Interview with Dr. Kei Sakaguchi, Professor at Tokyo Institute of Technology

5G – α Technology to Realize α "Super Smart Society"

By *Japan SPOTLIGHT*

Commercial use of 5G started in Japan in April 2020. The cellular communication system has been updated twice since 2000 when 3G service started, namely 4G in 2010 and 5G in 2020. With 5G, we can achieve ultra-high speed, ultra-reliable and low latency, or/and massive connectivity. What kind of services would 5G be able to realize?

Dr. Kei Sakaguchi of Tokyo Institute of Technology and dean of the Tokyo Tech Academy for Super Smart Society, talks about the "Super Smart Society" of our future.

(Interviewed on Feb. 28, 2020)

Self-Introduction

JS: First of all, could you please introduce yourself briefly?

Sakaguchi: I am an outside director of IT company ORO and a consultant of Fraunhofer Heinrich-Hertz-Institute, HHI, as well as a professor at Tokyo Institute of Technology. My specialty is wireless communication engineering and I am working on system design of wireless communication systems. We need this work around only once every 10 years and as such very few experts are working on it. Meanwhile, there are many companies producing systems based on the design or providing services for a system. Those companies are in the category of the information and telecommunication industry, including mobiles, and in Japan its market scale is the largest among all industries, larger than those of the commerce (retail and wholesale) or real estate sectors.

Dr. Kei Sakaguchi

5G Explained

JS: The telecommunication system of cell phones or smartphones has been updated to 3G and then 4G and now 5G, whose service for commercial use is to start in April 2020. Could you please tell us about each system's characteristics?

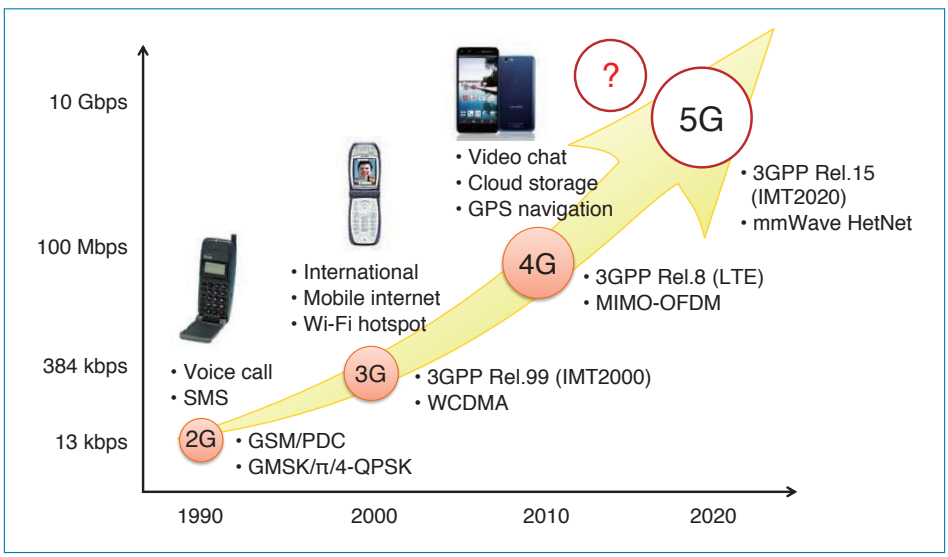
Sakaguchi: The updated mobile communication systems known as 3G, 4G and 5G started with 3GPP Release 99, a standard specification of 3G released in 1999. 4G was released in 2008 with a standard specification called Release 8, and 5G's standard specification is called Release 15 that was released in 2018 *(Chart 1)*. Although there is a drastic change of performance from 3G to 4G and 5G, a gradual update of the systems has been carried out around once a year. A system design is formulated on the basis of what needs to be pursued at the next generation and the technological seeds to be provided. The most crucial innovation in the case of 3G was to enable international roaming, having made it possible for a domestic cell phone to be used internationally. With 4G, we achieved a multi-media data communication. New services came into existence one after another with 4G. For example, watching and listening to videos, collaboration with a cloud system, navigation by using map applications, and so on.

With 5G standardized in 2018, we will achieve improved performance of communication characterized by the following metrics: "ultra-high speed", "ultra-reliable and low latency" and "massive connectivity". Growing attention is focused on what kinds of services will be born with the arrival of a 5G with significant improvement of performance.

JS: Could you tell us how much impact 5G will have on telecommunication in comparison with 4G?

Sakaguchi: The maximum data rate of 5G will achieve 20 Gbps

CHART 1
History of cellular networks



Source: Kei Sakaguchi, Tokyo Institute of Technology

(giga-bits per second), which is more than 100 times faster than that of 4G *(Table)*. In other words with 5G, a video content of a two-hour movie can be downloaded within a second. Moreover, the user experienced data rate with 5G might be about 1,000 times faster than that of 4G, since 5G will introduce small-cell base stations where the number of connected devices per base station is smaller than that of 4G. In addition, the communication latency of 5G will achieve 1 ms (millisecond), which is 10 times shorter than that of 4G. The shorter latency is very important to realize mission critical services such as automated driving. Furthermore, the maximum number of devices connected to 5G will achieve 1,000,000/km^2, which is 100 times larger than that of 4G. It is noted that the ultra-high speed and massive connectivity are exclusive. However, there are a lot of requests to support massive connectivity even with a lower data rate especially in IoT scenarios such as in smart agriculture.

TABLE
Specifications of 5G

	LTE (4G)	IMT 2020 (5G)
Data rate	100 Mbps	20 Gbps
Latency	10 ms	1 ms
Connectivity	10,000/km^2	1,000,000/km^2

Note: LTE: Long Term Evolution, IMT: International Mobile Telecommunication
Source: Kei Sakaguchi, Tokyo Institute of Technology

JS: What distinct technological innovations can be achieved by 5G with this ultra-high speed communication?

Sakaguchi: Let me talk about electromagnetic waves first. Both radio waves issuing from cell phones or smartphones and optical waves issuing from lighting equipment are electromagnetic waves. With lower frequency, their wavelengths will be longer and reach distant places; with higher frequency, their wavelengths will be shorter and become light with a frequency exceeding 3 THz. Light with shorter wavelengths cannot reach beyond a barrier due to the shadow it casts. This difference creates a different usage of electromagnetic waves, depending upon frequency. Electromagnetic waves with relatively lower frequency are used for telecommunication in ships or airplanes or AM radio by taking advantage of their capacity to reach distant places.

Meanwhile, wavelengths affect the size of receiving equipment. We need a large antenna to receive waves of longer length. In the case of a cell phone, as it is important for this to be connected and also to be

small, its length and frequency for use is limited. So far, we have been using a wave around 2 GHz with a 15 centimeter wavelength for a cell phone. But with 5G it is possible to use higher frequency waves with far greater traffic capacity. This is a significant technological breakthrough. The higher the frequency, the more information the electromagnetic waves can transfer. In 5G we combine the existing frequency waves and the higher frequency waves which has never been done so far and achieve both connectivity and ultra-high speed in mobile telecommunication. This is what we call heterogeneous cellular networks. Namely, lower frequency used in 4G supports connectivity, while higher frequency introduced newly in 5G supports ultra-high speed data communications.

JS: With 5G services starting, what services should be commercialized at the earliest opportunity?

Sakaguchi: I think services that use augmented reality (AR) will be commercialized at the early stage. For example, with AR when you watch sports in a stadium, you can have the athletes' information or what has happened in the game so far in a part of your field of vision by using a wearable terminal. Or, with navigation services using AR, you can have geographical information in a map in a part of your field of vision without looking at a map application on a smartphone fixed on a bicycle or the screen of a car navigation system.

5G has been developed for the purpose of enhanced entertainment during the Tokyo Olympic and Paralympic Games 2020, as well as providing a wide range of services including enhanced security for the benefit of visitors. Initially the areas receiving such services will be limited, but will be expanded later.

JS: What kind of services would be available in the more distant future?

Sakaguchi: A smartphone's display is currently palm-sized. With a telecommunication speed a hundred times higher than now, we will be able to have a scope of view of 100 displays on a smartphone's screen. This would enable us to achieve mixed reality (MR) where real space and virtual space are combined in our field of view. Thus, in business operation spots, you will not have to look at a manual instruction book while proceeding with your work. In education venues, virtual training and learning would be possible. The MR/AR terminals for use will be smaller and lighter, and wearable terminals equipped with a camera, display, microphone and speaker will be put into practice. In a 5G network, a picture you take can be uploaded to a network and analyzed by AI, and the result will be shown to you with low latency and thus you can see the analysis in real time.

With such technology, for example, you would be able to operate a robot in a remote place. You would not have to get on a tractor on your own on a farm. On a construction site, you would not have to get on a machine to operate it. There would be a variety of remote operations or virtual ones at medical and caregiving venues.

5G is also expected to contribute significantly to development of automated driving cars. We need to enhance safety to achieve this. There will be some occasions when some part of your driving area would be out of your view, such as turning at an intersection or parking in your garage. If cars equipped with 5G become prevalent, a number of sensors in these cars will replace your eyesight to enhance safety with the collected information on the surrounding traffic. With not only your own car's sensors but also nearby cars' sensors or the surrounding information collected by 5G set on a street, you could make a decision instantly based upon this collective information and your blind side would be reduced and safety enhanced *(Image)*.

Another distinction of 5G is the availability of private 5G which will be introduced in local areas for private businesses. With the introduction of private 5G into sports stadiums, commercial facilities, construction sites and factories, its use will be accelerated.

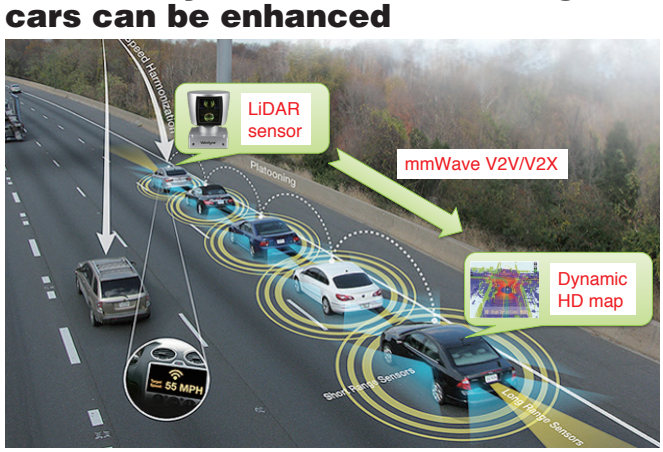
Tokyo Institute of Technology plans to introduce it in the 2020 academic year.

JS: What are some examples of services to be provided by private 5G?

Sakaguchi: One example would be automatic parking in a parking lot

IMAGE

How safety of automated driving cars can be enhanced



Source: Kei Sakaguchi, Tokyo Institute of Technology

at a commercial facility, such as a department store. Valet parking services in hotels can be replaced by this automatic service provided by private 5G. Stopping a car at a designated spot, your car will be automatically moved to a parking lot, and when you leave the hotel your car will come to you automatically. We define such a limited space of wireless telecommunication as private 5G.

JS: Judging from your examples, 5G would seem to have a greater impact on businesses rather than individuals. 5G is expected to contribute to productivity with expanded use of ICT, but would this have a negative impact such as a possible increase in unemployment?

Sakaguchi: It is true that the business needs for 5G would be very large. Whether new job opportunities would be born, or whether you would have more leisure time with changes in work style due to 5G, will depend on yourself.

What a Super Smart Society Will Look Like

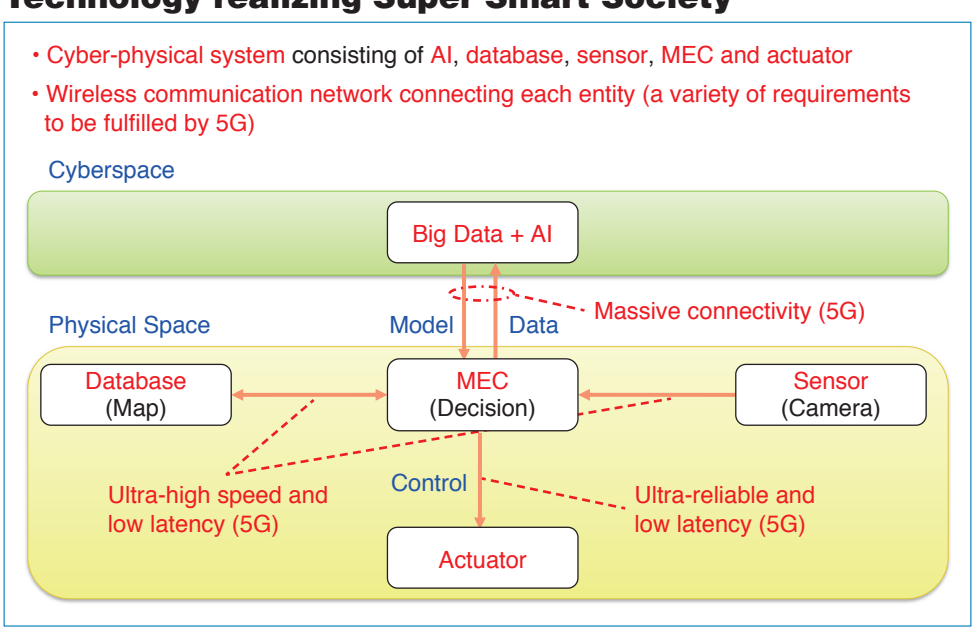
JS: What would this Super Smart Society achieved by 5G look like?

Sakaguchi: At the moment, smartphones are limited in use, enabling us to access information in cyber space and receive it. But we are now moving towards a Super Smart Society where remote control of machines or automated driving or telemedicine will be seen with the completion of a framework of connecting five components, i.e. sensors collecting information, a local database, an actuator for control, a mobile edge computing (MEC) for decision in a physical space, and Big Data (BD) and artificial intelligence (AI) in cyber space. The three main distinctions of 5G, namely ultra-high speed, ultra-reliable and low latency and massive connectivity, are used to connect these five components by satisfying their different requirements. In other words, 5G is an enabler to realize a Super Smart Society *(Chart 2)*.

In the domain of mobility, there are services emerging that have nearly been put into markets. For example, in April 2020 automated driving bus transportation starts and demonstration experiments are in progress for promoting practical use of an automated driving taxi to be realized within two or three years. Toyota has also announced a plan to develop land in Shizuoka Prefecture at the end of 2020 to create a "connected city" with the introduction of automated driving cars. There, we expect new businesses to be born and new services to resolve the issues of an aging society.

CHART 2

Technology realizing Super Smart Society



Source: Kei Sakaguchi, Tokyo Institute of Technology

JS: What are the main concerns in realizing a Super Smart Society?

Sakaguchi: We call the gap between the people capable of using ICT and those not capable of doing so a digital divide. In the future, we see a "digital gap" being born. While our smartphones only enable us to access information now, in a future Super Smart Society, depending upon your skill in taking advantage of the variety of information, you will be a winner or a loser in your working life. In this light we will see a large inequality in standards of living or job opportunities. For example, whereas some are obliged to work within the constraints of time and venues as before, with 5G some will be able to do their job connected with human networks in Tokyo while living far from the city, such as in a resort place like Hawaii, since with the use of 5G you can do your work in a remote place from your company.

JS: How can we reduce such a "digital gap"?

Sakaguchi: I think it will be important for all generations to learn about new digital technology. We call it "open education". That would reduce the "digital gap".

Developing Human Resources

JS: Who will be the human resources leading a Super Smart Society?

Sakaguchi: I think we need to develop human resources who will be not only knowledgeable about robots or AI but also experts in creating combined systems that work well in the physical life domain, such as automated driving, smart manufacturing, etc. Good progress has been achieved these 10 years in human resource development in the fields of data science and AI. Meanwhile, in the next 10 years we will need to develop human resources who can understand both the physical and cyber domains and think about how digital technology can be applied to our daily lives and lead the research and development for such applications. We are planning to enrich our education programs for this purpose in the next 10 years at Tokyo Institute of Technology.

JS: Do you have any specific human resource development plans?

Sakaguchi: Yes. We have a special human resource development program called the "World-leading Innovative & Smart Education program for Super Smart Society" (WISE-SSS) starting from April 2020 (https://www.wise-sss.titech.ac.jp/). This will offer a consistent academic program at both Master's and Doctoral level. We adopt "open education" and make it online, and thus anybody regardless of age or workplace could learn from this program. What we call the industry-academia alliance between universities and private business has not necessarily been proceeding very closely, but we will need to strengthen the links between education and R&D to promote learning about a Super Smart Society. For this purpose, we have founded the Super Smart Society Promotion Consortium and pursue an open platform for simultaneous promotion of open education and innovation. Currently, more than 40 partners have joined this consortium (https://www.sss.e.titech.ac.jp/).

There are not only private businesses and public research organizations but also local governments such as Ota Ward in Tokyo or Kawasaki city are participating in this consortium. For example, in Ota Ward where the population is increasing, they are planning to work on ideas like a city with automated driving or a flying taxi. In Kawasaki, workers in the industrial zone are facing significant aging and they need to think about how they can find their successors and how their technical expertise can be transferred to the younger generation. The Hiroshima prefectural government is now searching for a more efficient way to conduct evacuations in the event of natural disasters like typhoons and is trying to raise the human resources to find solutions for such issues.

As a crucial part of this education program, we will soon, in the 2020 academic year, introduce private 5G on the campus of Tokyo Institute of Technology and create a learning environment where a student can physically experience automated driving and the new services accompanying it as well as learning about them. So far we have not had any education venue for learning holistically about automated driving, as the lectures on automated driving were divided into several courses – studies on machines, electrical engineering, system control and computing technology – in our university. Our new education program will create a venue where students can learn holistically about technology and acquire the knowledge necessary to achieve a Super Smart Society. JS

Written with the cooperation of Naoko Sakai who is a freelance writer.