technology performance 101
Table 34 – Microwave link performance 103
Table 35 – Terrestrial microwave advantages and disadvantages 104
Table 36 – Terrestrial mobile radio technologies 104
Table 37 – Terrestrial radio advantages and disadvantages 105

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Table 38 – DMR advantages and disadvantages 106
Table 39 – Satellite radio advantages and disadvantages 107
Table 40 – LPWAN technology capabilities 110
Table 41 – Wireless technologies used for customer-side communications in Japan 111
Table 42 – Optical fibres: advantages and disadvantages 118
Table 43 – SONET and SDH hierarchies 126
Table 44 – Summary of SDH/SONET 133
Table 45 – Ethernet physical layers 135
Table 46 – Payload mapping using SDH/SONET and Next Generation SDH/SONET 145
Table 47 – Carrier Ethernet summary 147
Table 48 – IP/MPLS characteristics 154
Table 49 – MPLS-TP characteristics 155
Table 50 – MPLS summary 156
Table 51 – Differences between IPv4 and IPv6 164
Table 52 – IPv6 vs IPv4 addresses (RFC 4291) 165
Table 53 – List of DiffServ codepoint field values 169
Table 54 – IP Summary 175
Table 55 – VPN services 189
Table 56 – IEC 62351 series 201
Table 57 – Example of simple application priority assignment 203
Table 58 – Typical oscillator stability 208
Table 59 – IEC 61588 option comparison 217
Table 60 – Precision time distribution protocols based on IEC 61588 219
Table 61 – Main system specifications for wide area stabilizing control system 229
Table 62 – Main system specifications for PMU-based WAMPAC system 231
Table 63 – Requirements for the YONDEN IP network 233
Table 64 – Technologies for the YONDEN IP network 233
Table 65 – Pseudowire protocols 250
Table A.1 – 3GPP machine type communications 255

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-12: Wide area network engineering guidelines

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 61850-90-12, which is a technical report, has been prepared by IEC technical committee 57: Power systems management and associated information exchange.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) extension of use case with respect to distribution and customer-side applications;
b) extensions of wireless access technologies as well as power line communication ones applicable to the above-mentioned use case;

AVA Documents Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

c) revisions regarding radio communication technology performance;

d) extension of network migration with respect to packet switched network;

e) a new mapping of multiprotocol label switching technology to teleprotection.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
57/2136/DTR	57/2203/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 publication 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 publication will remain unchanged until the stability date indicated on the IEC website under "https://www.webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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.

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

INTRODUCTION

Utilities use data networks to interconnect equipment between their premises, over distances from under a kilometre to thousands of kilometres, called a "Wide Area Network" or WAN.

WANs encompass communication means of different natures (optical, radio, power line carrier, copper, etc.), with a variety of topologies (rings, trees, meshes, etc.), using different protocols (SDH/SONET, Ethernet, IP, MPLS, etc.), medium sharing (packet switching, time division multiplex, etc.) and for different applications (teleprotection, SCADA, voice, video, etc.).

This contrasts with substation automation networks as described in the LAN Engineering Guidelines (IEC TR 61850-90-4), which are based on one technology (switched Ethernet), make extensive use of Layer 2 multicast (GOOSE, SMV, PTP, etc.) and use Layer 3 communication (MMS, FTP, etc.), typically without routers within the substation.

The IEC 61850 series sets up numerous requirements on the network but does not state how to achieve them:

- IEC 61850-5 specifies the basic requirements for data networks used in Power Utility Automation networks;
- IEC 61850-7 focuses on data modelling, leaving out physical interconnection details;
- IEC 61850-8-1 and IEC 61850-9-2 specify interoperable communication within substations;
- IEC TR 61850-90-1 describes substation-to-substation traffic, specifies the requirements for communication, defines object models for substation-to-substation teleprotection, models the gateway and the tunneller, but leaves the WAN undefined;
- IEC TR 61850-90-2[1] provides substation to control centre network configuration for IEDs, proxies and applications;
- IEC TR 61850-90-5 (synchrophasor transmission) addresses the transport of synchrophasor data between PMUs and control centres and defines a tunnelling protocol as well as a data security method;
- IEC TR 61850-90-4 provides guidelines for network engineering focused on Ethernet-based real-time and highly available networks in substations. Some of these guidelines are applicable to networks outside of the substation;
- IEC 61870-6 (TASE2), IEC 61968 and IEC 61970 (CIM) describe the information interchange at the application layer without specifying the network.

Each of these documents deals separately with application, transport, or network layer mechanism. There exist no comprehensive engineering guides for wide-area and real-time networks for control and protection. The growing success of IEC 61850 calls for guidelines for engineering the WANs.

IEC TR 61850-90-4 provides guidelines for engineering of IEC 61850-based, local-area substation networks. In contrast, this Technical Report proposes guidelines for wide-area and real-time networks for various IEC 61850-based applications including teleprotection, wide area measurement, protection, and control (WAMPAC), power system monitoring (WASA, WAMS), operation SCADA, and condition monitoring and diagnosis (CMD) and non-operational traffic.

This document is based on existing standards for semantics, services, protocols, system configuration language and architecture. It is based on work done by various IEC working groups including:

- Power system IED communication and associated data models;

[1] In preparation. Stage at the time of publication: IEC TR/PWI 61850-90-2:2019.

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

- Energy management system application program interface;
- Data and communications security;
- Interoperability within TC 57 in the long term;
- Industrial networks;
- Highly Available Automation Networks.

Contributions were included from:

- IEEE 802.1 WG (Higher layer LAN protocols);
- IEEE 1588 WG (Precise Networked Clock Synchronization);
- IEEE Power System Relaying Committee (PSRC);
- UCA International Users Group;
- The North American Synchrophasor Initiative (NASPI);
- CEN/CENELEC/ETSI Smart Grids Coordination Group;
- CIGRE working groups D2.26, D2.28, D2/B5.30, D2.35; and
- Different utilities, providers and research institutes, in particular the Central Research Institute of Electric Power Industry (Japan), Hydro-Quebec [50][2] (Canada), Swissgrid (Switzerland) and ENEL (Italy).

[2] Numbers in square brackets refer to the bibliography.

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

Part 90-12: Wide area network engineering guidelines

1 Scope

This part of IEC 61850, which is a Technical Report, is intended for an audience familiar with electrical power automation based on IEC 61850 and related power system management, and particularly for data network engineers and system integrators. It is intended to help them to understand the technologies, configure a wide area network, define requirements, write specifications, select components, and conduct tests.

This document provides definitions, guidelines, and recommendations for the engineering of WANs, in particular for protection, control and monitoring based on IEC 61850 and related standards.

This document addresses substation-to-substation communication, substation-to-control centre, and control centre-to-control centre communication. In particular, this document addresses the most critical aspects of IEC 61850 such as protection related data transmission via GOOSE and SMVs, and the multicast transfer of large volumes of synchrophasor data.

The document addresses issues such as topology, redundancy, traffic latency and quality of service, traffic management, clock synchronization, security, and maintenance of the network.

This document contains use cases that show how utilities tackle their WAN engineering.

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, *Teleprotection equipment of power systems – Performance and testing – Part 1: Command systems*

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

IEC 61400-25 (all parts), *Wind energy generation systems – Communications for monitoring and control of wind power plants*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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

IEC 61850-8-1, *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*

AVA Documents Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

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

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 61850-9-3, *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[3], *Communication networks and systems for power utility automation – Part 90-2: Using IEC 61850 for the communication between substations and control centres*

IEC TR 61850-90-4:2013, *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 61850 to transmit synchrophasor information according to IEEE C37.118*

IEC 61869-9, *Instrument transformers – Part 9: Digital interface for instrument transformers*

IEC TS 62351-1:2011, *Power systems management and associated information exchange – Data and communications security – Part 1: Communication network and system security – Introduction to security issues*

IEC TS 62351-2:2008, *Power systems management and associated information exchange – Data and communications security – Part 2: Glossary of terms*

IEC 62351-3:2014, *Power systems management and associated information exchange – Data and communications security – Part 3: Communication network and system security – Profiles including TCP/IP*
IEC62351-3:2014/AMD1:2018

IEC TS 62351-4:2007, *Power systems management and associated information exchange – Data and communications security – Part 4: Profiles including MMS and derivatives*

IEC TS 62351-5:2013, *Power systems management and associated information exchange – Data and communications security – Part 5: Security for IEC 60870-5 and derivatives*

IEC TS 62351-6:2007, *Power systems management and associated information exchange – Data and communications security – Part 6: Security for IEC 61850*

IEC TS 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 TS 62351-8:2011, *Power systems management and associated information exchange – Data and communications security – Part 8: Role-based access control*

---

[3] In preparation. Stage at the time of publication: IEC TR/PWI 61850-90-2:2019.

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

IEC TS 62351-9:2017, *Power systems management and associated information exchange – Data and communications security – Part 9: Cyber security key management for power system equipment*

IEC TR 62351-10:2012, *Power systems management and associated information exchange – Data and communications security – Part 10: Security architecture guidelines*

IEC TR 62351-11:2016, *Power systems management and associated information exchange – Data and communications security – Part 11: Security for XML documents*

IEC TR 62357-200, *Power systems management and associated information exchange – Part 200: Guidelines for migration from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6)*

IEC 62439-1:2010, *Industrial communication networks – High availability automation networks – Part 1: General concepts and calculation methods*

IEC 62439-3:2015, *Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)*

ANSI T1.403-1999, *Network and Customer Installation Interfaces – DS1 Electrical Interface*

IEEE 487.3, *IEEE Standard for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Through the Use of Hybrid Facilities*

IEEE 802.1ag, *IEEE standards for local and metropolitan area network; Virtual Bridged Local Area Networks Amendment 5: Connectivity Fault Management*

IEEE 802.1ah, *IEEE standards for local and metropolitan area network; Provider Backbone Bridges*

IEEE 802.1Qay, *Provider Backbone Bridge Traffic Engineering*

IEEE 802.1X, *Port-based Network Access Control*

IEEE 802.3, *IEEE Standard for 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*

IEEE 487.3, *IEEE Standard for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Through the Use of Hybrid Facilities*

IEEE 802.1Q, *IEEE standards for local and metropolitan area network; Virtual bridged local area networks (VLANs and priorities)*

ITU-T G.703, *Physical/electrical characteristics of hierarchical digital interfaces*

ITU-T G.803, *Architecture of Transport Networks Based on Synchronous Digital Hierarchy (SDH)*

ITU-T G.811, *Timing characteristics of primary reference clocks*

ITU-T G.821, *Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an Integrated Services Digital Network*

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

ITU-T G.8265, *Architecture and requirements for packet-based frequency delivery*

ITU-T G.8265.1, *Precision Time Protocol telecom profile for frequency synchronization*

ITU-T G.8275.1, *Precision Time Protocol telecom profile for phase/time synchronization*

ITU-T G.7041, *Generic Framing Procedure*

ITU-T G.7042, *Link Capacity Adjustment Scheme*

ITU-T G.8032, *Ethernet ring protection switching*

ITU-T G.8261, *Timing and synchronization aspects in packet networks*

ITU-T G.8262, *Timing characteristics of a synchronous Ethernet equipment slave clock*

ITU-T G.8264, *Distribution of timing information through packet networks*

ITU-T Y.1731, *OAM functions and mechanisms for Ethernet based networks*

RFC 0768, *User Datagram Protocol (UDP)*

RFC 0791, *Internet Protocol (IPv4)*

RFC 0792, *Internet Control Message Protocol (ICMPv4)*

RFC 0793, *Transmission Control Protocol (TCP), Protocol Specification*

RFC 0826, *An Ethernet Address Resolution Protocol (ARP)*

RFC 0894, *A Standard for the Transmission of IP Datagrams over Ethernet Networks*

RFC 1240, *OSI Connectionless Transport Services on top of UDP, Version 1*

RFC 1661, *The Point-to-Point Protocol (PPP)*

RFC 1918, *Address Allocation for Private Internet*

RFC 1981, *Path MTU Discovery for IP version 6*

RFC 2104, *HMAC: Keyed-Hashing for Message Authentication*

RFC 2328, *OSPF Version 2*

RFC 2460, *Internet Protocol, Version 6 (IPv6) Specification*

RFC 2464, *Transmission of IPv6 Packets over Ethernet Networks*

RFC 2474, *Definition of Differentiated Services Field (DS Field) in IPv4 and IPv6 Headers*

RFC 2615, *Point-to-Point Protocol over SDH/SONET*

RFC 2663, *IP Network Address Translator (NAT) Terminology and Considerations*

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

RFC 3022, *Traditional IP Network Address Translator (Traditional NAT)*

RFC 3031, *Multiprotocol Label Switching Architecture*

RFC 3168, *The Addition of Explicit Congestion Notification (ECN) to IP*

RFC 3246, *An Expedited Forwarding PHB (Per-Hop Behaviour)*

RFC 3247, *Supplemental Information for the New Definition of the EF PHB (Expedited Forwarding Per-Hop Behaviour*

RFC 3260, *New Terminology and Clarifications for DiffServ*

RFC 3261, *SIP: Session Initiation Protocol*

RFC 3315, *Dynamic Host Configuration Protocol for IPv6 (DHCPv6)*

RFC 3376, *Internet Group Management Protocol, Version 3*

RFC 3410, *Version 2 of the Protocol Operations for the Simple Network Management Protocol (SNMP)*

RFC 3547, *The Group Domain of Interpretation*

RFC 3985, *Pseudo Wire Emulation Edge-to-Edge (PWE3) Architecture*

RFC 4193, *Unique Local IPv6 Unicast Addresses*

RFC 4213, *Basic Transition Mechanisms for IPv6 Hosts and Routers*

RFC 4291, *IP Version 6 Addressing Architecture*

RFC 4301, *Security Architecture for the Internet Protocol (IPsec)*

RFC 4303, *IP Encapsulating Security Payload (ESP)*

RFC 4330, *Simple Network Time Protocol (SNTP) Version 4 for IPv4, IPv6 and OSI*

RFC 4443, *Internet Control Message Protocol (ICMP v6) for the Internet Protocol version 6 (IPv6) specification*

RFC 4459, *MTU and Fragmentation Issues with In-the-Network Tunneling*

RFC 4664, *Framework for* Layer 2 *Virtual Private Networks* (L2VPNs)

RFC 4861, *Neighbor Discovery for IP version 6 (IPv6)*

RFC 4862, *IPv6 Stateless Address Autoconfiguration*

RFC 5246, *The Transport Level Security (TLS) Protocol Version 1.2*

RFC 5424, *The Syslog Protocol*

RFC 5641, Layer *2 Tunneling Protocol Version 3* (L2TPv3) *Extended Circuit Status Values*

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

RFC 5771, *IANA Guidelines for IPv4 Multicast Address Assignments*

RFC 5880, *Bidirectional Forwarding Detection (BFD)*

RFC 5905, *Network Time Protocol version 4*

RFC 6052, *IPv6 Addressing of IPv4/IPv6 Translators*

RFC 6550, *IPv6 Routing Protocol for Low-Power and Lossy Networks*

RFC 6864, *Updated Specification of the IPv4 ID Field*

RFC 7011, *Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information*

3 Terms, definitions, abbreviated terms, acronyms, and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-191 [6] and the following 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
availability

3.1.1.1
availability
<of an item> ability to be in a state to perform as required

Note 1 to entry: Availability depends upon the combined characteristics of the reliability (IEC 60050-192:2015, 192-01-24), recoverability (IEC 60050-192:2015, 192-01-25), and maintainability (IEC 60050-192:2015, 192-01-27) of the item, and the maintenance support performance (192-01-29).

Note 2 to entry: Availability may be quantified using measures defined in Section 192-08 of IEC 60050-192:2015, *Availability related measures*.

[SOURCE: IEC 60050-192:2015 [7], 192-01-23]

3.1.1.2
availability
<of a data security system> subjective quality of a data security system to maintain its service in the face of malicious attacks

3.1.2
access network
network that connects a substation or power plant LAN to a WAN, at a lower hierarchical level (in contrast to core network)

3.1.3
add-drop multiplexer
network node in the SDH/SONET network

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

3.1.4
backbone
core network

3.1.5
backhaul
access network (middle level with three levels of hierarchy)

3.1.6
bridge
network device that connects network segments at the data link layer (Layer 2) of the OSI model

[SOURCE: ANSI/IEEE 802.1D:2004]

3.1.7
Carrier Ethernet
extensions to Ethernet that enable use of Ethernet in a WAN or MAN

3.1.8
core network
top-level network in the utility hierarchy

3.1.9
commercial traffic
data traffic over excess bandwidth that utilities sell to internet service providers or lease to other companies

3.1.10
congruency
property of a network to allocate the same path for backward and forward traffic between end points, ensuring that the delays are approximatively identical

3.1.11
customer edge
IP router located at the edge of the customer network and administrated by the customer, which connects to the next IP router in the provider network

3.1.12
dependability
probability that a system will perform correctly when required to in the presence of faults

Note 1 to entry: This definition is aligned with IEC 60834-1 and is different from IEC 60050-192:2015 [7], 192-01-22.

3.1.13
encapsulation
transport from end to end of protocol data over another protocol

3.1.14
enterprise traffic
data traffic supporting the enterprise, such as email, data servers, accounting, software updates, etc.

3.1.15
fault
abnormal electricity flow requiring reaction of a protection device

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

3.1.16
Frame Relay
1990 telephony technology providing permanent virtual circuits

3.1.17
grid
electrical interconnection

3.1.18
integrity

3.1.18.1
integrity
<of a data stream> probability of undetected errors in a data stream subject to a certain bit error ratio

3.1.18.2
integrity
<of a system> quality of a system not to produce undetected erroneous data

3.1.18.3
integrity
<of a data security system> subjected quality of a data security system to resist malicious forging of information

Note 1 to entry: This document uses the term "authenticity" instead.

3.1.19
jitter
variation of the latency, expressed in relative time (e.g. ±10 ms) or in percentage of the latency (e.g. ±0,1 %)

3.1.20
latency
one-way time delay between two end-to-end network interfaces, excluding the delay that the end devices take to process the signal

Note 1 to entry: In this document, "latency" is synonymous with "communication delay" or "network delay", but not to "transfer delay" (IEC 61850-5), which is the application to application delay.

3.1.21
network
data transmission system

Note 1 to entry: The term "network" is reserved for data networks; for electrical interconnection, "grid" is used instead.

3.1.22
operational traffic
data traffic needed to protect, operate, and supervise the electrical elements of the grid

Note 1 to entry: This includes traffic critical for the maintenance of the grid, e.g. emergency phones, staff organization, messaging, or access to documentation.

3.1.23
persistency
ability of a system to continue producing correct data in the presence of faults

3.1.24
pseudowire
emulation of a direct, not shared wire with constrained latency using a PSN

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

3.1.25
protection

3.1.25.1
protection
<of a power grid> measures to avoid damages by acting on circuit breakers or other power control devices

Note 1 to entry: This document uses "protection" and "teleprotection" exclusively for this meaning.

3.1.25.2
protection
<in relation to a data path> measures taken to ensure availability in the case of failure of the active data path

Note 1 to entry: This document uses the terms "redundancy" and "fault-tolerance" instead. However, "protection" in this sense still appears in abbreviations and referenced documents.

3.1.25.3
protection
<in relation to a cyber-security> measures taken to prevent or fend off cyber-attacks

Note 1 to entry: This document uses the term "defence" instead. However, "protection" still appears in abbreviations and referenced documents.

3.1.26
private address
address belonging to an address range administrated by the network operator, reusable in another network

3.1.27
provider edge
node located at the edge of the provider network and administrated by the provider, which connects to the customer network's customer edge node

3.1.28
public address
address belonging to an address range allocated by IANA or IEEE, which is unique in the context of the network

3.1.29
public internet
worldwide network using public addresses

3.1.30
quality of service
QoS
set of metrics for the performance offered by a communication system, among them: latency (delay), jitter (delay variation), delay asymmetry, throughput (bit rate), packet loss rate, bit error ratio (BER), flow sequence preservation, but excluding security aspects

3.1.31
router
network node able to route traffic, either through dynamic paths (IP) or through pre-established paths (MPLS) at Layer 3

3.1.32
traffic engineering
allocation of network resources (prioritized queues, bandwidth, time slots, etc.) to achieve a certain QoS

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

3.1.33
unavailability
expression of availability as the time during which a system is not available over a time interval (e.g. 2 min/year)

3.1.34
virtual leased line
VLL
point-to-point connection overlaid on top of another network, also called VPC or VPWS

3.1.35
virtual private circuit
VPC
point-to-point connection overlaid on top of another network, also called VLL or VPWS

3.1.36
virtual private LAN service
VPLS
point-to-multipoint connection overlaid on top of another network

3.1.37
virtual private wire service
VPWS
point-to-point connection overlaid on top of another network, which it possibly shares with other VPCs, also called VPC or VLL

3.1.38
virtual private network
VPN
network overlaid on top of another network, which it possibly shares with other VPNs

3.2 Abbreviated terms and acronyms

3GPP	Third Generation Partnership Project (mobile networks standardization body)
5G	Fifth Generation (of mobile networks)
6LoWPAN	IPv6 over Low power Wireless Personal Area Network (RFC 4919, RFC 6775)
AAA	Authentication, Authorization and Accounting (security)
ACL	Access Control Lists(IP)
ADM	Add-Drop Multiplexer (SDH)
ADSL	Asymmetric Digital Subscriber Line
ADSS	All Dielectric Self-Supporting (optical fibre)
AF	Assured Forwarding (RFC 3260)
AH	Authentication Header (RFC 4302)
ALG	Application Layer Gateway
APLC	Analog Power Line Carrier
APS	Automatic Protection Switching
AR	Access Router (node)
A-record	32-bit IPv4 address record from DNS
ARP	Address Resolution Protocol (RFC 0826)
ATM	Asynchronous Transfer Mode (ITU-T)
BC	Boundary Clock (IEC 61588)
BER	Bit Error Ratio

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

BFD	Bidirectional Forwarding Detection (RFC 5880)
BGP	Border Gateway Protocol (successor of EGP in Internet)
BIDIR-PIM	Bi-Directional-Protocol Independent Multicast
BITS	Building Integrated Timing Supply
BLSR	Bidirectional Line Switch Ring
BMCA	Best Master Clock Algorithm (IEC 61588)
BPL	Broadband Power Line carrier
Capex	Capital expenditures
CBS	Committed Burst Size (MEF)
CC	Control Centre
CCTV	Closed Circuit Television
CDM	Code Division Multiplex
CDMA	Code Division Multiple Access
CE	Customer Edge (node)
CEM	Circuit EMulation
CES	Circuit Emulation Services
CESoPSN	Circuit Emulation Services over Packet Switched Network (ITU-T Y.1413, Y.1453)
CFM	Connectivity Fault Management
CIA	Confidentiality, Integrity, Availability (against malicious attacks)
CIDR	Classless InterDomain Routing (RFC 4632)
CIGRE	Conseil International des Grands Réseaux Electriques
CIR	Committed Information Rate
CMD	Condition Monitoring and Diagnosis
CoS	Class of Service (IEEE 802.1Q)
COSEM	Companion Specification for Energy Metering
COTS	Common, off-the-shelf software
CP	Control Plane
CPE	Central Processing Equipment (WAMPAC)
CPE	Customer Premises Equipment
CSMA/CD	Carrier Sense Multiple Access with Collision Detection
CWDM	Coarse Wavelength Division Multiplexing (ITU-T G.671, see WDM, DWDM)
D8PSK	Differential 8-Phase Shift Keying
DA	Distribution Automation
DAC	Doubly Attached Clock
DACS	Digital Access Carrier System (UK)
DACS	Digital Access Cross-connect System (US)
DANH	Doubly Attached Node with HSR (IEC 62439-3)
DCC	Data Communications Channel (SDH/SONET)
DCN	Data Communications Network (SDH/SONET)
DF	Don’t Fragment (IPv4)
DHCP	Dynamic Host Configuration Protocol (RFC 2131))
DiffServ	Differentiated Services (RFC 2474)

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

DLMS	Device Language Message Specification
DMR	Digital Mobile Radio
DLC	Distribution Line Carrie
DMZ	Demilitarized Zone
DNP3	Distributed Network Protocol (IEEE 1815)
DNS	Domain Name Server
DoS	Denial of Service (security)
DPI	Deep Packet Inspection
DPLC	Digital Power Line Carrier
DQPSK	Differential Quadrature Phase Shift Keying
DS	Digital Signal (SDH channel)
DSCP	Differentiated Services CodePoint (RFC 4594)
DSO	Distribution System Operator
DTLS	Datagram Transport Layer Security (RFC 6347)
DWDM	Dense Wavelength Division Multiplexer (ITU-T G.694.1)
DXC	Digital Cross Connect
EAP	Extensible Authentication Protocol (RFC 3748)
EAPoL	Extensible Authentication Protocol over LAN
EBS	Excess Burst Size (MEF)
ECMP	Equal Cost MultiPath Routing
ECN	Explicit Congestion Notification
EEC	Ethernet Equipment Clock (G.8261)
EF	Expedited Forwarding (RFC 3246/RFC 3247)
EGP	Exterior Gateway Protocol (RFC 904)
EHV	Extra High Voltage
EIR	Excess Information rate (MEF)
E-LAN	Ethernet LAN service (MEF)
E-line	Ethernet wire service (MEF)
E-LMI	Ethernet Local Management interface
eMBB	Enhanced Mobile Broadband (5G)
EMEA	Europe Middle East and Africa
EMS	Energy Management System
EoATM	Ethernet over ATM
EoS	Ethernet over SDH/SONET
EoSDH	Ethernet over SDH
EoSONET	Ethernet over SONET
EoTDM	Ethernet over TDM
EPL	Ethernet Private Line (MEF)
ERPS	Ethernet Ring Protection Switching (G.8032)
ESMC	Ethernet Synchronization Messaging Channel (G.8264)
ESP	Electronic Security Perimeter
ESP	Encapsulating Security Payload
E-tree	Routed-Multipoint EVC Ethernet (point-to-multipoint service) (MEF)

AVA Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

EVC	Ethernet Virtual Connection
EVPL	Ethernet Virtual Private Line (MEF)
EVP-LAN	Ethernet Private LAN (MEF)
EVPT	Ethernet Private Tree (MEF)
EXP	EXPerimental (MPLS)
FAN	Field Area Network
FCC	Federal Communications Commission (USA)
FCAPS	Fault Configuration Accounting Performance Security
FCS	Frame Check Sequence
FDB	Filtering DataBase (IEEE 802.3)
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
FDV	Frame Delay Variation (MEF)
FL	Fault Location
FLISR	Fault Location Isolation and Service Restoration
FRR	Fast Re-Route (MPLS)
FTP	File Transfer Protocol (RFC 959)
G-Ach	Generic Associated Channel
GDOI	Group Domain of Interpretation (RFC 6407)
GFP	Generic Framing Procedure (G.7041)
GMC	GrandMaster Clock (IEC 61588)
GMPLS	Generalized MPLS
GNSS	Global Navigation Satellite System
GOOSE	Generic Object-Oriented Substation Event (IEC 61850-7-2, IEC 61850-8-1)
GPRS	General Packet Radio Service (2nd generation mobile network)
GPS	Global Positioning System
GSM	Global System for Mobile communications (2nd generation mobile network)
HAN	Home Area Network
HC	Hybrid Clock
HDSL	High-bit-rate Digital Subscriber Line
HES	Head End System
HES	Home Electronic Systems
HMAC	Hash-based Message Authentication Code (RFC 2104)
HMI	Human-Machine Interface
HSPA	High-Speed Packet Access (3rd generation mobile network)
HSR	High-availability Seamless Redundancy (IEC 62439-3)
HTTP	Hypertext Transfer Protocol (RFC 7230-7237)
HV	High Voltage
IAM	Identity and Access Management
IANA	Internet Assigned Numbers Authority
ICCP	Inter-Control Centre Protocol (IEC 61870-6)
ICMP	Internet Control Message Protocol (RFC 792)
ID	IDentity

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

IDS	Intrusion Detection System
IED	Intelligent Electronic Device (IEC 61850)
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol (RFC 3376)
IGP	Internal Gateway Protocol
IntServ	Integrated Services (RFC 2210)
IOT	Internet Of Things
IP	Internet Protocol (RFC 791)
IPFIX	IP Flow Information Export (RFC 7011)
IPLS	IP-only LAN-like Service
IP/MPLS	MPLS with IP routing
IPS	Intrusion Protection System
IRIG	Inter-Range Instrumentation Group
ISDN	Integrated Services Digital Network (ITU-T)
IS-IS	Intermediate System to Intermediate System (ISO/IEC 10589)
ISM	Industrial Scientific and Medical radio bands
KDC	Key Distribution Centre
L2TP	Layer 2 Tunneling Protocol (RFC 5641)
L2VPN	Layer 2 VPN (RFC 7152)
L3VPN	Layer 3 VPN
LAN	Local Area Network
LCAS	Line Capacity Adjustment Scheme (SDH/SONET NG) (G.7042)
LDAP	Lightweight Directory Access Protocol
LDP	Label Distribution Protocol (RFC 5036)
LER	Label Edge Router (MPLS)
LLC	Logical Link Control
LLDP	Link Layer Discovery Protocol (IEEE 802.1AB)
LMU	Line Matching Unit
LOADng	Lightweight On-demand Ad-hoc Distance-vector routing – next generation
LoRaWAN	LoRa (Alliance) Wide Area Network
LPWAN	Low Power Wide Area Network
LQI	Link Quality Indicator
LSP	Label Switching Path (MPLS)
LSR	Label Switching Router (MPLS)
LTE	Long-Term Evolution (4^{th} generation mobile network)
LV	Low Voltage
MAC	Medium Access Control (IEEE 802.1)
MAC	Message Authentication Code (security)
MACsec	MAC security (IEEE 802.1AE)
MAN	Metropolitan Area Network
MC	Master Clock (IEC 61588)
MEC	Mobile Edge Computing (5G)
MEF	Metro Ethernet Forum

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

MEMS	Micro-Electro-Mechanical Systems
MF	More Fragment (IPv4)
MFA	MPLS Forum Association (now IPMPLS)
MIB	Management Information Base (SNMP)
MMS	Manufacturing Messaging Specification (IEC /ISO 9506)
mMTC	Massive Machine Type Communications (5G)
MP2MP	Multipeers-to-multipeers
MPLS	Multi-Protocol Label Switching (RFC 3031)
MPLS-TE	MPLS Traffic Engineering
MPLS-TP	MPLS Transport Profile
MSDP	Multicast Source Discovery Protocol
MSP	Multiplex Section Protection
MS-SPRing	Multiplex Section Shared Protection Ring
MSTP	Multiple Spanning Tree Protocol
MTBR	Mean Time Between Repairs
MTC	Machine Type Communications (5G)
MTTF	Mean Time To Failure
MTU	Maximum Transmission Unit
MV	Medium Voltage
NAC	Network Access Control
NASPI	North American Synchrophasor Initiative
NAT	Network Address Translation (RFC 2663/RFC 3022)
NB-IOT	Narrow Band IOT
NB-PLC	Narrow Band Power Line Carrier
NCD	Network Configuration Description (IEC 61850-6)
NDP	Neighbor Discovery Protocol (RFC 4861)
NERC	North-American Electricity Reliability Corporation
NFV	Network Function Virtualization (5G)
NG	Next Generation
NGMN	Next Generation Mobile Networks (5G Alliance)
NIC	Network Interface Controller
NIST	National Institute of Standards and Technology (USA)
NMS	Network Management Services
NPCC	Northeast Power Coordinating Council
NPDU	Network Protocol Data Unit (ISO/IEC 7498)
NSM	Network and System Management
NTP	Network Time Protocol (RFC 5905)
OAM	Operation, Administration and Maintenance
OC	Optical Carrier (SONET channel)
OC	Ordinary Clock
OFDM	Orthogonal Frequency Division Multiplexing
Opex	Operation expenditures
OPGW	OPtical Ground Wire (high voltage transmission cable)

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

OS	Operating System
OSI	Open System Interconnection (ISO/IEC 7498)
OSPF	Open Shortest Path First (RFC 5340)
OSSP	Organization Specific Slow Protocol (IEEEE 802.3)
OTN	Optical Transport Network (ITU-T G.709)
P2MP	Point To Multipoint (Peer to Multipeers)
P2P	Point-to-Point (Peer-to-Peer)
PABX	Private Automatic Branch eXchange (telephony)
PAN	Personal Area Network
PANA	Protocol for carrying Authentication for Network Access (IETF)
PBB	Provider Backbone Bridging ("Mac-in-Mac", IEEE 802.1ah-2008)
PBB-TE	Provider Backbone Bridge Traffic Engineering (IEEE 802.1Qay-2009)
PCM	Pulse Code Modulation
PDC	Phasor Data Concentrator (IEC TR 61850-90-5)
PDH	Plesiochronous Digital Hierarchy (ITU-T)
PDU	Protocol Data Unit (ISO/IEC 7498)
PDV	Packet Delay Variation (RFC 3393, ITU-T Y.1541 (IP), ITU-T Y.1563 (Ethernet))
PE	Provider Edge (node)
PFD	Probability to Fail (dangerously) on Demand (IEC 61508)
PHB	Per Hop Behaviour (MPLS)
PHY	Physical layer
PIM-SM	Protocol Independent Multicast – Sparse Mode (RFC 4601)
PM	Performance Monitoring
PMU	Phasor Measurement Unit (IEC TR 61850-90-5)
PON	Passive Optical Network
POS	Packet over SDH/SONET
POTS	Plain Old Telephone System
ppm	part per million (replaced by μHz/Hz or μs/s)
PPP	Point-to-Point Protocol (RFC 1661)
PPS	Pulse Per Second
PRC	Primary Reference Clock
PRP	Parallel Redundancy Protocol (IEC 62439-3)
PRTC	Primary Reference Time Clock
PS	Power Station
PSK	Phase Shift Keying
PSN	Packet Switched Network
PTP	Precision Time Protocol (IEC 61588)
PW	Pseudo-Wire (pseudo wire)
PWI	Proposed Work Item (IEC)
PWE3	Pseudo-Wire Edge-to-Edge (RFC 3985)
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

RADIUS	Remote Authentication Dial In User Service
RAN	Regional Area Network (see page 102)
RAN	Radio Access Network
RAS	Remedial Action Schemes (referred to as WAMPAC in this document)
RAT	Radio Access Technology
RBAC	Role Based Access Control
RF	Radio Frequency
RIR	Regional Internet Registry
ROBO	Robust Operation (NB-PLC)
RP	Rendezvous Point
RPL	Routing Protocol for Low power and lossy networks (RFC 6550)
RSPEC	Reservation Characteristics in IntServ (RFC 2210)
RSSI	Received Signal Strength Indication
RSTP	Rapid Spanning Tree Protocol (IEEE 802.1D)
RSVP	Resource ReSerVation Protocol (RFC 2205)
RSVP-TE	RSVP-Traffic Engineering
RTU	Remote Terminal Unit (decentralized measurement and control device)
SAToP	Structure-Agnostic TDM over Packet (RFC 4553), (ITU-T Y.1413), (Y.1453)
SCADA	Supervisory Control And Data Acquisition (control centre)
SCD	System Configuration Description
SCL	System Configuration Language (IEC 61850-6)
SCP	Secure Copy (UNIX service)
SDH	Synchronous Digital Hierarchy (ITU-T)
SDN	Software Defined Networks
SDSL	Symmetric Digital Subscriber Line
SEM	Security Event Management
SEN	Substation Edge Node
SFP	Small Form-factor Pluggable (Ethernet)
SGAM	Smart Grid Architecture Model (CEN-CENELEC-ETSI Smart Grid Coordination Group)
SHDSL	Single-pair High-speed Digital Subscriber Line
SIM	Security Information Management
SIP	Session Initiation Protocol (RFC 3261)
SIPS	System Integrity Protection Schemes (referred to as WAMPAC in this document)
SLA	Service Level Agreement
SLAAC	StateLess Address Auto Configuration (RFC 4862)
SMV	Sampled Measurement Values (IEC 61850-7-2, IEC 61850-9-2)
SNCP	SubNetwork Connection Protection
SNMP	Simple Network Management Protocol (RFC 3410)
SNTP	Simple Network Time Protocol (RFC 4330)
SONET	Synchronous Optical NETwork
SPDU	Session Protocol Data Unit
SPE	SONET Payload Envelope

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

SPS	Special Protection System (WAMPAC, called SIPS in this document)
SS	SubStation
SSH	Secure Shell (UNIX service)
SSL	Secure Socket Layer
ssPDC	substation Phasor Data Concentrator
SSU	Synchronisation Supply Unit (SyncE)
STM	Synchronous Transport Module (SDH/SONET)
STS	Synchronous Transport Signal (SDH/SONET)
SV	Sampled Values (of current and voltage) (IEC 61850-9-2)
SyncE	Synchronous Ethernet (ITU-T G.8010)
TAI	Temps Atomique International
TC	Transparent Clock (IEC 61588)
TCP	Transmission Control Protocol (RFC 0793)
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TDMoIP	Time Division Multiplexing over Internet Protocol (ITU-T Y.1413, Y.1453)
TE	Traffic Engineering
TLS	Transport Layer Security
TLV	Time-Length-Value (ISO/IEC 8825 and IEC 61588)
TM	Terminal Multiplexer (SDH/SONET)
ToS	Type of Service
TPDU	Transport Protocol Data Unit (ISO/IEC 7498)
TSPEC	Traffic description in IntServ
TSN	Time Sensitive Network (IEEE 802.1, 802.3)
TTL	Time To Live (IP, MPLS)
UDP	User Datagram Protocol (RFC 0768)
ULA	Unique Local unicast Address (RFC 4193)
UMTS	Universal Mobile Telecommunications System (3rd generation cell phone)
UNI	User Network Interface (MEF)
UP	User Plane
UPSR	Unidirectional Path Switch Ring
URL	Unique Resource Locator
uRLLC	Ultra-reliable and Low-latency Communications (5G)
UTC	Universal Time Coordinated
VC	Virtual Circuit
VCAT	Virtual Concatenation (SDH/SONET NG) (G.7043)
VCCV	Virtual Circuit Connectivity Verification (RFC 5085)
VDSL	Very high speed Digital Subscriber Line (ITU-T last mile)
VID	VLAN identifier (IEEE 802.1Q)
VLAN	Virtual Local Area Network (IEEE 802.1Q)
VLL	Virtual Leased Line (also called VPWS)
VoIP	Voice over IP
VPLS	Virtual Private LAN Service (RFC 4761 and RFC 4762)

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

VPMS	Virtual Private Multicast Services (IETF work in progress)
VPN	Virtual Private Network
VPRN	Virtual Private Routed Network (L3VPN for MPLS)
VPWS	Virtual Private Wire Service (pseudo-wire)
VRF	Virtual Routing and Forwarding
VRRP	Virtual Router Redundancy Protocol (RFC 5798)
VT	Virtual Tributary (SDH/SONET)
WAMPAC	Wide Area Monitoring, Protection and Control
WAMS	Wide Area Monitoring System
WAN	Wide Area Network
WASA	Wide Area Situational Awareness
WDM	Wavelength Division Multiplexing
XML	Extended Markup Language
ZBFW	Zone-Based FireWall

3.3 Network diagram symbols

This document uses the symbols shown in Figure 1.

Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

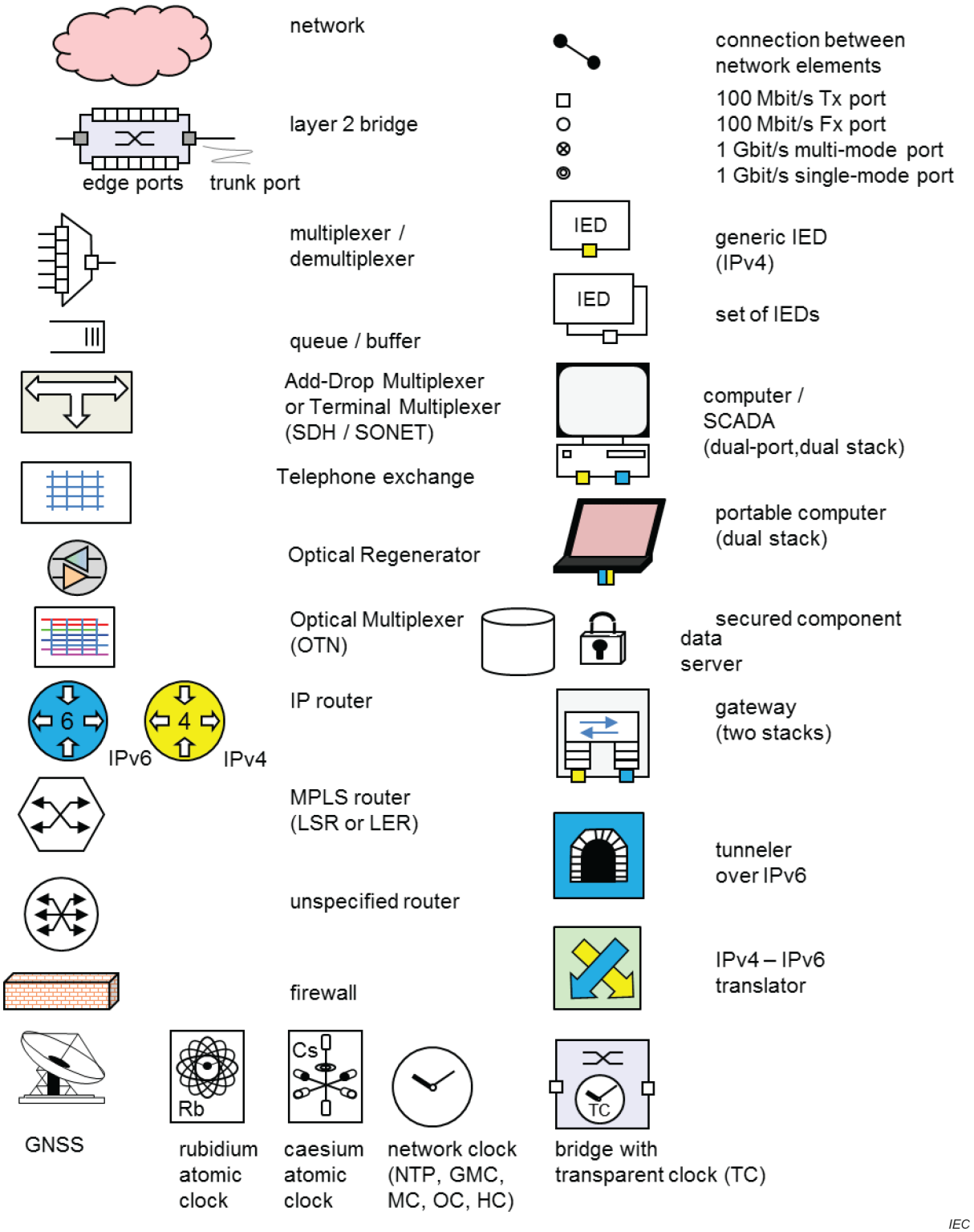


Figure 1 – Symbols

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

4 Wide area communication in electrical utilities

4.1 Executive summary

The electrical grid is part of the critical infrastructure of a country. The communication network on which the grid relies must have an even higher availability than the grid itself, and has to survive contingencies and blackouts in order to keep the grid stable and restore the grid as quickly as possible, even from a complete black start.

In the past, operational communication (teleprotection, telecontrol, operational voice, etc.) was separate from enterprise communication (energy management, mail, internet, company telephone, etc.). In particular, telephones in substations and control centres were independent from the public telephone system and used dedicated powerline, microwave, or radio links. The public telephone system was untrusted since it would break down in case of wide area emergency, due to the number of simultaneous calls; it would run on batteries for only a few hours after losing the grid, which is insufficient to recover from a land-wide blackout.

The operational network used robust technologies from the established telephony technology (e.g. ATM, SDH/SONET) that guaranteed bandwidth, deterministic latency, predictable jitter, and high reliability through redundant paths. The operational network changes little over the years, configuration changes are seldom. The personnel in charge of the legacy network are proficient in this technology, which is however becoming obsolete.

With the deployment of protocols using packet switching such as IEC 61850, the operational telephony network had to transport variable size, sporadic packet traffic in addition to its fixed-size cyclic traffic, a task that it was not designed for and that it did not perform efficiently.

New generation SDH/SONET NG allows more efficient packet transport. Deployment of this technology will continue for some years, especially to support operational traffic, but its further development (e.g. OTN) is uncertain.

New actors appeared as Smart Grids developed (e.g. distributed generation, demand side management, etc.), letting the operational packet-switched traffic grow.

On the other hand, the enterprise network based on internet technologies (email, business servers, internet access, etc.) grew exponentially, requiring bandwidth well in excess of what the operational network needs.

The personnel in charge of the enterprise network have a background oriented towards informatics. They are more experienced in managing large amounts of users and data but less acquainted with the requirements – especially temporal and dependability aspects – of operational networks.

Therefore, a divergence can exist between the philosophy of the department managing traditional operational networks and the department managing the enterprise network. Merging the departments could be as difficult as merging the infrastructures.

Technology advances and technical necessity are not the only motors for change. The lifespan of office equipment (5 to 10 years) is significantly shorter than the lifespan of teleprotection equipment (10 to 25 years). Early obsolescence will cause additional costs during the life cycle, with little benefit for the basic teleprotection function. Total cost of ownership is what counts.

The continuous technological evolution leads to heterogeneous networks, even in the rare cases that started on green field sites. Networks consist of clusters of hardware from the same manufacturer, interfacing over a reduced number of specially engineered devices with other clusters from other manufacturers, technologies, and vintage. While in networks within substations interoperability of equipment is a major incentive, interoperability within WAN clusters is not a primary goal, and interchangeability of equipment between manufacturers is not a requirement – as long as spares are available.

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

Utilities see savings and earnings by merging the operational network with the enterprise network. With the installation of optical fibres with excess bandwidth, they can also offer commercial services to Telecom companies and Internet Service Providers (ISPs).

Merging the networks makes sense as long as the non-operational services do not compromise operation. Indeed, enterprise and commercial communications should not be able to influence the operational communication, either through incorrect messages or through exhaustion of shared resources. In particular, the dynamic services of enterprise networks require frequent human intervention for fixes and updates. This presents a major risk for the grid when sharing the network, a risk the utilities must weigh against the economics of using public networks.

The traditional physical separation between operational, enterprise and commercial data can partially be enforced by virtual private networks (VPNs) and by priority management. However, since the same physical medium carries all traffic, the operational network will dictate the dependability requirements of the enterprise and commercial networks, possibly affecting their economics.

This not only applies to bandwidth and processing power allocation, but also to all resources such as battery backup, maintenance team deployment and spares disposition.

Therefore, a utility has to balance the benefits of merging the infrastructures against the disadvantages of imposing the strict requirements of operational networks onto the whole infrastructure, and may choose to keep the networks separated.

Cost savings also lead utility companies, especially small ones, to outsource communication entirely to a Telecom company or Internet Service Provider under a Service Level Agreement (SLA). Even if the service provider is a trusted entity, its business goals are different from that of the utilities and its operation is not transparent to the electrical utility. Since its teams are not familiar with grid contingencies, they are less aware of the importance of operational data, which they often do not identify as such.

Here again, a utility has to choose between keeping the infrastructure in the ownership of the utility and outsourcing the network.

The network becomes vulnerable to cyber-attacks when it spans over public ground, belongs to third-party providers, and connects in some places directly or indirectly to the public internet. The protection of the infrastructure goes beyond what traditional communication needs. A virtual separation may be insufficient, so cyber-security protocols become important, possibly at several levels, depending on the trusted entities. In both owned and outsourced networks, utilities must ensure cybersecurity policies and architectures sometimes exceeding the regulatory requirements (NERC for example).

Only continuous monitoring and sporadic exercising of contingencies with the network team can guarantee grid availability. Cost pressure cannot be an excuse for fair-weather solutions, which later on need costly extensions. Therefore, the evaluation of network solutions must consider comprehensive Operation And Maintenance (OAM) and simulation tools.

These guidelines intend to give advice on the potential conflict points:

- Traditional telephony vs. packet switching networks
- Operation vs. enterprise and commercial network
- Utility-owned vs. outsourced network
- Defence-in-depth security vs. simple application data authentication

Clause 5 deals with network metrics such as latency, jitter, time accuracy and availability in order to describe communication requirements for use cases, network technologies and technology mappings in the following clauses.

AVA Documents
Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Clause 6 consists of use case descriptions and WAN communication requirements derived from each of these use cases.

Clause 7 describes the communication technologies from the restricted viewpoint of electrical utilities. It mostly lists what is important to know for procurement and gives appreciation of their usefulness.

Clause 8 contains the mapping of appropriate communication technologies to the use cases described in Clause 6.

Clause 9 describes aspects of migration from legacy to modern communication network technologies and protocols.

The informative Annex A contains the description of some future promising or upcoming technologies.

4.2 Network and application example: ENDESA, Andalusia (Spain)

A typical Distribution System Operator (DSO) grid, the Andalusia (southern Spain) grid spans about a 100 km diameter and some 30 substations (Figure 2).



Figure 2 – Substation locations in Andalusia

The network topology is that of a partially meshed ring with spokes and subrings (Figure 3).

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

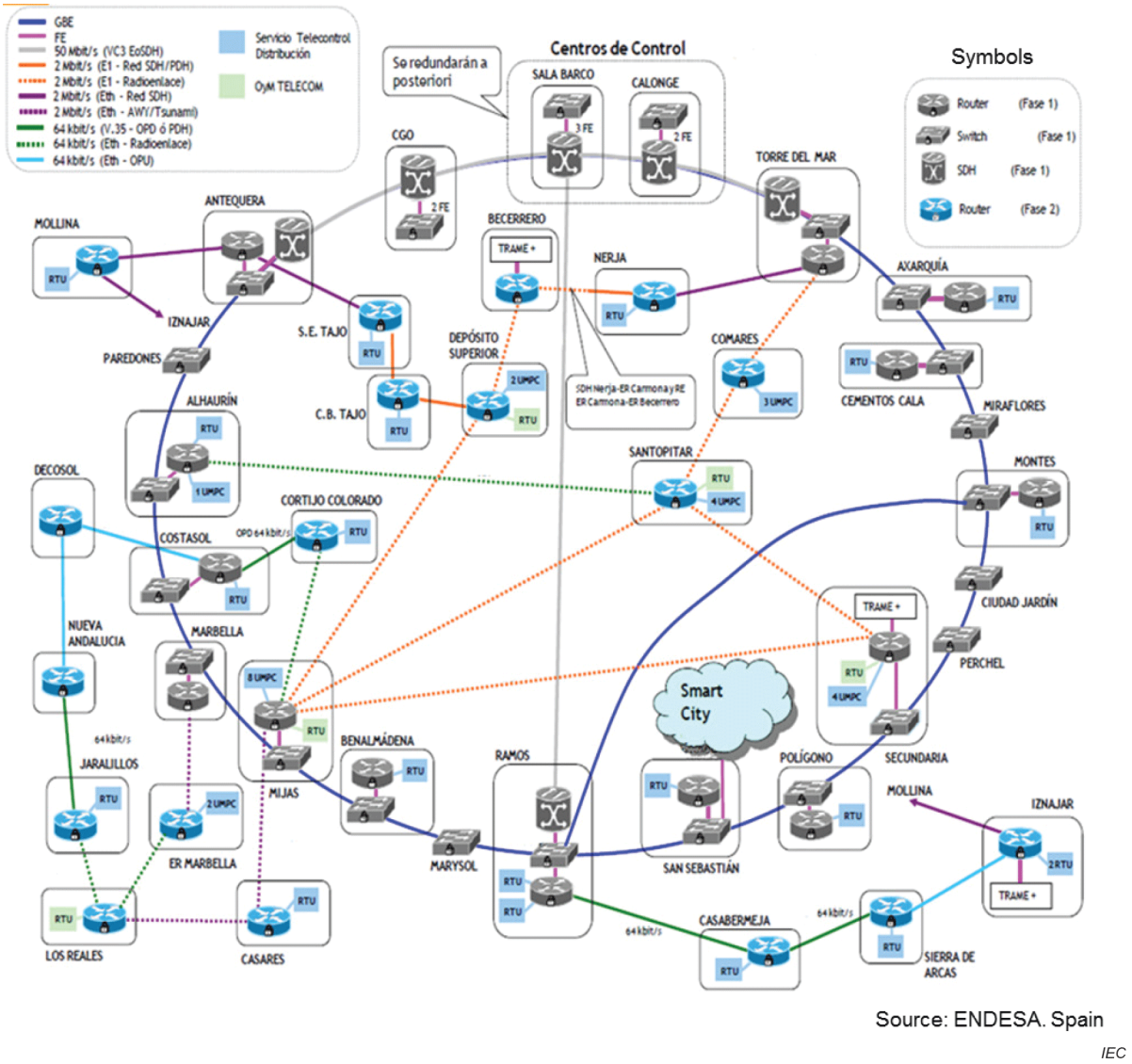


Figure 3 – Topology of the Andalusia network

The northern half of the main ring is a traditional SDH network over VC3; the southern part of the ring uses Gbit/s Metro Ethernet with bridges. Spokes and subrings interconnection use a variety of media: radio links, E1, 100 Mbit/s Ethernet, etc. Routers ensure IP connectivity. The diversity of media, protocols and manufacturers characterizes networks that evolved over time. A special case is the city of San Sebastian with its Smart Grid infrastructure.

The basic services that the Andalusia network provides are:

- teleprotection;
- telecontrol: generation, substations, regulation, measurements, batteries;
- voice;
- video surveillance;
- SCADA;
- OAM;
- metering;
- distribution automation;
- synchronization.

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

The guidelines for development were:

- keep a very high availability;
- reduce costs by sharing links and minimizing their number without losing redundancy;
- allow future evolution and scalability;
- allow integration of public operator and private network where convenient;
- define the SLAs.

Evaluation of the technologies considered:

- investments plan for the next 5 years;
- life cycle for investments (around 10 years);
- priority to choices with minor operational costs;
- quality of the recommended solutions is similar in terms of the provided service.

4.3 Typical interface between a substation and the WAN

Substations connect to a WAN through a Substation Edge Node (SEN), which aggregates a number of different traffic streams between the substation and the WAN. It can serve as a protocol converter, multiplexer and as a network element, switch, or router. The SEN is however not application-aware.

Figure 4 shows a typical SEN in the equipment cabinet of a substation.



Figure 4 – Cabinet of a substation edge node

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

Figure 5 shows the typical interfaces of a full-fledged SEN: the lower part goes to the substation equipment and the upper part to the transmission equipment. The actual interfaces installed depend on each substation. Redundancy is an option, depending on the importance; the communication equipment can be duplicated or only parts thereof. IEC 61850 is only a fraction of all communications.

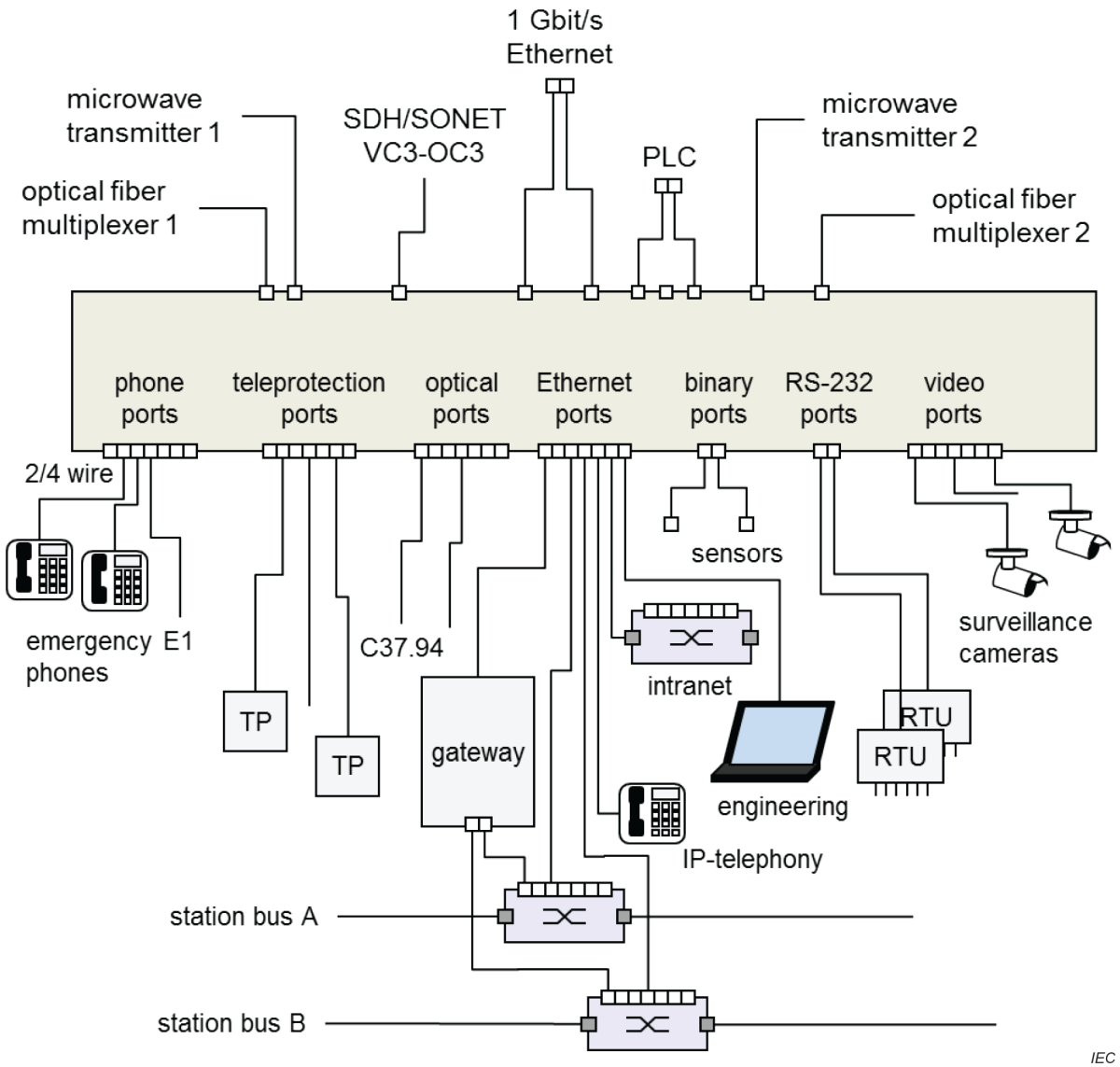


Figure 5 – Communication interfaces in a SEN

4.4 WAN characteristics and actors

WANs are categorized by:

- Ownership:
  - private network of a utility,
  - shared network operated by independent utilities or by a national grid, or
  - public network of telecom service providers;

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

- Hierarchy
  - core (backbone),
  - access (backhaul), or
  - local area (regional);
- Networks
  - physical communication media equipment, or
  - logical networks providing connectivity over unspecified physical networks.

Figure 6 shows the actors and the WANs.

- On top are the applications using communication, detailed with their requirements in Clause 6.
- The level below shows the processing entities.
- The next level WAN connects the processing entities among themselves and with the remote devices, considering two owners of WANs: utility and telecom provider (leased).
- The bottom level includes the remote devices, representing producers, consumers, and substations. The remote devices can also communicate directly over WANs.

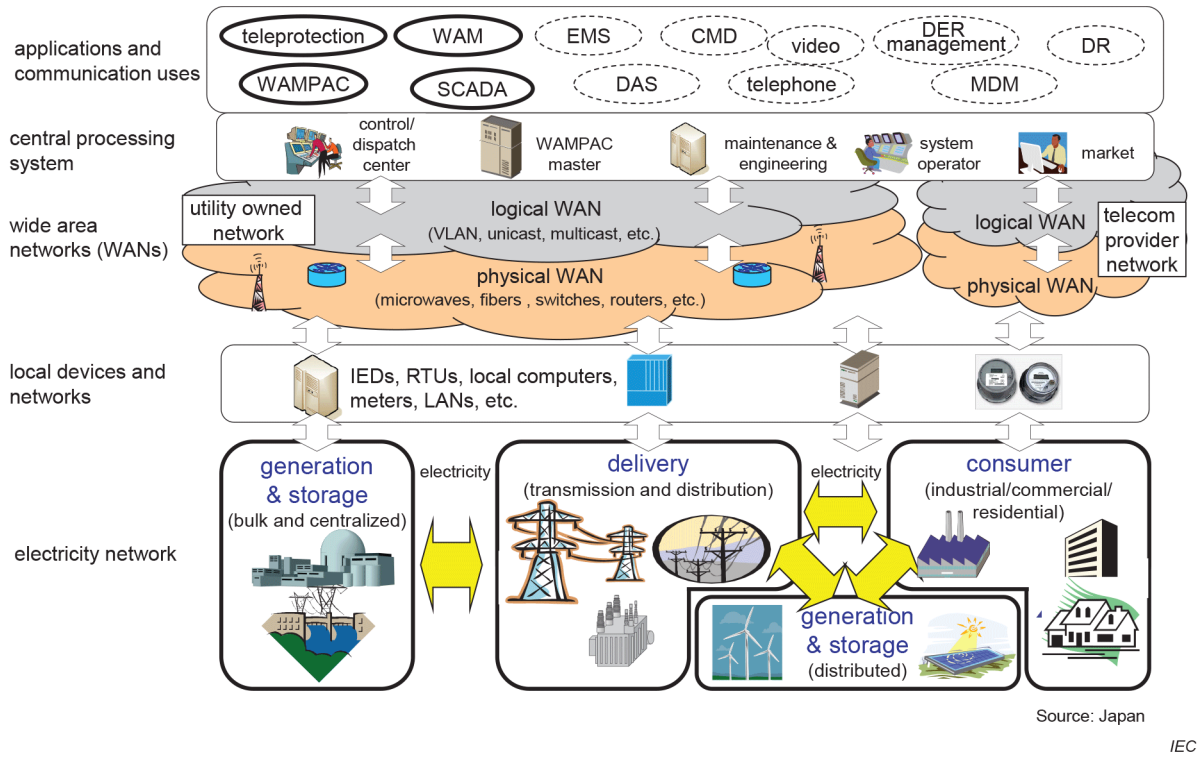


Figure 6 – Communicating entities

4.5 Smart Grid Architecture Model (SGAM) Mapping

The SGAM Communication Model [1] details the view of the networks (Figure 7).

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

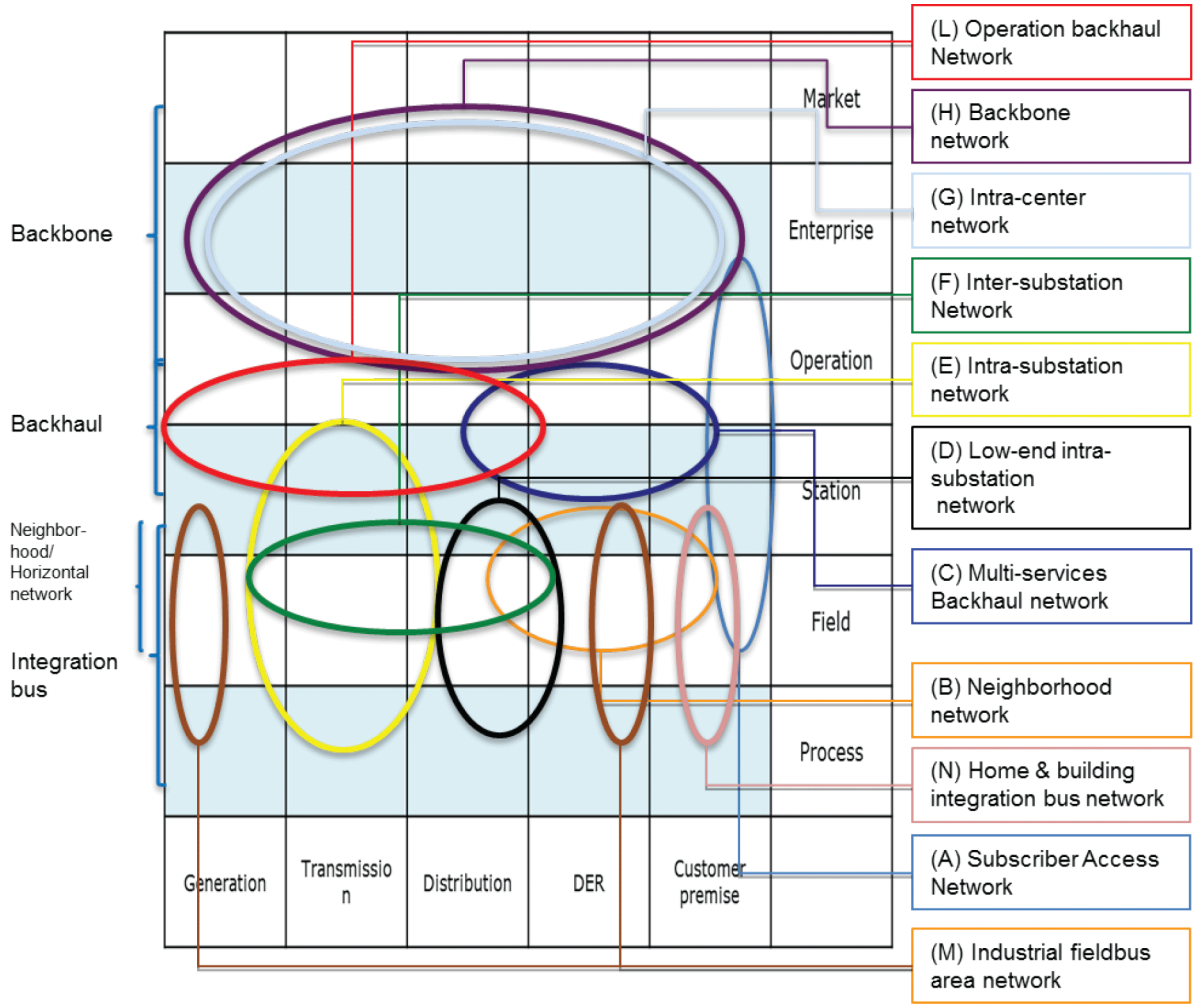


Figure 7 – SGAM communication model

SGAM defines a number of network types, in particular:

- subscriber access network;
- neighbourhood network;
- multi-services backhaul network;
- low-end intra-substation network;
- intra-substation network;
- inter-substation network;
- intra control centre network;
- backbone network;
- operation backhaul network;
- home and building integration network;
- industrial fieldbus area network.

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

This document only assumes two levels of hierarchy in the wide area network:

- core network, which roughly corresponds to the SGAM backbone network
- access or backhaul network, which roughly corresponds to the SGAM inter-substation network and operation backhaul network.

This does not preclude networks with more than two levels of hierarchy.

These concepts are shared with the National Institute of Standards and Technology (NIST), USA [36].

4.6 Network elements and voltage level

The relationship between voltage levels and network elements appears in Figure 8.

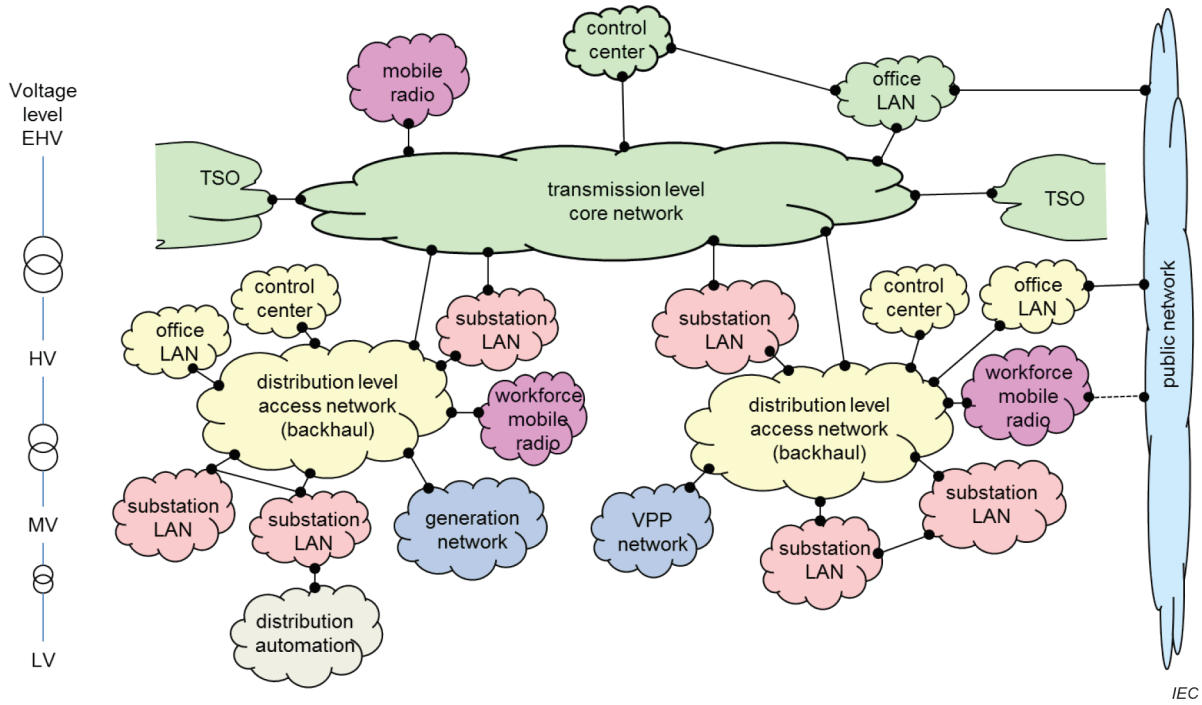


Figure 8 – Principle of grid voltage level and network technology

The communication architecture mirrors the grid voltage hierarchy:

- The core network ensures the operation of the extra-high-voltage transmission grid, under responsibility of the TSO. It interfaces to other TSOs and to the DSOs;
- The access networks ensure the operation of the high-voltage and medium-voltage distribution grid for a reduced number of substations, under the responsibility of the DSOs. They interface to the core network and to the substations;
- The substation LAN ensures the operation of the substation. Substations are normally identical with the connection points between the networks, except at the office and workforce buildings;
- The generation has its own network, e.g. for a wind farm;
- The distribution automation network extends down to the households;
- The networks have interfaces to the public internet (e.g. to access meteorological data and trading information) and to mobile radio networks, either public or operating over disaster-proof radio links.

AVA Documents Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

The networks are not homogeneous in technology, vintage and protocols, and require routers or gateways at the network connection points, symbolized by the connected circles in Figure 8.

The communication equipment is located in the substations, with some exceptions such as SCADA, dispatching centres, or trading offices.

4.7 WAN interfaces in substation automation (IEC 61850-5)

The model follows the interfaces as defined in IEC 61850-5, extended by WAN elements, as Figure 9 shows.

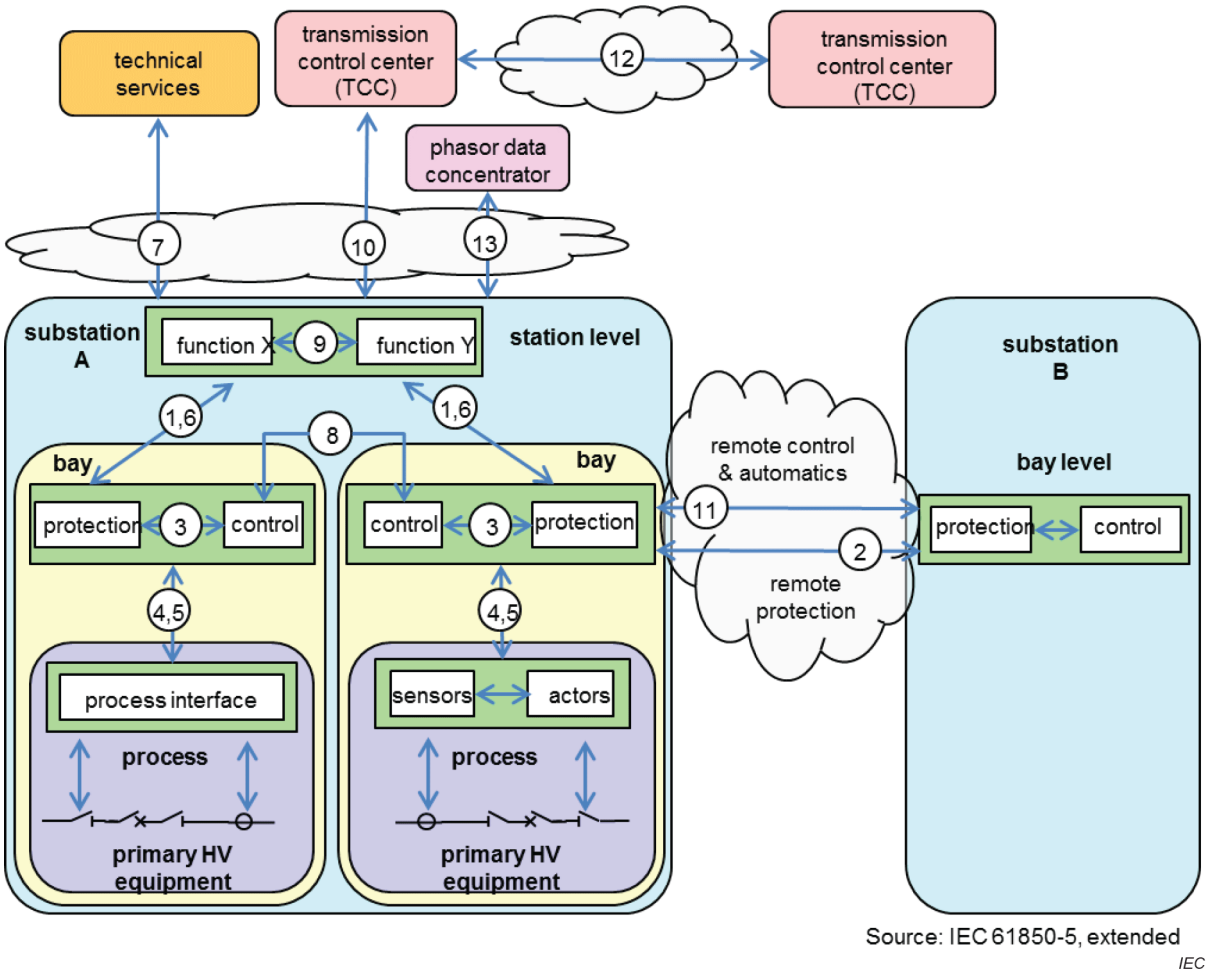


Figure 9 – Communication paths and interfaces

Meaning of the interfaces in Figure 9:

- IF1: protection-data exchange between bay and station level
- IF2: protection-data exchange between bay level and remote protection
  horizontal time-constrained exchange involving high traffic analogue data (e.g. line differential protection) and low traffic binary data (e.g. protection blocking), see IF 11.
- IF3: data exchange within bay level
- IF4: analogue data exchange between process and bay level (samples from current transformer and voltage transformer)
- IF5: control data exchange between process and bay level
- IF6: control data exchange between bay and station level
- IF7: data exchange between substation (level) and a remote engineer's workplace

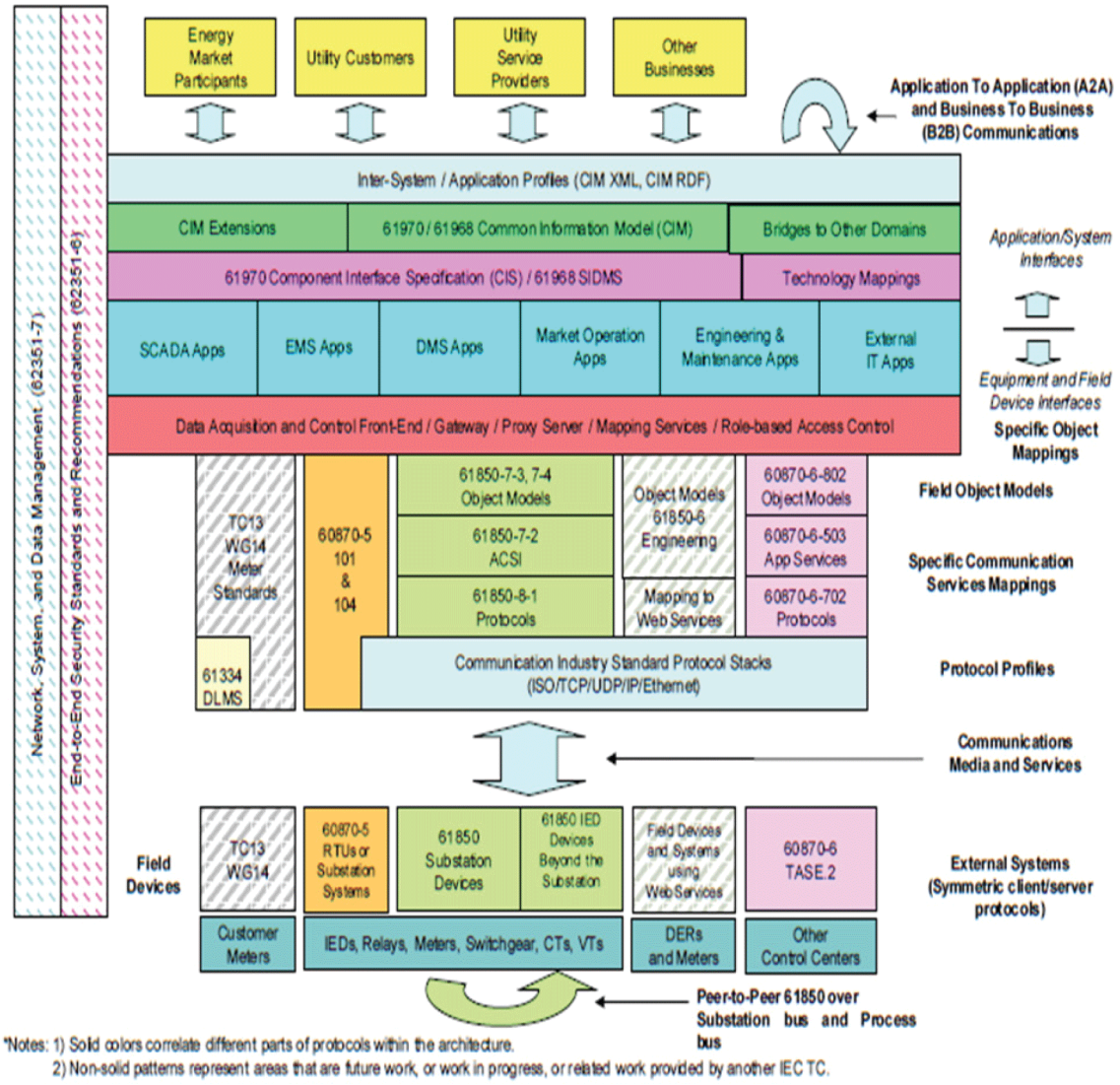
AVA Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

- IF8: direct data exchange between the bays especially for fast functions like interlocking
- IF9: data exchange within station level
- IF10: vertical data exchange between the substation and remote control centre(s) includes remote monitoring and telecontrol
- IF11: control data exchange between substations
  horizontal exchange involving mainly low-traffic binary data (e.g. for interlocking functions or other inter-substation automatics), see IF2.
- IF12: transmission control centre to transmission control centre (added here)
- IF13: synchrophasors to PDC and control centre (added here)

Figure 9 symbolizes the WAN by the clouds with interfaces IF2, IF7, IF10, IF11, IF12 and IF13. The WAN connects primary substations and Transmission Control Centres.

4.8 Logical interfaces and protocols in the architecture in IEC TR 62357-200

IEC TR 62357-200 describes the logical interfaces for standardized applications (Figure 10). The boundary between what is in the substation and what is outside can vary.



Source: IEC TR 62357

IEC

Figure 10 – IEC TR 62357 Interfaces, protocols, and applications

AVA Documents Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020

Applications use utility protocols to exchange data, especially considering the protocols defined in IEC 61850-8-1 and IEC 61850-9-2, IEC TR 61850-90-1, IEC TR 61850-90-2 and IEC TR 61850-90-5.

Several application-layer protocols coexist with IEC 61850, with similar technologies, such as:

- IEC 60870-5-104 (telecontrol);
- IEC 60870-6 (ICCP, TASE-2);
- IEEE 1815 (formerly DNP-3);
- IEC 61400-25 (wind turbines);
- IEEE C37.118 (formerly IEEE 1344) (synchrophasors).

While in substation automation the utility protocols represent the bulk of traffic, outside of the substation, WANs carry a number of other protocols related to operation, such as voice and video surveillance (CCTV).

The actual protocols used are not important for network engineering, only their addressing capability and their timely behaviour matter.

In all cases, engineering the different substations or terminals requires tools that generate the System Configuration Description (SCD) files of all participants and in addition the network information. These tools need to be able to import the SCD files of each substation and modify them to generate a NCD (network configuration description).

4.9 Network traffic and ownership

A utility company will strive to reduce the network Capex and Opex by using the same infrastructure for all three major functions:

1) operational services;
2) enterprise services;
3) commercial services.

There are strong reasons to keep the operational network separated from the other traffic:

- Company philosophy of keeping the infrastructure for disaster recovery completely independent of other entities. This especially includes black start ability after a long blackout;
- Easier migration from the traditional telephony services, risk mitigation;
- QoS requirements for the critical operational service that burden the enterprise and commercial services too much.

Utility Companies answer this issue differently. The commercial traffic increases drastically since the operational traffic requires only a low bandwidth and the utilities draw a large number of fibres that they themselves do not need.

Owing to the nature of the applications (discussed in Clause 6) and their requirements, utilities use dedicated private communication network, and more seldom service provider networks.

Documents
Document Sharing Hub
Full document details: PD IEC TR 61850-90-12:2020

5 WAN metrics

5.1 Traffic types

Independently from the application, two major traffic kinds are distinguished:

1) periodical or sporadic traffic with strict time constraints, requiring an upper bound to the latency, and consisting of small data items (100 to 200 octets); for instance, process data exchange for protection and commands (GOOSE and SMV), but also voice messages of high quality;

   Networks optimized for that traffic are characterized as time division multiplexing networks (TDM):

2) sporadic traffic of messages with relaxed time constraints, satisfied with an average latency, and consisting of large pieces of data, often distributed into separate packets; for instance: MMS data object exchange, events, file transfer, condition monitoring, but also video, management, mail, and document transfer;

   Networks optimized for that traffic are characterized as packet switching networks (PSN).

5.2 Quality of Service (QoS) of TDM and PSN

QoS expresses how well a network complies with the time and dependability constraints for a given traffic, e.g. throughput, packet losses, errors, latency, jitter, out-of-order, etc. The network provider guarantees a certain QoS in a service level agreement (SLA).

A basic difference exists between TDM and PSN:

- TDM networks such as SDH/SONET transmit data periodically in fixed time slots. Once a circuit is established, the latency from end to end is constant and depends only on the propagation delay of the signal over the medium and on the residence time in the multiplexers, which is nearly constant. When TDM networks are cascaded, depending on the coincidence of the cycles, the latency varies, but will never exceed the sum of the latencies in the individual subnets. This ensures a deterministic latency and jitter (see 5.3.6).

  In TDM, QoS consists only in allocating sufficient bandwidth to time-critical data, since in contrast to industrial networks; the period is fixed (64 kbit/s).

- PSNs such as Ethernet use statistical multiplexing and cannot offer the deterministic latency of a TDM network. While the propagation delay remains constant, the residence delay in the nodes depends on the traffic. Indeed, PSN nodes buffer the traffic in queues and delay incoming messages until their turn in the queue comes. Therefore, PSNs have a variable average latency depending on the traffic load. In the worst case, the queue overflows and incoming messages are dropped because of overbooking or traffic bursts.

  To ensure that time-critical data are forwarded, PSN use priorities to give the highest priority packets the minimum latency. Even the highest priority class packets may have to wait in output queues behind other packets of the same class or because transmission of lower priority packets already started.

QoS is a fundamental difference to consider in the migration from TDM to PSN.

QoS for WANs depends on the underlying network architecture and technology. QoS requires managing traffic based on pre-defined traffic classes, especially to achieve low-latency for critical applications. Typical traffic classes are derived from applications: teleprotection, SCADA, WAMPAC and network management, time synchronization/distribution, video surveillance, etc.

5.3 Latency calculation

5.3.1 Latency components

The (one-way, end-to-end transfer delay) latency may be broken down into propagation delay (5.3.2) and residence delay (5.3.3), while the recovery delay (5.7) is a particular case.

AVA Documents Document Sharing Hub

Full document details: PD IEC TR 61850-90-12:2020