5G | Future Core Network | Network Slicing

Technology Reports

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Future Core Network for the 5G Era

Networks in the 5G era will need to operate efficiently for services that have a wide range of requirements. This article describes a vision for a future core network, a 5G radio access technology being studied to realize this vision, technologies related to network slicing, and trends in standardization related to future networks that include these technologies.

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1. Introduction

An NTT DOCOMO 5G white paper [1] anticipates that by 2020, services will have advanced and diversified, with all kinds of items, such as vehicles, homes, and wearable devices, connecting to wireless networks as shown in **Figure 1**, gathering information and performing administration and control, both automatically and intelligently.

Figure 2 shows various services categorized according to the number of terminals and service requirements. The service requirements needed from 5G networks will be diverse, but with current networks, most of the traffic originates from smartphones and feature phones. As such, the network has been built suited to that traffic, namely region A in the figure, and all services are provided with that network, but this domain is expected to expand to region B due to the development of technologies and equipment.

On the other hand, as Internet of Things (IoT)*1 services develop, demand will also expand to services in region C provided at low cost with large numbers of low-specification terminals, such as smart meters and environmental sensors. It will also expand to region D, with services having fewer users than ordinary cellular services but having special, stringent requirements such as low delay or high reliability. Examples include factory automation and other industrial services and transport systems such as congestion mitigation using inter-vehicle communication. Future networks require balancing to fulfill various service requirements and reduce costs.

Considering these factors, a 5G radio access technology that is able to realize higher data rates, greater capacity and less delay than current 4G radio access technologies (LTE/LTE-Advanced) is highly anticipated.

*1 **IoT:** A general term for the network of diverse objects connected to the Internet or the cloud for control and data communications.

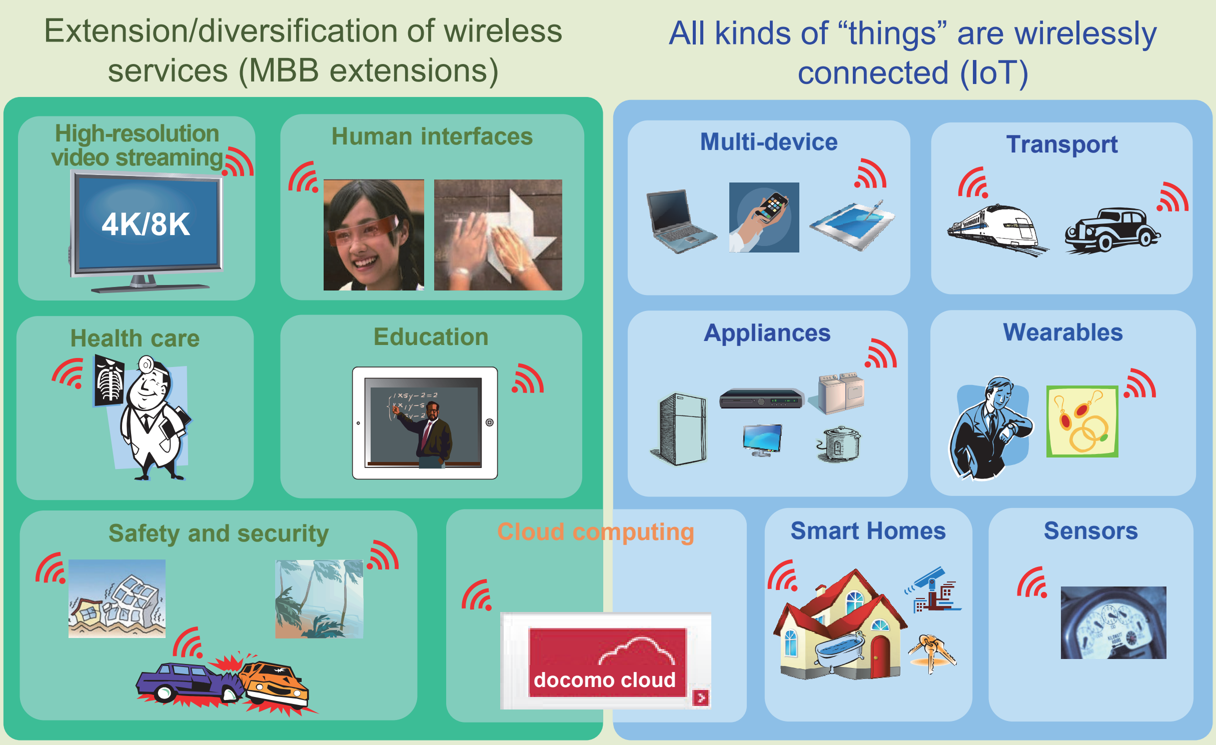

Figure 1 Various services envisioned for 5G

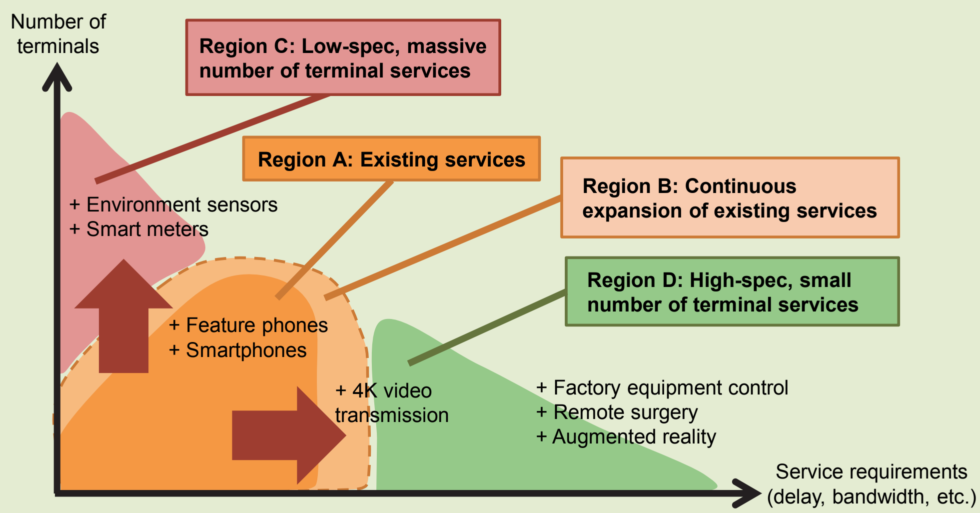

Figure 2 Expansion in number of terminals and service requirements

The existing Evolved Packet Core (EPC)*2 [2] network provides all services using the same network architecture and protocol control, regardless of the terminal type or services provided, but for services in region C, aspects

*2 **EPC:** An IP-based CN for LTE and other access technologies, specified by the 3GPP.

such as handover*3 are not needed at all, resulting in unnecessary overhead and inefficiencies. Furthermore, to provide services belonging to region D, measures such as bandwidth control, extensions to Quality of Service (QoS)*4, and high-level routing are required in order to satisfy stringent service requirements. These can affect all users accommodated in EPC, which would result in further increases in operating costs.

To resolve these sorts of issues and operate services with a diversity of requirements efficiently, a technology called network slicing, which creates and manages multiple virtual networks optimized according to terminal type or service requirements, and methods for selecting network slices suitable for each service are being studied.

This article first gives a vision for 5G networks and then describes a method for 5G radio access being studied to implement this vision. It gives details of network slicing technology and a control architecture using virtualization technologies. Finally, it introduces the current state of study at standardization organizations, on use cases, future service requirements and architectures.

2. Future Network Vision

The vision for future networks is shown in **Figure 3**. A future network will incorporate multiple radio technologies including LTE/LTE-Advanced, 5G New Radio Access Technology (RAT)*5, and Wi-Fi®*6, and be able to use them according to the characteristics of each service.

Utilizing virtualization technologies, network slices optimized for service

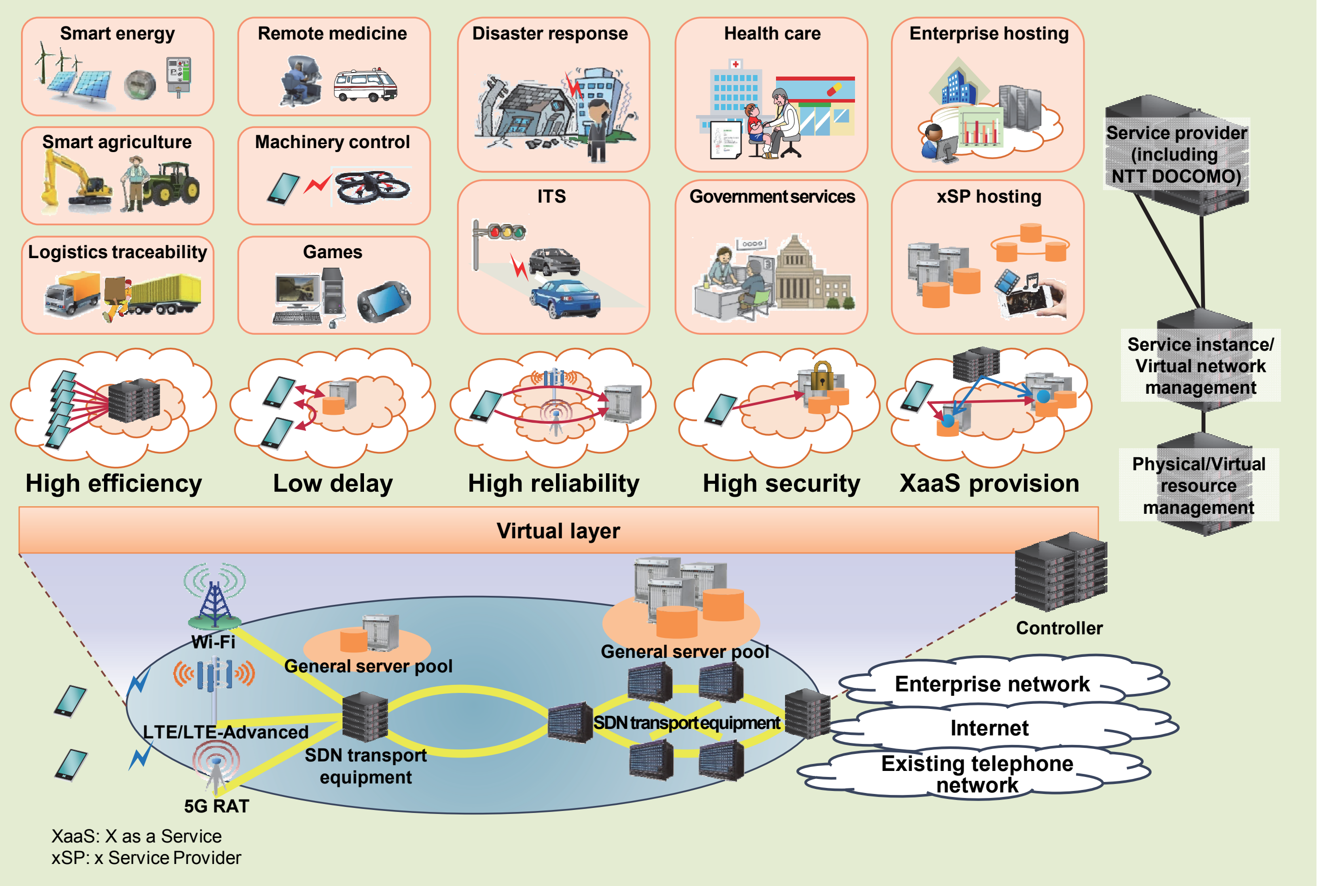

Figure 3 Future network vision

*3 **Handover:** A technology that enables a terminal that is communicating with a base station to switch to another base station while maintaining that communication while it moves from one to the other.

*4 **QoS:** The quality on the network, configured by service. Properties such as delay and packet drop rates are controlled by controlling bandwidth used.

*5 **RAT:** Radio access technologies such as LTE, 3G, and GSM.

*6 **Wi-Fi®:** A registered trademark of the Wi-Fi Alliance.

requirements such as high efficiency or low delay can be created. Common physical devices such as general-purpose servers and Software Defined Network (SDN)*7 transport switches will be used, and these networks will be provided to service providers. Network slices can be used either on a one service per network basis to increase network independence for originality or security, or with multiple services on one slice to increase statistical multiplexing gain and provide services more economically.

The specific functional architecture and the network topology*8 for each network slice are issues to be studied in the future, but in the case of a network slice accommodating low latency services, for example, GateWay (GW)*9 functions would need to be relatively close to radio access, service processing would be close to terminals, and routing control capable of finding the shortest route between terminals would be necessary to reduce latency. On the other hand, a network slice providing low-volume communications to large numbers of terminals, such as with smart meters, would need functionality able to transmit that sort of data efficiently, and such terminals are fixed, so the mobility function can be omitted. In this way, by providing network slices optimized according to the requirements of each service, requirements can be satisfied while still reducing operating costs.

3. Technical Elements for Implementation

Below, we describe elemental technologies for implementing the network vision described above, including a 5G radio access format, a slice selection technology using Dedicated Core Networks (DCN) [2]-[4], for which the Release 13 standard has almost been completed, and network slice control technologies based on virtualization technologies such as Network Function Virtualization (NFV)*10 and SDN.

3.1 5G Radio Access Accommodation

1) Simultaneous Connections with LTE/LTE-Advanced and New RAT

NTT DOCOMO is considering a structure for 5G radio access that combines continued development of the LTE/LTE-Advanced systems using current frequency bands with a new RAT capable of supporting higher bandwidth using higher frequencies than have been used to date [1]. In the 5G workshop at the 3rd Generation Partnership Project Technical Specification Group Radio Access Network (3GPP TSG RAN) held in September 2015, NTT DOCOMO proposed that for 5G radio access, technologies such as Carrier Aggregation (CA)*11 and Dual Connectivity (DC)*12 be used for simultaneous connections between the Radio Access Network (RAN)*13 and terminals using both LTE/LTE-Advanced and the New RAT (**Figure 4**). CA was specified in 3GPP Release 10 as the main technology in

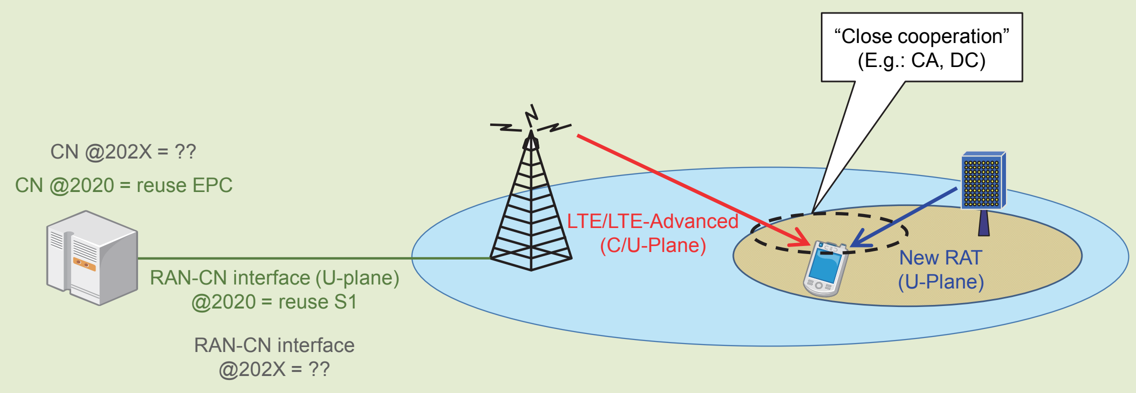

Figure 4 NTT DOCOMO connection proposal using CA/DC

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*7 **SDN:** A technology that SDN controllers manage physical (and virtual) switches centrally, enabling high-level automation of entire networks.

*8 **Topology:** Logical relationship of devices, network configuration, etc.

*9 **GW:** A node having functions such as protocol conversion and data relaying.

*10 **NFV:** A technology that uses virtualization technologies to implement processing for communications functionality in software running on general-purpose hardware.

*11 **CA:** A technology that realizes increased bandwidth and high-speed transmission, while maintaining backward compatibility with LTE, by using multiple carriers for transmitting and receiving. It is one of the technologies used in LTE-Advanced.

*12 **DC:** A technology whereby a single terminal connects to multiple base stations using different frequency bands.

LTE-Advanced, and DC was developed to further expand LTE/LTE-Advanced and specified in Release 12. They both enable increased-bandwidth transmission using multiple frequencies at the same time [5] [6].

Realizing 5G radio access by simultaneous connections of LTE/LTE-Advanced and New RAT is expected to enable the smooth introduction of 5G radio access since it allows service levels of the stable LTE/LTE-Advanced network area quality (connection quality including coverage and mobility) to be maintained, and provides improvements in user data transmission quality (data transmission rate and latency) through introduction of the New RAT.

At the 5G workshop, many vendors and operators in addition to NTT DOCOMO proposed the close linking of LTE/LTE-Advanced and the New RAT for 5G radio access, but details will be discussed by 3GPP RAN Working groups in 5G technical studies planned to start in March 2016.

2) CN and Interface between RAN and CN

(1) Reuse of existing EPC and S1 interfaces

One possibility for the interface between the 5G RAN and the Core Network (CN)*14 that supports it would be to reuse the S1 interface*15, which is the interface between eUTRAN (the RAN for LTE/LTE-Advanced), and EPC (the existing CN accommodating eUTRAN) (Fig. 4).

The network comprising eUTRAN and EPC was originally designed to support Mobile Broad Band (MBB), and EPC and the S1 interface are suitable for implementing enhanced MBB (eMBB), which is a use case for 5G. Also, by reusing the existing EPC and S1 interface, a large number of new design items and test cases for introducing the new 5G radio access can be avoided, effectively lowering the hurdles toward introducing 5G radio access.

(2) Reconsideration of system architecture

5G is required to support diverse use cases such as IoT and low latency/highly-reliable communication in addition to eMBB, and to satisfy various operational requirements, so the existing RAN-CN structure may not necessarily always be optimal. As such, the allocation of functionality between RAN and CN needs to be studied, together with functional extensions on the CN and the accompanying extensions to the RAN-CN interface. The need to reexamine the overall system architecture has also been recognized at the 5G workshop. Specifically, discussions on the pros and cons of revisiting allocation of functions and revisions and extensions to interfaces between RAN and CN is expected to happen in coordination with the 3GPP SA (Service and System Aspects) 2 architecture studies that is mentioned later.

The 5G workshop reached a consensus to perform the 3GPP RAN 5G radio access specification in two stages, with Phase 1 providing a subset to meet market demand in 2020 and Phase 2 meeting all requirements of all use cases for 5G, but consideration for meeting market demand with flexibility and for smooth migration must also be given when studying system architecture.

3.2 Network Slice Selection Technology Using DCN

1) Provision Method

We have discussed provision of services according to requirements using network slices, but actually, use of multiple services with different characteristics on a single terminal such as a smartphone or in-vehicle terminal is expected. In such cases, if a network slice is created for each service, multiple network slices would have to coordinate control for a single terminal, and the resulting increased complexity is a concern. As such, it seems appropriate to allocate functions such as terminal mobility and authentication by terminal rather than by service. Thus, network slices include a terminal management slice and service slices. A terminal will be attached to a terminal management slice and one or more service slices, depending on the services being used.

*13 **RAN:** The network consisting of radio base stations and radio circuit control equipment situated between the CN and mobile terminals.

*14 **CN:** A network comprising switching equipment, subscription information management equipment, etc. A mobile terminal communicates with the core network via a radio access network.

*15 **S1 Interface:** The interface connecting MMEs, S-GWs and other equipment to eNBs.

2) Proposed Application of DCN

If the continuous extension of the current EPC network is considered, a technology for allocating a DCN that a terminal can access according to terminal characteristics would be desirable. Although this method is expected to be applied for selecting the terminal management slice in future CNs accommodating 5G radio, it is currently being specified as a method for selecting a CN from existing networks. Using **Figure 5**, we give an overview of the network slice selection method with the DCN allocation technology. The explanation below uses mainly LTE entity names.

3) Network Selection through SSF

Allocation to a DCN, as described above, is a method of selecting a network according to terminal characteristics, and this can be considered to be controlled mainly by the Slice Selection Function (SSF)*16 in Fig. 5. In LTE, functionality corresponding to SSF is implemented in the Mobility Management Entity (MME)*17, which initially receives the attach*18 from a terminal, but various patterns are anticipated when accommodating 5G radio access, such as placing it in the base station (eNB) or implementing it in a separate node. Note that when accommodating 5G radio access, these eNB functions may be implemented as a 5G base station (5GNB).

4) Switching Procedure

When the SSF (MME) receives an attach request from a terminal, it gets the UE Usage Type, which is a terminal identifier, from the Home Subscriber Server (HSS)*19 and uses his value to select an appropriate CN (which is the terminal management slice with network slicing) (Fig. 5 (1)-(4)). It is expected that with 5G, the basis for slice selection will be more than just UE Usage Type, and slice selection by service using new parameters will be possible. When it is determined from the UE Usage Type that a terminal must be accommodated by a suitable terminal management slice, the attach request received from the terminal by the SSF (MME) is encapsulated in a redirect request message and sent to the eNB in order to forward it to a different MME within the applicable terminal management slice (Fig. 5 (5)). By redirecting the attach request to the

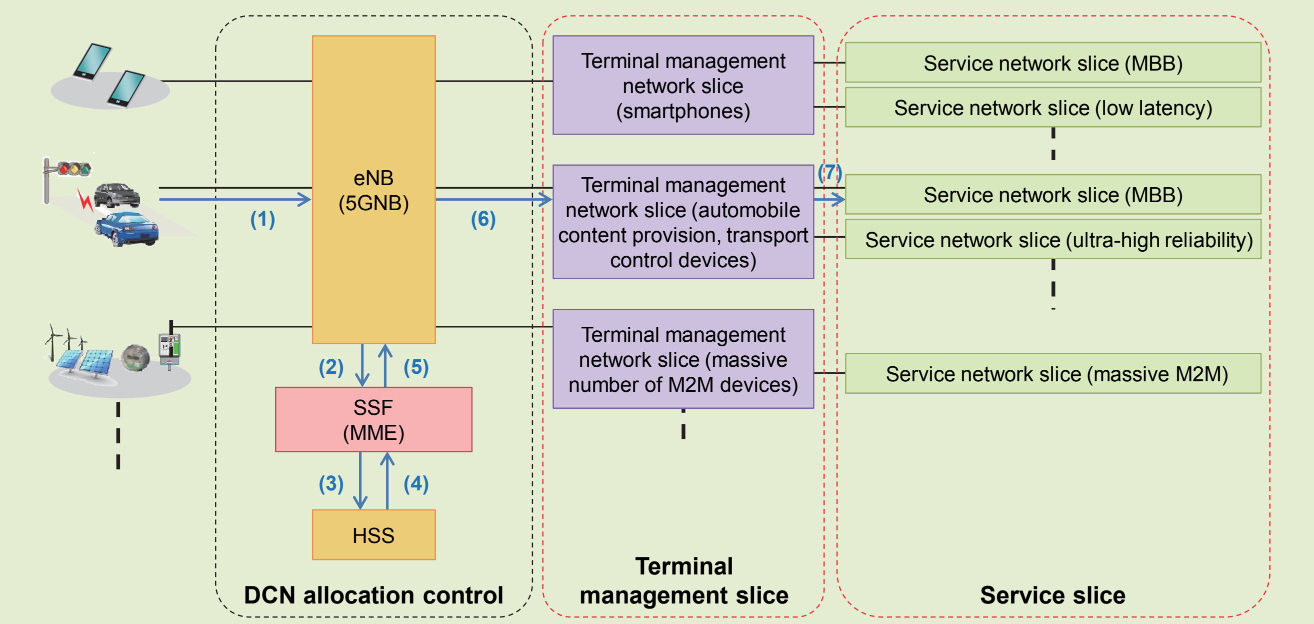

Figure 5 Applying DCN for network slice selection

*16 **SSF:** The function that selects the slice to which a service must connect.

*17 **MME:** A logical node that accommodates a base station (eNodeB) and provides mobility management and other functions.

*18 **Attach:** The process of registering a mobile terminal to a network when the terminal's power is turned on, etc.

*19 **HSS:** The subscription information database in 3GPP mobile communication networks. Manages authentication and location information.

MME in the specified desired terminal management slice, the terminal can attach to a suitable MME (Fig. 5 (6)), and thereafter services are also provided by the appropriate service slice (Fig. 5 (7)).

5) Issues with DCN Application

Since the UE Usage Type, which is a terminal identifier, is subscription data that is managed as part of the subscriber's contract, use of DCN allocation technology as the terminal management slice selection method has the benefit that operators can freely control selection of the slice that will accommodate the terminal by changing contract information, following conventional Service Order (SO)*20 procedures. This makes DCN allocation technology promising for implementing network slicing, but efficiency will need improvement and there are other issues that will need further study.

(1) The first issue is making SSF procedures more efficient. SSF equivalent functionality was provided in the MME in 3GPP Release 13 specifications, so for the desired terminal management slice to access the MME, it must first go through the MME (SSF) that is performing the terminal management slice selection. With the CN for the 5G era, the procedure can be made more efficient by, for example, placing the SSF on the RAN side, making it possible to select the desired terminal management slice MME all at once. However, in that case, a method to distribute UE Usage Types to the RAN side, or otherwise identify terminals on the RAN side would be an issue.

(2) The second issue is the implementation of the procedure to allocate service slices. With DCN allocation technology, there is no function to allocate user data transmission separately, so currently, the only way to select a connection route is based on the Access Point Name (APN)*21, but when multiple services are provided through the same APN, suitable service slices cannot be selected by this method. A service slice selection method that does not rely on just the APN needs to be considered.

(3) The third issue is deciding the node structure for each slice. Terminal management slices provide mainly C-Plane*22 functionality, while service slices provide mainly U-Plane*23 functionality, so the current allocation of functions in each entity in LTE must be reviewed, and the nodes comprising each slice must be optimized.

Concrete implementations of network slicing are still under study, so there are other improvements besides the above that need further study, and implementations other than application of DCN may also be proposed. It will be necessary to watch trends in future discussion very carefully.

3.3 Slice Control Technology through Virtualization

A network slice control architecture using NFV and SDN is shown in **Figure 6**. This architecture is composed of three layers: a physical/virtual resource layer, a virtual network layer, and a service instance layer.

1) Physical/Virtual Resource Layer

The physical/virtual resource layer is the lowest layer. It consists of physical and virtual resources that form networks, such as physical servers and transport switches, and these are managed as shared resources of the entire network by the Virtualized Infrastructure Manager (VIM)*24 which includes SDN Controller (SDN-C). These resources can be managed using methods studied by the European Telecommunications Standards Institute, Network Functions Virtualisation Management and Orchestration (ETSI NFV MANO)*25 [7]. Sets of resources are partitioned out as resource slices and used in the higher-level virtual network layer.

2) Virtual Network Layer

The virtual network layer is composed of network slices that contain Network Functions (NF) such as communication functions and service functions

*20 **SO:** When changes are made to contract and other information in the customer data management system, the process of notifying and reflecting those changes from the customer data management system onto network nodes.

*21 **APN:** The name of a connection point, consisting of a string conforming to the standard 3GPP domain name format.

*22 **C-Plane:** Control plane. Refers to the series of control processes and exchanges involved in establishing communication and other tasks.

*23 **U-Plane:** User plane. Refers to transmission and reception of user data.

*24 **VIM:** A system for managing physical and virtual machines as network resources.

*25 **ETSI NFV MANO:** A general term for the virtual resource management function defined by the European Telecommunications Standards Institute.

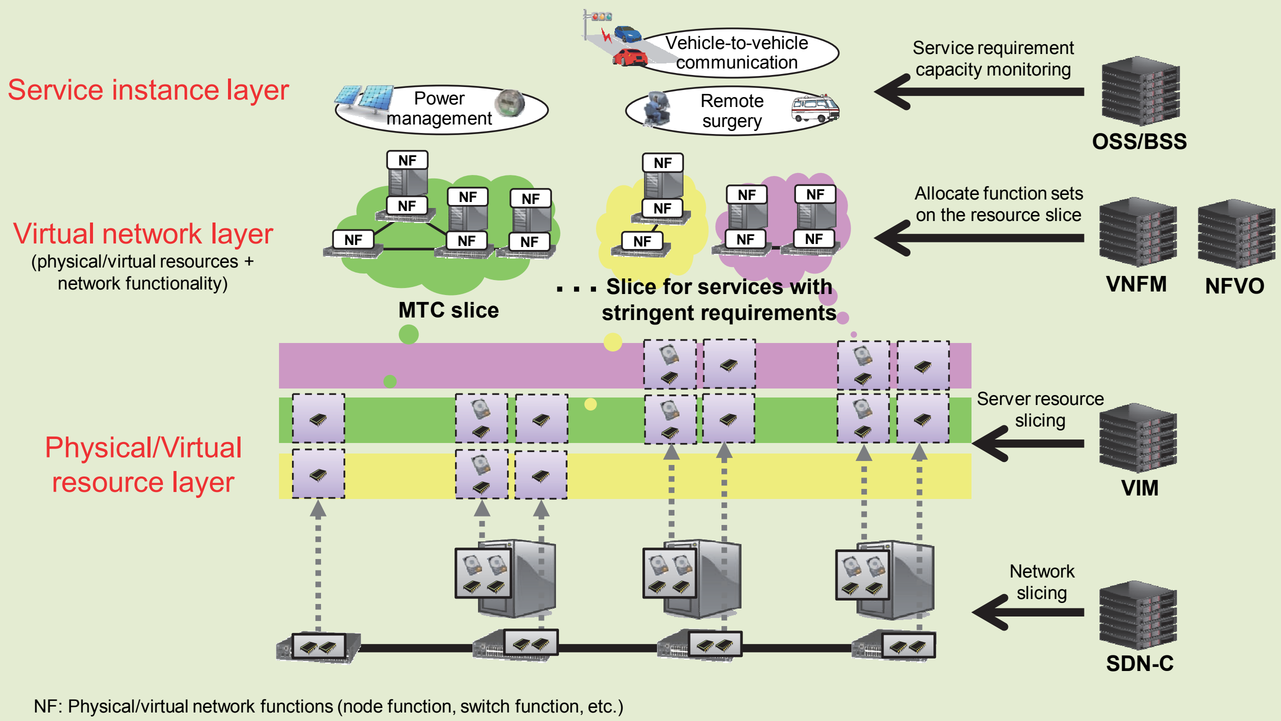

Figure 6 Slice control architecture using NFV/SDN

needed to implement services on top of the partitioned physical and transport protocols. The arrangement and management of this function set is performed for each network slice by the Virtual Network Function Manager (VNFM)*26 and the NFV Orchestrator (NFVO).

3) Service Instance Layer

Various service instances provided on network slices are managed in the service instance layer, which is the highest layer. Examples are MBB services, power management, Intelligent Transport Systems (ITS)*27, and services provided to end users such as remote surgery. The Operation Support System (OSS)*28 or Business Support System (BSS)*29 constantly monitors each service instance to ensure that service requests for each service instance are being satisfied.

The services implemented on network slices are not limited to services provided on conventional feature phones and smartphones as described above. They also include IoT services and a variety of industrial and societal infrastructure services. The radio technologies and network configurations used to provide them are implemented by combining functionality freely for each network slice.

The network slice to which a service instance is attached is initially determined by the OSS, BSS or NFVO, and dynamically maintained according to service request volume and network slice loading. In this way, individual services will be managed on future CNs as service instances, based on flexible resource management technologies, and service requirements will be satisfied while providing services economically.

4. Future Network Standardization Trends

The state of study at 3GPP related to technologies for implementing future networks is described below.

*26 **VNFM:** A system that manages functionality on virtual resources.

*27 **ITS:** An overall name for transportation systems using communications technology to improve vehicle management, traffic flow and other issues.

*28 **OSS:** Enterprise operational support systems. For communications operators, this can include some or all of: fault management, configuration management, charging management, performance management, and security management; for the networks and systems operating the services being provided.

*29 **BSS:** A system supporting operation for service providers.

4.1 Study Schedule Background

Discussion on the need to reform future network architecture and on methods of study was held in June 2014 at SA handling CN requirements and architecture. Operators in Europe have already advocated innovative developments at other organizations such as Next Generation Mobile Networks (NGMN)*30, have advocated for comprehensive review of architectures needed to introduce new services and business models, and examination of future CN requirements has been ongoing since the Release 14 SA1 meeting held in February 2015. SA2 studying architecture is also ongoing since October 2015. This study is expected to continue until the specifications are completed, with Release 15 or 16.

4.2 Current Study Items

The status of current study items is indicated below.

1) Use Cases

3GPP is conducting its study by incorporating appropriate elements with reference to preceding study results from regional standards organizations and industry organizations such as NGMN. Inclusion and priority of such items in the final specifications will be discussed further in the future, but as of now, the following use cases have been raised.

(1) Broadband access (immersive high-resolution 3D video, holograms, virtual reality services, etc.)
(2) IoT (Smart grid, smart city, environmental controls, health and medical related, automobile related (V2X), wearable terminals, etc.)
(3) Ultra-low-latency real-time communication (augmented reality*31, haptic communication, etc.)
(4) Highly reliable communication (industrial/factory automation, cooperative robot control, etc.)
(5) Lifeline communication (natural disaster response, police and fire communication, broadcast-type communication)

Note that provision of the above services could come in two forms; either the mobile communication providers provide services directly to users, or they create network slices according to service provider requests and the service providers provide services to users.

2) Service and Operational Requirements

Requirements will be derived from the above use cases in the future, but some of the requirements conceivable at this time are as follows.

(1) Network slices can be used.
(2) Network resources can be moved dynamically, effectively implementing an elastic core*32 concept.
(3) Services can be implemented with network edges.
(4) 5G and 4G radio access can be used simultaneously and selected according to services and applications.
(5) With 5G radio access, handover with 3G, including Circuit Switched FallBack (CSFB)*33 and Single Radio Voice Call Continuity (SRVCC)*34, will not be requested.

3) Architecture

Generally, investigation in SA2 would proceed after SA1, but this time they are proceeding in parallel while maintaining a loose connection between them. Architectural extension trends thought to be useful in the future that are already being studied in SA2 are as follows.

(1) Separation of C and U-Planes within the CN. Cost reduction of U-Plane equipment by replacing it with low-cost SDN switches.
(2) Small data transport. Efficient transport of low-volume IoT data (partially implemented in Release 13)

Issues for which companies could take differing positions in the future include the following.

- Whether to accommodate 5G radio access using the existing S1 interface or to create a new interface on the RAN side, and how to match such an interface with the existing interface of LTE/LTE-Advanced CN.
- The degree of integration of mo-

*30 **NGMN:** An organization composed of NTT DOCOMO and other vendors and operators that is creating a vision and roadmap for next generation mobile communications networks.

*31 **Augmented reality:** Technology for superposing digital information on the real-world in such a way that it appears to the user to be an actual part of the scene.

*32 **Elastic core:** A network architecture that achieves resistance to interruption by disaster and other causes by isolating state information.

*33 **CSFB:** A procedure for switching to a radio access system having a CS domain, when a terminal sends/receives a circuit switched communication such as voice while camped on an LTE network.

*34 **SRVCC:** A technology enabling seamless handover to a CS domain such as W-CDMA or GSM when in an LTE domain.

bile communication networks with fixed and Wi-Fi access.

5. Conclusion

This article has given an overview of elemental technologies being studied for future CN that will accommodate diverse services with varying requirements in the 5G era, and trends in standardization for future network implementation that will include these technologies. In the future, activity studying these technologies will increase at 5G-related organizations centering on 3GPP. NTT DOCOMO will continue to advance the study and standardization of technologies for future networks, as service provision infrastructure for new services and business models that could not have been provided earlier.

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