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Fifth Generation Fixed Network (F5G); F5G Network Architecture Release 2

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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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Introduction

The F5G network, as described in ETSI GR F5G 002 [i.2], has committed to three characteristics for extending and enhancing fixed networks, eFBB, FFC and GRE. These characteristics are derived from the F5G use cases (ETSI GR F5G 008 [i.1]) that require these enhancements. To implement these characteristics, the F5G architecture has introduced new design principles and new features. Such features include separation of data plane into Underlay Plane and Service Plane, dual network fabrics for the Aggregation Network, comprised of an IP/Ethernet and an OTN fabric, and the seamless and combined usage of PON and OTN, E2E slicing, etc. Based on these design principles and new features, F5G networks can provide a variety of services for residential and enterprise customers over one physical network with guaranteed SLAs. The new F5G architecture balances performance and operational efficiency through a higher degree of flexibility and choice. Network services can be carried by an IP/Ethernet or an OTN fabric depending on the network characteristics and the performance requirements and allowing for independent changes of the Underlay or Service Planes to match the needs of applications, services or users. Using EVPN as the unified Service Plane technology simplifies the Service Plane protocols and management. This Service Plane is easily programmable to adapt

to market needs and it supports different cloud-oriented Information and Communication Technology (ICT) architectures.

1 Scope

The present document specifies the End-to-End network architecture, features and related network devices/elements' requirements for F5G, including on-premises, Access, IP and Transport Networks. The present document defines new features and enhance existing ones.

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/.

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

[1] IETF RFC 8453: "Framework for Abstraction and Control of TE Networks (ACTN)".

[2] Recommendation ITU-T G.709/Y.1331: "Interfaces for the optical transport network".

[3] Recommendation ITU-T G.709.1/Y.1331.1: "Flexible OTN short-reach interfaces".

[4] Recommendation ITU-T G.709.3/Y.1331.3: "Flexible OTN long-reach interfaces".

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

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

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

[8] IETF RFC 8584: "Framework for Ethernet VPN Designated Forwarder Election Extensibility".

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

[10] 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".

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

[12] Recommendation ITU-T G.798: "Characteristics of optical transport network hierarchy equipment functional blocks".

[13] Recommendation ITU-T G.873.1: "Optical transport network: Linear protection".

[14] Recommendation ITU-T G.873.2: "ODUk shared ring protection".

[15] Recommendation ITU-T G.873.3: "Optical transport network - Shared mesh protection".

[16] Recommendation ITU-T G.8251: "The control of jitter and wander within the optical transport network (OTN)".

[17] Recommendation ITU-T G.8201: "Error performance parameters and objectives for multi-operator international paths within optical transport networks".

[18] IEEE 802.3.1™: "IEEE Standard for Management Information Base (MIB) Definitions for Ethernet".

[19] IEEE 802.1Q™: "IEEE Standard for Local and Metropolitan Area Networks–Bridges and Bridged Networks".

[20] ETSI GS F5G 006 (V1.1.1): "Fifth Generation Fixed Network (F5G); End-to-End Management and Control; Release #1".

[21] ETSI GS F5G 011: "Fifth Generation Fixed Network (F5G); Telemetry Framework and Requirements for Access Networks".

[22] ETSI GS F5G 012 (V1.1.1): "Fifth Generation Fixed Network (F5G); Security; F5G Security Countermeasure Framework Specification".

[23] ETSI TS 103 924: "Optical Network and Device Security Catalogue of requirements".

[24] IETF RFC 7950: "The YANG 1.1 Data Modeling Language".

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

[26] IETF RFC 8040: "RESTCONF Protocol".

[27] ETSI GS F5G 013 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Technology Landscape Release #2".

[28] ETSI GS F5G 015 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Residential Services Quality Evaluation and Classification".

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 008 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Use Cases Release #2".

[i.2] ETSI GR F5G 001 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Generation Definition Release #1".

[i.3] ITU-T Study Group 15/Q18, G.fin-SA: "High speed fibre-based in-premises transceivers - system architecture".

[i.4] IETF draft-ietf-ccamp-transport-nbi-app-statement: "Transport Northbound Interface Applicability Statement".

[i.5] IETF draft-ietf-teas-ietf-network-slices: "Framework for IETF Network Slices".

[i.6] IETF draft-ietf-teas-applicability-actn-slicing: "Applicability of Abstraction and Control of Traffic Engineered Networks (ACTN) to Network Slicing".

[i.7] IETF draft-ietf-ccamp-yang-otn-slicing: "Framework and Data Model for OTN Network Slicing".

[i.8] ITU-T Study Group 15/Q11 G.osu: "Optical Service Unit (OSU) path layer network".

[i.9] IETF draft-ietf-teas-enhanced-vpn: "A Framework for Enhanced Virtual Private Network (VPN+) Services".

[i.10] IETF draft-ietf-teas-ns-ip-mpls: "Realizing Network Slices in IP/MPLS Networks".

[i.11] ETSI GR IPE 005: "IPv6 Enhanced Innovation (IPE); 5G Transport over IPv6 and SRv6".

[i.12] IETF RFC 8655: "Deterministic Networking Architecture".

[i.13] IETF RFC 2702: "Requirements for Traffic Engineering Over MPLS".

[i.14] IETF RFC 3209: "RSVP-TE: Extensions to RSVP for LSP Tunnels".

[i.15] IETF draft-ietf-spring-resource-aware-segments: "Introducing Resource Awareness to SR Segments".

[i.16] IEC 61158: "Industrial communication networks -- Fieldbus specifications".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

access node: network node which has connectivity by access network technology to the customers and is connected to the aggregation network

NOTE: The access node is the delineation between the access network and aggregation network. The access node might consist of several physical network elements.

AggN Edge Node: network node which has connectivity to several access nodes and is connected to the core network

NOTE: The AggN Edge Node is the delineation between the aggregation network and the core network. The AggN Edge Node might consist of several physical network elements.

aggregation fabric: network connecting the access node and the AggN Edge Node

application list: list of applications and the associated attributes to identify the application in a network element

bearer connection: network connection instance in the Underlay Plane with particular QoS characteristics, transporting the traffic according to the service or network requirements

Dedicated Network (D-Net): set of preconfigured paths or bearer connections established on a shared networking infrastructure

NOTE: D-Nets operate independently from each other, are fully isolated from other paths and bearer connections, and meet the SLA requirements of the tenants. A D-Net can be managed by an independent management plane or several D-Nets can be managed by a single management plane.

digital twin: model of the network, including available resources and configurations and containing a real-time, equivalent model of the running network

EtherCAT (Ethernet for Control Automation Technology): Ethernet-based fieldbus system

NOTE: The protocol is standardized in IEC 61158 [i.16] and is suitable for both hard and soft real-time computing requirements in automation technology.

isolation: several levels of isolation including on data level, resource level and several mechanisms for soft and hard isolation

NOTE 1: On the data level, each instance has its own isolated data instance. On the resource level, it means isolation which includes tenants having their own basic resources like databases, logs, alarms, and networking resources. There is also soft isolation of resources like buffers, queues, control-plane processes, forwarding processes and hardware isolation like boards and ports, CPU cores, forwarding chips and sub-racks.

NOTE 2: Different isolation levels and mechanisms have different characteristics and complexities.

Management, Control and Analytics (MCA) plane: sub-system, which is responsible for the management, control and analytics of the complete end-to-end F5G network

network slice: logical network that achieves specific service requirements

Network Service Providers (NSPs): business entity which provides a logical or physical network or connectivity service

NOTE: The NSP defines network services including the network functions and the required E2E network resources including topology, transmission links, and ODN resources that can be exclusively used, and resources such as boards and ports of each Network Element (NE).

Network Slice Instance (NSI): instantiation of a network slice with particular defined network capabilities (e.g. QoS, OAM, reliability) and a set of resources

NOTE: The network slice instance is characterized by multiple parameters and covers management, control, and forwarding requirements of the services. The network slice instance is an end-to-end concept.

Network Slice Template: data structure with different parameters of the network slice instance's characteristics

Service Access Point (SAP): function that provides and controls the customer access to the service

NOTE: The SAP is a component in the Service Plane.

Service Mapping Point (SMP): function that maps the service traffic to a specific Underlay Plane infrastructure

NOTE: The SMP is a component in the Service Plane.

service plane: plane for the connectivity services to customers

NOTE: Connectivity services can be dynamically created, deleted and adapted, and provides the service with a customer agreed quality.

Service Processing Point (SPP): function that performs service specific processing

NOTE: The SPP is a component in the Service Plane.

Service Slice Type (SST): data structure that defines an expected network behaviour in terms of features and services (e.g. specialized broadband for a particular application) of a slice

tenant: business entity using and controlling a network slice

NOTE: The tenant can be different entities depending on the context and business relationship.

EXAMPLE: A tenant can be a Virtual Network Operator (VNO) or a Network as a Service (NaaS) user.

traffic steering: function deciding what traffic is steered to what destination or next node

NOTE 1: The traffic needs to be identified such that it can be steered.

NOTE 2: A bearer connection can be a tunnel or a native network connection depending on the technologies used.

trust domain: collection of entities between which there is either direct, delegated or transitive trust

NOTE: The trust is in the authenticity of identifiers and respecting the privacy requirements that share a set of security policies that mitigate any risk of exploit to the grouping and/or collection within the trust domain boundary (see ETSI GS F5G 012 [22])

underlay plane: physical network of the physical network elements and the interconnecting links

3.2 Symbols

Void.

3.3 Abbreviations

For the present document, the following abbreviations apply:

ACTN	Abstraction and Control of Traffic-Engineering Network
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
ARPU	Average Revenue Per User
ASG	Access Service Gateway
BGP	Border Gateway Protocol
BNG	Broadband Network Gateway
BSS	Business Support System
BYOD	Bring You Own Device
CE	Customer Equipment
CNC	Customer Network Controller
CPE	Customer Premises Equipment
CPN	Customer Premises Network
CPU	Central Processing Unit
CR	Core Router
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
DC	Data Centre
DC-GW	Data Center Gateway
DetNet	Deterministic Networking
DSCP	Differentiated Services Code Point
E2E	End-to-End
E-CPE	Enterprise CPE
EDCA	Enhanced Distributed Channel Access
eFBB	enhanced Fixed BroadBand
E-LAN	Ethernet Virtual Private LAN
E-Line	Ethernet Virtual Private Line
E-O-CPE	Enterprise-OTN-Customer Premise Equipment
ETH	Ethernet
E-Tree	Ethernet Virtual Private Tree
EVPN	Ethernet VPN
FEC	Forward Error Correction
FFC	Full Fibre Connection
FlexO	Flexible Optical transport network
FTTH	Fibre-To-The-Home
FTTR	Fibre-To-The-Room
GEM	GPON Encapsulation Mode
GMPLS	Generalized Multi-Protocol Label Switching
GPON	Gigabit Passive Optical Network

GRE	Guaranteed Reliable Experience
HGW	Home Gateway
ICT	Information and Communication Technology
IE	Industrial Equipment
IoT	Internet of Things
IP RAN	IP Radio Access Network
IP	Internet Protocol
IPTV	Internet Protocol Television
IT	Information Technology
L2VPN	Layer 2 VPN
LAN	Local Area Network
LDP	Label Distribution Protocol
LSP	Link State Protocol
MAC	Media Access Control
MAN	Metropolitan Area Network
MCA	Management, Control, and Analytics
MDSC	Multi-Domain Service Coordinator
MEF	Metro Ethernet Forum
MP2MP	Multi-Point to Multi-Point
MP-BGP	Multiprotocol Extensions for BGP
MPLS	Multiprotocol Label Switching
MPLS-TE	MPLS Traffic Engineering
MS-OTN	Multi-Service OTN
NaaS	Network as a Service
NAT	Network Address Translation
NE	Network Element
NFV	Network Function Virtualisation
NMS	Network Management System
NSI	Network Slice Instance
NSP	Network Service Provider
O&M	Operation and Maintenance
OAM	Operation, Administration and Maintenance
OAM&P	Operation, Administration, Maintenance and Provision
ODN	Optical Distribution Network
ODU	Optical Data Unit
OLT	Optical Line Terminal
OMCI	ONU Management and Control Interface
ONU	Optical Network Unit
OSS	Operations Support System
OSU	Optical Service Unit
OTN	Optical Transport Network
OTUCn	Optical Transport Unit-Cn
OTUk	Optical Transport Unit (k = 0 to 4)
OXC	Optical Cross-Connect
P2MP	Point to Multi-Point
pBNG	physical Broadband Network Gateway
PBX	Private Branch Exchange
PC	Personal Computer
PCP	Priority Code Point
PCS	Physical Coding Sublayer
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge
PHY	Physical layer
PLC	Power Line Communication
PNC	Provisioning Network Controller
POL	Passive Optical LAN
PON	Passive Optical Network
PPPoE	Point-to-Point Protocol over Ethernet
QoE	Quality of Experience
QoS	Quality of Service
RFC	Requests for Comments
RG	Residential Gateway

RoT	Root of Trust
RSVP-TE	Resource Reservation Protocol-Traffic Engineering
RU	Radio Unit
SAP	Service Access Point
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Networking
SID	Segment Identifier
SLA	Service Level Agreement
SME	Small and Medium Enterprises
SMP	Service Mapping Point
SPP	Service Processing Point
SR	Segment Routing
SRH	Segment Routing Header
SRv6	Segment Routing over IPv6
T-CONT	Traffic Container
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TID	Traffic IDentifier
TOS	Type Of Service
TSN	Time-Sensitive Network
VCPE	Virtual Customer Premises Equipment
VLAN	Virtual LAN
VNF	Virtual Network Function
VNO	Virtual Network Operator
VoIP	Voice over IP
VPN	Virtual Private Network
VR	Virtual Reality
VTP	Virtual Transport Path
VxLAN	Virtual extensible Local Area Network
WAN	Wide Area Network
WDM	Wavelength-Division Multiplexing
WG	Wireless Gateway
WMM	Wi-Fi® multimedia
XC	Cross-Connect
XGS-PON	10-Gigabit-capable Symmetric PON

NOTE: Also known as symmetric 10G-PON.

YANG	Yet Another Next Generation data modelling language

4 Business requirements for network architecture

4.1 Business requirements overview

When implementing a use case, the business requirements may be separated into a Physical Layer, a Network Layer and an Application and Management Layer. The focus of the present document is the F5G network architecture. This clause will summarize the business requirements of the network layer. However, this clause may also illustrate system-level requirements essential to network nodes and equipment for the F5G use cases. Other requirements not deduced from the F5G use cases may also be considered, such as network evolution trends.

4.2 Business requirements driving the F5G architecture

- Dual-Gigabit Networks:
  - The dual-Gigabit networks are represented by 5G mobile and fixed multi-gigabit optical networks (F5G), which provide fixed and mobile gigabit single user access capabilities. The dual-Gigabit network features ultra-high bandwidth, ultra-low latency and enhanced reliability. That means dual 5G and F5G networks need to be built for new application scenarios beyond the traditional applications. It is a key element for developing the digital economy, the digital society and the digital government.
- Rich set of Applications and Services for Different Market Segments:
  - The F5G architecture needs to support a rich and diverse set of application and service scenarios for a wide range of customer profiles including home users, large, medium, and small enterprises and specific vertical industries. Those applications and services for the different markets are ideally supported on the same infrastructure for improved operational efficiency of communication and networking services. This multi-service network shall allow flexible and dynamic service creation, development and deployment.
- F5G Infrastructure Convergence and Consolidation:
  - In the current fixed network business, the networking services are provided with dedicated networks and shared best-effort network infrastructure using copper- and fibre-based access networks. Consolidating and converging the fixed network infrastructure requires the overall infrastructure to enable a seamless connection between network segments (access, aggregation and core) and differentiate the services required by the different market segments and applications. The differentiation is expected over several dimensions, including bandwidth, latency, reliability, end-to-end delay assurance, and convergence through dynamic service awareness on a single, converged and agile management plane.
  - Also, studies show that enterprises from medium to small scale have a very diverse set of networking service requirements and are often co-located with other SMEs and residential housing. Sharing infrastructure on various levels is a suitable way of increasing operational efficiency.
- Converged Application Needs:
  - The line between home and enterprise networks is blurring since many more of those that work from home offices require enterprise-grade infrastructure. Also, industries and education institutions have moved more online and have massively digitized their processes, requiring the proper networking technology. On the other hand, some enterprises encourage Bring Your Own Device (BYOD), and some applications that the workforce are using are based on what they use at home. Also, enterprise networks are required to support residential oriented methods of working and processes, including on-demand ordering of communication services.
- Shift of Broadband Service Requirements:
  - So far, specifically for the residential markets, the services focus on the Internet Access Bandwidth. Also, in the enterprise markets, an important focus is on network bandwidth and reliability. For F5G, the assumption is that bandwidth is no longer the only dimension and that there is a shift from bandwidth to user experience to improve ARPU. This implies that the network needs to be more service-aware. Separation and isolation of user traffic from each other are a necessary mechanism to deal with guaranteed SLAs (e.g. through E2E slicing). More experience-based network policies are required to support more scenario-based broadband products for home, enterprise and verticals.
- Growing beyond Traditional Telecommunication:
  - The F5G architecture shall enable a wide range of services and functionalities, namely addressing specific vertical industries and other needs that support new business areas. For example, the functionality of E2E slicing and time-critical communication enables a larger set of industrial applications. In addition, the F5G architecture should support Passive Optical LAN (POL) as carrier-grade technology for campus and enterprise environments with the benefits of saving equipment rooms, having high-quality management capabilities, saving energy through passive optical technologies, removing radiation, and enhancing networking services in the customer premises.

- Increased Operational Efficiency:
  - The F5G architecture aims to improve operational efficiency by improving the quality of experience and better control over the quality of the services provided, such that potential user requirements are detected early and can be reacted upon. Integrating artificial intelligence and machine learning mechanisms into the F5G architecture will enable improved efficiency and more accurate network planning in terms of quality and capacity extension.
  - The F5G architecture is a unified architecture, which simplifies the O&M of the network. Decoupling the Service Plane and Underlay Plane using fabric networking simplifies and decouples capacity expansion from the service needs and improves bandwidth efficiency. Automatic operation and model-driven management simplify the interaction with different IT systems in the operator domain.
- Network Security:
  - The fixed network shall be a trusted infrastructure, requiring that the F5G architecture solves network security challenges. Secured networks and services are important for customer's trust in the network and make it a prerequisite for digitalization of industries and the society.

NOTE: The present document peripherally addresses security and privacy topics, but they are addressed in detail by ETSI GS F5G 012 [22] and ETSI TS 103 924 [23].

5 Network architecture

5.1 Architecture design principles

5.1.1 Multi-Service Network Platform

Multiple services for multiple customer types can be deployed based on the currently deployed broadband network architecture. However, it is not flexible, the deployment takes time, and the different customer requirements are difficult to fulfil cost-effectively. To enable flexible service deployment, SDN and NFV were introduced for network flexibility as tools to migrate fixed network architecture towards an SDN and NFV enabled F5G network architecture. SDN centralizes the control plane function and provides a concentrated network management functions. The management plane is now called the Management, Control and Analytics (MCA) plane; it enables more flexible and more efficient traffic route selection than a fully distributed control plane. NFV uses the virtualization technologies and cloudification to virtualize entire classes of network node functions into functions that are either stand alone or chained together to provide a communication service. This is especially beneficial for computing-based network functions, which can be easily deployed on IT-oriented cloud infrastructures.

NFV enables more flexibility to run the network functions and makes it easier to upgrade and enhance network services dynamically. The F5G architecture supports processing elements wherever needed including edge computing. However, the network's primary function is transporting bits at high speed, which means the base functionality of networking still requires major hardware support.

The multi-service network platform needs mechanisms to isolate a certain type of service traffic from other traffic. The platform should support guaranteed quality of service and a wide range of diverse services.

5.1.2 Dynamic and Flexible Service Creation

The F5G architecture is expected to support eFBB, FFC and GRE, which means ten times more speed, ten times more dense connections and ten times better SLAs. Besides fundamental features like SDN and NFV, the F5G architecture focuses more on flexible service enabling, reliable network performance guarantees, and autonomous service deployment.

The assumption is that customers can order or change their services on demand through a user interface (portal or API) to the OSS/BSS, which requires the Service Plane to be more flexible to adapt to a particular customer need.

5.1.3 Decoupling Service Plane and Network Plane

Therefore, broadband services shall be decoupled from the underlying network infrastructure. The decoupling allows for the independent upgrade of the network infrastructure without any effect or changes on the Service Plane. Also, the services can be adapted and changed without changing the basic network infrastructure. However, certain interdependencies will still exist, specifically in terms of what resources on the underlay can be used to provide a particular service. Also, in the cases of underlay network failures, these may affect the service quality.

5.1.4 AI-based Control, Management and Analytics

Artificial Intelligence shall be introduced on the Management & Control plane, making it a Management, Control & Analytics Plane, enabling more intelligent detection of faults and QoE degradation, network behaviour analysis and reaction to poor performing networks.

5.1.5 Security by Default

F5G applies the "security by default" paradigm, which means security claims for each element in the F5G system are verified. The connections and interfaces in the system (security-connections), which are potentially malicious, are verified to be secure. Details about the security design principles and directions are outlined in ETSI GS F5G 012 [22].

5.2 Architecture overview

Based on SDN and NFV principles, the F5G network architecture decouples services from the underlying physical network. Figure 1 illustrates an overview of the three planes of the F5G network architecture.

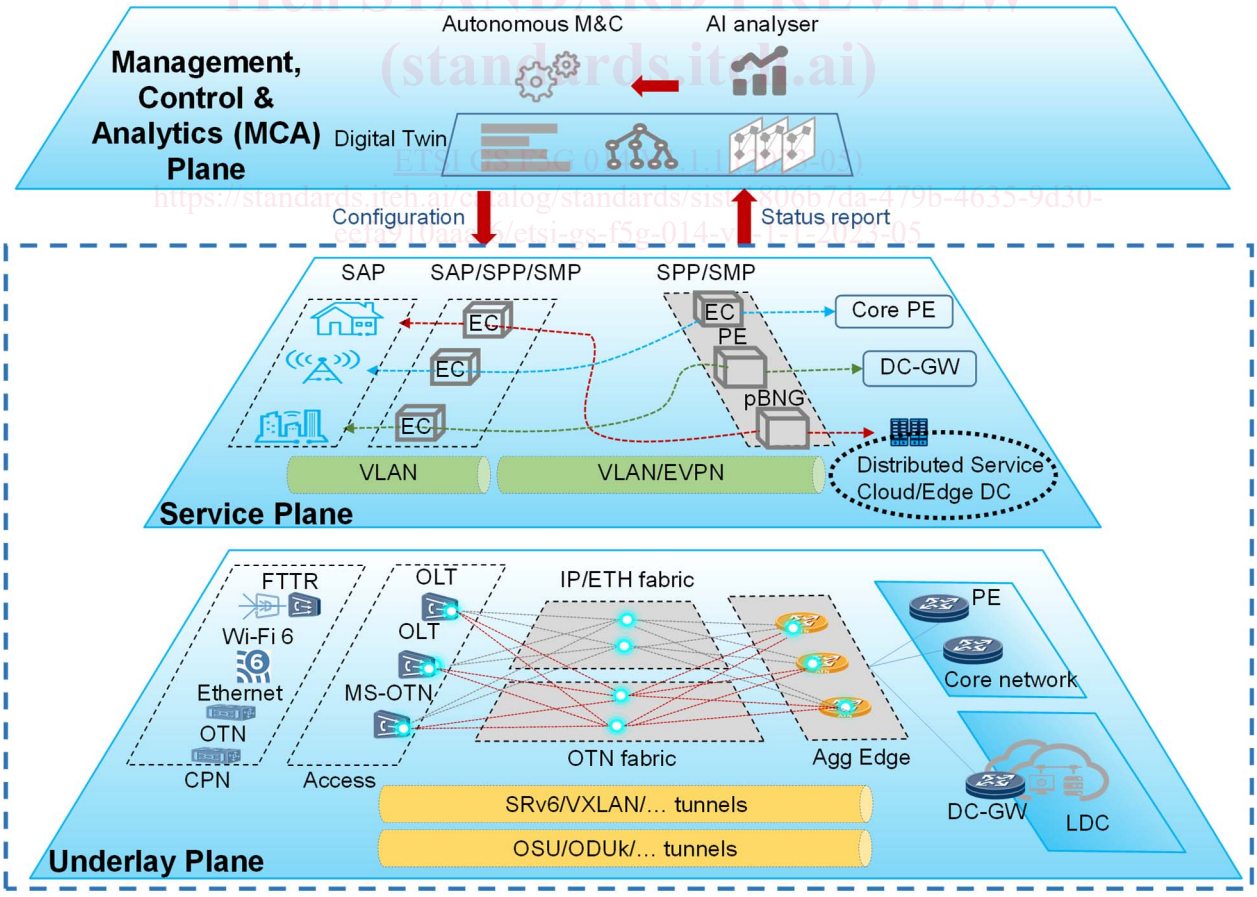

Figure 1: F5G network architecture

The F5G network architecture comprises three planes, an Underlay Plane, a Service Plane and a Management, Control & Analytics (MCA) Plane: