Research and Development of DX Solutions for Social Infrastructure Using 5G/6G and AR/VR

Featuring enhanced mobile broadband, ultra-reliable and low-latency communications, and massively simultaneous connections, 5G mobile communications is now in the roll-out phase. Meanwhile, work has already started internationally on the next generation of 6G mobile communication standards. 5G and 6G are expected to transform society, serving as a driver for expediting DX across a range of industries that in the past have been slow to adopt wireless technology. In order to supply DX solutions that meet the needs of customers in the social infrastructure sector, Hitachi has been combining 5G and Lumada in ways that ensure the reliable operation of edge computing while also working on the research and development of AR/VR. To provide a venue for conducting hypothesis testing for DX solutions that utilize these technologies, Hitachi has established 5G test environments at Hitachi America, Ltd. and at the *Kyōsō-no-Mori* facility of Hitachi's Central Research Laboratory. The intention is to develop DX solutions for a variety of different industries, with work already started on solutions for industry that assist with assembly work or provide remote support for on-site work by using 5G networks to analyze large amounts of video. This article provides an overview of these technologies, the 5G test environment, and future plans.

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1. Introduction

Fifth-generation (5G) mobile communications features enhanced mobile broadband (eMBB), ultra-reliable and low-latency communications (URLLC), and massive machine type communications (mMTC). The first commercial 5G services were launched in the USA and South Korea in April 2019, with Japan following in March 2020. Private 5G (called "local 5G" in Japan) for in-house use has also emerged as an option, primarily in Germany and Japan. In both cases, these networks are mostly non-standalone (NSA) 5G with a private fourth-generation [4G, namely Long-Term Evolution (LTE)] network serving as the anchor band. The rollout of dedicated 5G core networks is expected to get underway in the next year or two and this will enable standalone (SA) commercial 5G services that use 5G from base stations to the core network. Being able to take advantage of the true benefits of 5G, namely URLLC and mMTC features, SA 5G offers an order-of-magnitude improvement over 4G in terms of throughput, latency, and number of simultaneous connections. Meanwhile, work has already started internationally on the upcoming sixth-generation (6G) standards that are intended to deliver further performance improvements and lower power consumption. Also in prospect is an acceleration of digital transformation (DX) across a variety of industries through the use of semiconductor edge devices such as graphics processing units (GPUs), field-programmable gate arrays (FPGAs), and artificial intelligence (AI) chips to provide multi-access edge computing (MEC) that offloads computation from the cloud to base stations or aggregation hubs or the core network to achieve low-latency execution, and the use of network slicing in which networks are logically partitioned to deliver different levels of guaranteed communication quality to suit different uses.

In order to supply DX solutions that meet the needs of customers in the social infrastructure sector, Hitachi has been combining 5G and Lumada in ways that ensure the reliable operation of edge computing while also working on the research and development of augmented reality (AR) and virtual reality (VR). To provide a venue for hypothesis testing for these DX solutions, Hitachi has established a 5G test environment at Hitachi America, Ltd. and the *Kyōsō-no-Mori* facility of Hitachi's Central Research Laboratory.

2. Technology for Operation of Edge Computing

The progress of 5G and 6G and advances in edge devices have opened the way for building DX solutions that use edge computing with cooperative and autonomous decentralized processing, an approach that in the past was unrealistic for reasons of both cost and performance. To give an example from industry, it is now possible to look forward to a world of enhanced productivity across all areas of manufacturing operations, where each item of machinery can monitor what is happening in real time using many cameras and sensors, sharing this information with surrounding systems as well as using it internally for feedback control. This can also be extended beyond manufacturing plants to encompass optimization of the entire value chain, from end-user ordering to production, distribution, and services. As it seeks to make mobility smarter and the energy industry more efficient, Hitachi's ultimate goal is to implement DX solutions across all areas of social infrastructure and deliver citywide optimization. To this end, it is developing and testing ways of operating edge computing using a framework made up of three core technologies. (see **Figure 1**)[(1)].

2. 1 Three Core Technologies

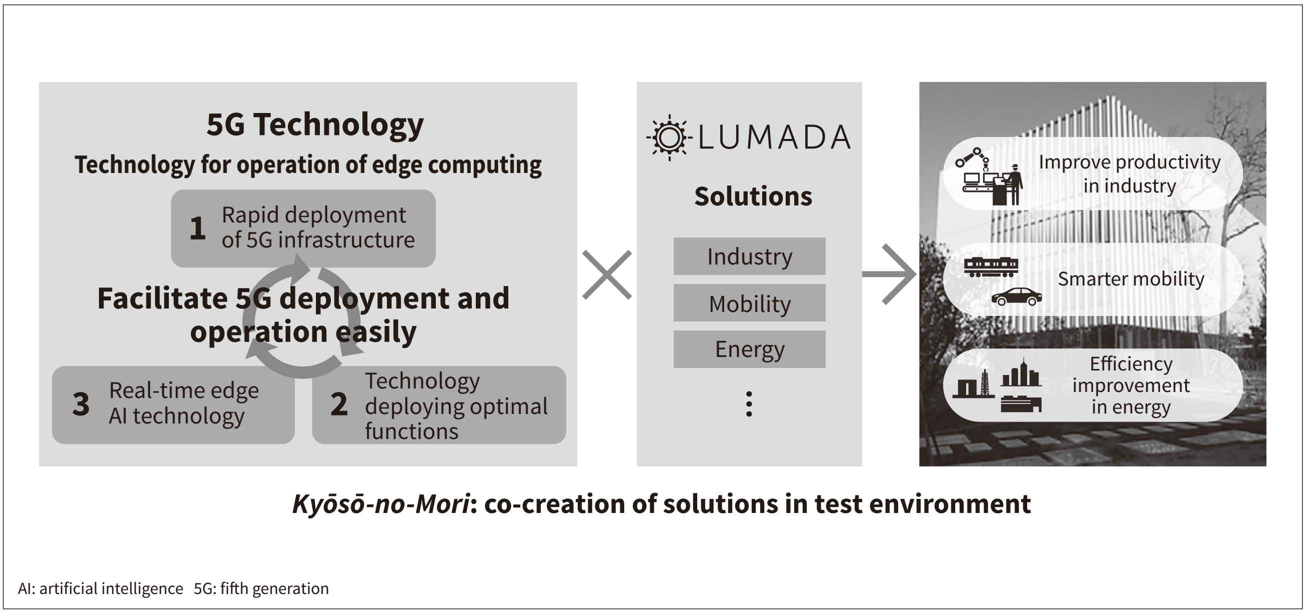
Able to be used for both 5G and 6G, the core technologies of this framework provide a telecommunications infrastructure that satisfies specific solution requirements, the optimal deployment of application functions needed to achieve this, and the execution of processing in real time.

(1) Rapid deployment of 5G infrastructure

Each solution, whether it be equipment control or video surveillance, has its own communication quality requirements with the site needing to provide each of these concurrently. This technology allows for an optimal choice of communication method to guarantee the communication quality required by each solution given the infrastructure at the site. While 5G delivered by a network operator will be handled differently from private 5G operated by the company itself, it is possible to provide reliable and low-latency communications over and above what is provided by the 5G infrastructure. When higher reliability is needed,

Figure 1 — How Edge Computing is Used in Practice

To facilitate the rapid deployment of digital solutions that incorporate 5G mobile communications, Hitachi has been developing and testing techniques for ensuring that edge computing is highly reliable and putting them to use in social infrastructure, including industry, mobility, and energy applications.



for example, a mix of techniques for highly reliable communications can be adopted, sending multiple packets via multiple pathways, selecting the first packet to arrive, etc.

(2) Provision of optimal functions

While an optimal mix of on-site edge computing for reduced communication latency and cloud computing for high-volume processing is needed to satisfy application performance requirements, the associated design and implementation work is very time-consuming. Designing site installations is particularly complex, being subject to computing and network constraints imposed by space, power supply, layout, and other such considerations. Accordingly, Hitachi provides ways of achieving flexible system operation that can easily identify these constraints and deploy or retrofit functions in ways that best match the available system infrastructure. The AI model described below is one example of a function implemented on the network edge.

(3) Real-time edge AI

The limited computing performance of edge devices makes it difficult to execute computationally intensive AI techniques such as image recognition in real time. To address this, Hitachi has found a way to automatically generate deep neural network (DNN) AI models in a lightweight and compressed form by using an algorithm that makes learning more efficient to remove unnecessary calculations without compromising the model's recognition performance when running on an edge device[2]. This enables heavy-duty AI to be executed in real time on resource-constrained edge devices. For example, a frame rate of 10 frames per second (fps) is needed to track the movements of a worker. In contrast to the 100-W power consumption that this would require on a conventional general-purpose server, this technique enables the same processing to run on an embedded system device and consume only 5 W.

2. 2 Example Applications for Edge Computing Support

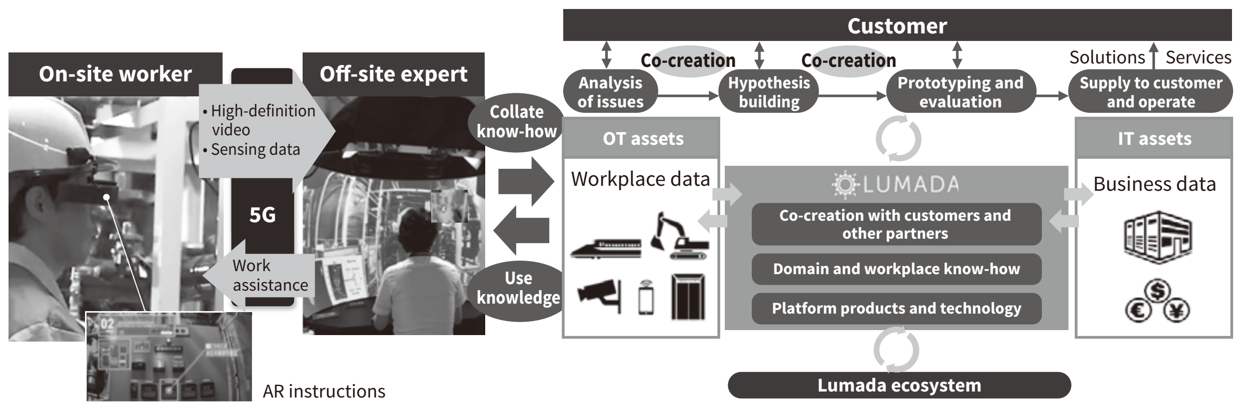
Hitachi replicated a short-run manufacturing operation characterized by frequent changes in production line functions to trial an AR-based guidance solution for assembly work that uses video together with the above three core technologies. The results demonstrated that high-quality communications could be achieved even when multiple systems such as equipment control and video surveillance were operating side by side, delivering the high reliability (0.0001% packet loss) and low latency (50 ms or less) needed for these systems to operate. The trial also demonstrated that application deployment, which took more than an hour when done manually, could now be completed automatically in less than a minute and without requiring any special expertise. Use of the technology should help improve plant productivity by enabling changes in production line functions to be made without the need for long shutdowns.

3. Solutions Using 5G with AR/VR to Provide Remote Support for On-site Work

The problems of a shrinking workforce and a shortage of skilled staff are driving demand for productivity improvement and ways of making efficient use of the skills that are available. To resolve societal challenges and create new value, Hitachi has developed a solution that provides remote support for on-site work by linking workplaces to distant

Figure 2 — How Hitachi Envisions Systems Providing Remote Support for On-site Work

The system collects site data and provides remote skilled staff with a highly realistic view of what is going on at the site. Hitachi intends to build a store of know-how in Lumada and in the future use this accumulated knowledge to assist both on-site workers and remote support staff.



AR: augmented reality OT: operational technology

Figure 3 — AR Smart Glasses Made by Hitachi-LG Data Storage, Inc.

The smart glasses feature high luminance (5,000 nits or more) and transmittance (94%).

sites. The following sections provide an overview of how Hitachi envisions systems will provide this remote support and describes its proprietary AR smart glasses.

3. 1 Overview of Systems for Remote Support of On-site Work

Figure 2 gives an overview of the composition Hitachi envisions for systems that provide remote support for on-site work. Hitachi's use of 5G for this purpose makes remotely located skilled staff able to view real-time, high-definition video of on-site workers and the surrounding area. In practice, this is done by having on-site workers wear AR smart glasses equipped with a camera to capture their first-person-view video and by installing a 360° camera somewhere nearby. 5G is used to relay real-time, high-definition video of the view from the smart glasses worn by an on-site worker together with a bird's-eye view video from the 360° camera. Skilled staff are able to give instructions in real time from off-site, using a large display screen that shows the overall scene and down to the small details. By providing both verbal guidance from remote support staff and video-based AR instructions delivered through their smart glasses as they work, these support systems enable even inexperienced workers to complete tasks confidently. Likely future developments include capturing various on-site data and integrating operation with Lumada supplied by Hitachi.

Lumada models digital solutions created by Hitachi through collaborative creation (co-creation) with numerous customers. By building up the practical know-how of remote workplace systems in Lumada, the aim is to use this as a basis for issuing alerts or recommendations automatically as needed, without the direct involvement of skilled staff, thereby providing ways of getting work done that does not rely on human skills in the workplace.

3. 2 Hitachi's AR Smart Glasses

If they are to be accepted, AR smart glasses need to be well-suited to the work being done. The AR smart glasses(3) of Hitachi-LG Data Storage, Inc. feature high luminance (5,000 nits or more) and transmittance (94%) (see **Figure 3**). Owing to the high luminance, displayed images are visible even when working outside in sunlight. And the very high transmittance of the glasses does not obstruct the view of the worker so the worker can work safely.

Figure 4 — 5G Test Environment at Hitachi America, Ltd.

Hitachi America established its own dedicated on-site 5G network in June 2020. It has commenced testing of manufacturing solutions, starting with the use of collaborative robotics developed in partnership with the Georgia Institute of Technology to enable people and robots to work together on the assembly of an electric screwdriver. Cameras, wearable sensors, and depth sensors are used to track what workers are doing, with the data being collected via 5G and analyzed on a multi-access edge computing (MEC) server. The next task to be performed is predicted and the robot arm is used to supply the required parts or to otherwise assist with the work.

4. Establishment of 5G Test Environment and Future Plans

4. 1 Hitachi's 5G Test Environment

Hitachi has established 5G test environments in Japan and overseas where it can conduct hypothesis testing and efficacy validation of edge computing using 5G or DX solutions based on AR/VR, and engage in locally based development and evaluation through co-creation with customers. Outside of Japan, Hitachi worked with Telefonaktiebolaget LM Ericsson in June 2020 to build a dedicated NSA 5G network at its Silicon Valley Research Center in California, USA (part of the Research and Development Division of Hitachi America, Ltd.). The center has commenced trials of manufacturing solutions that utilize collaborative robotics. This technology for enabling people and robots to work side by side was developed in partnership with the Georgia Institute of Technology (see **Figure 4**). The intention is to continue work on developing industrial solutions that use the new dedicated 5G network[4].

In Japan, NSA private 5G test environments with commercial operating licenses were established in October 2020 at two different locations in the *Kyōsō-no-Mori* facility of Hitachi's Central Research Laboratory (see **Figure 5**). The systems use the 28-GHz millimeter wave band allocated by the Japanese government in December 2019 and will be used in co-creation with customers in manufacturing and quality control to evaluate solutions that use high-volume wireless transmission of video, such as AR-based guidance for assembly work or the remote support of on-site work.

4. 2 Future Plans

Hitachi is also planning a test environment for SA private 5G that will use the Sub-6-GHz (4.7 GHz) frequency band allocated by the Japanese government in December 2020. The intention is to use this test environment for research and development on topics such as the seamless integration of private and public 5G and also the real-time control needed to implement solutions for automating or remotely controlling workplace tasks, which represent the next steps in this work.

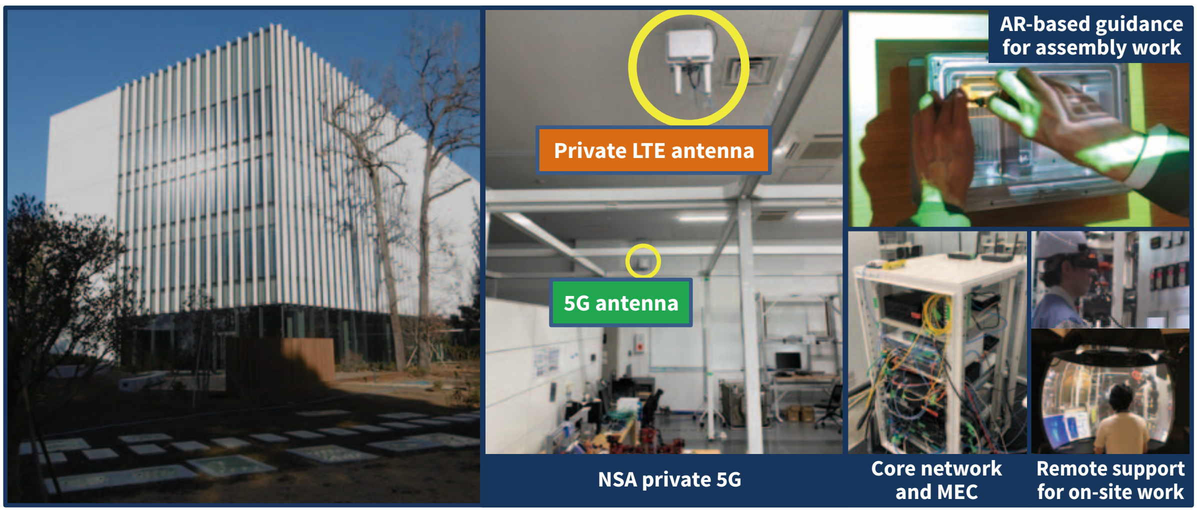
5. Conclusions

Leveraging the strength that comes from having IT such as AI and big data analytics, operational technologies (OT) such as the operation and control of social infrastructure, and a wide range of products within the same company, Hitachi utilizes co-creation with leading customers focused on services to build up the associated knowledge within Lumada in the form of customer cases.

In the future, Hitachi intends both to combine Lumada with 5G/6G mobile communications to further develop

Figure 5 — Private 5G Test Environment at *Kyōsō-no-Mori*

Private 5G test environments were commissioned in October 2020 at two different locations at Hitachi's Central Research Laboratory. The test environments have commercial operating licenses and use NSA 5G with a private LTE network serving as the anchor band. The intention is to upgrade these private networks to SA 5G and use them in co-creation with customers for the development and hypothesis testing of digital transformation (DX) solutions that utilize 5G.



LTE: Long-Term Evolution NSA: non-standalone SA: standalone technologies for using edge computing and for AR and VR and to implement DX solutions across all aspects of social infrastructure that transcend the boundaries between the different forms of infrastructure, thereby making industry more productive, mobility smarter, and the energy sector more efficient.

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