PCEI Architecture Document

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Blueprint overview/Introduction

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The purpose of Public Cloud Edge Interface (PCEI) Blueprint family is to specify a set of open APIs for enabling interworking between multiple functional entities or Domains that provide services needed for implementation of Edge capabilities/applications that require close integration between the Mobile Edge, the Public Cloud Core and Edge as well as the 3rd-Party provided Edge functions. As Public Cloud Service Providers and 3rd-Party Edge Compute /Application Providers deploy Edge instances to better serve their end users and applications, Telco/Mobile Network Operator (MNO) Edge deployments offer many opportunities for collaboration by exposing their network capabilities to provide value added services (note that in this document the terms Telco and MNO are used interchangeably).

Currently, the challenges include (but not limited to):

- How to interwork the public cloud management interface with telco orchestration interface?
- How to open more MNO capabilities to Public Cloud (and vice versa) and enable the DevOps model?
- How to open MNO capabilities to 3rd-Party Edge Compute/Applications (and vice versa)?
- How to manage and monitor these different APIs in an efficient way?
- How to ensure security such as avoiding the DDOS or SQL injection attack to the telco core network?
- How to leverage interconnection and network capabilities to provide value added services?
- How to leverage distributed Data Center infrastructure to instantiate Edge functions?
- How to enable orchestration of appropriate compute and network hardware resources used by the Edge functions/applications (including the Mobile Edge)?
- How to enable a flexible API architecture for multi-MNO, multi-Cloud, multi-MEC (Multi-access Edge Compute) interworking?

By leveraging Data Center and Interconnection infrastructures, this BP family is targeted to develop solutions addressing these challenges for MNOs, Public Cloud and 3rd-Party MEC providers,.

Use Cases

The Mobile Edge deployments will provide APIs to support below capabilities:

1. UPF Distribution/Shunting -- distributing User Plane Functions in the appropriate Data Center Facilities on qualified compute hardware for routing the traffic to desired applications and network/processing functions/applications.
2. Local Break-Out (LBO) – Examples: video traffic offload, low latency services, roaming optimization.
3. Location Services -- the location of a specific UE, or identification of UEs within a geographical area, facilitation of server-side application workload distribution based on UE and infrastructure resource location.
4. QoS acceleration/extension – provide low latency, high throughput for Edge applications. Example: provide continuity for QoS provisioned for subscribers in the MNO domain, across the interconnection/networking domain for end-to-end QoS functionality.
5. Network Slicing provisioning and management - providing continuity for network slices instantiated in the MNO domain, across the Public Cloud Core/Edge as well as the 3Rd-Party Edge domains, offering dedicated resources specifically tailored for application and functional needs (e.g. security) needs.
6. Mobile Hybrid/Multi-Cloud Access - provide multi-MNO, multi-Cloud, multi-MEC access for mobile devices (including IoT) and Edge services /applications
7. Enterprise Wireless WAN access - provide high-speed Fixed Wireless Access to enterprises with the ability to interconnect to Public Cloud and 3rd-Party Edge Functions, including Network Functions such as SD-WAN.
8. Authentication – provide service enablement (e.g., two-factor authentication) used by most OTT service providers
9. Security – provide service enablement (e.g., firewall service insertion)

Where on the Edge

Public Cloud Service Providers and 3rd-Party MEC Providers are deploying Edge instances to better serve their end-users and applications, A multitude of these applications require close inter-working with the MNO Edge deployments to provide predictable latency & throughput, reliability, and other telco-grade requirements. The purpose of this blueprint family is to specify a standard set of APIs to expose towards Public Cloud and 3rd-Party MEC Service Provider instances at the Edge.

The need to interface and exchange information through these open APIs will allow competitive offerings for Consumers, Enterprises, and Vertical Industry end-user segments. For instance, open APIs will be provided between Telcos and public cloud edge compute platforms such as Google Cloud Platform (GCP) Anthos, AliCloud Edge Node Service (ENS), AWS Wavelength, Microsoft Azure Edge Zones, Tencent ECM, to name a few. These APIs are not limited to providing basic connectivity services but will include the ability to deliver predictable data rate, predictable latency, reliability, service insertion, security, AI and RAN analytics, network slicing, and more. These capabilities are needed to support a multitude of emerging applications such as AR/VR, Industrial IoT, autonomous vehicles, drones, Industry 4.0 initiatives, Smart Cities, Smart Ports. Other APIs will include exposure to edge orchestration and management, Edge monitoring (KPIs), and more. These open APIs will be the foundation for service and instrumentation APIs when integrating with public cloud development environments and will be defined as part of the implementation. Even though these APIs will be common across all Telco operators, the differentiation will based on services provided through those APIs.

Overall Architecture

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The high-level architectural view of PCEI is shown below in Figure 1. This BP will bring a new "Enabler" layer as PCEI between the Mobile/Telco Network and Public Cloud as well as the 3rd-Party MEC platforms at the Edge. The PCEI Enabler layer is responsible for :

- API Gateway & Management
- Authentication
- Policy
- Composition
- Security services
- Discovery
- SDK

In the Southbound direction (PCEI to MNO), this layer will encapsulate the core network capabilities, interwork with BSS/OSS/management system from telco operators. Depending on the business model, this layer may be deployed as part of the MNO functions on MNO edge hardware resources. The PCEI Enabler may also be deployed by a neutral operator (e.g. a Data Center and Interconnection provider) in highly interconnected and distributed locations where the Public Clouds, the 3rd-Party MEC providers as well as many other ecosystem partners meet and exchange traffic and data.

Note that as part of the Southbound capabilities, there is a need for APIs exposed by the Data Center providers, Bare-Metal Hardware Orchestration providers as well as the Interconnection providers in order to facilitate distribution of processing resources as well as the interconnection between multiple entities providing/consuming Edge services/applications.

In the Northbound direction (PCEI to Public Cloud and/or 3rd-Party MEC providers), it exposes RESTFUL APIs and SDKs to be called and integrated by the Edge services/application providers.

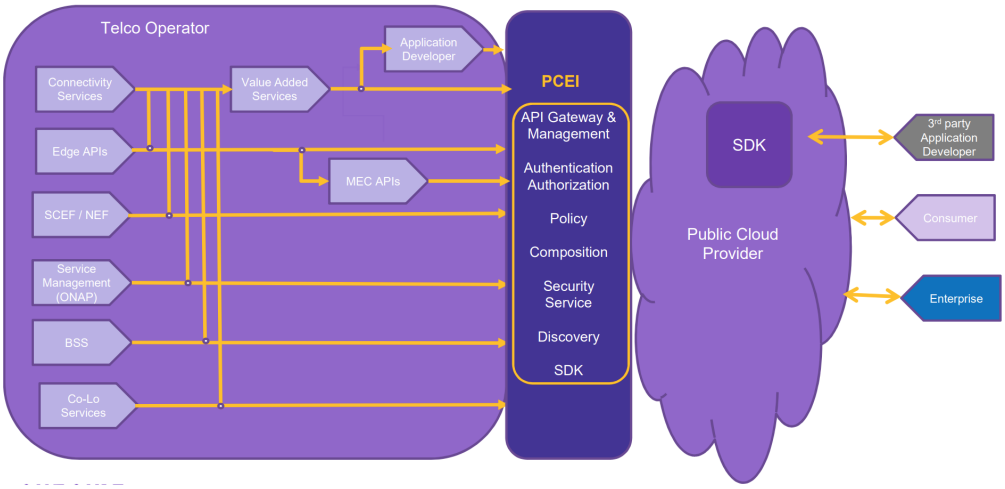

Figure 1. High-level Architecture of PCEI.

Platform Architecture

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The PCEI Enabler is expected to provide Multi-Domain Interworking capabilities between the following domains:

- The Mobile Network Operator (MNO) Domain
- The Public Cloud (PC) Domain. This includes the following sub-domains:
  - The Public Cloud Core (PCC)
  - The Public Cloud Edge (PCE)
- The 3rd Party Edge (3PE) Domain
- The Interconnection of Core and Edge (ICE) Domain
- The Data Center Facility (DCF) domain

The following figure shows high-level relationships between the domains:

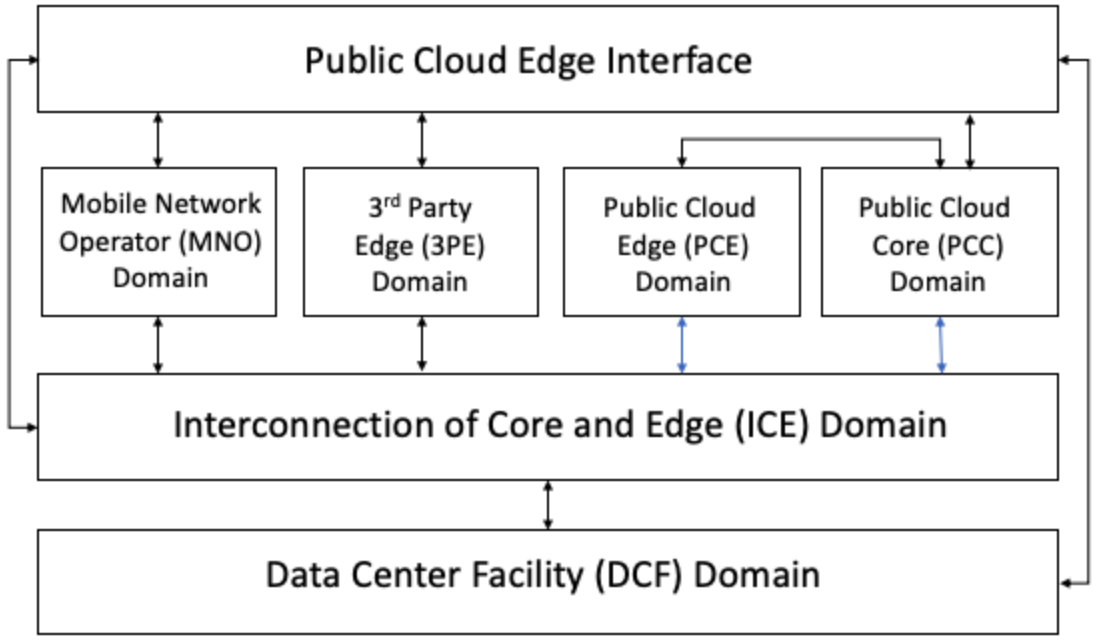

Figure 2. PCEI Domains.

The **Data Center Facility (DCF) Domain**. The DCF Domain includes Data Center physical facilities that provide the physical location and the power/space infrastructure for other domains and their respective functions.

The **Interconnection of Core and Edge (ICE) Domain**. The ICE Domain includes the physical and logical interconnection and networking capabilities that provide connectivity between other domains and their respective functions.

The **Mobile Network Operator (MNO) Domain**. The MNO Domain contains all Access and Core Network Functions necessary for signaling and user plane capabilities to allow for mobile device connectivity. These functions include the Radio Access Network (RAN), including the 5G New RAN (5GNR), Packet Core, including the Virtualized Evolved Packet Core (vEPC) and the 5G Core (5GC).

The **Public Cloud Core (PCC) Domain**. The PCC Domain includes all IaaS/PaaS functions that are provided by the Public cloud to their customers. These include Virtual Private Cloud and Public/Private Networking capabilities.

The **Public Cloud Edge (PCE) Domain**. The PCE Domain includes the PCC Domain functions that are instantiated in the DCF Domain locations that are positioned closer (in terms of geographical proximity) to the functions of the MNO Domain. In general, the PCE functions are expected to be managed from the PCC functions.

The **3rd party Edge (3PE) Domain**. The 3PE domain is in principle similar to the PCE Domain, with a distinction that the 3PE functions may be provided by 3rd parties (with respect to the MNOs and Public Clouds) as stand-alone instances of Edge Computing resources/applications.

PCEI Reference Architecture

The PCEI Reference Architecture and the Interface Reference Points (IRP) are shown in the figures below. Note this figure also provides a component layer view of the PCEI Architecture:

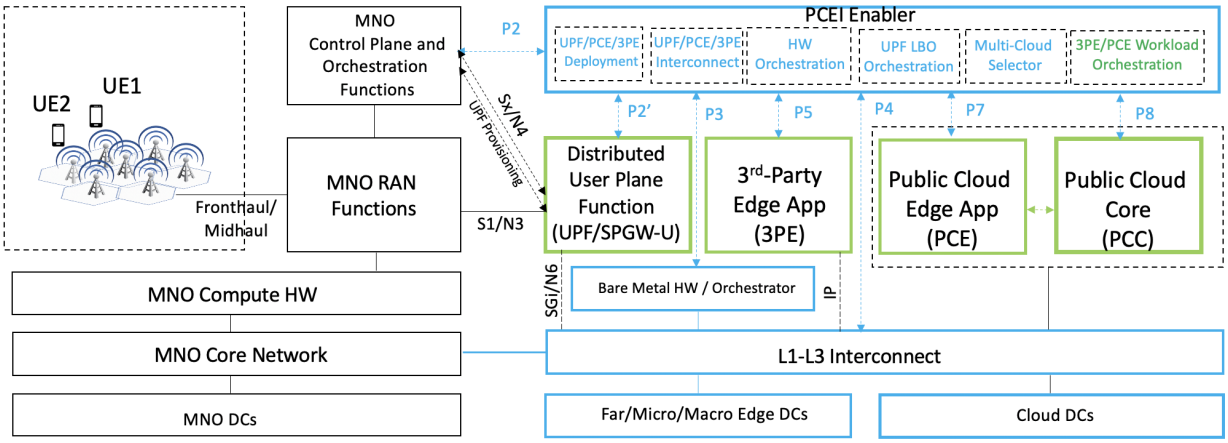

Figure 3a. The PCEI Summary Reference Architecture.

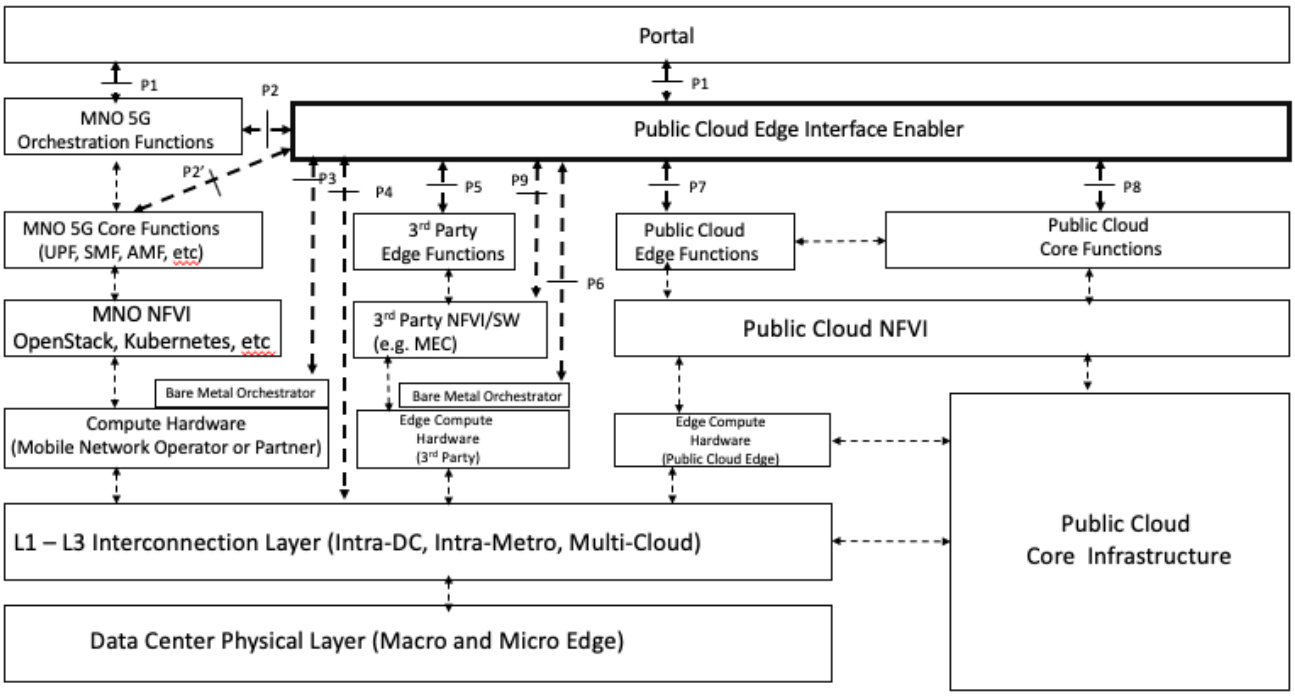

Figure 3b. The PCEI Detailed Reference Architecture.

The PCEI Reference Architecture layers are described below:

The PCEI Data Center (DC) Physical Layer belongs to the DCF Domain and provides the physical DC infrastructure located in appropriate geographies (e. g. Metropolitan Areas). It is assumed that the Public Cloud Core infrastructure is interfaced to the PCEI DC Physical Layer through the PCEI L1-L3 Interconnection layer.

The PCEI L1-L3 Interconnection Layer belongs to the ICE Domain and provides physical and logical interconnection and networking functions to all other components of the PCEI architecture.

Within the MNO Domain, the PCEI Reference Architecture includes the following layers:

- Compute Hardware. This includes Compute, Network and Storage resources that support MNO functions. Note that the PCEI Reference Architecture recognizes a model, where an MNO has the ability to distribute the compute infrastructure in appropriate locations in the DCF Domain in order to satisfy performance and functional requirements for the targeted application use cases. For example, an MNO may wish to implement a Local Break-Out (LBO) in locations that are geographically closer to the mobile subscribers and uses compute hardware provided by a qualified Bare Metal service provider.
    - The PCEI Architecture further recognizes a model, where the Compute Hardware layer is accessible via the Bare Metal Orchestrator that enables dynamic instantiation of compute/network resources for the MNO functions.
- Network Function Virtualization Infrastructure (NFVI). This is the virtualization layer (e.g. OpenStack, Kubernetes) that may be specific to MNO requirements and provides the ability to support MNO functions such as the 5GC User Plane Function (UPF).

- MNO Core Functions. This layer corresponds to the key MNO Core functions applicable to the PCEI. These functions include (but not limited to): UPF, SMF and other applicable 4G vEPC and 5G Core functions.
- MNO Orchestration Functions. These functions are responsible for communicating the MNO service/performance requirements to the PCEI Enabler and for orchestrating services within the MNO Domain. Examples of these functions include NSSF, NRF, etc.

Within the Public Cloud Domain, the PCEI Reference Architecture includes the following layers:

- Public Cloud Core Infrastructure. This includes all IaaS/PaaS functions that are provided by the Public cloud to their customers. These include Virtual Private Cloud and Public/Private Networking capabilities.
- Public Cloud Edge Compute Hardware. This is Compute, Network, and Storage resources that support PCE functions. The PCE compute hardware is usually a vertically integrated hardware resource set controlled by the PCC Infrastructure and connected to it by means of the L1-L3 Interconnection layer.
- Public Cloud NFVI. This is the virtualization layer specific to the Public Cloud service provider.
- Public Cloud Core Functions. These functions are the specific capabilities offered by the Public Cloud service provider to its customers. Examples include Virtual Public Cloud (and equivalents), Virtual and Physical Private Networking.
- Public Cloud Edge Functions. A set of Public Cloud resources executing on PCE hardware and controlled by the PCC functions.

Within the 3rd Party Edge Domain, the PCEI Reference Architecture includes the following layers:

- Compute Hardware. This includes Compute, Network, and Storage resources that support 3PE functions. Note that the PCEI Reference Architecture recognizes a model, where a 3rd Party provider has the ability to distribute the compute infrastructure in appropriate locations in the DCF Domain in order to satisfy performance and functional requirements for the targeted application use cases. For example, an online gaming provider may wish to implement their services in locations that are geographically closer to the mobile online gaming subscribers, and use compute hardware provided by a qualified Bare Metal service provider.
    - The PCEI Architecture further recognizes a model, where the Compute Hardware layer is accessible via the Bare Metal Orchestrator that enables dynamic instantiation of compute/network resources for the 3PE functions.
- 3rd Party Edge NFVI layer. These are the NFVI software and capabilities needed to support functionality such as the Multi-Access Edge Computing (MEC).
- 3rd Party Edge Functions. These are edge computing application functions including the Network Functions (NFVs, e.g. SD-WAN, vFW, vRouter) and the Processing Functions (e.g. CDN Cache, IoT Gateways, AI Inferencing Model).

The PCEI Enabler. A set of functions that facilitate the interworking between PCEI Architecture Domains. The structure of the PCEI Enabler is described later in this document.

The PCEI Portal. An optional component of the PCEI Architecture responsible for providing the users of PCEI a way to express and communicate their intended functional, performance, and service requirements.

PCEI Interface Reference Points

P1 – User Intent. Provides ability for User/Customer to specify PCEI access and functional requirements E.g. Type of Access, Performance, Connectivity, Location, Topology

P2 – Interface between PCEI and Mobile Network. Provides the ability to accept requests from MNO for PCEI service and request MNO to provide 4G/5G access to PCEI customers. E.g. Network Slicing, LBO.

P2' - Interface between PCEI and the MNO Core Functions such as UPF, SMF. In case of a UPF the P2' interface can be used to configure the parameters responsible for interfacing the UPF and the virtual/contextual configuration structures within the UPF with the PCC/PCE and 3PE resources by way of the L1-L3 Interconnection layer. The P2' interface implies the availability of standard or well-specified UPF provisioning models provided by MNOs.

P3 – Interface between PCEI and Compute Hardware Orchestrator for distributed MNO functions (e.g. non-MNO locations). Provides ability for PCEI to trigger orchestration of appropriate HW resources for MNO User Plane and other appropriate functions. May be triggered through P2 by MNO

P4 – Interface between PCEI and Interconnection Fabric. Provides abilities to request and orchestrate network connectivity and performance KPIs between MNO UPF, Cloud Core and Edge resources (including 3rd Party Edge)

P5 – Interface between PCEI and 3rd Party Edge Functions (e.g. NFV). Provides abilities to access Edge APIs exposed by 3rd Party Edge Functions (e.g. deployment of NFVs and Edge Processing workloads)

P6 – Interface between PCEI and Edge Compute Hardware Orchestrator. Provides the ability for PCEI to trigger orchestration of appropriate HW resources for Edge Compute functions including Public Cloud Edge and 3rd party Edge.

P7 – Interface between PCEI and Public Cloud Edge Functions (maybe part of P8). Provides abilities to access APIs to deploy Public Cloud Edge functions /Instances (may be done through P8)

P8 - Interface between PCEI and Public Cloud Core Functions (may include control over Public Cloud Edge functions). Provides the ability to access Public Cloud APIs including the ability to deploy Public Cloud edge functions.

P9 - Interface between PCEI and the NFVI layer of the 3PE Domain. P9 may be used If an MNO chooses to expose the NFVI layer to PCEI.

Software Platform Architecture

PCEI Enabler is based on EMCO - Edge Multi-Cluster Orchestrator:

https://wiki.onap.org/pages/viewpage.action?pageId=84668166

The target software architecture of the PCEI Enabler based on EMCO is shown below. Note that all references to specific APIs and SDOs are for mapping purposes only, subject to ongoing analysis and do not indicate compliance with APIs/SDO specs.

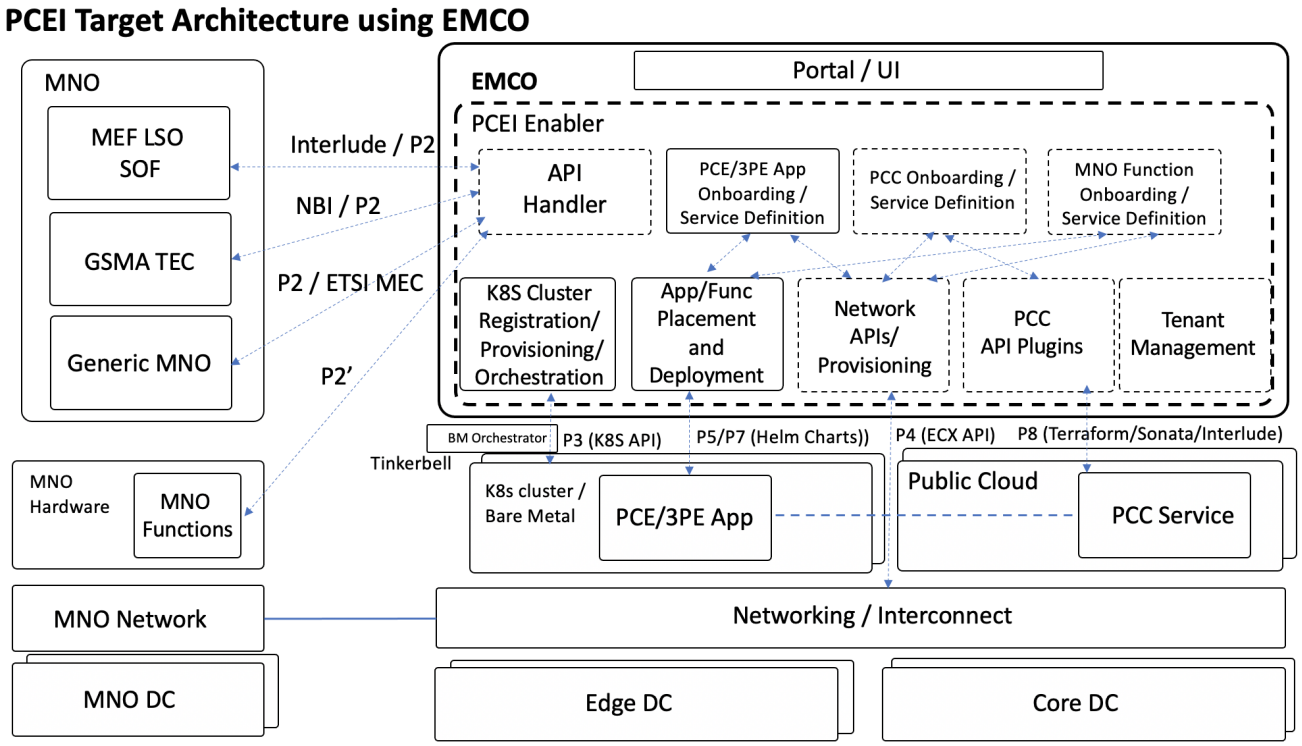

Figure 4. General structure of PCEI Enabler.

Components of Public Cloud Edge Interface

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APIs

APIs with reference to Architecture and Modules

High-Level definition of APIs are stated here, assuming Full definition APIs are in the API documentation

Hardware and Software Management

Objectives

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provide an end to end deployment with this enable layer between telco and public cloud.

Licensing

- GNU/common license