

5G Mobile Communications Systems for 2020 and beyond

Internet traffic has sharply increased along with the need for more network capacity and higher speeds as new content-rich services become more and more popular year after year. Services being offered are also diversifying as both human-to-human and human-to-device communication increases. Device-to-device communication, or what is called the Internet of Things (IoT), is also expanding worldwide as network and sensor technology advances, leading to a further increase in traffic, facilitating changes in ICT services for entertainment, transportation, industry/verticals, and emergency and disaster relief. Examples include artificial intelligence and adorable robots that assist people in their home and work lives, autonomous vehicles like unmanned taxis as well as vehicles that can provide mobility for senior citizens, and wearable devices that collect and analyze vital data to assist in health and medical services. These are just some of the services that are expected to be implemented in the near future as these trends continue to accelerate. (Fig. 1)

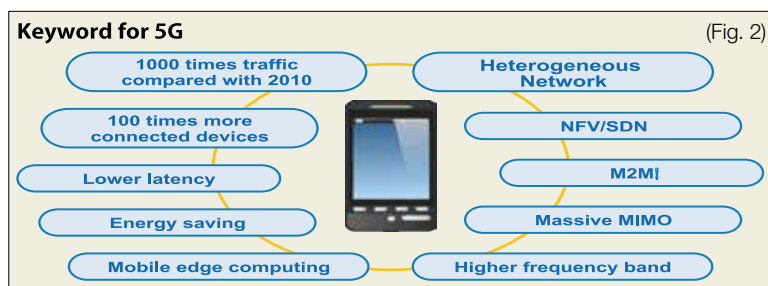
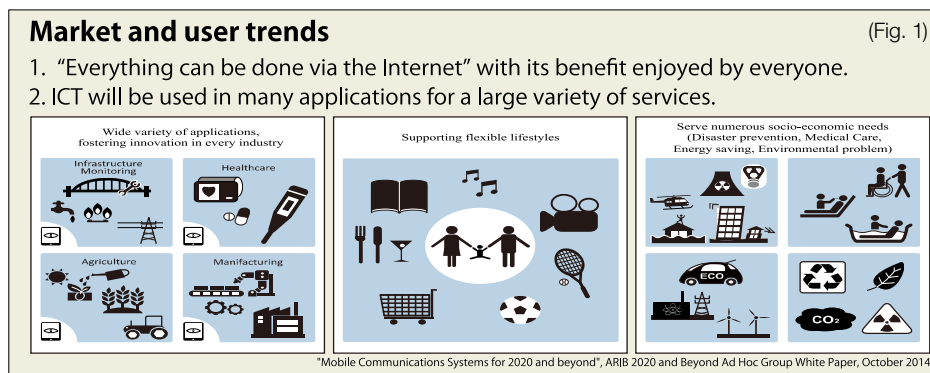
The Fifth Generation Mobile Communications promotion Forum, which was formulated in the Radio Policy Vision Council in Japan on September 30, 2014 to actively promote research into 5G in line with trends both in Japan and abroad based on the 5G implementation roadmap published by the government of Japan, has collected in this white paper the opinions and experts in industry, academia and government concerning their views of the future of applications, networks, and wireless technology related to 5G in order to provide a clear goal for the development of 5G. It discusses the many expected **new uses of ICT in the 5G era by various industries, as well as the new** businesses and markets that will be created and the expectations of the fuller lifestyle that it will bring to people everywhere.

5GMF proposes in this white paper two key concepts for 5G: "Satisfaction of End-to-End (E2E) quality" and "Extreme Flexibility." "Satisfaction of E2E quality" means providing every user satisfactory access to any application, anytime, anywhere, and under any circumstance. "Extreme Flexibility" is the feature of communications systems which will allow 5G to always achieve E2E quality. (Fig. 2)

The demands by users and needs by applications for E2E quality in the 5G era will be much more diverse when compared to previous generation systems. The dynamic ranges fluctuated by the temporal and spatial factors will also expand more dramatically. These changes determine a major requirement for 5G which is completely different from previous generation systems, for which providing best effort quality was sufficient.

In previous generation systems up to 4G, radio access networks were regarded as the dominant bottleneck in determining E2E quality of mobile applications and services, since the performance of radio access networks were limited by a number of constraints, including radio propagation characteristics, available bandwidth, handset power, and mobility. In the 5G era, however, it is expected that most of these constraints will be greatly relaxed by the advancement of radio technologies, meaning the performance of radio access networks alone no longer the sole bottleneck. The performance of core networks will also be taken into account to satisfy E2E quality. Therefore, the technologies for radio access and core networks should be studied jointly and developed on an equal basis in order to realize "Extreme Flexibility".

This white paper identifies two key technologies necessary to support "Extreme Flexibility" and thus the wide range of use cases expected in the 5G era: "Advanced Heterogeneous Network" and "Network Softwarization and Slicing". We believe that through the use of these two key technologies 5G standards will allow for wired and wireless networks to continue to have the ability continue to handle the growing demand for larger capacity and higher speeds as previous mobile communication systems have been able to do so in the past.



Using the research discussed above as a base, 5GMF has already contributed to ITU and 3GPP in discussions on frequency coordination, standardization, and other related activities, as well as built collaborative relationships with 5G related organizations internationally and disseminated 5G related information to relevant industry sectors. Along with continuing to carry out these activities going forward, 5GMF will accelerate the pace of actions needed to successfully implement 5G by the year 2020.

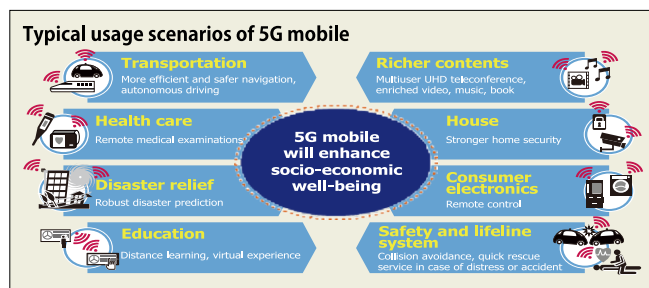
1. Market and User Trends related to 5G (Chapter 3)

This chapter, in addition to gathering information on ICT usage, broken down by age group, type of content, and type of device, and relevant industries and services, attempts to predict future trends in order to understand what the communication environment will be, and thus what mobile communication services will be in demand, in 5G era.

Current trends indicate that internet use will increase broadly across all ages and that young people, especially women, will increasingly access the internet through mobile devices. Unlike in the recent past, when internet was accessed through personal computers and similar devices, more and more people are accessing the internet through their smartphones, tablets, and wearable devices. In addition, many kinds of devices, such as new types of sensors, robots, including drones, and cars, are also increasingly connected to the internet.

Once 5G is introduced, many new services will be launched: artificial intelligence and friendly looking robots to assist people in their daily lives as well as in industrial services, autonomous vehicles such as driverless taxis and elder care support vehicles, and wearable devices that will track and analyze vital data to provide information for health services.

People will be able to access real time geographic information about traffic jams and road construction through maps that are updated dynamically. In addition, not only information but also objects and devices will become more easily sharable as information about the times and locations they are available to be borrowed will be able to be accessed dynamically, as well. Finally, as fintech becomes more advanced and its user base increases, support for the introduction of new financial services will also occur.



2. Traffic Trend (Chapter 4) and Cost Implications (Chapter 5)

This chapter introduces the most up to date analysis of data traffic.

We conclude that after analyzing communication system construction and operating costs, household mobile communication expenditure trends, and telecommunication carriers projected revenue, the projected increase in traffic will not simply lead to an increase in the communications market.

One example of the difficulties involve is the shift of populations in urban areas. Population surveys show large changes in populations of certain areas and especially large changes in daytime and night time populations. However, since the amount of connections between people and things means the future of mobile communication systems will be used in a much broader way than they are today, it will necessary to build a network that is both flexible and extendable in order to satisfy consumer demands economically.

3. 5G Key Concepts (Chapter 6)

5GMF proposes in this white paper two key concepts for 5G: "Satisfaction of End-to-End (E2E) quality" and "Extreme Flexibility." "Satisfaction of E2E quality" means providing every user satisfactory access to any application, anytime, anywhere, and under any circumstance. The use of "Extreme Flexibility" is what will allow 5G to always achieve E2E quality.

5GMF also identifies two key technologies necessary to support the wide range of use cases expected in the 5G era through "Extreme Flexibility". The first is an "Advanced Heterogeneous Network". The second is "Network Softwarization and Slicing".

4. 5G typical use scenarios (Chapter 7)

5GMF surveyed and analyzed market and user trends to understand the following use scenarios:

- 1) Entertainment, including providing high level experiences to end users;
- 2) Transportation, including providing a high level of services to comfortably support people and things while in transit;
- 3) Industry/verticals, including creating innovative and inventive ways of working by applying ICT in other industries, such as manufacturing and agriculture;
- 4) Emergency and disaster relief, including providing high level first aid and other needed functions during an emergency.

5. Radio and Network technology used to deploy 5G (Chapters 8 -12)

In order to realize "Extreme Flexibility" of 5G, it is required to utilize any frequency bands from low frequency bands to high frequency bands depending on their characteristics.

5GMF analyzed which frequency bands would be most desirable for use by 5G systems, especially in the ranges from the 6GHz band to the 100GHz band. The first stage of this research was an analysis looking only at their use for 5G systems, the second stage was an analysis looking at interactions between 5G and other systems, and the third stage was an evaluation from the viewpoint of international cooperation. This white paper presents a list of desired frequency bands as a result of second stage research.

This white paper also describes the network technologies 5GMF has found that will be needed to implement "Extreme Flexibility" in order to enable a wide variety of services to be provided. Network Function Virtualization (NFV)/Software Defined Networking (SDN) technology has been developed with the goal of promoting network virtualization. Network softwarization is an overall industry trend which includes NFV and SDN. It will be one of the main technologies implemented to promote network flexibility. There are four focus areas where these technological trends are to be further explored: network softwarization, network management technology, fronthaul/backhaul, and mobile edge computing. An overview of technologies in each area is given, followed by thorough discussion and how to implement these technologies. Possible use cases in 5G and beyond are also presented.