Orchestrating a brighter world NEC

NEC's Cloud Native Mobile Core Blueprint to 5G Innovation

Innovating Businesses and Services through Cloud Native 5G Core Technology

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CHAPTER 1

Working toward 5G Transformation

Aiming for Innovation, not Evolution, through 5G

The fifth-generation mobile communication system (5G) promises to revolutionize the way we interact with each other, our environment and the technology.

Looking back to the history of mobile telecommunications systems, the first generation (1G) allowed voice calls on the move, 2G enabled the transmission of circuit switched data, such as sending and receiving text messages. The transmission speed was improved dramatically by 3G and packet data, which enabled rudimentary internet browsing. A further boost in the data transmission capacity in 4G allowed the streaming of music and videos.

This process reveals that the focus of improvement until 4G was user communication on cellphones and smartphones. In other words, we managed to break free of landlines, and bolstered functions and performance, but did not succeed in stepping beyond communication between people.

By comparison, 5G promises the three advantages of "high-speed and high-capacity," "ultra-reliable and low latency communication" and "massive device connectivity" right from the beginning. It focuses on communication between not only people, but also things. Furthermore, 5G leverages the benefits of the cloud in terms of cost, elasticity and scalability. As a result, it is widely anticipated to spur the next-generation industrial revolution, which will create new value by driving innovation across industries and communities. Many industries, governments, organizations and businesses are currently discussing how to fully leverage 5G.

In other words, 5G is less an evolution of existing communications technologies, than a communication disruption that will pioneer a brand-new world. Fundamentally, there are great expectations from 5G across industries and businesses.

The Vision for the Future that 5G Will Realize

As mentioned above, 5G also targets communication between things, and there are high expectations for its use across a multitude of industries and businesses with many practical applications.

For example, in the logistics industry, 5G use cases such as truck platooning and drone delivery are being realized. It can also be used for remote control of construction equipment and agricultural work robots. Furthermore, manufacturers will be able to deploy local 5G networks in specific areas, which will be independent 5G communication environments set up for a specific purpose. They can also install sensors in all equipment and machinery at plants, and use 5G to transmit and analyze huge volumes of cloud data. This will enable a prior response to abnormal states and the breakdown of parts based on AI predictions, greatly reducing maintenance costs while also realizing safe and sustained plant operations.

As you can see, 5G will enable new services and

experiences.

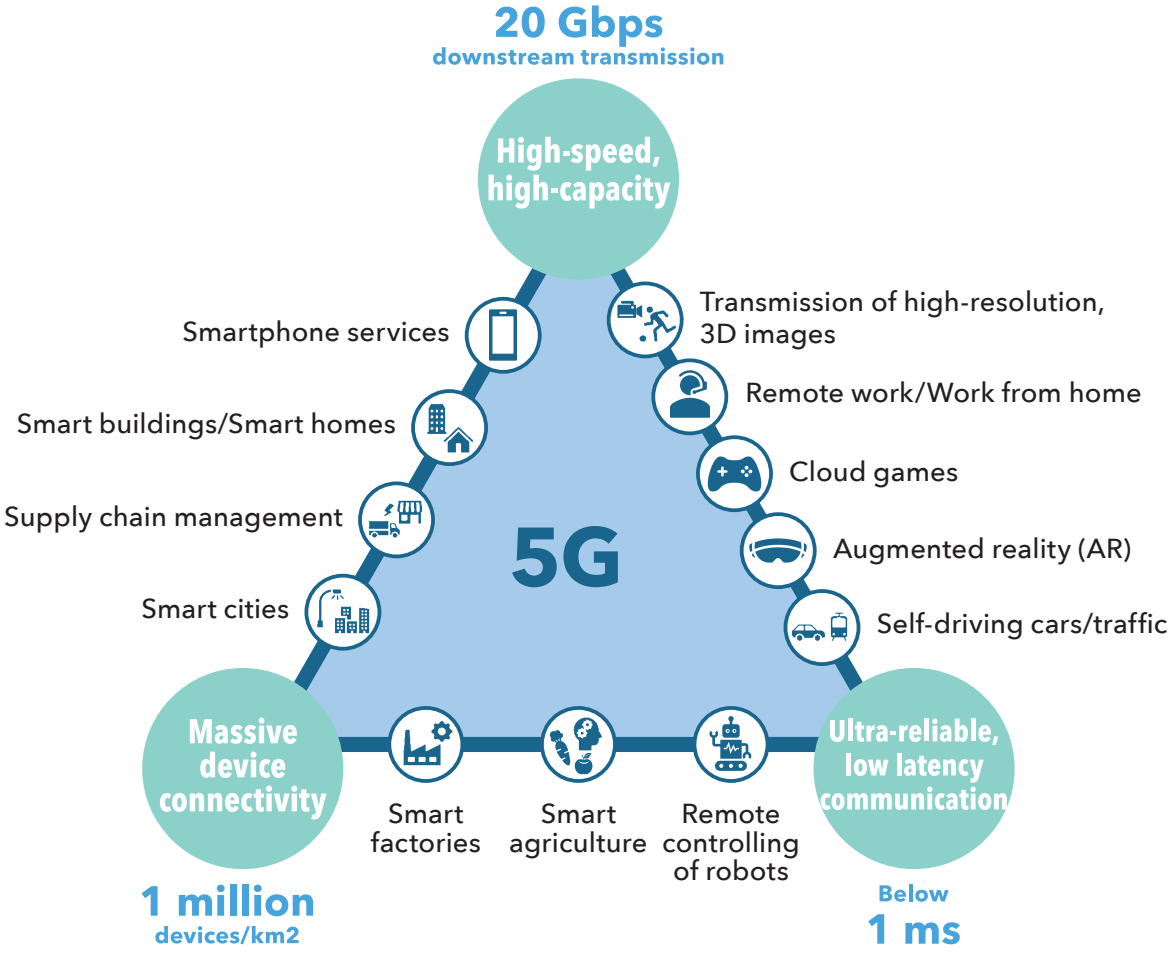
Many industries will benefit from 5G beyond telecom carriers. 5G is expected to trigger innovative disruptions in several verticals, including transport, logistics, manufacturing, medicine, education, tourism, and the public sector. The age of 5G is also expected to unlock new B2B2X business models that will deliver new services for various industries through collaborations between carriers and cloud providers. GSMA, an industry organization for mobile network operators, predicts that 5G will have a global economic impact amounting to USD2.2 trillion between 2024 and 2034 (*Taken from GSMA's "The Mobile Economy 2020": https://www.gsma.com/mobileeconomy/). It will also have a massive impact on the market.

Full-scale deployment of 5G has already begun in various countries in 2020. Along with telecommunication carriers and other network solutions vendors, NEC has launched initiatives to provide services that will create a new world.

Rapid Implementation of New Business Ideas

5G is the first telecommunications generation to embrace the cloud. Built from commercial off the shelf (COTS) hardware servers distributed in data centers, the software is virtualized and separated from the hardware. Extensive use of Software Defined Network (SDN) and software containerization allows 5G to be the first cloud native telco network. The packet core (5G Core) that powers 5G networks is a crucial vector of transformation from traditional networks.

As outlined in Chapter 2, 5G Core allows the creation, management and provision of virtual slices.



Example uses for "high-speed and high-capacity," "ultra-reliable and low latency communication" and "massive device connectivity" networks:

Network slices are a means to create varied experience for specific use cases and industries in a programmatic manner, using the same telecommunications cloud infrastructure. For example, it enables the use of the same infrastructure for different types of network services, such as high-speed, high-capacity communication for streaming live events, low-latency communication for autonomous driving, and massive device connectivity communication for smart factories.

Another benefit of the cloud native 5G Core is its architecture that can rapidly implement these new services. In previous generations, creating a new service took more than a year to change the network devices' configuration and settings. Because all the network devices were proprietary appliances, it was necessary for specialized personnel to manually log into each system and to change the configuration. This was slow, error-prone and required extensive testing of each element and then the whole system. Because of the cost and complexity of these operations, they were only performed during planned windows of maintenance who would in many cases necessitate network interruptions. A cloud-native 5G core like the one NEC is deploying can nowadays perform the same operations, tests configuration and roll out in an automated fashion in less than a week, without service interruption.

This velocity and flexibility have been a hindrance on innovation. When it takes a year and a much risk and cost to make changes, there is no room for experimentation. NEC cloud-native 5G Core allows for controlled, fast paced and iterative testing of new services. For example, you may come up with an interesting service idea and would need to field test it with a small number of users, in order to validate your business assumptions. This approach is simply impossible with a traditional network. To launch and validate successful digital services, you probably have to test dozens of them. With traditional core networks, this would take far too long and be far too onerous to ever consider. For this reason, hyperscalers and web giants have been innovating much faster than the telecom industry. There have probably been countless ideas that never materialized because of these limitations.

5G will pave the way for development of new businesses. It will also deliver faster solutions to social issues by providing opportunities that encourage innovation.

NEC Will Aim for the Full Automation of Networks

To achieve this ideal network environment, 5G aims to develop a fully automated network. Observing the various users' traffic patterns, the network itself relies on Artificial Intelligence to identify patterns, detect anomalies and deviations, propose recommendations and even autonomously predict behavior and proactively adjust settings and configuration to optimize against power consumption, cost, performance or availability criteria for instance.

TM Forum, a communications-related industry association, has defined different levels of automation in the carrier networks based on the automation in self-driving cars. There are six levels, from level 0 (all operational maintenance work is carried out manually) to level 5 (fully automated). The fully automated network described earlier is level 5. If this network becomes a reality, the necessary 5G network services could be made available on-demand within a few hours. A dramatic change on this level will have an immeasurable impact on our lives and businesses.

NEC is developing fully automated networks. NEC aims to achieve this goal quickly by using its rich experience and wealth of knowledge in AI, machine learning and big data analysis, as well as network operations. Further, NEC is developing cloud native 5G Core-based products and solutions and engaging in joint demonstration experiments with telecom carriers and enterprises to prepare for a post-5G world in the 2030s.

This white paper examines the core technologies behind 5G and their characteristics (Chapter 2). The paper then focuses on the concept and architecture behind NEC's cloud-native 5G Core (Chapter 3), the

characteristics and merits of the technology (Chapter 4), and introduces examples of demonstration in progress (Chapter 5). It examines in detail the fundamentals and characteristics of 5G, its issues, NEC's involvement, the creation of new social infrastructure and value, and NEC's contribution to the 5G transformation of various companies.

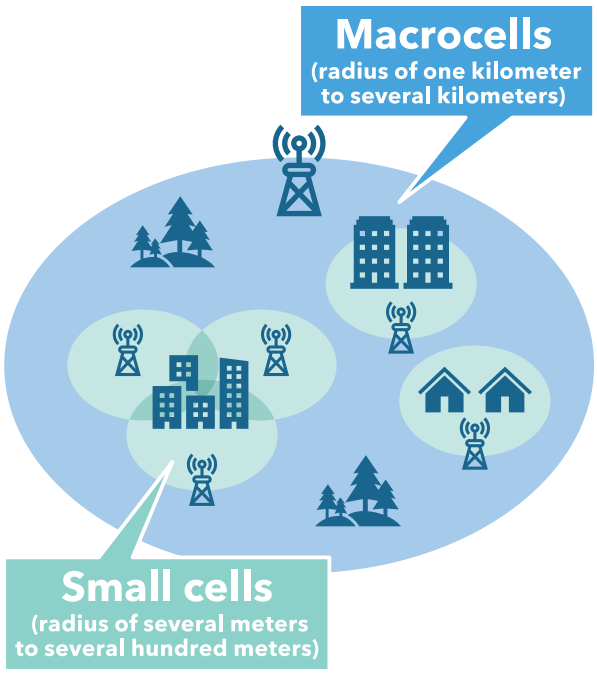
CHAPTER 2

5G Network and Key Technologies

Macrocells and Small Cells

The main components of a 5G communication network are a radio access network (RAN) and a 5G Core network. The RAN connects 5G devices to a base station, while the 5G Core network connects to the internet and the public cloud while managing and controlling multiple base stations and communication sessions.

In a RAN, the area covered by a single base station is known as a "cell." RANs till 4G mainly had macrocells (radius up to several kilometers) covered by large base stations. In contrast, the 5G RAN will rely on an heterogeneous network composed of macrocells and small cells (radius up to several hundred meters) covered by small base stations that played only a supplementary role until now.



Macrocells and small cells

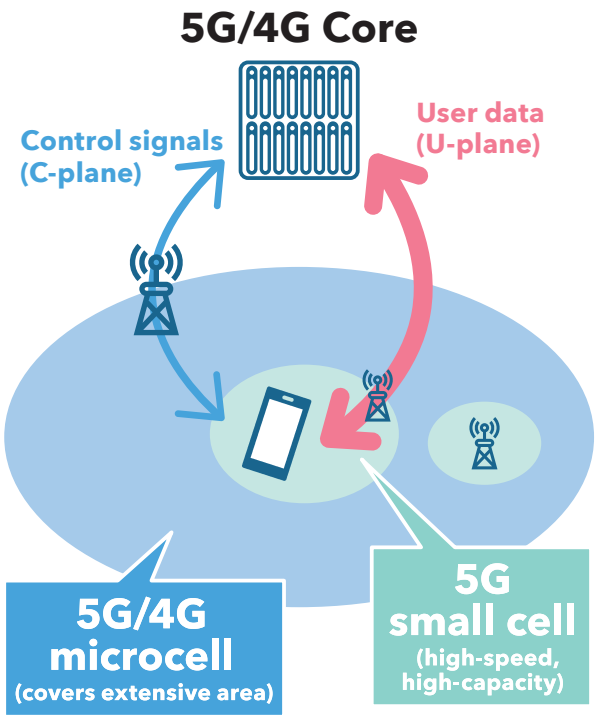
5G RAN has been allocated a frequency band known as "sub-6 GHz" (410 MHz – 7,125 MHz), along with another frequency band known as "millimeter waves" (24.25 – 52.6 GHz). The allocated millimeter waves have a wide bandwidth, which will help achieve 5G's promises of high speed, high capacity, and ultra-low latency. However, the relatively high frequencies limit their range and only allow them to travel straight, which means that they are easily obstructed by buildings and rain. In other words, they are not suited for macrocells.

On the other hand, covering an extensive area only with small cells is expensive because it requires a huge number of base stations and a lot of transport capacity to connect each base station.

5G RANs will deploy a combination of macrocells and small cells to leverage 5G with extensive and efficient coverage. Large areas will be covered by sub-6 GHz frequencies and large base stations, while small cells covered by millimeter waves and small base stations will be set up in stages (starting from the center of a large city) to provide both types of coverage.

Advanced, sophisticated RAN technologies such as massive MIMO, beamforming, Dynamic Spectrum Sharing (DSS) are key to realize the performance and flexibility of 5G RAN.

In addition, developing a communication network that combines macrocells and small cells requires



Coordination between macrocells and small cells through CUPS

optimal use of control and user plane separation (CUPS), which is explained below.

CUPS (Control and User Plane Separation)

The 5G Core consists of two functional layers: (1) the C-plane (control plane) to control communication sessions, device positional information, and to select the base stations to connect to (2) the U-plane (user plane) for high-speed processing of end-user data. The C-plane and U-plane were integrated in earlier generations, but they were gradually separated as 4G standards evolved. Complete separation is now the standard in 5G. This is known as control and user plane separation (CUPS).

CUPS offers many advantages. For example, it allows the independent development of functions and boosts performance of the C-plane and U-plane, which is expected to accelerate the evolution of the communication network itself. It is possible to separate the C-plane and U-plane functions physically and to scale them independently. This allows a variety of deployment scenarios taking advantage of the public cloud, private clouds and edge networks locations.

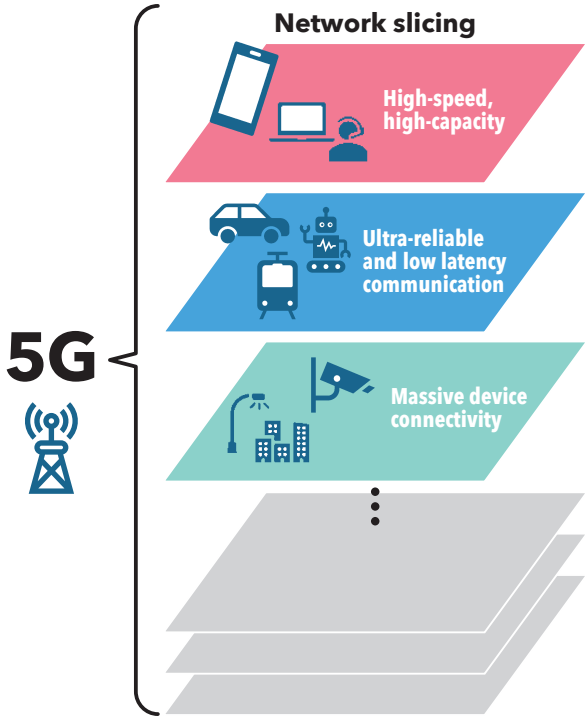
This will also be a major advantage in 5G deployment and development. The work involved in setting up and operating a 5G service is reduced through centralization (on data centers or the cloud) of C-plane processing, and the distribution of devices for U-plane processing throughout a service coverage area. It also allows quick deployment of service within the area. New developments are widely anticipated from local 5G networks, such as the launch of small-scale operations that combine a C-plane on the cloud with small U-plane devices deployed on premise or in the edge, or managed services with C-plane processes centralized on the cloud.

In addition, at an early stage of telecommunication carriers' migrating their network from 4G to 5G, they might opt for Non-Standalone (NSA) mode that uses 5G RAN as well as existing 4G LTE infrastructure and core network. In case of adopting the NSA mode, CUPS technologies can be also applied for efficient and optimized processing of massive user data. For example, while deploying a centralized control plane which interacts with existing LTE base stations located across a wide area depending on LTE network topologies, the deployment of the core network UPF at an area adjacent to 5G base stations for U-Plane communication enables an immediate offloading of massive data traffic that consumes network resources to the service networks as well as efficiently handling huge amounts of 5G data traffic.

Network Slicing

As described in Chapter 1, 5G allows a single core network to be virtually sliced to provide multiple networks experiences with different characteristics on the same physical infrastructure.

This technology is known as “network slicing.” It allows flexible development of telecom services with different characteristics, which are tailored to meet diverse requirements. To begin with, there are trade-offs between the 5G characteristics of “highspeed and high-capacity,” “ultra-reliable and low latency communication” and “massive device connectivity”



Network slicing allows provision of multiple networks with different characteristics

because it is impossible to achieve all three at the same time for all connections.

Network slicing creates a world that offers customized 5G communication services for diverse requirements on demand. As described in Chapter 1, this technology makes it easy to use 5G for short-term events or hypothesis verification of new ideas. It also powers innovation for new businesses and revolutionizes telecom services.

However, realizing this vision requires networks constant monitoring and tuning to ensure fulfillment of SLAs after customized network slices are designed and created on demand. 5G needs initiatives for full networks automation because it is very difficult to manually manage a virtualized network.

Further, functions to gather and analyze data on network communication quality are necessary to monitor and dynamically optimize the network slices and ensure that they fulfill user requirements and SLAs. 5G Core networks enable network devices operational status monitoring, as well as detailed end-user level analytics. The extensive use of AI and machine learning applied to this data leads to network automation.

Cloud-Native and MEC

As we have seen so far, the 5G Core network is required for rapid and flexible architecture and settings customization according to user requirements. That is why the 5G Core has a cloud-based architecture. This architecture enables quick creation of scalable networks, efficient maintenance and operations, cost optimization, as well as the easy addition of new functions (apps).

Another important point is the containerization of various network functions that constitute the 5G Core. The telecom industry has already been implementing initiatives to create virtual network functions (VNFs) using VMs (virtual machines) since 4G, but they are now discussing how to streamline this further by evolving these VNFs into CNFs (cloud native network functions) using container technology.

Multi access Edge Computing (MEC) is also crucial in extending the capabilities of 5G. The applications of service providers are normally uploaded onto the cloud, but they may not be able to fulfill requirements that need low latency processing, like control of automated driving or VR/AR applications. MEC meets these requirements by installing applications on edges that are closer to users (central offices and carriers data centers).

CHAPTER 3

NEC 5G: Concept and Advantages

A Set of Multi-Purpose Assets

5G is widely expected to become the foundation for stimulating creativity and driving a variety of innovations. To turn this vision into a reality, network solution vendors around the world are currently striving to develop new 5G solutions.

The focus is on 5G Core network solutions. Whether 5G develops into social infrastructure that drives an innovative future depends on our ability to ensure, for example, the flexibility, scalability, reliability, and efficiency of the 5G Core network. Technologies and solutions that support this core network will be critical to achieving these goals.

NEC's cloud native 5G Core (5GC) Solutions have attracted global attention and won universal acclaim as platforms that fulfill these challenging requirements, while also being advanced and practical. NEC's cloud native 5GC has won critical acclaim because it offers four key advantages.

The first advantage is NEC's 5G assets. These assets allow the establishment of flexible 5G networks to meet diverse requirements. They offer a wide range of core solutions for SA and NSA core networks in addition to 5G base stations (RU: radio unit, DU: distributed unit, CU: central unit). They also offer a lineup of diverse User Plane Functions (UPF) to meet a variety of needs based on conditions like traffic, location of installation, and power.

NEC is also developing solutions that can fully automate 5G networks by leveraging AI and machine learning technologies. The 5G network industry is becoming more complex and progressive in the face of increasing demand for better reliability and service quality. This scenario means that we need to address the need for full automation of everything from designing to operations. A sustainable increase in the level of automation is essential to convert these features of network slicing into a business that meets the needs of users.

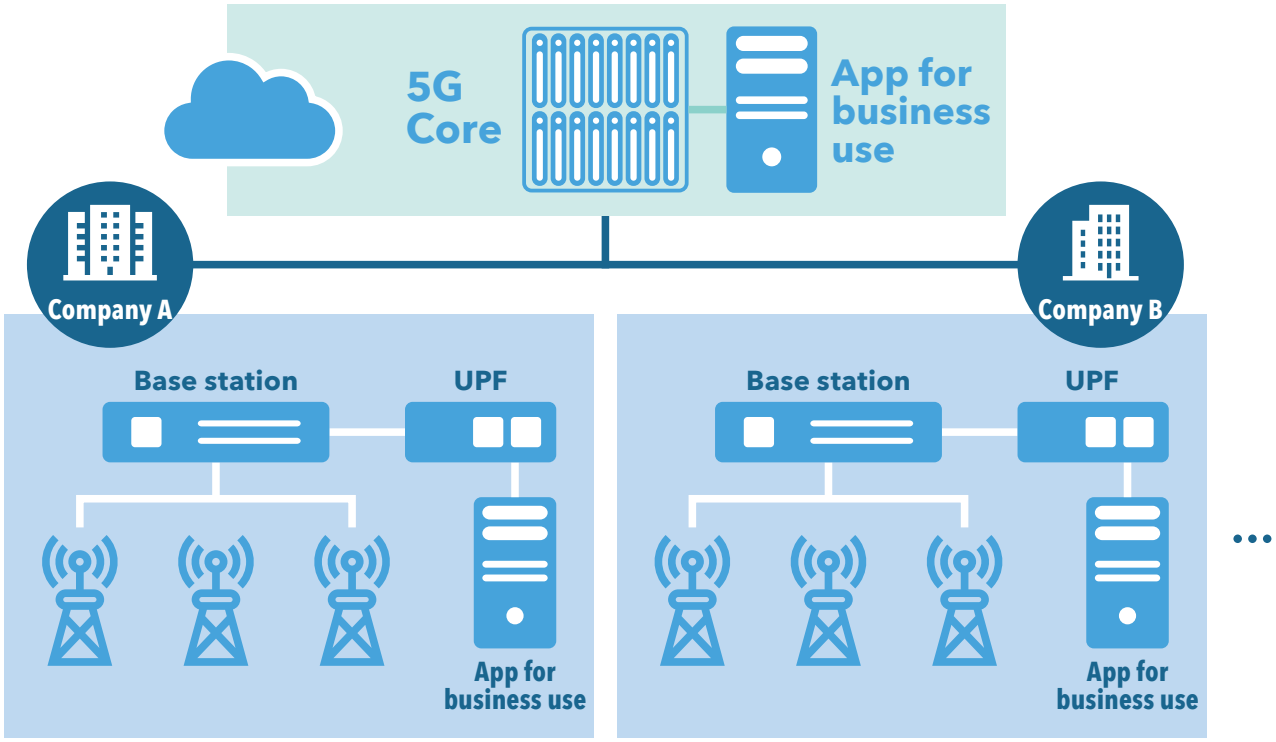
NEC's unique strengths lie in expertise honed through a rich experience in various domains that are essential for automation. NEC's expertise ranges from AI and machine learning technologies, to big data analysis and network operations. With this proficiency, NEC has developed a series of advanced functions for automating networks. For example, these functions can automatically design 5G systems adapted to a specific purpose, perform learning-based communications analysis, and perform automatic tuning when quality deteriorates.

Building a Cloud-Native 5G Core

The second advantage is its cloud native design.

A major characteristic of NEC's cloud native 5GC is multicloud compatibility. In addition to the virtualized Evolved Packet Core (vEPC) technology developed since 4G, efforts are underway to deploy container technology in 5GC, allowing it to be built on a public cloud as if it were on premise. Standalone 5G Core solutions that can run on the Amazon Web Services (AWS) cloud have already been available since 2020.

Building 5GC on the cloud enables rapid expansion of the 5G communication network with flexible



5G Core can be set up on a cloud

scalability, while exploiting numerous advantages like lower costs of initial deployment and infrastructure operations. Another advantage unique to multicloud-compatible 5GC is that it enables the optimized combination of on premise and cloud resources based on usage and size.

NEC Smart Connectivity, a management service for local 5G is a perfect example that highlights the advantage of these characteristics. This is a package that offers equipment needed to set up a local 5G, along with operation and maintenance services at a monthly subscription fee. It provides 5GC as a cloud service, allowing customers to use local 5G by simply setting up a local base station and UPF.

Telecom carriers can also use the public cloud to offer overseas roaming and other services. The public cloud provides the advantage of overseas on-site services with low investment in infrastructure. Another advantage is that it can be jointly operated with the domestic 5GC deployed on premise.

Open and Flexible Connectivity

The third advantage is its openness.

Earlier, telecom users were unable to overcome the problem of vendor lock-in, but the market is more open now with mutual connectivity between multiple vendors. The opening up of this market has allowed carriers to choose the right product for the right job with better cost effectiveness. It has also accelerated the deployment of the latest technologies. Users should focus on the products and openness of vendors when switching to 5G.

5G networks are becoming more disaggregated as they move to a cloud native environment. Network disaggregation means that telecom functions that used to be delivered as one monolithic product are now based on microservices and smaller functional elements. This is useful because it allows the emergence of new disruptive vendors that can offer best of breed or purpose-built elements that are simpler rather than complex systems. To function well, this ecosystem must rely on standardized, open interfaces and APIs and NEC has been a pioneer and leader in open disaggregated networks since the early days of SDN until the most recent open RAN initiatives. The multiplications of vendors and interfaces, requires strong control, integration capabilities and automation skills to realize its full

benefits.

As a part of key open networks organizations from the outset, NEC has contributed to discussions on researching, standardizing, and deploying 5G technologies. These key organizations include 3GPP international standards organizations that develop protocols for mobile telecommunications, along with, ONF (Open Networking Foundation), ETSI (European Telecommunications Standards Institute) and Facebook's TIP (Telecom Infrastructure Project).

For example, ETSI has been engaging in R&D on NFV (Network Functions Virtualization), a core network- virtualization technology, even before discussions on standardization. They pioneered the market by being one of the first to commercialize vEPC (virtualized Evolved Packet Core and virtualized 4G Core) solutions. Meanwhile, NEC has also participated in discussions with ETSI and other standards organizations to contribute actively toward collaboration and progress in the market through open technologies.

In the field of 5G RAN, NEC has been taking part in the O-RAN Alliance (Open-RAN Alliance) that is responsible for defining open interface specifications for 5G devices. NEC offers a lineup of numerous 5G base stations that allow multivendor connections between base station equipment (RU, DU, CU) that conforms to O-RAN specifications.

In addition, NEC collaborates extensively with global standards organizations, telecom carriers, network solution vendors, semiconductor manufacturers, and other partners in a sustained effort to achieve a world of open 5G that customers seek.

Diverse Implementations and Extensive Knowledge

The last advantage is NEC's ability to provide 5G solutions to businesses and industries by leveraging extensive domain knowledge that reflects its vast experience as an IT vendor.

The new social infrastructure of 5G will create new services and value in a variety of fields. NEC can provide not only 5G networks, but also entire systems that deliver such services.

Gathering and analyzing data is the key to business growth, especially in the age of digital transformation. NEC offers NEC Smart Connectivity that delivers innovative value through maximum use of data generated by people and things, and gathered via the 5G network. NEC Smart Connectivity is a solution that works with customers to achieve an ideal future through consultation, data connectivity, and network connectivity services.

NEC Smart Connectivity is already undergoing demonstration experiments with a wide range of clients and partners. These experiments tackle various challenges in realizing the next-generation Society 5.0, such as safe autonomous driving adapted to different environments, remote control of construction equipment at landslide-affected areas or other disaster sites, and sports viewing with augmented reality (AR).

CHAPTER 4

NEC's Valuable and Innovative 5G Products and Technologies

UPF Products (1BOX, Compact, and Software UPF)

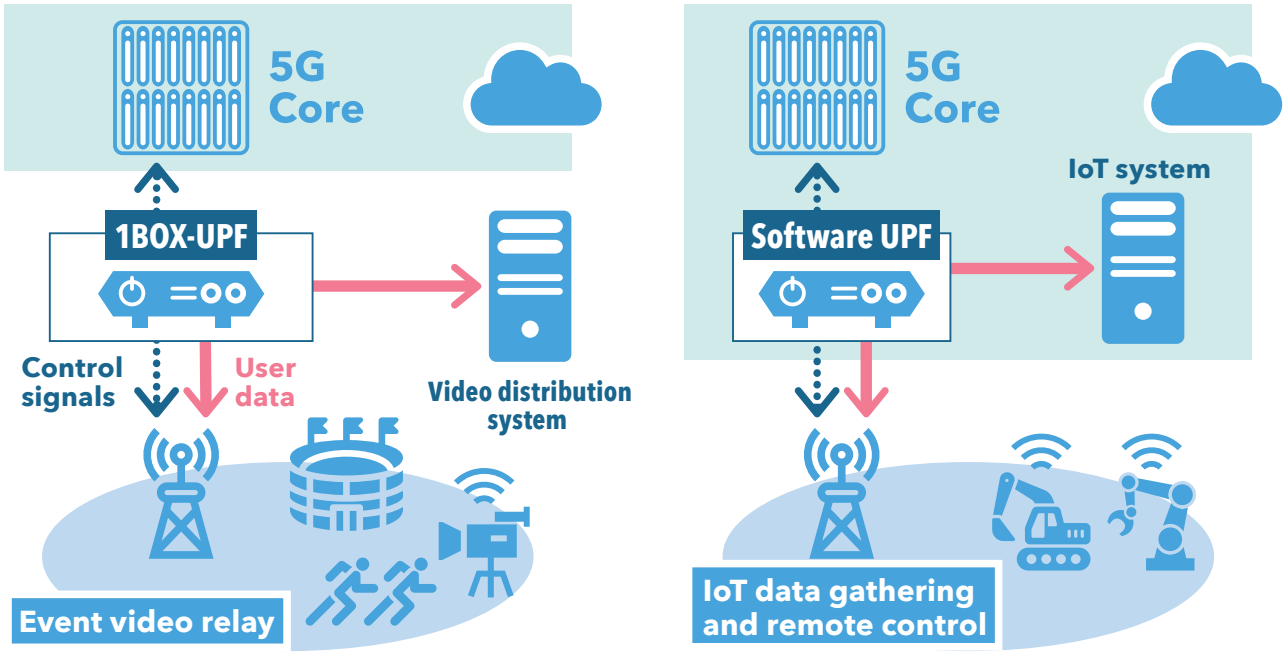
NEC's cloud native 5G network solutions have been recognized for the advanced technologies and know-how of the product groups that have 5G communications network. In this chapter, we will focus on introducing some of our most remarkable elements and technologies.

To begin with, NEC has UPF products that process user data with a U-plane.

NEC's UPF products are offered as software or as hardware appliances depending on requirements, such as the traffic scale and the installation environment.

We provide a 1BOX-UPF, an appliance for largescale 5G network for telecommunications carriers. Its most significant feature is its processing performance, as it can process more than 100 Gbps of traffic using one appliance. Furthermore, the processing performance per end user has also been maximized, making it capable of traffic processing that meets the required performance of 5G, namely a maximum of 20 Gbps per user.

However, an even broader range of use cases and installation environments can be considered for 5G networks, including local 5G. Therefore, NEC has



Examples of 1BOX-UPF and Soft UPF utilization in local 5G

also developed a compact user data processor Compact UPF and Software UPF provision formats.

The Compact UPF appliance has been reduced to less than half the size of the previous rack-mounted UPF. In addition to being compact and conserving energy, it has the durability to operate under harsh environmental conditions, so it can be installed anywhere. For example, it can be used at event venues where a 5G network is necessary for a limited time, and at sites that needs little installation space.

The Compact UPF can accommodate multiple network slices. It is also capable of detailed processing that involves execution tailored to the traffic requirements defined in each network slice to guarantee the QoS.

Our other product, Software UPF, links with the virtualization platform and the container platform to enable easy and fast service deployment. It is useful in cases where you want to use both the public cloud and the existing private cloud to decentralize the UPFs and locate them at multiple points. For example, in services such as local 5G and private 5G, it is capable of deploying a compact base station only to the site and then linking it to MEC. Because of this feature, the user is able to link to the business system in the cloud that helps to launch a variety of services, such as gathering information from IoT sensors, etc.

TMS (Traffic Management Solution)

5G radio waves are highly linear so communication can get interrupted easily, and this significantly impacts user experience. Moreover, it is a challenge to ensure stable network communications during handover between base stations, and also when deploying 5G and a communication service wherein both 4G and 5G radio waves are provided. The application of TMS solves all these issues.

NEC's TMS is a solution that analyzes and visualizes the quality of end-to-end communications, from log in to detecting abnormalities. This solution narrows down the location of the cause and carries out advanced traffic control. Its unique feature is that it does not monitor equipment failures but rather aims for user experience based efficient network operation, relying on quality of service indications. TMS has been adopted by more than 20 telecommunications carriers globally.

TMS has a communications control function. It is equipped with the Dynamic TCP Optimization function which controls the amount of data sent based on the constantly changing communications environment. This control includes handling traffic congestion and changes in the radio wave environment. High communication quality is required with 5G specifically. When deployed, TMS has achieved throughput improvements of approximately 24%, and 27% shorter download time when handing over from 5G to 4G . We have also succeeded in shortening the time until maximum speed is reached when handing over from 4G to 5G by approximately 64%. We aim to minimize the impact of the unstable radio waves environment to foster the potential for high-speed and high-capacity communications that 5G networks are capable of.

The second function is the analytical function. This analyzes the end-to-end communications quality from the TMS logs, and can directly monitor the quality of the service from user experience perspective. It facilitates simple and efficient network operation thereby improving customer satisfaction.

Being able to ensure stable and high-quality communication does not only improve user the experience, but can also potentially reduce the cost as it allows for coverage of an area with fewer base stations. Furthermore, the TMS established for a 4G environment can be migrated to a 5G environment with no alterations This way it offers an excellent cost-benefit performance as well.

Digital BSS, OSS, and E2E0

The 5G network service of communications carriers is much more than just installing the communications equipment. The 5G network service includes business management of customer (end user), and operations and management of the

network equipment. A business model is being advocated, specifically in the 5G era, that can divide out the network resources as slices, based on requests from a variety of industry and business users and provide a tailored on-demand network. E2EO (End to End Orchestrator) is an essential element to realize this.

NEC offers a business support system (BSS) for providing communications services that includes customer management, along with plan and billing management. It offers an operation support system (OSS) for the network equipment, and an E2EO that orchestrates the base stations, transports, and cores using cross-domains. All of these systems have extensive portfolios tailored to AI, machine learning, and big data analysis technologies.

With the BSS, the industry and business users can choose the network that suits their requirement from a catalog with the ease of a web catalogues, or can design a customized network. The E2EO uses AI technologies to interpret this request and automatically designs the configuration of the complex network equipment. Additionally, the OSS reads this design information, carries out the settings in the enormous network equipment, and opens the new network slices. In other words, because the BSS, E2EO and OSS function are all integrated, the network slices are finished like a bespoke suit. Furthermore, the completed network is constantly monitored by the advanced AI technologies of OSS and E2EO and those technologies autonomously operate to ensure that the quality of the network is maintained constantly. For example, they detect signs of a breakdown and automatically replace the equipment.

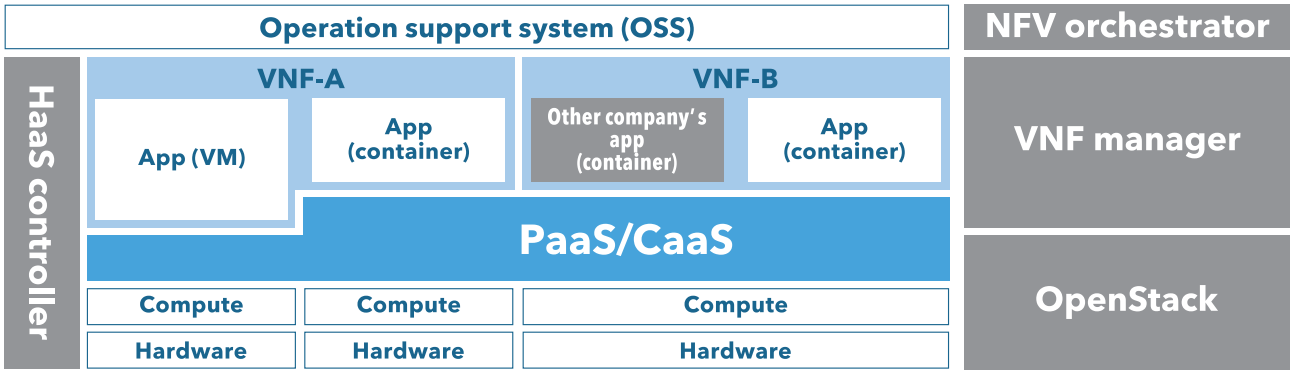
NEC is the only company in the global market which can comprehensively provide not only a cloud native 5G Core but also business support, operation management support, and orchestration using BSS, OSS and E2EO.

PaaS/CaaS

It is unquestionable that developing a cloud-native 5G Core network is vital for encouraging the growth of 5G as a platform that can foster innovation. It is an architecture which can configure and provide flexible and quick service with efficient and effective operations. The key word for realizing this is PaaS/CaaS.

PaaS (Platform as a Service), which is familiar as a public cloud, offers OS and middleware functions as a managed service. It provides a platform that can be used immediately for developing and executing applications. Furthermore, CaaS (Container as a Service) provides, as a managed service, a container platform which can unpack and execute containerized applications. Both of them are important elements for quickly developing and deploying new applications and network functions that are not dependent on the hardware platform. They allow to streamline the operational tasks by using a common and uniform platform.

NEC has integrated these services to provide a progressive PaaS/CaaS common platform for the 5G Core network. This common platform is capable of centralized and integrated management of



multivendor VNFs, CNFs, UPFs and vRANs with a single PaaS/CaaS, and can also deploy a dedicated PaaS/CaaS for each function. In case of the former, it can efficiently operate a large number of functions using common management functions (log management and backup, monitoring, etc.). In case of the latter, it can build with the optimal hardware configuration for each function and Pod (a cluster of containers), so it can ensure a performance that is good enough even for services with strict performance requirements.

NEC is able to provide a common platform that inherently has this kind of flexibility and scalability because the company has a track record and knowledge that has been built up over many years in the virtualization and operation of network platforms for communications carriers. NEC also possesses the HaaS (Hardware as a Service) controller technology which automates the building, monitoring, and controlling of the hardware, which serves as the platform. With this we can confidently conclude that NEC has an edge over the global market on this aspect as well.

CHAPTER 5

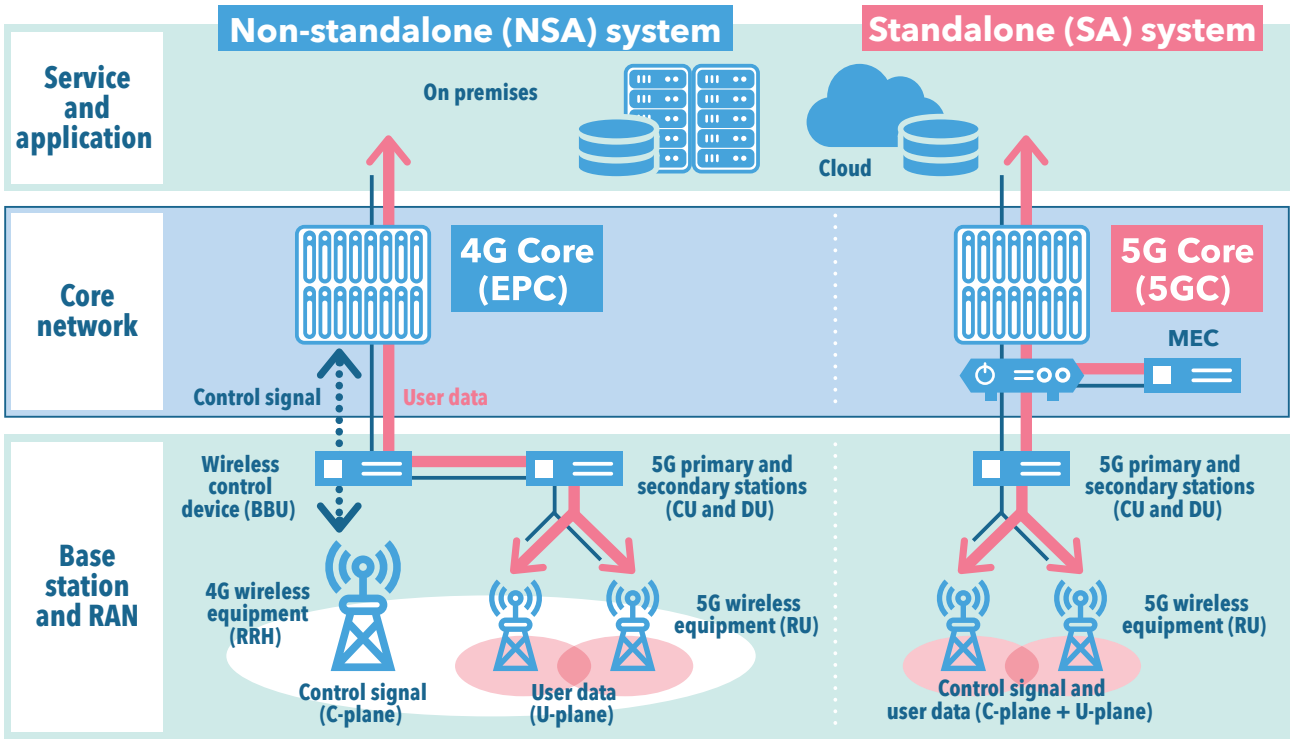
Performance History of NEC 5G, and "Beyond 5G"

Telecom Carriers Case Studies

NEC has extensive knowledge based on its accomplishments over many years in the domain of solutions for telecommunications carriers and enterprises. Currently, it is deploying those assets in the 5G domain, and is creating a vision for the next step while continuing to co-create the future with many enterprises. In this chapter, we will introduce some of those initiatives in three parts: solutions for telecommunications carriers, solutions for enterprises, and the future scenario.

Let us begin with the solutions for telecommunications carriers. NEC's virtualized core network for 4G (vEPC) is being employed and operated by NTT DoCoMo since 2016. Furthermore, the 5G service that NTT DoCoMo commenced in March 2020 is a Non-standalone (NSA) 5G service that expands the functions of this vEPC. Also, the Standalone (SA) 5G Core network that the company plans to offer in FY2021 is also provided by NEC.

NEC is widely supporting the deployment of NTT DoCoMo's 5G service in multiple ways, including the provision of 4G base stations and 5G base stations, and 1BOX-UPF, which is a user data processor. NEC is also deploying many demonstration experiments for various industries. in order to put into practice a



Schematic diagram of the Non-standalone system and the Standalone system

variety of use cases facilitated by 5G.

In addition to this, Rakuten Mobile is an excellent reference as well. NEC and Rakuten Mobile are jointly working towards development to provide NEC's containerized standalone 5G Core network to the Rakuten Communications Platform (RCP), RCP is a container platform for the cloud-native mobile network that Rakuten Mobile is currently building. Rakuten Mobile started providing a commercial 5G service within Japan from 2020, and in 2021 it plans to operate a 5G network based on a standalone 5G Core network built by NEC. Rakuten Mobile aims for a future in which telecommunications carriers throughout the world introduce various functions comprising Rakuten Mobile's fully virtualized, cloud-native mobile network from a web portal, similar to applications. The two companies will further advance their collaboration in order to globally deploy an open, high-quality, and highly reliable 5G Core network which operates on the network of Rakuten Mobile.

Next, we will present the NeutrORAN project as one of the representations of NEC aiming for "Open 5G." NeutrORAN is a project led by the government of the United Kingdom (UK) that demonstrates the effectiveness of supply chain diversification using 5G Open RAN. It adopts solutions that enable multiple telecommunications carriers to share and utilize RAN efficiently on a neutral infrastructure host. The UK government is supporting this project as one of the investments that will accelerate the introduction and deployment of 5G in the country. Furthermore, in November 2020 NEC established an Open RAN Center of Excellence in the UK.

NEC considers the system demonstrated in the NeutrORAN project to have potential on a global scale that goes beyond the UK. The project is scheduled to start operation during 2021 and great results are expected.

Supporting Enterprises and Local Governments

In Japan, NEC started providing a local 5G monthly payment service from November 2020 as a part of its local 5G solutions for enterprises and local governments. When enterprises and local governments introduce and operate local 5G, they need to apply to the competent authorities for a wireless station license, design a network taking into consideration the radio wave properties, and construct a system of continuous operations, maintenance systems, etc. Specialized knowledge and know-how is required to achieve this, and there have been cases wherein the lack of this has been an obstacle in introducing local 5G.

In order to solve this issue, NEC added local 5G-related services to the multi-connectivity menu that it provides through NEC Smart Connectivity.

NEC Smart Connectivity is a collective name for the network services that deploy as a service, information on network-related technologies and their performance history along with solutions that NEC has cultivated in order to support the construction of an optimal communications environment. Within this, the multi-connectivity menu is a menu for realizing IoT services, and it can freely combine multiple networks such as 4G and LPWA, etc.

To support local 5G, NEC has added a consulting service, an integration service and a managed service. The consulting service provides proposals including plans and requirement definitions, radio wave measurements, verification of 5G terminals, and demonstration experiments that are necessary for constructing local 5G. The integration service implements field surveys to achieve the performance required in the regions where local 5G is introduced, carries out design and verification based on the surveys, and supports the construction of networks. The managed service provides operational work to the 5G network 24 hours a day, 365 days a year. This includes monitoring, maintenance, and restoration work.

Moreover, NEC's knowledge is being applied in a wide range of industries and businesses as solutions for utilizing local 5G Solution demonstration experiments, and production operations are already being implemented in the manufacturing,

construction, transport, aviation, and the public sector domains. This trend is likely to gain momentum going forward.

"Beyond 5G" Our Future Society of 2030

At the beginning of this white paper, we explained that 5G is aiming for "innovation" rather than evolution. This transformation that started with 5G will continue in the post-5G world as well. NEC has also started taking initiatives focused on the future beyond 5G, and one of those initiatives is the creation of the "Beyond 5G Vision".

The Beyond 5G Vision portrays a network vision for the 2030s when the next networks generation, that is the 6G communications network, is anticipated. In "Beyond 5G", NEC envisages the emergence of a vast society in which physical constraints such as human beings, space, and time will be eliminated, new communication experiences will be born, and diverse values will be embraced. For the realization of that kind of society, NEC is working on the research and development of communications technologies which go beyond 5G. It will focus on continuous function enhancements, improvement of communications equipment, and the automation/optimization of network operations. For example, we can say that the joint research and development with NTT for realization of the IOWN (Innovative Optical and Wireless Network) concept is a good illustration of this.

The IOWN concept is an innovative concept for a network and information processing platform. This concept adopts cutting-edge optical communications technologies and information processing technologies to provide high-speed and high-capacity communications and enormous computational resources which go beyond the limits of conventional infrastructure. For the realization of this concept which NTT strongly advocates, NEC and NTT have established a capital and business alliance for joint research and development and global deployment of ICT products utilizing innovative optical and wireless technologies. We, at NEC, are handling the research and development with the belief that combining the strengths of our two companies will change the world of Beyond 5G, which feels like a feasible reality.

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