

White Paper

Network Evolution toward 2020 and Beyond

NEC Corporation

Executive Summary

Whereas 3G and 4G mobile network innovations have driven a revolution in personal communications, NEC believes the biggest impact of next mobile network innovations will be felt by society at large. NEC focuses on developing “Solutions for Society”, applying advanced ICT to help solve some of the world’s most pressing social challenges and create a sustainable and more enriching future. NEC believes that the flexible integration of future mobile networks with ICT-enabled urban and industrial infrastructure will bring wide ranging benefits to consumers and businesses in a diversity of vertical sectors. Relevant technologies will enable the world to support growing, ageing, and more urban populations in revolutionary new ways while minimizing our impact on the environment. These technologies include ultra-low latency connectivity for driverless cars, kilobits per second connectivity for M2M sensor networks for health and environmental monitoring, and up to a hundred megabits per second for ultra-high definition video broadcasts.

NEC believes that our vision will be a reality in mobile networks in around 2020 when global technology innovations, which are likely to be defined in emerging 5G standards, will increasingly be deployed. The “2020 network” will help to make our cities safer and improve the delivery of public services as well as citizens’ quality of life. It will also enable the creation of new, more efficient services in many industries, including transportation, entertainment, logistics, utilities, healthcare, manufacturing, and agriculture. Businesses in these sectors will be a key driving force in creating new mobile and ICT-related innovation ecosystems in partnership with network operators, vendors, and businesses in a variety of industry verticals.

The performance requirements of the “2020 network” will diversify as various new business models and services are developed to support the provision of new solutions for society. The concept of the IoT will

also accelerate this movement. Therefore, by cooperating with other industries, the “2020 network” is required to efficiently provide the necessary functionalities that enable various solutions for society. For that, a new network architecture that can be flexibly integrated with ICT platforms in other industries should be developed. SDN and NFV technologies will help to build such innovative architecture economically.

NEC will continue to exercise its leadership as a company that uniquely has very innovative technologies in both the networking and computing domains. By collaborating closely with our customers and business partners, NEC is committed to being a social value innovator using the new “2020 network” to help create a better world.

Introduction

Mobile networks have changed people’s lifestyles drastically. Communication services have expanded beyond traditional voice-based communications to cover various types of media, including videos, images, and online content, helping to connect consumers with anyone anytime and anywhere. Whereas 3G and 4G mobile network innovations have driven a revolution in personal communications, NEC believes the biggest impact of next mobile network innovations will be their contribution to the enrichment of societies around the world in more innovative ways than we’ve seen to date. To envision the role that future mobile networks can play, NEC believes that it is important to analyze the megatrends in society and emerging technologies that will benefit people’s lives in the future.

The world is expected to experience drastic population growth and increased urbanization in the future. Rising birth rates, and the emergence of a more affluent middle class, is driving economic growth in emerging countries. On the other hand, the increasing percentage of elderly people population in advanced countries is likely to result in a relative decline in their

economic power. The world economy is already shifting to a multi-polarized structure involving emerging countries.

The reduction in the digital divide brought about by the spread of the Internet will create a flat and open world, increasing interdependencies between each national economy. This will cause the impact of an incident, such as a natural disaster or a cyber-attack, in a certain country to affect every country in a blink. Every nation needs to construct new infrastructure that responds to the challenges created by these social megatrends, make full and efficient use of the limited resources on the earth, and create safety, security, and equality for every citizen.

NEC believes that ICT needs to play an even more important role in creating industrial infrastructure that increases economic efficiency and urban infrastructure that increases people's safety and security. From now on, ICT will penetrate into ever more diversified areas, linking various systems and harmonizing them as a whole. For example, advanced sensors and ICT platforms will capture the status of all humans, goods, and things to enable new types of big data analytics (*Physical-World Digitization*). New solutions can be developed through highly developed data science, involving real-time analysis and inference to create new value in society (*Analysis and Inference*). More intelligent data processing will enable us to better manage urban infrastructure, facilities such as factories and plants, and mechatronics such as robots and autonomous vehicles. This will also help to better guide decision making by enabling us to better understand human thought and emotion using

machine intelligence to compute in ways similar to the brain and expand human abilities. These insights can be fed back to the physical world to provide a control and guidance feedback loop (*Control and Guidance*).

An ICT platform that supports *Physical-World Digitization, Analysis and Inference*, and *Control and Guidance* will help solve the many challenges facing society. NEC believes future mobile networks will play an important role in helping to create new solutions for society when integrated with advanced ICT platforms to create new urban/industrial infrastructure to enrich society in many different ways.

NEC's 2020 Network Vision

NEC aims to create a sustainable world in which efficient industrial infrastructure creates economic growth, which encourages the development of safer and more secure urban infrastructure and in which people enjoy enriched lives and exercise their humanity and creativity, which encourages regrowth in society. There are many ways to solve today's social challenges. Each country and region may have a different approach to the solution. However, a basic framework is common among various solutions: mobile networks connect all humans, goods, and things in the physical world with ICT platforms to create solutions that provide society, industries, and people's lives with new values.

At an early stage, consumer services were developed and they evolved into enterprise solutions. Currently, innovative applications for smartphones and tablets are being released. Also, the concept of connecting various things in the physical world to the Internet (the IoT) is

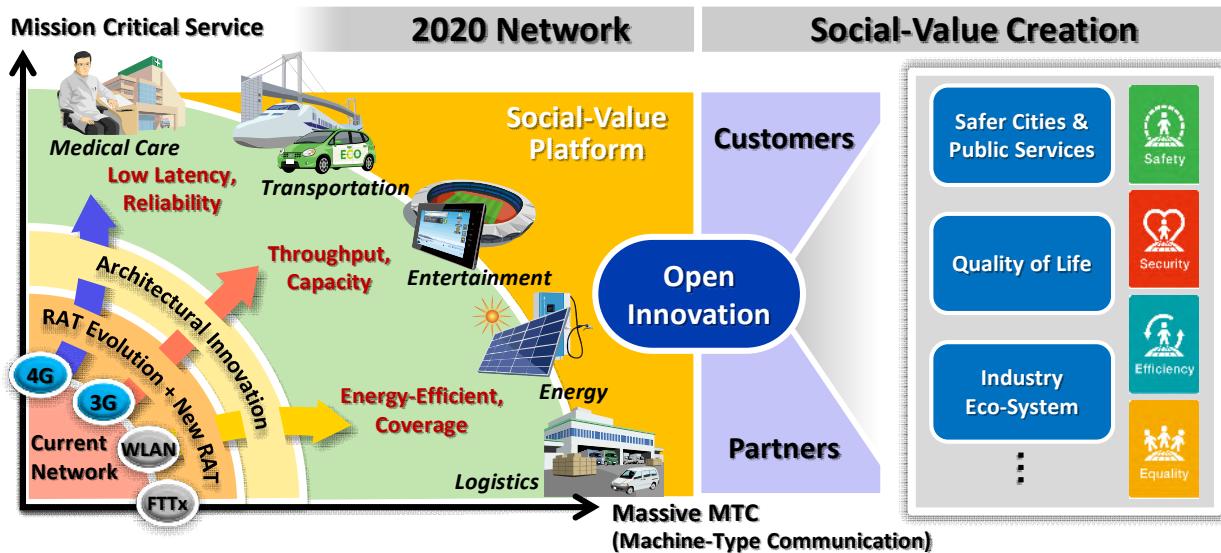


Figure 1. NEC's vision for the "2020 network"

gaining popularity with new services coming onto the market. However, the creation of social value through mobile networks is still at a transitional stage. Worldwide technology innovations that are likely to become part of an emerging 5G standard will be increasingly deployed in mobile networks by around 2020 (the “2020 network”). This will enable the creation of various solutions for society that provide a high level of social value: contributing to safety, security, efficiency, and equality (Fig. 1). NEC has formulated seven themes for social-value creation to embody our initiatives for solutions for society [1]. For example, the “2020 network” will contribute to the development of the following themes.

1) Safer Cities & Public Services

The “2020 network” will help to build safe and secure cities and advanced societies. For example, advanced transportation control, crash-avoidance, city surveillance, and telemedicine can be realized by enhancing network capabilities such as latency and reliability, and enabling mission-critical IoT solutions including vehicles and medical equipment.

2) Quality of Life

The “2020 network” will help people enjoy unimaginably high quality user experience and exercise their humanity and creativity. For example, advanced applications enabled by 8K video or Augmented Reality (AR) can be realized by enhancing network capabilities such as throughput and capacity.

3) Industry Eco-System

The “2020 network” will help to increase the efficiency of industrial infrastructure in a wide range of sectors, such as agriculture, manufacturing, logistics, energy, and infrastructure management. For example, the mass deployment of IoT sensor devices will only be possible by enhancing key network capabilities including the level of energy efficiency, capacity of connections, and geographic coverage.

ICT cannot realize solutions for society by itself. The most important aspect of these solutions is the knowledge and experience of the service providers and their users in the various areas of society. Partnering with other industries will help identify fundamental issues, create social values by using domain-specific assets, and develop sustainable business models. These open-oriented approaches can create innovations that provide a high level of social value.

The concept of open-oriented approaches that identify fundamental issues/values will encourage the

transformation of business models in the ICT market. For example, existing communication service providers mainly provide consumers and enterprises with connection services. From now on, the focus must be on providing a wider range of solutions for society to address the fundamental challenges and opportunities the world faces through the use of ICT and the development of ecosystems with other industries.

In addition, the transformation of business models will encourage architectural innovation in future networks. For example, various solutions for society can be realized efficiently if we use a common ICT platform (*Social-Value Platform*) that supports data gathering, analysis and inference, and control and guidance in the physical world. To establish such a social-value platform, involving other industries, we need to create an innovative platform architecture that decreases the interdependency among pieces of hardware, network functions, and applications and enables a flexible combination of these elements. In addition, openness of various types of relevant APIs should be encouraged.

The “2020 network” will realize an enriched society by transforming business models and technology innovations.

Potential Use Cases and Key Requirements

The “2020 network” will provide society, industries, and people with new values when it is integrated with ICT functionalities in a diversity of vertical industries. In this section, examples of “2020 network” use cases in the transportation control, personal entertainment, and logistics management sectors are presented (Fig. 2). In addition, security services to protect ICT platforms from diversifying threats like cyber-attacks are described. Finally, the performance requirements for the “2020 network” are summarized.

1) Transportation Control

By applying “2020 network” technologies to create more intelligent transportation system, we will be able to develop safe, secure, and efficient urban cities. By gathering and analyzing big data, including sensor information and video from connected cars and road infrastructure, it will be possible to help people drive more safely, reduce congestion, and curb greenhouse gas emissions.

Such a control system will be able to reduce traffic jams and journey time by advising each vehicle of its optimum route and speed of travel so that when it reaches the next traffic light, it's more likely to be

green. It will also be able to prevent traffic accidents by alerting neighboring vehicles in case of traffic accidents or road blocks. During an emergency, vehicles in danger could even be forcibly stopped or guided away from a hazard to a safer route.

Using a crash-avoidance system that informs vehicles and pedestrians of each other's location and roadside sensors that alerts vehicles at an intersection about traffic already on the road ahead, it will be possible to reduce traffic accidents. A platooning system that ensures a safe inter-vehicle distance is maintained will also help to reduce excessive speeding and braking which leads to start-stop traffic flows and increases greenhouse gas emissions.

To realize these real-time services, the “2020 network” needs end-to-end latency equal to or lower than 1 ms to 100 ms, depending on the service provided. In the case of mission-critical services, such as crash-avoidance, low latency needs to be achieved with almost 100% reliability. In addition, the “2020 network” should be capable of providing even an ultra-high speed vehicle with a means of reliable communication and accommodating connections with many millions of IoT/M2M devices on the road.

As described above, the “2020 network” with ultra-low latency and high reliability will enable the creation of new services when integrated with the ICT platform that provides real-time processing for video analytics and state prediction tasks. This will play an important role in the development of safe, secure, and efficient urban cities.

2) Personal Entertainment

In the “2020 network”, a range of new solutions for society will start to enrich people’s quality of life in many different ways. This includes enhancing their experience of big events, such as the Olympic Games, which create an economic boom in the cities in which they are held.

For example, ultra-high definition 4K video streaming, or possibly 8K technology, will become popular on mobiles in 2020 and beyond. This will provide consumers with a better viewing experience with more colors, textures, nuanced brightness levels, and smoother motion. Videos will also become more interactive and consumers will be able to turn on “metadata labels” to automatically track their favorite players when watching a football match and view the match statistics that relate to them. It could even be possible to gather video samples from wearable devices and video cameras in a stadium and create audience-selected viewpoint videos. Spectators could also use a navigation service to find amenities at the venue or be sent highly targeted ads. In addition, the “2020 network” could be used to ensure many more people are able to participate in such events with digital signage in public squares and railway stations that also provide information on the local area, which would be particularly beneficial to overseas visitors.

To realize these services, the “2020 network” will need to accommodate the huge volume of communications traffic generated by visitors to such big event. For example, if 15% of a typical stadium audience of about 80,000 replays an 8K video at around 100 Mbps to see close-up highlights of the



Figure 2. Potential use cases in the “2020 network”

match, around 1,200 Gbps of traffic would be generated. In addition, the analysis of the user's location and interests and the delivery of content, such as advertisements or AR-assisted navigation, should be processed in real time at around ~100 ms. These requirements will be fulfilled by the following solutions: accommodating 80,000 users by deploying an ultra-dense network of compact small cells using beamforming technology at intervals of about 10 m in the stadium, improving video quality by integrating the control provided at each layer from applications to wireless access level, delivering the user's favorite video or information in real time by analyzing the user's profile and interests locally at a base station level.

Such services that combine physical and digital experiences at an event will contribute to the enrichment of the consumer's experience. Targeted advertising and wayfinding can also help encourage their consumption in local restaurants, retail shops and other businesses, creating an economic boost in the surrounding area.

3) Logistics Management

One example of solutions for society that increase industrial efficiencies involves the application of the “2020 network” and IoT/M2M technologies in the field of logistics management to create more accurate and economical service for customers.

Often, deliveries of parcels or consignments of goods involve close collaboration between a number of separate companies who connect senders and receivers around the world by sea, air, road, and rail. However, existing logistics management systems are closed and proprietary to each company, so accurate real-time tracking of deliveries is currently not possible.

Logistics visualization can be improved by integrating the location information relating to individual items within a cargo shipment, with packages that are the responsibility of a range of different companies, with the operational information relating to the transportation system itself. Logistics companies need to know in real time about the location of their goods, transport network conditions, and the estimated delivery time of each parcel. By analyzing information such as the receiver's availability – determined using an Application-to-Person text message service –, road congestion levels, and weather conditions, the optimum route can be planned for each delivery. This reduces the time goods spend in the transportation network hub by avoiding redeliveries caused when the receiver is not at home, helping to drastically reduce total logistics costs.

In such advanced logistics management systems, IoT communication devices will be attached to individual goods at an item level. This means that the number of communication devices connected to networks will scale in line with the huge number of cargo shipments around the world each year. Indeed, the “2020 network” will be required to manage 100 to 1,000 times more parcel ID numbers than mobile terminal tracking systems do today. The location information also needs to be highly accurate to identify the location of a parcel in a warehouse or in a truck. This requires a location measurement resolution of at least 1 m. In addition, the relevant devices need to be connected to a network for a long time without being recharged as an external power supply is not available or practical during the end-to-end delivery process which may take several weeks.

As described above, the “2020 network” will help to improve the efficiency, accuracy, and economics of global logistics networks.

4) Security

The “2020 network” will help to support advanced security services that improve the safety and security of ICT platforms even when they are becoming larger-scale and more complicated. Specifically, a secure network service and a secure managed service will be required.

With the proliferation of IoT devices, it will be possible to manage business activities in virtually every industry and facility more efficiently. Meanwhile, cyber-attacks conducted via these huge number of connected devices will be made on the underlying ICT platforms. If users are not security experts, it is difficult for them to protect their ICT platforms against these threats appropriately by themselves. Therefore, security services to protect the users' ICT platforms against these threats should be provided. SDN/NFV technologies enable the security level of networks to be configured in each network node flexibly and easily in accordance with the users' requirements. Such a secure network service can be provided for various users with different security profiles and requirements including personal users, enterprises, and social infrastructure operators. For example, unauthorized network accesses by address spoofing, attacks on devices, and hijacking of devices can be prevented by authenticating devices in network nodes. Also, the processing of IoT data can be distributed to the network edge nodes which should be protected with localized data encryption and decryption.

On the other hand, social infrastructure operators and enterprises that use cloud services are faced with

advanced persistent threats by criminals who want to extract confidential information and interfere with a company's business activities. Cyber-attacks are predicted to be more advanced, particularly in light of the threat of insider attacks. A secure managed service prevents damage from these advanced cyber-attacks by integrating the monitoring of users' ICT systems in the cyber world and human behaviors in the physical world and using big-data analysis to detect attacks. Specifically, incidents can be detected immediately by analyzing image data like human behaviors captured by security cameras as well as the data log relating to the users' ICT systems and cloud infrastructure. After detection, security staff can take the appropriate actions in line with their security policies. For example, the ICT devices affected by the attacks will be identified and isolated to minimize the damage. Another option is to prevent the interruption of the users' business by steering the attacks toward a "honeypot trap" enabling the development of counter measures against the attackers without them noticing.

As described above, secure managed services will be enabled by the "2020 network" with the ability to configure security level flexibly and easily in accordance with the users' requirements. The safety and security of ICT platforms can be improved efficiently through the provision of such security services.

5) Performance Requirements

For the potential use cases mentioned above, Table 1 shows expected performance requirements for the "2020 network" and ICT functionalities to be integrated with the "2020 network". As shown in this table, the requirements for the "2020 network" are highly dependent on the use cases. For example, while transportation control requires ultra-low latency and high reliability, personal entertainment requires high user experienced data rates and sufficient capacity to accommodate a huge amount of communication traffic in ultra-densely populated areas. On the other hand, logistics management requires managing a huge number of IoT devices and estimating individual device location with a high degree of accuracy.

Some of these requirements conflict with each other, and it may be difficult to fulfill them simultaneously. However, these use cases do not have to be fulfilled "anywhere and anytime". Therefore, the "2020 network" is expected to realize a flexible architecture in which necessary functionalities and resources can be deployed to each network node on demand. These deployments need to be optimized in accordance with the use case and user context.

Table 1. Requirements for the "2020 network"

Use Case		Network	ICT Functionality
Transportation Control	Traffic-jam Reduction	Connection Density > 10^6 per km ²	Real-time prediction of traffic state by big-data analysis
	Crash-Avoidance	Latency < 5 ms with ultra-high reliability	Real-time analysis and indication of device location
	Ultra-High Definition Video Delivery	Area Traffic Capacity > 10 Tbps/km ²	Delivery of video in accordance with users' population density
Personal Entertainment	AR Navigation / Audience-selected Viewpoint Video	User Experienced Data Rate > 0.1 - 1 Gbps	Video composition in accordance with users' location and interest
	Management of a huge number of Parcels	Number of IDs > 100 - 1000 times of IMT-A	Management of parcels IDs integrated with time-series of location data
	Optimization of Delivery Routes	Location Accuracy < 1 m	Planning of optimum delivery route by analysis of device location, etc.
Logistics Management	Long Period of Operations	Energy efficiency > 100 times of IMT-A	---
	Security	Flexibility of security level configuration	Detection of security incidents by big-data analysis

Network Architecture

The advancements in network virtualization and programmability brought about by SDN and NFV will enable a wide range of network functionalities that fulfill users' service requirements to be provided on a common ICT platform in the "2020 network". As a result, each function in the various network layers, namely access, transport, core, and applications, will be implemented and deployed more flexibly. It will also be possible to deploy these solutions in a shorter time-frame.

NEC believes that such architecture evolutions will continue while integrating networks with ICT platforms in a range of vertical industries. Various software functions that enable the creation of social value (*Value Enabler*) will be integrated into a common ICT platform and deployed to appropriate nodes flexibly depending on user's service requirements. In addition, it will be possible to introduce software functions from external vendors to enable value-added services, such as advanced analysis and inference, more easily. Through these evolutions, an advanced common ICT platform (*Social-Value Platform*) that creates new social value will be realized. It will support a diversity of solutions for society by enabling the efficient

gathering of various data, analysis and inference, and control and guidance in the physical world (Fig. 3).

In the following sections, we describe MANO, which plays a central role in the “2020 network” architecture, followed by some technology components required for the core, transport and radio access layers.

1) Management and Orchestration (MANO)

As network virtualization advances, the role of MANO technologies to smoothly implement services, allocate resources in an optimal way, and dynamically change the configuration of the network based on real-time traffic and capacity levels, will become even more important. MANO will enable end-to-end service and network orchestration in close collaboration with OSS/BSS that already control service provisioning, monitoring, and billing activities in networks today.

A) Integrated Orchestration

It will be necessary to manage the life cycle of hybrid legacy and virtualized nodes in the “2020 network” to reduce OPEX and management complexities. Also this enables smooth migration from the existing network.

B) Service Provisioning

The MANO is essential to conduct service activation processes ranging from resource procurement to provisioning virtualized network resources efficiently in an automated way according to the application or users’ needs. It needs to provide the flexibility to enable service providers to create and alter services

economically and quickly to realize new value-added revenue generation opportunities. It will be important that service provisioning can be opened up to third parties through the use of open APIs (*Value-Enabling APIs*), leading to the creation of business models involving communication service providers and companies in a range of vertical industries.

C) Dynamic Control of Networks

It will be essential to be able to dynamically control networks by creating a continuous data gathering, analysis, and control feedback loop in the “2020 network”. This Traffic Management Solution (TMS) comprises a media optimizer, visualizer, and the service controller. The media optimizer enables traffic to consume as little bandwidth and resources as possible as it transits the network through techniques such as TCP optimization and the use of advanced compression algorithms. While the visualizer collects and stores traffic logs and visualizes the analyzed data. The service controller creates control policies based on how much traffic is on the network and directs the media optimization tasks.

The “2020 network” will also need self-learning and prediction capabilities provided by big data analytics solutions. For example, it will need to predict network congestion or a service outage and allocate additional network resources or change traffic routing in advance. These capabilities will ensure policies can be applied to traffic transiting the network in line with agreed service level agreements.

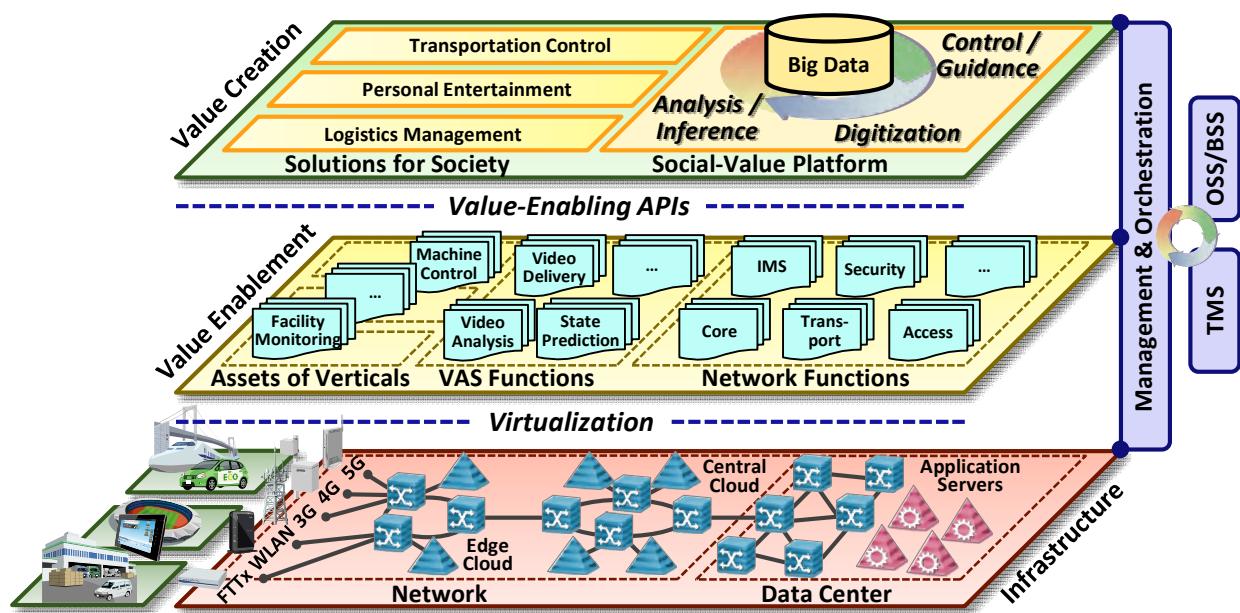


Figure 3. Architecture for the “2020 network”

2) Core Network Function

SDN and NFV technologies will create the shared, flexible and efficient network infrastructure for any communication services including super-fast fiber, WLAN, and mobile phones from 2G to 5G that can be used by different services in parallel. These technologies will also help avoid the need to build multiple specialized networks and the cost, disruption and duplication of effort this brings. This advanced infrastructure will enable traffic to take the best path through the network depending on real-time demand and the specific latency, bandwidth, safety, and security needs of each of application or end-user.

A) Network Optimization based on Device Behaviors

The “2020 network” will need to be optimized for a wider range of M2M devices and mobile applications as well as human communication services. The core networks will need to identify the access behavior of each device and provide the appropriate functions and resources while minimizing the need to over-provision the network. For example, stationary environmental sensors that send a small amount of data a few times a day will not need cell handover management and idle mode paging capabilities. Devices that send a large volume of uplink data while moving along a fixed route, such as online security cameras on trains, will also need to be assigned the appropriate resources in light of the locations of the devices on the basis of their route and timetable.

Devices that transmit or receive data with ultra-low latency in mission critical services, such as crash-avoidance in transportation control, will have an entirely different set of requirements. One approach is to reconfigure network routing to provide sufficient bandwidth on the topologically shortest path between the devices and service servers. Another approach is to deploy computing resources near the devices. Also, the processing of a network relay could be simplified to decrease its delay.

B) Advanced SDN/NFV-based Network Architecture

In the “2020 network”, the MANO will play a key role in allocating appropriate computing and networking functions and resources to each network node and fulfilling the requirements of services taking into account real-time access behaviors. The core networks will cooperate with the MANO and other upstream layers in a highly integrated, flexible, and agile way using abstract, common APIs.

The core network architecture will be able to upscale and hibernate resources in line with demand to minimize energy usage and costs. By making full use of advanced SDN and NFV features, it will be capable of

integrating or decomposing functions without impacting neighboring systems and fulfill mission-critical service requirements, such as a few-millisecond end-to-end latency.

C) Efficient Authentication and Identification for a Huge Number of IoT Devices

M2M and IoT devices that use the same services, exist in a specific area, or connect to the same sub-network will be grouped to enable more efficient user authentication. For example, typical authentication procedure today can be simplified for each device in such groups if relevant services do not require a high level of security.

New business models are likely to require the ability to identify devices independently of the SIM. Currently, each device belongs to a specific mobile operator and is identified by the IMSI record in the SIM card they provide. In the future, third parties will need to provide seamless M2M services using multiple networks managed by different operators. In this case, each device or user should be identified by an alternative mechanism.

3) Transport Network Function

Convergence between wired and wireless, backhaul and fronthaul, to name a few, will be necessary to lay the foundation for the more flexible usage of future networks. It will be possible to select the most appropriate backhaul paths on the fly in light of real-time network capacity, congestion and traffic levels. For example, if microwave transport is affected by bad weather, an optical path could be selected [2]. With technology innovations, such as high-order modulation and x Wavelength Division Multiplex (xWDM), NEC will provide higher capacity and lower latency of optical and microwave transport from the access layer to the metro or backbone network.

4) Radio Access Network Function

The transition toward a virtualized RAN will come in phases. An initial step has been made with the introduction of the centralized RAN that partitions base stations into a digital unit (DU) and a radio unit (RU) – often sited at different locations. Pooling DUs at base station hotels and installing compact RUs at cell site locations generate significant benefits including more effective interference coordination, reduced operational complexity, and simplified site acquisition processes. The next step towards a fully virtualized cloud RAN (C-RAN) architecture involves virtualizing the digital baseband units.

A) Virtualization of RAN Functions

Running baseband processing using virtual machines provisioned on commercial servers enables the switching network capacity and resources among cell sites with light traffic areas to regions experiencing heavy mobile traffic on demand. This enables efficient provisioning of computing resources for RAN functions and reduces TCO as the number of connected devices, the volume of traffic, and Quality of Service and Quality of Experience (QoS/QoE) required vary widely by time and place.

The DU reduces inter-cell interference by controlling the coordination between the relevant RUs in a centralized manner. This enables effective expansion of cell capacity even if a large number of RUs are densely deployed. Also, this type of coordination will be applied to access technologies other than 3GPP RAT, e.g. WLAN, and can realize seamless access between different technologies.

B) Mobile-edge Computing

In mobile networks today, end-to-end processing for network tasks such as big data analytics is mainly executed by external servers in data centers. In a 5G world, some core processing functionalities will be carried out at the network edge – such as a base station or an enterprise small cell server – while other tasks will continue to be performed centrally on highly efficient pooled general purpose servers. This will make it possible to provide new services that require real-time processing or analysis of massive data economically with lower levels of power consumption without putting a massive burden on the upper layers of the core network.

Innovations will be required to support devices that need to transmit and receive data with ultra-low latency requirements in mission critical services, such as crash-avoidance with driverless cars. One approach is to minimize the physical path between the devices and application servers. Another approach is to deploy contents cache to network nodes near the devices. Also, new RAT may be introduced to fulfill ultra-low latency requirements.

C) Virtualization of Cells

In cellular networks today, cell coverage to manage radio resource allocations is created around each geographical location of a radio antenna (i.e., site). In future RAN architecture, antenna sites will be virtualized as well as the digital baseband units. Creating cell coverage flexibly combining several virtual sites enables efficient provisioning of radio resources. This flexible architecture helps provide sufficient radio resources for users' services and

improve the users' QoE even if communications traffic varies widely by time and place.

Heterogeneous architecture that comprises a high-power RU and low-power RUs will help efficiently fulfill various requirements for solutions for society. Specifically, the high-power RU mainly undertakes control-plane tasks such as handover to ensure seamless connectivity. The low-power RUs transmit user-plane traffic coordinating with each other to fulfill QoS requirements. The inter-site coordination will be realized by various emerging technologies, such as massive MIMO and 3D beamforming that uses advanced antennas with massive elements [3]. These technologies help to increase cell capacity by focusing radio resources on geographical hotspots and reducing inter-site interference dynamically. Also, total power consumption can be saved by switching on and off RUs depending on the traffic load of each RU even when a huge number of RUs are densely deployed.

Conclusion

This white paper outlined our vision for future mobile networks that will emerge in the run-up to 2020 and beyond (the “2020 network”) and outlined the potential use cases and key enabling technologies. NEC believes that the flexible integration of future mobile networks with ICT-enabled urban and industrial infrastructure will help solve some of the world’s most pressing social challenges. It will create a sustainable and more enriching future and bring wide ranging benefits to consumers and businesses in a diversity of vertical sectors. NEC will continue to exercise its leadership as a company that uniquely has very innovative technologies in both the networking and computing domains. By collaborating closely with our customers and business partners, NEC is committed to being a social value innovator using the new “2020 network” to help create a better world.

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- [1] NEC, “NEC Vision for Social Value Creation 2014”, 2014.
- [2] NEC, “Reinventing Transport Networks for the Future”, 2015.
- [3] NEC, “Massive-Element Antenna for Small Cell Solutions in 5G”, 2015.

Abbreviations

3GPP	3 rd Generation Partnership Project
API	Application Programming Interface
AR	Augmented Reality
BSS	Business Support System
C-RAN	Cloud Radio Access Network
DU	Digital Unit
FTTx	Fiber to the x
ICT	Information and Communications Technology
IMSI	International Mobile Subscriber Identity
IMT-A	International Mobile Telecommunications-Advanced
IoT	Internet of Things
M2M	Machine to Machine
MANO	Management and Orchestration
MIMO	Multiple Input and Multiple Output
NFV	Network Functions Virtualization
OPEX	Operating Expense
OSS	Operations Support System
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RU	Radio Unit
SDN	Software-Defined Networking
SIM	Subscriber Identity Module
TCO	Total Cost of Ownership
TMS	Traffic Management Solution
VAS	Value Added Service
WLAN	Wireless Local Area Network
xWDM	x Wavelength Division Multiplex

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