6. 5G Key Concept

6.1 Key Concepts of 5G

End-to-end (E2E) quality required by applications and/or users will be far more diversified in the 5G era than what we have seen in the preceding generations. For example, the ITU-R Vision recommendation [1] illustrates a number of usage scenarios in which the capabilities required are not identical but diverse depending on their E2E quality expected.
Fig. 6.1-1 represents potential 5G applications mapped on a domain of the quality in user experience by the quantity of data. Some attractive services and more user friendly utilities will emerge as new applications by means of innovative technologies deployed in 5G.

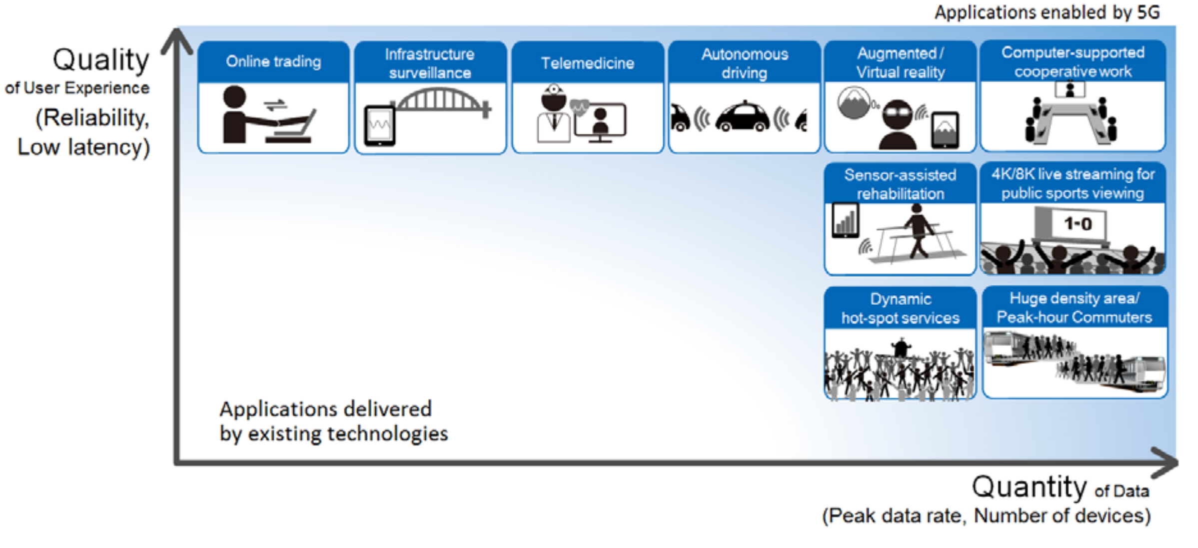

Fig. 6.1-1 Potential 5G applications

5GMF believes that one of the two key concepts of 5G consists in "Satisfaction of E2E quality" required in all usage scenarios, making users feel satisfied with the quality, whatever applications are used anytime, anywhere. Achieving "Satisfaction of E2E quality" in 5G is an essential goal that differentiates 5G from preceding generations, which were designed based on "best-effort" scenario.
Another key concept that 5G systems should have is the ultimate "Extreme Flexibility", in order to satisfy the E2E quality required in each use scene in a flexible manner, even if it is in the extreme.

6.2 5G key technical aspects

6.2.1 General

5G is expected to satisfy E2E quality of services in wider range of use cases in flexible, secure and efficient manner. It is necessary that radio access and core networks should work jointly to realize the "Extreme Flexibility". In this white paper, the two key technologies are identified as follows in order to support the "Extreme Flexibility";

- Advanced heterogeneous network
- Network softwarization and slicing

In the following sub clauses, these key technologies are illustrated.

6.2.2 Advanced Heterogeneous network

The term 'Heterogeneous network' could have several interpretations or definitions depending on the context used. In some wireless communication networks, the term refers to network consisting of smaller cells laid over a larger cell in order to increase their system capacity by offloading traffic from a single large cell to these smaller cells [1].

In case of 5G, the idea of 'Heterogeneous network' should be enhanced to involve more than the idea described above and represents configuration of communication networks that organize its entire elemental network portions to serve variety of use cases.

In [2], importance of 'heterogeneous network' integrating multiple Radio Access Technologies (RAT) existing, such as 2G, 3G, LTE, W-LAN with 5G RAT(s) was pointed out in order to achieve efficient utilization of higher and wider frequency spectrum beyond 6GHz in a cost effective manner. Considering the new use cases foreseen in 2020s especially, 5G RAT(s) should cover most of these cases efficiently and cooperate with legacy RAT(s) in the networks.

This white paper proposes that the scope of integrated radio access networks be largely extended to include multiple technologies shown above and that the network realizing the heterogeneity far beyond that in the previous heterogeneous network be called 'Advanced heterogeneous network'.

As has been described in the preceding sections, 5G should support wide range of services. Accordingly it would not be the best and efficient way to establish single technical solution that could serve all the range of the requirements for every use case of 5G. Instead, it would be reasonable to adopt proper radio communication technology with proper parameters as a unified system depending on the use cases required.

References:

[1] "Scenarios and requirements for small cell enhancements for E-UTRA and E-UTRAN," TS36.932 (Ver.12.1.0), 3rd Generation Partnership Project, Mar.2013.

[2] *"Mobile Communications Systems for 2020 and beyond," 2020 and Beyond Ad Hoc Group, Association of Radio Industries and Businesses, Oct.2014.*

6.2.3 Network Softwarization and Slicing

Network Softwarization is an overall transformation trend for designing, implementing, deploying, managing and maintaining network equipment and/or network components by software programming, exploiting the natures of software such as flexibility and rapidness all along the lifecycle of network equipment/components. The industry effort on Network Functions Virtualisation (NFV) and Software Defined Networking (SDN) are integral part of this transformation.

The basic concept of the Network Softwarization is "Slicing" as defined in [ITU-T Y.3011], [ITU-T Y.3012]. Slicing allows logically isolated network partitions (LINP) with a slice being considered as a unit of programmable resources such as network, computation and storage. Considering the wide variety of application domains to be supported by 5G or IMT-2020 network, it is necessary to extend the concept of slicing to cover a wider range of use cases than those targeted by the current SDN/NFV technologies, and the need to address a number of issues on how to utilize slices created on top of programmable software defined infrastructure.

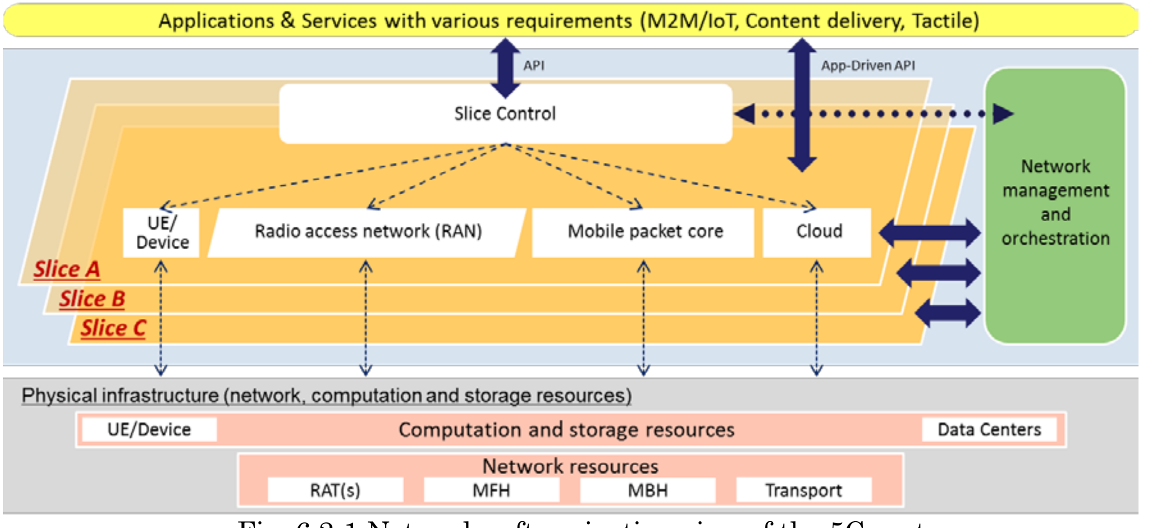

Fig. 6.2-1 Network softwarization view of the 5G systems

Fig. 6.2-1 illustrates the network softwarization view of 5G systems, which consist of a couple of slices created on a physical infrastructure by the "network management and orchestration". A slice is the collection of virtual or physical network functions connected by links to create an end-to-end networked system. In this figure, the slice A consists of radio access network (RAN), mobile packet core, UE (User Equipment)/device and cloud, each of which is collection of virtual or physical network functions. Note that the entities are shown rather symbolically and links are not described in Fig. 6.2-1 for simplicity. The "network management and orchestration" manages the life cycle of slices: creation, update and deletion. It also manages the physical infrastructure and virtual resources, which are abstraction of physical resources. The physical infrastructure consists of computation and storage resources that include UE/devices (e.g. sensors) and data centers, and network resources that include RATs, MFH, MBH and Transport. It should be noted that both computation/storage resources and network resources are distributed and are available for creating virtual network functions.

Network softwarization will greatly improve flexibility in design, implementation, deployment, operation and maintenance of network functions and components, and increase velocity of service delivery by making the best use of programmability. In addition, application of "Slicing" will increasing efficiency and dynamicity of 5G systems, since it enables just-in-time assembly of network functions and components for service delivery in concert with arrangement of advanced heterogeneous networks.

6.3 5G Typical Use Cases

This section addresses typical 5G use cases and enhancements required for individual usage scenarios, based on the IMT Vision recommendation ITU-R M.2083-0, which classifies typical 5G usage scenarios into following three use cases.

6.3.1 Ultra-reliable and low latency communications

The 5G should support not only human communications but also applications for non-human equipment, including machines, vehicles, sensors and etc. Some applications in this category will be more stringent to delay and loss of information than other applications or those in the preceding generation systems and will require that packets should be delivered to the other end in a specified period certainly. They will call for capabilities such as lower latency and higher reliability than in the preceding generation system.

The radio access networks, core networks and other part of the networks, which constitute E2E networks, should work closely to satisfy these E2E quality. For example, in order to achieve required E2E latency, distribution of latency budget to each constituent part of networks, i.e., handset, radio access network, fronthaul/backhaul, core network should be considered.

Typical use scenarios in this use case include wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.

Designers of mission critical applications will focus on end-to-end quality provided by 5G systems. In a typical arrangement of such applications, the end-to-end is comprised not only of radio access networks but also of terminals, fronthaul/backhaul networks, mobile packet core and inter-service provider networks and data-centers. This implies that the end-to-end quality depends on the quality provided by both radio part and wired part of networks, and in contrast, that 5G systems should have the capability to tailor the end-to-end by organizing functions and connectivity so as to satisfy the requirements of mission critical applications.

Mobile Edge Computing (MEC) is the concept to provide an IT service environment at a location considered to be the most lucrative point in mobile networks, characterized by proximity, ultra-low latency and high bandwidth.

One of the mission critical applications includes that requires low latency. It includes the maintenance and control of devices, instruments and equipment in factories, remote control of construction equipment and delivery robots, distance medicine, autonomous driving. Such applications require a close feedback system where the information from sensors that capture status of working environment is transmitted to a control function that makes decisions for reaction, and the commands that realize the reaction is conversely transmitted to the actuators that execute the commands. The overall propagation time of the system is of interest to the designers, which is usually required to be in a range of tens of milliseconds. Designers may consider where to place the control function to meet application's requirements: Usually it is considered to place it in a proximity to the sensors and actuators physically.

6.3.2 Massive Connection

As shown in Chapter 7 "Typical usage scenarios of 5G", in order to cover applications for non-human equipment in addition to human communications, specific capabilities are required by these applications. Those capabilities will include area coverage expansion to non-resident area, cell radius expansion, and massive connections in order to accommodate as many equipment as possible in the system and so on. In order to attain this objective, the system should be designed so as to accommodate numerous equipment in an efficient manner, while the data volume generated by the equipment may be relatively small as compared with signaling traffic in some cases. Also the system should be designed to reduce cost and power consumption of devices. This use case include infrastructure monitoring, sensor network, etc.

6.3.3 eMBB enhanced Mobile Broadband (Data rate, Capacity, Mobility)

This use case will require increasingly improved and seamless user experience as compared with the preceding generation systems. As stated in the previous section, the 5G systems should aim at providing sufficient user experienced data rate in every circumstance. Typical use scenarios in this use case will include enjoying a sports game in a stadium more vividly by watching the video, video communication employing augmented reality, virtual reality technologies.

The increase of the data rate will broaden the opportunity for supporting various high-quality streaming applications. The characteristics of such streaming applications depend on average bandwidth, end-to-end latency, and possible latency fluctuations, and so forth. In transport networks, we have sufficient knowledge and experiences to control such metrics. It is expected to explore how we control streaming applications in 5G radio access, and how we design end-to-end networking system so as to fulfill the E2E quality.

This use case requires enhancement of fundamental network capabilities sufficiently to satisfy user requirements without making users feel frustrated, which will be made possible by removing constraints and restrictions imposed by the network of succeeding generations. Examples of augmentation and enhancement to the capabilities are illustrated below.

－Peak data rate and system capacity
The eMBB usage scenario will require improvement of performance in terms of peak data rate and system capacity to satisfy user experience in new applications.

Availability of spectrum bandwidth is one of the mandatory requirements for 5G, since spectrum is a constraint to limit peak data rate and system capacity. This constraint should be relaxed by securing bandwidth sufficiently wide to provide peak data rate required by users and/or applications and to accommodate as many users as possible.

－Mobility
Maximum vehicular speed at which 5G systems can provide sufficient QoE should be enhanced to cover all surface vehicles to appear around 2020, including Magnetic Levitation train known as "linear motor cars" in Japan.

－Quality improvement by multi-antenna technologies
In the 5G era, beamforming technology is effective to improve quality by concentrating transmission power in a small area and/or on a moving user(s). Beamforming is based on multi-antenna technologies to control large number of antenna elements, which is more adaptable to higher frequency band.

In the practical usage scenario, requirements for 5G systems are changing constantly, varying with time, locations, applications in use, user distribution and other factors. It is foreseen that 5G systems should accommodate numerous users and/or applications of various requirement, therefore, the dynamic range of requirement will be much wider than in the previous generations.

Typical examples of usage scenarios are described in Chapter 7 of this white paper.