The First Report on 5G System Trials in Japan

2018

- Revised Edition 1 -

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5G Trial Promotion Group
Fifth Generation Mobile Communications Promotion Forum

Contents

Preface

Mr. Gaku NAKAZATO

Director of New-Generation Mobile Communications Office, Ministry of Internal Affairs and Communications (MIC)

As 5G networks' commercial deployment approaches, research in standardization, technologies, services and deployment modes are increasingly deepening. It has been proven that services, rather than technology, are the main driving force in network evolution. Therefore, the implementation of 5G networks needs to be analyzed from the perspective of application scenarios and service requirements.

The International Telecommunication Union (ITU) has classified 5G mobile network services into three categories: enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (uRLLC), and massive machine type communications (mMTC). eMBB aims to meet the people's demand for an increasingly digital lifestyle, and focuses on services that have high requirements for bandwidth, such as high definition (HD) videos, virtual reality (VR), and augmented reality (AR). uRLLC aims to meet expectations for the demanding digital industry and focuses on latency-sensitive services, such as autonomous driving and remote machine management. mMTC aims to meet demands for a further developed digital society and focuses on services that include high requirements for connection density, such as smart city and smart agriculture.

I am very much pleased with the first report on the field trials in Japan. The purpose of the report is to highlight and disseminate the Japanese achievements in the context of global progress. MIC has started six 5G field trial projects since May 2017. The details are described in this report. In order to realize smooth launch of 5G in 2020, it is imperative to try field trials as well as research and development with players from various industry segments and to share the good (or bad) practices with each other.

I look forward to your proactive engagement in the activities of 5GMF and any suggestive comments on this report.

Dr. Kohei SATOH

Secretary General, The Fifth Generation Mobile Communication Promotion Forum (5GMF) and Executive Manager on Standardization, Association of Radio Industries and Businesses (ARIB)

5GMF has begun its activities bringing together participants from industry, academia and government, promoting cooperation and collaboration among experts and specialists in a wide range of fields not limited to information and communications.

The “5G Trial Promotion Group (5G-TPG)” was established in January 2016 to study plans and frameworks for performing “Comprehensive field trials for 5G systems” in Japan, and summarized the outcomes as the first edition Report including 5G trial concepts, contents and plans of “5G Utilization Projects” in about one year.

5G-TPG developed and published the “First Report on 5G System Trials in Japan” in March 2018 as a result of adding the overview and plans of the “5G Comprehensive Field Trials” led by the Ministry of Internal Affairs and Communications to its first edition Report. Many partners in various utilization fields called “Verticals” participate in the trials as well as those related to the mobile communications industry to create a new market through actualization of 5G.

The practical 5G Comprehensive Field Trials has just started, and this report included only initial results. In addition, it is expected that more partners in various fields will participate in these field trials. Therefore, 5G-TPG will publish a report containing detailed results in the near future.

Dr. Yukihiko OKUMURA

Leader of 5G Trial Promotion Group (5G-TPG), The Fifth Generation Mobile Communication Promotion Forum (5GMF)

From 2016 to 2017, active discussion on possible “5G Utilization Projects” was made within 5G-TPG for the future system trials. More than forty 5G Utilization Projects were proposed by 5G-TPG members and each project includes technological supports, evaluation models, trial environments and relevant industries in addition to detailed use cases. 5G-TPG then summarized the 5G Utilization Projects by dividing it into 6 major use cases, and edited them as a public report entitled “5G System Integrated Verification Trial Report - 5G Utilization Project Plan -”, which was published in March 2017(Japanese version), and also in October 2017 (English version).

From May 2017, MIC started 5G Field Trial Projects in Tokyo and rural areas in Japan, and the report mentioned above was referred to in the planning of these projects. To support Japanese 5G system trials including MIC 5G Field Trials, a new 5G-TPG at the operational stage was re-established in January 2018. For promoting 5G system trials smoothly and efficiently, the 5G-TPG is undertaking the following activities:

- Collecting information on international 5G system trials and sharing it to 5GMF members
- Announcement of activities and outcomes of 5G system trials conducted by 5GMF members to outside
- Exchanging information on 5G system trials among foreign 5G promotion forums, and promoting collaborations with the forums

With the holding of the 5G international symposium by MIC in March 2018, this first report was edited and made public as part of 5G-TPG’s activities. I hope this report will trigger a further expansion of the trial projects, and 5G-TPG will continue to timely publish reports with valuable outcomes of each trial project in the future.

Chapter 1　Introduction

The Fifth Generation Mobile Communication Promotion Forum (5GMF) is publishing this report in order to provide information on the desired test contents and plans of the upcoming 5G system trials in Japan, which the 5GMF is facilitating. The 5G System Integrated Verification Trial Promotion Group (5G-TPG) was formed in order to further study these points and the results published here represent the outcome of their work.

Chapter 2 groups more than 40 proposals from the 5G Utilization Project, generated mainly from members of the 5G-TPG, into following six broad categories that were decided upon after discussion by the 5G-TPG:

- Entertainment
- Safe and secure society prevented from crime and natural disasters
- Logistics, agricultural and fisheries, offices, factories
- Remote controlled and managed devices such as robots and drones
- Connected cars, autonomous and remote driving
- High data-rate and reliable communication for high speed mobile

These utilizations of 5G as described by the 5G Utilization Project come out of the technological foundations of 5G technology, which are described in the published 5GMF White Paper, “5G Mobile Communications Systems for 2020 and Beyond”. An overview of the 5G Utilization Projects is provided in the 5GMF White Paper [1].

Other 5G Utilization Projects in the same field and the broader fields in addition to the 5G Utilization Projects described in the 5G-TPG’s report can be proposed and will being investigated by 5GMF. The Ministry Internal Affairs and Communications (MIC) Round-table Conference on Radio Policies 2020 Report discussed nine different fields where vertical industries (industries exploiting 5G) are categorized as the utilization field of the next generation mobile services. (see Fig. 1)

Chapter 3 introduces content, plan, and outcome of “5G Field Trials” that the Ministry of Internal Affairs and Communications, Japan has started from the fiscal year 2017. In the 5G Field Trials, six groups evaluate 5G system performance such as eMBB (enhanced Mobile Broad Band), mMTC (massive Machine Type Communication), and URLLC (Ultra Reliable and Low Latency Communication) in various locations all over Japan in addition to Tokyo. Many partners in various utilization fields participate in the trials as well as those related to the mobile communications industry to create a new market through actualization of 5G.

Fig. 1 Nine fields from the MIC Round-table Conference on Radio Policies 2020 Report.

This figure provides examples of some practical uses of beyond uses for smartphone consumers, including health care, agriculture, finance, transportation, and various other industrial uses. By unearthing basic needs of industrial applications, such as improving operation efficiency of various industries or making connections increasingly convenient as well as confronting new problems of an advanced industrial nation like Japan, such as a low birth rate rapidly aging society or the decrease in the working population, 5G will not only promote market and industrial growth but will become another tool to help solve social issues.

However, if only those involved in wireless industries attempt to lead 5G R&D and promotion, it will be impossible to uncover the true needs of a diverse range of industrial applications. And it is important to look for specific recommendations and receive proposals from those industries who will actually use these applications. Therefore, we also held application ideathons at public events, which gave us the opportunity to bring new ideas to the forefront of our vision. (see Fig. 2)

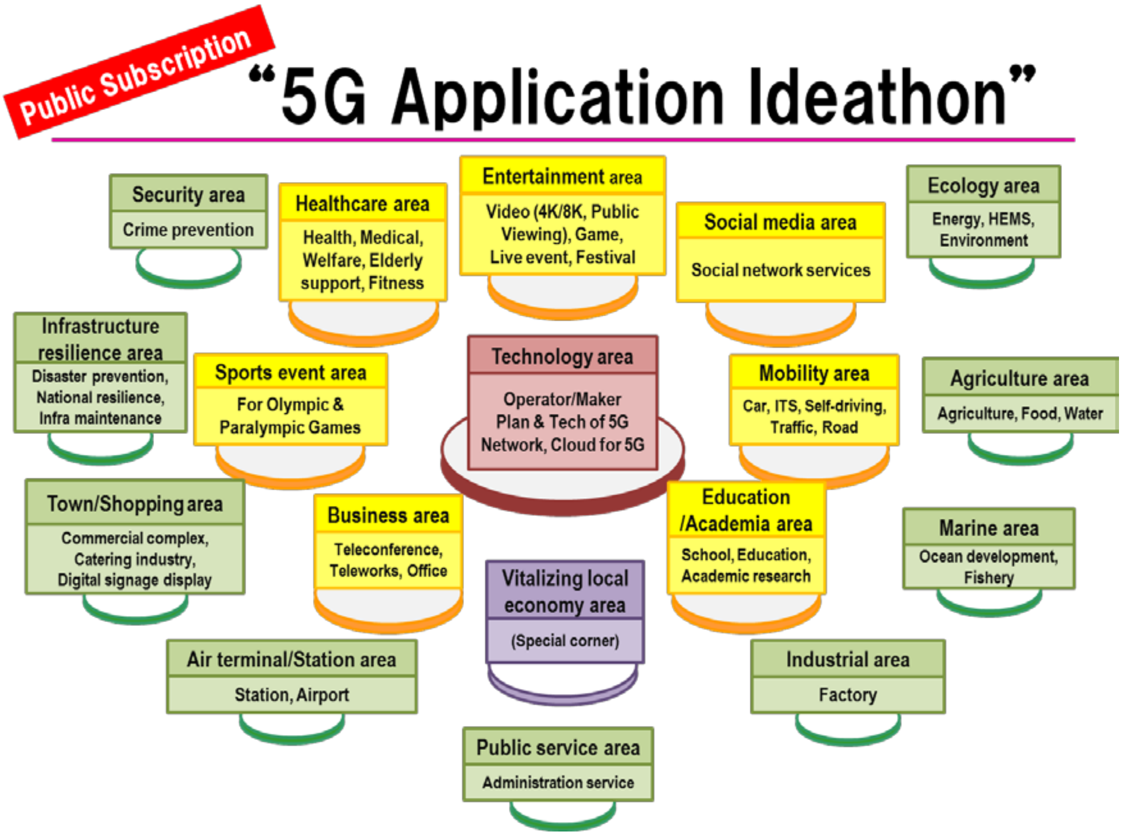


Fig. 2 Public 5G application ideathons.

Looking at Fig. 2, the middle section shows how experts in in wireless industries introduce 5G technologies in ways that are easily understood by the general public. Surrounding that are various other industrial applications of 5G. As the awareness of these technologies is high among those using ICT, the quality of ideas among the collected proposals was very good. This means there is a high level of public understanding among those who use these industrial applications.

In addition, user surveys were conducted by the 5GMF Application Committee. The ways of thinking of the generation of smartphone natives opened a "different dimension" of new ideas from newly discovered needs, beyond the needs of vertical industries. Therefore, we need to add an additional area in Fig. 2, a "smartphone native student area" that must also be researched.

The public 5G ideathons are one way to collaborate with the public to uncover the real needs of users as well as encourage more awareness generally about 5G. Therefore, as the number of these meetings increase, discussions around 5G will also deepen, ultimately increasing the general public's awareness in 5G.

Chapter 2　5G Utilization Project

2.1 Entertainment

【Editors】

- NTT DOCOMO, INC.
- Mitsubishi Electric Corporation, Panasonic Corporation, NEC Corporation, NIPPON TELEGRAPH AND TELEPHONE CORPORATION, National Institute of Information and Communications Technology, Advanced Telecommunications Research Institute International (ATR), Huawei Technologies Japan K.K., KDDI CORPORATION, Nokia Solutions and Networks Japan Corp., Kansai Telecasting Corporation, INFOCITY, Inc., Sony Corporation, WASEDA University, Sophia University

【Overview】

The 5G Utilization Projects in this section “Entertainment” foresee 5G’s ultra-high speeds, its high capacities, and ultra-low latency will provide users with experiences up until now they have been unable to enjoy.

What this means in concrete terms is offering users ultra-high definition 8K video transmissions including live broadcasting/multicasting and high-presence multimedia data transmissions in which videos are taken by multiple cameras from multiple different points of view, which meet user needs.

Video and data will be delivered to users not only through devices like smartphones and tablets but through the use of head mounted displays and large high-definition signage that require ultra-high-speed data transmissions.

These services will be offered where users congregate, such as concert or event venues, stadiums and race tracks like those used at the Olympics. These services will also be able to offer users the chance to experience and participate in events remotely that they cannot attend in person.

In addition, utilizing virtual reality, history and art museums will also be able to provide remote experiences, hold remote chats from multiple locations, and hold remote competitions and games and as well as provide full body experiences from festival locations.

It is planned to provide some of the above mentioned services as part of a new entertainment experience to be able to more deeply enjoy the 2020 Tokyo Olympics and Paralympics.

2.1.1 Large Screen High Definition Signage Services

【Overview】

Technology improvement of mobile devices is rapidly progressing. In the 2020s, higher definition and multi-positioning will become popular for image collection, storage, and viewing. Especially, very large capacity image data will be delivered in dense environment such as stadiums, railway stations, and airports. High definition on demand video delivery methods are one of the most important technologies for wireless digital signage with easy assembled.

【Field】

② Entertainment (Games/Tourism)

【Supported Technology】

Multi-User MIMO ([1] 11.3.4 Information of technical works related to MIMO or multiple antenna technologies)

Adaptive high definition 4K/8K video delivery method, taking into account variable bitrates due to the wireless channel condition.

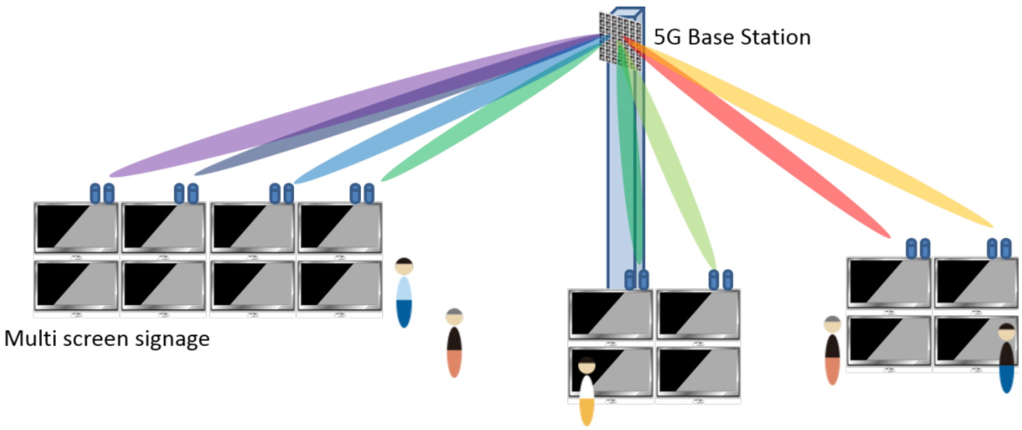


Fig. 2.1.1.1 Image of wireless signage system.

【Evaluation Model (Use Cases)】

eMBB - Dense urban

【Trial Environment】

Large scale open spaces in stations, airports, and buildings

【Trial Schedule】

Year One: Preparation of trial platform, connection test with wired/wireless condition

Year Two: Verification trials of SDM transmission in indoor open spaces

Year Three: Verification trials in different locations, with various parameters such as the number of users and distances

【Relevant Industries】

- Content delivery providers
- Rail and airport operators
- Video equipment makers

【Projected Results】

Using large capacity of 5G, many video images can be delivered simultaneously to displays located within 10 meters in indoor environment. Because number of super high definition 4K/8K images can be displayed simultaneously, various user needs about video transmission will be realized.

2.1.2 Mobile Remote Meeting Systems

【Overview】

To be able to engage in high quality teleconferences with high-definition sound and video while moving in a vehicle.

To be able to carry on a remote meeting without worry while moving using a technology that selects the most suitable RAT and uses a high capacity wireless transmission technology of 5G cells and various wireless LANs (2.4GHz/5GHz/60GHz)

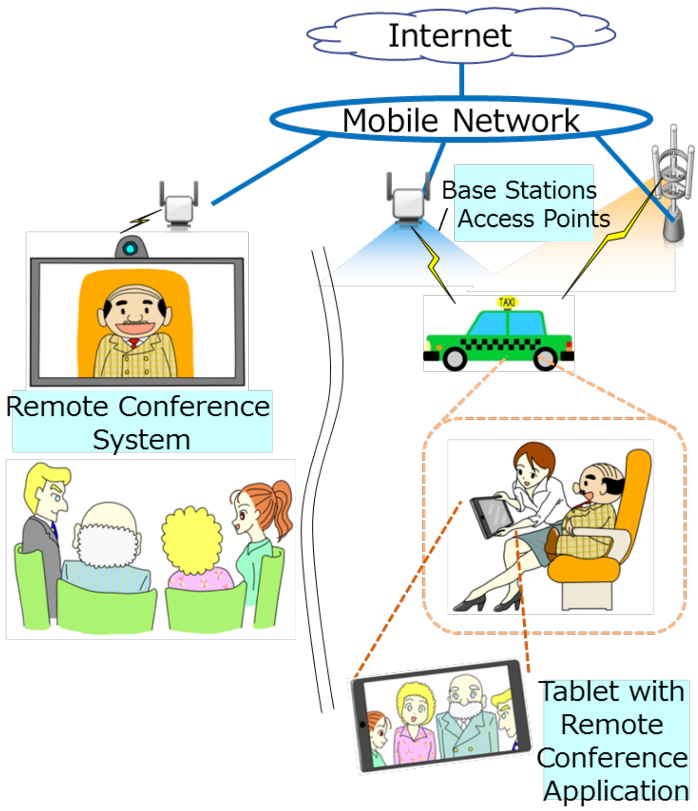


Fig. 2.1.2.1 Mobile remote meeting system.

【Field】

② Entertainment (Games/Tourism)
③ Office/Workplace

【Technological Support】

1. High Capacity Wireless Transmission Technology
   Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4)
2. Multi-RAT selection technology
   Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)

A selection technology that chooses the most suitable RAT using a variety of data from the device in question (properties of the device, how fast the device is moving, location data, historical data, etc.)

3. Using a transmission technology for high-definition video
    - Technology to effectively use available band in wireless
      It projects QoE by being able to control the video bit rate and being able to move to different bands to use the most effective video bit rate from what is available to be selected in any given areas various wireless quality conditions.
    - Ensure network QoS using slicing
      network softwarization in 5G ([1] 12.2.2)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Indoor

【Trial Environment】

Fixed locations: typical office/meeting rooms
Mobile locations: vans equipped with mobile devices

【Trial Schedule】

Year One: verification trials testing basic functionality and prototype applications
Year Two: verify application configuration with knowledge of basic functionality and utility
Year Three: verify system with a focus on actual use

【Relevant Industries】

- Remote meeting systems manufacturers
- Wireless communication system producers

【Projected Results】

With the progress made in this verification trial companies and other organizations will be able to revolutionize how work is done by being able to realize the objective of conducting high quality remote meetings utilizing 5G in mobile environments or in route to a destination.

2.1.3 Entertainment System inside Stadiums

【Overview】

- The ability of spectators to choose different views inside the stadium through use of their personal tablets and smartphones as well as touch panels built into stadium seating
- Showing in real time various scenes from inside the stadium and surrounding areas by uploading high definition video from cameras
- Utilize 5G network cells in addition to various wireless LAN networks (2.4GHz/5GHz/60GHz) using an optimal RAT selection technology so that

spectators at a stadium can use multiple devices and cameras to upload and watch high-definition video.

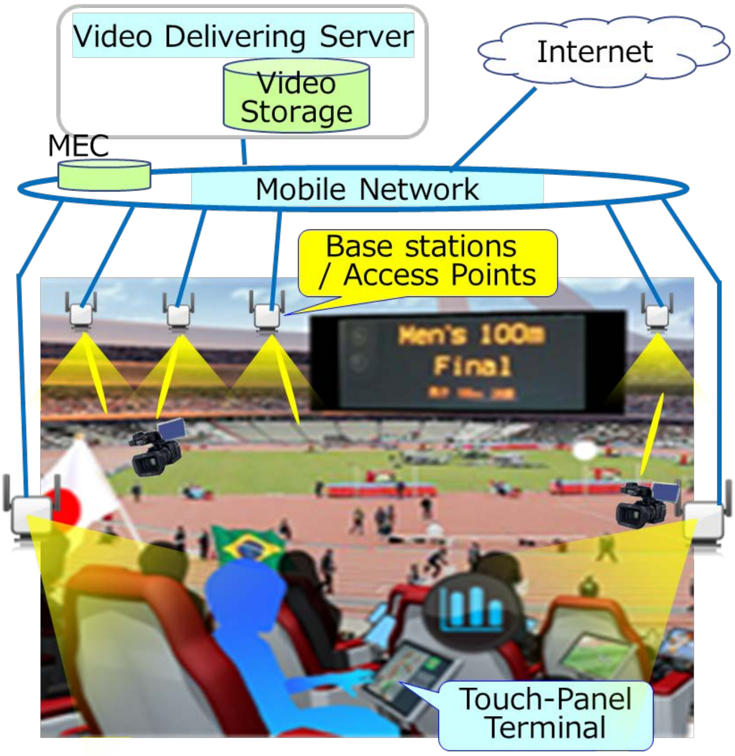


Fig. 2.1.3.1 Entertainment system in stadium.

【Field】

① Sports (Fitness)
② Entertainment (Games/Tourism)

【Technological Support】

1. High capacity wireless transmission technology
   Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4)
2. Multi-RAT selection
   Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)
   A RAT selection technology that chooses the most suitable network based on a variety of data from the device in question (properties of the device, how fast the device is moving, location data, historical data, etc.)
3. High Definition Video Transmission Technology

- Technology that transmits high-definition video using a variable bit rate that makes use of the most effective bandwidth possible from the various quality wireless networks in a given area for a given camera-equipped device. Video transmission technology that protects QoE through providing the optimal bitrate for customers in a given wireless environment in or around a stadium.

- Ensuring network QoS through slicing
  Network softwarization in 5G ([1] 12.2.2)
- Video Transmission Technology using MEC
  Application of MEC ([1] 12.5.2)
  Creating and transmitting video contents using MEC as a base to receive video data from multiple cameras.

【Evaluation Model (Use Cases)】

eMBB - Dense Urban

【Trial Environment】

Stadiums and event locations with large numbers of regular spectators

【Trial Schedule】

Year One: verification trials testing basic functionality and prototype applications
Year Two: verify application configuration with knowledge of basic functionality and utility
Year Three: verify system with a focus on actual use

【Relevant Industries】

- Wireless system producers
- Audio visual equipment vendors
- Content producers

【Projected Results】

Using 5G to effectively connect large numbers of devices will lead to progress to the use of ICT in large stadiums and theme parks, which will be a concrete example for relevant industries in uncovering new challenges and new service needs.

2.1.4 Offering Video and Data that Meets User Needs

【Overview】

User profiles and video samples can be collected from individual spectator’s cameras and wearable devices, and with that information can deliver high definition video from the fan’s favorite point of view while also providing individualized user information, including information about the stadium itself, as well.

Fig. 2.1.4.1 Offering entertainment video and data that meets user needs.

【Field】

② Entertainment (Games/Tourism)

【Technological Support】

4K/8K video and AR technology will use 5G ultra-high-speed data transmission to display and transmit information from inside a stadium, such as HD video of what is happening or personalized advertising for users. Massive MIMO technology will be used to achieve these high transmission speeds: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5).

In addition, advertising or navigation information will be provided to individual users in a timely manner through realizing ultra-low latency, as it will be important that providing other users with these services does not influence the ability to provide services to everyone else. This will be made possible through mobile edge computing and network virtualization: Network softwarization ([1] 12.2.2), Mobile Edge Computing ([1] 12.2.5).

【Evaluation Model (Use Cases)】

eMBB - Dense Urban

【Trial Environment】

Athletic Grounds (for example, stadiums, rugby fields, etc.)

【Trial Schedule】

Year One: Basic transmission testing of the network structure and prototype applications.

Year Two: Assessments with the goal of demonstrating high quality applications in a high-speed high capacity environment

Year Three: Field trials at actual athletic fields and demonstration assessments with steadily increasing numbers of devices.

【Relevant Industries】

Broadcasting companies, video content rights holders, stadium management firms, event organizers.

【Projected Results】

By creating new event experiences through new services that combine real world experiences with digital ones, spectators and participants at stadium events will increase, leading to a strengthening of the local economy around these areas.

2.1.5 5G and the “Exciting Stadium 2020”

【Overview】

Stadiums used for athletic competitions or entertainment shows will be able to collect and analyze video from in real time from multiple camera viewpoints using wireless and optical transmission systems through deploying a large number of small cell base stations and wireless LAN access points. Spectators will be offered replays via on-demand and stress free multiple camera viewpoints due to 5G’s ability to offer large capacity and low latency.

This project needs to ensure good cost efficiency to deliver multiple camera viewpoints to spectators. To achieve that, a multiple wireless system that can efficiently accommodate TDM-PON systems, LTE, New RAT, wireless LAN and WiGig together will be needed. By aiming to constructing such a multi-access control system that is efficient and can accommodate a high capacity of users we will provide spectators with the maximum QoE.

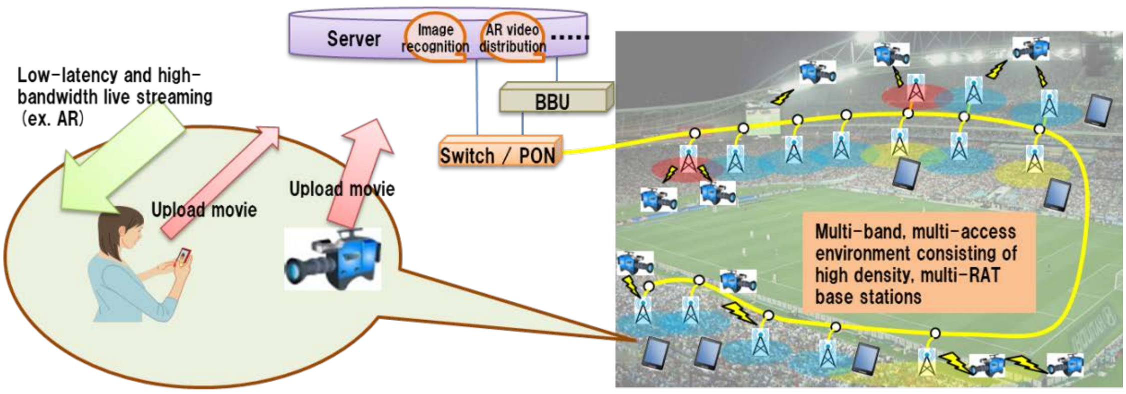


Fig. 2.1.5.1 Sports or entertainment events held at stadiums.

【Field】

② Entertainment (Games/Tourism)

【Technological Support】

System control technologies with wireless LAN in multi-band and multi-access layered cells ([1] 11.3.5 (5))
Economization using PON technology ([1] 12.4.2.1)
Function splitting ([1] 12.4.2.3)
Network softwarization in 5G ([1] 12.2.2)

【Evaluation Model (Use Cases)】

eMBB - Dense urban

【Trial Environment】

Stadiums such as Meiji Jingu Baseball Stadium, Tokyo Dome

【Trial Schedule】

Year One:

- Laboratory Demonstration using PON systems and Wireless LAN access points.
- Conduct basic testing and demonstrations in stadiums of connected systems at stadiums of LTE cellular systems and wireless LAN proposed systems consisting of 5G multi band/multiple access multilayer cell (Multi-RAT) system.

Year Two:

- Laboratory demonstrations of integrated network and server APL using PON systems and small cell (4G) base stations.
- Conduct basic testing and demonstrations in stadiums of the new RAT tested in the previous year with combined additional control functions of a 5G multi-band/multiple access multilayer cell (Multi-RAT) architecture system.

Year Three:

- Conduct an integrated outdoor demonstration at stadiums with PON systems and small sell base stations, in addition to multi rat cooperative control system, SND logical control network, server APL integrated outdoor demonstration.
- Conduct testing and demonstration at multiple stadiums of the system tested in the previous year and test and demonstrate the system technology of a 5G multiband/multiple access multilayer cell (Multi-RAT) architecture system using a SDN logical network and server APL system.

【Relevant Industries】

Broadcast companies, data collection and analysis firms, stadium management firms, device vendors, base station vendors, optical network system vendors, device application vendors.

【Projected Results】

This technology will be able to offer real time reception and delivery of statistics and stress-free replay video.

2.1.6 Heterogeneous Networks at Event Venues

【Overview】

Stable network environments that can handle various kinds of data traffic can be realized at event venues where user density is high. Achieving this goal will allow spectators and event participants to "share the excitement" through many new tools and apps, which will create a better event experience for everyone.

【Field】

① Sports (Fitness)
② Entertainment (Games/Tourism)

【Technological Support】

Information of technical works related to modulation or coding scheme ([1] 11.3.2)
Information of technical works related to multiple access scheme, duplex scheme ([1] 11.3.3)
Information of technical works related to MIMO or multiple-antenna technologies ([1] 11.3.4)
Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)
Information of technical works related to energy saving nature ([1] 11.3.7)
Information of technical works related to RAN virtualization ([1] 11.3.8)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro
mMTC - Dense Urban, Urban Micro/Macro
URLLC - Dense Urban, Urban Micro/Macro

【Trial Environment】

We propose that the trial environment be at event venues or stadiums where large crowds of spectators gather, a high density of users using 10,000 devices in an area one km squared.

These devices include the smart phones used by spectators, as well as devices such as wearables that officials use, and security cameras that security will use. In addition, cameras are needed to take 4K video to be broadcast on large screens and signage in and around the stadium. There will also be robots which will give directions to spectators, sensors to track the weather, like the temperature, humidity, and rainfall, as well as devices to track ID tags on tickets.

These many kinds of devices will be used at the same time at the same location and must be offered a stable and worry-free communication environment to be used successfully, so many different themes and environments have been selected for this trial so we can solve problems to achieve this. (see Fig. 2.1.6.1)

There will be many kinds of traffic that will use this network, a mix of low capacity to high capacity needed uses, are supposed, including 4K video, images, murmuring, voice and text messaging, other types of data, such as maps of the stadium or results from the action on the field, robot control signals, other types of sensing data.

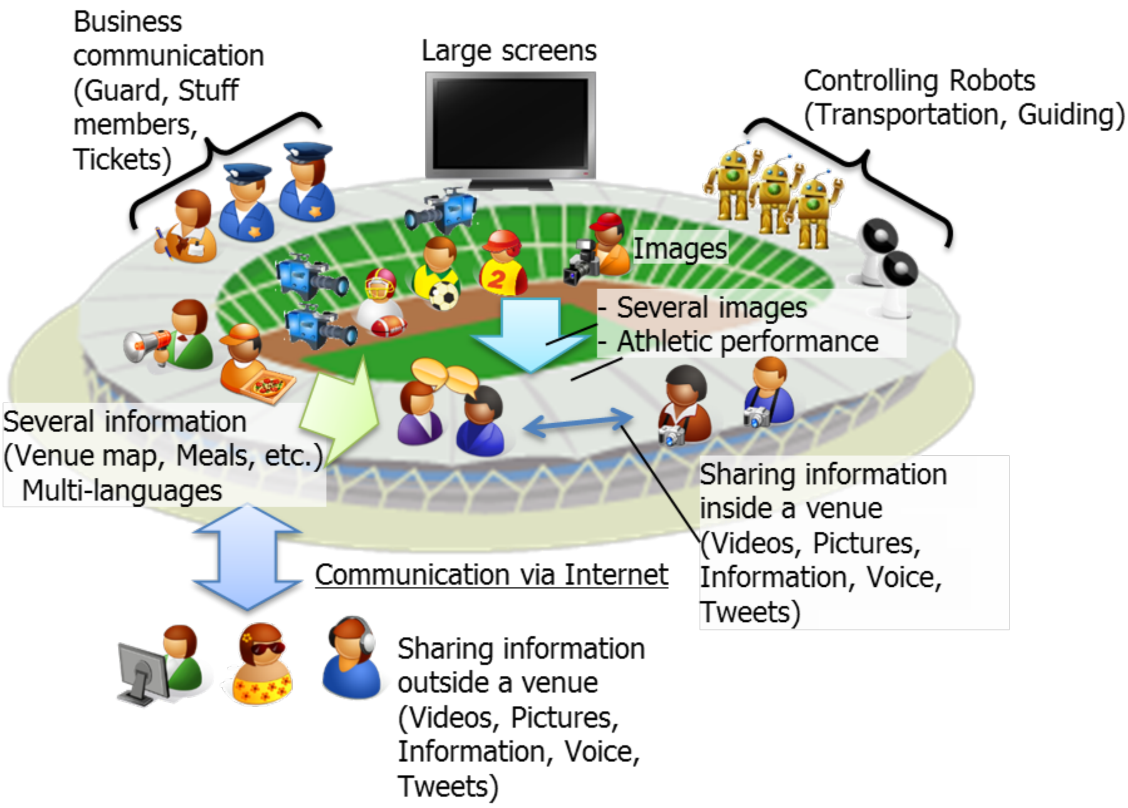


Fig. 2.1.6.1 Trial environment.

This proposed trial environment supposed a high density of users with a variety of traffic types that can accommodate a various types of wireless communication systems and mobile communication systems, including private networks and mobile carrier networks, and bandwidth, including millimeter-wave and shared bandwidth. In addition, network load reduction to assist with device to device communication is also a goal. (see Fig. 2.1.6.1)

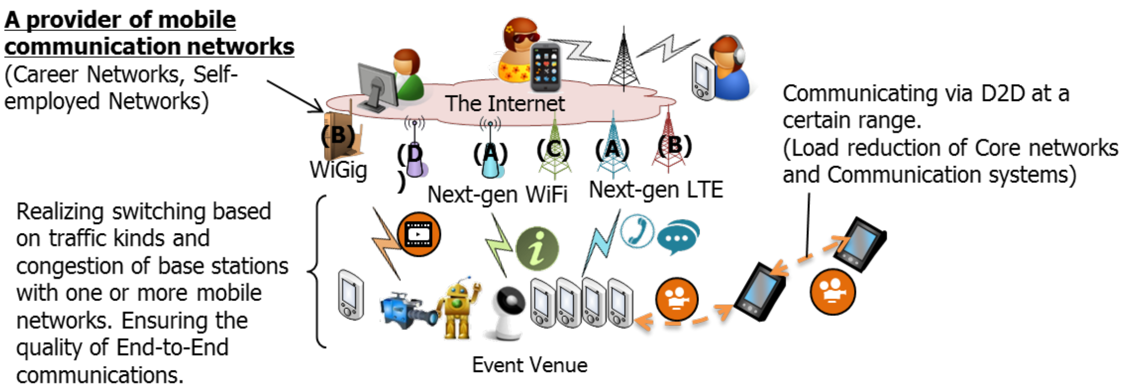


Fig. 2.1.6.2 Trial image.

In addition, as the graphic below on bandwidth use illustrates, the trial environment proposes using existing mobile communication networks and existing private networks, in addition to newly allocated frequencies for shared use of mobile communication networks and millimeter-wave bands on private networks such as WiGig.

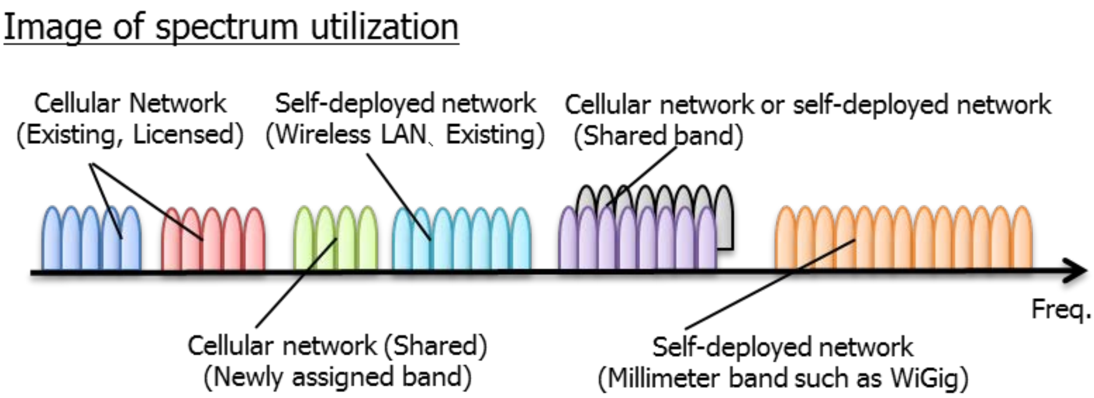


Fig. 2.1.6.3 Bandwidth use.

【Relevant Industries】

- Radio wave use researchers,
- Vendor firms,
- Event management firms, including venue management firms

【Projected Results】

Ultimately, this new technology will not only help events to be run smoothly and managed easily, but will allow participants to "share the excitement" with each other by offering various tools which will lead to a better experience for everyone.

2.1.7 Using 5G to Create a Virtual Museum Experience

【Overview】

5G's high speeds will give people the opportunity to have a virtual experience at history, science, and art museums, as well as circuses and casinos, even if they are unable to go in person. 5G's special characteristics, its high speeds as well as its capability for handling high capacities, will offer virtual reality experiences by delivering HD video and audio through head mounted displays and HD tablets. 3D virtual spaces can also be constructed, offering participants the ability to view cultural and artistic objects from different points of view, different angles, and with light sources, for example, making interactive experiences possible.

Other services that can be offered to give users a more enjoyable experience include: museums providing more easily understood explanations, casinos providing more kinds of experiences, close-ups, and odds databases, etc. Many new services like these will be offered.

【Field】

② Entertainment (Games/Tourism)
⑤ Smart House/Life (Daily Goods/Communications)

Fig. 2.1.7.1 HD virtual entertainment experiences.

【Technological Support】

4K/8K video will be able to be transmitted through 5G's ultra-high-speed transmission capabilities, allowing museums to provide users HD video. Massive MIMO technologies will be used to make this a reality: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5).

In addition, many channels with HD audio and video will need to be transmitted efficiently, so processing latency and power consumption will need to be reduced to realize highly compressed wireless transmission of video and voice data. In addition, RF technology to miniaturize the size of wearable devices like head mounted displays for enjoying HD video and audio is also needed. Interactive access technology and automatic video editing software technology are also needed.

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban

【Trial Environment】

Event locations, museums, convention centers, and casinos.

【Trial Schedule】

Year One: Build the experimental design, create basic content.
Year Two: Field test of 5G high speed transmissions, create perfect contents for use.
Year Three: Field test of ultra-high speeds and low latency transmissions with 5G

【Relevant Industries】

Entertainment related firms, museums, cultural organizations, image device manufacturers (cameras, HD display), sound and sensing equipment manufacturers, receiver manufactures, 3D interactive content creators, game designers

【Projected Results】

The ability to offer remote virtual experiences at anytime, anywhere in the world when the users wants to, by providing ultra-realistic contents including 4K/8K video, via 5G networks. These experiences can be provided inexpensively while also promoting to participate in the actual experience, as well.

2.1.8 Dynamic Hot Spot Services

【Overview】

Network resources will need to be offered dynamically n areas with large amounts of traffic, such as stadiums with sports spectators or concert goers or disaster areas, in order to maintain application quality of service. In addition, as traffic levels change, network resources will also need to be allocated optimally and power conservation be maintained.

Fig. 2.1.8.1 Dynamic hot spot services.

【Field】

② Entertainment (Games/Tourism)

【Technological Support】

Many people who gather in large groups around a stadium or concert venue will be offered video delivery and real-time communication and in order to achieve the required high speeds, high capacity, and low latency the following wireless technology and network management technology is needed: Advanced modulation, coding and Waveform, New radio frame structure, Flexible spectrum management, Management and orchestration of intelligent mobile networks.

In addition, wireless base stations and applications servers connected through backhaul networks need to have optimal transmission links (network slicing) that can be constructed dynamically: Dynamic control of NW resources and path optimization ([1] 12.4.3.2), Energy saving methods ([1] 12.4.3.3).

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban
URLLC - Indoor, Dense Urban

【Trial Environment】

Stadium and event venues

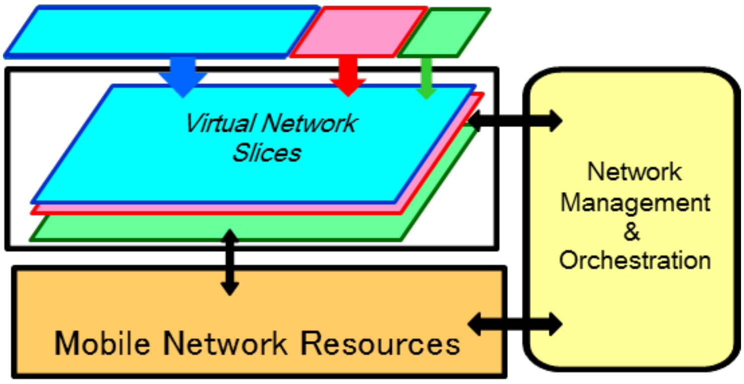


Fig. 2.1.8.2 Network resource slicing.

【Trial Schedule】

Year One: Laboratory Demonstrations of network slicing prototypes
Year Two: Laboratory demonstrations of applications to be used on the network
Year Three: Field demonstrations

【Relevant Industries】

Event venues, event management firms, content delivery firms, network management firms, system integrators

【Projected Results】

- User QoE Experience will increase
- Total cost will decrease

2.1.9 Experiencing Super Live Broadcasts of Japanese Festivals through Immersive Virtual Reality

【Overview】

Festivals are an important part of Japanese culture. The data processing power in a 5G network environment can provide an immersive virtual reality experience for people from beginning to end. This will allow even foreigners abroad the chance to experience a festival, strengthening the Japan brand, which will create more demand for experiencing local cultures and local lifestyles.

Putting various values on the live streaming by full use of motion sensors, AR and CG, a real immersive virtual experience, that can't be experienced at the festival venue, will be provided.

【Field】

② Entertainment (Games/Tourism)

Fig. 2.1.9.1 Overview of a super live immersive virtual reality experience.

【Technological Support】

- Ultra-low latency to give people the experience of dancing simultaneously although in different places: Fronthaul and Backhaul ([1] 12.4)
- Multiple connections to many sensors together to give a sense of presence over a long distance: Information of technical works related to certain use cases or applications ([1] 11.3.6)
- High capacity network transmission to enable to easily send high-quality multiple-viewpoint video: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4)

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

Festival locations, urban areas

【Trial Schedule】

Year One: Field testing at two locations, festival locations, big cities.
Year Two: Field testing from various locations around Japan.
Year Three: Field testing from locations around Japan and around the world.

【Relevant Industries】

Local festival participants, event organizers at distant locations, tourist related organizations, communications companies

【Projected Results】

Increasing value of the Japan brand, contribution to inbound tourism, and regional revitalization are expected, as those who virtually experience festivals will be induced to visit the actual festival venue.

2.1.10 New Entertainment Experiences through Virtual Reality

【Overview】

Visual remote experiences from viewpoints that have never been offered, such as 360-degree 3D video and audio, will be transmitted in real time. This will be made possible through 5G's characteristic ultra-high speed and high capacity with cameras that will be installed in any location.

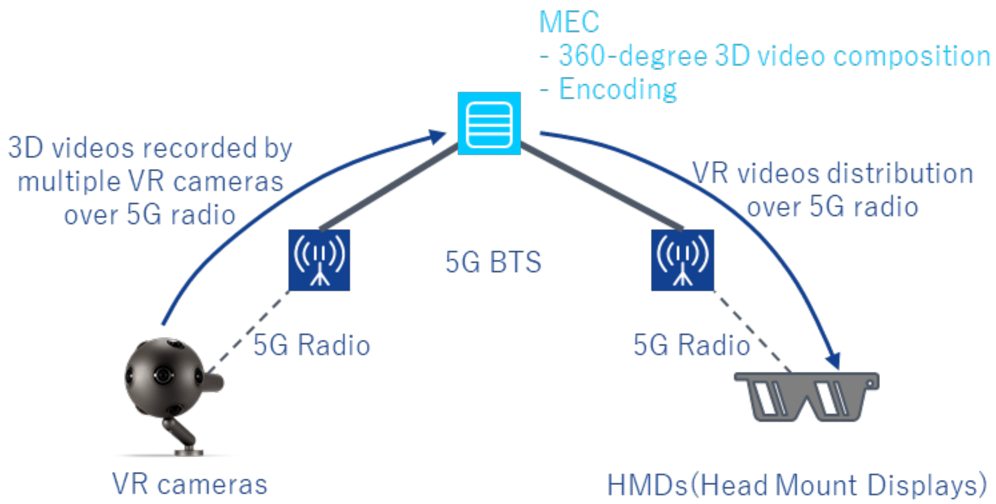


Fig. 2.1.10.1 Entertainment experiences using virtual reality.

Use Case Examples:

- People who want to attend an event but cannot do can be represented by an avatar (viewing can be done at a distance by VR cameras installed in seats)
- Another example is by purchasing the rights of the front row seat at an area, a fan can get the front row view at a broadcast live.
- Fans can experience a concert from the perspective of the stage, specifically individual band members.
- Marathons and cycling races can be viewed from the race broadcast car

【Field】

② Entertainment (Games/Tourism)

【Technological Support】

- Massive MIMO, MU-MIMO ([1] 11.3.4)
- Ultra-low latency networking ([1] 12.5.2.1)
- Control and Management for low latency and resilient networks ([1] 12.5.2.2)
- QoS classify/slicing using virtualization ([1] 12.4.3.1)
- VR technology (camera, display)
- Highly efficient compression technology as well high-speed encoding/decryption as well
- 360-degree video composition technology

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban

【Trial Environment】

Stadium, event venues, wedding center

【Trial Schedule】

Year One:

- Severs connected to the MEC for 360-degree video composition as well as testing of 360-degree composition technology with MEC as well as from cameras that transmit data not through MEC (for example, to head mounted displays)
- Create contents, choose event to perform field trials

Year Two:

- Field test transmission of camera data through MEC, creation of video by MEC, and then delivery to multiple users

【Relevant Industries】

VR content creators, event organizers, electronics makers

【Projected Results】

Use of 5G new RAT as well as MEC on the high capacity low latency network will allow for real time delivery of 360-degree video.

2.1.11 Live Broadcast and Transmission of HD Video

【Overview】

Prompt transmission of video will increase as 5G will be used to deliver high quality and stable live broadcasts and video transmission services as FPU and SNG are used complementary. Concretely, users of 5G wireless networks will be offered the ability to transmit live broadcasts from the camera itself as well as the files from filming locations of pre-recorded video, even from a moving vehicle. In addition, broadcast helicopters and drones will also be able to transmit HD video on this network

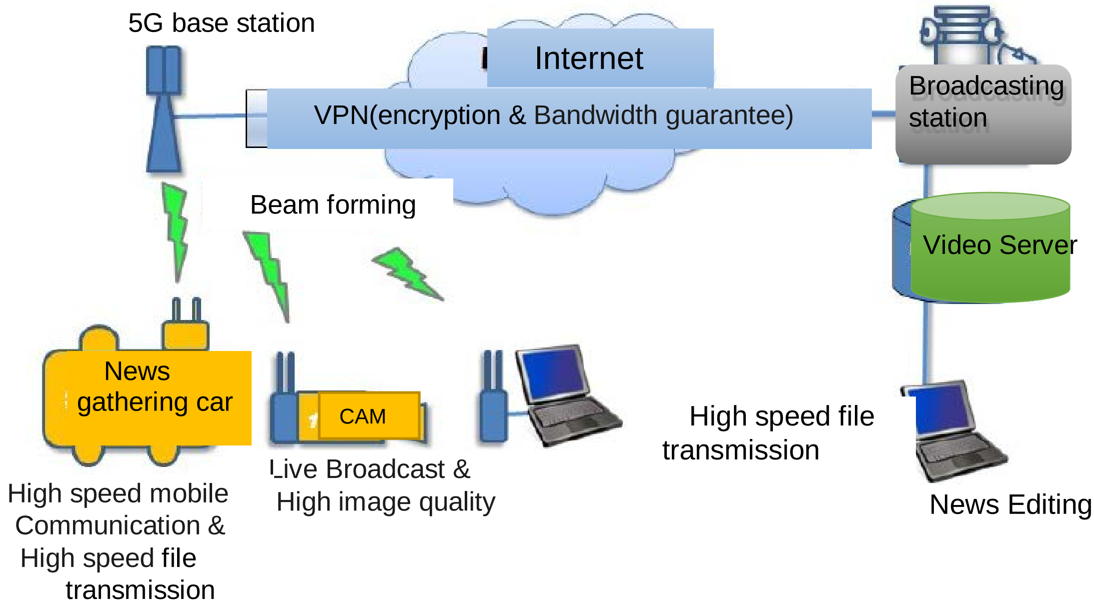


Fig. 2.1.11.1 Transmitted live broadcasts and recorded video from recording location.

【Field】

② Entertainment (Games/Tourism)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural

【Technological Support】

High speed transmissions with 5G using massive MIMO technology: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5)

High quality live broadcast and recorded video transmission broadcast technology, video and audio encoding technology, complementary use of FPU and SNG technology is also needed

【Trial Environment】

Filming locations, live broadcast areas, moving broadcast vehicles, the sky

【Trial Schedule】

Year One: Basic testing of the 5G network to deliver live and prerecorded video transmissions

Year Two: Field verification trials of proposed simultaneous transmissions of multiple recordings using 5G.

Year Three: Field trial of the entire proposed system

【Relevant Industries】

Broadcasters, media, broadcast equipment makers

【Projected Results】

Up until now high-quality data broadcast and video transmission has been difficult to achieve through wireless communication, but with the stability 5G can offer, along with the ability of FBU and SNG to work complementary, it can be achieved. In addition, vehicles in a moving environment, including media cars, helicopter and drones, can also be used to transmit high density, multiple high capacity files can be transmitted over the high-speed network, bringing about the possible of live broadcasts in these environments and better quality data and information transmission overall.

2.1.12 Linear Video Streaming

【Overview】

Smartphones, global models as well as high tech specialized use phones, are now converging into being one in the same, but they have also been unable up until now to access terrestrial broadcasts like one segment (One-Seg.) mobile phones were. In order to ensure access to TV broadcasts, which are a major party of the daily infrastructure of society, 5G networks will be able to deliver terrestrial broadcast TV programs to smartphones.

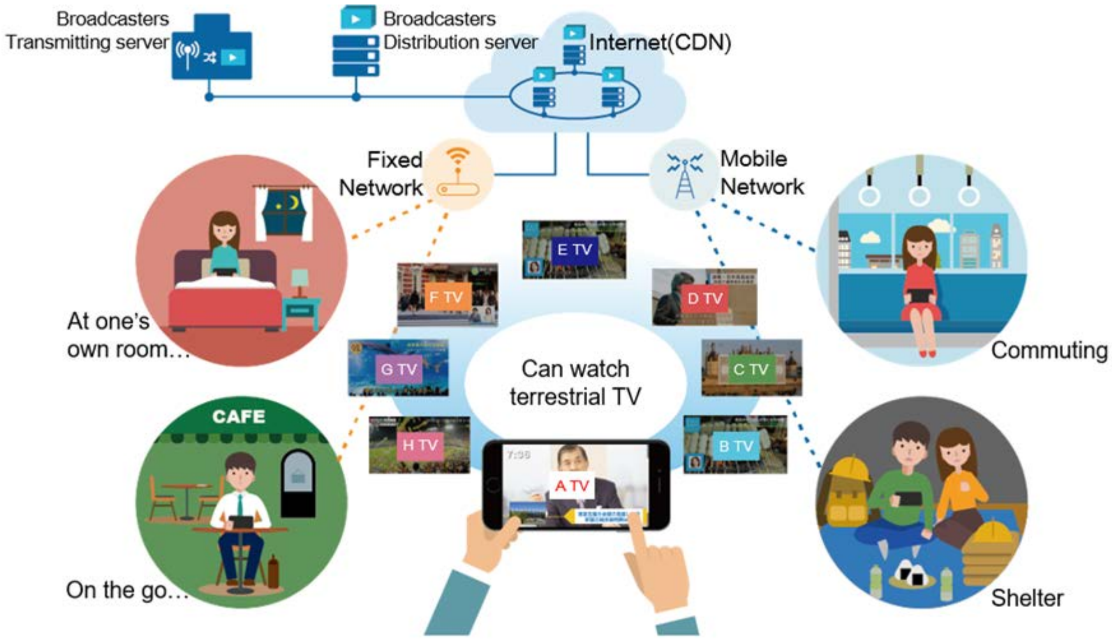


Fig. 2.1.12.1 Linear video streaming.

【Field】

② Entertainment (Games/Tourism)

【Technological Support】

Network softwarization in 5G ([1] 12.2.2), Application of MEC ([1] 12.5.2)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban

【Trial Environment】

- Reception positions
- Transmission positions (field)
- Communications carrier facilities (CDN)
- Individual users, families, schools, workplaces, commute facility, tourist locations, shelters

【Trial Schedule】

Year One: Test TV viewing services of terrestrial broadcasts over 5G networks with special monitors and special prefectural broadcasts

Year Two: Test above services with simultaneous rebroadcasts with efficient transmission process using mobile edge computing and high-quality transmission network

Year Three: Hold trials that use many more monitors from the public over a wider broadcast area than the first or second years. Conduct user surveys to find out general public's views.

【Relevant Industries】

Mobile communication firms, broadcast firms, media firms, application makers

【Projected Results】

The realization of watching TV broadcasts on a smart phone by providing terrestrial broadcast TV as a service on 5G networks, providing the opportunity to offer One-Seg. mobile services to provide TV broadcasts on mobile phones that have not been possible on smart phones.

2.2 Safe and Secure Society Prevented from Crime and Natural Disasters

【Editors】

- Fujitsu Limited
- Panasonic Corporation, WASEDA University, NEC Corporation,
  Mitsubishi Electric Corporation, NTT DOCOMO, INC.,
  National Institute of Information and Communications Technology.

【Overview】

The 5G Utilization Projects aim to help ensure a safe and secure society through the use of cameras and sensors to provide information, so that victims of disasters, accidents, or crimes can receive proper information and feedback, ensuring that this technology can help people feel secure in their lives in a safe society. 5G's special characteristics of ultra-high speeds, high capacities, and ultra-low latency can be used to collect data and provide feedback in real time. These capabilities can be used to offer many services to provide a safe and secure society for everyone.

2.2.1 Real Time Evacuation Guidance System

【Overview】

Cameras spread around community areas collect data which is aggregated in the cloud, and with big data analysis, natural disasters or crimes can be predicted. Wearable devices can also receive spatial images, giving individuals immediate feedback on the area.

Depending on a person's situation, anything from an alarm to evacuation assistance can be provided in real time, which can minimize any damage or prevent a crime from happening, creating a safe and secure society

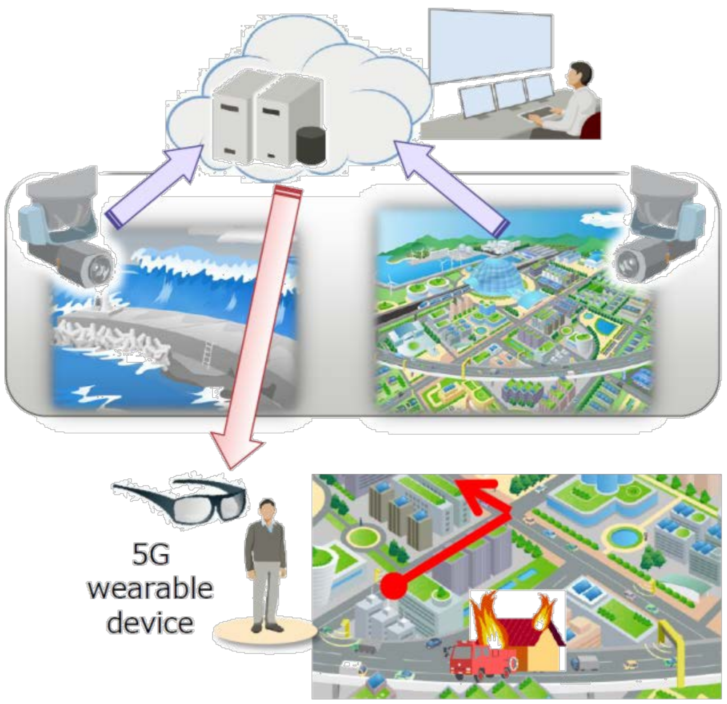


Fig. 2.2.1.1 Prediction of natural disasters and individuals immediate feedback.

【Field】

⑧ Smart Cities/Areas (Construction/Maintenance)

【Technological Support】

Anticipate the outbreak of a natural disaster and provide feedback to individuals in real time with 5G's high speed high capacity transmission technology.

Ultra-high-speed transmission will be realized using spatial multiplexing technology MIMO: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4).

In addition, provide multiple users with simultaneous feedback using high capacity transmission technology: Information of technical works related to RAN deployment or control schemes ([1] 11.3.5).

Technology to also provide predictive and early warning big data analysis, the technology that considers privacy during data collection, special video systems that can send information to wearables are all needed.

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro, Urban Macro

【Trial Environment】

Urban area, shopping centers

【Trial Schedule】

Year One: Investigation of system configuration and basic functionality, choose trial sites.

Year Two: Test transmission of data to wearable devices using 5G.

Year Three: Expand testing to use cases and applications.

【Relevant Industries】

- Municipalities, police agencies, fire departments
- Big Data Firms

【Projected Results】

Offering the ability to anticipate natural disasters, and providing individuals with real time information, alarms or evacuation information, based on their own situation, thereby minimizing damage, preventing crimes, and terrorism

2.2.2 Mobile Surveillance/Security

【Overview】

Real time safety management can be conducted by security guards with wearable surveillance devices, sending high-definition video and audio data to security centers to be collected, and when an unknown object, need to check safety, or when a public area is known to become suddenly crowded, a security center can dispatch a security guard in a timely manner.

In addition, high-definition video can provide static and dynamic analysis of the situation or movement of people and objects, specifically sick people or suspicious objects and communicate to this information to security personnel or security centers. 5G cells or various wireless LANs (2.4GHz/5GHz/60GHz) will provide the high capacity wireless transmission technology and multi-RAT selection technology will provide a stable environment so that surveillance video and audio can be shared even while moving, providing appropriate security oversight.

【Field】

⑤ Smart House/Life (Daily Goods/Communications)
⑧ Smart Cities/Areas (Construction/Maintenance)

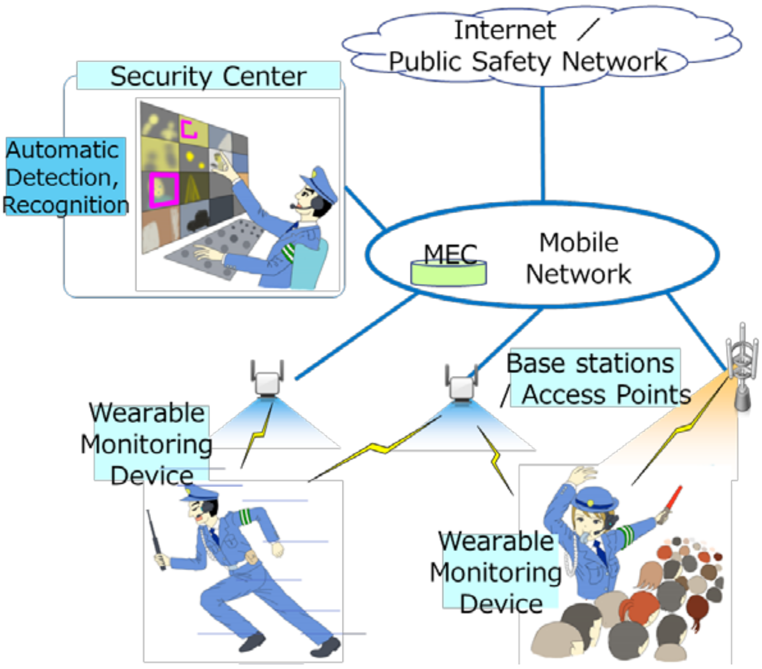


Fig. 2.2.2.1 Mobile surveillance/security system.

【Technological Support】

Security personnel and security centers transmit high-definition video to each other using up and down links with high capacity wireless network technology: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4)

Various data can be held in devices (depending on device attributes, movement of device, location and history) using multi-RAT selection technology: Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)

Plus, the use of network technology that ensures QoS through slicing: Network softwarization in 5G ([1] 12.2.2), and based on the video data from various cameras, automatically detect and follow a targeted object using MEC: Application of MEC ([1] 12.5.2)

New technology will also be needed so that within any certain area, where the wireless quality situation will vary, moving devices will be able to change their image bit rate to the most useful for the frequency being used to be able to transmit high-definition image signals.

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Indoor

【Trial Environment】

- Theme parks, shopping malls, train stations, places where people gather
- At the above locations, experiments on face recognition technology or flow analysis will need to gain the permission of people gathered (in consideration of privacy issues)

【Trial Schedule】

Year One: Test Basic functions and applications.
Year Two: Test application structure with basic functions and actual use.
Year Three: Test actual systems to be used.

【Relevant Industries】

- Surveillance/Security System Management Firms
- Wearable Surveillance tool manufacturing vendors
- Wireless communication systems management firms
- Police agencies, security companies
- Railways

【Projected Results】

Public areas such as event venues, airports, stations, and terminals are very crowded, so using a 5G network makes it possible to transmit high-definition video for pinpoint security, surveillance, and quick response and dispatch emergency services. In addition, firms whose role is to protect safety and security can value test and find further issues in the technology.

2.2.3 Safety Systems with Video Surveillance Technology

【Overview】

In places where many people gather, video taken from fixed, wide area observation cameras as well as security wearable cameras can detect abnormal behavior or suspicious people. Users can also request finding lost children or friends.

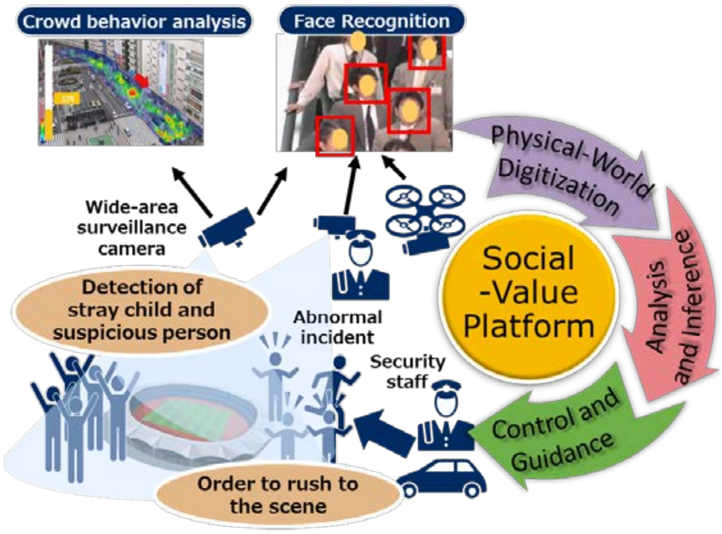


Fig. 2.2.3.1 Safety and security solutions using facial recognition and crowd control system.

In addition, using information from a GPS equipped security device, outbreaks of civic disturbances can be detected and video information with location information can be collected, the existence of said disturbance can be verified, and if confirmed, analyzed information can be offered to police agencies. In addition, search for suspects can be conducted and information can be sent to policy agencies and family members of the victim in real time.

Fig. 2.2.3.2 Security system solutions by image recognition.

【Field】

⑧ Smart Cities/Areas (Construction/Maintenance)

【Technological Support】

To create a safe and secure environment in shopping centers and stadium, 5G's ultra-high speed data transmission can be used to collect video from HD cameras and wearable devices and for data communication with robots. Specifically, massive MIMO will be needed to realize ultra-high speed transmission: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5)

Additionally, low latency is needed to control robots and drones and also to not have any adverse effects on other services, as well. This will specifically require network mobile edge computing and network virtualization: Network softwarization ([1] 12.2.2), Application of MEC ([1] 12.5.2).

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro, Urban Macro

【Trial Environment】

- Shopping centers, theme parks, stadiums
- Event areas around Tokyo, outdoor open spaces

【Trial Schedule】

Year One: Basic transmission tests of network design and simple apps

Year Two: Verification trials using advanced applications and high speeds and high capacities

Year Three: Field testing in the trial environment

【Relevant Industries】

- Security companies
- Police agencies, municipalities
- Surveillance/security system firms

【Projected Results】

Image/video analysis technology connected to a high capacity, multiple connection, low latency equipped 5G network will be able to spot lost children and suspicious people easily and security will quickly be able to ensure safe and secure environments, supporting a more fruitful society for everyone.

2.2.4 Providing Rich Contents to Airplanes and Ships

【Overview】

By providing high speed data transmission service to low-altitude helicopters and airplanes by 5G, the high-definition video and data which the helicopters and the airplanes gather in the sky are transmitted to the ground, which can realize a safe and secure society. Ships moving at high speeds on the open seas, such as luxury liners or motor boats, can also be offered more high-quality transmission services from the coast than they can today, which will also help contribute to a safe and secure society.

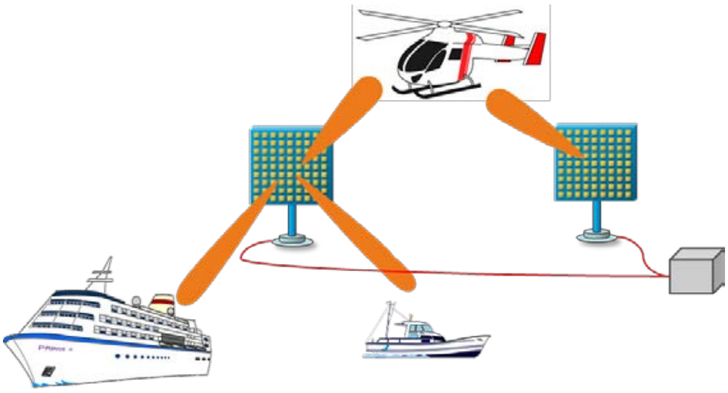


Fig. 2.2.4.1 Realizing a safety and security with high-definition video transmission in the sky and the sea.

【Field】

④ Medical (Health/Welfare)
⑧ Smart Cities/Areas (Construction/Maintenance)
⑨ Transport（Commute/Logistics)

This is also related to Sec. 2.6, "High Data-rate and Reliable Communication for High Speed Mobile" in this report.

【Technological Support】

3D beam tracking technology related to high speed moving objects, high speed wireless entrance links: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5), wireless relay transmission tech. to high moving objects, relay data cache tech., ultra-low latency and highly efficient HD video transmission tech.

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

On the sea, areas with few buildings, around heliports.

【Trial Schedule】

Year One: Shape the service image (run transmission simulations)
Year Two: Field test of 5G transmissions with highly speed moving objects
Year Three: Field test of 5G transmission with very high speed moving objects

【Relevant Industries】

- Medical related personal, police agencies, Japan Coast Guard
- Helicopters, airplanes, shipping companies
- Video content providers

【Projected Results】

- Police helicopters and coast guard patrol ships use high speed transmissions for patrols and distance observation
- Medical helicopters transmitting information while providing emergency remote medical care

2.2.5 Ensuring Communication with Shared Frequency Use during a Disaster

【Overview】

There is a need to protect and ensure stable communication during a disaster when infrastructure in an area is damaged. It is also important that there is a telecommunications infrastructure in place that can be used to support ICT use in disaster relief immediately after a disaster occurs

In the situation where communications become difficult after a disaster, it is possible to have devices that can understand the frequency use situation and the capability to judge which shared frequencies are usable. Shared based stations from telecommunications companies and device to device communication capabilities will ensure that communications can continue to flow during a disaster.

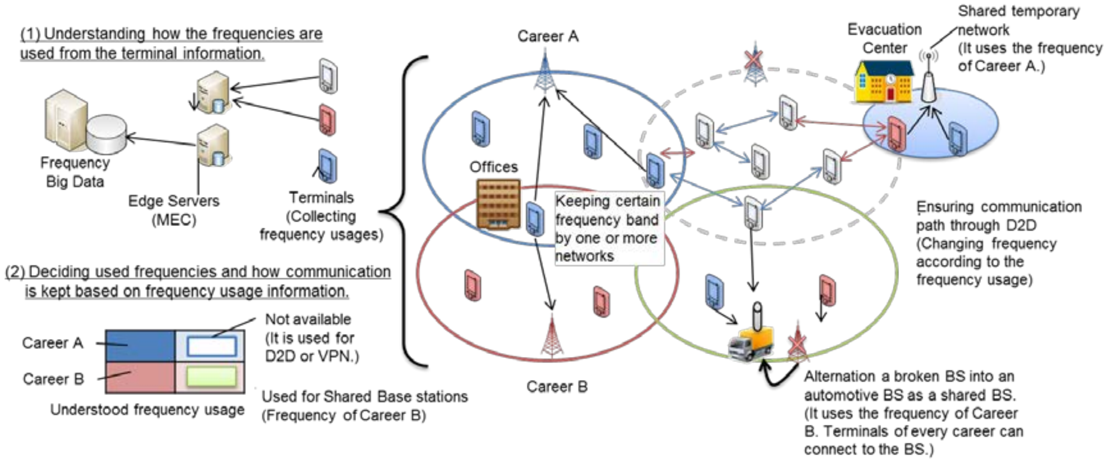


Fig. 2.2.5.1 Examples of ensuring swift and prompt communications during a disaster.

【Field】

⑧ Smart Cities/Areas (Construction/Maintenance)

In addition, this section is related to shared frequency and disaster communication

【Technological Support】

High-level heterogeneous networks as well as shared frequency use technology: Information of technical works related to RAN virtualization ([1] 11.3.8)

Multiband, multi-access multilayered cell structures from wireless LAN systems: Information of technical works related to RAN deployment or control schemes ([1] 11.3.5)

Application of MEC ([1] 12.5.2)

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban, Rural
mMTC - Urban Macro

【Trial Environment】

Tourist attractions, event areas

【Trial Schedule】

Year One: Basic simulation testing
After Year Two: field verification trials

【Relevant Industries】

- Event organizers, event venue managers
- Local municipalities

【Projected Results】

Ensuring stable communications during a disaster, even the damage to infrastructure and communication systems is concentrated in one place.

2.2.6 Reference Themes

Other group's themes related to ensuring a safe and secure society include

- 2.4.2: Surveillance Using Camera-Equipped Robots
- 2.4.3: Surveillance Using Camera-Equipped Drones
- 2.5.1: Smart Automobiles (over the Horizon Accident Prevention)

2.3 Logistics, Agricultural and Fisheries, Offices, Factories

【Editors】

- National Institute of Information and Communications Technology.
- Advanced Telecommunications Research Institute International(ATR), SoftBank Corp.

【Overview】

The 5G Utilization Projects offer new lifestyles through broadly separated areas such as efficiency in logistics, an optimized heterogenous wireless environment, a network environment that can be used anytime anywhere, which can be offered do to the ability to freely choose from 5G special characteristics, such as multiple connections, ultra-high speeds, and high capacities.

In addition, with the 2020 Olympics and Paralympics in mind, new forms of entertainment will be offered through transmitting of high-definition video from new locations. Scenarios also include ways 5G technology will be able to offer new styles of work.

2.3.1 Logistical Efficiency

【Overview】

By tagging objects (such as daily goods, food and drinks, etc.), which will make managing goods in supply chains more efficient, especially for retail stores management, following customer purchases and restocking support.

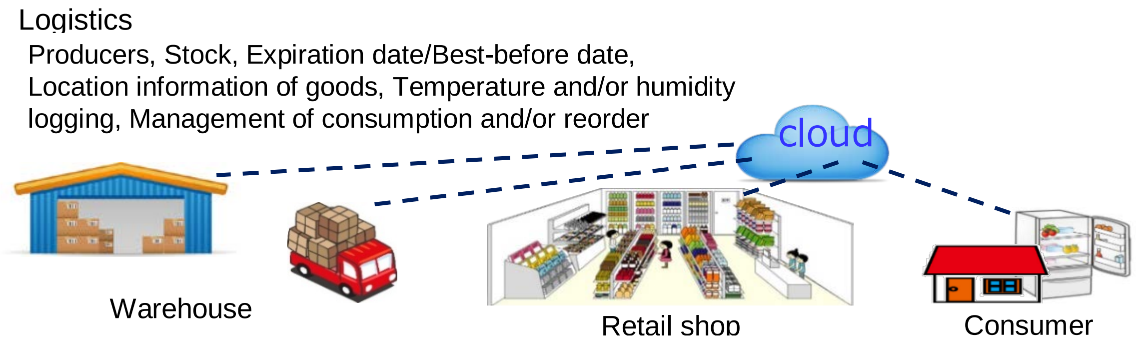


Fig. 2.3.1.1 Managing logical efficiency from warehouse to an individual's home.

【Field】

⑥ Retail (Finance/Payments)
⑨ Transport (Commute/Logistics)

【Support Technology】

Security management for many kinds of high demand family goods that are transported, from storage, delivery, sales, to the household. The needed technologies are thought to include filtered OFDM, massive MIMO, SCMA, Polar Code, RAN virtualization.

【Evaluation Model (Use Cases)】

mMTC - Indoor, Urban Micro, Urban Macro

【Trial Environment】

Warehouses, typical family homes, retail stores

【Trial Schedule】

Year One: Test in indoor environments
Year Two: Field test in an urban micro environment and an urban macro environment
Year Three: Overall test in actual logistics system.

【Related Industries】

Logistics companies, ordinary buyers

【Projected Results】

These demonstrations will show how to use 5G to manage the logistics process of delivering goods from warehouses to retail shops to consumer at home as well as how to efficiently manage household goods

2.3.2 Using an Optimized Heterogeneous Wireless Environment

【Overview】

An increase in convenience will come to users by being able to access many different kinds of networks, ultra-high definition video (4K/8K) of event highlight in near real time that can be watched on trains and at train stations, or in cars and street corners, as well as the ability to access high speed networks (such as WiFi and WiGig) on high speed trains or while driving on an expressway. This will make events more exciting at more locations.

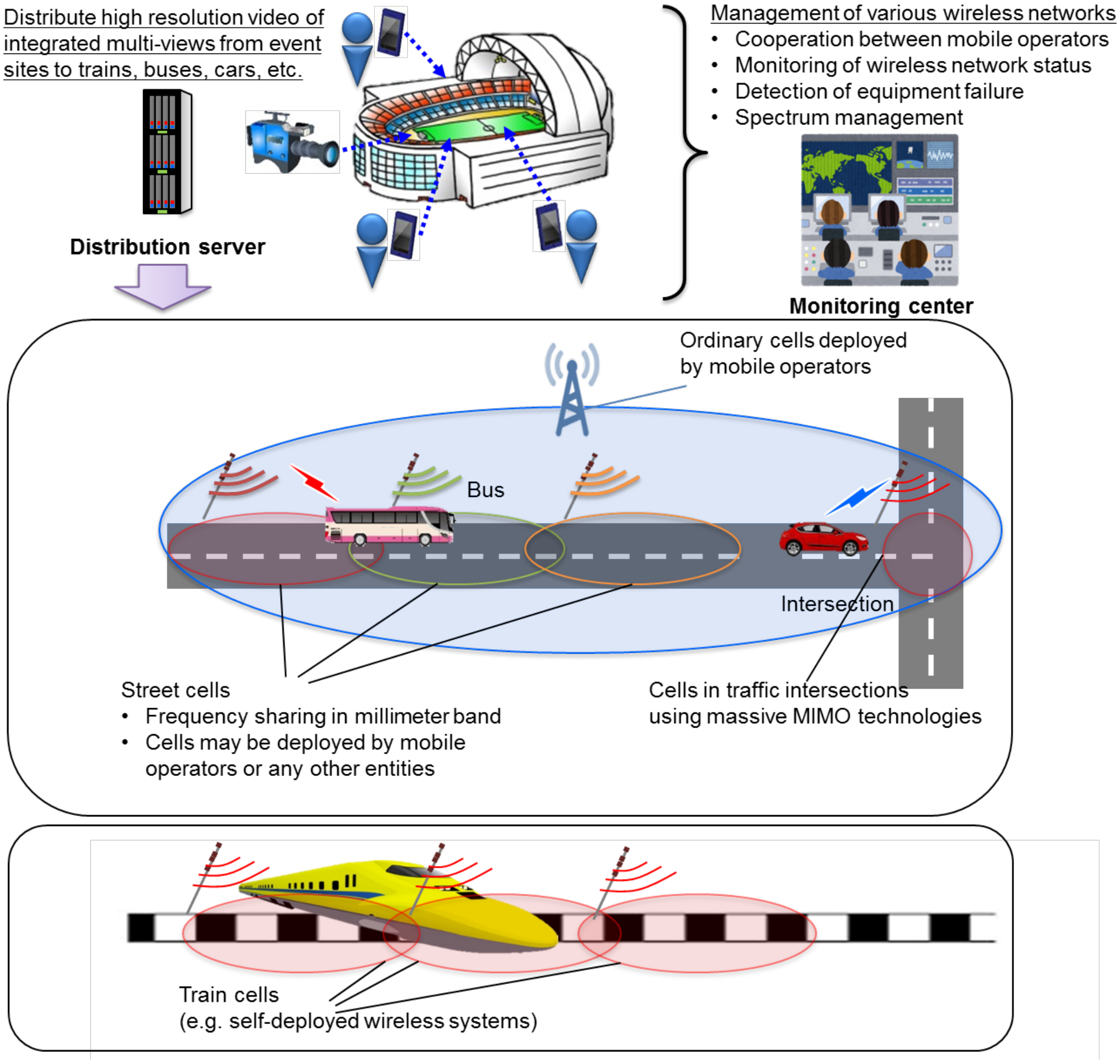


Fig. 2.3.2.1 Use case examples of delivering event information over optimized heterogeneous networks.

【Field】

② Entertainment (Games/Tourism)
⑤ Smart House/Life (Daily Goods/Communications)
⑨ Transport (Commute/Logistics)

In addition, this section also relates to Sect. 2.1 (stadiums), Sect. 2.5/2.6 (automobiles/railways)

【Support Technology】

Event venue, highways, railways, use possibility wireless system best choice, and those services will become realized through high speed communication, the needed technology is.

The wireless system will be able to optimally choose the most useful, wireless system to use at places such as an event venue, highway, or railway. These services will be made possible by high speed communications. It is thought that this will require the following technologies: Linear Cellularization, RAN Virtualization, Fronthaul/Backhaul, Mobile Edge Computing

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban, Rural
mMTC - Urban Macro

【Trial Environment】

Stadiums, roadways, railways, YRP area, large field test areas in the Keihan region

【Trial Schedule】

Year One: Tests of standalone functions of network and wireless devices in a simulated environment

Year Two: Integrated tests of the equipment in the simulated environment

Year Three: Integrated verification trials of different individual functions using actual services and events

【Relevant Industries】

Vendor firms, highway/railway management, event venues

【Projected Results】

It will be difficult for one standalone wireless system to provide all the special characteristics of a 5G network, so showing how existing systems will be to be integrated with new systems to be used effectively and demonstrate how it will function as part of the age of IoT’s mobile infrastructure, with the goal of connecting many kinds of services together.

2.3.3 A Network where It Is Possible to Keep the Same Environment Everywhere at Any Time

【Overview】

Users can freely combine services on a network, making the network something that is actually by your side at all times. Even when users move to another location, users will have their own network by their side, so that they have access to that same communications environment wherever they go, whenever they go. This network, used as end to end virtual network, can provide many services in different locations, creating a personalized network for individuals. Combining many styles of networks, with stable transmissions using a secure technology, the possibilities are open

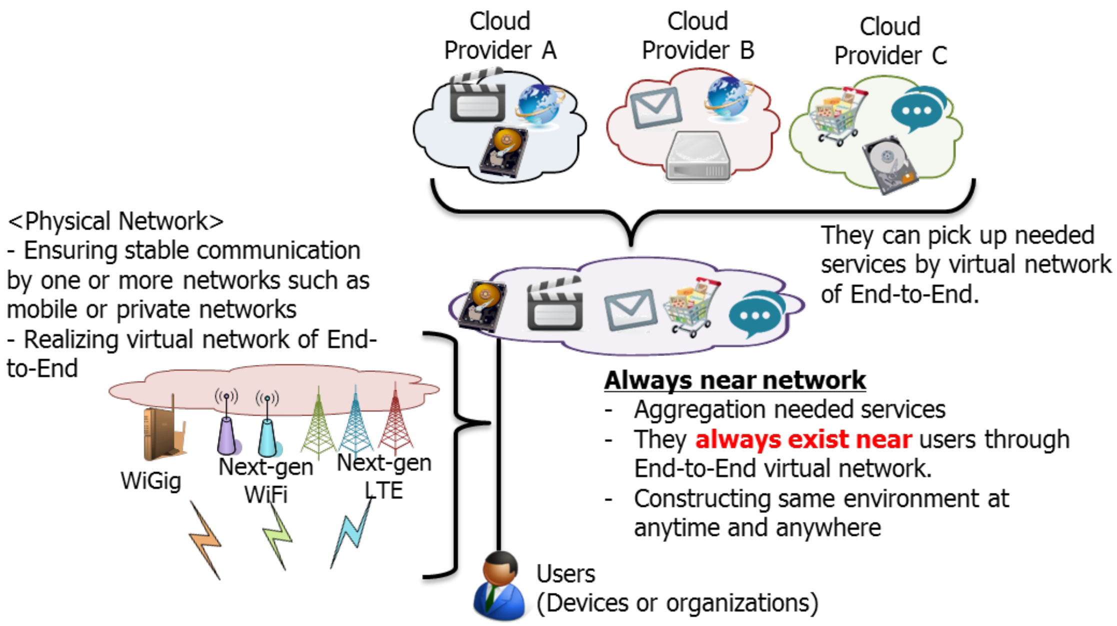


Fig. 2.3.3.1 Offering a network environment that is always by your side.

【Field】

③ Office/Workplace
⑤ Smart House/Life (Daily Goods/Communications)

【Support Technology】

Selecting to connect to the optimum wireless system depending of the requested use, while accessing the same transmission environment wherever the user goes. It is believed that technology following technology is needed Advanced Heterogeneous Network, Network Softwarization, RAN Virtualization, Dynamic network resource allocation based on service requirements

【Evaluation Model (Use Cases)】

eMBB - Indoor, Dense Urban, Rural

【Trial Environment】

YRP area/Keihan area wide filed test area

【Trial Schedule】

Year One: Build and design the field environment
Year Two: Verification Trials at the field environment
Year Three: Demonstrations using the actual services

【Relevant Industries】

Universities, cloud service firms, research organizations

【Projected Results】

It will be as if the user's network is always by their side, and will be able to freely combine network services.

2.4 Remote Controlled and Managed Devices Such as Robots and Drones

【Editors】

- NIPPON TELEGRAPH AND TELEPHONE CORPORATION
- Hitachi, Ltd., KDDI CORPORATION, Nokia Solutions and Networks Japan Corp.,
  ITOCHU Techno-Solutions Corporation

【Overview】

The 5G Utilization Projects see the role of 5G in of remotely controlled and managed devices such as robots and drones in the following situations, remotely controlled robots, surveillance using camera-equipped robots or drones, autonomously cooperative distributed control of connected machines. They include the aspects such as the type of connected devices, HD cameras equipped for monitoring activities, as well as a way to deploy monitoring and control systems for edge computing.

From these scenarios, many different situations can be explored using 5G's special characteristics of high-speeds, high-capacity, and low-latency, a variety of new services can be imagined and created.

2.4.1 Robot Monitoring and Remote Control

【Overview】

Various kinds of facilities, such as shopping malls and stadiums, train stations, airports, can utilize service robots to provide information to meet the various needs of regular customers or meet the demands of a sudden increase of foreign tourists. In order to make this a reality, large numbers of robots need to be operated in a safe manner so remote observation and control of the robots is essential. Robot systems, as seen in Fig. 2.4.1.1, need to ability to process audio, images, and languages and be able to send and receive observation and control commands to the operation center, so it can oversee the various robots its location.

The monitoring center and the robots located at various areas around a given site need to be able to connect to a broadband network that can efficiently accommodate many devices as well as provide low latency times in order to enable real time observations and control of large numbers of robots. This ability to provide highly precise control management with high confidence needs to be tested.

【Field】

② Entertainment (Games/Tourism)

【Support Technology】

- Robot observation in real time
- High reliability control information transfer
- Highly accurate robot control

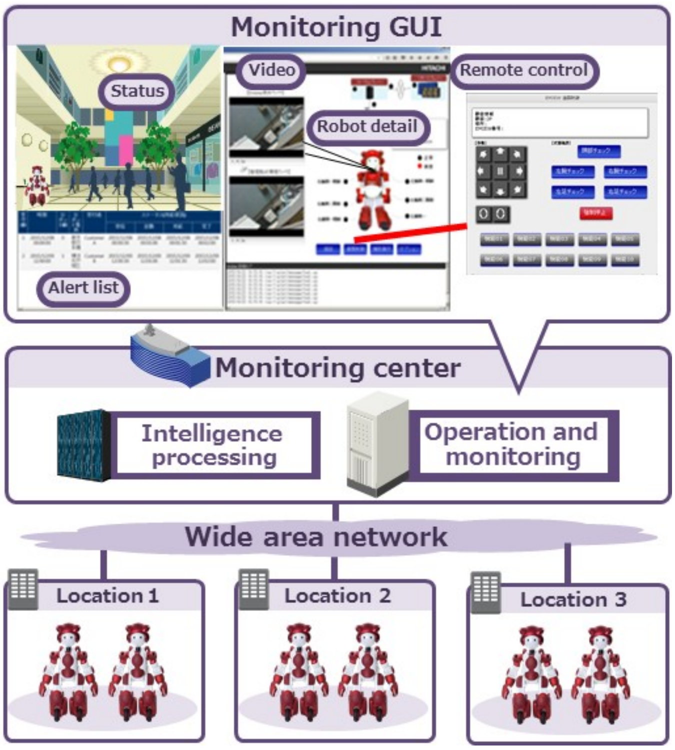


Fig. 2.4.1.1 Robot monitoring and remote control.

【Evaluation Model (Use Cases)】

eMBB - Indoor
URLLC - Urban Macro

【Trial Environment】

Large shopping facilities (malls, stadiums), train stations, airports

【Trial Schedule】

Year One: Trials for the basic components (use of wireless LAN, for example)
Year Two: Hold trials at multiple locations
Year Three: Hold Trials to determine problems under difficult conditions

【Relevant Industries】

Operators of larger establishments such as shopping malls, operators of large public transportation, areas such as train stations and airports, (joint verification trials)

【Projected Results】

- Provide quick, diverse range of information to visitors at a variety of establishments during the Olympics and other events.
- Robots that can monitor commercial establishments that are open year round

2.4.2 Surveillance Using Camera-Equipped Robots

【Overview】

Robots equipped with high-definition cameras will be able to transmit omnidirectional video and other high-capacity video from distant locations. In addition to being able to conduct real time observation/surveillance, users can move and manipulate the robot remotely. Robots will also be able to exchange video from remote location, so other advanced monitoring activities, like image processing, can also occur.

High reliable and low latency communications will be required by users, otherwise users will face strong uncertainty that this will not be a stable platform for image delivery and the transmission of their operating instructions.

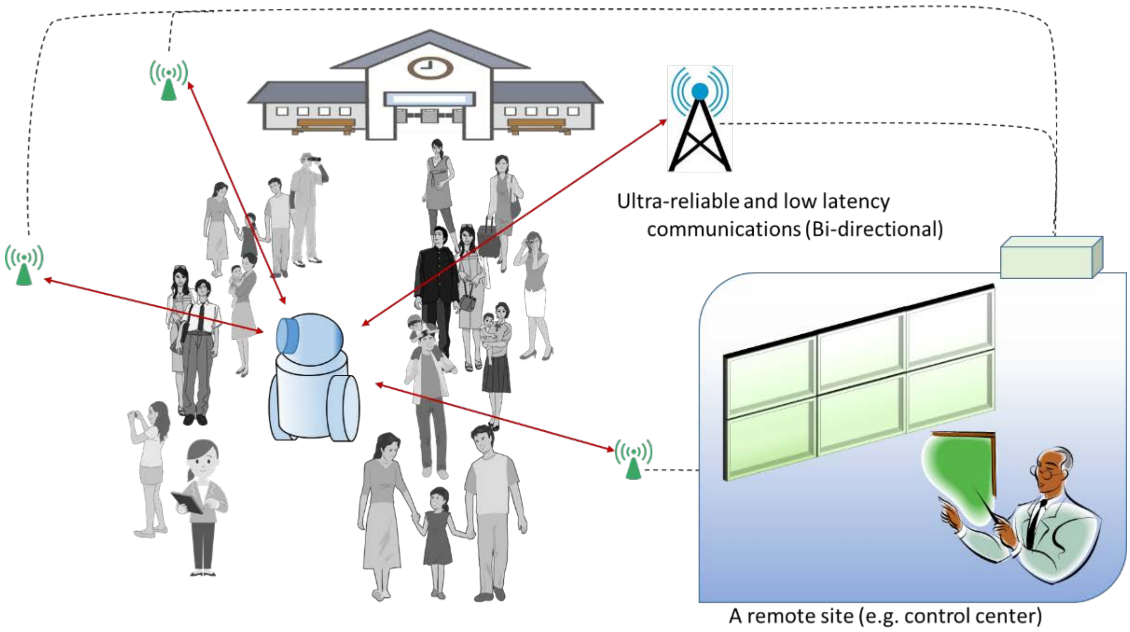


Fig. 2.4.2.1 Surveillance by camera-equipped robots.

【Field】

② Entertainment (Games/Tourism)
This project is related to Sect. 2.1

【Support Technology】

- Highly-reliable and low-latency wireless delivery technologies
  System control technologies with wireless LAN in multi-band and multi-access layered cells ([1] 11.3.5 (5))
- Economization using PON Technology ([1] 12.4.2.1)
- Robot operation methodology

【Evaluation Model (Use Cases)】

URLLC - Urban Micro, Urban Macro
eMBB - Urban Micro, Urban Macro

【Trial Environment】

Baseball, soccer, rugby fields, as well as the surrounding areas

【Trial Schedule】

Year One:

- Broadband, multiple simultaneous transmission with low latency
- Reduction of end-to-end transmission latency

Year Two:

- Trials for operating robots in a 5G systems environment

Year Three:

- Demonstration of surveillance and remote operation using bidirectional video transmission

【Relevant Industries】

- Robot Makers
- VR control systems

【Projected Results】

- Enable stable remote monitoring in environments which are crowded, such as large events, as well as during critical missions in disaster areas and other severe conditions where human workers cannot enter, to support disaster victims or remove a dangerous object.
- Offer new ways of communication (tele-existence) beyond conventional data transmissions at public viewing of sports events.
- Enable support robots that assist with the daily lives of older people or disabled people who have difficulty in walking, through providing help in their daily lives (shopping or household errands), and provide virtual experience of climbing mountains and travelling, by letting robots do instead of their owners and sending back images to them.

2.4.3 Surveillance Using Camera-Equipped Drones

【Overview】

Observation systems with high-definition camera equipped drones. There is also a possibility that by using 5G networks' low latency and ultra-wideband technology that high-definition video can be transmitted uncompressed. With mobility extended across several base stations, being able to extend the flying range of the drone then difficult viewing areas becomes a reality. And with an MEC equipped analytics engine, actions for a drone may be decided immediately.

Planned uses include, discovering and tracking suspicious people in crowds and helping support personnel in a disaster area.

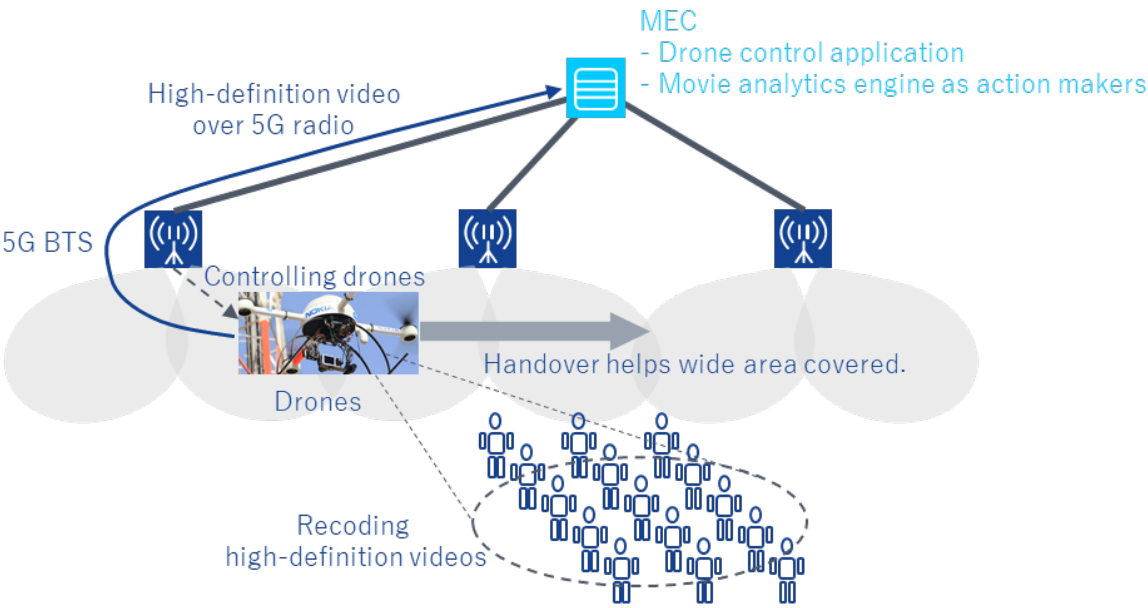


Fig. 2.4.3.1 Observation systems using camera equipped drones.

【Field】
② Entertainment (Games/Tourism)

【Support Technology】
- 5G New RAT
- Edge computing

【Evaluation Model (Use Cases)】
URLLC - Urban Macro

【Trial Environment】
Cities, disaster areas

【Trial Schedule】
Year One:
- Test handover coordination with the MEC
- Test drones using MEC
- Testing functionality of MEC to analyze images taken by drones

Year Two:
Integrated evaluations of applications connecting 5G, MEC, and Drones

【Relevant Industries】

- Drone and Camera makers
- Automatic Control Application Venders
- R&D organizations (image analysis
- Regulatory authorities

【Projected Results】

The use of MEC requires that a network that cannot only handle large capacity, but also one with high confidence and low latency. These requirements are also needed for drone control and image analysis, so these qualities of the network will be confirmed.

2.4.4 Autonomously Cooperative Distributed Control of Connected Machines

【Overview】

Autonomous distributed controlled connected machines will be realized using a combined 5G system and cloud based technology, with appropriate requirements and SLA, in order to provide applications and services such as controlling robots located far from the control center, autonomous car systems (including dynamic maps), remote controlled construction vehicles, and other means to support driving.

In an aging society, it has been difficult to find a solution to the absence of people to whom experts can hand down their skills. However, rather than machines replacing people, robotic operations based on telemetry can be used to by experts to support and assist people at far-away locations.

【Field】

⑧ Smart Cities/Areas (Construction/Maintenance)

【Support Technology】

- High bandwidth, low latency wireless networks and evaluation
- Cloud Computing, Fog Computing (Mobile Edge Computing)
- Autonomous distributed controlled systems and 5G dynamic slice network

【Evaluation Model (Use Cases)】

mMTC - Urban Macro

【Trial Environment】

Trial environments that are far way (island chains like Okinawa) from the control center

【Trial Schedule】

Year One:

- Testing “Cloud-Fog” to “5G(w/MEC)”
- Test the results of connection latency for fog/MEC at near and far distances

Year Two:

- Test closed loop

1. Data collection (from Network,5G devices)
2. Insight, Data Analytics
3. Automate network operation

Year Three:

- AI/Deep learning automatic distributed cooperation
- Demonstrations of various services

【Relevant Industries】

- Construction related firms
- Drivers
- Communication firms, service providers

【Projected Results】

- Many social problems exist due to a low birth rate, rapidly aging society. However, people can still live fulfilling lives in a society which uses IoT and with robots which can action to support individuals without distance and space restrictions
- Realizing a safe and secure society through the use of IOT services offered by autonomous distributed control systems

2.5 Connected Cars, Autonomous and Remote Driving

【Editors】

- KDDI CORPORATION
- Oki Electric Industry Co., Ltd., Mitsubishi Electric Corporation, Nokia Solutions and Networks Japan Corp., Ericsson Japan K.K., SoftBank Corp.

【Overview】

The 5G Utilization Projects see that 5G's special characteristics, mainly ultra-high speeds and capacity, high reliability and low latency, will be able to explore new users by bringing about a safe and secure society through the use of connected cars, remote control and monitoring of railway cars, and autonomous driving.

The 5G mobile communication systems from, will be able to assist in autonomous driving through the collection of traffic information data and the creation of dynamic maps, services which can be offered through 5G's high speeds and capacity (Sect. 2.5.1, 2.5.2, 2.5.3). In addition, the 5G offers the needed ultra-low latency, high capacity, high speed communications for autonomously driven cars (smart automobiles) or at a mining site with remote controlled, remotely monitored very large-scale construction vehicles (Sect. 2.5.4, 2.5.5, 2.5.6 and 2.5.7).

Through these technologies, the large-scale growth in the autonomous vehicle market is anticipated, and users of advanced vehicles from family cars to large scale construction vehicles will be able to use the 5G network to help bring about a safer, and more secure and pleasant society.

2.5.1 Smart Automobiles (over the Horizon Accident Prevention)

【Overview】

By installing cameras at intersections where it is difficult to see, through high speed image processing, people and cars who enter the intersection can be monitored in real time. If a car or pedestrian is detected entering the intersection, through use of the 5G network's low latency, cars will be notified of the danger and will be given the order to slow down. In addition, automobiles will be sent a warning if there anything dangerous occurs around the area of the intersection, as well.

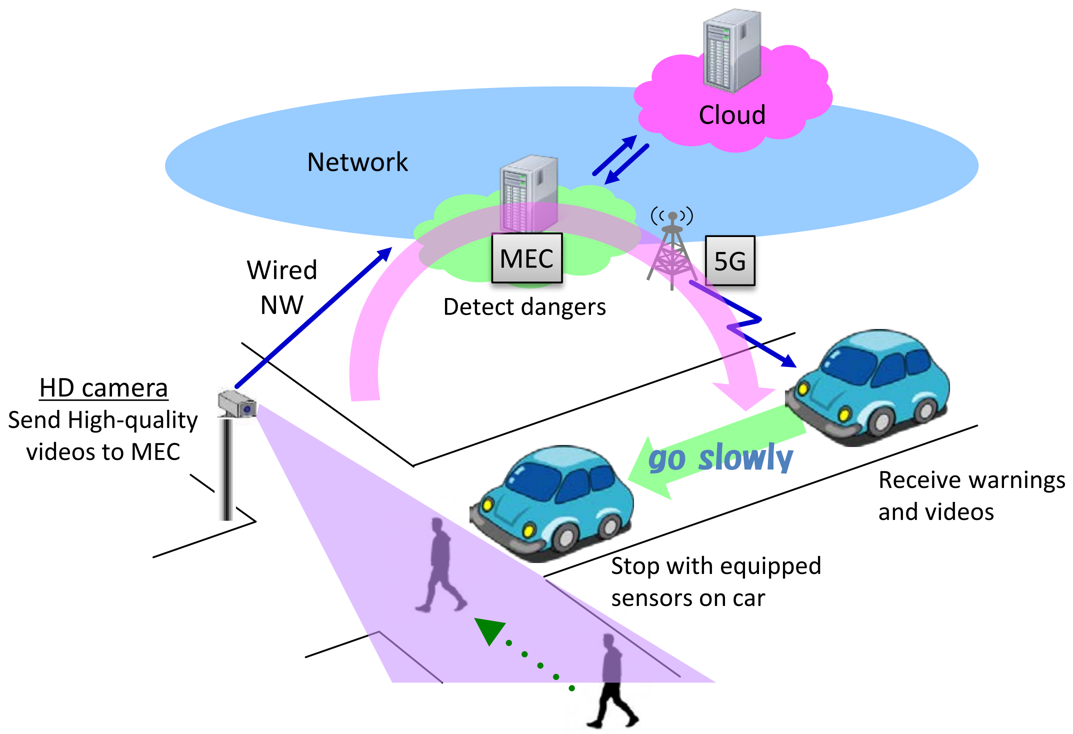


Fig. 2.5.1.1 Overview of smart automobiles with over the horizon accident prevention.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

- Low latency mobile fronthaul ([1] 12.4 Fronthaul and Backhaul)
- High speed image processing with MEC ([1] 12.5 Mobile Edge Computing(MEC))
- Monitoring/following of automobile location
- Predictive algorithm of intersection entry flow

【Evaluation Model (Use Cases)】

URLLC - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

- Intersections with poor visibility where many accidents occur
- Crowded intersections without traffic signals
- Mountain roads with warning traffic signs
- Expressways where many accidents occur

【Trial Schedule】

Year One:

- Risk information (warnings and images sent to devices)
- Data collection (PON/5G), image analysis (MEC), warning delivery (5G)

Year Two:

- Predicting intersection entry flow (predictive warnings and images sent to devices)
- Following the above, increase the area of data collection and predictive software
- Based on the above, create automotive controls (Controlling automobiles from the warning)
- Collaborating with automobile manufactures, build systems to manage cars via the warning signal.

【Relevant Industries】

Road and highway administrative and management organizations, automobile manufactures

【Projected Results】

- Demonstrate the one of the special characteristics of 5G by managing cars through connecting to the 5G network and utilizing its low latency requirements
- Demonstrate the possibility of even more safe autonomous driving by combining autonomously driven vehicles with the demonstrated warning notification system.

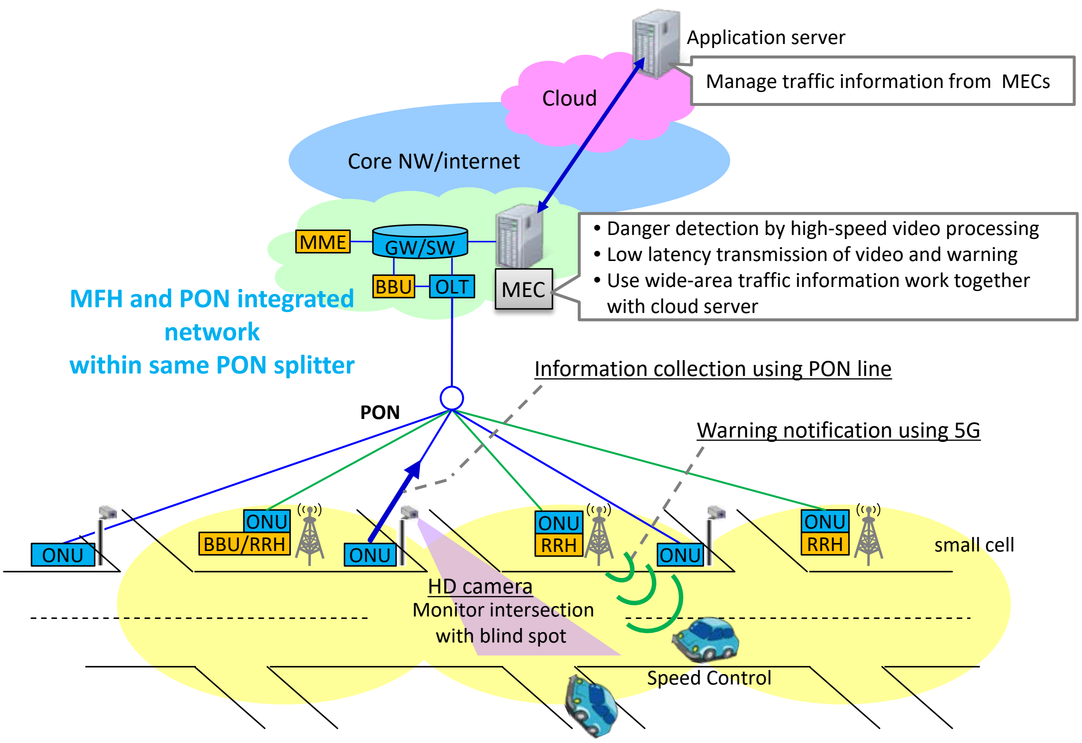


Fig. 2.5.1.2 Overview of the verification trial.

2.5.2 Delivery of High Capacity Maps for Use in Autonomous Driving

【Overview】

Safe and efficient autonomous driving will be assisted through the transmission of real time maps, which will be made by collecting data from sensors and cameras installed in streets which will be collected at a central location and dynamically updated with information including other surrounding vehicles, obstacles, and pedestrians.

Other information will be updated in near real time, using 5G's ability to handle high capacity data transmission. Information concerning the vehicles surrounding neighborhood, such as traffic information, construction and accident information, status of upcoming traffic signals, will be collected efficiently and transmitted to the central server to keep the map updated in near real time.

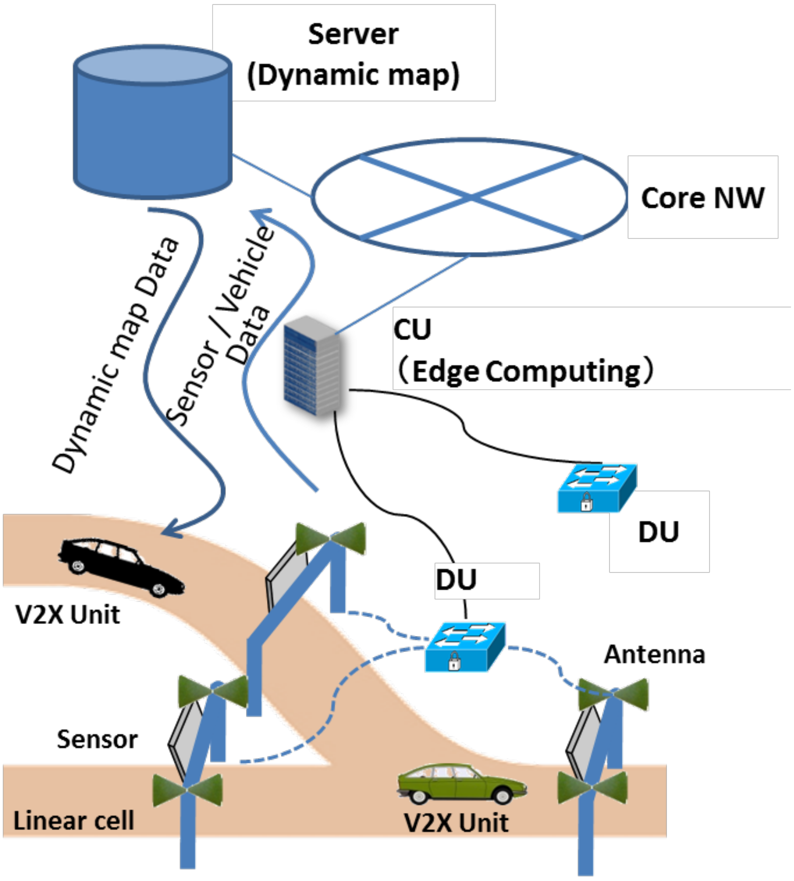


Fig. 2.5.2.1 Overview of the high capacity map and how it assists the autonomously driven vehicle.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

- Linear cell: Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)
- Edge computing: Mobile Edge Computing (MEC) ([1] 12.5)
- Low latency fronthaul: Dynamic control of NW resources and path optimization

([1] 12.4.2.2)

- NW virtualization, decentralization/node cooperation: Dynamic control of NW resources and path optimization ([1] 12.4.3.2)

【Evaluation Model (Use Cases)】

eMBB - Urban Macro, Rural
URLLC - Urban Macro, Rural

【Trial Environment】

- Vehicular roads connecting to the Odaiba area
- Japan Automobile Research Institute (JARI) Test Course

【Trial Schedule】

Year One: Order and manufacture necessary equipment
Year Two: Install/Construct necessary equipment and infrastructure, conduct demonstrations

【Relevant Industries】

- Autonomous vehicles, road infrastructure installations, trial scenario decisions: Car makers, road instrument vendors
- Dynamic maps to be used by autonomous cars: High quality mapping firms
- Permissions to install new equipment on roadways and highways: MIC, MLIT, local municipalities (responsible for road administration)

【Projected Results】

Expectations include improving driverless transportation with improved quality of service and less latency, decrease traffic accidents, alleviation of traffic congestion

2.5.3 Specialized Network for Connected Cars (Architecture)

【Overview】

In the 5G era, the 5G mobile communication system will meet remarkably various requirements, and simultaneously, the 5G mobile communication system should achieve sufficiently efficient and continuous operations in its service provisioning. For example, in entertainment (Sect. 2.1), realizing a safe and secure society even in disasters and emergencies (Sect. 2.2), and connected cars, remote controlled and observed vehicles, and autonomous driving (this section), have distinctly different requirements, as shown below. One of promising approaches to realize the 5G mobile communication system is leveraging NFV/SDN technologies. This allows the mobile network operators to construct and accommodate multiple service systems with individually different requirements. The detail requirements are as follows.

- Entertainment (Sect. 2.1): In order for participants in leisure activities, such as spectators at sports events at stadiums, game players, tourists and travelers, to enjoy their experiences, scenarios offering unique, cutting edge experiences are being considered. These experiences, whether real world experiences or virtual reality ones, including those virtual reality experiences that mirror real world ones, must be offered smoothly and uninterrupted even in very crowded conditions. The ITU-R value model for eMBB corresponds to this specific requirement.

- Realizing a safe and secure society even in disasters and emergencies (Sect. 2.2): The mobile communication systems must be able to deal with situations such as traffic accidents and medical emergencies as well as natural disasters such as earthquakes, floods, fires, and typhoons. In these situations, even if the infrastructure is damaged, mobile communication systems must be able to be reconfigured to continuously provisioning telecommunication services. There may be giving preferences on the individual telecommunication services when the infrastructure is severely damaged while the demand of services increases. In addition, one of the significantly important telecommunication services in disaster would be provisioning evacuation information and relief assistance, and allows disaster victims and emergency patients to survive and move to safe areas. The ITU-R value model for mMTC is a concrete way these requirements can be met.
- Connected cars, remote controlled and observed vehicles, and autonomous driving: the 5G mobile communication systems will be expected to improve conveniences for passengers using any kind of high level transport, from individual automobiles to maglev trains. Advanced sensing technology will be able gather a large amount of data and very quickly influence the movement and behavior in a variety of scenes, for example, autonomous driven vehicles strongly requiring no intervention from a human passenger, driving assistance services avoiding or mitigating traffic jams, and other obstacles on the road, behavior and movement information for events where large numbers of people are gathered, due the large capacity and low latency of the network. The ITU-R value model for URLLC is a concrete way this requirement will be met.

The 5G mobile telecommunication services will not need to offer all these requirements by a single system. The unique aspect of the 5G is the desire that depending on, for example, the use case scenario, the time, the location, the overall situation, and additionally, these requirements for the network will change. Therefore, it is preferable that the 5G mobile communication system can change dynamically, depending on the needs of the resources available for the telecommunications or computation services demanded. This is why a logical dedicate communication system that can be built using sliced network using SDN/NFV is desired.

【Field】

The many use case models discussed above include

- High speed simultaneous delivery model (ultra-broadband)
- Wireless presence model (ultra-broadband)
- Multiple simultaneous connections model (Wireless IoT)
- Next Generation “Connected Car” Model (Next Generation ITS)

【Support Technology】

In order for the verification trial to support the wide variety of use cases in the 5G era, it is necessary to test network slicing ([1] 6.2.3). The network slicing enables the telecommunication service provider and the other service providers to arrange to build logical service system and networks composed of processing power, storage (hardware), and network topology with the functions implemented by software. The communication capacity can change as the network slices are reformed by relocating the network and computational resources in different ways, and these services can be offered through the new dedicated network built from these slices.

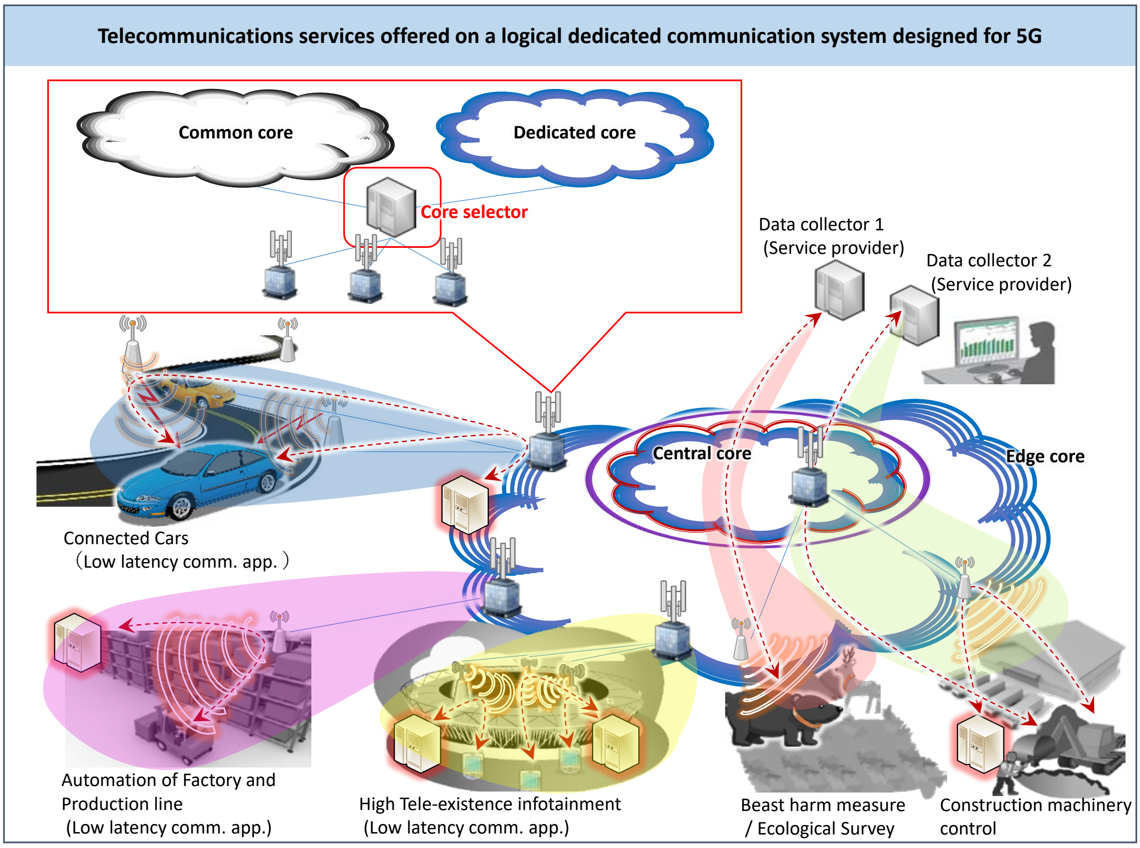


Fig. 2.5.3.1 Telecommunications services offered on a logical dedicated communication system designed for 5G.

【Evaluation Model (Use Cases)】

eMBB - Dense Urban: Enlarged Mobile Broadband

In order to bring more experiential value to users of smartphones and VR/AR devices, the communication services need to offer a larger capacity in telecommunications throughput (expanding the peak rate for data transmission) than what already exists in 4G mobile communication systems

mMTC - Rural: Large scale communications/multiple connections

IoT devices including sensor networks and infrastructure monitoring is expected to massively increase. This includes to mountainous areas and on the seas, as well. This means that the area where data is transmitted will expand, many kinds of devices will receive data, and more data receiving devices will need to conserve power

URLLC - Dense Urban, Urban Macro/Micro, Rural: High confidence low latency communications

Applications that connect IoT devices, such as machines, cars or sensors, are susceptible to delays and data loss, so the amount of data that is transmitted in any given time period must be ensured. In addition, in order to have satisfactory end-to-end communication quality and communication capacity in a 5G mobile communication system, radio, core network, and front and back haul all need to rigorously work together.

【Trial Environment】

To develop the 5G mobile communication system a trial environment that promotes the development of services is needed

- Stadiums and concert venues are hoped for to demonstrate entertainment services
- It is unquestioned that a robust test environment is needed to demonstrate the proposed 5G mobile communication system to ensure a safe and secure society in case of emergencies or natural disasters.
- It is desired that public roads (preferably in the suburbs), driving test tracks, and circuits where there may be sensors places to test connected cards, remote controlled and observed vehicles, and autonomous driving.

【Trial Schedule】

The following schedule shows the progress of the verification trial

Year One: Test the form of the structure of the logical communication system

Year Two: Conduct basic verification trials of the system management structure and the logical system structural form

Year Three: Conduct verification trial connecting wireless access and the mobile core together

During year one's "test the form of the structure of the logical communication system" with mobile core system at the center, common functions and the specific functions of communication services will be classified. The common functions will be logically divided into a number of groups so that device reception, separation and exchange as well as communication and processing power can be flexibly structured and active sampling and visualization can work together in order to define the necessary requirements, architecture, and implementation.

In Year Two, conduct basic verification trials of the system management structure and the logical system structural form from the results in year one tests a prototype will be built, and the basic operations and performance bottlenecks will be clarified. After receiving this feedback based on the year one tests, the concept for the 5G mobile communication system requirements, architecture, and structure will be expanded.

In Year Three, Conduct verification trial connecting wireless access and the mobile core together, wireless access and mobile core are connected together, and the entire system (communication end to end performance and communication quality) will be made clear. In addition, the various logical communication systems will be built in the same trial environment, and verification trials to realize various communication services will be held.

【Relevant Industries】

Mobile network operators, mobile virtual network operators, fixed line telecommunication network operators, cloud service providers. It is thought to assign different roles of the structure of the mobile communication system, with fixed line telecommunication network operators requesting telecommunications recourses from the mobile communication firms and the mobile virtual networks, while the cloud based providers will offer processing resources.

【Projected Results】

Various IT service providers are expected to promote new communication service uses. Especially easy to use IT technologies in industries that up until now have not used telecommunication as much, with the expectation that these same industries will contribute to their revitalization and grown. Additionally, in industries already using telecommunication services (for example, e-commerce and video delivery firms), their competitiveness is expected to increase with the more efficient telecommunication services.

2.5.4 Valet Parking Systems in Large Scale Parking Lots

【Overview】

Shopping Centers will be able to have an open parking space where cars automatically parked and then return cars to their owner without the need for a valet driver. Using 5G as well as MEC technology's low latency characteristics, the network will be able to drive the cars to the parking spot.

Since the test area in a parking lot is restricted, it is possible to demonstrate the lower risks for autonomous driving in them. Also, since the network will control the vehicle, there is no need for the vehicle to have excessive intelligence.

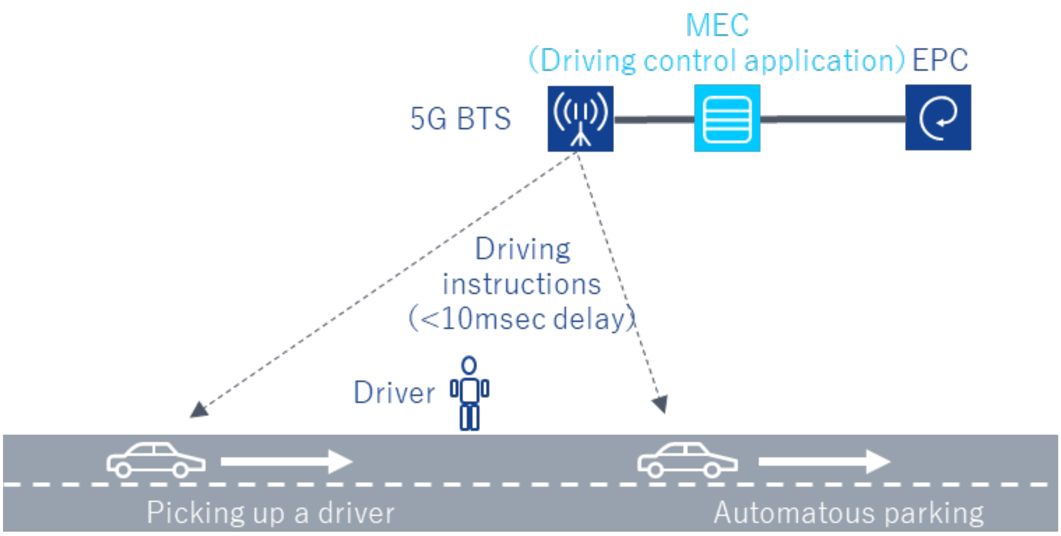


Fig. 2.5.4.1 Diagram of the valet parking system.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

- Ultra-low latency networking ([1] 12.5.2.1)
- Control and Management for low latency and resilient networks ([1] 12.5.2.2)
- QoS classify/slicing using virtualization ([1] 12.4.3.1)
- Autonomous driving
- Dispatch car services

【Evaluation Model (Use Cases)】

URLLC - Urban Macro

【Trial Environment】

Shopping center parking lots

【Trial Schedule】

Year One:

- Evaluate the low latency capabilities of MEC
- Evaluate autonomous driving as well as ability to park

Year Two:

- Integrated evaluations of the valet parking system

【Relevant Industries】

- Car manufactures, car electronics makers
- Autonomous driving service providers
- Shopping center and parking complex owners
- Regulatory authorities

【Projected Results】

MEC technology will be used to realize low latency. In addition, since cars will be managed and controlled by the 5G network, the practical use of the quality low latency network will be verified.

2.5.5 Remote Management of Autonomous Driving

【Overview】

A car being automatically driven can provide the remote operator (driver) video of what is happening inside and outside the car in real time and if necessary the remote operator can take over control of the car

The goal of this project is to acquire the knowledge to realize a remote controlled automatic driving system.

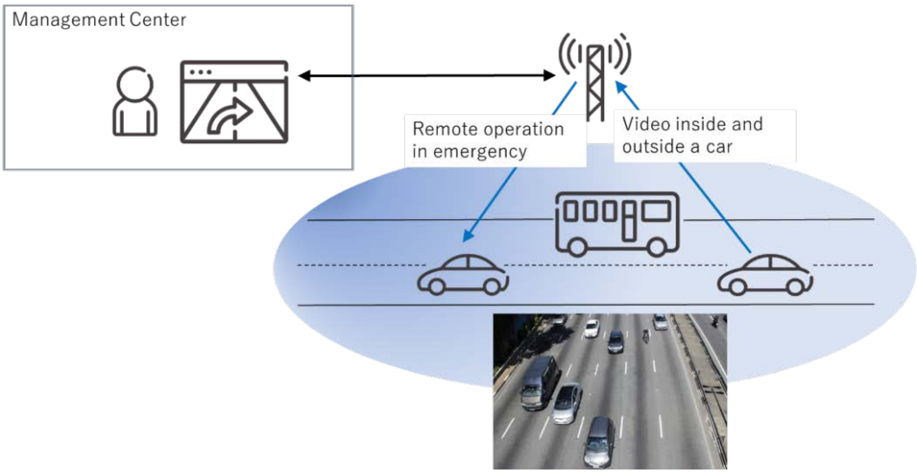


Fig. 2.5.5.1 Overview of remote controlled automatic driving.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

MIMO or multiple antenna technologies ([1] 11.3.4), Network Softwarization ([1] 12.2), Mobile Edge Computing ([1] 12.5)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural
URLLC - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

Regular streets, expressways

【Trial Schedule】

Year One: Design the project
Year Two: Develop the wireless network, prepare the core network (first half), carry out the trial (second half)

【Relevant Industries】

Autonomous driving service providers, car makers, surveillance camera vendors

【Projected Results】

Make possible an increase in the safety of autonomous driving.

2.5.6 Remote Controlled Operation of Large Vehicles at a Mining Site

【Overview】

Work at a mining site is in extremely difficult environments due to dangerous events such as gas outbursts and cave-ins. By connecting large vehicles used for mining operations to a network to be controlled in a remote location, it is possible to appeal the merits of an unmanned system, and to find out challenging points of this application.

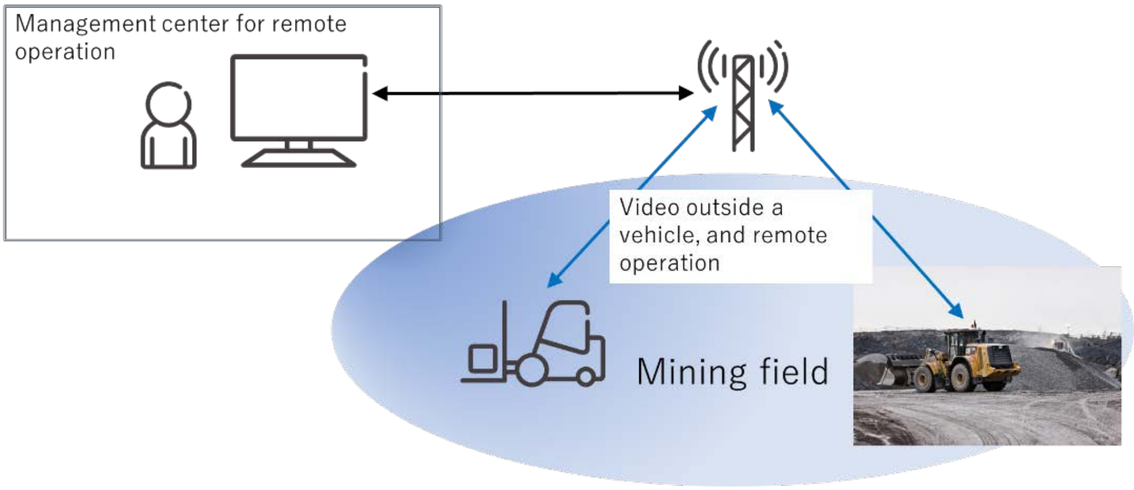


Fig. 2.5.6.1 Overview of remotely controlled vehicles at a mining site.

【Field】

③ Office/Workplace

【Support Technology】

MIMO or multiple antenna technologies ([1] 11.3.4), Network Softwarization ([1] 12.2), Mobile Edge Computing ([1] 12.5)

【Evaluation Model (Use Cases)】

eMBB - Indoor/Hotspot, URLLC – Indoor/Hotspot

【Trial Environment】

Mines

【Trial Schedule】

Year One: Design the project
Year Two: Develop the wireless network, prepare the core network (first half), carry out the trial (second half)

【Relevant Industries】

Mining research firms, large vehicle vendors, surveillance camera vendors

【Projected Results】

It is possible to increase safety and efficiency by using remote controlled vehicles at a mining site

2.5.7 Platooning of Trucks

【Overview】

In order to realize platooning of trucks, i.e. to run trucks in convoys (with one manned, lead vehicle followed by several unmanned ones), the high reliability and low latency communication between trucks is needed, which 5G can provide. The operation management center for the platoons of trucks needs to remotely monitor and control the trucks, as well.

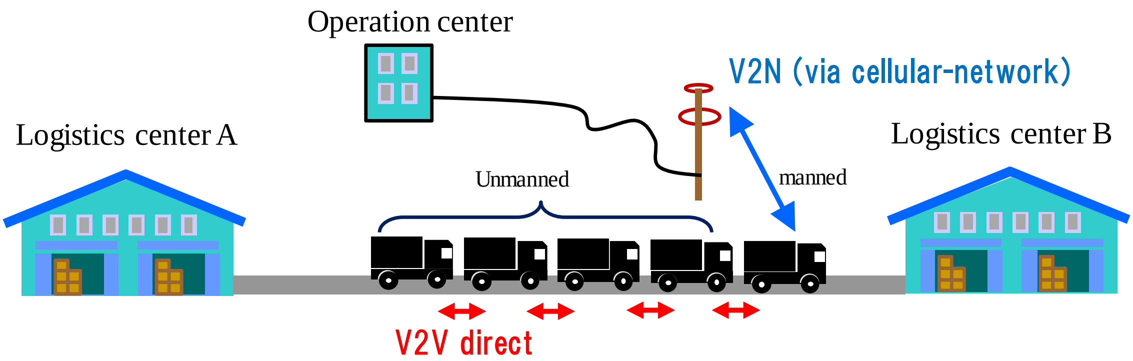


Fig. 2.5.7.1 Truck platooning overview.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

- Massive MIMO: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4)
- Linear cellularization: Information of technical works related to RAN deployment or is control schemes ([1] 11.3.5)

【Evaluation Model (Use Cases)】

URLLC - Urban Macro/Micro, Rural
eMBB - Urban Macro/Micro, Rural

【Trial Environment】

Test Course

【Trial Schedule】

Year One: Test low latency transmission between trucks, and between the road and the tuck while the trucks are not moving

Year Two and beyond: Test actual moving vehicles on an outdoor road course

【Relevant Industries】

Autonomous Driving Service Providers, Communication Network Vendors, Autonomous Driving Technology Research Vendors

【Projected Results】

Make an appeal about 5G's target qualities of highly-reliable low-latency transmissions to the autonomous driving world.

2.6 High Data-rate and Reliable Communication for High Speed Mobile

【Editors】

- Ericsson Japan K.K.
- NTT DOCOMO, INC., Sumitomo Electric Industries, Ltd.,
  Mitsubishi Electric Corporation,
  National Institute of Information and Communications Technology

【Overview】

The 5G Utilization Projects will demonstrate the viability of high speed high quality transmissions to high speed moving vehicles, including trains (Sect. 2.6.1), buses (Sect. 2.6.2) and aircraft and ships (Sect. 2.6.3)

5G's special characteristics of ultra-high speeds, high quality, and low latency will offer devices which are moving at high speeds high speed broadband services, as well as management and monitoring services

New optimal services with applications can also be offered by integrating existing wireless systems and new wireless systems. The ultimate aim is to show the merits of 5G networks to both users of high speed vehicles as well as transportation firms.

2.6.1 Services for Railways

【Overview】

In order to offer high speed, high quality connections in areas where there are many people and devices moving at high speeds, such as railways, it is necessary to build a beaming network. By building a virtual cell network of broadband linear cells with a range of a few kilometers each, which can manage the handover of mobile terminals moving at high speeds and high quality can be ensured. High capacity content like 8K video, as well, with beam controlled highly reliable parallel transmissions, can also be realized. This also means that onboard equipment can be monitored in real time.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

Liner Cellularization ([1] 11.3.5), RAN Virtualization ([1] 11.3.8), Single Frequency Network, Long distance fronthaul

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

Railways (test lines)

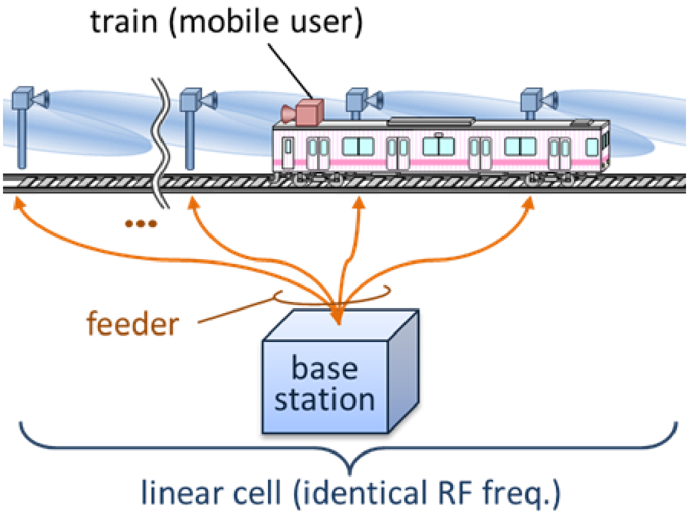


Fig. 2.6.1.1 Broadband services on public transportation systems (trains).

【Trial Schedule】

Year One: Project Planning
Year Two: Manufacturing/placing of instruments
Year Three: First half, construct verification trial areas. Second half, run the verification trial

【Relevant Industries】

Railways, train manufacturers, maintenance firms, information distribution firms, roadside unit vendors, MIC, MLIT, municipalities

【Projected Results】

Verification trials for high speed high quality transmissions for passengers. In addition, applications for driverless vehicles and crime prevention test real time monitoring from inside vehicles is a possibility

2.6.2 Services for Buses

【Overview】

5G is expected to provide high speed broadband services to passengers of public transportation such as buses and trains, where large numbers of users are moving together.

Demonstration trials will show how high-speed broadband can be offered inside vehicles, by building 5G areas on public transportation lines and building 5G automotive UE (user equipment) on the vehicles that go through the 5G area.

All users inside the vehicles will be able to access high speed broadband as well as high-definition video (4K/8K), providing them to experience the wonders of 5G. Furthermore, a built-in communication system will be offered inside of buses, collecting information about the bus or delivering business communications information will be collected inside bus and management business correspondence will be proposed to public transportation agencies when 5G is introduced.

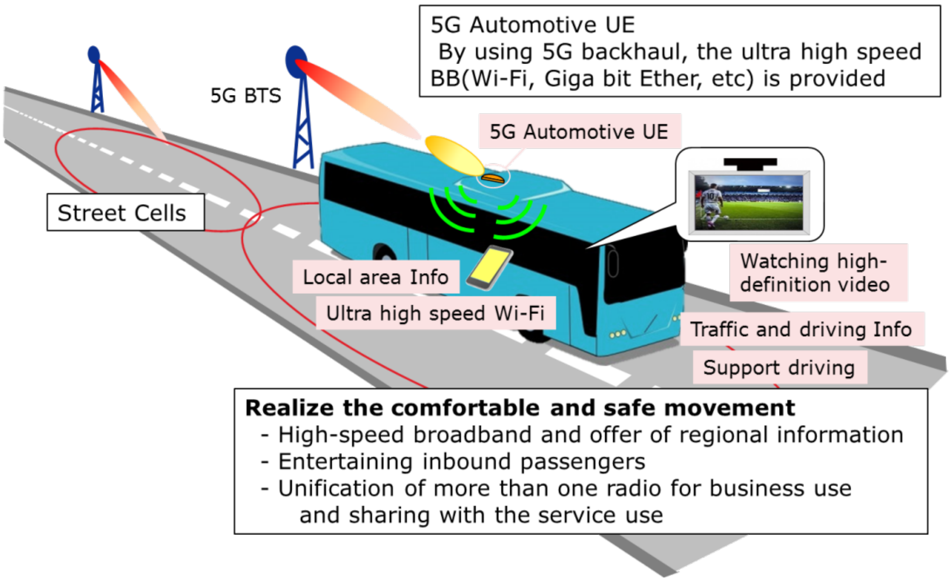


Fig. 2.6.2.1 Bus services.

【Field】

⑨ Transport (Commute/Logistics), ② Entertainment (Games/Tourism)

【Support Technology】

MIMO or multiple antenna technologies ([1] 11.3.4), RAN deployment or is control schemes ([1] 11.3.5), Backhaul technologies ([1] 12.4.3)

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

Bus and train routes that are crowded due to events or busy school or work commute routes, research areas, etc.

【Trial Schedule】

Year One: Verification plan and system specifications are decided.
Year Two: Manufacture test equipment and secure offered contents, and test in a mock environment.
Year Three: Run integrated verification trials using actual equipment

【Relevant Industries】

Public Transportation Agencies, Municipalities, Regional Development Organizations, Content Providers, Advertising Agencies, Radio Wave R&D Trustee, Vendor Firms

【Projected Results】

Public transportation can be offered the opportunity to enjoy mobile broadband in a moving vehicle, just like at home. In addition, the operational efficiency of transportation firm can be improved by the management communications delivered at high speed and internal vehicle data.

In addition, an expected effect is that data traffic's positive offload inside the vehicle will also avoid traffic congestion outside. With a view to the 2020, this system will provide the experience the wonders of 5G to inbound passengers.

2.6.3 Services to Ships and Airplanes

【Overview】

Helicopters and airplanes, which move at fast speeds, will also be able to ultra-high-speed communications services, and can exchange high definition video while above the ground.

High speed moving vehicles on the seas, such as luxury cruise ships and motor boats, can also be offered high quality services at a better quality than what has been available until now.

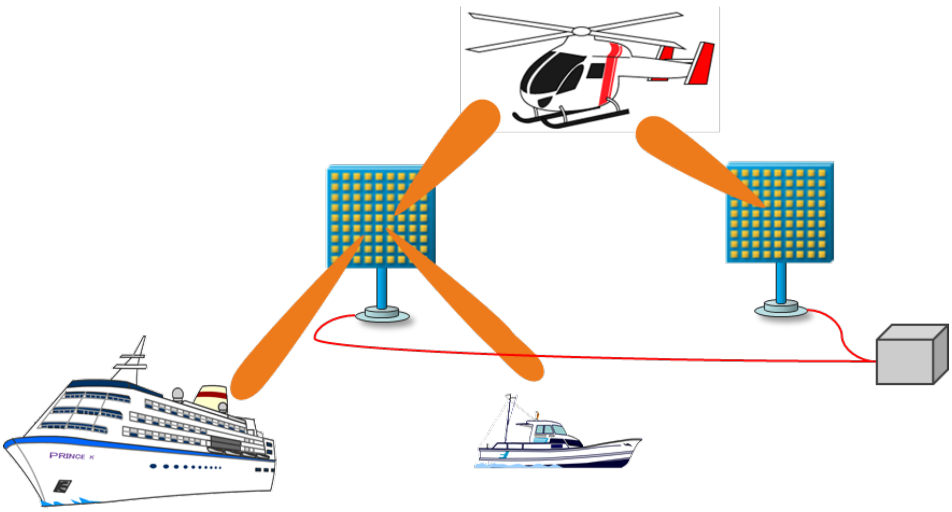


Fig. 2.6.3.1 Services to ships and aerial vehicles.

【Field】

② Entertainment (Games/Tourism), ④ Medical (Health/Welfare), ⑧ Smart Cities/Areas (Construction/Maintenance), ⑨ Transport (Commute/Logistics)

【Support Technology】

3-D beam tracking to connect with high speed moving objects, ultra-high-speed wireless network entry locations: Information of technical works related to MIMO or multiple antenna technologies ([1] 11.3.4), Information of technical works related to RAN deployment or control schemes ([1] 11.3.5), wireless broadcasting to high speed vehicles, broadcast data cache ultra-low latency, high efficiency, high definition video transmission technology

【Evaluation Model (Use Cases)】

eMBB - Dense Urban, Urban Micro/Macro, Rural

【Trial Environment】

On the seas, areas on land with few buildings, around heliports

【Trial Schedule】

Year One: Create concrete service scenarios (run transmission simulations)
Year Two: Field trials for 5G transmissions using high speed moving vehicles
Year Three: Field trials using 5G transmission using ultra high speed moving vehicles

【Relevant Industries】

- Medical and health care facilities, police agencies
- Helicopters, airplane, and shipping firms
- Video content distributors

【Projected Results】

- Make ultra-high-speed, usable data transmission to air and sea transportation a reality
- Provide mobile heath care through emergency transportation vehicles such as medical helicopters
- Provide information support and strengthen security through the use of police helicopters

2.6.4 Services on Public Transportation Vehicles Using Multiple Network Systems

【Overview】

Offer optimal wireless communication system by utilizing a variety of transmission network, together, such as delivering event highlights in high definition video (4K/8K) to trains and train stations and street corners and cars and provide high-speed wireless connections (WiFi, WiGig) to users of expressways and express trains. User confidence in 5G will increase as events become more enjoyable with its use.

【Field】

⑨ Transport (Commute/Logistics)

【Support Technology】

RAN deployment or is control schemes ([1] 11.3.5), RAN Virtualization ([1] 11.3.8), Fronthaul technologies ([1] 12.4.2), Backhaul technologies ([1] 12.4.3), Mobile Edge Computing ([1] 12.5)

【Evaluation Model (Use Cases)】

eMBB - Dense urban, Urban Micro/Macro, Rural
URLLC - Urban Macro

【Trial Environment】

Research facilities (for example, Keihanna Science City, Yokosuka research park) railways and roads and highways

【Trial Schedule】

Year One: Test environment with wireless apparatus and network apparatus to simulate the actual uses with the basic functions to be offered.

Year Two: Test in a mock environment the equipment with integrated functions

Year Three: Integrated verification trials of different aspects of the technology using real world services and at real world events

【Relevant Industries】

Public transportation firms, content providers, advertising agencies, event venues, R&D researchers of radio waves

【Projected Results】

It would be difficult for 5G to meet its requirements as one singular system, so this new wireless system must be integrated with older systems to be used effectively. Demonstrations will show how the mobile communications infrastructure is significant in the age of IoT, with the connection of many different services now and in the future a main goal of 5G infrastructure.

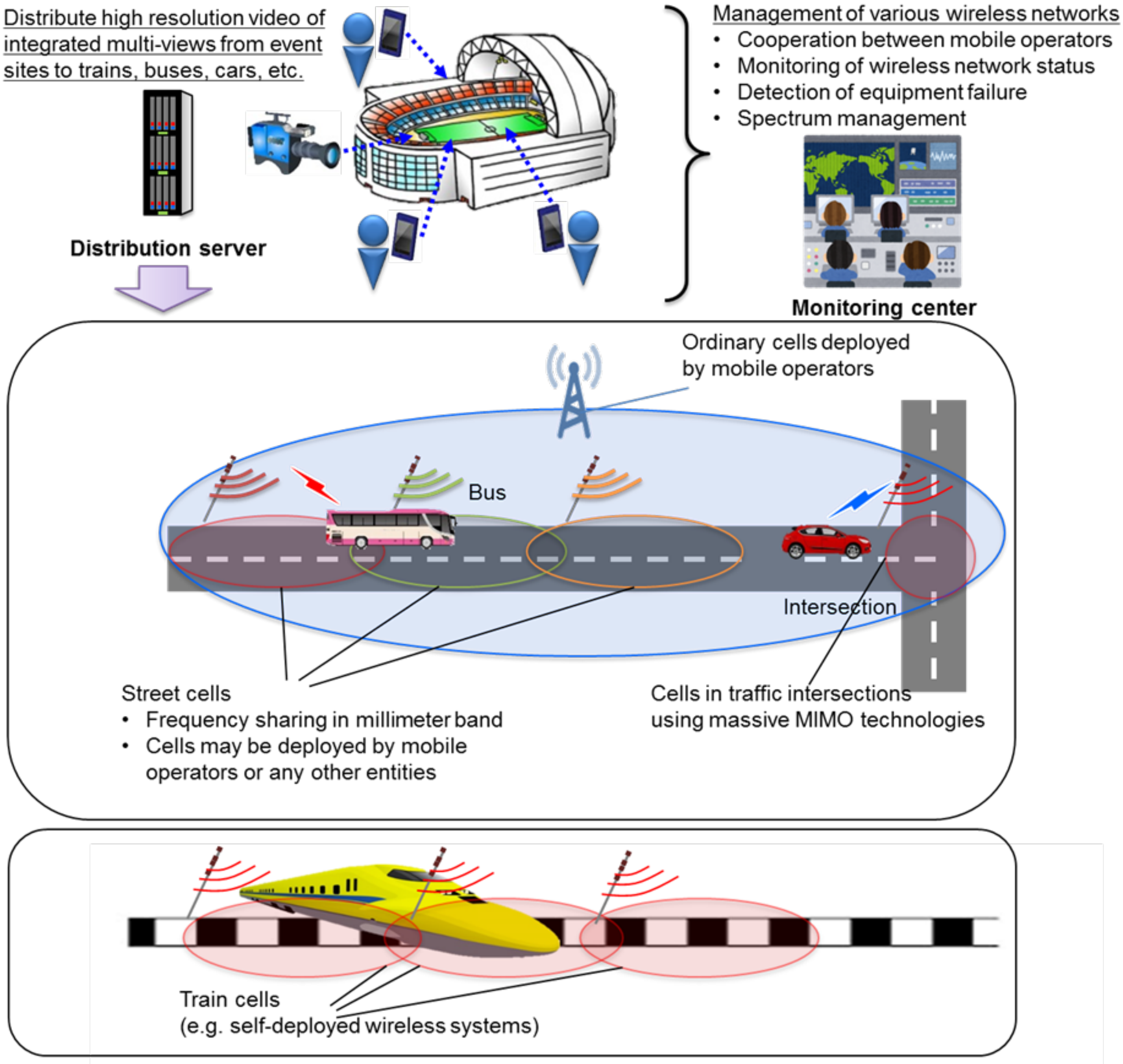


Fig. 2.6.4.1 Services for public transportation systems using a variety of networks.

References

[1] "5G Mobile Communication Systems for 2020 and beyond" 5G Mobile Communication Promotion Forum (5GMF) White Paper, ver. 1.1, Sept. 2017.

Chapter 3　5G Field Trials in Japan 2017-2018

3.1 Overview

The 5th generation mobile communication system 5G is a next generation mobile communication system having features such as "ultra-high speed/large capacity", "large number of connections", "ultra-low latency" etc., which further developed the existing system. It is expected that 5G will be realized as an ICT base of the advanced information society at an early stage.

In recent years, in Japan, activities related to research and development and international standardization of technologies and functions supporting 5G, such as radio access network technologies and others, are rapidly accelerating toward the actualization of 5G in 2020.

From this fiscal year 2017, the Ministry of Internal Affairs and Communications (MIC) "5G Field Trials" has been started, and many stakeholders in various utilization fields participate in the trials as well as those related to the mobile communications industry to create a new market through actualization of 5G.

In this chapter, each group leader promoting the 5G field trial will introduce the content, plan, and outcome of each trial.

	Responsible organization	Main partners	Field	Main locations	Technology
Ⅰ	NTT DOCOMO	・TOBU TOWER SKYTREE ・ALSOK ・Wakayama Pref.	・Sightseeing ・Smart cities ・Telemedicine	・Tokyo ・Wakayama	eMBB
Ⅱ	NTT Communications	・Tobu Railways ・Infocity	・Transport	・Tochigi ・Shizuoka	eMBB
Ⅲ	KDDI	・Obayashi Corp. ・NEC ・Toyota IT Center	・Construction ・Connected car	・Saitama	URLLC
Ⅳ	ATR	・Naha City ・Keikyu Railways	・Entertainment	・Okinawa ・Tokyo/HND	eMBB
Ⅴ	Softbank	・Advanced Smart Mobility Co., Ltd. ・SB Drive Corp.	・Transport	・Ibaraki	URLLC
Ⅵ	NICT	・Itoki ・Sharp ・Softbank	・Logistics ・Smart office	・Miyagi ・Kanagawa ・Osaka	mMTC

Table.3.1.1 5G Field Trials in FY2017

3.2 Demonstration experiment on 5G ultrahigh speed Communication in dense urban environment - Entertainment / Smart City / Medical applications -

- Responsible organization: NTT DOCOMO, INC.
- Partners: SOHGO SECURITY SERVICES CO.,LTD., Ericsson Japan K.K., Fujitsu Limited, Huawei Technologies Japan K.K., INFOCITY Inc., Japan Display Inc., NEC Corporation, Nokia Solutions and Networks Japan Corp., NIPPON TELEGRAPH AND TELEPHONE CORPORATION, NTT Communications Corporation, Panasonic Corporation, Sharp Corporation, TOBU RAILWAY CO., LTD., TOBU TOWER SKYTREE CO.,LTD., WAKAYAMA MEDICAL UNIVERSITY, Wakayama Prefecture

3.2.1 Introduction

The next generation mobile communications system, known as the Fifth Generation mobile communications system (5G), will build upon characteristics, such as eMBB (enhanced Mobile Broad Band), mMTC (massive Machine Type Communication), and URLLC (Ultra Reliable and Low Latency Communication) that enhanced previous generations of mobile communication systems.

Research and development (R&D) of 5G key technologies, such as radio access network technologies, is being directed toward 2020, when 5G will be realized. The 3GPP has also all but completed its deliberations for Release 15, which will define international standards for 5G's initial release in 2020. The MIC began carrying out the 5G Field Trials in fiscal year 2017 [1].

This section introduces NTT DOCOMO's 5G field trial on ultra high bit-rate communication in dense urban environments for entertainment, smart city, and medical applications that is carried out as a part of 5G Field Trials [2],[3].

3.2.2 Overview of 5G Field Trial on Ultra High Speed Transmissions in Dense Urban Areas

NTT DOCOMO tested whether eMBB could achieve the necessary requirements in a dense urban area. In concrete terms, this means that in a proposed outdoor environment with mobility speed of less than 30 km/h, base stations would be able to achieve transmission speeds of 2.4 Gbps (with user equipment (UE) achieving 0.6 Gbps) using the 4.5 GHz band (with a bandwidth of 100 MHz), while base stations using 28 GHz band (with a bandwidth of 800 MHz) would be able to achieve transmission speeds of 10 Gbps, with UE achieving 5 Gbps). The trial to evaluate 5G system performance were carried out with the cooperation of partners working in the fields of entertainment, smart city, and medicine, which are all proposed services that 5G systems will provide. In addition, factor analysis was also carried out in dense urban areas at the 4.5 GHz band as well as the 28 GHz band to establish a radio propagation model (channel model) in order to evaluate system performance. Finally, the channel model was used in a simulation on the assumption of 5G trial equipment at the 4.5 GHz band and the 28 GHz band to evaluate transmission characteristics.

3.2.3 Measuring Radio Propagation Characteristics and Evaluating Transmission Characteristics in Simulations and Field Trials

In order to evaluate the performance of Massive MIMO technology, which will be used to support ultra-high speed transmission, the characteristics of radio propagation characteristics was measured in the dense urban areas of Shinjuku-Ward and Chuo-Ward, Tokyo. The 4.5 GHz band radio propagation characteristics were measured using Massive MIMO technology that came out of 5G R&D project of the MIC. The 28 GHz band radio propagation characteristics were also measured using the power angular profile using multiple horn antennas. In addition, Doppler spectrum, propagation loss, and power delay profile were also measured at the maximum bandwidth of 780 MHz. From the measured radio propagation characteristics, a new channel model in dense urban areas was established by changing propagation parameters in the ITU-R channel model [4].

Furthermore, evaluation of transmission characteristics was also carried out using a 5G link level simulation. A throughput of 2.4 Gbps was confirmed at the 4.5 GHz band using digital beamforming in a four-user environment from a base station at a distance of 900 meters. At the 28 GHz band, a throughput of 10 Gbps was confirmed in a two-user environment using analog beamforming at a distance of 60 meters.

In order to evaluate the 28 GHz band transmission characteristics using the 5G trial equipment, transmission experiments were conducted in over 10 Gbps throughput and long-distance transmissions. In the over 10 Gbps transmission experiment, two transmission points (TPs) in a base station (BS) were mounted in the dense urban Tokyo Skytree area as shown in Fig. 3.2.1. Two UEs in a van and on a trolley measured downlink (DL) throughput, and peak DL system throughput (total throughput) of 10.2 Gbps was achieved.

Moreover, in the long-distance transmission experiment, BS was placed at the Tokyo Skytree's observatory, at a height of 340 meters from ground level, while UE was located on the roof of Tobu Railway's Asakusa station 1.2 kilometers away. Fig. 3.2.2 shows evaluation results in the long-distance transmission using 700 MHz bandwidth. DL and uplink (UL) maximum throughput were 4.5 Gbps and 1.5 Gbps, respectively. The 4.5 GHz band transmission characteristics were also evaluated in Shinjuku-Ward, Tokyo, where four UEs were used for the evaluation, and over 2.4 Gbps DL system throughput was measured.

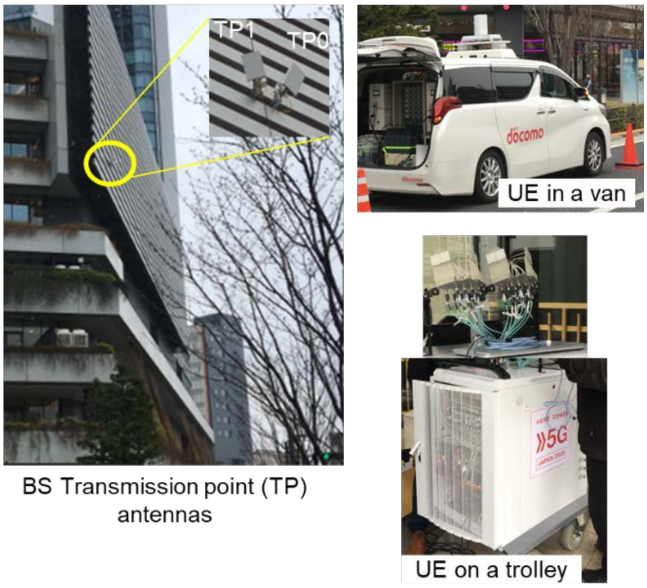


Fig. 3.2.1 Over 10 Gbps transmission experiment using two UEs

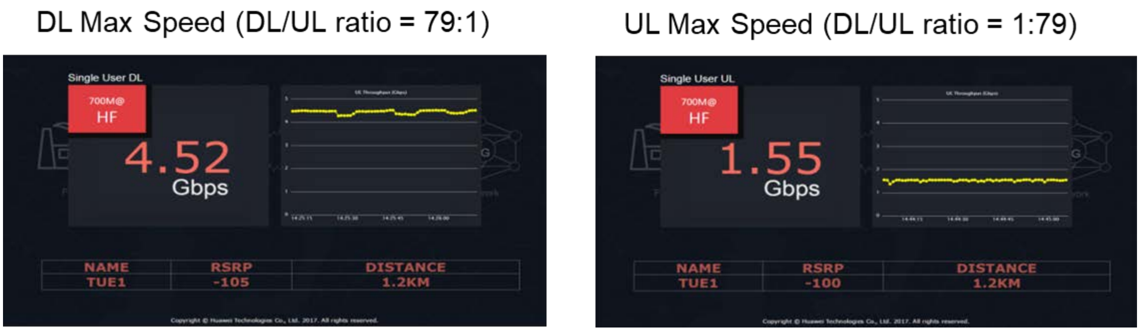


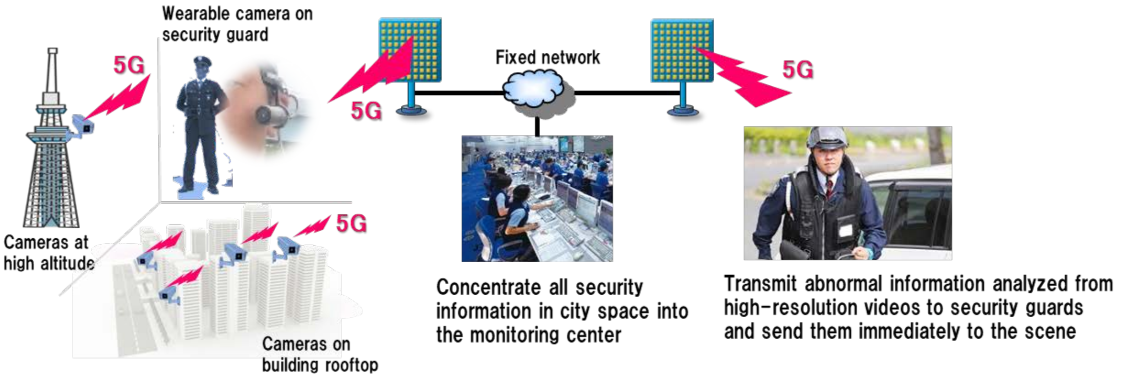
Fig. 3.2.2 Evaluation results in long-distance transmission

3.2.4 5G System Performance Evaluations while Using Services

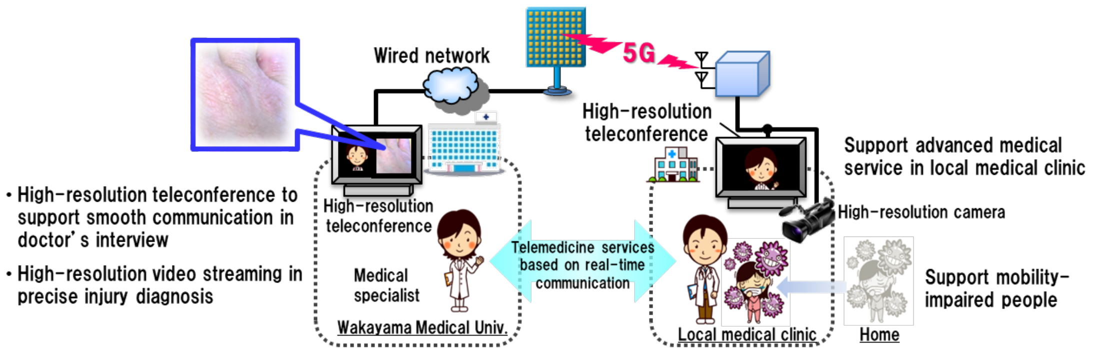
Figure 3.2.3 shows an overview of 5G system performance evaluations for proposed services in the fields of entertainment, smart city, and telemedicine. Specifically, the dense urban areas such as stadiums during the Tokyo Olympics and Paralympics are being considered for the field of entertainment. Assessments of high speed transmissions to deliver high definition high presence video will be carried out. 5G trial equipment systems could deliver 12 channel transmissions of 8K video as shown in Fig.3.2.4 [5]. Since 12 channels transmission of the 8K video requires about 1 Gbps, the larger number of channels can be realized by 5G capability over 10 Gbps. In addition, various kinds of entertainment services such as 4K high-resolution 360-degree camera video transmission, signage by low reflection display in the shopping mall, live transmission of multiple high-resolution 4K videos in the stadium, 3D video chatting by using mixed reality technology were evaluated through the 5G trial equipment.

Moreover, security services in the field of smart city were evaluated. This includes placing security cameras and security personnel with wearable cameras in the dense urban areas such as stadiums at the Tokyo Olympics and Paralympics. These cameras deliver high definition video via 5G networks provided by 5G trial equipment to a security center to be analyzed to cover wide areas to be observed. Evaluations of high definition video delivered to security guards by the 4.5 GHz band 5G trial equipment were carried out in the dense urban areas of Shinjuku-Ward, Tokyo as shown in Fig.3.2.5.

(a) Entertainment

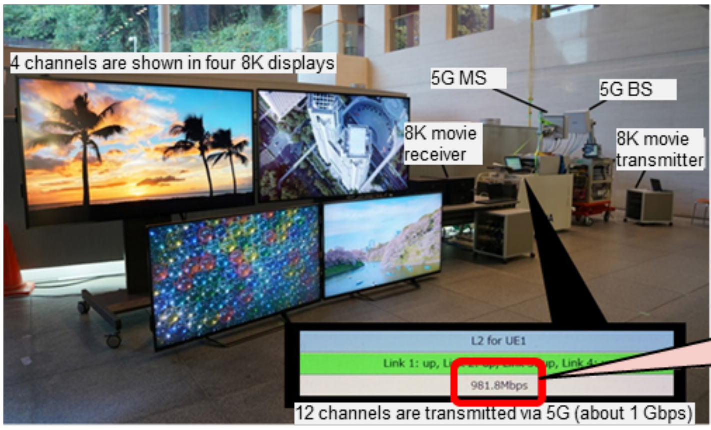


(b) Smart City / Smart Area



(c) Telemedicine

Fig. 3.2.3 5G system performance evaluations



Parameters	
Resolution	8K :7680 x 4320
Frame rate	60 fps
Bit depth	10 bits
Compression method	HEVC
Media transmission method	MMT
bitrate	Average 80 bits / channel

Fig. 3.2.4 8K video multi-channel transmission

Fig. 3.2.5 Remote monitoring by high-resolution video for security

On the other hand, in the field of telemedicine services, Wakayama Medical University and local medical clinic in Wakayama Prefecture were joined to host this trial as an example of a general hospital with advanced medical care and welfare services that could support telemedicine activities. These facilities were connected via 5G networks including wired network and 5G trial equipment. Doctors carried out remote real time diagnostics by exploiting 4K high definition teleconference (video communications), 4K high definition close-up camera, and full HD video taken by tablet-type ultrasonic image diagnosis (echography) as shown in Fig. 3.2.6. Several comments from doctors after actual medical diagnosis for patients were obtained in department of dermatology, cardiovascular internal medicine, orthopedic surgery, and it includes that "improving the quality of the telemedicine services by applying 5G is very useful and it is possible to do medical treatment without feeling that it is a remote location."

Fig. 3.2.6 Telemedicine services exploiting 5G

3.2.5 Conclusion

This section introduced the plans and content, as well as the partial results, of the 5G field trial which NTT DOCOMO carried out on ultra high bit-rate communication in dense urban environments for the MIC's 5G Field Trials. The transmission characteristics at the 4.5 GHz and 28 GHz bands were evaluated by the 5G trial equipment in addition to measurement of the radio propagation characteristics, and over 2.4 Gbps and 10 Gbps system throughput were measured, respectively. In addition, the trial evaluated 5G system performance with the cooperation of partners working in the fields of entertainment, smart city, and telemedicine, and the evaluation results verified that 5G can provide powerful eMBB solutions in the fields.

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[6] NTT DOCOMO, "DOCOMO's Results of MIC 5G Field Trial in FY2017", https://www.nttdocomo.co.jp/binary/pdf/info/news_release/topics_180326_03.pdf, March, 2018.

3.3 Demonstration experiment on 5G high speed communication during high speed movement in rural environment - Entertainment applications -

- Responsible organization: NTT Communications Corporation
- Partners: NTT DOCOMO, INC., NEC Corporation, Ericsson Japan K.K., TOBU RAILWAY CO., LTD., INFOCITY, Inc., Japan Display Inc., Dandelion Ltd.

3.3.1 Introduction

The next generation mobile communications system, known as the Fifth Generation Mobile Communications System (5G), will build upon those characteristics, such as eMBB (enhanced Mobile Broad Band), mMTC (massive Machine Type Communication), and URLLC (Ultra Reliable and Low Latency Communication) that enhanced previous generations of mobile communication systems.

Research and development (R&D) of 5G key technologies, such as radio access network technologies, is becoming stronger as we near 2020, when 5G will be realized. The 3GPP has also all but completed its deliberations for Release 15, which will define international standards for 5G's initial release in 2020. The MIC began holding 5G Field Trials in fiscal year 2017 in order to support the development of new markets for 5G [1].

This section introduces the plans and content of the 5G trial that was contracted out to NTT Communications as part of this 5G Field Trials [2],[3].

3.3.2 5G Field Trial of High Speed Communications While Moving at High Speeds

The 5G trial described here tested the ability to use eMBB at transmission rates of up to 2 Gbps while moving at a speed of 90 km/h in urban or rural areas.

Specifically, a scenario was envisioned where users could access entertainment services that utilize high speed broadband of 2 Gbps on the 28 GHz band (with 800 MHz bandwidth) while travelling in a high-speed vehicle such as a bus or train utilizing 5G system benchmarks supported by NTT DOCOMO and cooperating partners in related fields. A propagation model was established in order to analyze radio propagation characteristics in urban or rural areas while moving in a high speed vehicle at 90 km/h at both the 28 GHz and 4.5 GHz bands. In addition, this propagation model was used to simulate transmission characteristics in order to evaluate the 5G trial apparatus at the 28 GHz band.

The location chosen to evaluate performance of Massive MIMO technology to support high speed transmissions at the 28 GHz band as well as test radio wave propagation characteristics at high speeds of 90 km/h in urban or rural areas was Fuji Speedway.

The trial in 4.5 GHz band used Massive MIMO equipment that came out of 5G R&D project by the MIC. It also measured the power angular profile using multiple horn antennas of the 28 GHz band, as well as measured the Doppler Spectrum, propagation loss, and power delay profile at the maximum bandwidth of 780 MHz.

Fuji Speedway was chosen as the trial environment for the ability to safely evaluate the transmission characteristics of the 5G trial equipment at the 28 GHz band while moving at high speeds of 90 km/h. Trials were also conducted on the Tobu Nikko Line of Tobu Railway.

The overview of 5G system performance evaluation shown in figure 3.3.1 was considered as entertainment services were being planned.

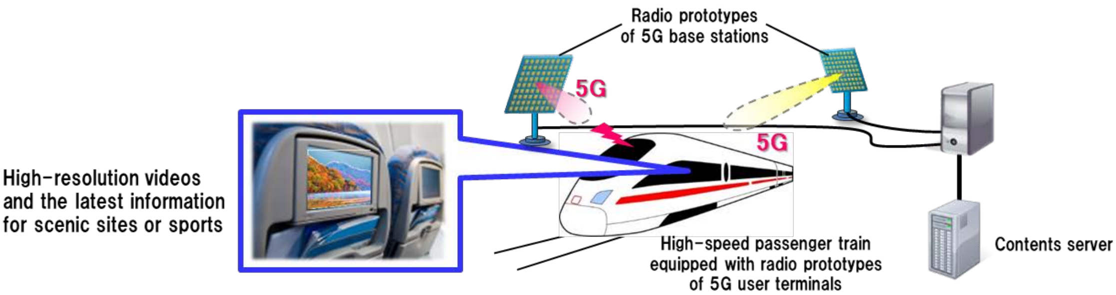

Fig.3.3.1 Overview of 5G system performance evaluation

The delivery of high-presence and high-definition video contents, in both urban or rural areas to be used during the 2020 Tokyo Olympics and Paralympics, not only for spectators of sporting events but also for tourism, were tested using the 5G trial apparatus at the 28 GHz band on vehicles in high-speed environments traveling at over 90 km/h. The trial was conducted in February on the abovementioned Tobu Nikko Line.

Fig.3.3.2 Evaluation environment of 5G transmission characteristic (Tobu Nikko Line)

3.3.3 5G system performance evaluation using 28GHz band for high bit-rate communication with high mobility over 90km/h in urban or rural environments

(1) 5G transmission characteristic evaluation I - Fuji Speedway -

5G radio prototype equipment of mobile station mounted inside measurement vehicle and transmission characteristic is evaluated with moving speed of more than 90 km/h in Fuji Speedway. Transmission characteristic evaluation is conducted in Fuji

Speedway in February, 2018. 5G radio prototype equipment of base station is installed at the end of grandstand in Fuji Speedway. Mobile station antenna is mounted on the rooftop of measurement vehicle that runs a home straight with moving speed of more than 90 km/h.

Item	Specifications of transmission system
Center frequency	27.875GHz
Bandwidth	700MHz
Transmission scheme	MIMO-OFDM
Transmission bit-rate	2Gbps/user
Feature	Handover connect

Fig.3.3.3 Evaluation environment of 5G transmission characteristic (Fuji Speedway)

2.241Gbps throughput is achieved in 90km/h. Ping RTT that is measured from the PC connected to Core to the PC at mobile station is almost 8ms.

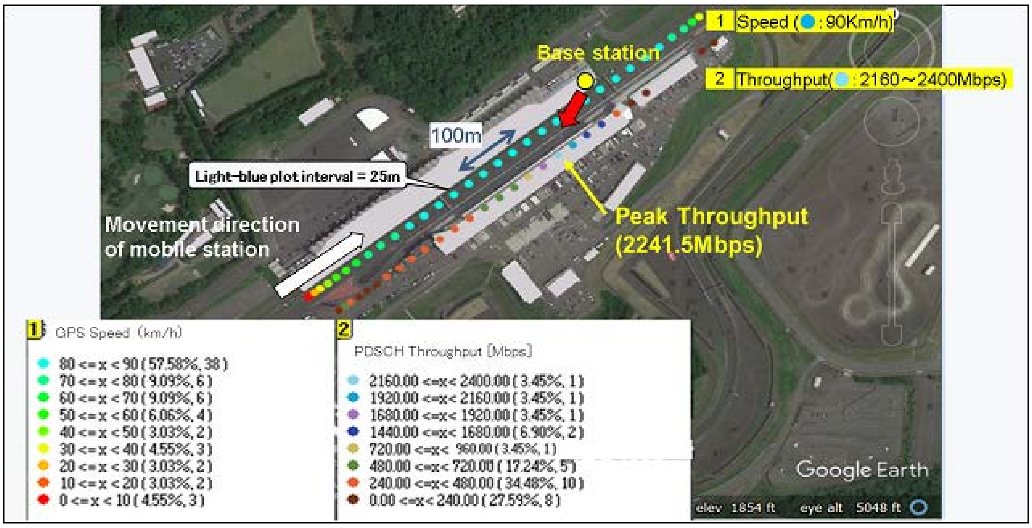

Fig.3.3.4 Evaluation result

(2) 5G transmission characteristic evaluation Ⅱ - Tobu Nikko Line -

5G radio prototype equipment of mobile station is put on train and transmission characteristic is evaluated on the train with moving speed of more than 90 km/h near Ienaka Station of Tobu Nikko Line. Two base stations are installed in Ienaka station. Base station #1 is installed in northern end of the platform and base station #2 is located at a vacant lot in south area of the station building. Mobile station antenna is fixed in crew office area on the Skytree Train to receive the transmitted signal through front window, and the train travels with moving speed of 90 km/h.

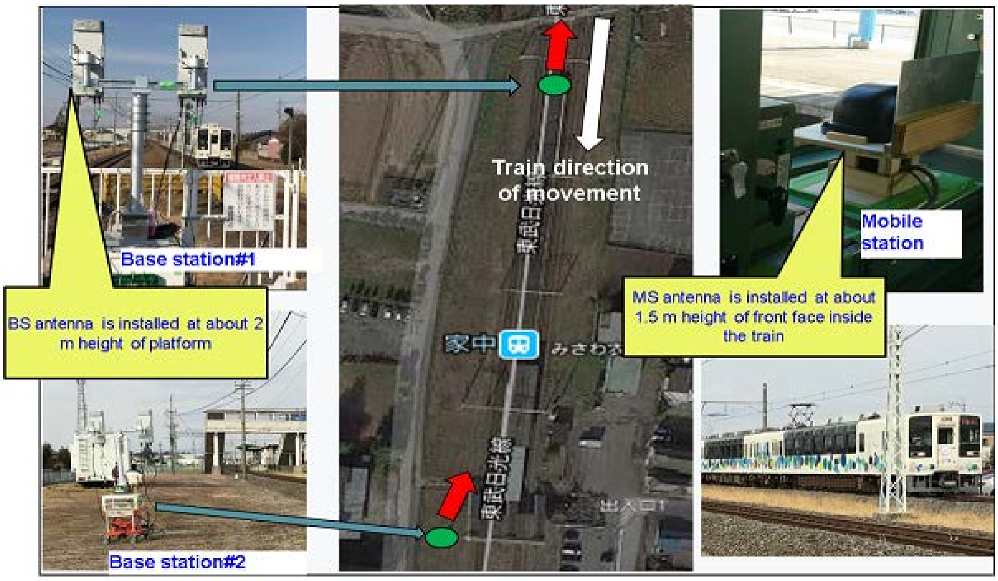

Fig.3.3.5 5G field trial environment for transmission characteristic using train

2.077Gbps throughput is achieved in 90 km/h. Ping RTT that is measured from the PC connected to Core to the PC at mobile station is almost 8ms.

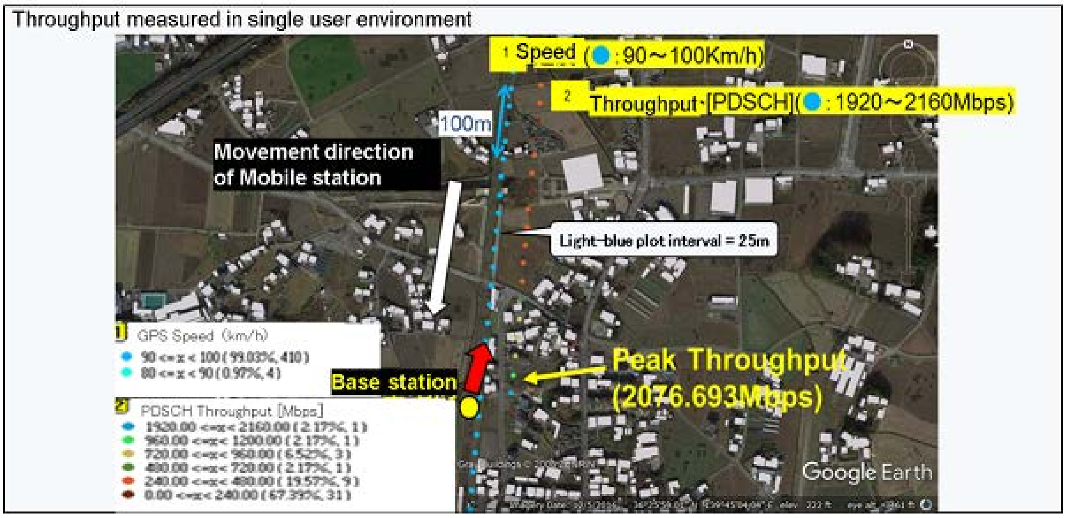

Fig.3.3.6 Evaluation result

(3) 5G system performance evaluation using service

As a entertainment service for railway passengers traveling at speeds of over 90km/h, railway operators are assuming a service that provides large-capacity contents of high-definition video according to a large number of users' request. After 5G transmission of super high definition video contents with 4K/8K is performed, the video contents are played back on display and smart phone.

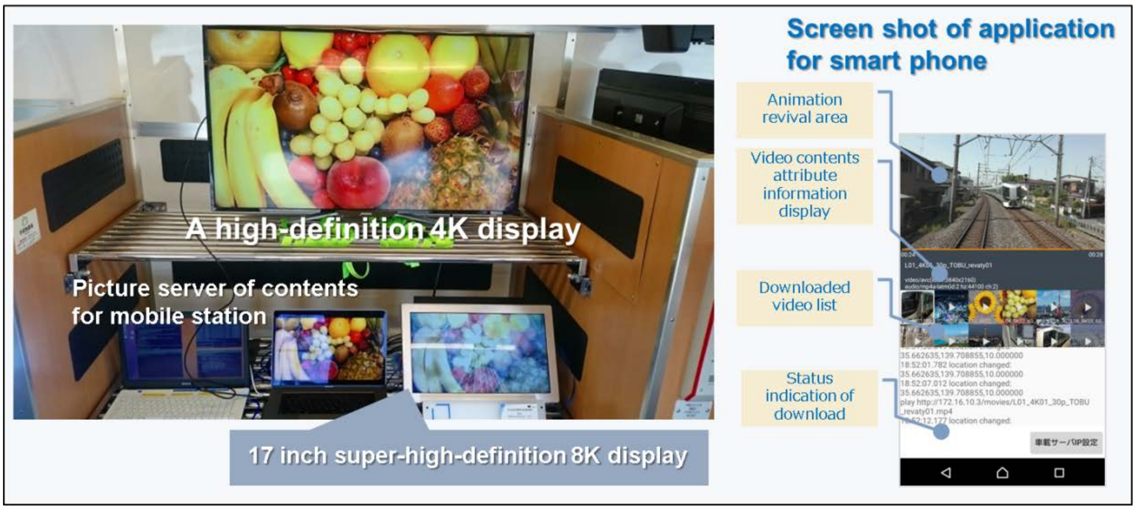

Fig.3.3.7 High-quality video delivery service for high-speed moving vehicles

Actually connected time duration in high mobility of more than 90km/h is almost 21 seconds, and total transmission quantity is 9.524Gbit. In high speed mobility, the transmission bit-rate is changed by the distance between the base station and mobile station and RTT, and thus it's necessary to estimate and establish the quality of the contents in video delivery and required specification of 5G transmission by the most suitable balance.

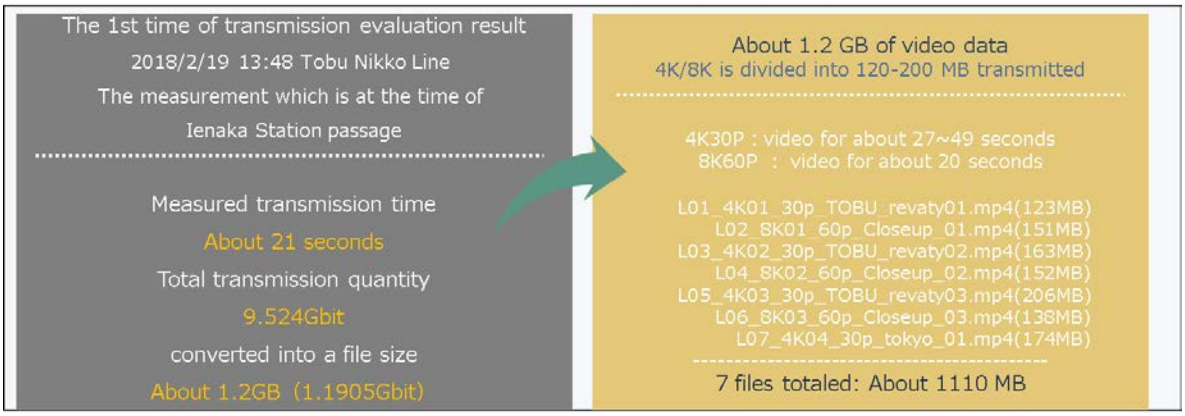

Fig.3.3.8 Evaluation result

3.3.4 Conclusion

Measurements of radio wave propagation characteristics of 4.5GHz / 28GHz band and 5G system performance evaluation using 28GHz band for high bit-rate communication with high mobility over 90 km/h in urban or rural areas. In transmission characteristic evaluation in Fuji Speedway and Tobu Nikko Line, it was confirmed that 2Gbps throughput was achieved.

As an entertainment service for railway passengers traveling at speeds of over 90km/h, railway operators are assuming a service that provides large-capacity contents of high-definition video according to a large number of users' request. After 5G transmission of super high definition video contents with 4K/8K is performed, the video contents are played back on display and smart phone. It's considered by high-speed communication of Gbps order in the high-speed movement environment to deliver a picture clip of the latest news that the 2020 Tokyo Olympics and Paralympics were assumed timely for a passenger of high-speed train.

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[1] MIC, "Beginning the 5G Field Trials", http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000297.html, May, 2017.

[2] NTT DOCOMO, "The State of Cooperative Activities and Progress in the MIC's 5G Field Trial", https://www.nttdocomo.co.jp/info/news_release/2017/05/19_01.html.

[3] Okamura, et al., "System Trials toward Actualization of 5th Generation Mobile Communication System 5G", MWE 2017 WEIB, November, 2017.

3.4 Demonstration experiment utilizing 5G ultra low latency - Remote control for construction machinery , Connected cars, HD video transmission from drones –

- Responsible organization: KDDI CORPORATION
- Partners: TOYOTA InfoTechnology Center Co., Ltd., Obayashi Corporation, NEC Corporation, The University of Tokyo(Nakao Lab.)

3.4.1 Introduction

Ministry of Internal Affairs and Communications (MIC) of Japan started "Field Trials of 5th Generation Mobile Communication System" in the fiscal year 2017, towards the realization of the Fifth Generation Mobile Communication System (5G). Participants of the trials include telecommunication operators as well as "verticals" to be involved in a variety of 5G use cases.

Authors are involved in the trials to verify use cases utilizing the ultra-low latency of 5G and carried out radio propagation characteristics measurement, performance evaluation of 5G radio technologies and 5G applications in both 4.5 GHz and 28 GHz bands, in collaboration with relevant partners in both urban and rural areas. This section overviews the trials.

3.4.2 Evaluation Trial Frequencies, Locations, and Use Case Examples

Table.3.4.2 shows the use cases to be verified by this trial, i.e., connected cars, ICT construction, and 4K video transmission from a drone in the air.

Use Case	Environment	Trial Location	Frequency bands
Connected Car	Urban Rural	Tokyo Aichi	4.5 GHz 28 GHz
ICT Construction	Rural	Saitama	28 GHz
4K video transmission from drone	Urban	Tokyo Kanagawa	28 GHz

Table.3.4.2 Trial Case Examples (GIII)

3.4.3 Overview of Trials

The following three sections overview the use cases of the trials.

3.4.3.1 Connected Car (Fig.3.4.3.1)

In the trial, it is assumed that an instruction is given from a remote operator to a camera mounted on a vehicle moving at 60 km/h, to capture a video stream of the target object. Ultra-low latency is necessary so that the relative location between the target object and the camera will not change drastically from that of the moment when the instruction is given.

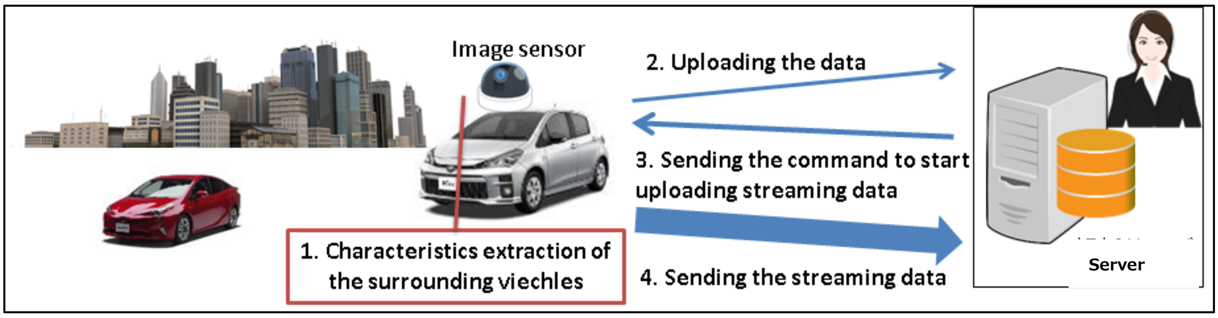


Fig.3.4.3.1 Proposed trial for the Connected Car

3.4.3.2 Remote control of Construction machinery (Fig.3.4.3.2)

In this trial, HD and 4K/3D video streams taken by multiple cameras installed at the construction machinery are transmitted to a remote site via 5G, where an operator controls construction machinery remotely by watching the video streams. The efficiency of remote control is expected to increase by utilizing high resolution video, however, it is not feasible for 4G networks to support high resolution video due to the limitation of data speeds, capacity as well as latency. In the trial in FY2017, the advantage of 5G over Wi-Fi is verified quantitatively.

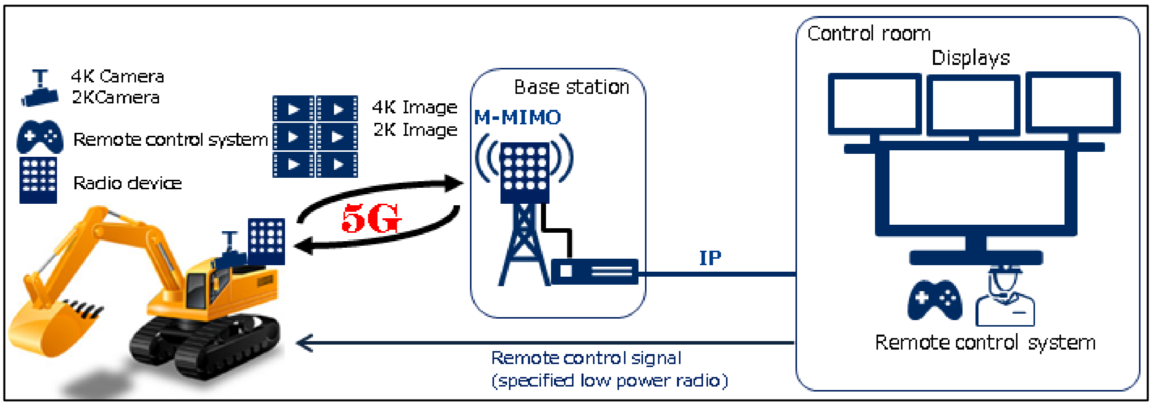


Fig.3.4.3.2 Proposed trial for the ICT Construction

3.4.3.3 4K video transmission from drone (Figure 3.4.3.3)

The objective of this trial is to verify the use case, in which 4K video stream will be delivered from a drone in the air. The video will be used effectively on the occasion of major events, natural disasters and so on. In FY2017, evaluation of 4G performance is carried out as an initial step, as a base line to be compared with 5G.

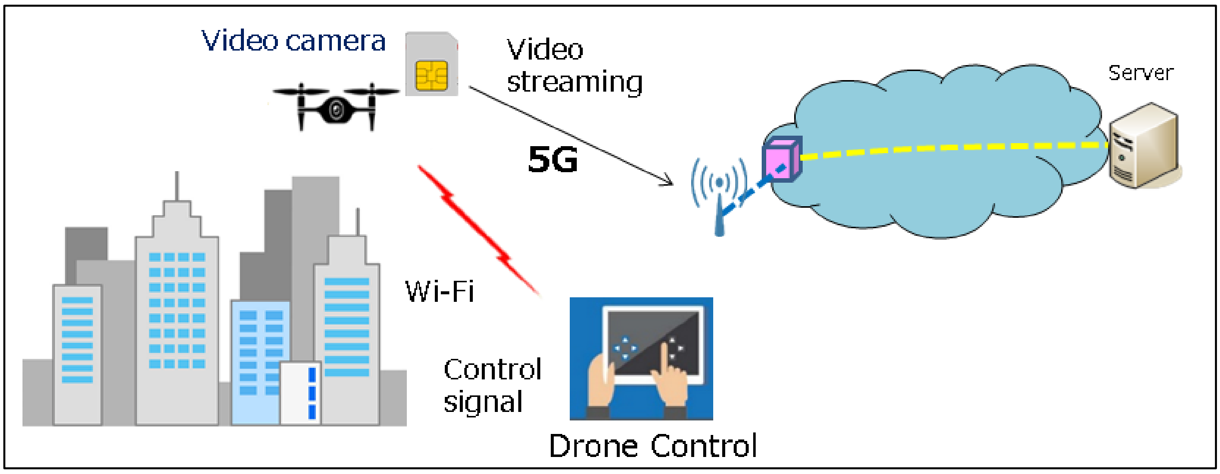


Fig.3.4.3.3 Proposed trial for transmitting 4K video from a Drone

3.4.4 Results of Trials

3.4.4.1 Connected Car

In FY 2017, 5G radio performances were measured in two areas chosen for field trials for connected car applications. One represents urban area: Shinjuku in Tokyo, while the other represents suburban area: Ichinomiya in Aichi. (Figure 3.4.4.1-1, Figure 3.4.4.1-2)

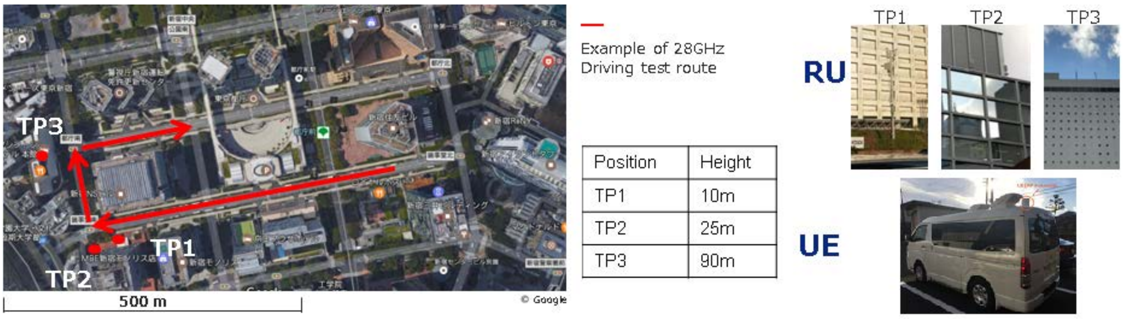


Fig 3.4.4.1-1 Field trial area and locations of base stations in Shinjuku

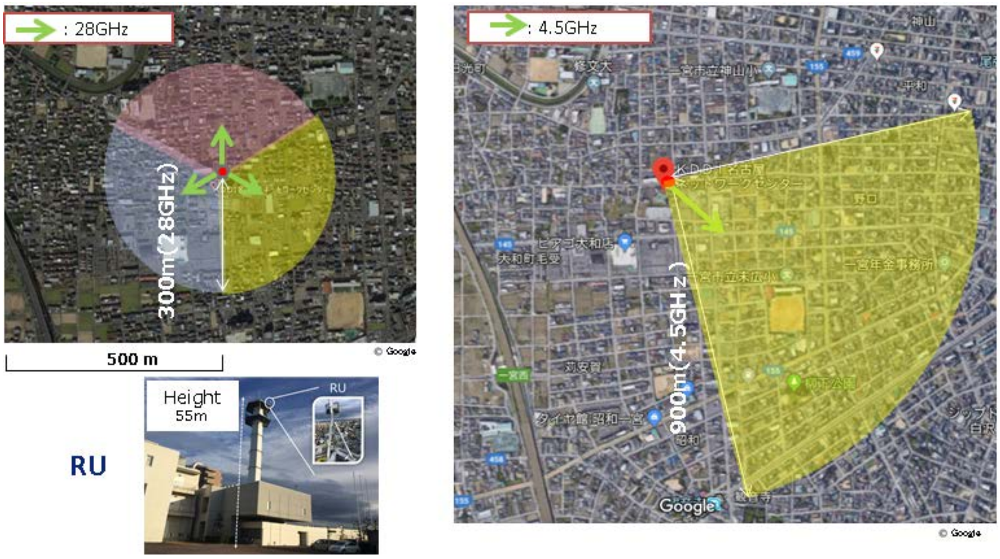


Fig 3.4.4.1-2 Field trial area and locations of base stations in Ichinomiya

Figs. 3.4.4.1-3 and Fig 3.4.4.1-4 illustrate sample radio performances in Ichinomiya in 4.5GHz and 28GHz.

In both 4.5GHz and 28GHz, following results are observed;

- Throughputs fluctuate according to the surrounding environment, including buildings and distance between BS and UE.
- Correlation between DL and UL throughput is observed.
- Throughputs are affected by blocking. The degradation is severer in 28GHz than in 4.5GHz.
- The median value of latency in one-way radio link is 0.935ms in 4.5GHz and 0.915ms in 28GHz, respectively, although latency increases according to channel quality degradation.

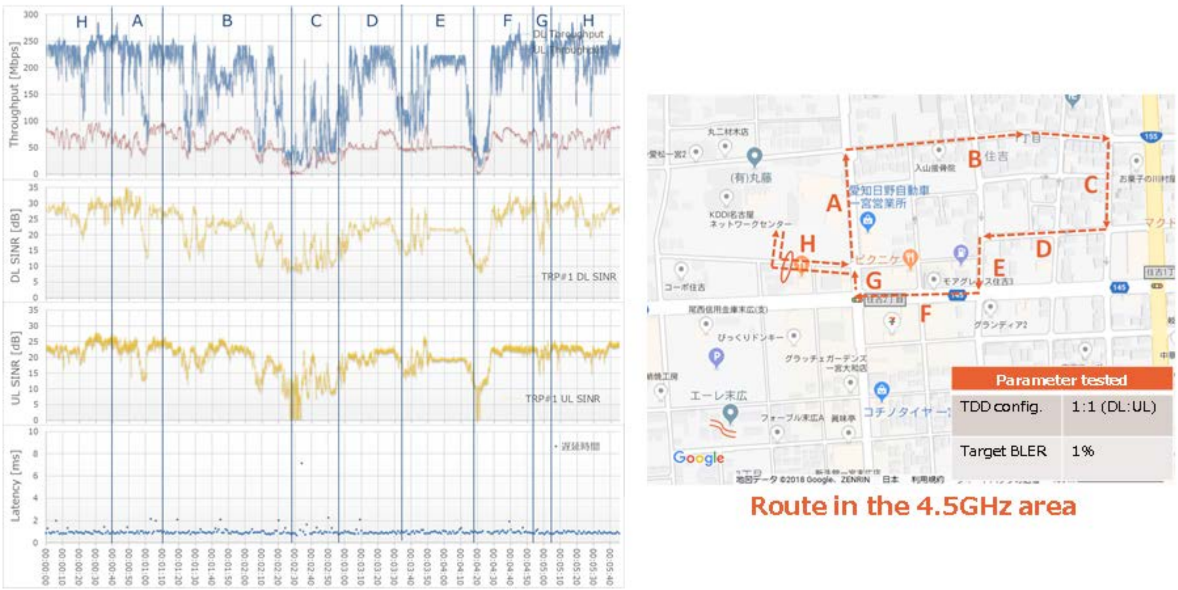


Fig 3.4.4.1-3 Measured Result in 4.5GHz (Ichinomiya)

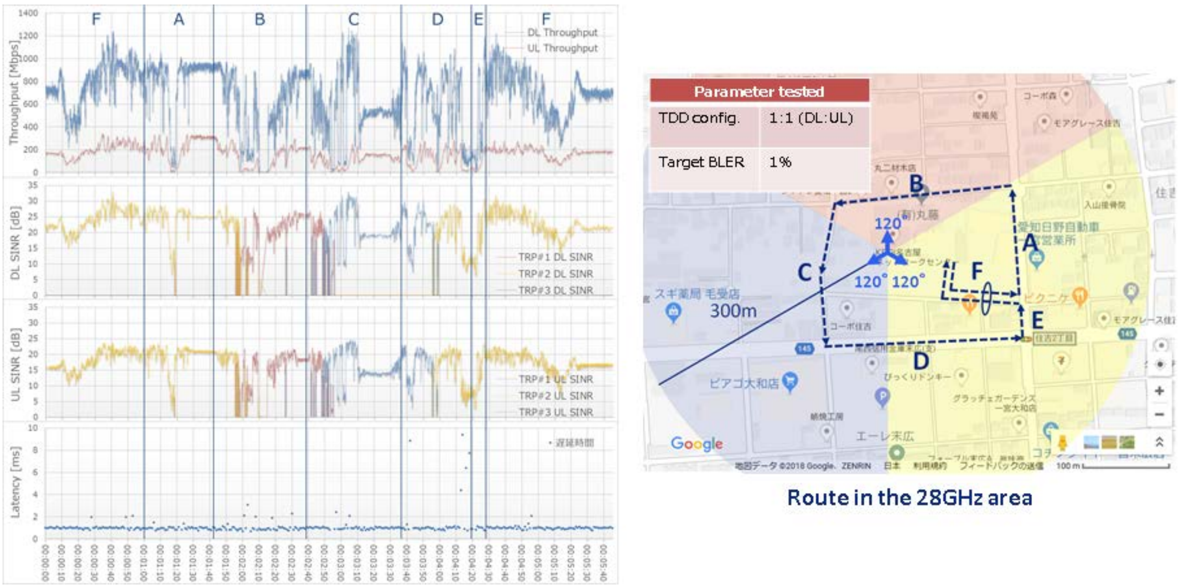


Fig 3.4.4.1-4 Measured Result in 28GHz (Ichinomiya)

Degradation of 4.5GHz is comparatively smaller than that of 28GHz in “section 2”, where influence of surrounding buildings is susceptible.

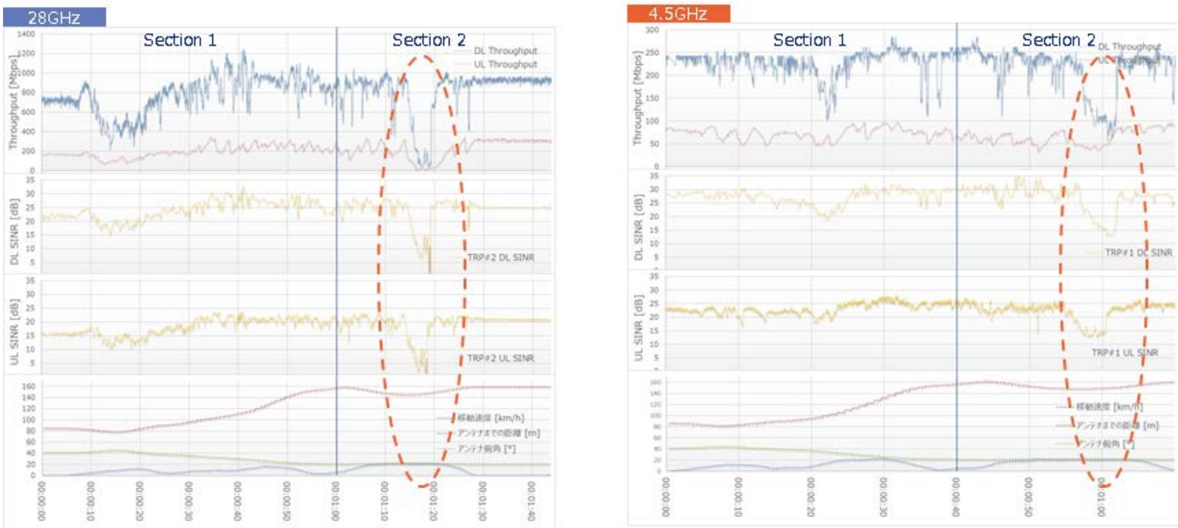


Fig 3.4.4.1-5 Comparison between 4.5 & 28GHz (Ichinomiya)

3.4.4.2 Remote control of Construction machinery

Quick relief and recovery of social infrastructure are of imminent importance in case of natural disasters in Japan. In some cases, operation of construction machinery is required in inaccessible environment. Working population is on the decrease in Japan, in particular, shortage of specially skilled workers is prominent.

Remote operation of construction machinery is one of the solutions in order to cope with the issues above and is already in use in some cases. However, current remote operation system using Wi-Fi bear following restrictions;

- Capacity is not sufficient. Video quality and the number of machinery controllable at the same time in one place is restricted.
- Radio quality may not be stable, affected by radio interference.

As a result, efficiency of remote operation using Wi-Fi is reduced by about 50-60% in general, as compared with manned operation. The capability of 5G is expected to improve efficiency in remote operation.

In the testing illustrated in Fig 3.4.4.2-1, time required for stacking three blocks by construction machinery (i.e. backhoe) was evaluated as a quantitative measure of efficiency.

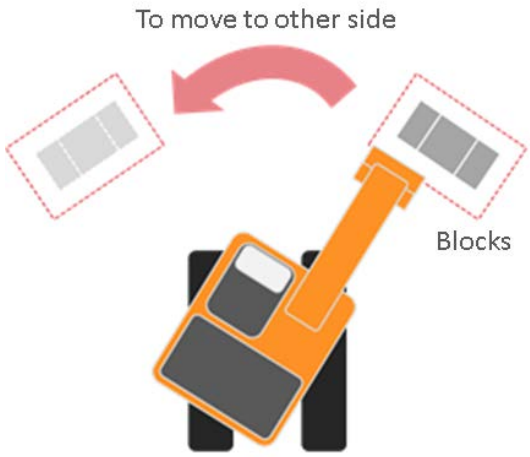


Fig 3.4.4.2-1 Image of experiment

Fig 3.4.4.2-2 shows the test results: remote operation using 5G improved construction efficiency by 35% as compared with Wi-Fi, mainly due to improved information quality and reduction of burden on an operator by three-dimensional 4K high definition video. Total system delay (E2E) is about 600ms, comprising processing delay of codec, 4K video equipment, 3D monitor etc.

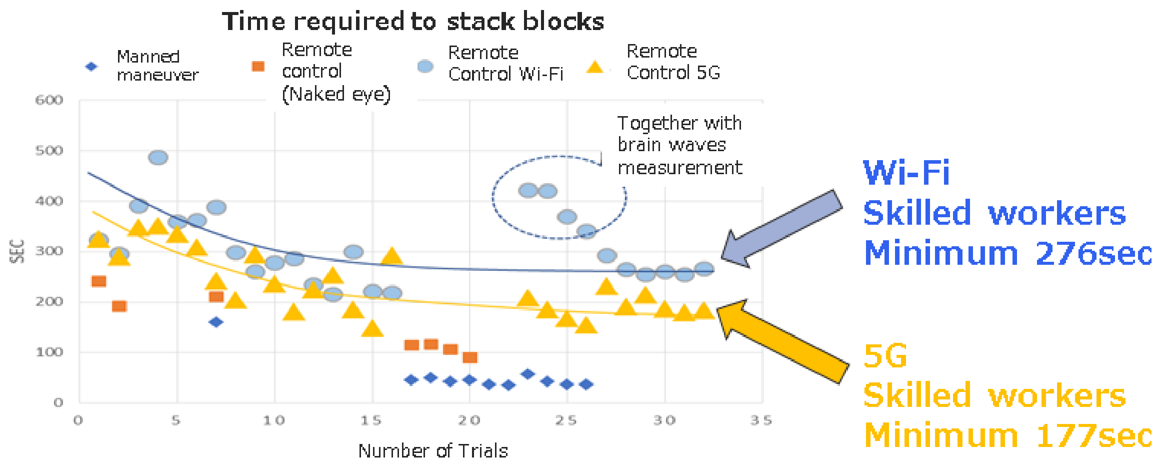


Fig 3.4.4.2-2 Experimental result of ICT construction

3.4.4.3 4K video transmission from drone

In FY 2017, preliminary testing using 4G/LTE was performed and it was revealed that it was difficult for 4G system to provide sufficient capability for 4K video uplink from drone in a stable manner.

3.4.5 Conclusion

This section provides an overview of the Group III trials of the 5G integrated verification trials in FY2017, taking advantage of ultra-low latency characteristics of 5G.

References

1. MIC, "Beginning the 5G Field Trials,"
http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000297.html May, 2017.
2. Okumura, et al., "Integrated Verification Trials Looking Towards the Realization of a Fifth Generation Mobile Communication System" MWE 2017 Proceedings, 2017.

3.5 Demonstration experiment utilizing 5G ultra high speed in indoor environment - Stadium entertainment, Safety and security in train stations, ICT education -

- Responsible organization: Advanced Telecommunications Research Institute International(ATR)
- Partners: KDDI CORPORATION, Keikyu Corporation, Koganei City Board of Education (Maehara Elementary School), Naha City Board of Education, Panasonic Corporation, WASEDA University

3.5.1 Introduction

Japan's Ministry of Internal Affairs and Communications (MIC) started the 5G Field Trials in 2017 as part of the move towards the realization of the fifth generation mobile communication system (5G). Trial participants not only include relevant mobile telecommunications firms but also those in other relevant use fields, because 5G is expected to bring about the creation of new markets in a variety of sectors. Trial participants were divided into six groups considering 5G's unique characteristics (such as ultra-high speeds, massive multiple communications, and ultra-low latency) and evaluation environments.

This section was written by members of group IV working with their affiliated organizations researched the utilization of ultra-high transmission speeds in indoor environments. The trial used the 28 GHz band to analyze 5G's performance as well as proposed applications in specified use cases. In addition, radio propagation characteristics were also analyzed. This section discusses our plans and outcomes of this research.

3.5.2 Trial Locations

Trials were held in the following representative indoor and enclosed spaces.

Environment	Place	Location
Stadium	Okinawa Cellular Stadium Naha	Naha, Okinawa
Station (Underground)	Haneda International Airport Terminal Station (Keikyu Line)	Ota Ward, Tokyo
School	Maehara Public Elementary School	Koganei City, Tokyo

Fig.3.5.2 Overview of Trials

3.5.3 Process of Evaluating Proposed Applications

We evaluate performance of proposed trials for utilizing 5G. Overviews of three trials are shown as follows.

3.5.3.1 Stadium

There will be more ways to enjoy live entertainment through the application of the unique characteristics of 5G, such as being able to freely choose any viewing point instantaneously via video transmission. We held a trial evaluating multiple simultaneous transmissions of High Definition Video in 2017 in order to make this a reality.

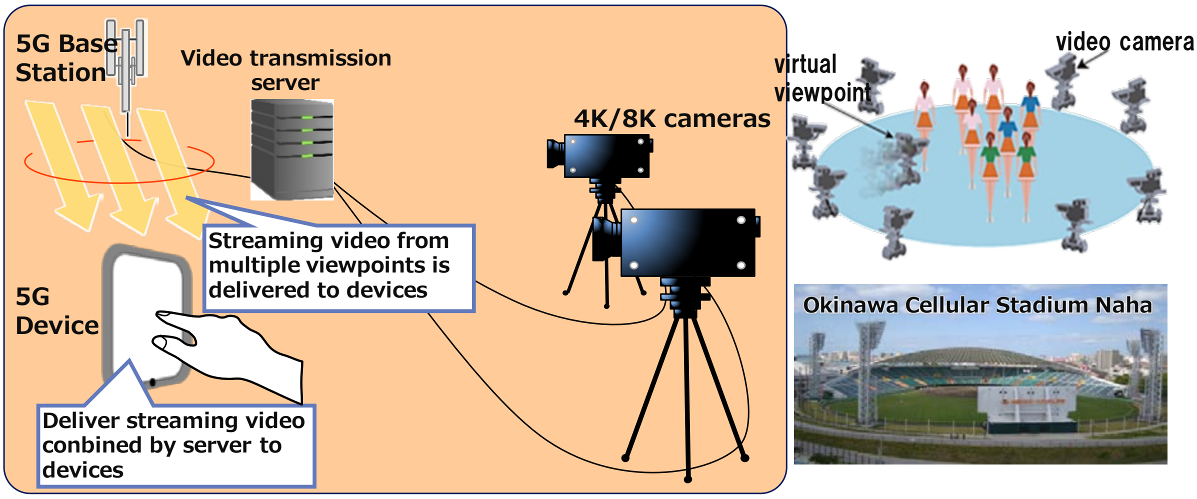


Fig.3.5.3.1-1 Proposed Trial for Stadium

(1) 28GHz Propagation Measurement

We conducted propagation measurements in a stadium using 28GHz band which is assumed to be used in 5G. A heat map of propagation losses in the stadium is shown below. As there were few obstacles in the stadium, the propagation loss was close to free-space propagation loss.

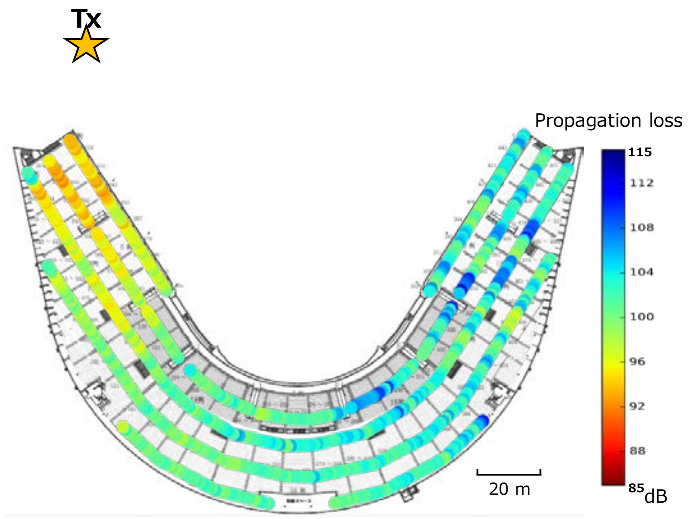


Fig.3.5.3.1-2 Propagation loss in the stadium

(2) High-Definition Video transmissions tests

We conducted a simultaneous transmission test of High Definition video using 5G, with fifty 5G terminals set on the audience seats in the stadium.

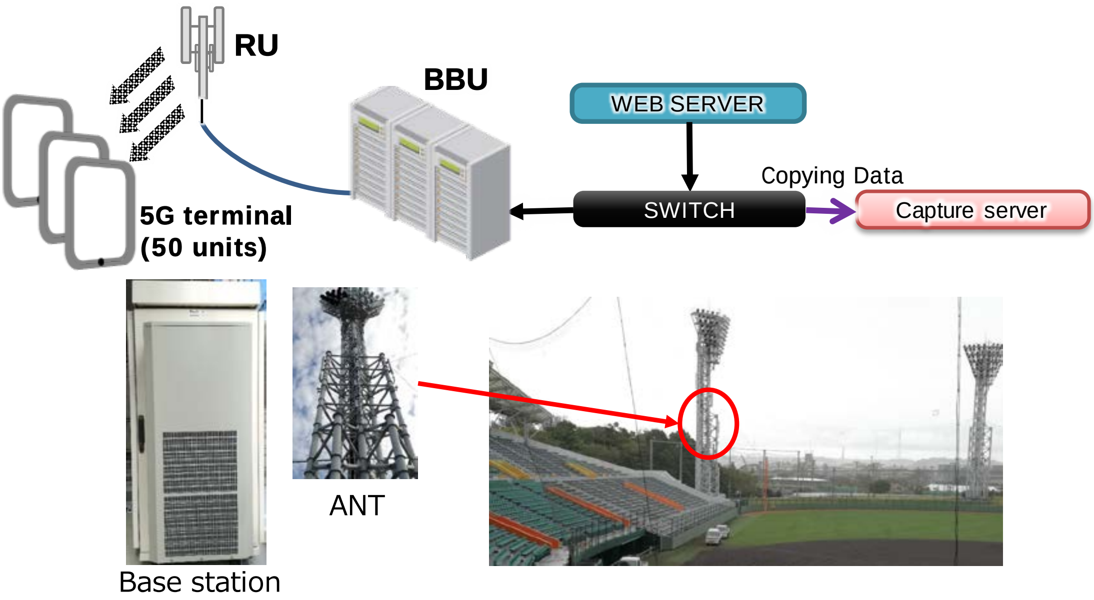


Fig.3.5.3.1-3 Test Configuration

As a result, we confirmed that 4K High-Definition video was successfully transmitted to each 5G terminal using 5G.

3.5.3.2 Station

We have a plan to evaluate applications that analyze high definition video via 5G to autonomously detect dangerous items and suspicious situations in order to provide a safe station environment for passengers and staff in a railway station.

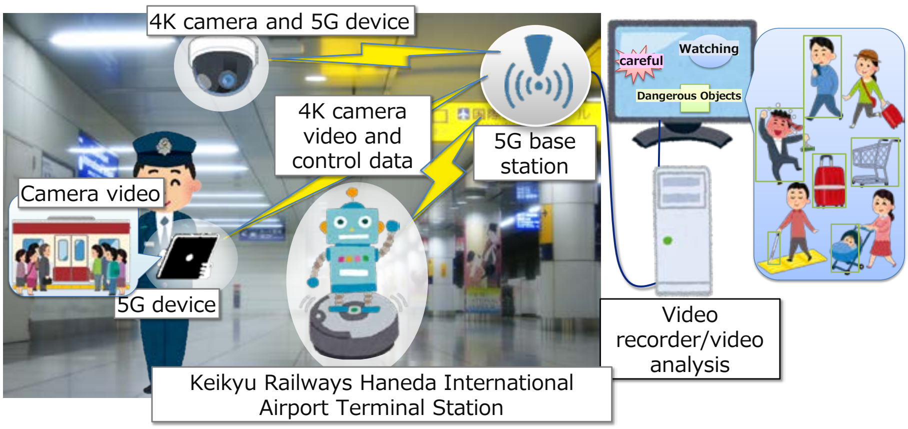


Fig.3.5.3.2-1 Proposed Trial for Station

(1) 28GHz Propagation Measurement

We measured 28 GHz band propagation in the station platform. Photographs of experimental scenery are shown below.

Fig.3.5.3.2-2 Experimental site and experimental system

A heat map of propagation losses in the station platform is shown below. In a LOS area on the platform, the propagation loss was close to free-space propagation loss.

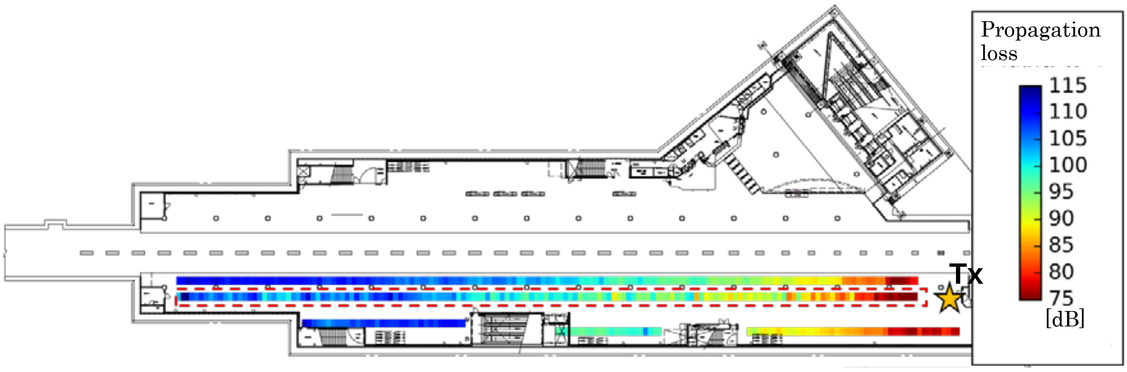


Fig.3.5.3.2-3 Propagation loss in the station platform

(2) Basic evaluation of image analysis application of High-Definition image

We conducted a basic evaluation of high definition image analysis application using 4K video as a preliminary study and evaluation in 2017.

Fig.3.5.3.2-4 Comparison of human detection ranges

In human detection using image analysis, it was confirmed that human detection range of 4K image was almost twice as much as of 2K image.

3.5.3.3 School

One desired use case at schools for 5G is to give schools the ability to access large data files simultaneously using multiple ICT devices in order to improve a learning environment.

Fig.3.5.3.3-1 Proposed Trial for Schools

(1) Basic evaluation using 4G system

In 2017, we evaluated a performance of simultaneous access of large size contents using 4G as a preliminary study and evaluation. 71 elementary school students participated in the experiment.

The evaluation results are shown below. The left diagram shows the distribution of time spent to upload the videos (size 37 MB to 400 MB) created by students. The right diagram shows 4G uplink throughput (upload rate).

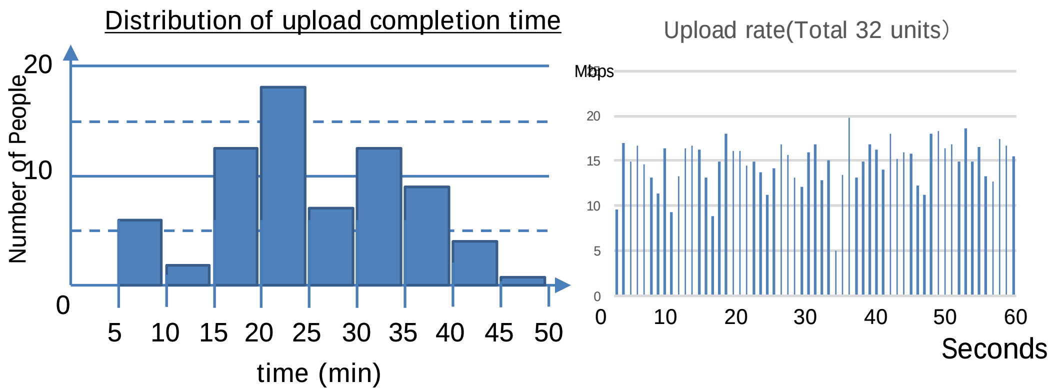


Fig.3.5.3.3-2 Evaluation results

We found the following from the evaluation.

- Uploading is not completed during class due to uplink speed limit (10-20Mbps).
- In the class, upload is required in about 1 minute (questionnaire to the teachers).
- High speed (1Gbps) is required for uplink. 5G ultra high speed is expected.

3.5.4 Conclusion

This section discussed our plans and performance evaluations of proposed trials at indoor and enclosed spaces, utilizing the special characteristics of 5G such as ultrahigh speed communications in 28 GHz.

References

1. MIC, "Beginning the 5G Field Trials," http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000297.html May, 2017.
2 Okumura, et al., "Integrated Verification Trials Looking Towards the Realization of a Fifth Generation Mobile Communication System" MWE 2017 Proceedings, 2017.

3.6 Demonstration experiment on 5G ultra low latency communication for assisting autonomous driving - Truck platooning applications -

- Responsible organization: SoftBank Corp.
- Partners: Advanced Smart Mobility Co., Ltd., SB Drive Corp.

3.6.1 Introduction

Research and development is underway towards the commercial roll-out of the Fifth Generation Mobile Communication System (5G) in 2020. 5G supports not only an enhanced Mobile Broadband (eMBB) but also Ultra Reliable and Low Latency Communication (URLLC) and massive connections for Machine Type Communication (MTC), massive-MTC (m-MTC). Especially, URLLC and m-MTC would potentially expand the mobile communication market to the new areas, such as mission critical and networked industrial applications. It is therefore urgent to identify new and concrete use cases as applications utilizing 5G.

In Japan, the Ministry of Internal Affairs and Communications (MIC) began its 5G Integrated Verification Trials in 2017 [1]. This trial not only attempts to demonstrate the technical evaluation of 5G systems for their future commercial roll-out, but also to invite vertical industries and a telecommunication industry to participate the trials with a view to assessing potential 5G applications and use cases.

SoftBank Corporation actively participates the MIC's trials as a member of the Trial Group V, which focuses a 5G URLLC aspect. This section introduces the Group V's activities, including the use case of truck platooning utilizing 5G networks.

3.6.2 Utilizing 5G for Truck Platooning

Truck platooning is the electrical linking of two or more trucks in convoy. They move on the highway together as one group to reduce fuel consumption and CO2 emission as well as to achieve more efficient use of roads, i.e. to improve road traffic capacity. The research and development of truck platooning is currently being conducted all over the world to this end.

Truck platooning can solve several social problems, such as CO2 emission, traffic congestion and aging drivers and their severe work environment. If platoons drive with a shorter inter-vehicle distance, air resistance affecting vehicles could be reduced, resulting in lower fuel consumption and less emission of CO2 into the atmosphere. For example, it has been demonstrated that 3 trucks running in a platoon, driving at 80 km/h while separated by the distance of 4 meters, decreases those vehicles' fuel consumption by 15% [2]. If the distance between the trucks further reduces to be only 2 meters, there could be fuel savings of 25%. At the same time, this would also lead to an increase in the capacity of roads while mitigating traffic congestion. This would result in further CO2 reductions. In Japan, the aging of drivers and overworking are becoming crucial social issues, since these increase traffic accidents and severe working environment. It is expected that stress of the driver be reduced and safety be improved by the introduction of the truck platooning.

Adaptive Cruise Control (ACC) measures a distance between a lead vehicle and a trailing one by using radar and keeps an inter-vehicle distance safe, corresponding to its vehicle speed. ACC is widely introduced in trucks to help to improve safety on the roads. There is, however, a large time delay from the instant that the deceleration of the vehicle ahead begins and that the distance between the lead and trailing vehicles becomes shorter. It further takes a larger delay until the deceleration of the trailing vehicle begins. So, in general, the longer inter-vehicle distance is needed to prevent a collision by using ACC alone. On the other hand, a Cooperative ACC (CACC) can significantly improve the controllability when the vehicle ahead suddenly brakes, because the CAAC controls vehicle speed by transmitting the speed and acceleration data of the vehicle ahead to the following vehicles. In addition, CACC provides stable running without hunting (fluctuation of inter-vehicle distance) due to its shorter latency. To realize further improvement in fuel economy and to increase road traffic capacity, less inter-vehicle distance and larger numbers of vehicles in the truck platooning is necessary without compromising safety. The application of 5G URLLC to the area of truck platooning is highly expected since 5G provides ultra-low latency and high reliability.

3.6.3 Trial Overview

The Group V is working on two use cases to demonstrate 5G's ultra-low latency capabilities as follows; (1) communications between vehicles for platooning, (2) communication for remote monitoring / control of platoon from a remote site.

These use cases are shown in Fig.3.6.3.1 and Fig.3.6.3.2.

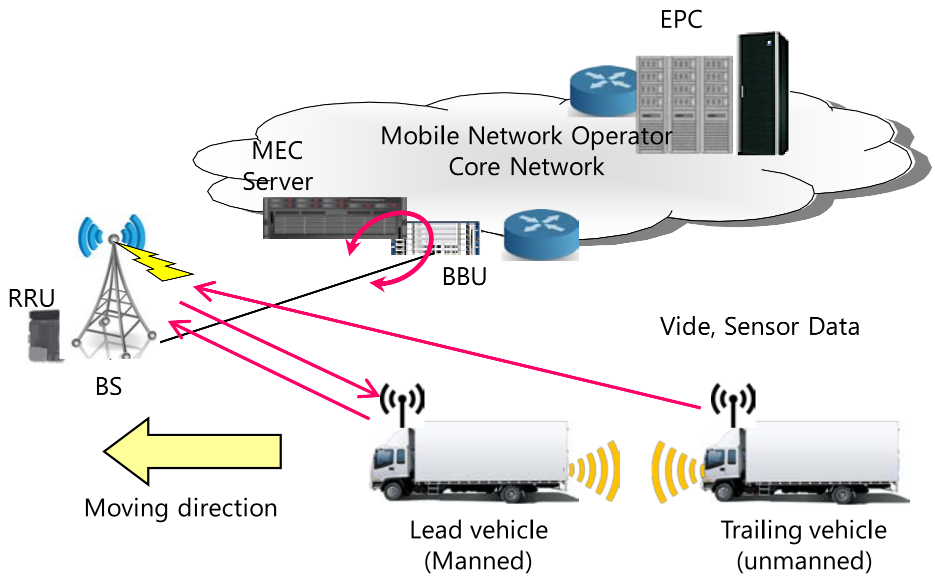


Fig.3.6.3.1 Use Case 1: Communications between vehicles in Truck platooning

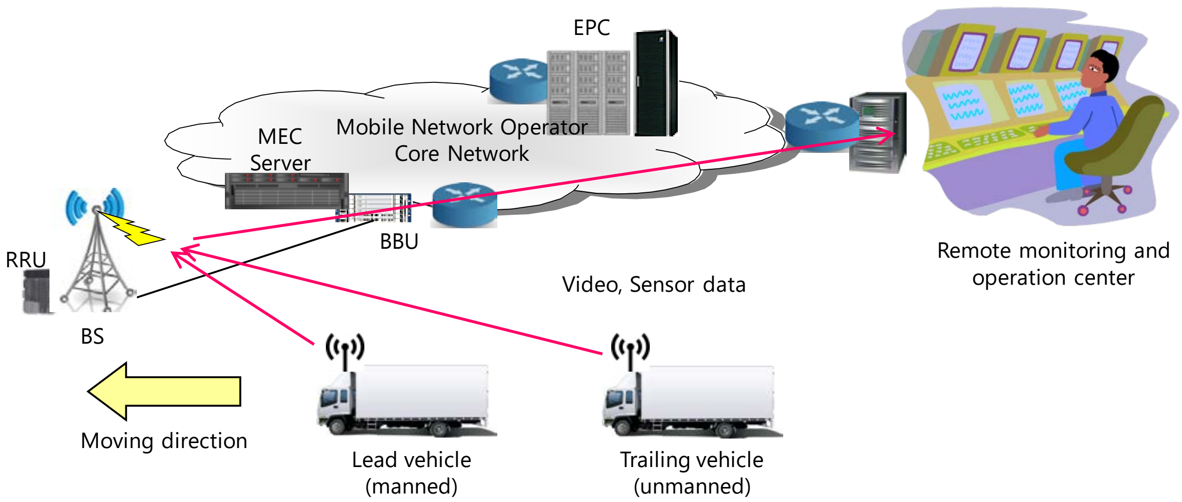


Fig.3.6.3.2 Use Case 2 : Remote monitoring / control for truck platooning

Communication Requirements for these use cases can be classified into two categories; (1) low capacity and low latency communication and (2) high capacity and low latency. The first category is required for vehicle control system, which transmits and receives information of vehicle speed, acceleration and vehicle positioning. This category also requires high reliability. The second category is required for video monitoring system for platooning, which transmits and receives video streams to monitor areas around the trailing vehicles.

Fig.3.6.3.3 shows three types of communication for platooning; (1) V2N2V (Vehicle-to-Network-to-Vehicle), (2) V2V (Vehicle-to-Vehicle) Direct / Sidelink and (3) V2N (Vehicular-to-Network).

V2N2V is a vehicular-to-vehicular communication link via a base station to connect the vehicles. V2V direct is a communication link, which directly connects the vehicles. V2N is a communication link which connects the vehicles to a mobile network. The V2N2V link (1) provides relatively low latency and stable communication with the support of a base station. The V2V direct link (2) provides lower latency communication, being compared with the link V2N2V (1), but has a possibility of less reliable communication due to the interrupt of radio waves by other vehicle going in between the two trucks. The V2N link (3) is required for a remote monitoring of vehicles and a remote operation of vehicles. The link has a large latency which mainly comes from the mobile core network.

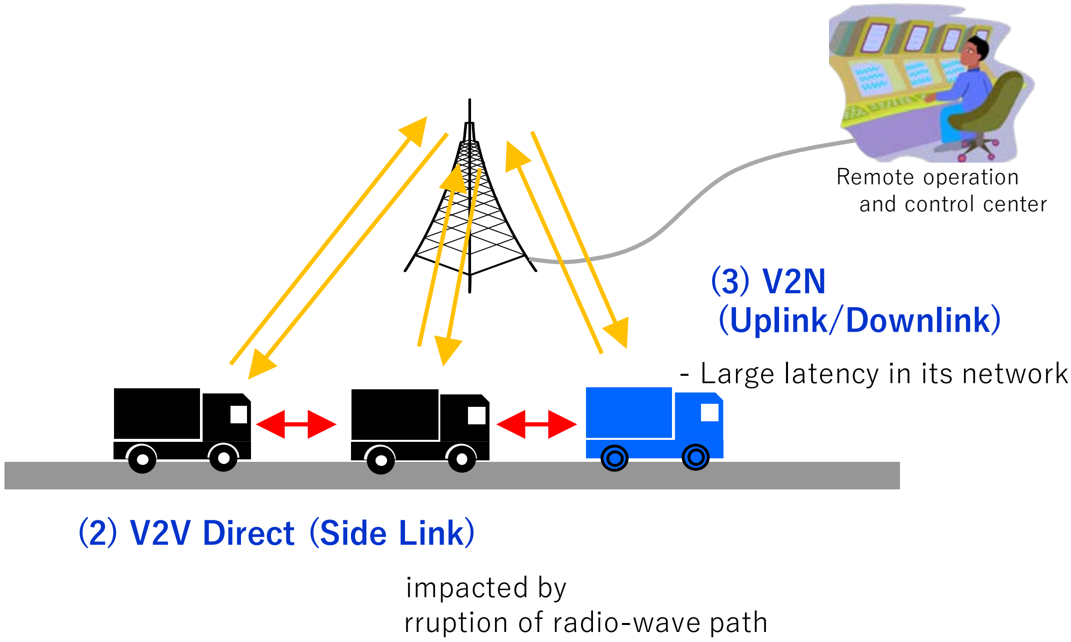


Fig.3.6.3.3 Types of communication in platooning

Performance evaluations were being conducted in 2017 to assess 5G URLLC capabilities required for vehicle control in platooning and video monitoring around trailing vehicles. Specifically, communication links (1) and (2) above were tested by using the equipment listed in Table.3.6.3.1.

Item #	Item	4.7GHz Equipment	28GHz Equipment
1.	Carrier Freq.	4.74 GHz	27.9 GHz
2.	Bandwidth	100 MHz	700 MHz
3.	Duplex	TDD	
4.	Radio Access	Downlink: OFDMA, Uploink：OFDMA	
5.	Sub-carrier interval	60 kHz	120 kHz
6.	Radio sub-frame length	0.125 ms	
7.	Data modulation scheme	Downlink：QPSK、16QAM、64QAM、256QAM Uplink：QPSK、16QAM、64QAM	
8.	Tx/Rx antenna configuration	BS: 64Tx/64Rx TUE: 4Tx/8Rx	BS: 4Tx/4Rx TUE: 2Tx/4Rx

Table.3.6.3.1 Specification of the Test Equipment

3.6.4 Trial Results

5G communication test equipment was evaluated with big trucks in Tsukuba-city, Ibaraki-prefecture, Japan, considering rural radio environment for platooning, e.g. a highway in a rural area. Field trials were performed for Vehicular-to-Network (V2N) and Vehicular-to-Vehicular (V2V) direct communications. (Figs.3.6.4.1 and 3.6.4.2)

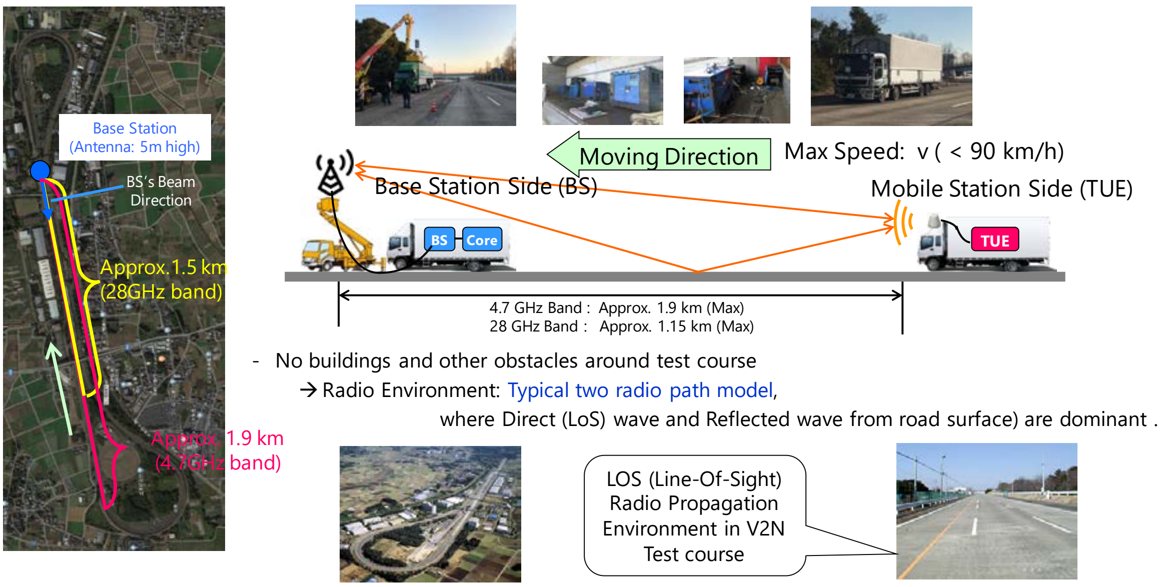


Fig.3.6.4.1 Field trial test environment for V2N communications

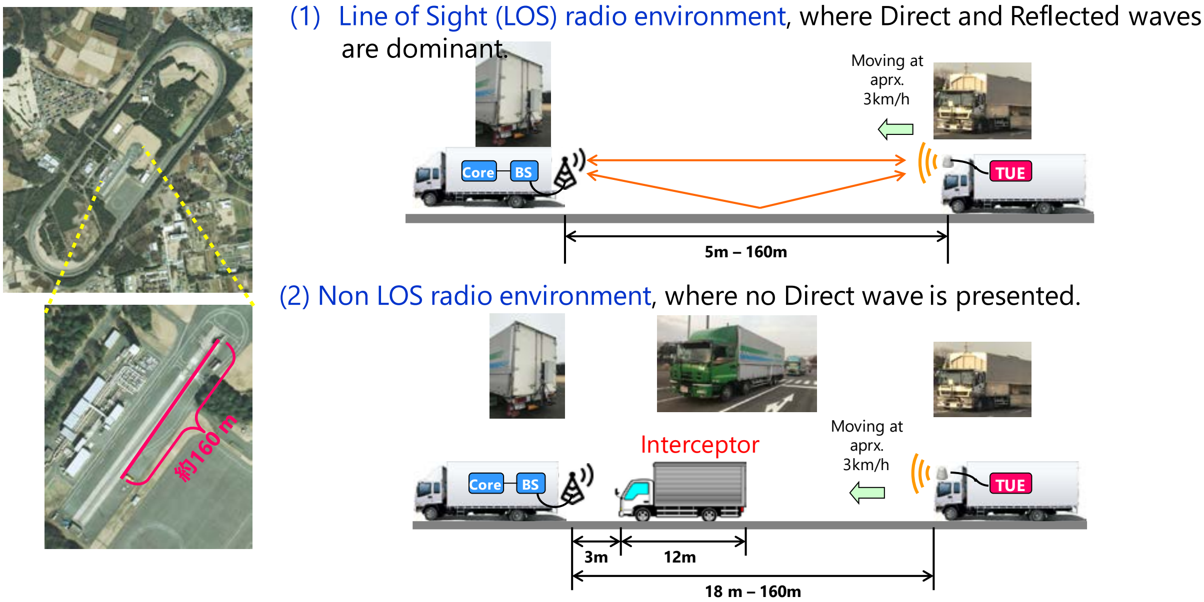
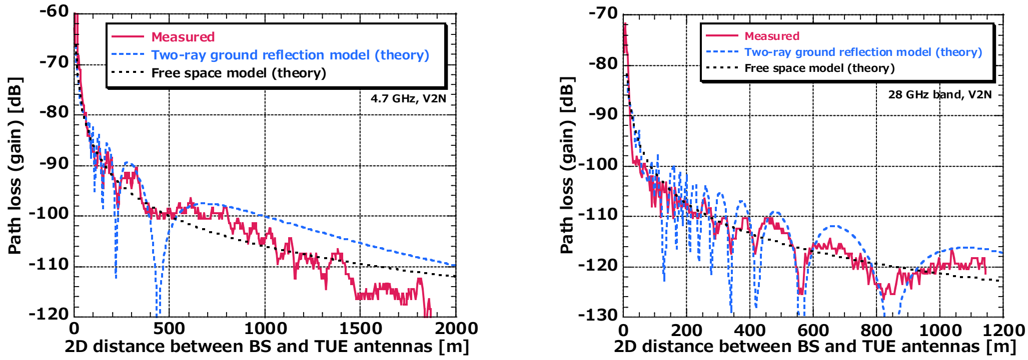


Fig.3.6.4.2 Field trial test environment for V2V direct communications

3.6.4.1 Propagation environment evaluation

Radio propagation environments were evaluated at the test course. The evaluation was carried out to measure reception power strength by using Reference Signal (CSI-RS: Channel State Information – Reference Signal) which is periodically transmitted from Base Station in order to calculate propagation loss considering antenna gain, its pattern and feeder cable loss. Figs. 3.6.4.3 (a) and (b) show measured propagation loss in 4.7 GHz and 28 GHz bands, respectively.



(a) 4.7 GHz band (b) 28 GHz band

Fig.3.6.4.3 Measured propagation loss at the test course.

It was found that at the test course path loss fluctuation well-meets that of two-ray ground reflection model.

3.6.4.2 Latency characteristics

Considering a 5G application to the vehicle control system in platooning, trial was conducted to test the latency characteristics of the 5G communication system. The trial was carried out on 4.7 GHz in a rural radio environment. The speed of the trucks was set from 0 km/h to 90 km/h. The results show that the over-the-air latency of 0.58 ms was achieved and demonstrated at the speeds of 87 km/h, as shown in Fig.3.6.4.4.

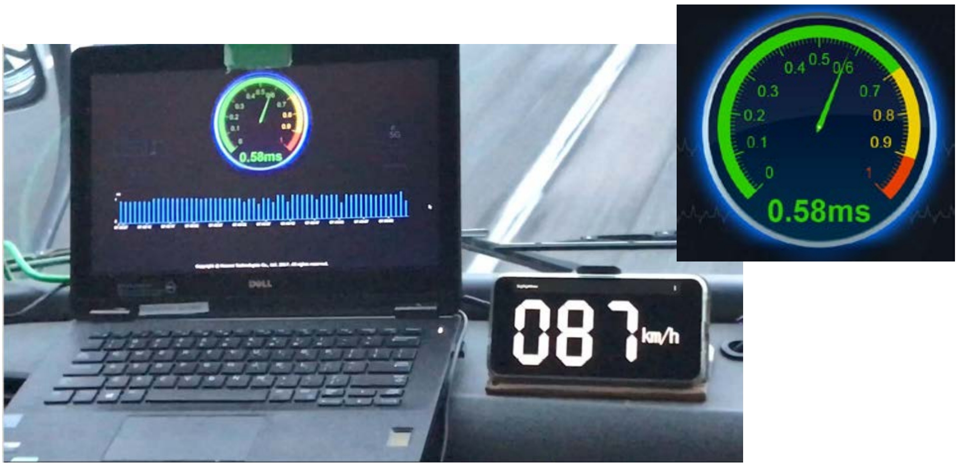


Fig.3.6.4.4 Over-the-air Latency Characteristics

Figs 3.6.4.5 and 3.6.4.6 show round trip delay performance of our 4.7 GHz 5G URLLC test equipment in V2N, i.e. via BS, communication for UE-BS (over-the-air delay) and UE-ICMP server (E2E delay), respectively. Fig. 3.6.4.5 shows that round trip delay over-the-air was less than 2 ms, independent from vehicle speed. It can be concluded that one-way over-the-air delay of less than 1 ms can be achieved. Fig. 3.6.4.6 shows that end-to-end round trip delay, including delay in network, i.e. between BS and core-network device, was less than 2.4 ms.

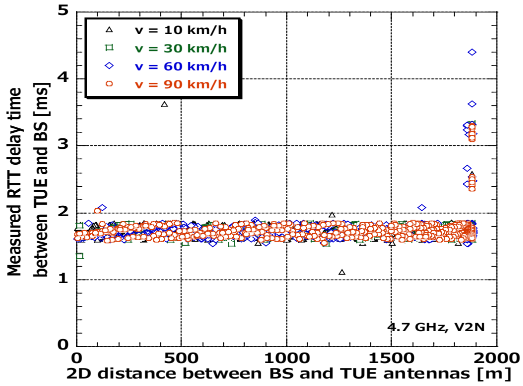


Fig. 3.6.4.5 over-the-air round-trip delay

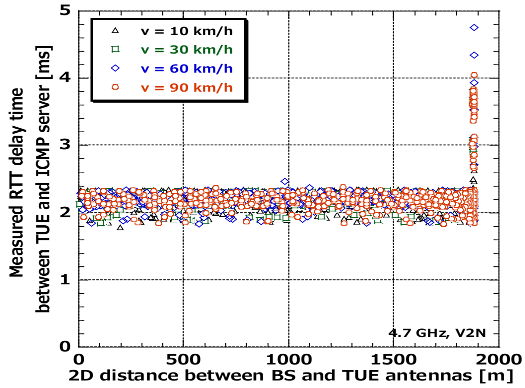
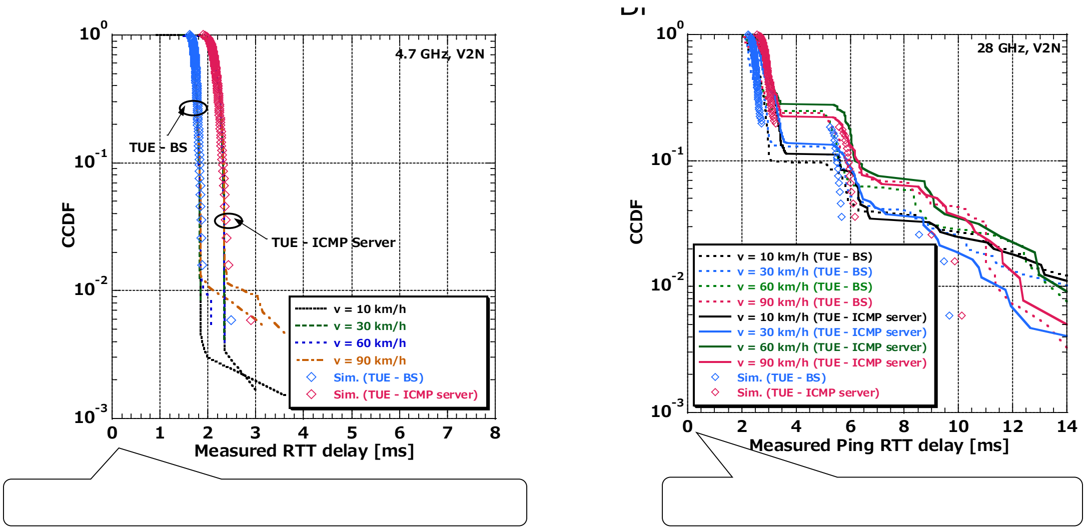


Fig. 3.6.4.6 End-to-End round-trip delay

Figs. 3.6.4.7 (a9 and (b) are complementary CDF of the measured round-trip delay of our 5G test prototypes for 4.7 GHz and 28 GHz, respectively. The prototypes have different AMC's target initial BLERs (Block Error Rates) of 1% and 10 %, respectively.



(a) 4.7 GHz prototype (b) 28 GHz prototype

Fig. 3.6.4.7 Complementary CDF of our 5G test equipment

Figs. 3.6.4.7.(a) and (b) show that achievable round-trip time delay was different, due to the different target BLER tailored for message and broadband transmission, respectively.

3.6.4.3 Throughput characteristics

In truck platooning, it is required to monitor the surrounding of trailing trucks for safety driving. Field trial tests were carried out to assess the feasibility of low-latency and high capacity (or high throughput) communication systems by 5G. In the tests, V2V direct communication was evaluated. The inter-vehicle distance was 10 m. 28 GHz band is used since the band provides wider band width, e.g. a band width of 700 MHz. Fig.3.6.4.8 shows traveled distance versus achieved throughput. This figure shows that the throughput of 2 Gbps is achieved.

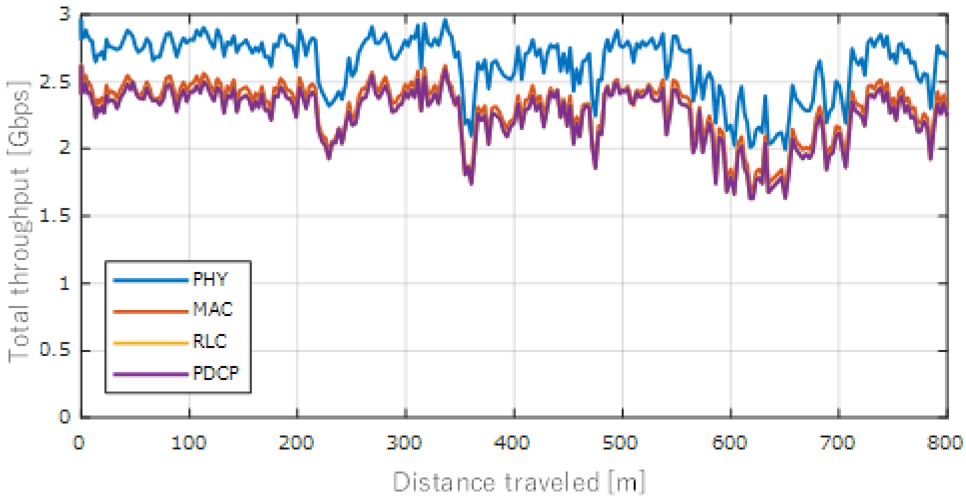


Fig.3.6.4.8 Throughput characteristics

3.6.5 Conclusion

Performance evaluation of 5G URLLC was carried out in real automotive test course with a view to applying 5G to track platooning. Two use cases of (1) low capacity and low latency communication for vehicular control and (2) high capacity and low latency for video monitoring, were considered. The results shows that both of these communication requirements could be met with 5G capability. Further tests on the reliability of 5G communication is planned towards complete platooning test.

References

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[2] Aoki Keiji, "Achievements in Automated Truck Platooning," ITS Japan, ITS Symposium, December 2012

3.7 Demonstration experiment utilizing 5G massive simultaneous connectivity - Disaster shelter and Smart office applications -

- Responsible organization: National Institute of Information and Communications Technology.
- Partners: ABIT Corporation, ITOKI CORPORATION, Sharp Corporation, Softbank corp.

3.7.1 Introduction

The ability to handle massive multiple connections is one of the special characteristics of the fifth-generation mobile communication system (5G). Other characteristics of 5G, including ultra-high-speed communications and ultra-low latency, they will affect the communication quality of individual devices, but the ability to handle massive multiple connections will affect communication capabilities over a coverage area. With the current demand for massive Machine Type Communication (mMTC), this unique characteristic of 5G is expected to change how mobile communication systems are used by society.

The authors of this section built a demonstration system focusing two usage scenarios of accessing emergency relief warehouse supplies and smart offices. These usage models need the ability of a mobile communications system to handle massive multiple connections. The effectiveness of 5G ability in these situations will be demonstrated by comparing the use of 4G in the same situations. This section discusses these usage scenarios and the built system to demonstrate their potential.

Massive multiple connection communications are defined as one million devices connected within a 1km^2 area. In this specific trial, especially, aims to demonstrate that one base station can be connected to 20,000 devices simultaneously.

3.7.2 Usage scenarios of Massive Connections

3.7.2.1 Emergency Relief Warehouse

Once a disaster strikes, it is necessary to control the movement of a large number of goods and to support people in extreme, emergency conditions. This means knowing where goods are stored and where they need to be delivered, what types of goods are available or needed, and what their expiration dates are. For supporting people, knowledge of where doctors and volunteers are, as well as knowing the victim's location in the disaster area, as well as their conditions, such as biometric data from people with heart conditions and other medical issues. This data can be collected and distributed over a wide area by a base station of 5G system that is managed by authorities of city or at a disaster relief center. This scenario, which is illustrated in Fig.3.7.2.1, shows how delivery of goods will be able to be managed efficiently to and from locations such as relief supply warehouses in areas not affected by the disaster or evacuation centers.

5G will be able to adopt a grant free access for machine type communications that makes the overhead of the communication process smaller and more efficient. Fig.3.7.2.2 shows the evaluation system to compare the performance of the 5G system with the grant free method to that of the 4G system. In this system, 20000 connections from 5G system are emulated in 4.6 GHz over the air and 100 real devices of 4G LTE are operated in 2.6 GHz with RF cables. Regarding 5G, the system was configured so that packets are transmitted every 5 second and it was confirmed that all the data from 20,000 devices has been received in 70 second. It was revealed that, depending on applications and configurations, an optimal transmission interval exists to receive the maximum number of packets. In case of 4G, simultaneous attempts of 100 or less connections sometimes make the network system unstable

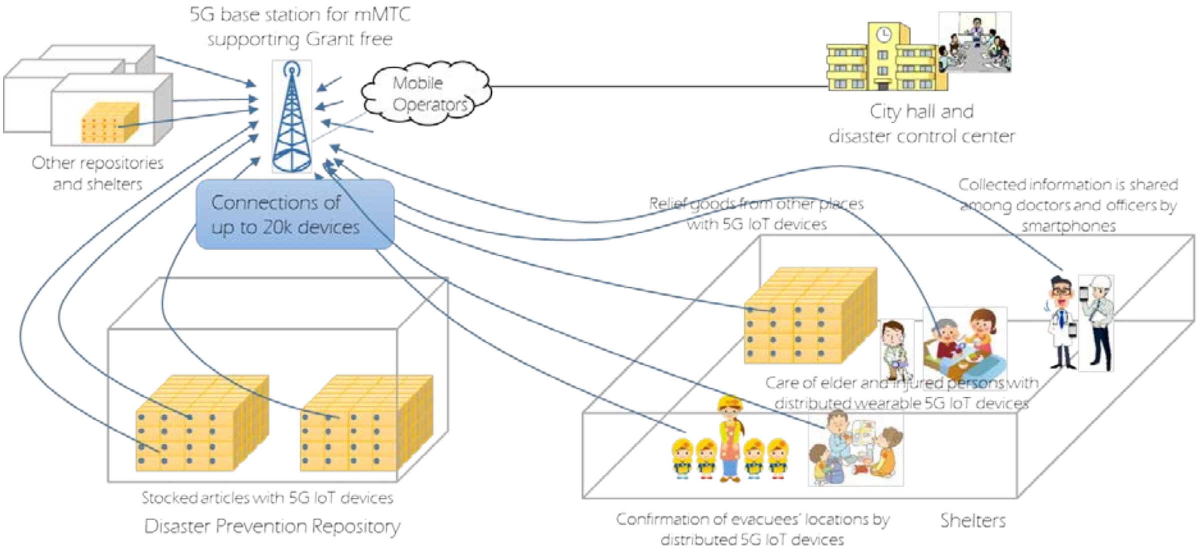

Fig.3.7.2.1 A Disaster Relief Warehouse Use Scenario

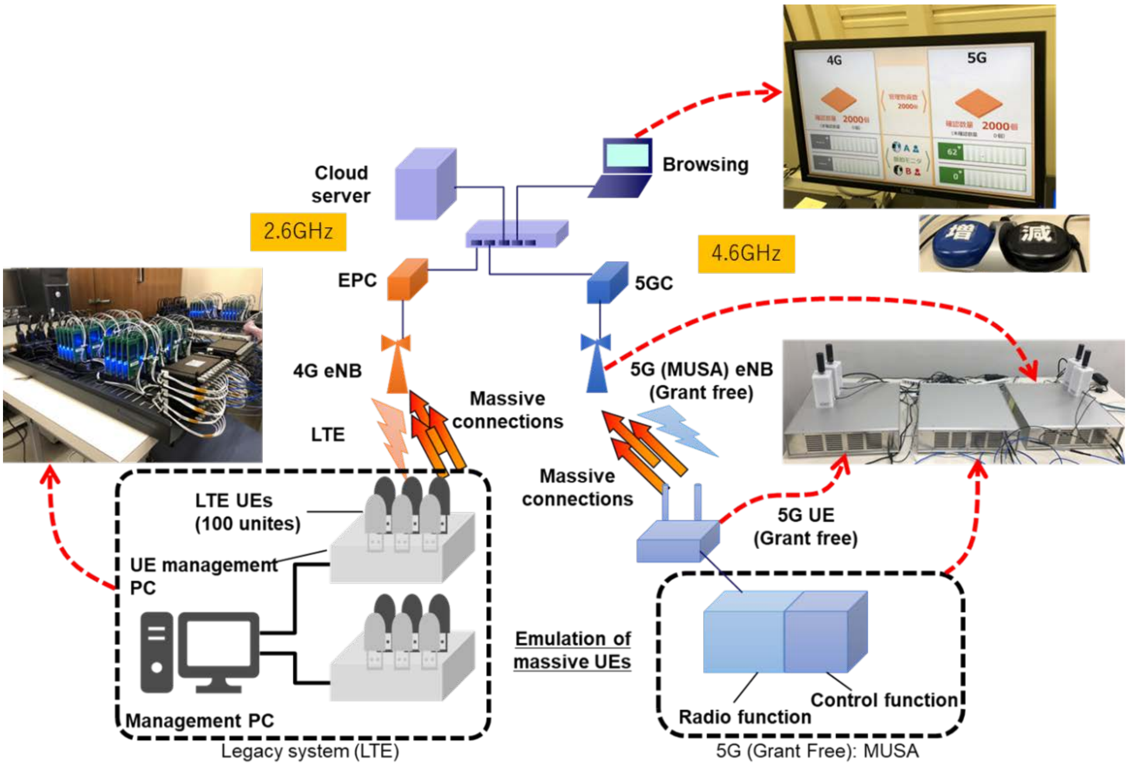

Fig.3.7.2.2 Evaluation system to compare the mMTC performance of 5G and LTE

3.7.2.2 Smart office

In the future, it will be expected that all the devices in an office are connected to one network. This network paradigm shift will bring a smart concept to the office that is more harmonized with human sensations and feelings than those of today. These offices will be able to hold high presence teleconferences where a sense of distance won't exist, allowing people to be able to feel as if all the participants of the meeting are in the same room and be able to understand accordingly atmosphere. In addition, news and information related to what is being discussed in the meeting will automatically be displayed if desired. And if progress in a particular meeting slows down, a robot will start to join the meeting and lighten any tension through some timely words of encouragement or soften a place by a friendly joke. Through innovations such as these the efficiency of the office is expected to increase.

One method to achieve massive multiple connections that this trial will demonstrate is creating a closed proximity communications area through a sheet that is placed on table, through which only devices in the area can be connected to a high speed, secure network. Since the communication area is limited near the table, the same frequency can reuse for the communication around the table. Thus the frequency reuse efficiency will be improved. As one of application, electronic white boards using 5G with its low latency capabilities enable a smooth and less delay teleconference being held over long distances. Simultaneous writing on white boards from multiple conference sites will be demonstrated. Chairs will also have sensors in them that will receive and analyze a variety of information about the participants, which will allow for the creating of a feedback system to help create a positive meeting atmosphere, even in teleconferences.

With the items described above, a smart office environment was developed to validate its scenario as shown in Fig 3.7.2.3. The Smart chair is operated using the Bluetooth Low Energy technology assuming to be replaced with 5G mMTC system. The smart table supports 3.7GHz as well as 2.4 / 5 GHz of wireless LAN systems. Two sets of the whiteboards were deployed in two NICT branches in Sendai city and Nomi city to test the function with conventional TV conference system. Fig 3.7.2.4 gives closeup shots of the smart office environment.

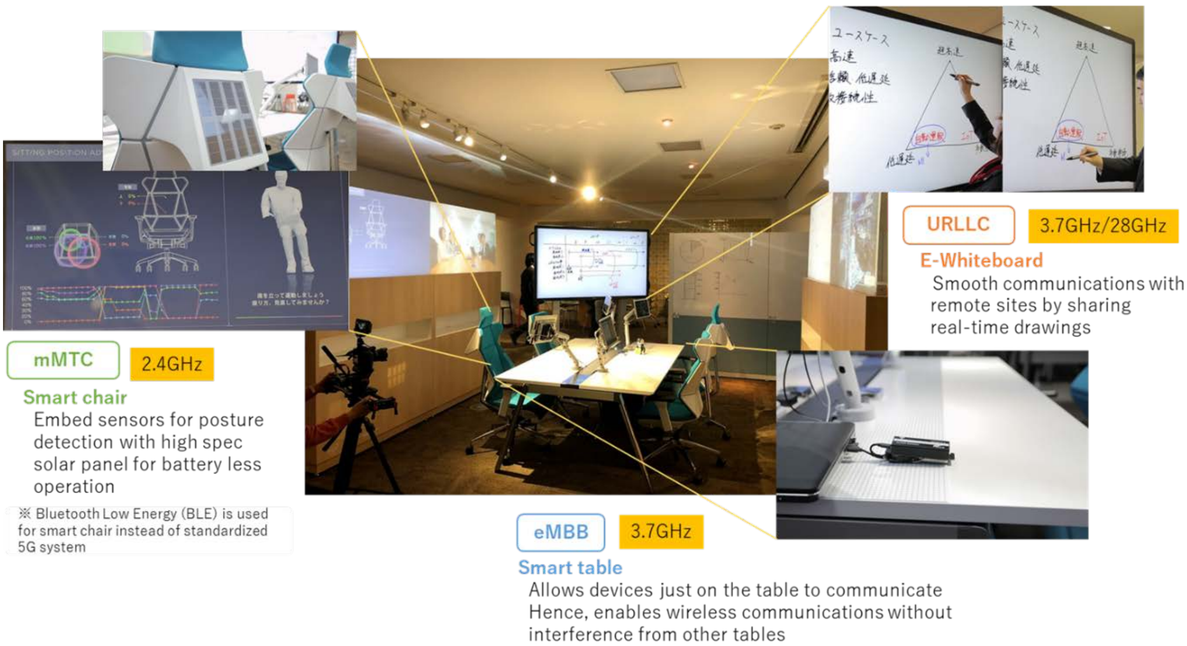

Fig.3.7.2.3 A Smart Office environment assuming to use 5G features

Fig.3.7.2.4 Components of the Smart Office environment assuming to use 5G features

3.7.3 Conclusion

This section introduced the results of performance evaluation and demonstration on 5G mMTC. It was realized that the prototype system with grant free method assumed to be utilized for mMTC achieved to accommodate up to 20 thousand of devices where the massive devices are emulated and their data are transmitted over the air using an original equipment. A scenario of disaster was demonstrated and showed that health parameters including heart rate measured on wearable devices are successfully displayed at a monitor system during 20 thousand of emulated devices. Also, smart office was constructed with smart table, smart chair and e-whiteboard, each of which is based on eMBB, mMTC and URLLC. The smart office environment aroused interests of participants at a demonstration site.

3.8 Summary

This chapter introduced the plans and content, as well as the outcome, of "5G Field Trials" that the MIC, Japan has started from this fiscal year 2017. From section 3.2 to 3.7, six groups showed the overview of 5G system performance evaluation by using eMBB, URLLC, and mMTC technologies in dense urban, urban, rural, or indoor areas all over Japan. The frequency bands used for the 5G Field Trials are 3.7 GHz, 4.5-4.7 GHz, and 28 GHz, and many partners in various utilization fields participated in the trials as well as those related to the mobile communications industry to create a new market through actualization of 5G. Since 5G Field Trials have only just begun and are still ongoing, further detailed results will be shown in the near future.

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