
NTT DOCOMO
Technical Journal
25th Anniversary
NTT docomo

NTT DOCOMO
Technical Journal
25th Anniversary 2018

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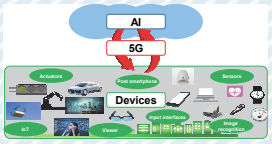

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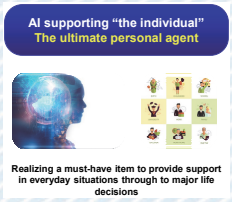

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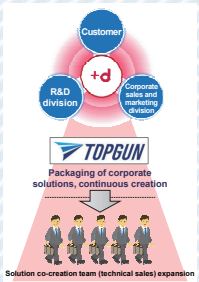

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On the Publication of the 25th Anniversary Issue of NTT DOCOMO Technical Journal

Executive Vice President,
Member of the Board of Directors
Executive General Manager of
R&D Innovation Division

Hiroshi Nakamura

The inaugural issue of the NTT DOCOMO Technical Journal was launched in July 1993, the year following the establishment of NTT DOCOMO. This year marks its 25th anniversary as a technical public relations magazine providing a broad introduction to the latest research and development trends at NTT DOCOMO.

As one milestone in the history of the NTT DOCOMO Technical Journal, this 25th anniversary issue highlights technical innovation and business innovation as envisioned by NTT DOCOMO over the next 25 years. A separate volume looks back at the history of mobile communications services over a period of about 40 years as indicators of future progress. For that volume, we have extracted and compiled articles on epoch-making R&D from the NTT DOCOMO Technical Journal and from Nippon Telegraph and Telephone Public Corporation and NTT technology-development materials (Electrical Communications Laboratories Technical Journal).

Mobile communications services began on December 3, 1979 with the launch of the world's first mobile communications system (first generation) based on a cellular system by Nippon Telegraph and Telephone Public Corporation (forerunner to NTT). For the roughly 40 years since then, NTT DOCOMO has fostered much technical innovation and contributed greatly to the development and transformation of the mobile market in both quantitative and qualitative terms.

Technically speaking, a new generation of technology has arisen about every ten years to meet the demands of the market. The 1980s broke ground with the first generation of a mobile communications system based on analog technology, but the 1990s saw the coming of a second-generation system based on digital technology to satisfy the skyrocketing demand for telephones and lay a foundation for mobile data communications. This was followed by a third-generation system in the 2000s supporting the expansion of mobile multimedia and packet communications, and today, in the 2010s, by a fourth-generation system providing further gains in high-speed, broadband communications based on the LTE system.

Viewing this history from a service perspective, it can be said that our lives have been transformed about every 20 years. In the 20-year period of the first-generation and second-generation mobile communications systems starting in 1979, the telephone that had so far been "fixed" in our homes and offices developed into a business tool that could be used anywhere by anyone. In this period, the first car phones were viewed as a status symbol used by very few people, but the appearance of the "mova" series of mobile phones small enough to fit into a breast pocket marked a radical transition to a business tool that businesspersons could use both inside and outside the office. This development had a great effect on the business environment. Then, in the 20-year period of the third-generation and fourth-generation systems starting in 2000 and continuing to the present, the mobile

phone underwent another transformation from a business tool to a "lifestyle tool" indispensable to our daily lives. The i-mode service launched in 1999 gave birth to a world in which e-mail and various types of content and services could be accessed from the palm of one's hand. It made the mobile phone into an essential tool for living that could be used not only by businesspersons but also by anyone from children to adults anytime and anywhere.

The smartphone helped to further expand and accelerate that world. It also transformed the business model of the telecom market from vertical integration driven by carriers to horizontal integration centered on content.

We can see from this review of the past 40 years that technical revolutions occur in 10-year cycles while changes in social value having a significant impact on society occur in nearly 20-year cycles. If we believe, as the saying goes, that history repeats itself, surely 2020 will be a year that gives birth to great change from both a technical and social-value perspective.

Today, NTT DOCOMO is focusing its energy on the research and development of the 5th-generation mobile communications system (5G) with an eye to 2020. Technical studies are now in progress with the aim of making 5G into a system that can satisfy three key requirements: "high-speed and high-capacity" mobile communications, "low-latency" for use in remote control and other applications, and "massive device connectivity" for achieving the Internet of Things (IoT).

However, 5G is not limited to progress in mobile system performance. Working with a wide variety of industry partners, we can expect 5G to transform the social infrastructure by making business more efficient, creating new business opportunities, and solving social problems. Indeed, we can expect 5G to trigger the launch of the Fourth Industrial Revolution.

That is to say, we can expect 5G to play a role not only in advancing communications technology but also in supporting IoT, creating new user devices, providing new services using big data and AI, and finding solutions to social problems. These business cases will be achieved not by the conventional carrier-centered vertical-integration business model but rather by the Business to Business to X (B2B2X) business model that promotes co-creation with business partners in an open

manner. At present, NTT DOCOMO is exploring the creation of new business models together with diverse partners through a variety of means including 5G trial sites and a 5G open partner program. As of the end of July 2018, co-creation activities had already begun with more than 1,600 partner companies.

Today, mobile communications is not simply a telecom infrastructure—it is also a tool essential to daily life that each and every one of us cannot do without. At the same time, it looks to become a social infrastructure that drives the Fourth Industrial Revolution. To achieve this and make further progress, co-creation through open innovation with diverse industries and people including readers of the NTT DOCOMO Technical Journal will be essential.

In the inaugural issue, then president Koji Oboshi had the following words to say about the publication of the NTT DOCOMO Technical Journal: "This magazine will serve to introduce the R&D activities of NTT DOCOMO and some of its key accomplishments and to provide its readers with a reference to voice their comments and opinions. In this way, we ourselves will be able to improve our mobile communications technologies and services."

As a forum for open and vigorous exchange of information with readers, we will work to enhance the NTT DOCOMO Technical Journal toward the next quarter-century. We look forward to a wide variety of opinions from our readers.

Roundtable Discussion

History of Mobile Communications with a Look Back at NTT DOCOMO R&D and Outlook for the Future

— The long and winding road —

Kota Kinoshita — Former NTT DOCOMO CTO, former DOCOMO Technology President (front left)
Takanori Utano — Former NTT DOCOMO CTO, former DOCOMO Technology President (front right)
Seizo Onoe — Former NTT DOCOMO CTO, presently President of DOCOMO Technology (rear, second from left)
Kiyohito Nagata — Former General Manager of NTT DOCOMO Communication Device Development Department, presently President and Chief Executive Officer of Asurion Technology Japan (rear, first from right)
Koji Yamamoto — Former General Manager of NTT DOCOMO Core Network Development Department, presently President of NTC Technology (rear, second from right)
Chie Togawa — Moderator (rear, first from left)

—To begin with, let me thank all of you for taking time today to participate in this roundtable discussion. In the history of mobile phones, which today have become ubiquitous, there must have been all sorts of dramatic moments behind the scenes in technology and product development. Today, I would like to ask all of you about this story, from the early days to the present and into the future, divided into five generations.

■ 1st Generation (1980s, Analog System)～

Early Days

From car phones to mobile phones: birth of the compact mova handset

—Mr. Kinoshita, you were head of development in the early days. Can you tell us about the birth of the mobile phone?

Kinoshita Mobile communications originally appeared as a car phone system, not as mobile phones. The car phone was the first product to be commercialized.

Yamamoto December 3, 1979, to be exact.

Onoe/Nagata That's right, December 3, 1979.

Yamamoto Which was year 54 of the Showa era.

—Everyone remembers that well!

Nagata That's because it's a historic day. All NTT DOCOMO employees have that date in their head.

Kinoshita The first model weighed 8 kilograms occupying a volume of about 6 liters.

At that time, the chief technical engineer of Nippon Telegraph and Telephone Public Corporation was astonished at that weight and volume, and I remember him saying, "Redo it, soon!" With NTT Laboratories being newly organized, we puzzled over how to go about reducing the volume of this model from 6 liters. Then, on seeing a smaller prototype of a car phone, perhaps the second generation, the person in charge of this project commented, "You know, if we were to attach a battery, the user would be able to walk around with the phone."

The word got around that "If we can do this, we get a mobile phone!" Certainly, this was the origin of the mobile phone concept. However, the radio band license here was assigned to car phones and could not be used for mobile phones. We therefore set our sights on commercializing a "removable mobile device that could be used outside the car." We succeeded in developing and commercializing a device that had the appearance of a mobile phone, but unfortunately, it was a system with limited connectivity with a terminal price tag of 1 million yen, so in the end, it came to be used by only a few people.

Utano That was certainly a time dominated by the development of car phones throughout the world. A full-fledged mobile phone was the MicroTAC manufactured by Motorola. Based on the car phone system, the idea at that time was to lower the terminal's transmission power and construct a terminal with the size and shape of a so-called mobile phone.

The problem here was that changing the form of the device from a car phone to a mobile phone made it difficult for radio signals to reach the base

Motorola MicroTAC

Extracted from the WIRED News article "The 12 Cellphones That Changed Our World Forever."
https://wired.jp/2013/04/06/influential-cellphones/#galleryimage_61239-519_2

station. How to go about correcting this was the next major problem.

Kinoshita Here in Japan, we pursued a system design targeting a national system capacity of 100,000 subscribers with one unit of switching equipment installed in Tokyo and Osaka each.

Utano Having a car phone at that time gave a person some status. Against this background and taking international developments into account, we came to realize within the company that full-scale downsizing was essential, and we kept this in mind while moving forward with system development. However, the "pocket bell," or pager, had become a mainstream product by that time.

Kinoshita This created much anxiety for individuals on the development side leading the push for a first-generation mobile phone. The thinking at that time was that having a pager and access to a public telephone would make car phones unnecessary, so the implementation side was dismissive of mobile phones in general. I remember that the car-phone/mobile-phone business began with the view that 100,000 subscribers out of a population of about 100 million would be sufficient.

Onoe That being said, in 1982, the year I joined the company and three years after the car-phone business launch, the number of subscribers had reached only about 10,000, but the development of a so-called large-capacity system had begun. It was thought that perhaps we were "counting our chickens before they hatch."

Utano As a result, in the ten-year period following the launch, the number of subscribers rapidly increased first to 100,000 and then to 1 million.

Yamamoto At the time of NTT DOCOMO's founding, that is, in 1993, or year 4 of the Heisei era, the number of subscribers had reached 1.7 million!

Nagata This period also saw the birth of the "Shoulder phone" that was used by removing the receiver from the main unit hanging from the user's shoulder. It became popular with news reporters for making on-site reports. In "Yoru No Hit Studio" ("Evening Hit Studio"), a popular music show of the time, the appearance of popular singer Masahiko Kondo walking down a flight of stairs using a shoulder phone helped to promote it among the general public.

Yamamoto The shoulder phone turned out to be extremely useful in providing behind-the-scenes support for rescue teams involved in the 1985 airplane crash on Mount Osutaka.

Shoulder phone

Nagata Before the actual launch of this service, we assembled and delivered what shoulder-phone equipment we had at Yokosuka R&D Center for this purpose.

Utano I remember that we would also lend out shoulder phones to Japan's Self-Defense Forces at that time for use in disaster recovery operations.

Nagata By the way, the mova® series of analog handsets only 150 cc in size made its appearance in 1991. However, that was an era in which we were receiving all sorts of comments from both inside and outside the company, such as "Why can pagers connect while mobile phones cannot?" This was the first generation of mobile phones.

■ 2nd Generation (1990s, Digital PDC System)～

Period of Explosive Growth

From voice to data communications: birth of i-mode

—With mova, terminal size contracted from 6 liters to 150 cc and the number of subscribers grew explosively. At long last, a transition was made to 2nd Generation mobile communications (2G).

Yamamoto In this era, the years 1998 and 1999 saw the birth of i-mode.

Nagata And that was preceded by the introduction of the Personal Digital Cellular (PDC) system, which allowed for data communications at 2,400 kbps or 1,200 kbps and facsimile communications too.

Kinoshita At that time, network digitization was a major trend, and a move toward developing a digital network for mobile communications had begun. I had received my orders, and thinking that, in the end, we had to enable clear and uninterrupted conversation during communications, we first changed the system so as to achieve a balance between the signal strength on the uplink (mobile terminal to base station) and that on the downlink, which was a problem in the first-generation system. In addition, instead of having the base-station side search for a base station to which a mobile terminal should be transferred, we made it so that the terminal itself would report on which base station it should move to, a scheme called Mobile Assisted Hand Off (MAHO). Thanks to this MAHO scheme and digital multiplexing effect, we were able to reduce base-station size significantly. In this way, call quality improved and system capacity increased, and the number of subscribers that could be accommodated by the digital PDC system at peak times increased to 40 million.

Utano In Europe and the United States, it was a period of vigorous studies on digital systems including efforts to achieve early standardization.

Onoe The Global System for Mobile communications, or GSM, centered in Europe was the first standard digital system in the world to be commercialized.

Kinoshita The PDC system, meanwhile, was initially commercialized only as a voice system.

Nagata And data communications in PDC was initially accomplished using voice-based circuit switching.

Kinoshita Data communications by circuit switching turned out to have a very complex

structure. Since the interface consisted only of analog modems, the mobile terminal would have to perform an analog-to-digital conversion on the uplink while the network side would have to convert that back to analog. Nevertheless, despite the complexity of this system, we really had no choice, so we endured much hardship. This was because the interface of the fixed network was analog while the mobile communications interval had been digitized creating a discrepancy between the fixed and mobile networks. We therefore had to find some way of eliminating this mismatch, which placed a burden on development.

Nagata Sales of a new system usually begin with the corporate world, so we naturally promoted FAX machines and modems to corporate enterprises that would likely have a need for them. However, there were times in which the system did not function as desired. Yet, right around the time that the system was starting to work for the most part, a transition to the packet-communications era and genuine data communications had begun.

It was decided on the executive level at that time that the network would move to packet communications at an early stage, which made this technology available for use throughout the country ahead of services. While a variety of proposals had been set forth about implementing i-mode by circuit switching since a reasonably efficient platform had by that time been established for data communications, the talk eventually turned to running i-mode by packet communications.

Kinoshita At first, it was proposed from a telecom-operator point of view that X.25 be applied as a protocol for packet communications. However, as X.25 had yet to prove itself even in the fixed network, it was decided to look for a new protocol. Then, around 1995, people began to talk about something called the “Internet” that was gaining momentum in the United States, so we decided to look into this phenomenon.

Nagata At that time, probably no one really understood the structure of the Internet. But I think that catching up in the way that we did resulted in a dramatic leap in both technology and business.

Utano It was a time in which the use of e-mail made pagers no longer necessary.

Yamamoto I think the vision we had and the

choices we made at that time were quite good all in all. For example, selecting protocol compatible with portable devices such as compact HTML for i-mode surely contributed to the expansion of mobile communications.

—However, wasn't the so-called Galápagos approach also a target at this time.

Kinoshita The system adopted by NTT DOCOMO as its 2G system was different from the international standards being studied in Europe and elsewhere. In other words, it came to be a system unique to Japan. Drawing an analogy with the Galápagos islands on which living things evolved independently of the outside world, the "Galápagos syndrome" was a term that disparaged the way in which Japan's unique system was isolated from the rest of the world.

Nagata Generally speaking, terminals with an abundance of functions have also been targets since the 3rd Generation (3G), but a contributing factor here was the rapid and super growth of i-mode. In contrast, true Internet services on mobile terminals were not provided in Europe and the United States until the smartphone era.

A chance to give shape to what we wanted to do-challenging ourselves to do what we thought we could not

—At this time, I would like to ask all of you about your thoughts at that time, when everyone was starting out from zero.

Kinoshita Honestly speaking, I did my work because it was very interesting. I did not ponder about anything grandiose like the future of mobile communications. However, I enjoyed giving form to totally new things.

Nagata Being in charge of device development, I was happy to see the actor Bruce Willis advertise mova handsets for us. It was quite a thrill to see people using this type of mobile phone inside a train. We had quite a lot of freedom back then. Though it was said that there were few customers, that no one was paying attention, etc., this was a chance for those of us on the technology side to realize what we wanted to do with mobile phones.

Yamamoto I think that people associated with technology and engineering have a fundamental love of making and creating things. The road that we have traveled was sometimes painful, but nothing gave us more pleasure than the fruits of our labor. Even our way of thinking was sometimes rejected. Nevertheless, we persevered by becoming absorbed in our work and engaging with the "present" to constantly create better things. At the time of NTT DOCOMO's founding, I moved to the company for the simple reason that I found the work interesting. I had a dream that progress in mobile communications would make life more convenient and prosperous.

Onoe Doesn't everyone think that we should be proud of creating something that at one time we thought we couldn't? For example, there were many people who thought that a cellular system couldn't operate at high frequencies. I don't think there was anyone 20–30 years ago at the least that believed that cellular systems could be achieved at 2 GHz, but today, they are commonplace.

In the light of this story, I can give a more recent example. Though it's been said that radio signals at even higher frequencies such as millimeter waves won't propagate well in the 5th Generation mobile communications system (5G), I tell my subordinates, "Even if it cannot be done today, I want it doable in about ten years time."

Yamamoto That's why it's important that we challenge ourselves to do not what can easily be done but what we may think cannot be done. This makes the world a more convenient place. Yes, it may be hard to try doing everything on one's

own, but I think that avoiding the challenge is bad.

Kinoshita It was often said at one time in the past that the world of R&D includes a "valley of death." This refers to research and development that does not lead to commercial products. In this sense, there has thankfully been no valley of death in NTT DOCOMO development. Researchers, developers, and implementers would all cooperate closely enabling things created on the research side to move along after the development team has closely digested the requirements and conditions specified by the implementation side. We achieved a very effective workflow in this way.

Utano Since the number of people involved were not many, we could not help but do it that way. I would actually visit both development sites and business-implementation sites. In some cases, there was a division of labor as in operations, but here as well we would introduce the systems and add functions in an integrated manner. It's exactly because of such an environment at NTT DOCOMO that it is not uncommon even today for people with development experience to visit business departments and conduct interdepartmental exchanges.

■ 3rd Generation (2000s, W-CDMA System)～

Multimedia era

Standardization and internationalization making international roaming possible

—We then entered the 2000s, an era of increasing globalization with the need for globally uniform standards.

Onoe By this time, mobile phones had already become popular, and we were forced to confront the fact that ordinary travelers would not be able to use their handsets elsewhere in the world without a uniform interface. Working to provide such an interface was the original idea behind 3G system. This was the period in which a globally uniform standard was discussed and established as an objective by the International Telecommunication Union-Radio communication sector (ITU-R). These discussions set a bit-rate target of 2 Mbps and promoted common recognition of this standard.

Nagata Manufacturers were naturally excited about 3G systems. Compared with second-generation PDC, 3G mobile communications represented a dramatic leap in technology. Although technology progressed in a continuous manner from ana-


Koji Yamamoto


Takanori Utano

log times to the PDC era, it made a big jump with the coming of 3G, and the considerable investment made by each manufacturer to accommodate 3G was likely due to their expectations of worldwide sales.

Yamamoto However, despite this uniform standard for 3G, it was said that there was a need overseas for incorporating not only 3G but GSM too, which placed additional pressure on development for Japanese manufacturers. It appeared that Europe with GSM already well entrenched was not eager to expand entirely into 3G.

Onoe As for the 3G system itself, the proposals made by Japan have made a big contribution. In a sense, these contributions have spread throughout the world. However, to what extent those contributions have been a plus for Japanese industry depends greatly on manufacturer and market circumstances, so I will not go into that here.

Kinoshita At the beginning of the 3G era, on being relieved that PDC development had come to an end and that we had managed in one way or another to get it working and to thrive, our development boss exclaimed, "It's now time for Wideband Code Division Multiple Access (W-CDMA)." To make W-CDMA into a world standard, we decided to call various operators and manufacturers with the aim of developing some partnerships. At that time, on demonstrating to the Chief Technical Officer (CTO) of Nokia a transmission experiment of the system that the research group had been working on, he was surprised to see that we had made what appeared to be about two years' worth of progress. Then, on returning to his country, he talked with the CTO of Ericsson. The result of this discussion was that wireless technology would unite Europe through NTT DOCOMO's W-CDMA while control protocol would be left to GSM. This was the starting point for NTT DOCOMO in establishing a partnership with Europe.

Onoe In Europe, there were about five candi-

dates for a standard system, and one of those was W-CDMA. In this regard, the European Telecommunications Standards Institute (ETSI), a European standardization body, was the scene of intense discussions for about one year with a particular focus on the Time Division CDMA (TD-CDMA) system. Then, at the January 1998 meeting, it was decided that the European standard would be based on W-CDMA while incorporating TD-CDMA in part. With this concluded, our next challenge was the United States. On the American side, discussions centered on the CDMA2000 system, so the result was a "Japan and Europe versus the United States" scenario. This was not just a dispute centered on technology—it evolved into a struggle that included aspects of a trade dispute such as patent rights. After passionate discussions, a compromise was reached on some parameters, but W-CDMA for the most part became the standard. However, the end result was one standard with multiple modes including CDMA2000, so it was not a single standard in the truest sense.

—So the reason for reaching this decision was not the superiority of a certain type of technology.

Onoe At that time, I didn't think that 3G would last.

Utano Among European manufacturers at that

time, I remember clearly how some top executives would say, "The adoption of W-CDMA is not a question of its technical merits—for us, achieving W-CDMA from a technical perspective including intellectual property rights (IPR) is not realistic, so we oppose this standard." Those manufacturers also stressed that, "There's no way that we could adopt something that offers us no advantage at all."

Utano That was because most European manufacturers providing mobile communications equipment at that time also had a large share of fixed communications. I think they were exploring to some extent what they could do to become major players in the next stage of mobile phones. This tug-of-war within Europe increased in severity, and I think that one major reason for this was that the market had increased in size against a backdrop of GSM and its success.

Onoe However, yesterday's enemy is today's friend, and I would like to say that it's precisely because we were able to hold fruitful discussions on not just rights and interests but on technology too that we are today building good relationships.

■ 4th Generation (2010s, LTE/LTE-Advanced System)～

Smartphone era

Toward a more pleasant communications environment

—How did 3G that expanded the market come to change in the years that followed?

Kinoshita 3G was constructed independent of 2G. We made a considerable investment, but revenues for the several years after service launch were not that great. Under these circumstances, we could hardly be allowed to create a 4th generation (4G) anew, which is why we launched enhanced versions of 3G such as 3.9G and Super 3G (today's LTE).

Onoe At that time, 4G research was progressing steadily, and data transmission speeds of 100 Mbps were being achieved in 2002–2003 along with 1 Gbps on the research-laboratory level. However, 3G business conditions were somewhat disastrous with initial investment yet to be recovered. This period overlapped with the drafting of NTT DOCOMO's medium-term plan for R&D, and since we were hardly in a situation in which we could freely promote 4G development, in one week we repackaged our proposal in terms of "Super 3G," which was subsequently reflected in the plan.


Kota Kinoshita


Kiyohito Nagata

Of course, when it came time to deal with standardization, we did so in a careful and polite manner!

Utano That is to say, the question here was how to soften the resistance to new investment on the listening side. One way we did this was by making improvements within 3G a little at a time. For example, we increased bit rates gradually such as by High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA). Furthermore, if we advised that such extensions would comprise Super 3G, we thought that resistance on the listening side might become even smaller. We thought that mounting such an extension on existing infrastructure would not be a project requiring so much investment or present such a problem.

In this sense, the atmosphere at that time was completely different from now. Today, whether it's 4G or 5G, talking about new things one after the other turns into business. This is the era of looking for something new. The thinking here is that only what is fresh and original will turn into business.

Nagata As transmission speeds increase with 3G, 4G, and 5G, it is often said, "Let's think about what kind of services we can provide with higher speeds." In recent years, however, faster transmission speeds have come to be used by all sorts of users resulting in the birth of new services and cultures. For example, while YouTube has been around for some time, users can now upload videos from their smartphones thanks to faster transmission speeds. This capability has given rise to "YouTubers" (YouTube celebrities) and has increased the use of Instagram while giving birth to the word "instagrammable."

Utano Users will use a system in line with communication capacity. This results in a cycle in which more usage requires a system that can accommodate that usage. Everyone has been using capacity liberally especially of late, so there is a need for the development side to consider how we are going to deal with such vigorous demand.

Onoe With each cycle, something new is born extending beyond previous discussions. Trust me, this is the path taken every time. 5G technology is a prime example. If we don't aim for more than what the customer wants or something slightly higher, that technology will soon be commonplace. That is, if we don't aim for something difficult, it's not going to go well. This may be in hindsight, but that's the type of cycle that occurs.

Utano In this sense, we are about to plunge into

a very difficult era. In the past, services in the fixed network generally came first and the task was to determine how best to incorporate those services in a mobile phone. From here on, however, we must think about what kinds of new business will be possible, which means a very different atmosphere from the past. I don't think the infrastructure will change, but I do think that the things that must be thought about will be very difficult compared with our times.

—The Tokyo Olympics is fast approaching. It appears that new things will again be in demand.

Onoe In the case of 5G, we have Internet of Things (IoT) technologies in mind, and we are working to lower latency and raise reliability. People outside the telecom industry have an eye on 5G, and new business opportunities will come to be born through partnering, that is, through various types of collaboration. It is being said that NTT DOCOMO will launch 5G services in 2020, and I think that this will become a reality.

To future technology developers: Use your abilities to give birth to "something slightly ahead of the times !"

—It has come time to talk about the near future. Can you give some words of encouragement to your next-generation colleagues?

Nagata During my time as manager, I was allowed to use a considerable amount of money for development. And the most money I used was during a three-year period in which 3G had yet to be launched. In the sense of launching 3G terminals, we achieved our short-term goals, but these terminals were entirely different from Google's Android phones and the iPhone. That is to say, we probably made a mistake in where we used that money. Perhaps a sense of the global market would have been helpful, but at that time, we were not in such an environment. Today, an environment conducive to global consciousness has been established. I would like those that follow in our footsteps to focus on key technologies from a

global perspective or on leaving a legacy of prime technologies, and to think long-term in connecting those technologies to business opportunities.

Onoe But in a sense, this is also in hindsight. Our role has been to launch something totally from scratch. I think there is value in this. At the risk of repeating myself, I would like the next generation to achieve what they think cannot be done and to create new things not within the scope of their imagination but beyond it.

Nagata Yes, there is value there, but in the case of OSs and LSIs, Japan, in the end, lost the whole thing. I would like the next generation to dream of global activities and to leverage their ideas to the maximum to get on the path to success.

Yamamoto I was in charge of an area that was formerly called "circuit switching," so while my advice may be different from that of the others here, my sincere request to my young colleagues would be as follows. Given ten technologies, engage in world-leading, cutting-edge research and development for one of them, and for the remaining nine, combine them with things in the real world to create a NTT DOCOMO original network.

Utano I really don't have any advice, but let me share this. I feel that our generation, while having little understanding of "mobile communications" at first, did what we had to do while deepening our knowledge of international conditions and technology thereby arriving at long last where we are today. So going forward, I would like to ask the next generation of developers to think carefully about what they need to improve and step up to the next level. Please search out what kind of abilities will become necessary. However, I'm afraid that what we have to say on this matter will not have much value. I believe that each of you must think about and find the understanding, knowledge, and technology that will be necessary in conjunction with changing times and environmental conditions. In this regard, I wish all of you much success.

Kinoshita Roughly speaking, I think it's a good idea to set targets that provide clear benefits to operators, enterprises, and end users at the launch of the product or service. My advice is "Don't do only what you can do now." That is, begin by setting targets for things that have benefits and sale potential regardless of whether they can or cannot be done. You can then devote your efforts to meeting those targets. After all, it's only communications, and just about anything can be accomplished here.

—Many diverse opinions! Let me thank all of you for your precious memories and valuable advice.

Current and Future R&D at NTT DOCOMO for the 5G Era

Current State and Progress in Each Area

Radio Access Network in 5G Era

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5G Laboratories Takehiro Nakamura

Standardization of the specifications for 5G at the 3GPP was completed in June, 2018. Due to the 5G capabilities of increased data rate and capacity, low latency, and massive-terminal connectivity, 5G is expected to lead to creation of new industries and solutions to problems in society. Japan and other leading nations are considering commercial introduction of 5G around 2019 or 2020. This article introduces NTT DOCOMO's view of the world regarding 5G, scenarios for the deployment of 5G and also prospects for further development of 5G in the future.

1. Introduction

As smartphones have continued to spread, the use of mobile services such as social networking services and video streaming have expanded, and data traffic from mobile phones continues to increase. With such circumstances, mobile telecommunication operators have a duty to ensure that data rate and capacity of the wireless networks are increased so that users can communicate without feeling stress, even when users are in concentrated areas such as around train stations during rush hour. On the other hand, there is increasing anticipation for realizing the Internet of Things (IoT), connecting all kinds of objects to the Internet, creating new industries through collaboration with enterprises and organizations in other industries, and contributing to solutions for various issues in society. With IoT, since many devices could be in locations where it is difficult to secure power or could be in

motion, the wireless network is expected to play an important role. The ability to connect with many devices simultaneously is also a feature of 5G, so in addition to increasing data rate and capacity of the wireless network, aspects such as low power consumption in terminals, expanding coverage areas, increasing reliability, reducing latency, and reducing cost must also be supported.

To meet all of these requirements, NTT DOCOMO began R&D on 5th Generation mobile communications system (5G) in around 2010, and has participated actively in creating standard specifications with the 3rd Generation Partnership Project (3GPP), an international standardization organization for mobile communications. The 3GPP standard specifications for 5G were completed in June 2018, and major countries around the world, including Japan, are planning to introduce commercial 5G services in around 2019 or 2020.

This article introduces the view of the world regarding 5G held by NTT DOCOMO and describes the main technologies for implementing 5G, along with deployment scenarios. Finally, it describes prospects for the further development of 5G in the future.

2. The 5G World Ahead

The greatest advancements from 2G (Personal Digital Cellular (PDC)*1, PDC-Packet (PDC-P)*2) to 3G (Wideband Code Division Multiple Access (W-CDMA), High Speed Packet Access (HSPA)*3), and from 3G to 4G (LTE, LTE-Advanced) were increases in the data rate and capacity of mobile communications. From 3G to 4G, the data rate increased from 10 to 50 times, and capacity increased from three to five times. NTT DOCOMO introduced 4G in 2010, and at almost the same time, smartphones began to become common. Since then, as smartphones have advanced, the transition to 4G networks and increase of the data rate have continued. This progress is still continuing, and as of September 2018, NTT DOCOMO has achieved reception data rates of up to 988 Mbps. One could say 4G has matured together with the smartphone and become an indispensable tool providing comfort and convenience to life.

As such, what sort of network is anticipated with 5G? NTT DOCOMO's view of the world regarding 5G is "Building an advanced and flexible network able to connect all things and provide safe and stress-free use of mobile services. A network able to create a new ecosystem*4 exceeding the frameworks of industry."

As discussed at both the International Telecommunication Union – Radiocommunications sector (ITU-R) and the 3GPP, 5G has been developed along three major axes, which are: high speed and capacity, low latency, and massive-terminal connectivity. Earlier generations were developed along the high speed and capacity axis, but even higher data rates will be essential for providing highly realistic media services such as 4K/8K high-definition video distribution and Virtual Reality (VR). On the other hand, low latency is anticipated for applications such as supporting control of self-driving vehicles and factory automation. Massive-terminal connectivity is an important technology for providing services using all kinds of IoT devices, in applications like smart cites and smart agriculture. **Figure 1** shows relationships among services envisioned utilizing these three axes. Each of the services is

*1 PDC: A Second-generation mobile communications system widely used in Japan, adopted by NTT DOCOMO and others.

*2 PDC-P: A mobile packet communications system which applied packet exchange technology to the PDC system, enabling flexible, high-speed data transmission with few transmission errors.

*3 HSPA: A specification for increasing packet-data rates in W-CDMA, and a general term encompassing High Speed Downlink Packet Access (HSDPA), which increases the speed from the base station to the mobile terminal, and High Speed Uplink Packet Access (HSUPA), which increases speed from the terminal to the base station.

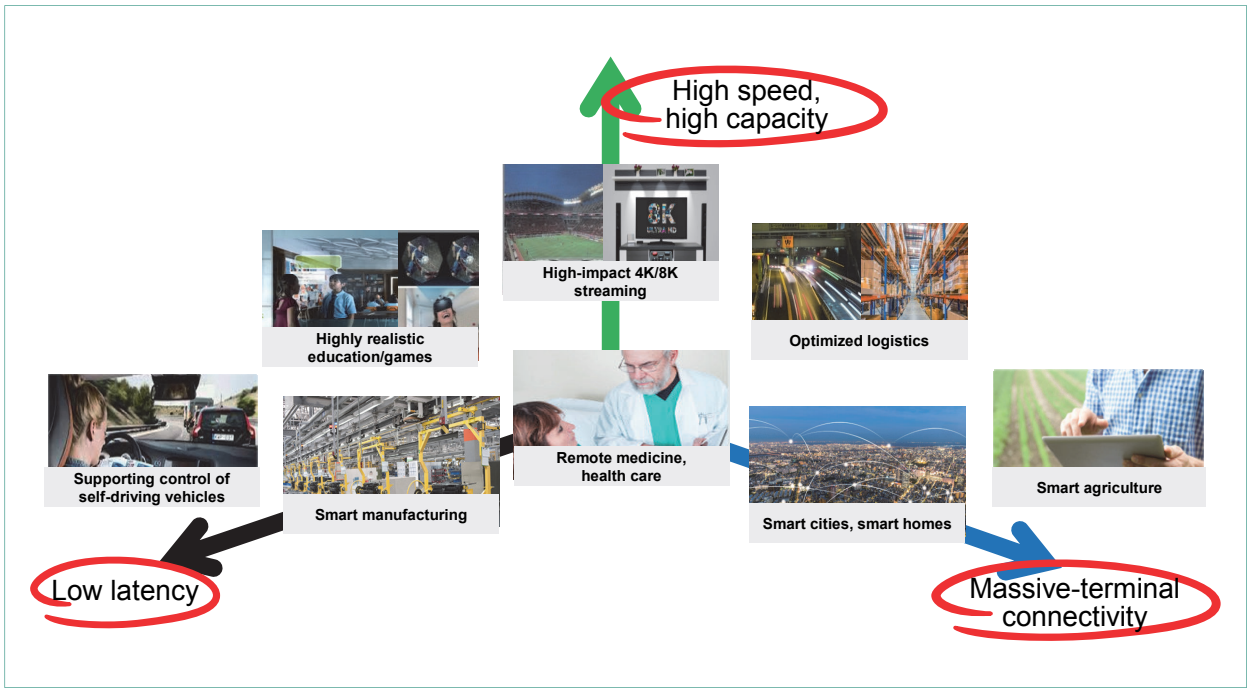

Figure 1 The 5G world ahead

shown combining technologies, and even more connections to all kinds of things can be provided by extending these three axes further. Creation of such new services will be made possible by building a network that can expand with flexibility to provide the functionality needed.

3. Radio Access Technologies for Realizing 5G

3.1 Promotion of 3GPP Standardization

In around 2010, NTT DOCOMO began technical studies foreseeing the implementation of 5G and has advanced various activities such as proposing technology concepts that will pioneer the new era, conducting experimental demonstrations, and promoting 5G related research projects. At the 3GPP RAN Workshop on 5G held in September 2015, we made proposals to promote phased creation of 5G standard specifications, with the initial targets of increased data rate and capacity. Regarding standardization of the radio access network, we also created a proposal on technologies to link New Radio (NR) (i.e., a new radio access technology for 5G) and LTE/LTE-Advanced, and a proposal on making the front-haul interface*5 as open technologies for 5G [1]. Since the 3GPP began concrete work on this, in addition to submitting many technical proposals, we also contributed to completing the initial 3GPP 5G specifications in June 2018 by managing progress and coordinating among involved parties as the Rapporteur*6 for creating the 5G NR standard specifications, and taking on the roles of chairperson and vice-chairperson of the specification study group.

*4 Ecosystem: A system in which multiple enterprises collaborate within a certain field or for business purposes, making use of each other's technologies and resources and even involving consumers and society. It gives form to the flow of processes from R&D to sales, advertising, and consumption.

*5 Front-haul interface: On base stations, the optical fiber interface connecting the baseband processor, which handles digital signal processing, with the radio component, which handles radio transmission and reception.

*6 Rapporteur: A position whose role includes managing progress, summarizing discussion, and editing technical reports that capture results of discussion for Work Items.

3.2 Major 5G Radio Technologies

An overview of the 5G technologies specified by the 3GPP, on the axes of increased data rate and capacity, low latency, and massive-terminal connectivity, is given below.

1) Technologies for Realizing High Speed and Capacity

Technologies for realizing high speed and capacity include ultra-wideband transmission using high frequency bands, and antenna technologies such as Massive Multiple Input Multiple Output (Massive MIMO). Up to 4G, the specifications created used frequencies below 6 GHz, but for 5G, use of high frequencies up to the 100 GHz band in addition to these frequencies is also being studied. Currently, 5G standardization for using several frequency bands in the range of around 25 to 40 GHz in various countries, in addition to frequencies under 6 GHz, is being studied concretely [2]. In particular, the radio propagation characteristics of frequencies in the 25 to 40 GHz range are different than in bands below 6 GHz, so new factors suitable to using such high frequencies (subcarrier*7 intervals, etc.) and a channel bandwidth of 400 MHz have been specified. This is twenty times the channel bandwidth of 20 MHz used by LTE. Although area coverage is different, we can expect a 20-times increase in capacity and data rate.

An overview of Massive MIMO [3] is shown in **Figure 2**. Massive MIMO is a technology that is able to optimize area configurations according to the environment, by using many antenna elements to control the shapes of transmission and reception beams. In an environment emphasizing area coverage, signals for each antenna element can be synthesized in-phase*8, to focus the energy in a particular direction (Fig. 2 (a)). Or, in an environment with many users, multiple beams can be generated simultaneously, equivalent to having

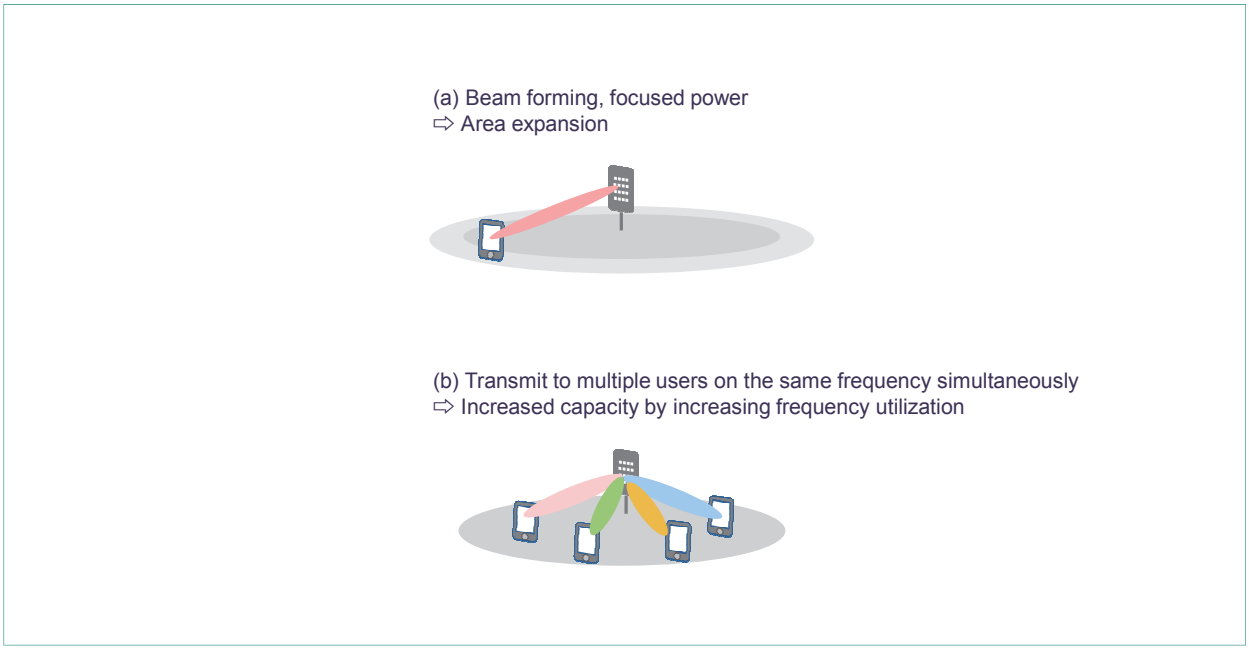

Figure 2 Massive MIMO

*7 Subcarrier: An individual carrier for transmitting a signal in a multi-carrier transmission scheme such as Orthogonal Frequency Division Multiplexing (OFDM).

*8 In-phase: When to different signals with the same period have the same timing within the cycle.

multiple small cells, increasing the number of simultaneous connections and realizing higher capacity (Fig. 2 (b)).

2) Technologies for Realizing Low Latency

Methods that have been standardized for reducing the latency in the radio access network are shown in **Figure 3**. Further reductions in latency have been achieved by shortening the smallest unit of radio transmission (the Transmission Time Interval (TTI)*9) in 5G NR. The time required to decode data with 5G NR was reduced by transmitting data in units of 0.25 ms instead of 1 ms, which was the transmission unit for conventional 4G. Another technology being studied for further reducing latency is a self-contained mechanism that sends ACKnowledgement/Negative ACK (ACK/NACK)*10 signals for completing reception in the same subframe as the received data.

To realize low latency services, the end-to-end latency must be reduced, so in addition to the radio access network, delay must be reduced on the wired segment. For example, when a user in Osaka accesses a server in Tokyo, the wired segment is the dominant contributor to the time interval. As such, methods such as placing server equipment closer to the edge (the base station) are being studied to reduce the delay in the wired segment.

3) Technologies for Realizing Massive-terminal Connectivity

One use case envisioned for massive-terminal connectivity is where wireless devices such as environment sensors or meters are installed in locations that cannot always be supplied power. In such use cases, power can be maintained by using batteries, but it can be difficult to change these batteries,

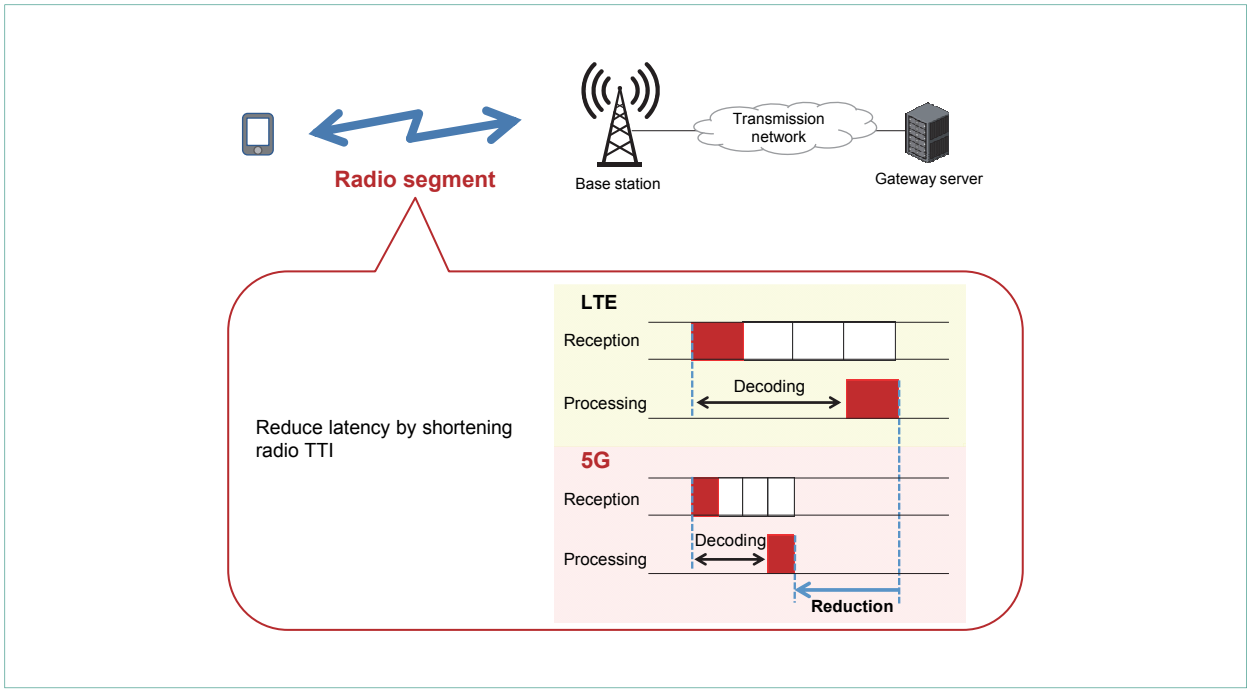

Figure 3 Reduction of latency on radio segment

*9 TTI: Transmission time per data item transmitted via a transport channel.

*10 ACK/NACK: Control signals sent from the receiving party to the transmitting party indicating whether the data signal was received properly.

particularly when many terminals have been deployed. As such, battery life is an important issue for these terminals. Usually with such use cases, only a small amount of data is sent infrequently, so battery life is greatly affected by power consumption while the terminal is not communicating (while standing by). For this reason, the standard specifications stipulate simplifications to signal processing by extending the cycle of intermittent reception and reducing the transmission bandwidth, as shown in **Figure 4**.

4. Initiatives toward Commercialization of 5G

4.1 5G Deployment Scenarios

5G is expected to be deployed gradually in the areas needed, according to various use cases as discussed above. Deployment scenarios are shown in **Figure 5**. It will proceed, using the ultra-wideband characteristics of 5G to increase capacity in areas with high user density and very high traffic, such as business districts, shopping malls, train stations, and stadiums.

Then, by introducing 5G in environments requiring low latency, such as for smart manufacturing in factories and remote diagnosis and treatment in medicine, and environments requiring massive-terminal connectivity, such as for smart agriculture in agricultural areas and for implementing smart cities and smart homes in urban and suburban residential areas, we will contribute to creating new industries, solving societal issues, and regional revitalization.

4.2 Smooth Introduction of 5G

1) Introduction of LTE-Advanced with Advanced C-RAN*11

When NTT DOCOMO introduced LTE-Advanced, we advocated the concept of Advanced C-RAN [4] [5],

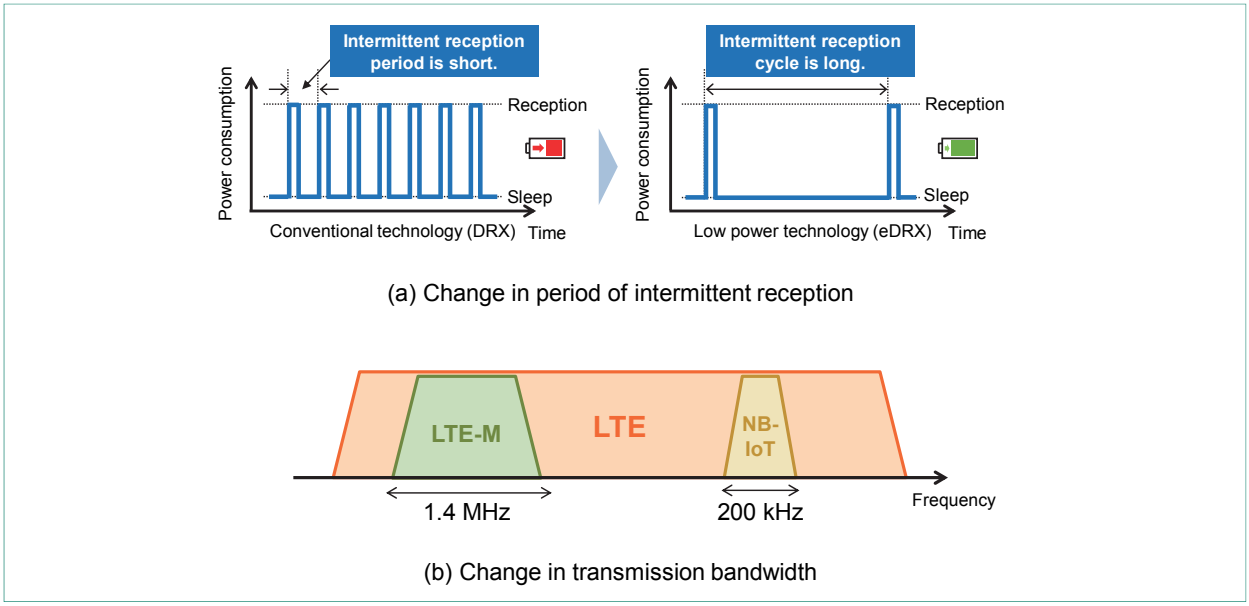

Figure 4 Low power consumption technologies

*11 Advanced C-RAN: A new network architecture for radio access networks being advocated by NTT DOCOMO, which uses a major LTE-Advanced technology called CA (See *13), and a single base-station control component to coordinate between macro cells (See *16), which cover wide areas, and small cells (See *15), which cover more local areas.

as shown in **Figure 6**. This concept gathers together the baseband*12 processing components, enabling it to configure combinations of multiple frequencies with flexibility for Carrier Aggregation (CA)*13, enabling flexible deployment of a heterogeneous network*14. In this way, capacity can be increased

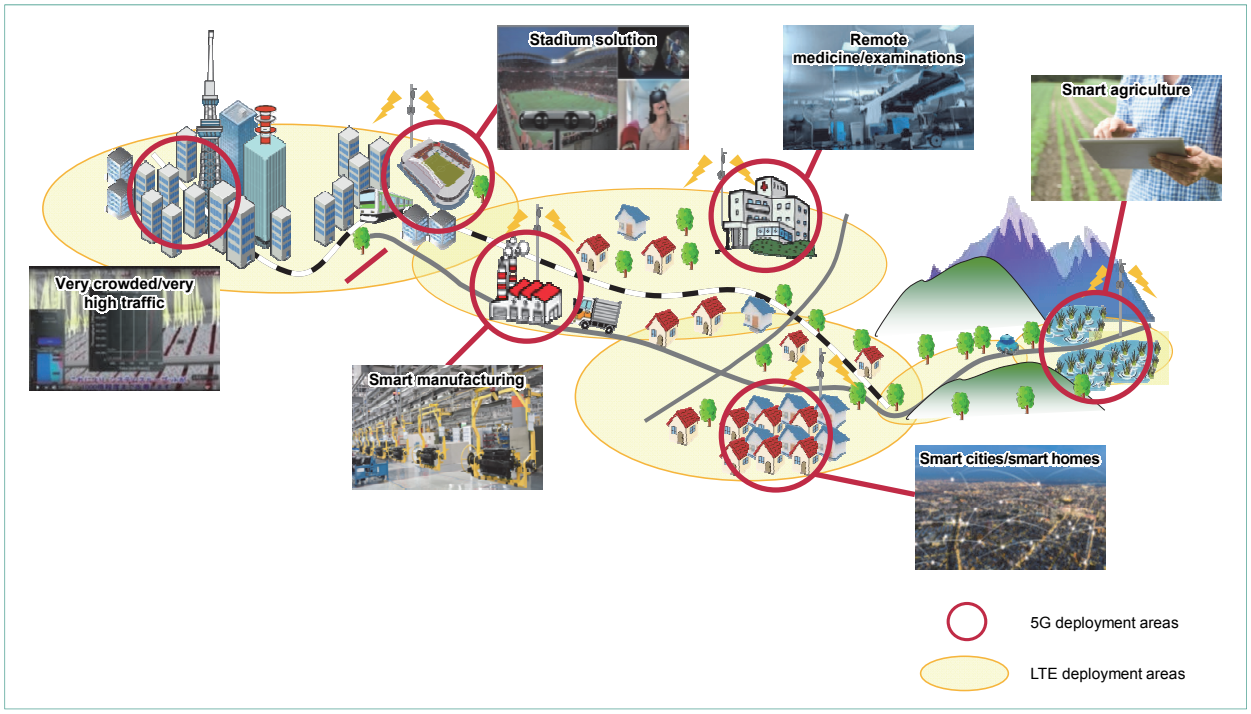

Figure 5 5G deployment scenarios

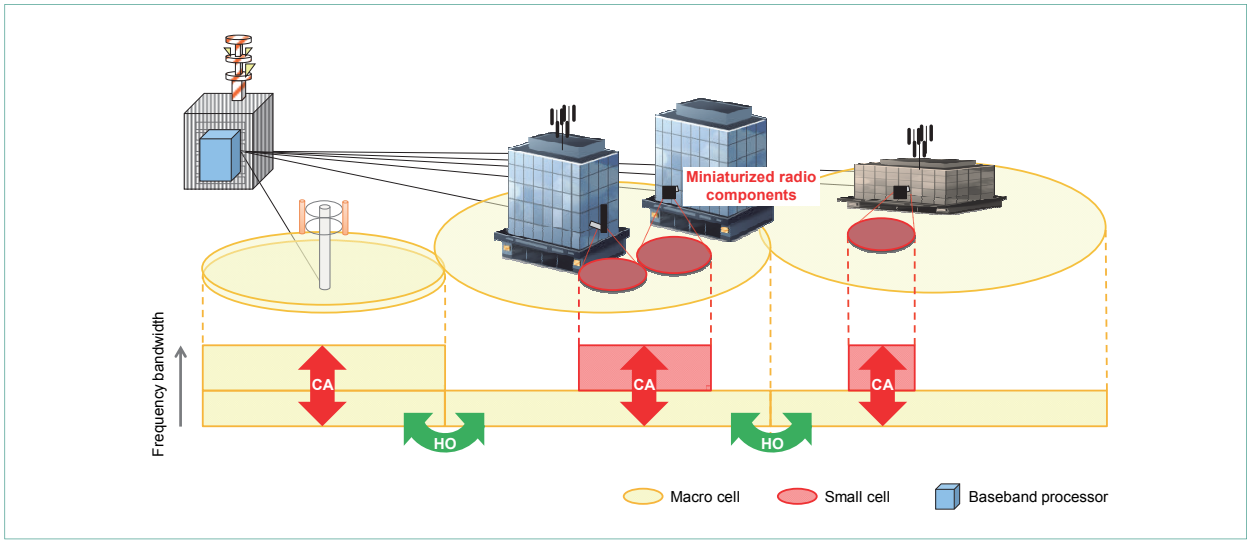

Figure 6 Advanced C-RAN concept

*12 Baseband: The circuits or functional blocks that perform digital signal processing.

*13 CA: A technology for increasing bandwidth and transmission speed, while maintaining backward compatibility, by simultaneously transmitting and receiving multiple carriers.

flexibly, where traffic is heavy, by establishing small cells*15 (hereinafter referred to as "add-on cells") deployed over a macro cell*16 area. The connection between base station and terminal is also maintained by the macro cell, regardless of where add-on cells are deployed, so frequent Hand-Overs (HO)*17 between adjacent add-on cells can be avoided, and increased data rate and capacity while mobility can be realized without degradation in quality.

2) Extension of Advanced C-RAN to 5G

As already mentioned, provision of various new services is expected with 5G, and the network will need to be deployed when and where it is needed, with guaranteed connectivity. NTT DOCOMO is planning to extend the Advanced C-RAN concept to 5G, and deploy a network with Dual Connectivity (DC)*18. **Figure 7** is a schematic diagram of a Non-StandAlone (NSA)*19 network advocated by NTT DOCOMO and agreed upon by the 3GPP. It is anchored by LTE, so it guarantees connectivity with a quality equivalent to current networks, while being able to provide services utilizing 5G features in 5G NR areas.

5. Prospects for the Further Development of 5G

Various use cases are anticipated with 5G, so a flexible network must be built. It is desirable that the most suitable equipment can be selected and installed in urban areas, rural areas, indoors, stadiums, factories, and so on. To achieve this, the front-haul interface between the radio components and control components must be open, so that equipment from different vendors can interconnect. NTT DOCOMO has been actively working to ensure the open front-haul interface [6]. To support different services with flexibility, we also hope that control components will be virtualizable and that equipment will be implemented with good extensibility.

On the other hand, as 5G spreads, new devices

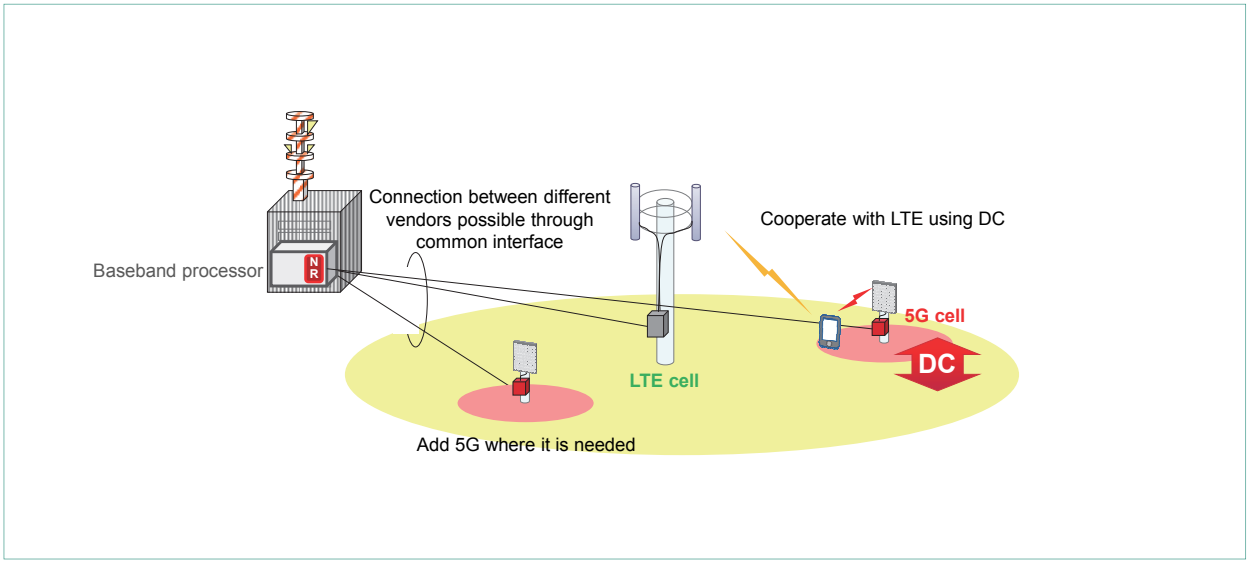

Figure 7 5G NSA deployment using DC

*14 Heterogeneous network: A network structure with overlaid base stations having different transmission power. Macro cell (See *16) base stations covering wide areas are overlaid with small cell (See *15) base stations that transmit with less power.

*15 Small cell: A cell is the area covered by a single base station in a mobile communications system. "Small cell" is a general term for a cell that transmits with low power relative to a macro cell (See *16), which transmits with higher power.

*16 Macro cell: A cell that covers a relatively large area (generally a radius of several hundred meters or more).

*17 HO: A technology for switching from one base station to another without interrupting communications when a terminal is moving.

will enter the market and new services will be created, which will generate new requirements for the radio access network and new technologies to meet those requirements will be needed. It is difficult to anticipate what the world will be like in 2020 and beyond, but radio access networks must be able to see beyond the current era. As an example, if all kinds of objects are to be connected, individual devices may perceive that they are always connected, but from the network perspective, it is more efficient to connect only when communication is needed, and to do so, very low latency connections and data transmission are needed. Also, as machine type communication becomes more common, it may become necessary to transmit metadata of a different dimension than, for example, images that a person would recognize. These may go beyond extensions to 5G requirements, so new breakthroughs may be needed to build the world beyond what we can currently imagine. Battery life has also always been an issue with mobile phones, but if it becomes possible to charge them by capturing energy from radio waves in the air through energy harvesting*20, this problem could be solved instantly. Beyond working to introduce 5G smoothly, we will continue to study future technologies that will develop 5G further and to contribute to development of mobile communications.

6. Conclusion

5G is expected to begin commercial service in 2020, and this article has given an overview of its objectives, principle technologies, and deployment scenarios. 5G will provide all kinds of connectivity and contribute to creating new industries, solving societal issues, and regional revitalization.

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*18 DC: A technology whereby a single terminal can connect to multiple base stations using different frequency bands.

*19 NSA: A 5G radio access network that assumes that it will be used together with LTE (or enhanced LTE (eLTE)), with the benefit that it can be commercialized quickly since it is able to use existing 4G infrastructure.

*20 Energy harvesting: Technology that harvests small amounts of energy from the surrounding environment and converts it to electrical power.

Current and Future R&D at NTT DOCOMO for the 5G Era

Current State and Progress in Each Area

Core Network for Social Infrastructure in 5G Era

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Research Laboratories Wataru Takita

In the 5G era, services will continue to advance and diversify and new value will be created through collaboration among various industries and businesses, so increasing demand for networking as social infrastructure is expected. This article describes the principal technologies required in the core network to realize this, based on 5G use cases, and also introduces initiatives for more advanced operations, required for efficient operation of this increasingly complex network.

1. Introduction

5th Generation mobile communications systems (5G) will meet various needs beyond those addressed with 4G, which focused on mobile phones and smartphones. It will evolve in various ways, not limited to increased speed and capacity. For example, requirements also include low latency, increased reliability, and the ability to connect to large numbers of devices.

To realize a network as social infrastructure that satisfies these requirements, advances in the core network*1, in addition to advances in wireless communications, are needed, and various technologies have been specified for 5G. This article describes network development as social infrastructure for the 5G era, together with related principal technologies.

*1 Core network: The part of the network comprising equipment for switching, for subscriber information management and other functions. Mobile terminals communicate with the core network via a radio access network.

2. Network Deployment for the 5G Era

In the 5G era, all kinds of objects, such as automobiles, homes, and wearable devices, will connect to wireless networks, and the Internet of Things (IoT), which automatically and intelligently gathers information and manages and controls these "things," is expected to spread. On the other hand, as IoT develops, various services composed of large numbers of IoT devices, such as smart meters[*2] and environmental sensors, will emerge. To support them, communications requirements such as high speed and capacity, low cost, and low latency will also be needed. As such, NTT DOCOMO's vision of the 5G world is to provide an advanced, flexible network to which all of these things can connect, and that can be used by services confidently and without stress. We are cooperating with various industries to develop such a social infrastructure network. Below, we introduce some concrete 5G use cases and describe technologies that will be needed to support them.

3. 5G Use Cases

The main usage scenarios for 5G discussed at the 3GPP are 1) high speed and capacity (enhanced Mobile Broadband (eMBB)), 2) high reliability and low latency (Ultra-Reliable and Low Latency Communications (URLLC)), and 3) Machine-type communications[*3] with many simultaneous connections (massive Machine Type Communications (mMTC)). These are summarized in the specifications.

1) High Speed and Capacity: eMBB Use Case

Video On Demand (VOD) viewing on smartphones and tablets was a major use case for 4G, and accounts for a large share of the traffic.

As the amount of high-resolution video content, such as 4K/8K broadcasts and other rich content increases in the future, demand is also expected to increase for high-capacity communications on mobile networks.

2) High Reliability, Low Latency: URLLC Use Case

Advanced driver support and self-driving vehicles are expected to become more common in the future and they are basically expected to operate autonomously, using the vehicle's own sensors and processing system, and not utilizing external networks. However, there are use cases for using mobile networks, such as to get information beyond the scope of onboard sensors (nearby blind spots, information beyond sensor range, wide-area information), or for inter-vehicle communication, and these need to occur reliably and with low latency. Reliable and low latency communication is also needed when the mobile network is used in smart factories, such as for remote control of industrial robots, to ensure control and safety.

3) Many Simultaneous Connections: mMTC Use Case

Agricultural sensors, smart meters and plant equipment only produce small amounts of data, but use cases with many sensor devices connected simultaneously are envisioned. In such cases, a mechanism to manage the large numbers of terminals, and a specialized architecture to transmit small amounts of data efficiently (such as sending user data over control signals) could be needed. For large numbers of devices, reduced cost and power consumption for each device also becomes a requirement.

*2 Smart meter: A device that enables real-time measurement and visualization of electricity usage.

*3 Machine-type communication: A collective term for 3GPP machine communication with no intervening communication operations performed by humans.

4. Technologies for Creating New Value in the 5G Era

4.1 Initiatives to Advance Current Networks for the 5G Era

1) Network Function Virtualization (NFV)[*4]

As smartphones have spread rapidly in recent years, data traffic has increased, but even under these conditions, a network that users can connect to at any time must be built at reasonable cost. NTT DOCOMO has implemented NFV by applying virtualization technology, which is used widely in IT, to our communication carrier network, and we are expanding the scope of equipment being virtualized.

The virtualization technology used for NFV removes restrictions due to a particular physical configuration by logically integrating and partitioning hardware resources (CPU, memory, HDD) and treating them as resource pools[*5], so various communication software can coexist and operate on general purpose hardware.

This technology reduces costs by enabling use of general purpose hardware rather than dedicated hardware, and reduces the amount of equipment by utilizing hardware resources efficiently. When the network is stressed by sudden increases in traffic, such as during a disaster, the capacity of network equipment can be scaled[*6] automatically to maintain connectivity, and if new services need to be implemented quickly, it can be done through instantiation[*7] of communications software on general purpose hardware.

2) DEdicated CORe Network (DECOR)[*8]

Recently, IoT devices have become inexpensive and are spreading rapidly and the number and types of devices connecting to LTE are increasing steadily. If separate networks could be created to accommodate the resulting traffic having differing characteristics and priorities, the networks could be controlled more flexibly and appropriately than previously, with more efficient localization and accommodation design. As such, NTT DOCOMO is currently introducing technology called DECOR to partition the core network and accommodate terminal traffic separately according to its characteristics.

At the 3GPP, there have been earlier schemes to partition the network itself, but due to implementation of terminal functionality, it could not be applied to widespread existing terminals. With DECOR, the network partitions terminals based on a terminal identifier[*9], so the networks they connect to can be separated without having an impact on the terminals themselves. In this way, networks can be designed according to the characteristics and priorities of the traffic from the terminals they accommodate. This should help ensure reliability and reduce costs.

4.2 5G Network Technical Elements

This section describes 5G core network technologies for implementing the use cases mentioned above (eMBB, URLLC, and mMTC).

1) High Speed and Capacity: Technologies for Implementing eMBB

(a) Initial method for providing 5G

Methods to increase speed and capacity in the core network include extending the existing Evolved Packet Core (EPC)[*10], and introducing a newly specified 5G architecture. NTT DOCOMO will be providing the

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

*5 Resource pool: A set of resources achieved by bundling together many units of hardware each possessing certain types of resources (CPU, memory, HDD, etc.). Various types of virtual machines can be created from a resource pool.

*6 Scaling: The optimization of processing power by increasing or decreasing Virtual Machines (VMs) that configure communications software whenever processing power is insufficient or excessive according to hardware and VM load conditions.

former for its initial 5G deployment (**Figure 1**). This is because by using EPC, high speed and capacity can be implemented while maintaining stable quality in areas where LTE/LTE-Advanced has already been deployed. Thus, 5G can be introduced earlier and with more stability than if a new 5G network was introduced.

(b) Content delivery technology for full operation of 5G

For full operation of 5G, supporting distribution of richer content will require increased capacity in the wireless component, but it will also require technology that can distribute the rich content efficiently in the core network. To realize this use case, we will apply a Content Delivery Network (CDN)*11 on a Mobile Edge Computing (MEC) server, which places a gateway*12 relatively close to the wireless access point and performs service processing at a location close to the terminal. This can increase practical communication speed by reducing both traffic and latency on the wired segments.

For 4G and earlier, no standard method had been established to perform MEC and Internet access at the same time according to traffic characteristics, while also maintaining terminal mobility in this way. However, new methods have been added to allow MEC and mobility at the same time with 5G, such as UpLink CLassifiers (UL CL), which identify specific traffic and offload it near the terminal (Local Breakout*13), and Session and Service Continuity (SSC), which is described below.

UL CL is a technology that identifies packets sent by a terminal to a specific IP

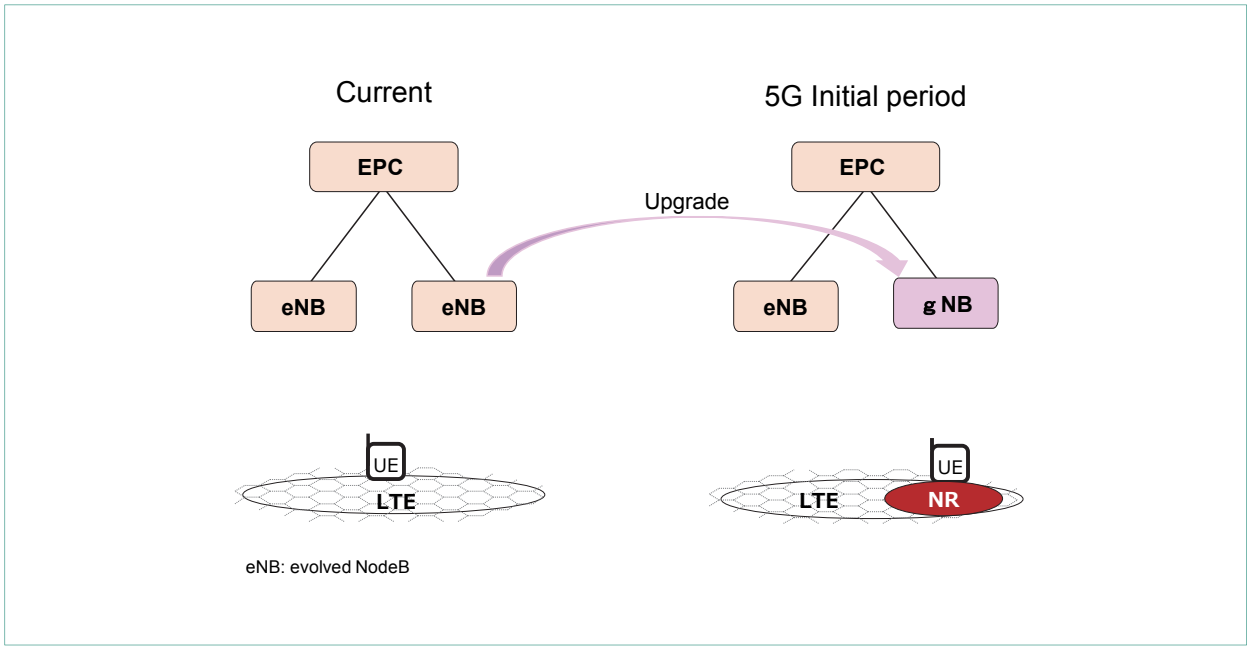

Figure 1 Accommodating 5G access in the initial period

*7 Instantiation: A procedure for launching a communications application in a cloud environment.

*8 DECOR: A dedicated core network that is partitioned according to terminal-type identifiers that express the type of each terminal, and gathers terminals with the same terminal identifier together and accommodates them.

*9 Terminal identifier: An identifier in the subscriber information that indicates the type of terminal or device and its use.

*10 EPC: A core network accommodating a radio access network such as LTE. It consists of MME, S-GW, P-GW, and PCRF and provides functions such as authentication, mobility control, bearer management, and QoS control.

address, and routes them differently than other packets. It is generally used to connect to an MEC server as shown in **Figure 2**.

2) High Reliability, Low Latency: Technologies for Implementing URLLC

Besides MEC, which reduces delay that is dependent on the distance between the terminal and the server, we are making changes for implementing services that require high reliability and low latency, such as improving the functionality that prevents interruption during hand over*14, which is another cause of delay, and adding extensions to the routing control functionality to enable communication over the shortest route between terminals.

These functions are called SSC. SSC is a new technology that, as with MEC connections, the network and server to which a terminal connects could change as the terminal moves from one area to another. SSC has the following three modes (**Figure 3** (a)-(c)).

(a) SSC mode 1 is similar to 4G and earlier, connecting to a single place in the network regardless of area. It is used for ordinary Internet connections.

(b) With SSC mode 2, if a terminal is connected to an MEC server associated with a given area, A, and then moves to a new area, B, it then changes its connection to the MEC server associated with area B.

(c) With SSC mode 3, if a terminal is connected to an MEC server associated with a given area, A, and then moves to a new area, B, it connects to the MEC server for area B while maintaining the connection with the former server from area A. With SSC mode 3, a new "Make Before Break" option has been added, to avoid interruptions when reconnections are made during hand over. The connection to the old area A network is kept while connecting to the new area B network and communication with the area A network is only terminated after the new

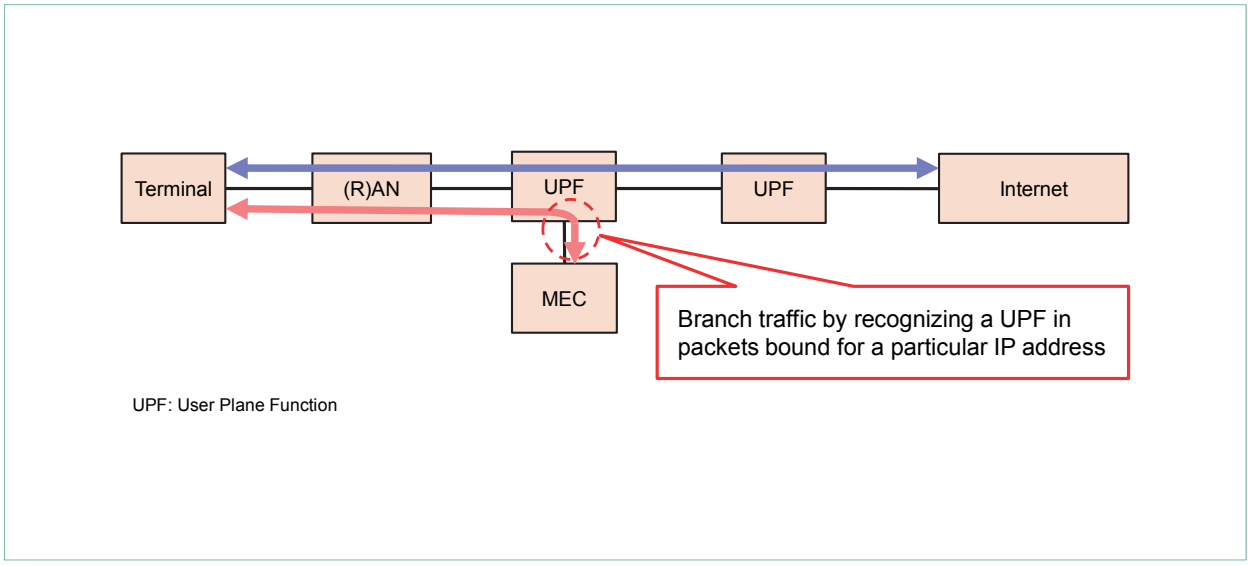

Figure 2 UL CL

*11 CDN: A network solution optimized for fast and stable distribution of large files such as images and video.

*12 Gateway: An intermediate device that has functions such as protocol conversion and data transfer to allow communication between devices.

*13 Local Breakout: A method that allows specific traffic to flow from each base directly to the Internet, in order to avoid stress on lines connecting the central base with other bases.

*14 Hand over: The technique of switching from one base station to another without interrupting communication when a terminal moves between base stations.

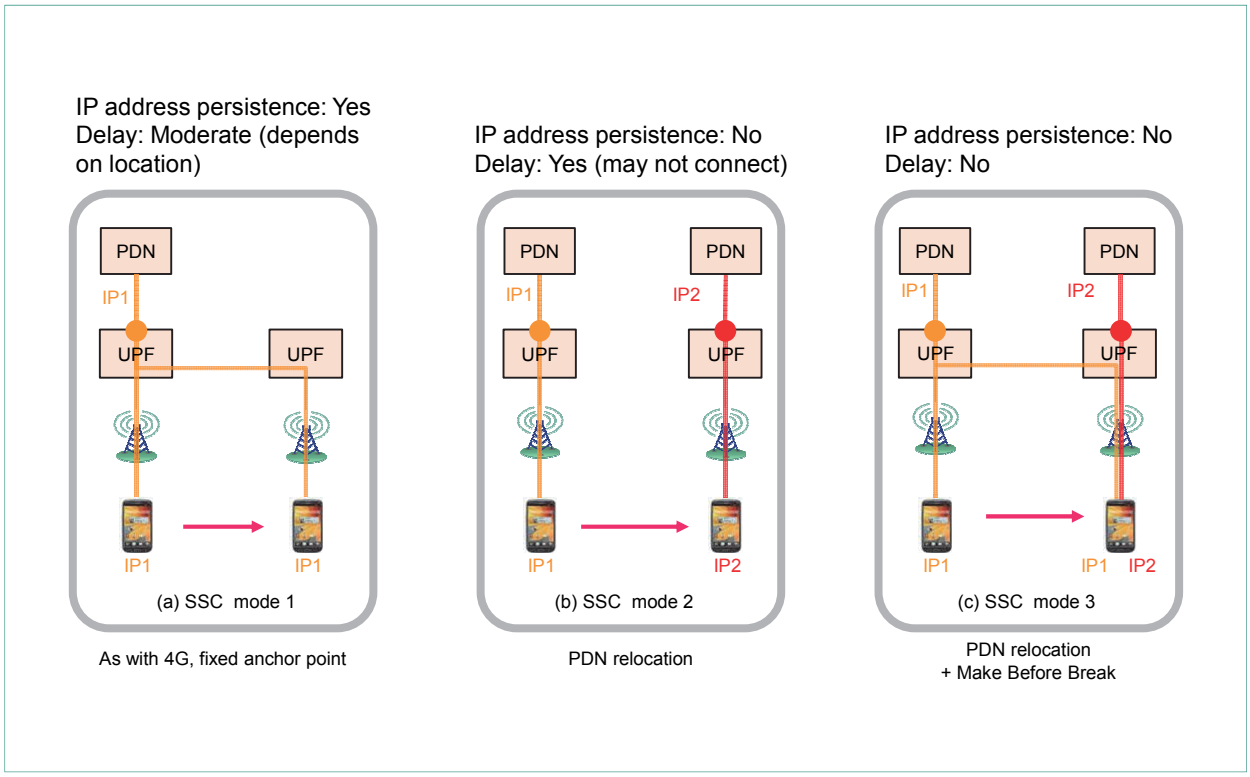

Figure 3 SSC

connection is completed.

3) Many Simultaneous Connections: Technologies for Implementing mMTC

One way to manage many devices efficiently is to not perform registration of location for devices that are installed at fixed locations, such as sensors. Also, to reduce the cost of sensor devices, security and other functionality can be offloaded to the core network, and to avoid concentration of very large numbers of sessions[*15] in one place, the data collected from sensors can be processed with MEC.

Another technology being studied to improve utilization of the network is to layer data onto control signals when the amount of data is small.

4.3 Accommodating Diverse Networks Efficiently

Performance requirements are more strict than ever before for the diverse use cases of 5G and aspects such as latency, bandwidth, and number of terminals, but each of these use cases can be realized, even if all of these capabilities cannot be maximized at the same time.

It is also possible to use different Radio Access Networks (RAN)[*16] depending on the use case, and it is expected that future networks in the 5G era will accommodate multiple radio technologies including 4G wireless access, 5G wireless access and Wi-Fi®[*17], according to the characteristics of the service. By also using virtualization technology, logical networks specialized to the requirements

*15 Session: A series of communications exchanged between a client and a server or between servers.

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

*17 Wi-Fi®: A registered trade mark of the Wi-Fi Alliance.

of each service, whether high efficiency or low latency, can be built as network slices*18, while sharing physical network devices such as servers and transport devices (**Figure 4**). A technology called Service Based Architecture (SBA) is being introduced to deploy network functions on network slices, adding flexibility for building networks and reducing the time required to provide services.

4.4 SBA

In the 5G era, a platform able to provide various types of services quickly is needed. To realize various requirements quickly, the core network must do more than simply transfer data, adding functionality suited to the characteristics of the application. It must also be possible to add such functionality quickly, to meet the development cycles of terminal and server applications. However, current core networks have a monolithic architecture*19, and due to the tight coupling between devices a long development cycle is needed to ensure overall consistency in the system, even when adding small-scale functionality to the core network.

In contrast, for terminal applications themselves, and the server applications linked to them, as with smartphone applications, a wide range of services are being developed, rapidly adding functionality to both of them. SBA has been standardized so that functionality can also be added rapidly to the core network in this way.

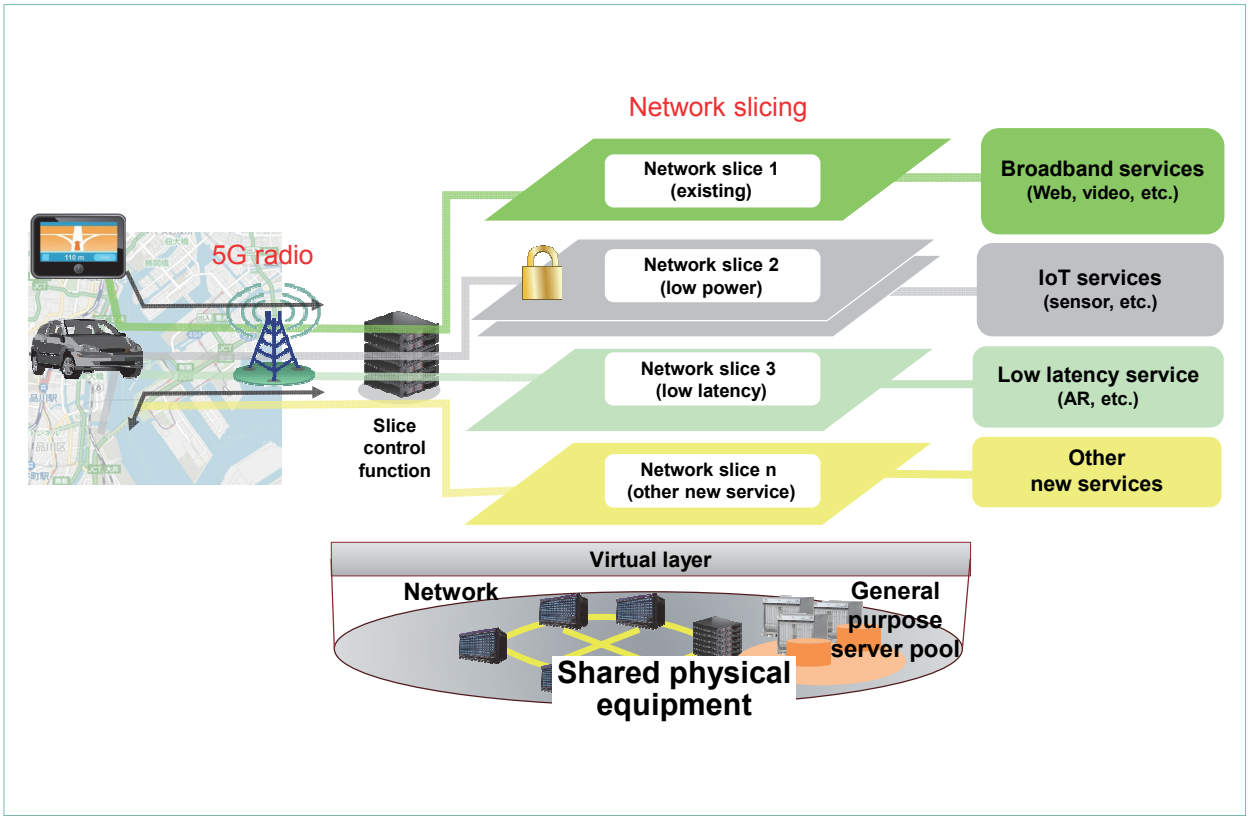

Figure 4 Network slicing

*18 Network slice: One format for achieving next-generation networks in the 5G era. Architecture that optimally divides the core network in units of services corresponding to use cases, business models, etc.

*19 Monolithic architecture: An architecture in which the functional components are tightly coupled and the overall system operates as a single module.

SBA is an application of micro-service architecture in the 3GPP standards. A micro-service architecture separates the application realized by a service into functions called micro-services. By loosely coupling the interfaces of each of the micro-services, the effects of adding or changing functionality are localized, reducing the time required to implement and test services and accelerating the process (**Figure 5**).

SBA is a principal technology for realizing a cloud-native*20 core network, and the goal of a cloud-native core network combined with network slicing is to reduce operating costs and fulfill the various requirements at the same time.

4.5 Network Operation Expansion

With the implementation of 5G in the future, mobile networks are expected to offer more diverse services, which will lead to more complexity in networks than ever before. Virtualization technology will allow for hardware configurations similar to or even simpler than before, but logical configurations providing services, such as network slices, will increase in complexity, using multiple virtualized logical resources. We can expect an increasing number of issues with manual maintenance and operation of these configurations. As such, NTT DOCOMO is working to make conventional operations systems more economical and efficient using automation and Artificial Intelligence

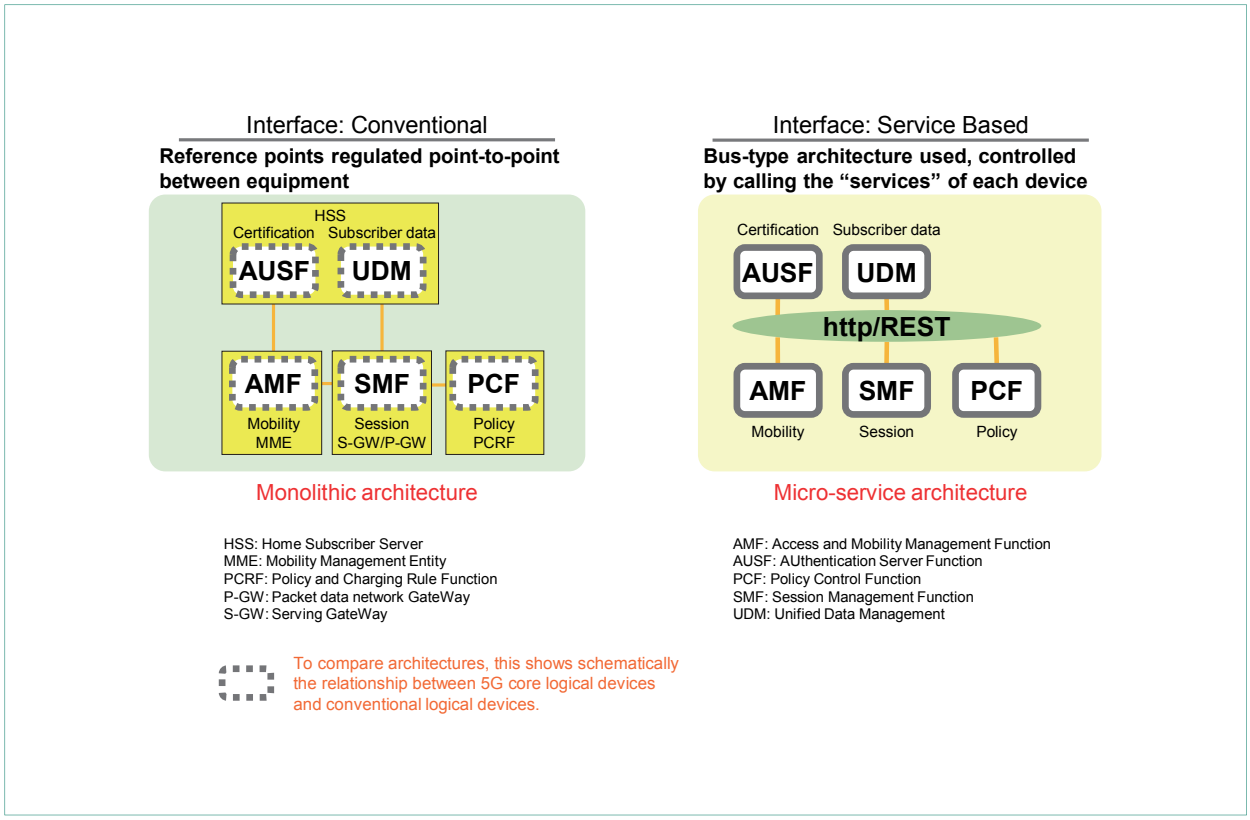

Figure 5 SBA architecture

*20 Cloud native: Refers to systems and services designed for configuration and operation on the cloud, rather than on premises.

(AI), and to generally advance operations work.

In automation efforts, we have introduced a Fulfillment Operation Support System (F-OSS)*21, which automates the increasingly complex and intricate manual work being done by people. Network virtualization has enabled structures that separate hardware and software, but by automating this with an OSS, OPerating EXpenses (OPEX)*22 can be reduced and significant improvements to reliability and availability can be made.

Remarkable progress has also been made in AI in recent years, which is expected to improve work efficiencies in various fields. Increasingly, there are also opportunities to improve efficiencies in mobile-network maintenance and operations work (hereinafter referred to as "operations work") by using AI technologies.

Automation is a key aspect of advancements in operations work, including automation that uses systems and tools to replace work conventionally done by people, and also automation that performs work that could not be done previously by people, such as predicting equipment faults or drops in service quality from current conditions, or preventing degradation in service quality due to equipment fault before it happens. There is hope that using AI technology for the latter will improve efficiencies.

Operations work can be broadly categorized into monitoring, analysis, and taking measures. Advances in operations utilizing AI are described below.

(1) Monitoring

AI technologies such as deep learning*23 and other forms of machine learning*24 can be used together with the large amounts of data that can be collected from the network, such as warnings, the state of equipment, and traffic conditions, to automatically detect symptoms of equipment fault or to predict factors that will affect services in ways not previously possible manually. Detected symptoms can then be visualized in terms of the state of quality by service or area using existing systems.

(2) Analysis

When degradation in service quality is predicted, the suspicious part within the logical network configuration, made more complex due to network slicing, is inferred automatically. Systematic isolation of faults into scenarios, which was previously done manually, is done automatically, and measures to be taken are proposed to operators dynamically, such as changing network resources, according to the details of the fault.

(3) Taking measures

Depending on the measures to be taken, automatically determined in the analysis, measures to recover automatically and maintain service continuity are taken at the discretion of the operator for phenomena that can be dealt with remotely. For phenomena that require on-site attention, such as replacing equipment due to a server fault, information such as a description of the required work, the parts, management of the work scheduling, and efficient travel routes are presented to support the on-site worker.

Implementing the above enables a change from performing maintenance conventionally, after the

*21 F-OSS: A system that manages data for building networks centrally and automates design and construction work to make network virtualization work more efficient.

*22 OPEX: Amount of money expended for maintaining and operating facilities.

*23 Deep Learning: Machine learning using a neural network with a many-layer structure.

*24 Machine learning: A framework that enables a computer to learn useful judgment standards through statistical processing from sample data.

equipment has issued warnings, to performing it based on predictions of the future. This promises to improve service continuity, preventing any effects on services to customers before they occur.

5. Conclusion

This article has described principal technologies needed in the core network and developments in network operations based on 5G use cases. NTT DOCOMO is providing connectivity for all kinds of "things" through 5G technology, and we will continue to contribute to deploying our network as social infrastructure.

Current and Future R&D at NTT DOCOMO for the 5G Era

Current State and Progress in Each Area

Evolution of Devices for the 5G Era

Communication Device Development Department Toshiyuki Futakata

NTT DOCOMO plans to begin full 5G commercial services in 2020 and is currently studying new devices and services toward that goal. However, although 2020 is one of our targets, we are also pushing forward with R&D to develop further after that. This article discusses prospects for the high-speed, high-capacity, low-latency, and many-terminal connectivity features introduced with 5G, as well as advances in the network expected in the future, technologies that will be required for various types of terminal devices and the services, and a vision for devices in 2020 and thereafter.

1. Introduction

NTT DOCOMO is working toward full commercial operation of a 5th Generation mobile communications (5G) system conforming to the specifications set by the 3GPP standardization body. The introduction of 5G will further increase speed on the downlink and the uplink, and also bring other advances to the network, anticipating connection of all kinds of objects to the Internet to make the Internet of Things (IoT). The speed of the uplink is being increased because devices are producing video and other high-volume data, in contrast with earlier devices that mainly retrieved and displayed information. As the IoT spreads further, we also anticipate that various new types of device not seen yet will appear, in addition to mobile phone and smartphone devices, which have already become

familiar and permeated our lives.

We can even consider that the roles of communication tools for making calls or exchanging messages, and of communication devices for data communication, sending and receiving information, are different.

This article describes the significance of devices and advancing device technologies in the 5G era. It also discusses future trends from the perspectives of both consumer and industrial devices.

2. Significance of Devices and Evolution of Technology in the 5G Era

Here we discuss the significance of new devices that we can expect to appear in the future and also the evolution of various related technologies to consider what sort of devices will be needed in 2020 and later and to ascertain future device trends.

2.1 Significance of Devices in the 5G Era

The medium-term strategy of the R&D division of NTT DOCOMO has the three main themes of 5G, Artificial Intelligence (AI), and devices (**Figure 1**). Device technologies will certainly be used when 5G is introduced, and with the huge amount of all kinds of data, devices will have the role of gathering such data, using it with various Big Data and AI technologies, and outputting any valuable data obtained as a result. An important element for using AI is to somehow collect the necessary data. NTT DOCOMO has redefined devices in the 5G era as connecting through various communications technologies, including mobile wireless communications, wireless LAN, Bluetooth®*1, and fixed communications, and inputting the data collected to the cloud.

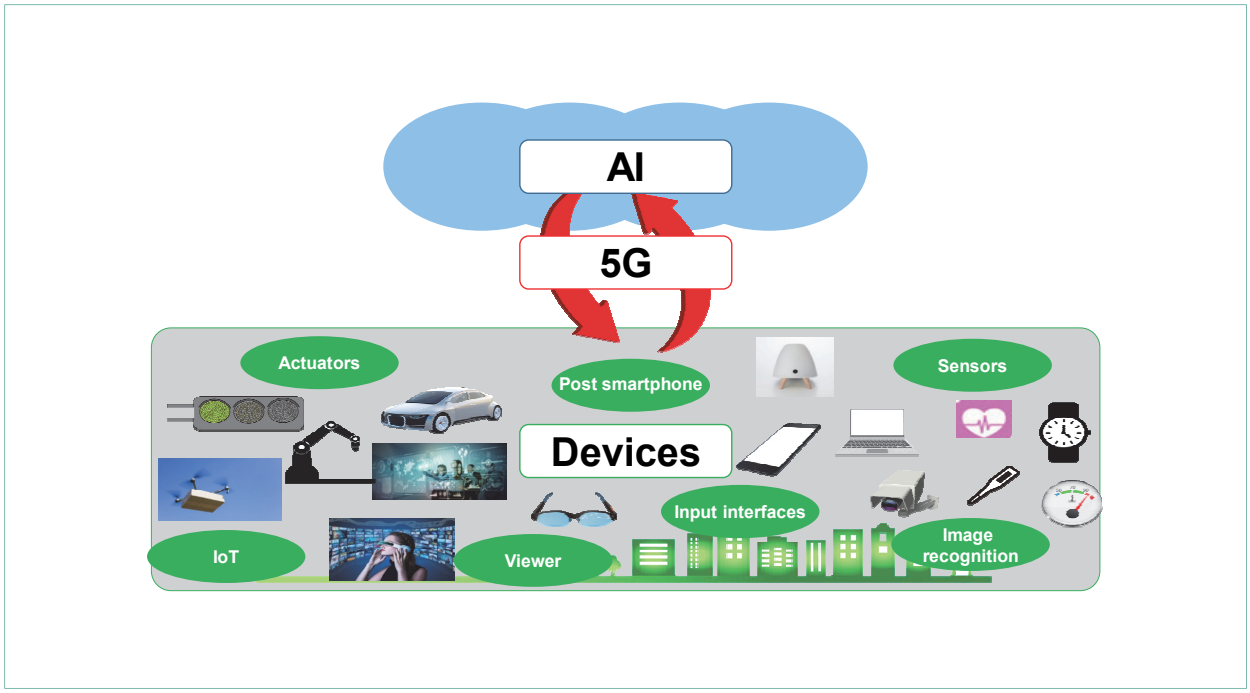

Figure 1 Three main themes in the NTT DOCOMO R&D medium-term strategy

*1 Bluetooth®: A short-range wireless communication specification for wireless connection of mobile terminals, notebook computers, PDAs, and other portable terminals. Bluetooth is a registered trademark of Bluetooth SIG Inc. in the United States.

2.2 Evolution of Device Technology

In device related technologies, technologies already being used in current smartphones and tablets will advance, including various sensors and cameras, but other types of device utilizing individual functions will also emerge in the future, such as IoT home devices, fixed displays, wearable devices and flexible displays*2 (**Figure 2**). This polarization is continuing, on the one hand gathering all functionality into smartphones, and on the other, strengthening links with peripheral devices by using various types of connectivity to link devices to handle all types of requirements.

3. Trends in New Devices for the Future

Below, we describe target markets and device trends from various market viewpoints. In addition to devices for consumers, which have been the main target previously, we expect great advances in devices for industry. For this reason, in addition to new personal devices such as smart glasses and various other display type devices for consumers, there is also increasing anticipation for specialized devices that can be used in various industries (**Figure 3**).

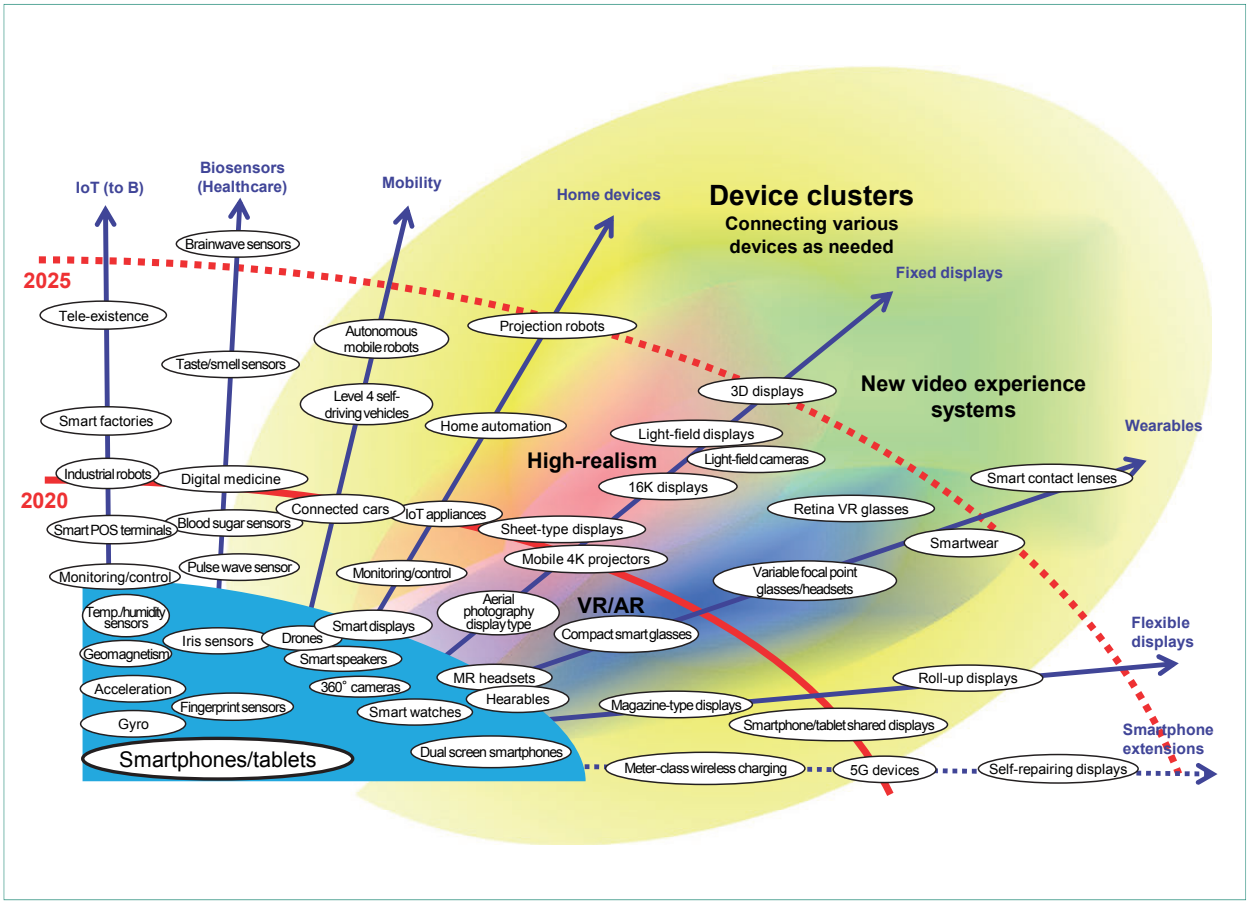

Figure 2 Trends in evolution of device technologies

*2 Flexible display: Flexible video display equipment that can be folded or rolled up like fabric or paper.

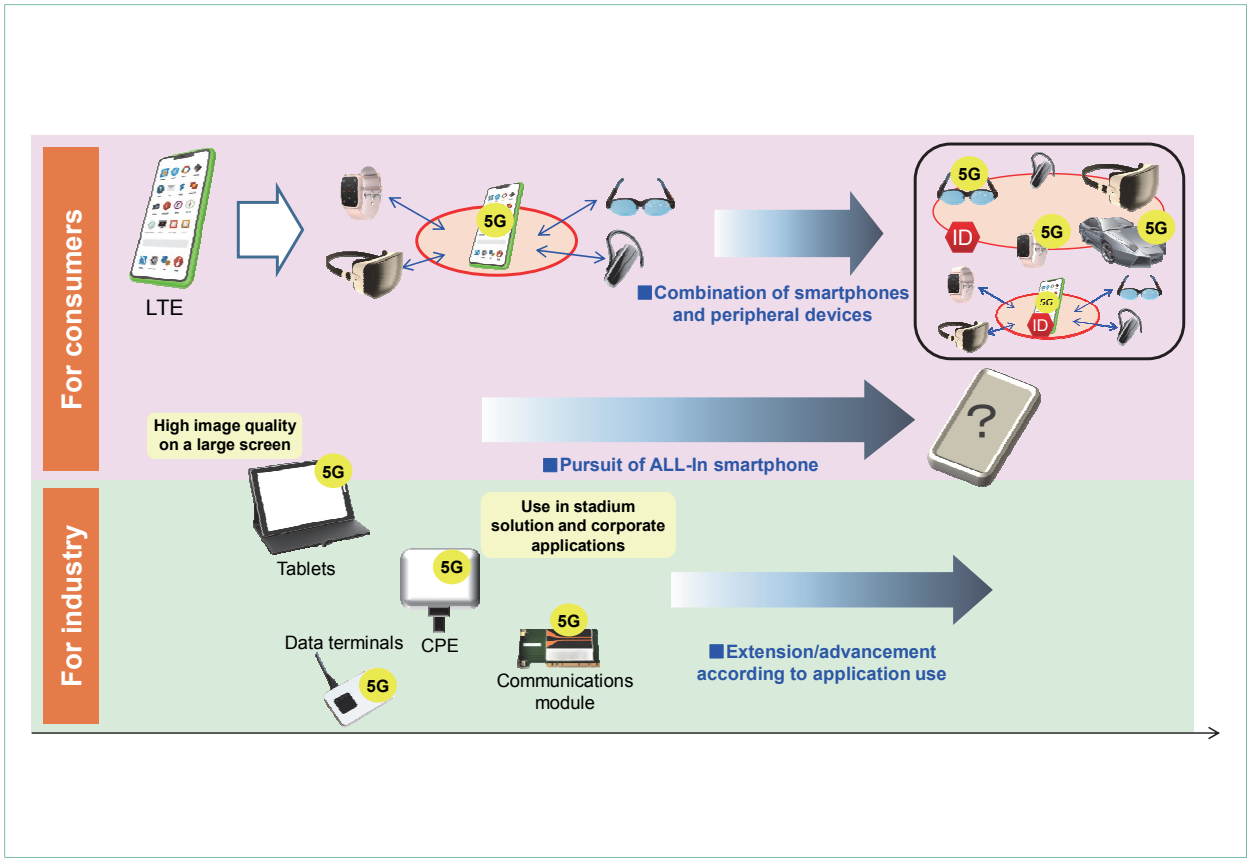

Figure 3 New device trends for the future

3.1 Trends in Consumer Devices

With devices for consumers in 2020, we expect further polarization between the usual progression toward an "ALL-In smartphone," and specialized devices such as smart glasses, VR, and home devices (Fig. 3). Farther into the future, we may be entering a time when multiple devices cooperate with each other, using a variety of devices nearby for various purposes, according to the user's application or usage scenario.

As such, we now discuss concretely, what sort of future will be realized due to device advancement, in a world with specialized devices and linkage among devices.

1) Global Perspective for Specialized Devices

Figure 4 (a) gives an example of providing a realistic experience using a large display, while Fig. 4 (b) gives an example of providing new value using small, high-image-quality glasses. The former can realize communication that is similar to meeting face-to-face while remaining at a remote location using transmissive or reflective projection technologies. With the latter, video is input through the glasses, the location and objects in it are instantly recognized, information about them is found, and is overlaid on the scene being viewed, adding convenience for the user.

2) Global Perspective for linlage among Devices

Figure 5 shows a world view with linkage among devices, where environments can be set to suit each user, freely switching between input devices by

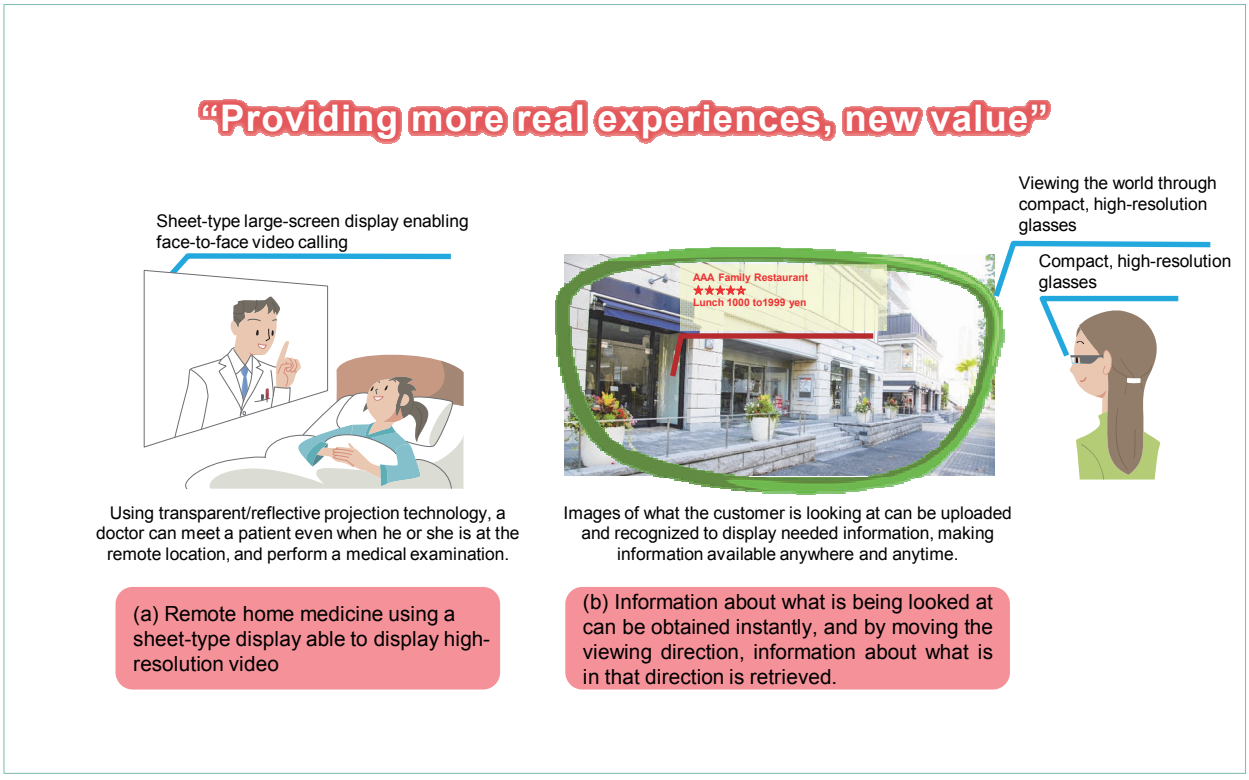

Figure 4 World view of new types of device and example use cases

Figure 5 World view of device linking

just carrying an ID, and obtaining necessary information by simply logging in. One proposed way of using new devices in the 5G era is to provide an experience not dependent on specific devices, so that users can treat the various devices nearby as their own.

3.2 Trends in Devices for Industry

Currently, in most cases services are provided using carrier or manufacturer branded communications modules (a communication modem equipped with an interface to external equipment). Since devices for industrial use will have to cover many diverse scenarios in the future, some carriers foresee popularization of one-chip solutions that use a single semiconductor that includes a communication modem together with other functions such as an interface to a sensor or other external device.

We also expect polarization depending on the application to continue here, with some devices requiring high speed and capacity, such as high-resolution surveillance cameras and infotainment[*3] devices, and others requiring low-capacity, low-power devices, such as smart meters[*4] (**Figure 6**).

These devices will be used in various applications, on site in agriculture and other industries, in medicine and disaster prevention, for advancing transportation systems, and even for sports events such as those planned for 2020. We can expect them to contribute to safe, secure, and rich lifestyles, and to realizing a convenient and highly efficient society (**Figure 7**).

4. Conclusion

This article has discussed the significance of

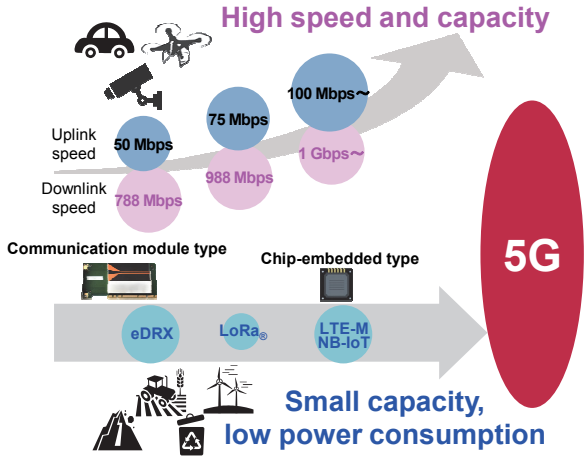

Figure 6 Trends in devices for industry

*3 Infotainment: A service integrating information and entertainment, such as a service combining enjoyment of video or music with viewing of information such as maps and traffic conditions provided in a vehicle.

*4 Smart meter: A device that enables real-time measurement and visualization of electricity usage.

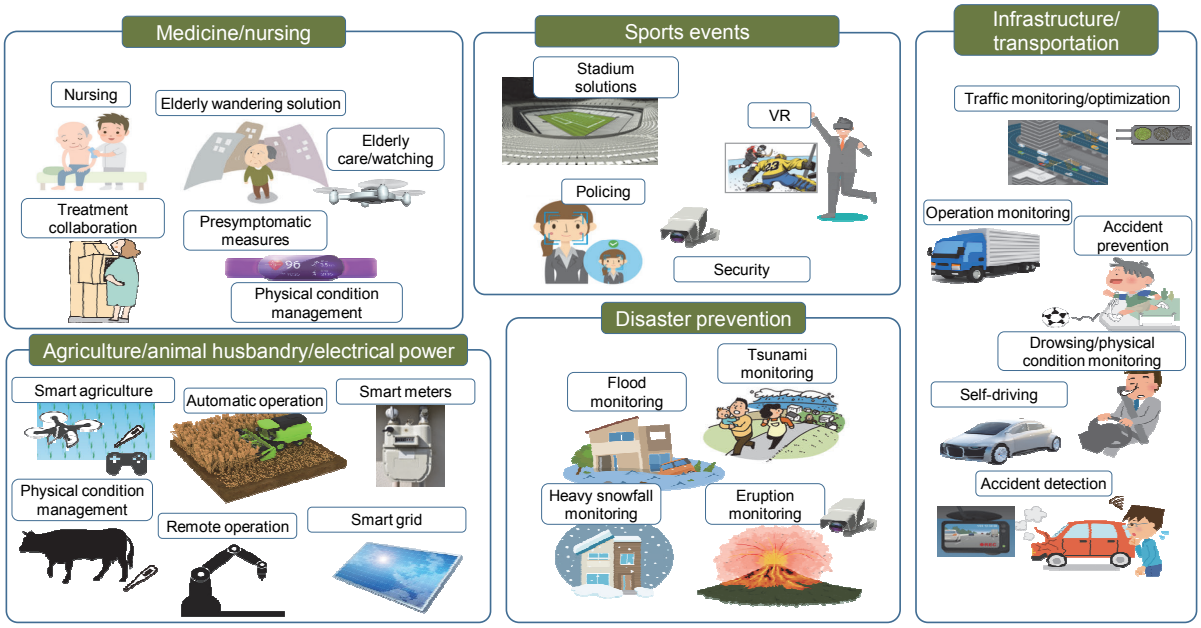

Figure 7 Applications of new devices in industry

devices, trends in their evolution, their roles and a world-view that could be realized with the full commercialization of 5G. Not much time remains till 5G is commercialized, but for further development after that, we will continue work to develop devices and services worthy of the so-called fourth industrial revolution.

Current and Future R&D at NTT DOCOMO for the 5G Era

Current State and Progress in Each Area

Trends in AI and Big Data Analysis

Service Innovation Department Masayuki Tsuda Research Laboratories Wataru Takita
Innovation Management Department Tomoyoshi Oono

In recent years, the attention given to AI has increased dramatically, and NTT DOCOMO is continuing its various initiatives to create value and solve social issues with AI. This article describes the significance of AI in DOCOMO's thinking, and DOCOMO's AI core technology developments and AI platform strategies. Also, this article introduces "AI agent," "AI taxi," "AI stamp rally" and "disease prevention and early discovery" as specific examples of DOCOMO's AI initiatives. Finally, this article describes the future outlook for the "Beyond 2020" vision.

1. Introduction

We are now in the third Artificial Intelligence (AI) boom after the two previous booms since AI first appeared in 1956. This is because it's now possible to handle big data at practical costs thanks to advances in computing power and algorithms.

There are three specific reasons why the boom in AI has occurred, as follows:

(1) Increases in the amount of available data

Data now exists at an effective level for machine learning due to the increase in the amount of data available with the spread of digital devices such as smartphones, cameras, and PCs, and information publishing services such as social networking services, User Generated Contents (UGC)*1, and video sites.

(2) Improvement of computing power

The spread and increase of hardware

*1 UGC: A generic name for contents created by users.

environments such as General Purpose computing on Graphics Processing Unit (GPGPU)*2 that enable high-speed, large-scale floating-point computations, cloud computing environments that are easily scalable to suit different purposes, and high-performance memory, Solid-State Drives (SSD), and optical networks to handle high speeds with infrastructure have made it possible to use large-scale computing resources cheaply.

(3) Advances in learning algorithms and the spread of libraries*3

In addition to the dramatically improved performance of learning through "deep learning*4," one of the types of machine learning technologies, the open sourcing of software libraries such as TensorFlow®*5 and the spread of library environments that enable easy trial-and-error have accelerated the machine learning Plan, Do, Check, Act (PDCA) cycle*6.

With these factors, the focus on AI has increased in academia, business and the mass media, and a large movement of investment and human resources into these fields from all over the world has occurred, resulting in the wide spread of AI.

Generally, AI applications are split into two types - "general-purpose" and "specific-purpose."

Theoretically, general-purpose AI is not restricted to particular work or tasks, but has generalized capabilities similar to or greater than humans, and can apply its own capabilities to respond beyond the scope of its specifically programmed functions. A typical example is an autonomous robot with its own will that appears in animation and so forth. However, there are no current prospects for the realization of such technology due to hurdles such as the difficulty of gathering correct training data over a wide area.

In contrast, specific-purpose AI is designed to perform a specific task, and is specialized with one function such as the games Go or Shogi or for tasks such as image recognition, machine translation or dialogue. A typical example of specific-purpose AI is Google's "AlphaGo*7" developed using deep learning, and renown for beating professional Go players. Currently, the AI that has spread in society and through various fields of business is this specific-purpose type. This does not simply entail the use of AI technology - more important is the way it is used in combination with domain knowledge*8. In addition, because better results can be gained efficiently by machine learning with large amounts of data in some cases rather than humans thinking up the procedures to solve a problem using their knowledge and experience, securing overwhelming amounts of data is becoming ever more crucial.

NTT DOCOMO has also built a specific-purpose AI (known as "narrow-AI") platform for analyzing and using data, and we are which it is continuing to apply it to various areas of business with the aim of creating value and solving social issues. This article describes the future direction of AI at NTT DOCOMO.

2. NTT DOCOMO Initiatives

2.1 The Significance of AI Technology in NTT DOCOMO's Thinking

With AI technology, we aim to achieve the ultimate personal agent, and solve social issues and

*2 GPGPU: The use of GPUs ordinarily used in computers for rendering and other types of image processing for other types of applications. GPGPU excels at parallel distributed processing.

*3 Library: A collection of high-versatility programs which are reusable.

*4 Deep learning: Machine learning using a neural network with a multi-layered structure.

*5 TensorFlow®: A deep learning programming framework. A registered trademark of Google LLC.

make industry more efficient (**Figure 1**).

As part of our medium-term strategy to 2020, the "Declaration beyond," the former initiative aims to achieve an AI agent that will transform the lifestyles of our customers and become an indispensable item for "personal" lifestyles in various scenes. This agent will use AI technologies for natural-language dialogue and behavior prediction to accurately understand information that customers want and provide optimized suggestions with appropriate timing. An example of this is the "my daiz™*9" AI agent service.

The latter is the "+d*10" (co-creation) initiative to generate new value by using the core technologies and big data required to achieve the aforementioned personal agent combined with the big data and domain knowledge of partner companies. An example of this is the "AI taxi" to predict future taxi demand using deep learning by combining NTT DOCOMO's population statistics data generated from cellular networks with the operational data of a taxi company [1], described later.

2.2 AI Core Technology Development

The main AI technology field is broadly divided into four categories:

- Recognition: Recognition of images, voice and language etc.
- Judgment/optimization: Demand prediction, error detection, optimal route discovery, judgment support in medicine/law etc.
- Generation: Generation of images, voice and text etc.
- Control: Control of autonomous driving and robots etc.

At NTT DOCOMO, we are developing competitive AI core technologies focusing on recognition, judgment/optimization using big data collected through NTT DOCOMO's customer base. These developments also include applying technologies to solve current issues, polishing technologies while

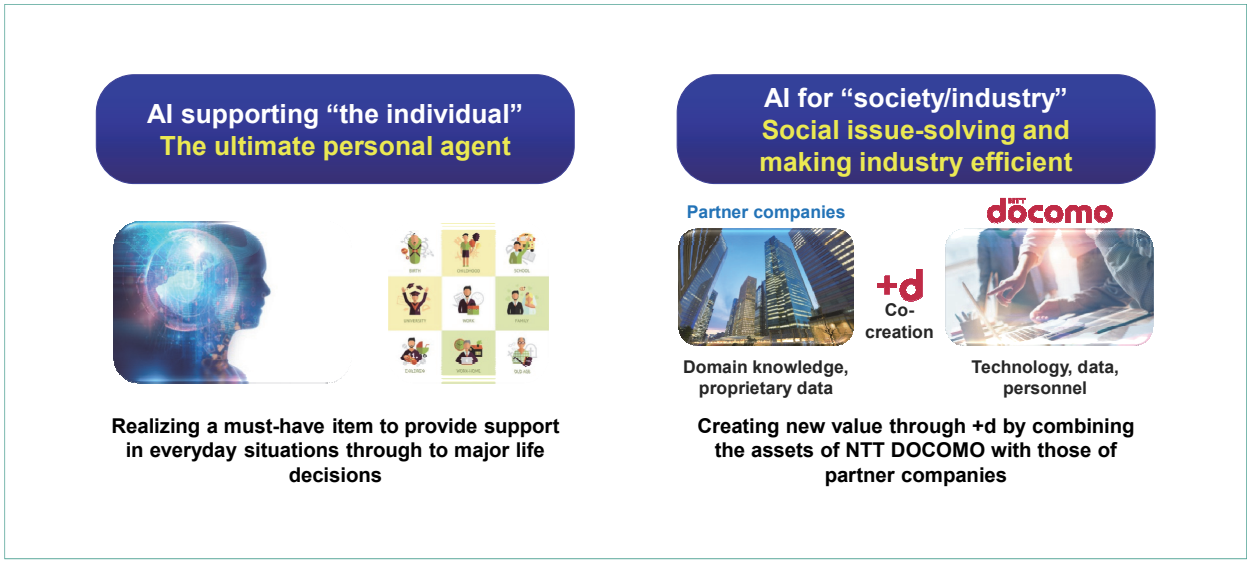

Figure 1 The significance of AI Technology in NTT DOCOMO's thinking

*6 PDCA cycle: A method of ensuring smooth running of business. The PDCA cycle entails repeatedly and continually running through the four steps of (1) Plan (planning), (2) Do (performing), (3) Check (measuring results) and (4) Act (making improvements).

*7 AlphaGo: A trademark or registered trademark of Google LLC.

*8 Domain knowledge: Knowledge or information such as trends and so forth about a target business or industry.

*9 my daiz™: my daiz and the my daiz logo is a trademark of NTT DOCOMO, INC.

*10 +d: Name of the NTT DOCOMO initiative for creating new value together with partner companies.

acquiring feedback, and pursuing cutting-edge technologies through the use of NTT group technologies and partnerships with top class research institutions both in Japan and abroad, such as participation in the Stanford Data Science Initiative (SDSI)*11 run by Stanford University [2].

2.3 AI Platform Strategies

Regarding the aforementioned AI core technologies, we are progressing with the creation of a platform in co-creation with partners to expand the scope of industries using the technology. This process consists of:

(1) "Point" stage: Generating specific cases for each core technology and accumulating know-how as "points"

(2) "Line" stage: Deployment and development like "lines" including know-how in target business areas of each core technology

(3) "Surface" stage: Deployment and development like "surface" with a platform organically linking core technologies

As described above, we are aiming to create a platform with deployment and development from points to lines, and then lines to surfaces (**Figure 2**).

The platformization of natural-language dialogue technology is being driven through the process described above. This technology was used in 2012 with "Shabette Concier," after which NTT DOCOMO began offering a natural-language dialogue platform after improving performance and accumulating know-how using data collected from several hundred million instances of use. In 2015, we developed the communication toy "OHaNAS®*12" jointly with Tomy Company. Then in 2016, we began providing the "Oshaberi Robot for Biz," a customizable service to which companies can add their unique scenarios, and then in 2017, we jointly developed the "ATOM®*13" communications robot with Kodansha, Tezuka Productions, FUJI SOFT and VAIO. In this way, our developments went from "point" to "line." Then in 2018, our developments moved from "line" to "surface" with the deployment of the AI agent API*14, which is the core of the AI agent platform, and was achieved by organically linking

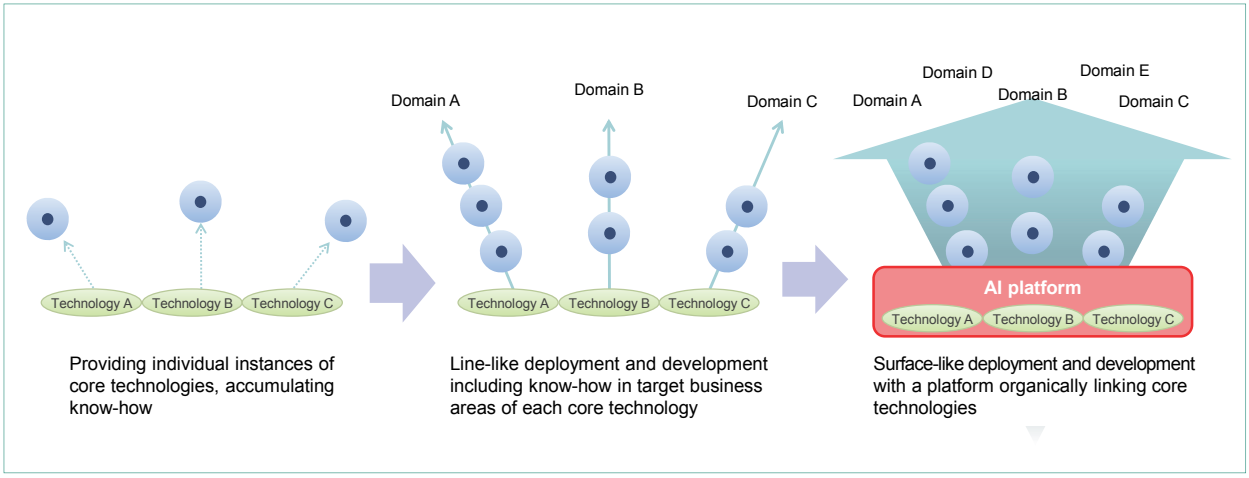

Figure 2 The platform promotion process

*11 SDSI: A joint industry-academic program to support collaboration between the Graduate School of Engineering at Stanford University and companies involved in data science and big data.

*12 OHaNAS®: A registered trademark of TOMY Company, Ltd.

*13 ATOM®: A registered trademark of Kodansha Ltd.

*14 API: A general-purpose interface for using functions and data.

the separate prediction engine and IoT access control engine AI core technologies.

3. Specific Examples of NTT DOCOMO AI

3.1 AI Agent

1) AI Agent API

As part of our medium-term strategy to 2020, the "Declaration beyond," we are developing and providing the "AI agent API" to form the core of the platform to achieve the new AI agent that will transform the lifestyles of our customers [3]. This API is the basic system for creating the new AI agent, and consists of the prediction engine, a multipurpose dialogue engine, and the IoT access control engine (**Table 1**). Part of the NTT group AI technology "corevo®*15" is used for the prediction engine and the multipurpose dialogue engine.

Also, we have been promoting the "DOCOMO AI Agent Open Partner Initiative" as a joint development for a new "open for services and devices" service provision style based on the audio interface by making this API openly available. With this initiative, we are aiming for the following three points by making the services and the API for device providers that NTT DOCOMO has fostered to date openly available (**Figure 3**).

- To create new service experiences for end-users through text and audio

Table 1 Characteristics of the three engines

Prediction engine	Behavior analysis technology enables timely provision of information tailored to individuals.
Multipurpose dialogue engine	Natural language processing technology enables provision of services through natural dialogue.
IoT access control engine	Device Web API technology enables control of IoT devices with different communication standards from a single application.

Device Web API: A mechanism that achieves linkage between various devices discussed and studied by the Device Web API Consortium, which consists of 120 participant companies (as of July 2018).

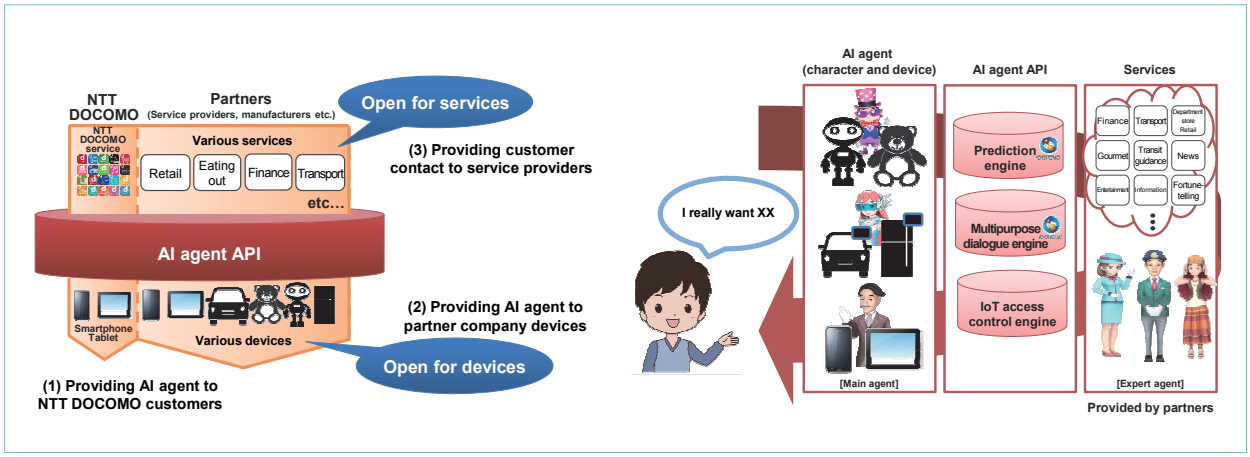

Figure 3 Generating new services by making AI agent API openly available

*15 corevo®: A registered trademark of Nippon Telegraph and Telephone Corporation.

- To build win-win business relationships with partner companies
- To shorten the development period for AI agent services

2) The my daiz AI Agent Service

Using the aforementioned AI agent API etc., NTT DOCOMO began providing the "my daiz" AI agent service in the spring of 2018, which enables NTT DOCOMO or partner companies to provide optimized suggestions with appropriate timing by the AI agent understanding the information that customers seek.

This service makes possible to provide customers with optimized suggestions with appropriate timing by understanding each customer **(Figure 4)** such as:

- Sounding an alarm early, once weather and traffic information is understood if it looks like commuting to work or school might take time due to rain
- Purchasing insufficient food supplies through Internet shopping and having them delivered to the home
- Providing weather and peripheral information of destinations as well as travel bookings

3.2 AI Taxi

For taxi drivers to increase their income, it's important to find passengers efficiently in unfamiliar areas or timeslots to reduce the time the taxi is vacant and maximize the time it's engaged. To address this issue, NTT DOCOMO has begun commercially providing "AI taxi" developed technology to predict taxi passenger demand in particular areas using past taxi operational data and NTT DOCOMO's real time population statistics data generated from cellular networks. This enables taxi drivers to keep track of changing passenger demand in real time and operate their taxis more efficiently.

This technology uses data input of real time

The Google Chrome logo is a trademark or registered trademark of Google LLC.

Figure 4 my daiz

population statistics, weather forecasts, past taxi passenger rates, and uses deep learning to effectively extract latent feature values*16 and then perform regression. Then in combination with the Vector Auto Regressive model (VAR, also multivariate autoregression model), the technology estimates taxi demand in 500 m mesh*17 units 30 minutes in the future (the number of passengers predicted to be picked up in the mesh) (**Figures 5, 6**).

In field trials, we confirmed 93 to 95% accuracy of these predictions, and there was an approximately JPY 1,400 average sales increase per day per driver for drivers using the prediction system.

3.3 AI Stamp Rally

The way people acquire tourism information has

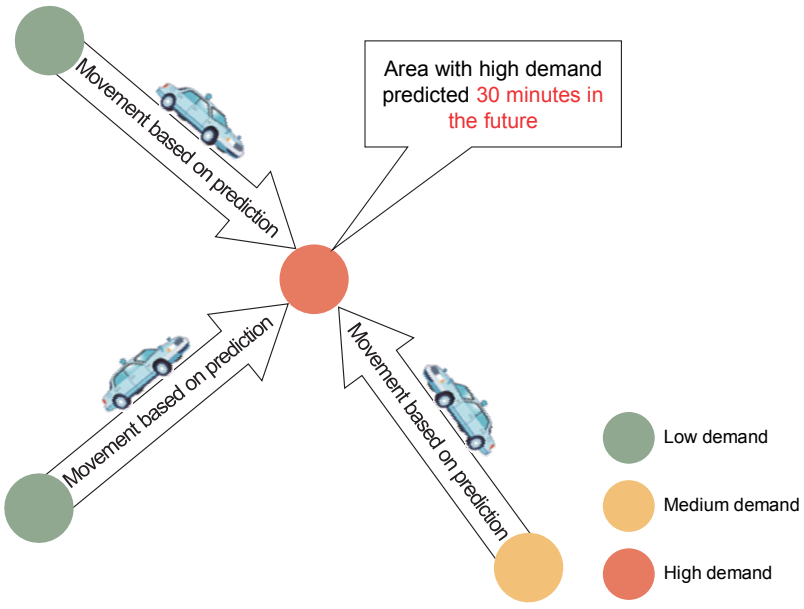

Figure 5 Demand prediction and taxi movement

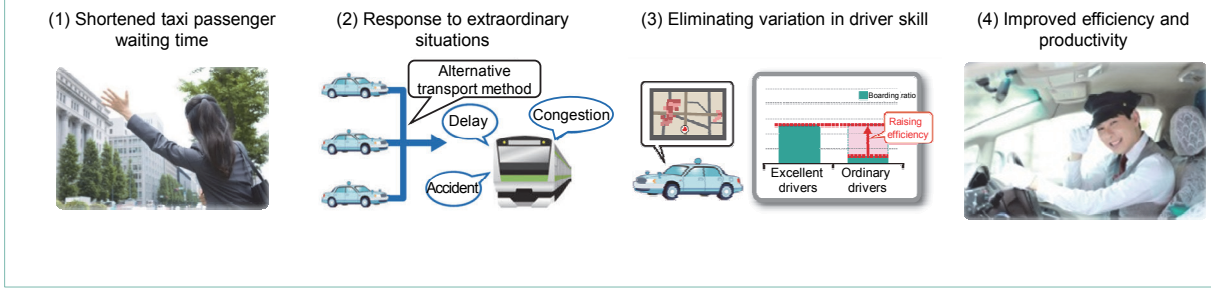

Figure 6 Anticipated effects of AI taxi

*16 Feature values: Values extracted from data, and given to that data to give it features.
*17 Mesh: A grid dividing the country into square sections, along lines of latitude and longitude.

changed dramatically with the spread of smartphones and social networking services. Hence, disseminating information about sightseeing requires not only publication in conventional travel magazines or posting on Web sites, but also requires new and more efficient methods.

To provide value as a sightseeing information dissemination method using dialogue AI technology, NTT DOCOMO developed "AI Stamp Rally™*18" with partners, which disseminates sightseeing information in conversation with dialogue AI (chat bot) on social networking services with many users and achieves a stamp rally using image recognition AI, and performed trials of this service in Ishinomaki city in Miyagi Prefecture from March to August 2018 (**Figure 7**). This service is available on social networking services prior to sightseeing so that users can find out recommended information about sightseeing or events while enjoying conversation with a character (dialogue AI) before setting out. Users can tour around sightseeing spots while enjoying a bingo rally by taking photographs, and easily find out the closest dining and sights from location information. After sightseeing, it's also possible to find out about new sightseeing information such as events.

Main advantages compared to conventional sightseeing spot information dissemination are:

(1) Effective information dissemination: Information disseminated to individuals in conversation by dialogue AI

(2) Attract tourists, generate migration: Attract tourists and generate migration to sightseeing spots with stamp rallies

(3) Information acquisition: Acquire tourist attribute information and migration information

Figure 7 AI stamp rally service image

*18 AI Stamp Rally™: A trademark of NTT DOCOMO, INC.

through conversation with dialogue AI and stamp rallies

(4) Generate constant contact: Create contact through connection on social networking services to continually disseminate information

Figure 8 describes an image of the AI stamp rally Web API linkage. With the Web API, NTT DOCOMO's dialogue AI links with image recognition AI to recognize images of sightseeing spots with deep learning, and stamp rally systems developed by partners. According to the details of the conversation, the dialogue AI responds to the users, for example, by disseminating sightseeing information or providing stamp rally functions. In future, this service will make it possible to achieve more advanced and effective sightseeing information dissemination by linking existing sightseeing spot services and data using the Web API.

3.4 Disease Prevention and Early Discovery

Many diseases, including lifestyle-related diseases, are caused by a complex interaction between congenital genetic factors and acquired environmental factors such as lifestyles and living environments. To prevent the onset or progression of diseases, it is desirable to predict the risk of future onset of diseases by evaluating the current state of the individual's health from periodic monitoring for any signs or abnormalities of physiological data in which genetic and environmental factors are reflected.

Pregnancy complications*19 including preterm birth, gestational diabetes and hypertensive disorders of pregnancy are social issues that affect one in five pregnant women in Japan, but so far no fundamental preventive or therapeutic methods have been discovered. Taking the initiative to address this issue, NTT DOCOMO has embarked on "Maternity Log Study" collaborating with Tohoku University Tohoku Medical Megabank Organization to investigate the differences between pregnant women who develop pregnancy complications and those who don't to exhaustively analyze big data on both genetic and environmental factors [4] [5]. This initiative entails working on identifying risk factors for pregnancy complications

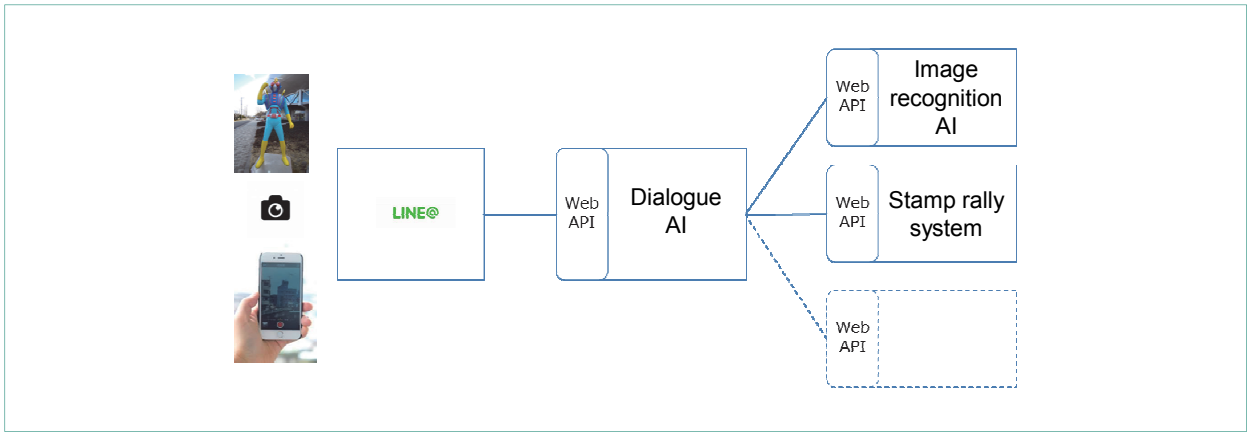

Figure 8 AI stamp rally Web API linkage image

*19 Pregnancy complication: Refers to diseases associated with pregnancy, and can include diseases that existed prior to a person becoming pregnant, or diseases that occur during pregnancy.

and constructing prediction models for disease onset by integrated analysis of a wide variety of data such as the DeoxyriboNucleic Acid (DNA)*20 and RiboNucleic Acid (RNA)*21, metabolites in urine and plasma*22, oral cavity bacterial flora*23, life log including activity and sleep etc., and diagnostic information such as medical records of pregnant women (**Figure 9**). In the future, we would like to contribute not only to the improvement of the health of pregnant women but also to the extension of the healthy life expectancy*24 of more people by using the knowledge obtained from this research to prevent the onset of disease in both non-pregnant women and men.

4. Future Outlook

Toward the Beyond 2020, we envisage the arrival of a convenient and comfortable society in which AI is integrated throughout society in various ways (**Figure 10**). Thus, we will work with our partners to develop core technologies and services so that NTT DOCOMO can play a driving role in the realization and growth of this coming society.

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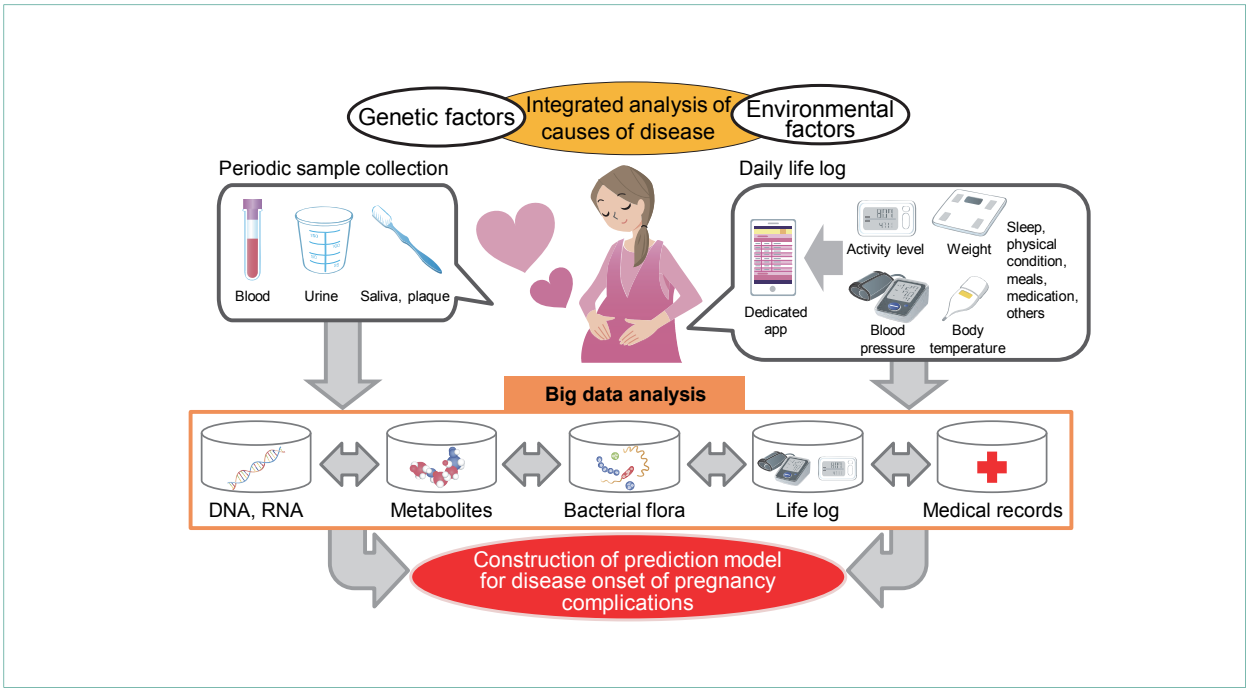

Figure 9 "Maternity Log Study" overview

*20 DNA: A substance carrying genetic information in an organism and consisting of deoxyribose and phosphoric acid, and four types of nucleobases: adenine, guanine, cytosine, and thymine.

*21 RNA: A substance transcribed using DNA as a template, and composed of ribose and phosphoric acid, and four types of nucleobases: adenine, guanine, cytosine, and uracil. While DNA primarily plays the role of accumulating and preserving information in the nucleus, RNA is responsible for temporary processing of that information.

*22 Plasma: A liquid component of blood that contains proteins, lipids and electrolytes etc.

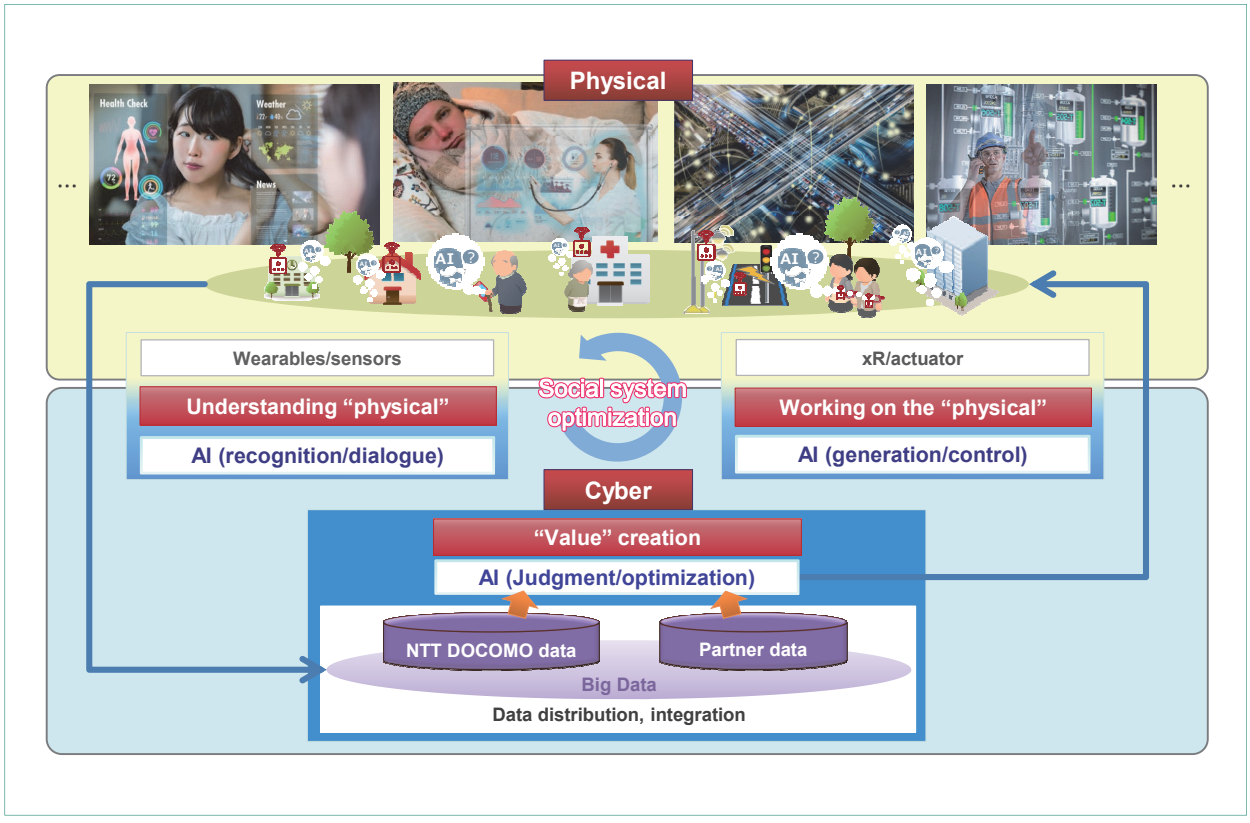

Figure 10 A convenient and comfortable society in which AI is integrated throughout society in various ways

Agent API" will help accelerate increasing collaboration -," Jun. 2017.
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*23 Bacterial flora: A collection of bacteria growing in a certain environment.

*24 Healthy life expectancy: The expected period of good health in daily life.

Current and Future R&D at NTT DOCOMO for the 5G Era

Open Innovation with 5G Co-creation Partners

Views of the Future Pioneered by 5G — A World Converging the Strengths of Partners —

5G Laboratories Takehiro Nakamura

Currently, efforts to commercialize 5G around the world are in full swing, and many businesses have great expectations for 5G to create new services. This article introduces the new technologies NTT DOCOMO has advanced for the 5G era with its principal global vendors, field trials using the new frequencies, the state of partnerships in a wide range of industries, and the beginning of the DOCOMO 5G Open Partner Program for co-creating new services.

1. Introduction

Since first studying 5th Generation mobile communications systems (5G), NTT DOCOMO set 2020 as the target for commercial introduction of these technologies, and began field trials of new technologies and new frequencies for the 5G era in 2014. Then DOCOMO constructed a 5G Trial Sites and has been conducting comprehensive end-to-end experiments including not only radio but also networks and service applications since 2017 [1]. NTT DOCOMO then began the DOCOMO 5G Open Partner Program in February 2018 [2] to accelerate new 5G service co-creation through various industry partnerships.

This article describes our field trials and initiatives to strengthen partnerships with our 5G business partners.

2. The State of 5G Partnerships

2.1 5G Field Trials

Many radio access technologies have been studied to support a wide range of frequency bands

and use cases with 5G. NTT DOCOMO begun field trials of promising candidate technologies jointly with principal global vendors in 2014, and has acquired a vast amount of test results and knowledge to commercialize these technologies. These efforts have resulted in global top level achievements such as improvements to spectral efficiency*1, super high-speed radio data transmission, high-speed motion support, and securing of coverage with high frequency bands. Testing will also be accelerated going forward towards commercialization.

Photo 1 4K multistream live distribution at 5G Trial Sites [1]

2.2 5G Trial Sites

NTT DOCOMO has been operating 5G Trial Sites®*2 at Tokyo Waterfront City Region (Odaiba, Aomi District) and around TOKYO SKYTREE TOWN ®*3 since May 2017. The sites are used to test consumer services in areas with many customers including tourists and visitors to Japan, and the Odaiba site has been used effectively to perform field trials of the connected car*4 technologies over wide areas. To introduce 5G radio communications, the opening ceremony of the trial site was jointly held with Tobu Railway Co., Ltd., and featured 4K multistream live video distribution from the 340 m-high Tembo Deck of the TOKYO SKYTREE ®*5 to the TOKYO Solamachi®*6, and demonstration of content delivery to a tablet computer onboard a train (**Photo 1**). Also, experimental results using 5G include successful 4K video transmission to the "EKIMISE" Asakusa station building from the Tembo Deck of TOKYO SKYTREE and the achievement of transmission rates of 10 Gbps in the area surrounding TOKYO SKYTREE TOWN (**Figure 1**).

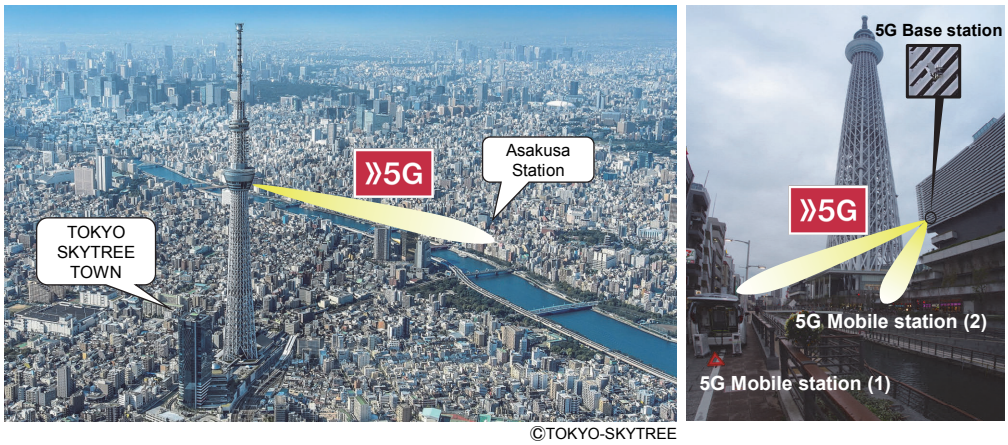

Figure 1 5G transmission experiment in the area around TOKYO SKYTREE TOWN

*1 Spectral efficiency: The number of data bits that can be transmitted per unit time and unit frequency band.
*2 5G Trial Sites®: A registered trademark of NTT DOCOMO, INC.
*3 TOKYO SKYTREE TOWN®: A registered trademark of TOBU RAILWAY CO., LTD. and TOBU TOWER SKYTREE CO., LTD.
*4 Connected car: An automobile connected to an external network via a communications device.
*5 TOKYO SKYTREE®: A registered trademark of TOBU RAILWAY CO., LTD. and TOBU TOWER SKYTREE CO., LTD.

2.3 Activities to Create 5G Services

For a number of years, NTT DOCOMO has been engaging in partnerships in a wide range of industries such as the automotive, railway, travel, construction, manufacturing, medical and healthcare, video and contents, sports and games for experimentation and to demonstrate services (**Figure 2**). These activities have included developments to create the seeds of 5G services, put these into a form that can be seen and experienced and hence create specific services. Going forward, NTT DOCOMO plans to provide support to its partners to promote the creation of services in all industries using DOCOMO's R&D technological assets. In addition, NTT DOCOMO began the DOCOMO 5G Open Partner Program in February 2018 (which has participation from more than 1,600 companies as of end of July 2018). Centering on 5G, this program provides beneficial information on technologies and business, holds related events, provides indoor and field testing environments, and offers opportunities for communication among partners (**Photo 2**). In particular, as an indoor 5G testing environment, NTT DOCOMO opened the DOCOMO 5G Open Lab™*7 Yotsuya, and will open similar facilities, OSAKA (in Osaka) and OKINAWA (in Okinawa) (as of end of July 2018) [3] [4]. These testing environments are directly connected to cloud computing facilities (a cloud platform), and offer the "DOCOMO 5G open cloud" testing environment for testing telecom cloud technologies [5]. Through these activities, NTT DOCOMO will also cooperate with new partners to expand the potentials for 5G usage scenes, and complete equipment and systems designed for actual implementation with full 5G commercial introduction in 2020. If an effective cooperation system more broadly combining assets between industries can be achieved, it will leave the comprehensive strength of the ICT industry unchallenged. For partners also, these developments promise opportunities to create even better services through interaction with partners in a wide range of industries.

Figure 2 Partnerships in various industries to create 5G services

*6 TOKYO Solamachi®: A registered trademark of TOBU RAILWAY CO., LTD.

*7 DOCOMO 5G Open Lab™: A trademark or registered trademark of NTT DOCOMO, INC.

Photo 2 The opening of the DOCOMO 5G Open Partner Program

3. Examples of 5G Partnerships

1) 5G Field Trials

To date, NTT DOCOMO has driven field trials of the latest radio access technologies jointly with principal global vendors, and has achieved results at the global top level. Recently, we have tested long-distance, high-speed transmission in the so-called "milliwave band" - a promising 5G high-frequency band. These outdoor tests were performed in a macrocell[*8] environment from the TOKYO SKYTREE Tembo Deck to the Asakusa district more than 1 km away. Also in the Yokohama Minatomirai 21 area, we performed outdoor testing of Ultra-Reliable and Low Latency Communications (URLLC), another promising usage scenario, and verified its requirements. In addition, we succeeded in the world's first 5G 28 GHz radio data transfer and 4K live video broadcast in an ultra high speed moving environment of maximum 300 km/h **(Photo 3)** [6].

2) Connected Car Field Trials Using 5G Communications

There is a lot of anticipation for a variety of connected car service applications to improve the safety and security of transport systems and lifestyles involving vehicles etc. To achieve the next generation of mobility pioneered by 5G, we have accelerated studies on achieving connected car services by testing them with moving vehicles at the Odaiba 5G Trial Sites and examining collection and distribution of high-precision sensor data with vehicles running on a test course and transport infrastructure such as roads and constructions.

3) Future Construction with 5G

The high speed and low latency of 5G will be extremely useful in meeting the substantial requirements for remote and automated operation of construction equipment in construction sites. Using these characteristics, we have been performing experiments to bidirectionally transmit high-resolution worksite video from cameras mounted on remotely located construction equipment and control signals to the construction equipment in real time **(Photo 4)** [7]. These experiments entailed actual real-time remote control via 5G with clear images of the worksite, and will expand the potential

*8 Macrocell: A cellular communications area with a radius from several hundred meters to several tens of kilometers covered by a single base station.

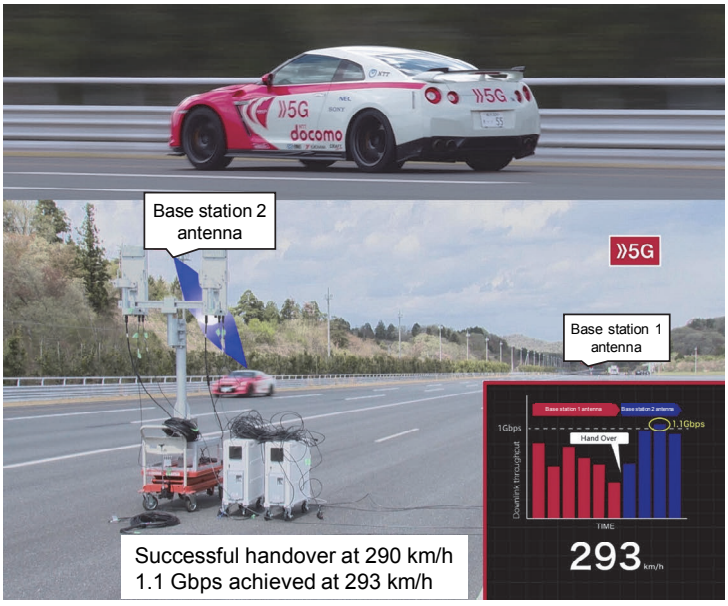

Photo 3 5G radio communications test in a high-speed moving environment

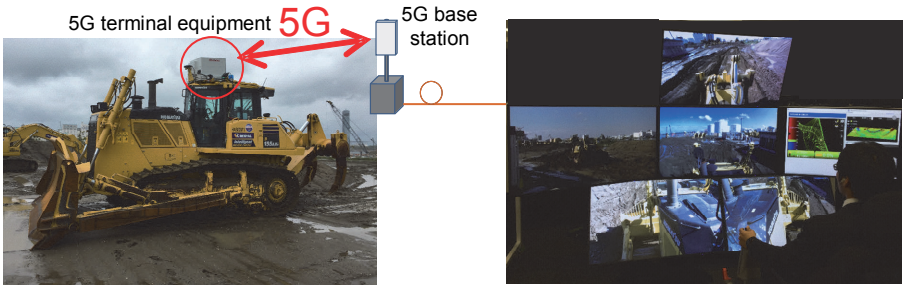

Photo 4 Demonstrating remote control in construction

for Internet of Things (IoT) at construction and mining sites while enabling the highly efficient and safe workplaces of the future.

4) 5G FACTORY®*9

Using 5G to operate robots in remote locations will enable rapid, safe and secure disaster recovery operations. NTT DOCOMO has jointly developed 5G technology to achieve remote control of robots, etc. in production worksites using free viewpoint video technology (Augmented Reality (AR), Virtual Reality (VR) technologies) (**Photo 5**) [8]. In addition to this achievement, the technology can be applied in a wide range of scenes from factories and production workplaces through to distribution warehousing, and holds promises for providing new solutions for labor shortages.

5) New Sports Viewing, Games and Live Performance with AR/VR

We propose new ways to view and enjoy sports with AR by acquiring comprehensive sports data

*9 5G FACTORY®: A name for technologies and systems that will achieve the factories for the future using 5G. A registered trademark of NTT DOCOMO, INC.

Photo 5 Demonstrating 5G FACTORY III in MWC2018

covering a wide area of sport, such as stats data*10 that pop up in the view when the user looks out across the entire soccer stadium and focuses on the player who has the ball or any interesting player. Combining 5G with interactive games and so forth will also make it possible to enjoy games without stress by sharing ultra-high-resolution images in ultra-low latency communications environments. We are also developing a new virtual entertainment experience project with the latest NTT Group technologies including 5G, which will enable network distribution combining live performances from various locations around the world into one image in real time etc [9].

6) Remote Medical Treatment

In the medical field, as part of the Ministry of Internal Affairs and Communications "5G comprehensive demonstration test," we have tested remote treatment services in Wakayama Prefecture using high-resolution images by connecting an urban general hospital with a clinic in a remote area using high-speed communications networks with 5G [10]*. In addition to achieving a 4K TV conferencing system for medical examination, we confirmed advances to telediagnosis services and reduction of doctor work load with real-time transmission of 4K diagnostic closeup camera images and images from medical equipment such as ultrasonic imaging (ultrasonography) diagnosis devices and MRI devices with 5G ultrafast communications (**Photo 6**).

4. Conclusion

To create even better services in the 5G era, we are continuing to cooperate with an increasing number of partner companies in a wide range of

*10 Stats data: Statistical numeric values of details about athlete and team player performance in sport.

* This experiment was contracted from the Ministry of Internal Affairs and Communications in FY2017, and conducted by NTT DOCOMO as "Contracted survey and study on technical conditions etc. of 5th generation mobile communication systems to enable super high-speed communications exceeding 10 Gbps in populated areas".

Photo 6 Testing remote medical treatment in Wakayama Prefecture [10]

industries. Going forward, DOCOMO R&D aims to proactively continue open innovation to improve co-creation environments in +d[*11] partnerships, and further expand its partnerships.

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*11 +d: Name of NTT DOCOMO initiative for co-creating new value with partner companies.

Current and Future R&D at NTT DOCOMO for the 5G Era

Open Innovation with 5G Co-creation Partners

R&D Also on the Front Line! Co-creating Corporate Solutions with “TOPGUN”

Innovation Management Department Tomoyoshi Oono

In October 2017, NTT DOCOMO began its “TOPGUN™*1” initiative to generate solutions in a three-way partnership between DOCOMO’s R&D division, corporate sales and marketing division and its customers. This initiative aims to create real solutions to customer issues by having R&D engineers actually go to the front line with corporate sales and marketing staff to uncover the latent needs of customers, verify business potential and commercialize services all at once. Through TOPGUN, DOCOMO R&D is accelerating the co-creation of solutions for the 5G era.

1. Introduction

To date, NTT DOCOMO has taken initiatives to create corporate solutions using its R&D assets*2. However, due to the ongoing diversification and complexification of customer and social issues, and the increasing number of ICT players intensifying the competitive environment, the importance of quickly creating solutions to generate revenue, by understanding the front line to uncover latent issues and needs, has reached a new level. To address these circumstances, NTT DOCOMO launched the TOPGUN initiative to drive speedy co-creation of solutions through stronger collaboration between R&D and corporate sales and marketing divisions, and a three-way partnership with customers.

This article describes the TOPGUN initiative by DOCOMO’s R&D to generate new value in the 5G era.

*1 TOPGUN™: TOPGUN and the TOPGUN logo are trademarks or registered trademarks of NTT DOCOMO, INC.
*2 Assets: Specifically, technology assets.

2. TOPGUN Accelerating Co-creation of Solutions

2.1 The TOPGUN Objective

DOCOMO's R&D and corporate sales and marketing divisions form small elite teams to solve issues by quickly uncovering issues and needs, creating solutions, verifying business potential, and commercializing services to generate revenue all at once in three-way partnerships with customers. This initiative also entails the establishment of maintenance and operations team, packaging as a corporate solution service and deployment nationwide. These are the objectives of TOPGUN (**Figure 1**). This initiative aims to accelerate +d[*3] co-creation, and achieve Declaration 4 "Industry creation" and Declaration 5 "Solutions co-creation" in the DOCOMO Medium-Term Strategy to 2020 "Declaration beyond."

2.2 Creating Solutions to Issues

1) The TOPGUN Business Stages

TOPGUN is an initiative to create solutions to issues that puts emphasis on uncovering issues, proposing hypotheses and verifying business potential. This entails a team consisting of R&D and corporate sales and marketing personnel actually going to the front line to understand customer issues and uncover latent needs (business stage (1)). Then, the team will set a problem-solving hypothesis and Key Performance Indicators (KPIs)[*4], and conduct field trials to verify the hypothesis in the customer's actual location (business stage (2)). When KPIs are achieved, and when a maintenance and operations team that can withstand large-scale

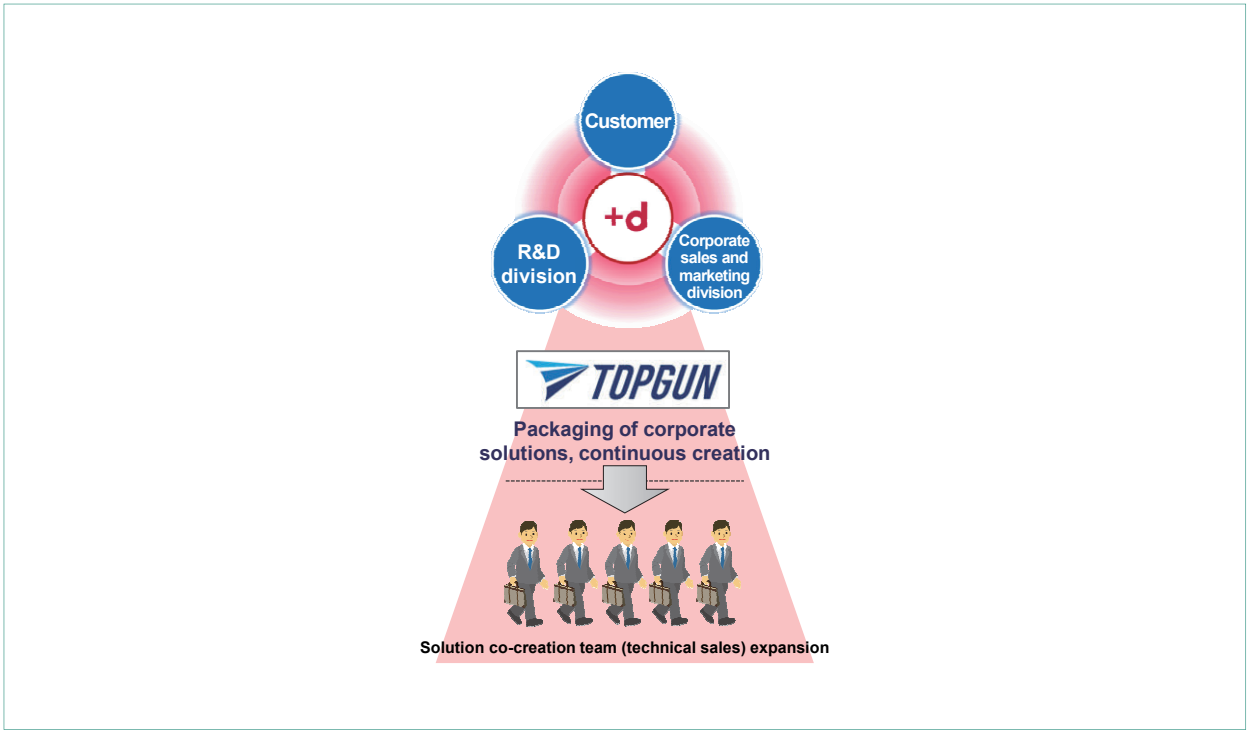

Figure 1 What is TOPGUN?

*3 +d: Name of the NTT DOCOMO initiative for creating new value together with partner companies.

*4 KPI: The main indices for measuring user or system performance.

deployment is set up, the solution collaboration team (technical sales) will deploy the solution as a corporate solution nationwide (business stage (3)). This flow is described in **Figure 2**.

2) Partnership with Nationwide Corporate Sales and Marketing

The TOPGUN collaboration between R&D and corporate sales and marketing does not stop in our headquarters. Gradually increasing in number, corporate sales and marketing staff from regional offices and branches all over Japan can also actively participate in the TOPGUN initiative to solve the issues faced by their clients such as local companies and municipalities. The initiative endorses sharing of TOPGUN related information nationwide through close collaborations between our regional offices and branches, and provision of office space in our headquarters so that regional office and branch staff can hold discussions with HQ staff. Active and deep interactions between the R&D division and corporate sales and marketing division of regional offices and branches, is another key characteristic of the TOPGUN initiative.

3) Expected Results

A number of results can be expected from R&D and corporate sales and marketing divisions personnel going to the front lines and linking needs with seeds[*5], as described below.

- Find solutions quickly and make improvements on the spot by rapidly and simultaneously verifying problems and solutions and sharing objectives with customers, as new issues are discovered through testing.
- Create solutions to customer issues with

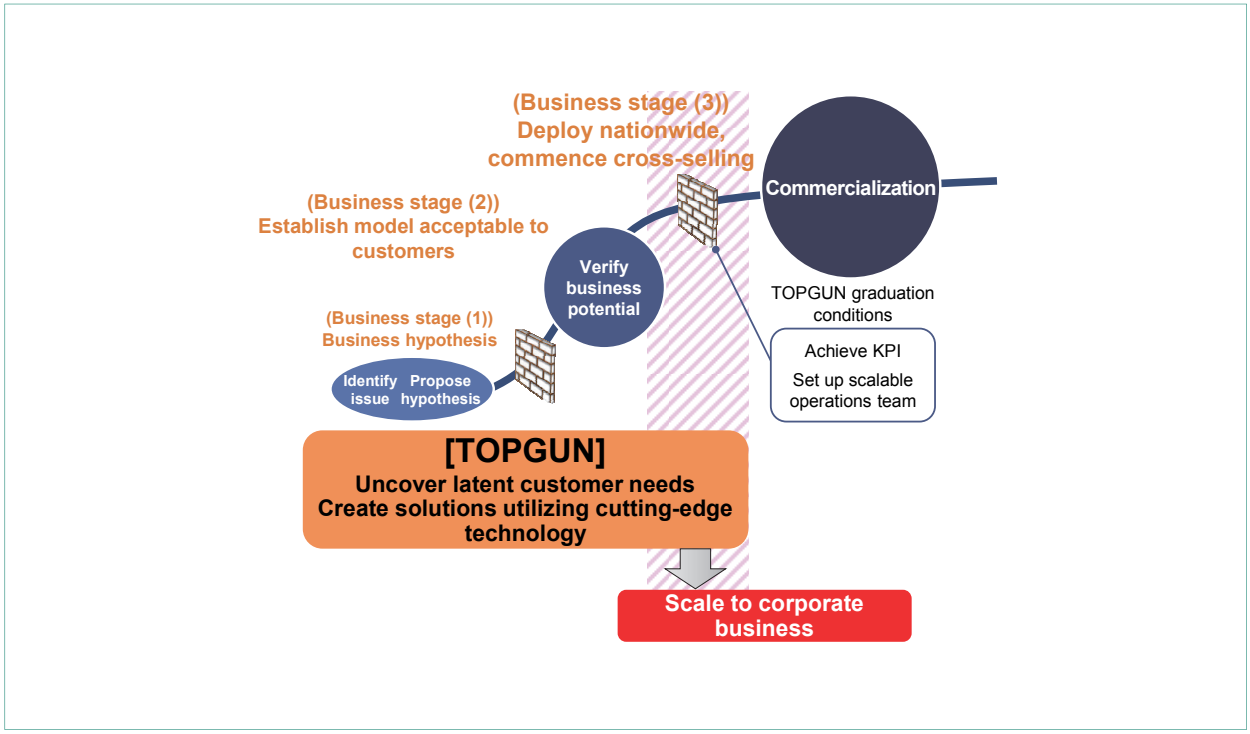

Figure 2 The TOPGUN business stages

*5 Seeds: Technology or know-how that could lead to new business.

cutting-edge technology by changing technical potential into customer value.

- Flexible creation of corporate solutions tailored to various industries and fields to meet various customer needs, and nationwide sales expanded through corporate sales and marketing teams throughout Japan.

3. Current Status of the Initiative

In ten months since TOPGUN began, it has entailed ten projects (as of July 2018) (**Table 1**). The following describes two of these projects.

3.1 Location Net

Location Net®*6 is a service that enables detecting and managing location information of people or things with a Bluetooth® Low Energy (BLE)*7 tags (**Figure 3**). We confirmed the effectiveness of this system by testing child monitoring in collaboration with Kobe city, and testing location management of child strollers and wheelchairs in collaboration with All Nippon Airways (ANA). Aiming to further expand Location Net usage, R&D project members and corporate sales and marketing division staff are currently traveling to various parts of the country and performing field trials in various fields such as elderly monitoring, and staff management in facilities such as factories. **Photo 1** shows pasture cattle headcount management, one of the field trials we have performed. Based on these trial results, we aim to expand Location Net

Table 1 TOPGUN project list

No.	Project name	Overview
1	Location Net (Section 3.1)	Location-detecting service/solution to easily manage location of people and things etc. using BLE tags
2	Image recognition platform	Platform to achieve business efficiency and improved service value for partners, using automatic image recognition
3	Big data analysis	State of the art analysis and solutions combining our corporate customers' data with NTT DOCOMO's data
4	Robot for teaching programming "embot" (Section 3.2)	Teaching kit for kids to learn programming by creating a robot out of cardboard and controlling it with visual programming, while having fun
5	Sports scene sensing	Solution for athletes and sports enthusiasts which visualizes distance moved, maximum speed, the amount of exercise such as calories consumed, and trajectory of movement
6	Touch conversation	App for visitors to Japan to quickly translate language by touching fixed phrases
7	AI agent	AI solution for conversation, content usage, and device operation through natural dialogue with various objects
8	Ad hoc communications	Application that makes use of short range communications technologies between terminals without using a telecommunications carrier network
9	Vacancy visualization	Solution that visualizes toilet or meeting room vacancy using sensors
10	Mobile camera platform	Monitoring and surveillance solution which uses low-power mobile cameras

*6 Location Net®: A registered trademark of NTT DOCOMO, INC.

*7 BLE: An extension function of Bluetooth®, and a standard defined for low powered devices as part of the Bluetooth 4.0 standard. Bluetooth is a short-range radio communication specification for radio connection of mobile terminals, and is a registered trademark of Bluetooth SIG, Inc. in the United States.

business by packaging solutions for various fields and applications with business potential and deploying them nationwide.

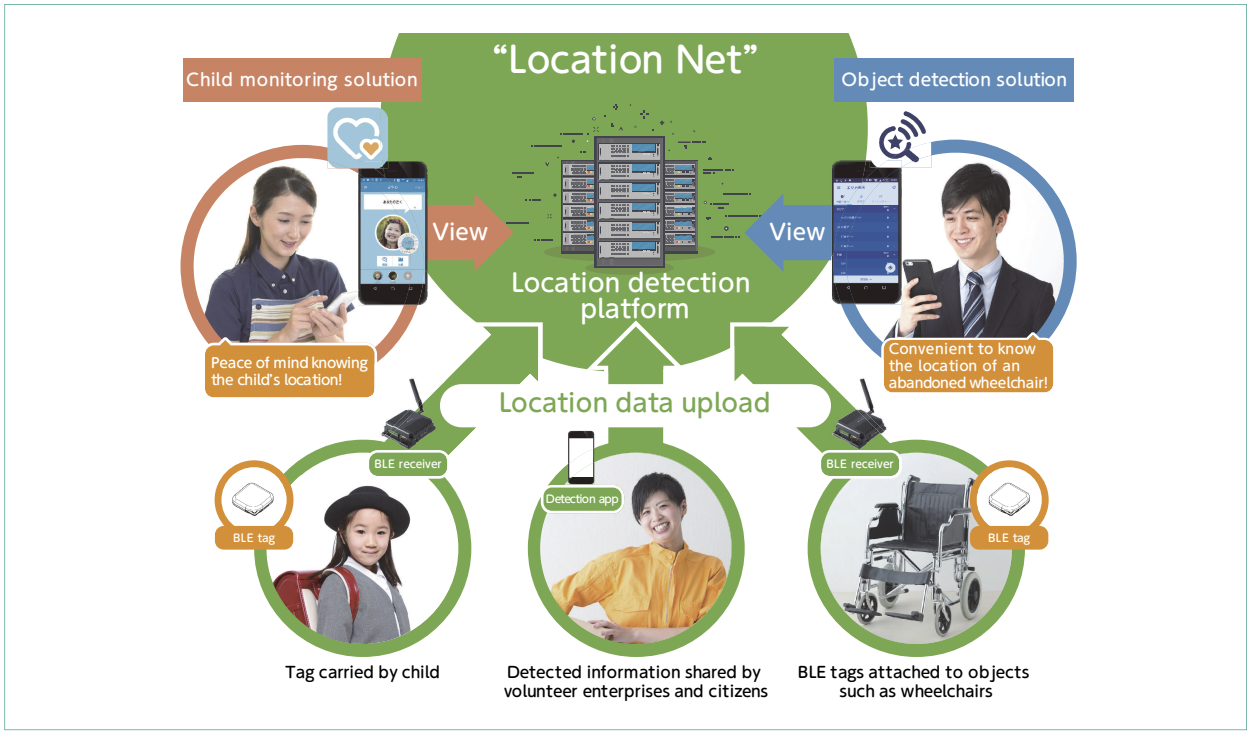

Figure 3 Location Net Service

Photo 1 Field test of pasture cattle headcount management

3.2 Robot for Teaching Programming “embot”

embot®*8 is a programming kit that helps elementary school students learn programming thinking and logical thinking by simple assembling of a robot from cardboard and a printed circuit board that they then operate with a special programming app that runs on a tablet device (**Photo 2**).

Interest in programming education has increased since it will become compulsory in elementary schools from FY 2020, but many primary school teachers are troubled by teaching it as they have no such experience. Thus, using embot, the TOPGUN team has been holding hands-on programming classes and demonstration lessons around Japan, and is currently working with teachers to verify lesson management know-how to get children interested in programming and ways to include it in the primary school curriculum. The hands-on programming class is shown in **Photo 3**.

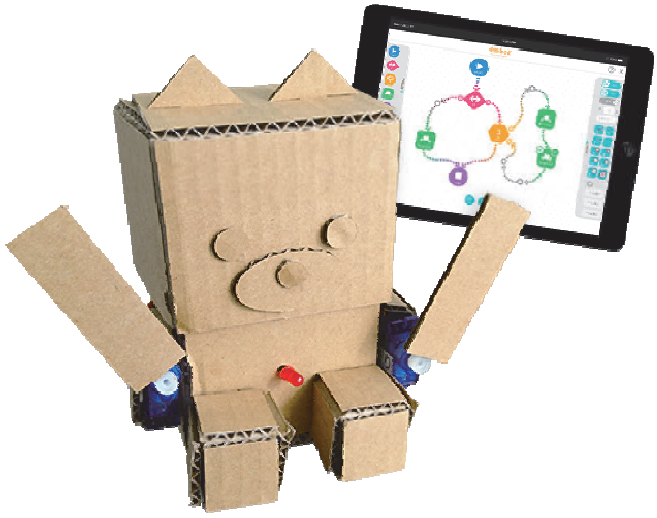

Photo 2 The “embot” robot for teaching programming

Photo 3 Hands-on programming lesson

*8 embot®: A registered trademark of NTT DOCOMO, INC.

The commercial launch of embot is planned for September 2018, and the programming education package which includes an embot set and lesson support materials will be prepared for education committees and programming classes. The nationwide TOPGUN team plans to sell the package all over Japan (as of end of July 2018).

4. Conclusion

This article described DOCOMO R&D’s active role in the TOPGUN initiative. Going forward, we believe we can create a wide range of solutions by matching DOCOMO’s technological assets with the issues and needs of customers through TOPGUN, and plan to launch at least ten new projects per year towards 2020. From among these, we will speedily commercialize effective and profitable projects and develop them as businesses through our nationwide corporate sales and marketing channels to solve many of our customer’s issues.

Through the TOPGUN initiative, DOCOMO R&D will go to the front lines and use the technological assets it has fostered to the fullest, and continue the challenging work of creating greater value to solve customer issues and expand NTT DOCOMO’s businesses.

NTT DOCOMO
Technical Journal　25th Anniversary

Editorship and Publication
NTT DOCOMO Technical Journal is a quarterly journal edited by NTT DOCOMO, INC. and published by The Telecommunications Association.

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