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Fifth Generation Fixed Network (F5G); F5G Advanced Network Architecture Release 3

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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 end to end F5G Advanced network architecture, features and related network elements' requirements including On-premise, Access, Aggregation, and Core Networks. The present document defines new features and enhances features from previous releases.

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 at https://docbox.etsi.org/Reference.

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 necessary for the application of the present document.

[1] ETSI GS F5G 014 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Network Architecture Release 2".

[2] IETF RFC 4760: "Multiprotocol Extensions for BGP-4".

[3] ETSI GS F5G 023 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Advanced Technology Requirements and Gap Analyses; Release 3".

[4] Recommendation ITU-T G.9940 (2023): "High speed fibre-based in-premises transceivers - system architecture".

[5] Recommendation ITU-T G.9941 (2024): "High speed fibre-based in-premises transceivers - physical layer specification".

[6] Recommendation ITU-T G.9942 (2024): "High speed fibre-based in-premises transceivers - data link layer".

[7] Recommendation ITU-T G.988 (2022): "ONU management and control interface (OMCI) specification".

[8] Recommendation ITU-T G.709: "Interfaces for the optical transport network".

[9] Recommendation ITU-T G.709.20: "Overview of fine grain OTN".

[10] Recommendation ITU-T G.9804.2:"Higher speed passive optical networks - Common transmission convergence layer specification".

[11] Recommendation ITU-T G.9804.3: "50-Gigabit-capable passive optical networks (50G-PON): Physical media dependent (PMD) layer specification".

[12] IETF RFC 8402: "Segment Routing Architecture".

[13] IETF RFC 8986: "Segment Routing over IPv6 (SRv6) Network Programming".

[14] IETF RFC 7209: "Requirements for Ethernet VPN (EVPN)".

[15] ETSI GS F5G 018 (V1.1.1): "Fifth Generation Fixed Network (F5G); Architecture of Optical Cloud Networks".

[16] Recommendation ITU-T G.959.1 (01/2024): "Optical transport network physical layer interfaces".

[17] IEEE 802.3:2022™: "IEEE standards for Ethernet".

[18] IEEE 802.11-2020™: "IEEE Standard for Information Technology -- Telecommunications and Information Exchange between Systems -- Local and Metropolitan Area Networks -- Specific Requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

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 021 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Advanced Generation Definition".

[i.2] ETSI GR F5G 020 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Advanced Use Cases; Release 3".

[i.3] ITU-T SG15/Q3 Work Item G.wmci: 'WLAN management control interface (WMCI) for in-premises network'.

[i.4] Recommendation ITU-T Y.110 (1998): "Global Information Infrastructure principles and framework architecture".

[i.5] Recommendation ITU-T G.9943: "High speed fibre-based in-premises transceivers - management".

[i.6] Recommendation ITU-T G.709.1: "Flexible OTN common elements".

[i.7] Recommendation ITU-T G.709.3: "Flexible OTN B100G long-reach interfaces".

[i.8] Recommendation ITU-T G.709.5: "Flexible OTN short-reach interfaces".

[i.9] Recommendation ITU-T G.709.6: "Flexible OTN B400G long-reach interfaces".

[i.10] Recommendation ITU-T G.872: "Fine grain flexible ODU (fgODUflex) path layer network".

[i.11] Recommendation ITU-T G.672: "Characteristics of multi-degree reconfigurable optical add/drop multiplexers".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

compute functionality: generic term for the basic computing functions, which include input, processing, storage, and output. Usually, processing is flexibly programmable

NOTE: The compute functionality needs compute resources for the computational success of a program.

compute resource: compute resources are measurable quantities of compute power that might be requested, allocated, and consumed for computing activities

EXAMPLE: Possible compute resources include Central Processing Units (CPU) and Memory among others.

control process: control process is a sub-class of a compute process, which is a generic compute functionality (see above)

NOTE: The control process is the way compute might be used for controlling components, devices, systems, or equipment. The compute function is scoped to the input from, and output to the controlled components, devices, systems, or equipment. A control process might control other control processes building overall hierarchy of control processes.

customer: depending on the market segment, the customer is either a subscriber, a user, or both

equipment: implementation of one or more functions in a single physical container

NOTE: The term is derived and adapted from Recommendation ITU-T Y.110 [i.4]. The equipment will have at least one function implemented in hardware and will have interfaces through which it might be connected to other equipment. It may be designed in a modular way in that the equipment might be made up from a number of smaller pieces of equipment. In addition, some functions may be implemented in software, which might be changed during the lifetime of the equipment.

fgOTN: stands for fine grain Optical Transport Network (OTN) that supports from 10 Mbit/s up to 1 Gbit/s

NOTE: See [8] for the specification of OTN including fgOTN in Annexes M and N of Recommendation ITU-T G.709 [8] and see Recommendation ITU-T G.709.20 [9] for an overview of fgOTN.

(fg)OTN: is defined as an OTN network supporting both standards OTN and fgOTN with service rates from 10 Mbit/s up to 800 Gbit/s and beyond

NOTE 1: See the following for more detailed information and the specification of (fg)OTN for a variety of deployment options and situations [8], [i.6], [i.7], [i.8], [i.9], [9] and [i.10]

NOTE 2: (fg)OTN network elements supports OTN with or without support for fgOTN.

(fg)O-CPE: Customer Premises Equipment (CPE) supporting OTN with or without support for fgOTN

fibre sensing network element: network element that has fibre sensing capabilities

interface: point where independent and distinct systems or equipment interact and communicate with each other

NOTE 1: In the industry there are various definitions and more specialized terms for the term interface, such as a Reference Point, logical or physical interface. Depending on the interface described in the present document, any of those terms apply.

NOTE 2: ITU (see Recommendation ITU-T Y.110 [i.4]) has defined the terms "implementational interface" and "physical interface", which has a similar meaning to interfaces used in the present document.

Lambda (λ) fabric: network consisting of optical connections only with different wavelength being switched

NOTE: In the context of the present document, the λ fabric is used for the Aggregation Network, other applications for the λ fabric are for further study.

non-real-time control: non-real-time control process, is a compute process, where the time from receiving the input data to the output action is non-urgent and might take some time for the process to finish

NOTE 1: Due to that characteristic the control process might be located remote from the component being controlled and the component and the control process need to be connected with a communication channel with more relaxed requirements than in the real-time control case. The bandwidth and latency of the communication channel depends on the control process and the amount of data being transmitted between the component and the control process.

NOTE 2: The present document describes concepts that are predominantly classed as real-time control of the F5G-A network. Non-real-time control features are for further study and are usually part of a network management related work items.

real-time control: real-time control process, is a compute process, where the time from receiving the input data to the output action is very short

NOTE: Due to that characteristic the control process needs to be located close to the component being controlled and the component and the control process need to be connected with a high-speed, low latency communication channel.

subscriber: legal entity who pays regularly to receive or access a service

user: somebody using a service

3.2 Symbols

Void.

3.3 Abbreviations

For the present document, the following abbreviations apply:

(fg)O-CPE	(fg)OTN Customer Premises Equipment
AEL	Aggregation Edge Leaf
AgF	Aggregation Fabric
AggN	Aggregation Network
AI	Artificial Intelligence
AL	Access Leaf
AN	Access Network
AP	Access Point
API	Application Programming Interface
BGP	Border Gateway Protocol
BNG	Broadband Network Gateway
BSS	Business Support System
CDC	Central Data Centre
CE	Customer Equipment
CO	Central Office
CPE	Customer Premises Equipment
CPN	Customer Premises Network
DC	Data Centre
DC-GW	Data Center Gateway
DCI	Data Centre Interconnect
DDS	Data Distribution Service
DECT™	Digital Enhanced Cordless Telecommunications
E2E	End-to-End
EC	Edge Compute
E-LAN	Ethernet virtual private LAN
E-Line	Ethernet virtual private Line
E-ONU	Edge Optical Network Unit
EoS	Ethernet over Synchronous
E-Tree	Ethernet virtual private Tree
EVPN	Ethernet VPN
F4G	4th Generation Fixed Network

NOTE: See the F5G Advanced generation definition in ETSI GR F5G 021 [i.1].

F5G-A	F5G Advanced
FAN	Fibre Access Node
FDM	Frequency Division Multiplexing
fgOTN	fine-grain Optical Transport Network
FIE	FAN Intelligent Engine
FlexO	Flexible Optical transport network
FMCI	Fibre Management and Control Interface
FTTM	Fibre to the Machine

FTTO	Fibre to the Office
FTTR	Fibre-To-The-Room
GMPLS	Generalized Multi-Protocol Label Switching
GUI	Graphical User Interface
GW	Gateway
HGW	Home Gateway
HS-PON	High-Speed PON
ICT	Information and Communication Technology
IE	Industrial Equipment
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol Television
KPI	Key Performance Indicators
KQI	Key Quality Indicator
L2VPN	Layer 2 VPN
L3VPN	Layer 3 VPN
LAN	Local Area Network
LCAS	Link Capacity Adjustment Scheme
LDC	Local Data Centre
MAC	Media Access Control
MCA	Management, Control and Analytics
MD-ROADM	Multi-Dimensional ROADM
MP-BGP	Multiprotocol extensions for BGP
MPLS	Multiprotocol Label Switching
NaaS	Network as a Service
NAS	Network Attached Storage
NE	Network Element
O&M	Operation and Maintenance
OAM	Operation, Administration and Maintenance
OCh	Optical Channel
OCN	Optical Cloud Network
ODN	Optical Distribution Network
ODU	Optical Data Unit
ODU0	Optical Data Unit 0
ODUk	Optical Data Unit k
OE	OTN Edge
OLT	Optical Line Terminal
OMCI	ONU Management and Control Interface
OMS	Optical Multiplex Section
ONU	Optical Network Unit
OPEX	Operational Expenditure
OSP	Optical Service Protocols
OSS	Operations Support System
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTSiA	Optical Tributary Signal Assembly
OTUCn	Optical Transport Unit-Cn
OTUk	Optical Transport Unit (k = 0 to 4)
P2MP	Point to Multi-Point
P2P	Point to Point
PBX	Private Branch Exchange
PC	Personal Computer
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge
PHY	Physical layer
POL	Passive Optical LAN
PON	Passive Optical Network
P-ONU	Primary Optical Network Unit
PPPoE	Point-to-Point Protocol over Ethernet
QoD	Quality on Demand
QoE	Quality of Experience
QoS	Quality of Service

RaaS	Robotics as a Service
RG	Residential Gateway
ROADM	Reconfigurable Optical Add/Drop Multiplexer
SAP	Service Access Point
SC	Sub-Carrier
SCM	Sub-Carrier Multiplexing
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Networking
SDO	Standards Development Organization
SLA	Service Level Agreement
SME	Small and Medium Enterprises
SMP	Service Mapping Point
SPP	Service Processing Point
SR	Segment Routing
SRv6	Segment Routing over IPv6
STM	Synchronous Transport Module
STM-N	Synchronous Transport Module N (N = 1, 4, 16, 64, 256)
TDM	Time Division Multiplexing
VC	Virtual Container
VCAT	Virtual Concatenation
VC-n	Virtual Container n (n = 1, 2, 3, 4, …)
vCPE	Virtual CPE
VLAN	Virtual LAN
VNF	Virtual Network Function
VoIP	Voice over IP
VPN	Virtual Private Network
VR	Virtual Reality
VxLAN	Virtual extensible Local Area Network
WDM	Wavelength-Division Multiplexing
WG	Wireless Gateway
WMCI	Wireless Management and Control Interface
WSS	Wavelength Selected Switch
XC	Cross-Connect
xDSL	x(Version) Digital Subscriber Line
XGS-PON	10-Gigabit-capable Symmetric PON

NOTE: Also known as symmetric 10G-PON.

XR	eXtended Reality

4 Business requirements for the F5G Advanced Network Architecture

4.1 Context

The F5G-A Use Cases [i.2] show the various services and application that the F5G-Advanced architecture needs to support. The F5G-Advanced Generation Definition [i.1] has defined a set of network characteristics that the F5G-A network architecture shall support.

The present clause lists the various requirements from a business perspective. Note that they are not technically exact but show the direction and business benefits of the F5G-Advanced network architecture.

4.2 Flexible on-demand new residential user service packages

The transition from a relatively limited residential service portfolio, such as triple play service (High-speed Internet, Voice, IPTV) to a much wider service portfolio including but not limited to IoT, new entertainment (4K and 8K video, VR gaming), metaverse applications, digital twin, e-medicine, etc., implies that application specific network requirements are needed. Due to on-demand service deployment, more flexibility allocation and adaptation of the network is needed. The on-demand aspect means full configuration automation of specific service packages with the necessary networking capabilities and automated delivery of high-quality services.

4.3 Flexible on-demand new business service packages

The transformation of enterprise networking to an "as a Service" model, requires additional functionality in the network to access multiple clouds from different cloud providers. Having Software "as a Service" requires network adaptation to service specific needs. Enterprise services might be bundled into packages such that these packages are ordered on-demand and based on the actual business needs.

4.4 Evolution to application-oriented 10 Gigabit guaranteed residential services

The introduction of many service packages, means that a network subscription requires network quality differentiation within the residential premises as well as in the access and core networks. For some of the services, guaranteed QoS also needs to be supported. A subscription needs differentiated network performance for the network operator to provide its own applications and as well as for 3rd party applications.

Due to the higher number of end-systems and higher bandwidth services more network capacity per customer is needed. The network speed will increase from 1 G to 5 G today to 5 Gbit to 25 Gbit in the future [i.1].

4.5 Optimization of large Wi-Fi® networks for residential and enterprises

For both residential and business scenarios, the customer premises network needs extensive coverage providing connectivity to every corner of the customer premises without interruptions. In addition, it is not just about providing connectivity, but having high quality and high capacity capability in all areas of the customer premises. This means the on-premises Wi-Fi® network is expanding to include a Wi-Fi® Access Point in every room or office (FTTR2H or FTTR2B).

In many cases it is about a Wi-Fi® network providing high quality of experience to the residential or enterprise users including easy installation or self-install and low network wide energy usage. From a service provider perspective self-install might help lower operational cost and significantly reduce the number of residential or business call-outs.

4.6 Automation of application scenario detection and network adaptation networking to provide the best services

Since various applications are running in various network scenarios, the network should be capable of automatically detecting and reacting to them providing the best possible service. This also means that network adaptation to changes in the environment, application usage profile, or any other changes affecting the service quality shall be performed automatically.

4.7 Advanced services through networking in conjunction with computing capabilities

More advanced services are not restricted to communication and networking anymore. Combinations of networking and computing/storage resources in a single platform enables combined service creation and deployment. The network providing compute and storage capabilities benefits the overall service twofold. Firstly, compute and storage are used to improve the quality of the service and experience through AI. Secondly the service itself is deployed as a combination of networking and compute/storage. Examples include cloud storage easily accessible from residential or business, application as a service installed in the cloud and the GUI provided to the customers.

4.8 Improved energy usage through all optical networking to the edge

The need to lower energy usage is addressed by reducing the number optical to electrical to optical conversions in the E2E network. Transitioning the longest portion of an end-to-end network path to all optical is beneficial in lowering the energy usage as well as OPEX. The service providers improve market positioning thought providing climate neutral and sustainable network services.

4.9 Flexibly sharing optical resources

Transforming to all-optical networks, requires additional steps as optical communication gets closer to the network edge. Since wavelengths are a precious resource and underutilising them is wasteful, therefore the sharing of wavelengths lowers the cost of deployment of optical communication in the all-optical space. To realize the automatic allocation and management of wavelength resources, the F5G-A network should be capable of fast tracing and monitoring of optical channels, and evaluating optical parameters. This effectively avoids the manual process during network maintenance and shortens the network adjustment time. Moreover, for wavelength-level one-hop direct services, this automatic wavelength allocation and management need to be performed across different network layers. Still electrical aspects need to be envisioned, when all-optical solution is either cost prohibitive. Either there are insufficient users to justify the wavelength approach or the services are too fine granular that a wavelength-based communication is an excessive concept.

4.10 Service-oriented Optical Networks

The business requirement for optical communication is to enable the full the spectrum of networking capabilities, such that small to large capacity connections are possible. The various levels of infrastructure sharing provide isolation of different service from each other. Since typically services are provided using cloud computing, which is a dynamic approach to deliver compute functionality in the "as a Service" model, the optical network needs to support the "as a Service" model as well. So dynamic provisioning and adaptation of the optical network to cloud services requires the Network as a Service (NaaS) model.

4.11 Use optical communication for special dedicated networks

There are several special dedicated networks (non-typical telecommunication networks) being deployed today including networks in power distribution, utilities, railways, and subways (see the F5G-A Use Case Document Release 3 [i.2]). In the context of special dedicated networks, which are typically purpose built and isolated for a particular application. This is not a cost effective and efficient use of resources. The reuse and sharing of a common telecommunication network infrastructure is cost effective and efficient, while still maintaining the requirements of the special dedicated networks.

4.12 Deterministic Optical Networks

Due to the move to the cloud and growing trend towards digitalization in the various industries, enterprises and residential. Many of the applications require deterministic network performance to operate securely and reliably. The requirements may change over time due to the evolution of the applications and the business criticality of the application. Therefore, the required determinism needs to be supported in all segments of the F5G-A optical network. Since the optical networks many times include on-premises network segments, a more service-oriented operation and flexible adaptation is needed.

4.13 Operation as a Service

One aspect of the "as a service" model is outsourcing the operation of ICT tasks and network infrastructure. That is relatively straightforward for virtual components in the compute and storage space. However, it is more difficult for physical equipment on-premise. Therefore, there is a business interest of outsourcing the operation to knowledgably business partners, being more efficient due to the consolidated knowledge operating similar networks for several customers. The F5G Advanced network architecture shall support the operation "as a service" model for customer premises networks specifically including the physical equipment, besides the already supported network and compute as a service area.

4.14 Use of Optical Infrastructure for Sensing

The optical infrastructure either the existing communication infrastructure or specifically deployed fibre infrastructure is used to sense environmental conditions or to sense the fibre quality or failure itself for operational purposes. The sensed information is used for various applications for monitoring pipelines, fences, railway tracks (see the F5G-A Use Case Document Release 3 [i.2]). in addition to being reused for communication.

5 F5G Advanced Network Architecture

5.1 Architecture design principles

5.1.1 Quality on Demand (QoD)

Since the F5G Advanced architecture is service driven and enables a plethora of different services and applications, the F5G Advanced (F5G-A) network shall make the Application Programming Interfaces (APIs) available to service management functions to configure a specific quality of service in the F5G-A network for an excellent user experience for given applications.

5.1.2 Autonomous End-to-End Slice Creation and Adaptation

Various services and applications require isolated network slices to enable the delivery of high quality and secure services and applications to the customers. The services and applications shall be automatically detected by the F5G-A network and the network slices are automatically created as required. The adaptation of the network slice to changes of the service or the addition of more users or devices to the service shall be automatically facilitated. The F5G-A MCA plane shall support the autonomous E2E slice features based on the collected knowledge of the F5G-A network and appropriately optimized end-to-end.

5.1.3 Large Wi-Fi® Networks and Policy Control

The F5G architecture [1] provides FTTR with a single Wi-Fi® Access Points (APs) and multiple AP for both residential and SMEs. For large enterprise sites, the F5G-A architecture needs to support a larger number of Access Points. In order to achieve best in class performance, the control of radio interference and easy deployment for excellent data rate coverage on the customer premise is essential to achieve high QoE. In addition, the definition and enforcement of various business policies shall be supported.