ETSI GS F5G 004 V1.1.1 (2022-01)

Fifth Generation Fixed Network (F5G); F5G Network Architecture

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Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00   Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
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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 001 [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 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 F5G Use Cases document ETSI GR F5G 002 [i.1] has defined many use cases for F5G. To support these use cases, the network architecture will need to be simple, agile, optimized and intelligent. The present document defines the F5G E2E network architecture and related network node requirements, including Customer Premise Network (CPN), Access Network and Aggregation Network. F5G takes SDN/NFV into account for the network's control layer. The F5G architecture will explore new network features like a seamless connection between Optical Transport Network and Access Network, E2E full-stack slicing, etc.

The F5G end-to-end management architecture is considered out of scope for the present document.

The present document also specifies technical requirements for the network nodes and elements in the architecture. The focus will be on Telecommunication networks in particular.

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.

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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] 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™: "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".

2.2 Informative references

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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 002 (V1.1.1): "Fifth Generation Fixed Network (F5G); F5G Use Cases Release #1".

[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: "sport 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-zheng-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-bestbar-teas-ns-packet: "Realizing Network Slices in IP/MPLS Networks".

[i.11] ETSI GR IPE 005: "IPv6 Enhanced Innovation (IPE); IPE_5G Transport and Cloud and IP network Convergence".

[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".

[i.17] ETSI GS F5G 006: "End-to-End Management and Control of F5G Networks".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

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

EtherCAT: Ethernet for Control Automation Technology is an 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.

network slice: logical network that achieves specific service requirements

3.2 Symbols

Void.

3.3 Abbreviations

For the present document, the following abbreviations apply:

AI	Artificial Intelligence
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
CPE	Customer Premises Equipment
CPN	Customer Premises Network
CPN-A	CPN Agent
CPU	Central Processing Unit
DC	Data Centre
DC-GW	Data Center Gateway
DSCP	Differentiated Services Code Point
E2E	End-to-End
E-CPE	Enterprise CPE
eFBB	enhanced Fixed BroadBand
ETH	Ethernet
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
ICT	Information and Communication Technology
IE	Industrial Equipment
IP RAN	IP Radio Access Network
IP	Internet Protocol
IPTV	Internet Protocol Television
IT	Information Technology

L2VPN	Layer 2 VPN
LAN	Local Area Network
LSP	Link State Protocol
MAC	Media Access Control
MAN	Metropolitan Area Network
MEF	Metro Ethernet Forum
MP-BGP	Multiprotocol Extensions for BGP
MPLS	Multiprotocol Label Switching
MS-OTN	Multi-Service OTN
NAT	Network Address Translation
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
OTU	Optical Transport Unit
OTUCn	Optical Transport Unit-Cn
pBNG	physical Broadband Network Gateway
PBX	Private Branch Exchange
PC	Personal Computer
PCS	Physical Coding Sublayer
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge
PHY	Physical layer
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
SDH	Synchronous Digital Hierarchy
SDN	Software Defined Networking
SLA	Service Level Agreement
SME	Small and Medium Enterprises
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
VCPE	virtual Customer Premises Equipment
VLAN	Virtual LAN
VNF	Virtual Network Function
VNO	Virtual Network Operator
VPN	Virtual Private Network
VR	Virtual Reality
VxLAN	Virtual extensible Local Area Network
WAN	Wide Area Network
WDM	Wavelength-Division Multiplexing
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 customers 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.

- Security and Privacy:

  The fixed network shall be a trusted infrastructure, requiring that the F5G architecture solves security and privacy challenges. Secured and privacy-aware 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 addresses only peripheral security and privacy topics, but they are addressed in detail by other documents of the ETSI ISG F5G.

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.

5.2 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.

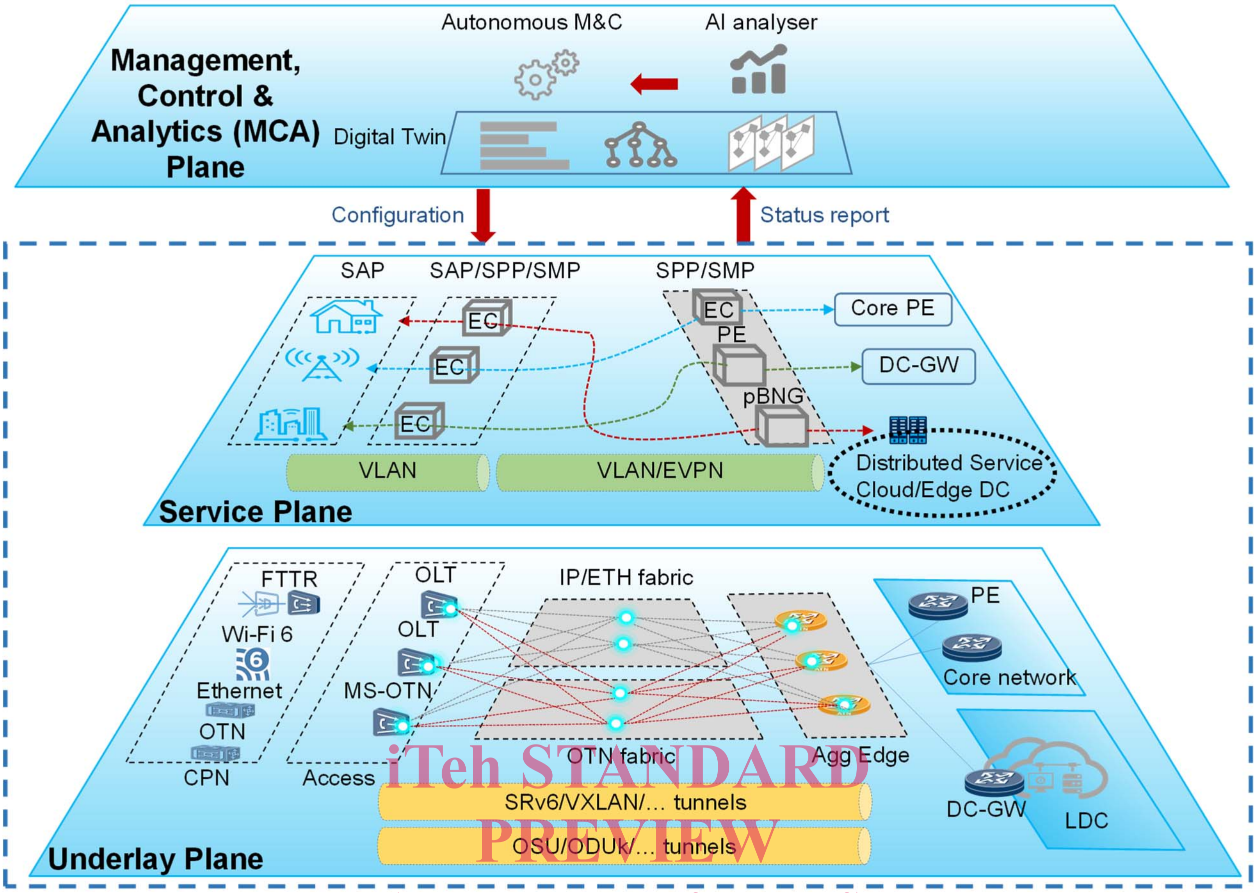

Figure 1: F5G network architecture

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

- Underlay Plane:

  This is fundamentally the physical network plane, which comprises physical network nodes. The Underlay Plane provides connections and dynamic programmable path selection under the control of the F5G controller in the MCA Plane. The network switching capacity shall scale without interfering with the Service Plane.

  The Underlay Plane has four segments, Customer Premises Network (CPN), Access Network (AN), Aggregation Network and Core Network. Various Technologies are used in the CPN, depending on the end-user requirements. For example, in Home Access, Wi-Fi 6 and FTTR can be introduced as new technologies, while Enterprise Access can benefit from POL to gain easy deployment and high bandwidth. OTN can also be deployed in the CPN for customers requiring high-quality VPN service. The Access Network shall be based on XGS-PON technology and OTN, depending on customer type and service delivered. The Aggregation Network has two parallel fabrics, an IP/Ethernet fabric and an OTN fabric. The IP/Ethernet fabric comprises spine switches, while OTN fabric is comprised of OTN nodes. For the actual deployment of IP/Ethernet or OTN fabrics, there could be multiple physical fabrics of the same type co-existing in one network. Both fabrics have a common Aggregation Edge handover point to the Core Network. There might be multiple tunnels between Access Network and Aggregation Edge, which go over either the IP/Ethernet fabric or the OTN fabric. There may be multiple paths through different nodes for differentiated SLA tunnel instances in one fabric. Typically, there is only one tunnel instance for a certain SLA. The Access Network connects both IP/Ethernet fabric and OTN fabric.

  The Underlay Plane and the associated network nodes shall support network slicing.

- Service Plane

  This plane provides service connectivity for customers and the broadband service above. Compared with coarse granularity tunnels of the Underlay Plane, service connections on the Service Plane can be dynamically created when triggered by protocols, e.g. PPPoE, or configured from the MCA Plane.

A Service Access Point (SAP) provides customer service access. A Service Processing Point (SPP) performs L1/L2/L3 service processing, which may be enhanced by Edge Computing. A Service Mapping Point (SMP) is where traffic is directed to proper underlay fabric and channels. An Access Network typically contains SAP, SPP and SMP. Besides providing the access function, it also identifies services, adds or removes encapsulations, and directs the traffic to the proper underlay fabric and channels. An Aggregation Edge typically contains SPP and SMP, because it needs to perform service-specific processing and egress/ingress traffic mapping to appropriate underlay tunnels.

A service connection refers to the service pipe between a Service Access Point (SAP) from the Access Network and the Service Processing Point (SPP) on the Aggregation Edge. Examples of SPP on the Aggregation Edge are pBNG, wholesale Gateway, VPN PE and VNF for value-added services. Internet service pipes between ONU and pBNG are typical service connections. The Service Plane also provides service connections between SPPs, e.g. a service chain between a vCPE instance and a vFirewall instance, a VPN from the OLT to the Aggregation Edge. For IP based services, the SPP in the Access Network can perform subscriber authentication, while pBNG mainly terminates PPPoE services.

By defining new SPPs, new services can easily be created by programming service chains with SPPs.

The Service Plane is decoupled from the Underlay Plane. The Underlay Plane is unaware of changes in the Service Plane, e.g. adding, deleting and directing service traffic to SAPs and SPPs. The SAP and SPP can be scaled independently. The Service Plane can support multiple services with different SLAs. The requirements for deploying services on the Service Plane include connecting endpoints with guaranteed SLAs. The Service Plane shall negotiate resource requirements with the Underlay Plane, which is coordinated by the MCA Plane. It is unnecessary for the Service Plane to be aware of the creation of paths through network nodes, protection, etc.

- Management, Control & Analytics (MCA) Plane:

MCA Plane is the intelligent core of the network, which is in charge of management, control and analytics of the complete network. It is comprised of three logical components. However, the logical components can be implemented as distributed, centralized or hybrid mode. So the functional allocation to locations in the network topology is for further study:

- Digital Twin: The digital twin of the network is the model of the network, including available resources and configurations. The digital twin also contains an equivalent model of the running network. A network digital twin is generated through the real-time collection of network status and combining that with network resources and configurations. Network statistics are continuously computed. A digital twin is the real-time status and configuration of the network, which is the input for autonomous operation and artificial intelligence-based analysis.

- Autonomous Management and Control: This is the main function for network configuration, service deployment, and network operation. Besides the controllers for Service Plane and Underlay Plane, it also contains Intent Engine and Autonomous Engine:

    - Intent Engine: provides an Intent API for the OSS. The Intent API is an interface similar to natural language, describing "what I want". It is abstract and decoupled from specific network configurations. The Intent Engine can translate and understand the intent from the interface and drive corresponding operation, validation and feedback.

    - Autonomous Engine: implements operations such as resource management, device management, service deployment and tunnel selections on the Underlay Plane. It also implements resource management, device management and service deployment on the Service Plane. One important function of the Autonomous Engine is the coordinated configuration of the planes, which enables plug and play of network nodes, and programmability of both underlay tunnels and services.

- AI analyser: analyses network data, identifies, locates and predicts network failures, provides management tools for QoE and analysis tools for network operations. It includes the Analysis Engine and the AI Engine:

    - Analysis Engine: a data management platform and algorithms for analytics. Analysing network digital twin enables optimal tunnel selection on Underlay Plane, identifies and analyses network failures, and drives close loop control of the Autonomous Engine.

- AI Engine: it performs reasoning and training using Artificial Intelligence. The Analysing Engine leverages the AI Engine for analytics and reasoning, in order to perform prediction of network failure and usage, and failure identification and analysis.

5.3 Network topology and interfaces

5.3.1 Network Overview

The F5G network architecture is developed based on the current fixed network deployment and provides more Full Fibre Connections (FFC) with high-quality user experience (GRE).

Compared with previous generations, the introduction of FTTR will be a major improvement in fibre connection numbers. FTTR is not restricted to residential customers but can also be applied to business customers. This will fundamentally change the network topology, flow model and management.

Considering GRE, E2E service quality relies on QoS for each network segment, where network topology and technologies play an important role. For example, for Cloud VR, Cloud VR terminal devices communicate with the Cloud VR Service Platform through the CPN, the Access network and the Aggregation Network. All three segments need to provide good quality to guarantee an E2E high-quality user experience.

PON can provide on-premises network connectivity and is considered part of the CPN (use case #4 in IETF RFC 8453 [1]). XG(S)-PON is the leading F5G Access Network technology. For the Aggregation Network, IP/Ethernet based network has been widely deployed for years. For residential customers, BNG is necessary for subscriber authentication, authorization and accounting. However, for business customers, especially Private Line customers, the BNG may not be required.

Provisioning and management of MPLS-based VPN is complicated, especially Traffic Engineering (TE), which typically needs manual configuration.

To improve the flexibility, efficiency and performance of the Aggregation Network in F5G, an OTN network is introduced to complement the IP/Ethernet-based network and build a full fibre E2E network. F5G requires differentiated carrier capabilities to support high-quality services with guaranteed bandwidth and latency, as well as low cost best-effort services. The IP Network can be improved with new IP technologies to meet the requirements of GRE and potentially simplify the management. OTN can be used to provide high quality carrier service, which is enhanced by adding fine granularity. There are several benefits with the addition of OTN, including supporting transparent transport, high bandwidth multiplexing, powerful OAM, etc.

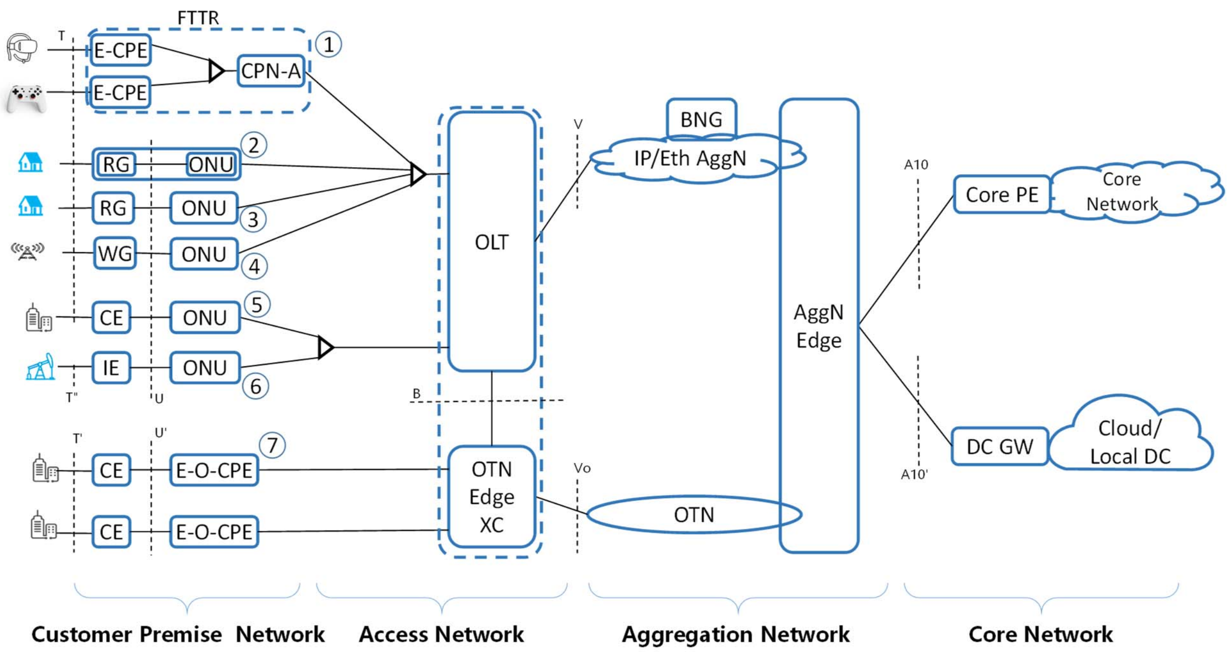

Figure 2: F5G Network topology