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Fifth Generation Fixed Network (F5G); F5G Advanced Generation Definition

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Foreword

This Group Report (GR) 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 studies the driving forces and the characteristics of the fixed network evolution from F5G to F5G Advanced. It includes all segments of E2E connectivity between on-premises networks and data centres, and extends the F5G concepts and characteristics initially described in ETSI GR F5G 001 [i.12].

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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] [Cisco Annual Internet Report, 2018-2023](#).
- [i.2] G.fgOTN project in ITU (in progress).
- [i.3] Wikipedia: "[Software as a Service](#)".
- [i.4] TM Forum: "[Autonomous Networks: Empowering Digital Transformation for Smart Societies and Industries](#)".
- [i.5] Recommendation ITU-T Series G Supplement 51 (05/2012).
- [i.6] ETSI GR F5G 008 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Use Cases Release #2".
- [i.7] TM Forum IG1218 (V2.2.0): "Autonomous Networks - Business requirements & architecture".
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- [i.9] ETSI GR ZSM 011 (V1.1.1): "Zero-touch network and Service Management (ZSM); Intent-driven autonomous networks; Generic aspects".
- [i.10] [Introducing the Knowledge Graph: things, not strings](#).
- [i.11] Wikipedia: "[Large language model](#)".
- [i.12] ETSI GR F5G 001: "Fifth Generation Fixed Network (F5G); F5G Generation Definition Release #1".
- [i.13] ETSI GS F5G 006: "Fifth Generation Fixed Network (F5G); End-to-End Management and Control; Release #1".
- [i.14] ETSI GS F5G 011: "Fifth Generation Fixed Network (F5G); Telemetry Framework and Requirements for Access Networks".
- [i.15] ETSI GS F5G 005: "Fifth Generation Fixed Network (F5G) F5G High-Quality Service Experience Factors Release #1".
- [i.16] ETSI GR F5G 007 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Industrial PON".

- [i.17] [Europe's Digital Decade: digital targets for 2030.](#)
- [i.18] Recommendation ITU-T Y.2501: "Computing power network - Framework and architecture".
- [i.19] ETSI TR 103 775: "Access, Terminals, Transmission and Multiplexing (ATTM); Optical Distribution Network (ODN) Quick Construction and Digitalization".
- [i.20] IEEE 802.11ax™: "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 Amendment 1: Enhancements for High-Efficiency WLAN".
- [i.21] IEEE 802.11be™: "IEEE Draft 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 Amendment: Enhancements for Extremely High Throughput (EHT)".
- [i.22] IEEE 802.11bf™: "IEEE Draft 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 Amendment 2: Enhancements for Wireless LAN Sensing".
- [i.23] Recommendation ITU-T G.9804 series: "Higher speed passive optical networks".
- [i.24] Recommendation ITU-T G.984.series: " Gigabit-capable passive optical networks (GPON)".
- [i.25] Recommendation ITU-T G.9701: " Fast access to subscriber terminals (G.fast) - Physical layer specification".
- [i.26] Recommendation ITU-T G.987 series: "10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms".
- [i.27] Recommendation ITU-T G.9807 series: "10-Gigabit-capable symmetric passive optical network (XGS-PON)".
- [i.28] [Fifth Generation Fixed Network \(F5G\); F5G Advanced Release Documentation \(Release 3 and 4\).](#)
- [i.29] [Fifth Generation Fixed Network \(F5G\); F5G Release Documentation Release 1 and 2.](#)

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

Artificial intelligence as a Service (AIaaS): service that outsources AI-related computing to enable individuals and companies to explore and scale AI techniques at a minimal cost

NOTE: The motivation for AIaaS is because developing in-house AI-based solutions is a complex process that requires huge capital investment, outsourcing and getting it as service is beneficial

computing power networks: type of network that realizes optimized resource allocation, by distributing computing, storage, network and other resource information of service nodes through a network control plane (such as a centralized controller, distributed routing protocol, etc.)

NOTE: It combines network context and user requirements to provide optimal distribution, association, transaction and scheduling of computing, storage and network resources (see Recommendation ITU-T Y.2501 [i.18] for the definition).

digital twin: virtual representation of a physical object or system across its lifecycle, using real-time data to enable the understanding, learning and reasoning

Fibre to the thing (FTTThing): integrated technology scheme to provide connection to end devices in a communication system, in which the fibre is directly connected to end device instead of a network terminal

metaverse: proposed network of immersive online worlds experienced typically through virtual reality or augmented reality in which users would interact with each other and purchase goods and services, some of which would exist only in the online world

3.2 Symbols

Void.

3.3 Abbreviations

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

50G-PON	50 gigabit Passive Optical Network
AI	Artificial Intelligence
AIaaS	Artificial Intelligence as a Service
ANL	Autonomous Network Level
API	Application Programming Interface
AR	Augmented Reality
CIaaS	Compute Infrastructure as a Service
CO	Central Office
DAS	Distributed Acoustic Sensing
DSP	Digital Signal Processing
DU	Distributed Unit
E2E	End to End
EC	Edge Computing
EMI	Electro-Magnetic Interference
F5G	Fifth Generation Fixed Network
F5G-A	F5G Advanced
FEC	Forward Error Correction
fgOTN	fine-grain OTN
FTTD	Fibre To The Desk
FTTM	Fibre To The Machine
FTTO	Fibre To The Office
FTTThing	Fibre To The Thing
FTTR	Fibre To The Room
GPON	Gigabit PON
HD	High Definition
HMD	Head-Mounted Display
IaaS	Infrastructure as a Service
ICT	Information & Communication Technology
IEEE	Institute of Electrical and Electronic Engineers
IoT	Internet of Things
IP	Internet Protocol
IT	Information Technology
LAN	Local Area Network
LDPC	Low Density Parity Check
NETCONF	Network Configuration protocol
NFV	Network Functions Virtualisation
NRZ	Non Return to Zero
O&M	Operation & Management
OAM	Operation Administration and Maintenance
ODN	Optical Distribution Network
ODU	Optical channel Data Unit
OLT	Optical Line Termination
ONU	Optical Network Unit
OT	Operational Technology
OXC	Optical Cross-Connects

PON	Passive Optical Network
QoE	Quality of Experience
QoS	Quality of Service
SDH	Synchronous Data Hierarchy
SNMP	Simple Network Management Protocol
SaaS	Software as a Service
SOHO	Small Office and Home Office
SONET	Synchronous Optical NETwork
TDM	Time-Division-Multiplex
TDMA	Time-Division-Multiple Access
UHD	Ultra-High Definition
VNF	Virtualized Network Function
VoIP	Voice over IP
VPN	Virtual Private Network
VR	Virtual Reality
WDM-PON	Wavelength Division Multiplexing Passive Optical Network
Wi-Fi®	Wireless Fidelity
XG	10 Gbps
XG-PON	10-Gigabit-capable Passive Optical Network
XGS	10 Gbps Symmetrical
XGS-PON	10-Gigabit-capable Symmetric Passive Optical Network
XR	Extended Reality
YANG	Yet Another Next Generation.

4 Overview

The ETSI Industry Specification Group (ISG) F5G has established a continuous evolutionary approach to the fixed network defining generations that may direct the industry toward a consistent E2E network vision.

ETSI GR F5G 001 [i.12] defines the Fifth Generation Fixed Network generation, to enable a wider technological standards adoption and boost the creation of a global market. There are many drivers that motivate the advancement of F5G networks towards their next evolutionary step, such as the digitization or cloudification of various services or application domains, new emerging technologies and improvements to the network infrastructure, the growing density and applicability of the network for various purposes and environments. The evolution of F5G needs to be considered and the next steps to F5G Advanced are defined.

The present document explores the evolution path from F5G to F5G Advanced and details the six dimensions of F5G Advanced. Three of the dimensions were already specified for F5G [i.12], and F5G Advanced introduces enhancements for those. In addition, F5G Advanced introduces three new dimensions that will allow to meet the requirements of emerging services. The key enabling technologies for these six dimensions are addressed. Looking forward, the outlook of F5G Advanced and beyond is described in clause 8 of the present document.

5 From F5G to F5G Advanced

5.1 Application requirements for F5G Advanced

5.1.1 F5G Advanced - an enabler for emerging applications

In the ETSI GR F5G 001 [i.12], some major emerging application requirements are discussed. These requirements are mainly from residential, business and vertical industries. Several typical applications are analysed as Cloud VR, 8K HD videos, SOHO, as well as smart cities and smart manufacturing. These applications impose requirements such as network bandwidth, E2E quality assurance, security and network coverage based on FTTR and Wi-Fi®.

F5G Advanced supports the next generation of emerging digital services such as digital twins and metaverses, to name two, and continues to accelerate the popularization of fibre services and meet people's needs for personalized and higher-quality services. These emerging digital services impose more stringent requirements on the communication network technologies.

At the same time, the scientific, technological and industrial evolution are accelerating worldwide. Digital development has become an important growth engine for the world economy. Industrial digitalization has promoted the transformation of production methods achieving more intelligent infrastructure and higher quality.

The current F5G network technology, compared to the previous generations such as F4G, improved not only the network performance, but also the energy efficiency by expanding fibre to everywhere and replacing power hungry traditional copper networks. With the common global goal of reducing carbon emissions and achieving carbon neutrality, it is necessary to promote further advances in F5G network technology to meet the future green transition and low-carbon trends, e.g. achieving lower power per bit. At the same time, the low-carbon transformation of various high-energy- industries can be supported by further enhancing F5G network technology to provide a more intelligent network infrastructure to meet these needs.

5.1.2 Emerging applications

5.1.2.1 Digital Twin

The digital twin is an integration approach and an innovative application of multiple digital technologies, based on advanced modelling tools to define accurate digital models of the physical objects, based on the collection of real-time data for improved operation. The digital twin achieves the integration of physical objects and digital models, and thereby builds a comprehensive decision-making capability, and supports the optimization of the operation of physical objects.

The digital twin can be used to improve management decisions and outcomes via the visualization and support of individual objects, like a car or a robot and up to the complexity of smart robotic fleets, complex manufacturing operations and smart cities.

For the digital twins to achieve accurate real-time information capture and real-time interaction with the physical world, improvements to the existing architecture and capabilities of networks need to be accomplished. F5G Advanced aims at providing the needed key performances such as the connection of a large number of devices, high data throughput, and deterministic transmission capabilities.

5.1.2.2 Metaverse

The Metaverse is a persistent and immersive digital environment of independent but interconnected networks. It enables persistent, decentralized, collaborative, interoperable digital content that intersects with the physical world's objects.

The Metaverse needs the combined use of multiple technologies like Augmented Reality (AR), eXtended Reality (XR) or Mixed Reality (MR), Internet of Things (IoT), Artificial Intelligence (AI) and cloud computing technologies. These technologies combined, form a complete metaverse solution.

The Metaverse needs that the network supports the wide-scale interconnection of a large number of users, supporting flexible and elastic networking, and imposes more extreme requirements for network performance. In terms of network service interaction and collaboration, the network needs to change from capability-oriented to service-oriented, enhancing the integration of network service applications, establishing a collaboration model, and better supporting the needs of highly interactive services.

It is necessary to implement fine grain QoS assurance for multi-stream services, and coordinate transmission of various data streams such as video, audio, network control signalling, and performance monitoring. This ensures the respective QoS of all streams to achieve an excellent overall service experience.

Due to the high metaverse service requirements for network bandwidth and deterministic performance, serving concurrent user poses greater challenges to the dynamic real-time optimization and adjustment of network resources.

5.1.2.3 Deterministic networking for vertical industries

The Internet technologies reached global coverage and are more and more used in industrial production. It is becoming more difficult for the traditional best effort network architecture and capabilities to support future vertical industry service requirements for differentiated networking, low latency and low jitter transmission capabilities.

Deterministic network technologies, which optimize network latency, packet jitter, packet loss and other key parameters that define the service quality metrics, can provide reliable and guaranteed transmission capabilities. The needs of smart factories, smart grids, remote industrial control, traffic safety control, telemedicine, unmanned driving and other applications can therefore be met, greatly improving real-world productivity and creativity.

Deterministic network technology can be combined with network virtualization and network slicing technology to partition application scenarios, separate deterministic capabilities for different business needs, and realize differentiated deterministic performances for different customers.

Deterministic network technology can also be employed to optimize the QoS of the computing power networks [i.18], improving the support of the stringent network performance requirements. Thereby ensure the coordination of end-to-end computing and networking, and assign tasks to the appropriate computing nodes in real-time. In addition, it can meet the requirements of massive data processing, transmission, and storage access, providing customers with an improved service experience of computing and networking convergence.

5.1.2.4 Digitization and cloudification of applications

The move to cloud environments is spreading in all market segments, adding network requirements on bandwidth, availability, low latency and jitter. In addition, an efficient balance between computing, storage and networking in an edge cloud architecture enables the optimisation of total energy consumption.

These factors largely influence the success of enterprise and campus digitization and cloudification. For network operators, this creates the opportunity to develop premium computing power networks-based services in an "as a Service" model, adding more intelligence for services creation and the improvement of customer interaction. Through appropriate frontend portals, users are able to select and customize the needed services. F5G Advanced networks enable this evolution, expanding the scope of Fibre To The Office (FTTO) solutions.

Another emerging area, either for business and or residential users, are the Ultra-High Definition (UHD) immersive experience applications that frequently need cloud resources, and large bandwidth and low latency.

5.2 Trends and demands on network infrastructures

5.2.1 The quest for higher bandwidth and Quality of Experience (QoE)

Services and bandwidth evolution make up a virtuous cycle, where new services demand more bandwidth and more bandwidth favours the creation of new services.

The digitization and cloudification is a trend in all segments including residential users, public services, health or industry. The evolution to UHD video, extended reality or remote work generate an increase in the number of users and endpoints and drive the quest for higher and improved broadband capacity and functionality.

F5G Advanced is the next step in the fixed network evolution, providing an ecosystem that integrates higher bandwidth technologies with the appropriate architecture and E2E management, enabling the required flexibility and agility to address a wide range of services and deployment environments.

This evolution can take different paces depending on specific services, applications and market segments. However, as stated in the EU digital targets for 2030 [i.17], a next step is to ensure Gbit network access for everyone in 2030.

The vision of "fibre to everything and everywhere" set forward by ETSI ISG F5G is becoming a trend, extending fibre deeper into several environment as FTTR, FTTD or FTTM.

Along with the growth of the number of end-points and diversity of applications, there is a growing demand for quality of the network infrastructure, where the focus on speed is complemented by specific requirements on latency, jitter and functionalities such as E2E slicing, providing premium Quality of Experience (QoE). The resources need to be available and guaranteed for all services using the infrastructure. The rich service functionality needs the infrastructure to be able to meet a variety of requirements along multiple dimensions of those represented in Figure 1.

An initial QoE framework was specified in ETSI GR F5G 005 [i.15] and is embedded in the evolution to F5G Advanced.

5.2.2 Digitization and automation of network operations

Optical networks are expanding fast in number of users, number of connected devices and diversity of service requirements, covering different segments that may share the network resources. To address this growing dimension and complexity, the digitization and automation of network operations is a key requirement. A holistic perspective on the network management is needed. For the F5G generation these aspects are addressed in ETSI GS F5G 006 [i.13] and ETSI GS F5G 011 [i.14]; an evolution will be required in F5G Advanced.

Furthermore, the adoption of autonomous network approaches adds intelligence and simplicity to Operation Administration and Maintenance (OAM) increasing the ease of operation and reducing operational costs. This trend has already started in ISG F5G and is expanded in further evolutions. Core technologies, such as service intent, multi-dimensional experience awareness, and adaptive network adjustment, can be used to upgrade the network management system to a higher Autonomous Network Level (ANL), as defined by the TMF. It includes achieving close to zero wait for services, zero touch for network maintenance, and zero trouble in services.

5.2.3 Optical fibre networks becoming ubiquitous

Optical networks, either in access, aggregation or core, are a key infrastructure for broadband development, addressing a growing number of applications and requirements from a wide range of segments such as residential, enterprise, campus or industry. They are also fundamental to support many other networks such as offloading of mobile and wireless networks (e.g. Wi-Fi®) or Data Centres interconnection.

This key role of optical networks, becoming ubiquitous, also leads to the massive and fast deployment of optical fibre cable infrastructures, that being passive, face several management challenges such as the accumulation of a large number of passive resources, assets location mapping, reliable real-time occupancy status and performance monitoring. To address these challenges, new technologies and architectures need to be introduced, aiming to facilitate the visualization of passive fibre resources, topologies, and connection status of the Optical Distribution Network (ODN). ETSI TR 103 775 [i.19] addresses some of these questions. F5G Advanced improves the overall O&M efficiency of the optical fibre infrastructure and the automation capability of upper-layer service networks.

Furthermore, optical fibre cables have "sensing" capabilities that are be exploited for the improvement of the optical fibre infrastructure management. The optical fibre sensing technology, represented by Distributed Acoustic Sensing (DAS), can capture and collect environmental information such as vibration, stress, and temperature changes. It has been applied in oil and gas pipeline intrusion monitoring and coal mine conveyor belt monitoring, opening a new dimension to optical networks.

5.2.4 Green and Digital for a Sustainable Society

The digital transformation is crossing all areas of the society, requiring capable and flexible networks that can adapt to the needs of the various stakeholders. This transformation contributes to meet the challenges of a greener society and reduction of CO₂ emissions.

Optical networks are a key infrastructure to achieve the green and digital objectives.

Productivity gains, adoption of virtual meetings or remote work are just some examples of the energy savings brought by the digital transformation supported by efficient networks. But the energy consumption of the network itself needs also to be managed and reduced whenever possible, and optical networks have a key role also in this.

In access, the passive structure of PON networks makes it very energy efficient when compared with other options. In aggregation and core networks, the development of optical switching and AI assisted enhanced routing intelligence, ensuring the traffic paths with the highest energy efficiency.

Improvements in the optical fibre infrastructure management contributes to the reduction of carbon emissions. The field operations require to perform maintenance and fix network faults, demanding for travel and human resources; they are the major sources of cost and carbon emission in network operation. That leading to self-operating networks and, ultimately, to self-healing networks is therefore an important trend.

5.2.5 Integration of computing in the network

The digital transformation implies the implementation of computing power networks, where Artificial Intelligence (AI) is an enabler for flexibility, adaptability, and efficiency in infrastructure operations.