White Paper TE-524262

Empowered by Innovation

NEC Virtualized Evolved Packet Core – vEPC

Design Concepts and Benefits

INDEX

Leading the transformation into Mobile Packet Core Virtualization

Massive growth in traffic fueled by the proliferation of smart devices, the popularity of online videos and the emergence of Internet of Things (IoT) is putting an ever-increasing pressure on packet core infrastructure. Such emerging services are expected to bring new revenue opportunities to communication service providors (CSPs), but in the meantime, adoption of new services will also diversify network requirements. Network capacities to be allocated and KPI qualities to be assured vary according to service types and purposes. For example, IoT service to share patient monitoring data in an ambulance with emergency medical staff in a remote site mandates very low latency with mobility and probably high volume of data transport. On the other hand, IoT service using sensors for climate observation requires no mobility and allows latency, but sensors to observe landslide risks require no mobility but very low latency to alert people who are in the hazard area before the landslide occurs. Diversity of such IoT services will multiply mobile devices in number and in variety.

Tackling communication demands with diversified varieties of services and traffic behaviors and large number of devices—while optimizing resource usage and total cost of operation—is inevitable for CSPs to plan the next evolution of mobile packet cores. Faced with these challenges, many CSPs have choosen to virtualize functions on open platforms, breaking away from expensive, purpose- built hardware appliances for each network function. Mobile core network function's virtualization provides operators with flexibilities in function deployment, capacity allocation and performance delivery.

An example of virtual mobile core benefits is to enable CSPs to offer EPC-as-a-service bundled with other value-added network services (IPS/IDS, video optimization, firewall, DPI, etc.) in a multi-tenant fashion, which expands target users to include enterprises, content service providers, IoT service providers without any dedicated service platform. Such a packet core infrastructure-as-a-service will provide flexible, rapid and on-demand infrastructure deployment and capacity provisioning while increasing options in function bundles, service sets and service level agreements.

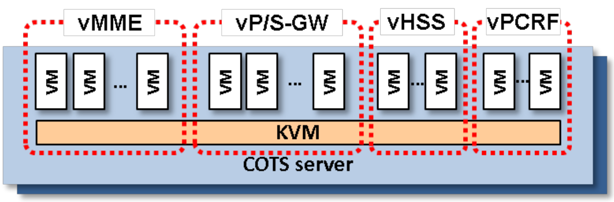
Closed solutions on application-based platforms, even if virtualized, cannot deliver the benefits of virtualization with multi-tenant resouce sharing – a key requirement in any service-driven network abstraction. Platforms in an NFV environment need to be open and ecosystem-based to enjoy the real values brought by NFV, such as function allocation flexibility, cost and resource optimization, management simplicity and automation, and service agility and enrichment.

NEC is one of the first to deploy virtualized Evolved Packet Core (vEPC) in the field to provide mobile packet core NFV services. NEC vEPC marks a key step towards operators' much needed transformation into the NFV space. Stability of NEC vEPC application is already proven through field operation for more than a year to date. In the meantime, NEC has proven openess of its EPC applications including User Plane processing, which worked on a third party platform achieving carrier-grade stability, reliability, resiliency and high performance during Proof of Concept testing by a major CSP. In addition, it has successfully completed interoperabilities to physical-based neighboring nodes, data plane performance evaluation and resiliency testings conducted at multiple CSP sites.

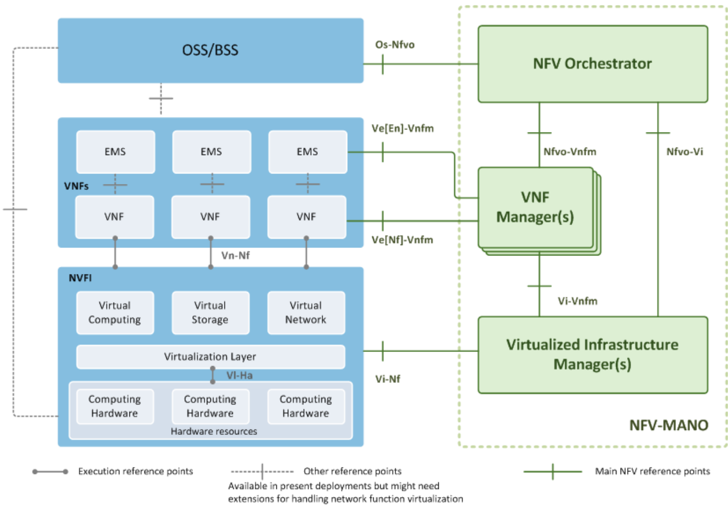
Openness with Carrier-Grade Quality

vEPC in NEC's virtual network solution suite, complied with 3GPP standards, provides all the EPC functions as virtual network functions (VNFs); vMME (Mobility Management Entity) and vS/P-GW (Serving and PDN gateway), vHSS (Home Subscriber Server)and vPCRF (Policy Control and Charging Rules Function). vS/P-GW, which can integrate vSGSN (Serving GPRS Support Node) and vGGSN (Gateway GPRS Support Node) functionalities, can be deployed as totally separated vS-GW and vP-GW or integrated vS/P-GW with collapsed interface.

NEC vEPC runs on open platform. It runs on industry standard and open sourced hypervisor such as KVM, and fully aligned with the ETSI NFV recommendation as shown below. NEC vEPC achieves carrier-grade quality in the VNF application layer with its resiliency inherited from decades of network deployment experience, which is augmented with new virtualization and cloud technologies. Apart from the VNF appliances, NEC also provides add-ons and plug-ins to open NFVI and VIM platform and sophisticated Management and Network Orchestration (MANO) solutions, which provide end-to-end control of both NEC and third-party VNFs with carrier-grade quality. The MANO system contains service orchestrator, VNF manager and VIM (Virtual Infrastructure Manager) which supports OpenStack.



NEC vEPC virtualized environment



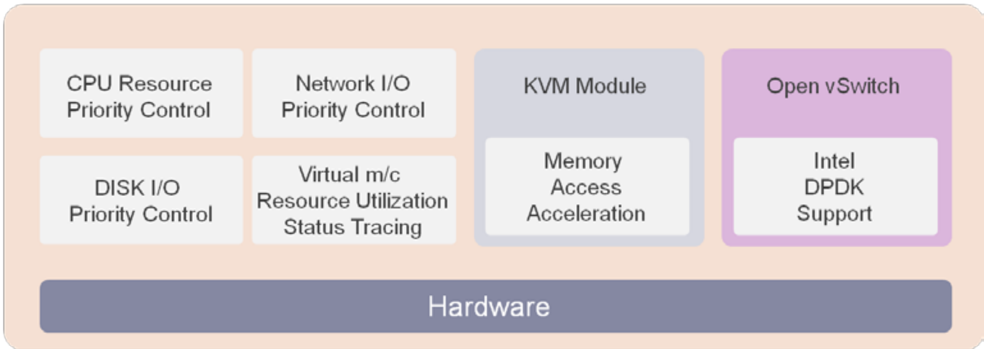
NFV architecture

The NEC vEPC is aligned with the ETSI NFV recommendations

Even with benefits of NFV, CSPs, who are keen to be carrier-grade and own responsibilities to assure network quality and resiliency for life-critical communications such as voice over LTE, may feel anxious about service resiliency with openness and commodity IT technologies. NEC provides solutions to eliminate such anxiety even on open platform,filling in the gaps between open standard platforms and network-specific requirement.

Fundamental problems in an IT-grade virtualized environment are: a) Processing delay and high variability in performance due to hardware resource contention between VMs; b) Degradation of performance due to virtualization layer overhead; and c) I/O throughput limitation by the introduction of vSwitch for network virtualization. Mobile operators expect a predictable environment without packet processing delay that achieves high I/O throughput for user-plane traffic. For example, a VoLTE call will require certain packet delay and jitter bound from P-GWs in order to meet end-to-end QoS requirements.

In order to address these challenges, NEC has contributed several extension to open KVM hypervisor functionality to eliminate overhead and hardware resource contention, as shown in figure below. Furthermore, in collaboration with Intel, NEC vEPC leverages DPDK to provide I/O throughput optimization for user -p-lane traffic. Additionally, NEC vEPC adds an extensive set of diagnostic and tracing tools to enhance fault management.



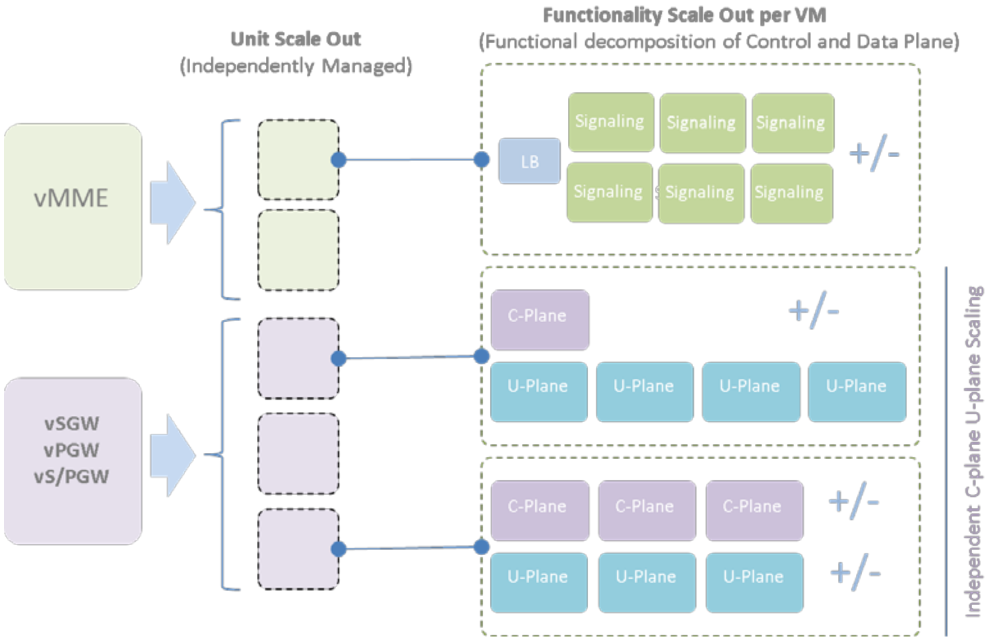
Extensions to KVM

Additionally, NEC provides plug-in to OpenStack agents to realize a quick hardware failure detection and failover trigger for the application and management and orchestration system. It enables vEPC application VM to initiate failover in real time and without service interruption. Another plug-in provides capabilities to collect hardware architecture information considering NUMA and CPU pinning, virtual network status and physical machine resource availability so that VMs can be allocated to appropriate physical environments to deliver performance stability and make optimal use of hardware resources. The plug-ins are the result of rich and deep knowledge that NEC experienced both in commercial telecom network and IT domain for decades.

vEPC System Architecture Overview

Beyond openness with the qualities, the distinct advantage of NEC vEPC is flexibility to scale elastically per intelligent decomposed function, maximizing agility and elasticity. The decomposition separates the control plane (C-Plane) from the data plane (U-Plane). Even in vEPC gateway, control plane and data plane are saparated in each functional VM, resulting in totally independent scaling of control plane and data plane. NEC vEPC system components can be provisioned on-demand and can be scaled based on diverse and time-varying control and data plane traffic requirements with flexible C-Plane and U-Plane capability balancing.

As shown below, the decomposed elementary functions, C-Plane function and U-Plane processing of vS/P-GW run as each separte VM, which enables operators to deploy each function with optimzed balance. In case of C-Plane and U-Plane integrated architecture, function capacities can only scale by fixed performance balance, but the C-Plane and U-Plane separated architecture enables each function to scale independently and with best balance for each service type and traffic requirement.



NEC vEPC features an intelligent function decomposition that enables agility and elastic system scaling

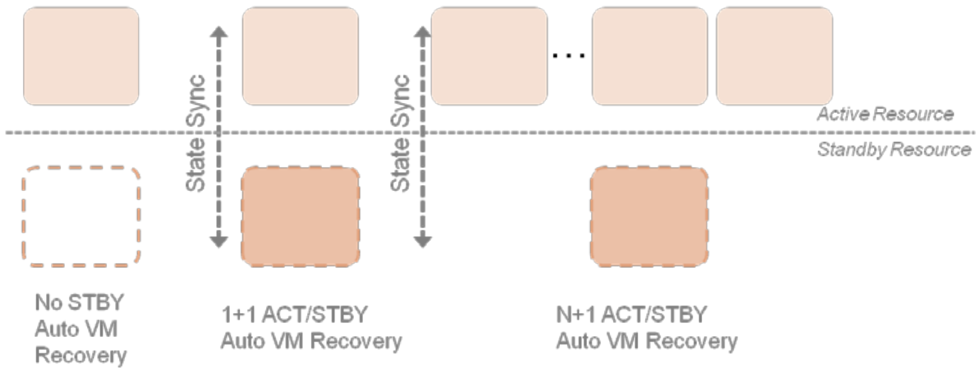
The architecture provides flexibility to reactive (auto-scaling) and predictive (service order based) horizontal scaling of resources by automating the provisioning of the functional processing unit through virtual machine instantiation. In the case of auto-scaling, the system can scale each functional unit capability while monitoring real-time load parameters, thereby adapting to time-varying application specific traffic. Service order-based scaling allows service end users to request capacity scaling through their service portal, and predictive scaling allows operators to allocate capacities at a service launch or planned capacity expansion, whereby the VNF manager provisions the appropriate amount of resources to meet capacity demands. It will take only minutes for the scaling on a common platform, and such dynamic VM deployment capability will ensure creation and preservation of revenue opportunities through service agility and business planning flexibility.

The C-Plane and U-Plane separated architecture also brings about deployment flexibility. For example, operators who want to offload data plane traffic can deploy vS/P-GW's U-Plane in distributed local data center for local breakout, while deploying vS/P-GW's C-Plane in centralized data center with MME functionality, which will result in transaction optimization and cost savings.

In the meantime, it also simplifies the operation and management of packet cores via smart automation and orchestration of provisioning and other operational processes. At the management and provisioning level, vEPC defines logical units which can be independently managed, deployed and scaled. Operators can configure logical units consisting of an optimized number of functional VMs by increasing or decreasing flexibly the number of VMs on common hardware resources. For example in the case of vMME, signaling capability per logical system unit can be scaled along with adding/deleting signaling processing VMs for operator's convenience of management.

Redundancy and Auto-healing

Migrating functions to a virtualized environment brings challenges in stability and availability of the overall system. NEC vEPC tackles these challenges through well-designed redundancy and auto-healing schemes in order to meet carrier-grade requirements. As shown in the figure below, three different redundancy mechanisms each have a different impact on resource requirements. CSPs can select suitable configuration considering each service requirement and service level thresholds. When it takes Active-Standby configuration (1+1, N+1), in-memory state synchronization enables fast failover with consistent state migration.



NEC vEPC's redundancy, failover and VM recovery schemes meet carrier-grade requirements

The entire process of functional failover is done autonomously by the application. As NEC provides plug-ins to the OpenStack agent for extensive virtual and physical system monitoring, the entire recovery process for failover is immediately automated and quickly completed. In addition to failover, VNF manager for vEPC initiates an auto-healing process to create a new standby VM after failover. It drives availability higher by making it always run in dual mode even right after a failover.

A key requirement when deploying VNFs is to have a predictable virtual environment, while ensuring optimal resource usage. From a carrier-grade standpoint, use of NEC Converged E2E Orchestration ensures intelligent affinity control. For example, active and standby virtual machines are located on separate physical machines to ensure high availability in case of hardware failure.

Besides functional application redundancy, NEC vEPC also provides physical and virtual network level redundancy by having dual paths for inter-virtual machine communication to achieve carrier-grade reliability.

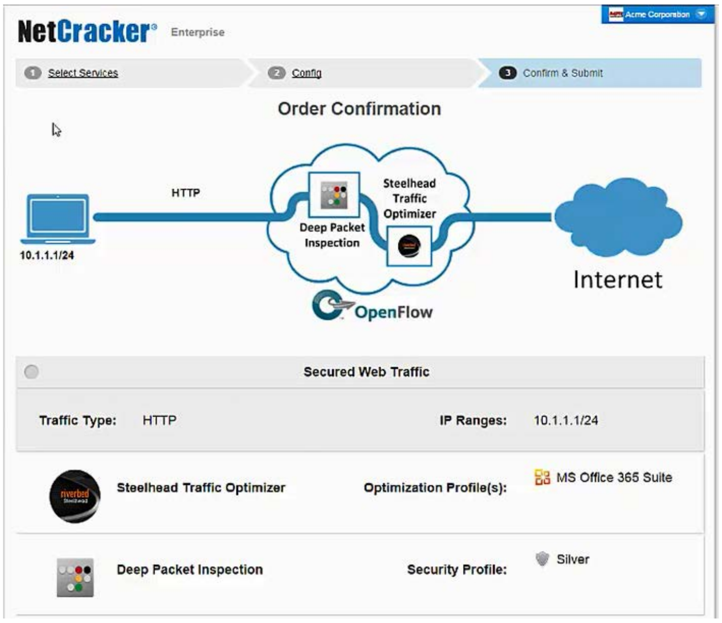
Self-Service Portal and E2E Orchestration

Introduction of SDN/NFV brings new opportunities for CSPs. However it also raises additional requirements to supporting systems infrastructure, such as:

- Customer control over the service ordering process
- Policy-driven, real-time, event-driven orchestration at scale
- Real-time management of virtualized network resources, including on-demand creation of virtual resources
- Support of new service models enabled by SDN/NFV (e.g. on-demand, rather than pre-provisioned approach)
- Fully automated closed control loop between Fulfillment and Assurance processes
- Adoption of best practices from IT world

NEC addresses all these new requirements and associated challenges through intuitive Self-Service Portal and Converged End-to-end Orchestration solutions, which are aligned with ETSI NFV Management and Orchestration (MANO) and is unique in the SDN/NFV marketplace because it enables end-to-end orchestration of service provisioning and assurance for hybrid networks that comprise both virtualized SDN/NFV-based components and traditional network technologies.

Excellent self-service capabilities become even more crucial to get all benefits of network virtualization. NEC Self-Service Portal is designed to cover all aspects of efficient self-care function, which in conjunction with end-to-end orchestration provides excellent capabilities for a customer with online service activation, new service ordering, order status tracking, etc.



NEC's intuitive self-service portal

The Self-Service Portal provides unified look & feel across applications, ease of use, and unified operational procedures and delivers the following key functional capabilities:

- Service monitoring
- Service modification
- Value added services ordering
  - Malware protection
  - personalized security services
  - URL filtering
  - Other

Using a common orchestration for end-to-end service management, operations, administration and maintenance reduces time and operating costs for service instantiation, monitoring and fault finding. NEC allows service providers to integrate multiple SDN/NFV appliances from different vendors without incurring significant integration costs and vendor lock-in.

End-to-end service orchestration layer integrates with existing BSS/OSS, automates service chaining across physical and network functions, and unifies policy-based service instantiation and assurance management for physical and virtual networks.

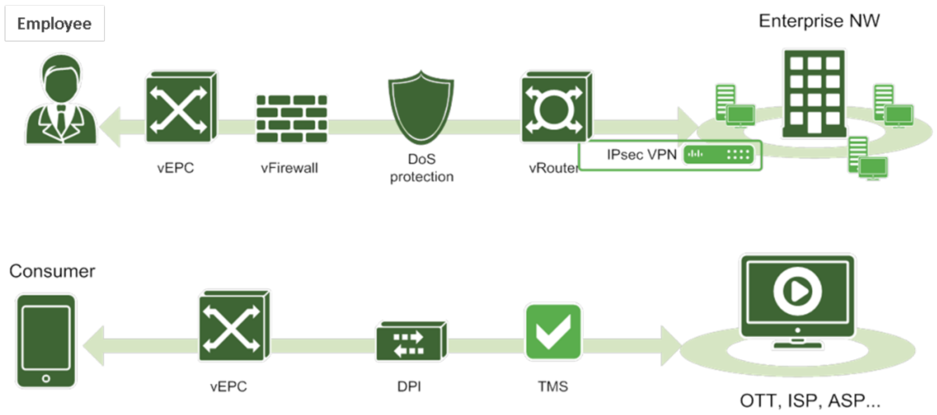
NFV orchestration layer maintains a global view of an individual NFV Infrastructure (NFVI) domain and coordinates operations of multiple VNF Managers and VIMs.

Use Cases

Dynamic service chaining

Central to NFV is the ability to compose different VNFs to provide rich and flexible end-to-end services. With the adoption of NFV, multiple virtualized SGi functions can be dynamically added to an end-to-end path through service chaining.

NEC vEPC with SGi service chaining solution has the unique ability to implement service chaining using software defined networking (SDN) or another service chaining technology so that SGi services such as virtualized router, DPI (Deep Packet Inspection), NAT (Network Address Translation), Media Optimizer, or TMS (Traffic Management Solution) could be inserted selectively in the end-to-end path. In addition, since the SGi functions provided form third parties can share common platform and hardware resources with NEC vEPC, they can be located in an optimal manner considering performance and latency. For example, with a DPI function for a specific network domain, users can be located very close or even on the same platform with vEPC data plane processing VM.



Dynamic and flexible service chaining in multi-vendor environment

Function deployment flexibility

NEC vEPC also delivers flexibility in terms of deployment options. It gives operators various deployment options according to operator's networking design or location. Operators can now deploy functionalities of S-GW, P-GW or S/P-GW either at the edge (RAN), in the Core Network (CN) or centralized or local data center site.

Because NEC vEPC takes separated C-Plane and U-Plane architecture, U-Plane processing VMs of gateway can be located near a local Point of Presence and C-Plane processing VMs can be deployed in centralized data center, if an operator finds it reasonable in performance with reduced transit cost and maintenance . In another case, deploying VNFs at existing RAN or CN site may result in better existing network utilization. In addition, deploying VNFs at common DC infrastructure can result in lower real estate cost , lower transaction latency and better automation effects. Depending on traffic profiles, network technologies and service/business models, operators now have the flexibility to choose a combination of the above deployment models in reducing overall operational cost.

On-demand auto-scaling and auto-configuration

NEC vEPC enables unique use cases that are not possible with existing physical-based EPC. One such use case is multi-tenant on-demand P-GW-as-a-service. CSPs can now offer enterprise customers services where mobile core bandwidth and applications are configured on demand from a mobile VPN service portal, enabling selection of different capacity and scale, e.g. the number of employees and networking configurations. Operators can offer suitable P-GW provisionings meeting application-specific requirements, with allowing customers to use favorite IP address ranges. It provides real-time auto-scaling and auto-configurations to meet service demands along with new application instantiation and service chaining ordered from end-users.

Service-dependent network configurations and redundancies

NEC vEPC provides various options also for redundancy configurations. For example, an IoT application like gas or electricity metering will probably not need redundancy configurations as it is only machine communication and service interruption is acceptable. However, in different IoT service cases such as in health care, where data transfers made at first aid sites to medical staff in hospitals needs very low latency and high volumes of critical data. It will need enough capacity of both C-Plane and U-Plane with severe level of redundancy. Also, data transfer for emergency and ambulance service are typically within a regional area, therefore U-Plane processing for the service

can be decentralized, resulting in higher quality of experience (QoE) from optimized data transfer routing.
Thus, flexibility in configuration, function allocation, capability balance and deployment location are all core benefits of NEC vEPC that drive optimization of a wide range of new, innovative virtualized services.

Disaster resiliency

Another important use case for vEPC is to deploy a disaster-resilient mobile core where resources can be pooled from geographically diverse sites to meet the urgent resource demands during a disaster scenario. Also, resources can be dynamically re-allocated based on priority of different services. For example, in a disaster scenario, necessacy functionality for a voice call will receive prioritized resources instead of huge data-plane centric applications such as streaming video.

Conclusions

NEC vEPC is poised to lead the transformation of operators’ mobile core infrastructure from a proprietary hardware appliance-based model to an open, virtualized and software-defined infrastructure-as-a-service model. The NEC vEPC design focuses on bringing key innovations to meet challenges in adapting to a virtualized mobile core: availability, stability, performance, agility on open platform in service provisioning and bundling, and operational simplicity. Beyond meeting the above challenges, NEC vEPC meets the central goal of any virtualized system: service optimization and agility with creating revenue opportunities through on-demand, elastic capacity scaling, efficient and dynamic service provisioning, flexible function deployment and optimized resource allocation.

Abbreviations

3GPP	Third Generation Partnership Project
API	Application Programming Interface
BSS	Business Support System
COTS	Commercial off-the-shelf
C-Plane	Control Plane
CPU	Central Processing Unit
CSP	Communication Service Provider
DC	Data Center
DPDK	Data Plane Development Kit
DPI	Deep Packet Inspection
E2E	End-to-end
EMS	Element Management System
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
GGSN	Gateway GPRS Support Node
HSS	Home Subscriber Server
IDS	Intrusion Detection System
I/O	Input/Output
IoT	Internet of Things
IPS	Intrusion Prevention System
KVM	Kernel-based Virtual Machine
KPI	Key Performance Indicator
LTE	Long Term Evolution
MANO	Management and Network Orchestration
M2M	Machine to machine
MME	Mobility Management Entity
NAT	Network Address Translation
NFV	Network Functions Virtualization
NFVI	NFV Infrastructure
NUMA	Non-Uniform Memory Access
OSS	Operation Support System
PCRF	Policy Control and Charging Rules Function
P-GW	PDN Gateway
QoS	Quality of Service
RAN	Radio Access Network
SDN	Software-Defined Network
S-GW	Serving Gateway
SGSN	Serving GPRS Support Node
S/P-GW	Serving and PDN gateway
TMS	Traffic Management Solution
U-Plane	User Plane
VIM	Virtualised Infrastructure Manager
VM	Virtual Machine
VNF	Virtual Network Function
VoLTE	Voice over LTE