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Fifth Generation Fixed Network (F5G); Specification for PON based Industrial Network

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Foreword

This Group Specification (GS) has been produced by ETSI Industry Specification Group (ISG) Fifth Generation Fixed Network (F5G).

Modal verbs terminology

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1 Scope

The present document specifies the network architecture, functional requirements, performance requirements, management and provisioning specifications for PON based industrial networks deployed in typical industrial application scenarios, and satisfies the requirements from industrial services.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found in the ETSI docbox.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI GS F5G 013: "Fifth Generation Fixed Network (F5G); F5G Technology Landscape Release 2".

[2] ETSI GS F5G 024: "Fifth Generation Fixed Network (F5G); F5G Advanced Network Architecture Release 3".

[3] IEC 61158: "Industrial communication networks - Fieldbus specifications".

[4] IEEE 802.3as™-2006: "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".

[5] IEEE 802.1Q™-2018: "IEEE Standard for Local and Metropolitan Area Networks -- Bridges and Bridged Networks".

[6] IEEE 802.1ad™-2005: "IEEE Standard for Local and Metropolitan Area Networks -- Virtual Bridged Local Area Networks -- Amendment 4: Provider Bridges".

[7] Recommendation ITU-T Y.1291 (2004): "An architectural framework for support of Quality of Service in packet networks".

[8] IEEE 802.1D™-2004: "IEEE Standard for Local and metropolitan area networks: Media Access Control (MAC) Bridges".

[9] IETF RFC 7348: "Virtual eXtensible Local Area Network (VXLAN): A Framework for Overlaying Virtualized Layer 2 Networks over Layer 3 Networks".

[10] IEEE 802.3ad™-2000: "IEEE Standard for Information Technology -- Local and Metropolitan Area Networks -- Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications-Aggregation of Multiple Link Segments".

[11] Recommendation ITU-T G.9807.1 Amendment 2 (2020): "10-Gigabit-capable symmetric passive optical network (XGS-PON)".

[12] Recommendation ITU-T G.987.1 (2016): "10-Gigabit-capable passive optical networks (XG-PON): General requirements".

[13] IEEE 802.1Qci™-2017: "IEEE Standard for Local and metropolitan area networks -- Bridges and Bridged Networks -- Amendment 28: Per-Stream Filtering and Policing".

[14] Recommendation ITU-T G.983.5: "A broadband optical access system with enhanced survivability".

[15] IEEE 802.3af™-2003: "IEEE Standard for Information Technology -- Local and Metropolitan Area Networks -- Specific Requirements -- Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications -- Data Terminal Equipment (DTE) Power Via Media Dependent Interface (MDI)".

[16] IEEE 802.3at™-2009: "IEEE Standard for Information technology -- Local and metropolitan area networks -- Specific requirements -- Part 3: CSMA/CD Access Method and Physical Layer Specifications Amendment 3: Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements".

[17] IEEE 802.3bt™-2018 IEEE: "Standard for Ethernet Amendment 2: Physical Layer and Management Parameters for Power over Ethernet over 4 pairs".

[18] IEC 60529: "Degrees of protection provided by enclosures (IP Code)".

[19] IEC 61000-4-2:2008: "Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test".

[20] Recommendation ITU-T G.988: "ONU management and control interface (OMCI) specification".

[21] IETF RFC 6241: "Network Configuration Protocol (NETCONF)".

[22] ISO/IEC 20922:2016: "Information technology — Message Queuing Telemetry Transport (MQTT) v3.1.1".

[23] IEEE 802.3™-2018: "IEEE Standard for Ethernet".

[24] IETF RFC 4789 (2006): "Simple network management protocol (SNMP) over IEEE 802 networks".

[25] IEEE 802.1X™-2020: "IEEE Standard for Local and Metropolitan Area Networks -- Port-Based Network Access Control".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI GR F5G 001: "Fifth Generation Fixed Network (F5G); F5G Generation Definition Release #1".

[i.2] ETSI GR F5G 007 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Industrial PON".

[i.3] ETSI GR F5G 008 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Use Cases Release #2".

[i.4] IETF RFC 8040: "RESTCONF Protocol".

[i.5] Recommendation ITU-T G.Sup51 (06/17): "Passive optical network protection considerations".

[i.6] ETSI GR F5G 021: "Fifth Generation Fixed Network (F5G); F5G Advanced Generation Definition".

[i.7] IETF RFC 4241: "A Model of IPv6/IPv4 Dual Stack Internet Access Service".

[i.8] IETF RFC 4213: "Basic Transition Mechanisms for IPv6 Hosts and Routers".

[i.9] IETF RFC 8305: "Happy Eyeballs Version 2: Better Connectivity Using Concurrency".

[i.10] IETF RFC 8200: "Internet Protocol, Version 6 (IPv6) Specification".

[i.11] IETF RFC 2474: "Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers".

[i.12] IETF RFC 9099: "Operational Security Considerations for IPv6 Networks".

[i.13] Recommendation ITU-T G.987.3 (2020): "10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification".

[i.14] Recommendation ITU-T G.9804.2 (2021): "Higher speed passive optical networks - Common transmission convergence layer specification".

[i.15] Recommendation ITU-T G.Sup71: "Optical line termination capabilities for supporting cooperative dynamic bandwidth assignment".

[i.16] Recommendation ITU-T G.984.3 (2014): "Gigabit-capable passive optical networks (G-PON): Transmission convergence layer specification".

[i.17] Recommendation ITU-T G.984.1 (2008): "Gigabit-capable passive optical networks (GPON): General characteristics".

[i.18] Recommendation ITU-T G.9804.1 (2019): "Higher speed passive optical networks – Requirements".

[i.19] IEEE 802.1Qbv™-2015: "IEEE Standard for Local and metropolitan area networks -- Bridges and Bridged Networks -- Amendment 25: Enhancements for Scheduled Traffic".

[i.20] IEEE 802.1Qbu™-2016: "IEEE Standard for Local and metropolitan area networks -- Bridges and Bridged Networks -- Amendment 26: Frame Preemption".

[i.21] Recommendation ITU-T E.419 (2006): "Business oriented Key Performance Indicators for management of networks and services".

[i.22] ETSI EN 300 019-1-4: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-4: Classification of environmental conditions; Stationary use at non-weather protected locations".

[i.23] ETSI EN 300 019-2-4: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 2-4: Specification of environmental tests; Stationary use at non-weather protected locations".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

deterministic networking: network feature primarily in a best-effort packet network, in which the deterministic quality of service is applied to flows designated as being critical to a real-time application

field data network: network transporting factory intra-plant industrial data

NOTE: The industrial PON-based network serves as a connection and convergence network for the machines within the factory because the product line data is carried over the industrial PON-based network.

industrial environment adaptation: capability of a device to adapt to the industrial environments while maintaining an acceptable level of service

industrial protocol adaptation: capability of a device to adapt to the industrial scenarios to interpreting and/or converting a range of industrial communication protocols

network resilience: capability of a network to protect against and maintain an acceptable level of service in the presence of network failure(s)

PON slice: resource allocation and isolation mechanism in Passive Optical Networks (PON), which divides the physical PON network into multiple logically independent networks

NOTE: Each slice is configured to support the specific Service Level Agreements (SLAs), ensuring that various types of traffic are appropriately handled and isolated on a shared physical infrastructure, guaranteeing that the quality of critical applications and services is not affected.

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

10GE	10 Gbit/s Ethernet
10G-EPON	10 Gbit/s Ethernet Passive Optical Network
40GE	40 Gbit/s Ethernet
50G-PON	50 Gbit/s Passive Optical Network
100GE	100 Gbit/s Ethernet
ACL	Access Control List
AI	Artificial Intelligence
AN	Access Network
ARP	Address Resolution Protocol
BNG	Broadband Network Gateway
CAN	Controller Area Network
CLI	Command-Line Interface
CO DBA	Cooperative Dynamic Bandwidth Allocation
CPU	Central Processing Unit
CPN	Customer Premises Network
CVBS	Composite Video Baseband Signal
DA	Destination Address
DBA	Dynamic Bandwidth Allocation
DHCP	Dynamic Host Configuration Protocol
DHCPv6	Dynamic Host Configuration Protocol for IPv6
DoS	Denial of Service
DSCP	Differentiated Services Code Point
EMC	Electromagnetic Compatibility
ERP	Enterprise Resource Planning
EMS	Element Management System
EPON	Ethernet Passive Optical Network
FE	Fast Ethernet
FEC	Forward Error Correction
FP16	16-bit Floating Point
FP32	32-bit Floating Point
GE	Gigabit Ethernet
GEM	GPON Encapsulation Method
GFLOPS	Giga Floating Point Operations Per Second
GPON	Gigabit Passive Optical Network
GPU	Graphics Processing Unit
GTC	GPON Transmission Convergence
HART	Highway Addressable Remote Transducer Protocol

ID	Identifier
IGMP	Internet Group Management Protocol
IPv6	Internet Protocol version 6
IP	Internet Protocol
IPG	Inter-Packet Gap
ITU-T	International Telecommunication Union - Telecommunication Standardization Sector
LAND	Local Area Network Denial Attack
MAC	Media Access Control
MB	Megabyte
MES	Manufacturing Execution System
MLQ	Multicast Listener Query
MQTT	Message Queuing Telemetry Transport
NPU	Neural Processing Unit
NETCONF	Network Configuration Protocol
NNI	Network-to-Network Interface
OLT	Optical Line Terminal
OMCI	Optical Network Terminal Management and Control Interface
ME	Managed Entity
ONU	Optical Network Unit
ONU-ID	Optical Network Unit Identifier
OSI	Open Systems Interconnection
PLOAM	Physical Layer Operations, Administration, and Maintenance
PLC	Programmable Logic Controller
PoE	Power over Ethernet
PPPoE	Point-to-Point Protocol over Ethernet
PRI	Primary Rate Interface
QoS	Quality of Service
RA	Router Advertisement
RESTCONF	RESTful Configuration Protocol
SA	Source Address
SAP	Service Access Point
SLA	Service-Level Agreement
SDN	Software-Defined Networking
SNI	Server Name Indication
SNMP	Simple Network Management Protocol
SPP	Service Processing Point
SSD	Solid State Drive
SYN	Synchronization
TCP	Transmission Control Protocol
T-CONT	Transmission Container
TFLOPS	Tera Floating Point Operations Per Second
TOS	Type of Service
TSN	Time-Sensitive Networking
UDP	User Datagram Protocol
UCL	User Control List
UNI	User-Network Interface
VLAN	Virtual Local Area Network
VNI	VxLAN Network Identifier
VTEP	VxLAN Tunnel End Point
VxLAN	Virtual eXtensible LAN
Wi-Fi™	Wireless Fidelity
XGEM	10 Gigabit GPON Encapsulation Method
XG-PON	10-Gigabit-capable Passive Optical Network
XGS-PON	10-Gigabit-capable Symmetric Passive Optical Network
XGTC	10 Gigabit GPON Transmission Convergence

4 Overview

Industrial networks are designed to connect and control devices, systems, machines, and other assets within the industrial environment. With digital transformation, remote control machinery and sensors are deployed to automate production, monitoring, and management. Industrial networks are incorporate facilities related to the Industrial business including R&D centres, warehouses, administrative offices and customer service branches.

Industrial PON, is inheriting a mature PON technology from the residential access network, and enhancing it to include functions required by the industrial customers. Industrial PON shall support high quality connectivity for communication between sensors, devices, machines, and people within the industrial parks.

NOTE: For more detailed description of PON based industrial network see ETSI GR F5G 001 [i.1], ETSI GS F5G 013 [1], ETSI GR F5G 007 [i.2] and ETSI GR F5G 021 [i.6].

The present document describes the typical industrial PON deployment scenarios, encompassing the architecture, the key industrial functions and the interfaces of the industrial PON system. The PON based industrial network architecture includes the management system, the OLTs, and ONUs used in industrial scenarios. PON based industrial network shall comply with the industrial environmental recommendations.

In the present document, the network architecture, the functional requirements, the performance requirements, the management and provisioning specifications for PON based industrial networks are specified.

5 Industrial scenarios and requirements

5.1 Overview

There are three deployment scenarios for PON based industrial networks, as described in ETSI GR F5G 007 [i.2] (Industrial PON) and in ETSI GR F5G 008 [i.3] (Use Cases Release #2), namely:

1) The field data network which is primarily in the industrial environment.

2) The office network including sales, marketing, finance and managerial staff areas.

3) The surveillance network including internal and external video surveillance and sensors.

PON based industrial networks shall support the above three sub-networks within a single network infrastructure. Network slicing is essential for the isolation of these sub-networks.

Smart network monitoring and management functions based on NETCONF/YANG and telemetry technology are needed for smart operation and rapid service configuration in the PON based industrial networks.

5.2 Field Data Network

The primary application in PON based industrial networks is transport factory intra-plant industrial services. PON serves as a connection and convergence network for the machines within the factory.

There are several industrial field level interfaces and protocols defined in the IEC 61158 series [3]. Therefore, the ONUs in the industrial network need to be equipped with the corresponding physical interfaces and the built-in protocol-related functions, or provide connectivity to existing industrial gateways, to support the communications between the Programmable Logic Controller (PLC), other industrial gateways, and production management systems. Deterministic network transmission and high service availability are required for these field data network scenarios. The PON based industrial network integrated with deterministic networking functions, shall support the configuration of bounded transmission times, and various network protection schemes for the differential network resilience scenarios.