# Demonstration of Disaster-proof Warehouse and Smart Office Applications Using the Multiple Simultaneous Connectivity of 5G

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## 1. Introduction

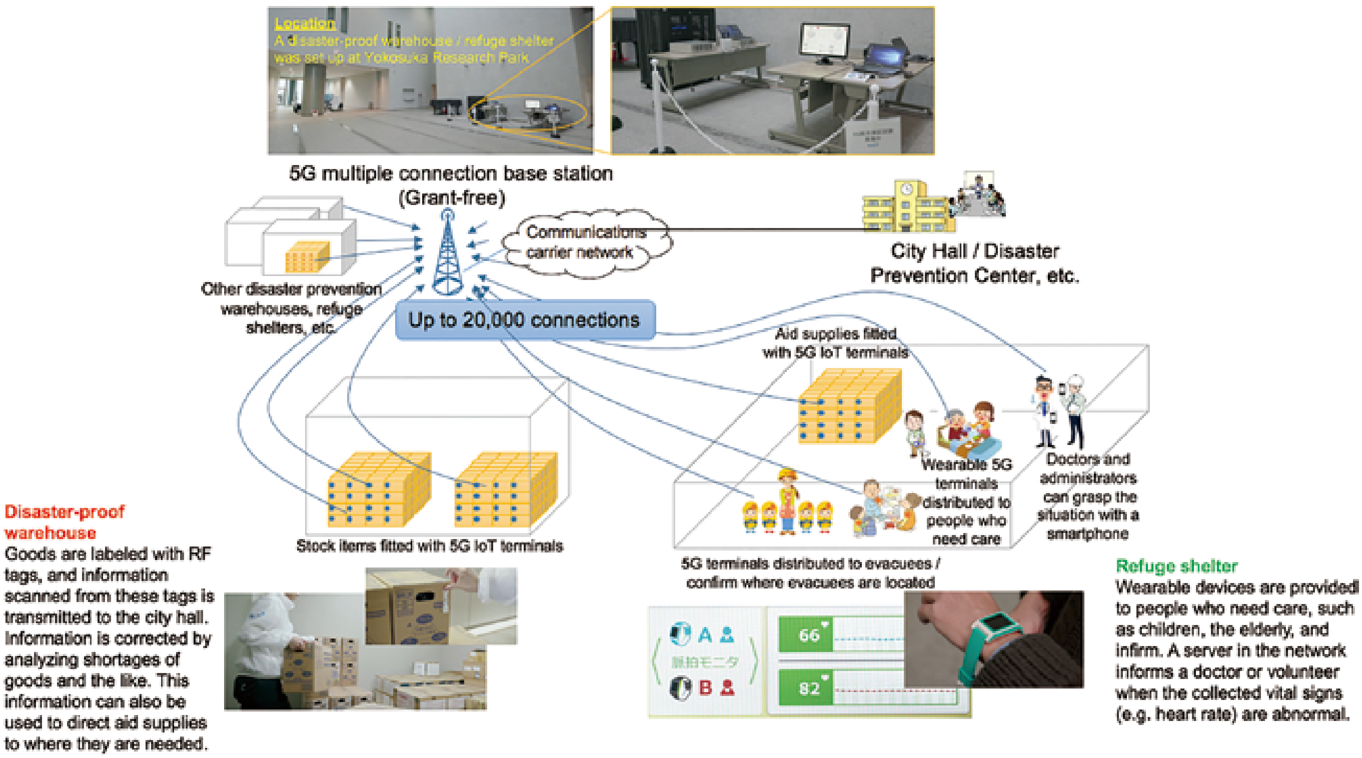
One of the advantages of the 5th generation (5G) mobile communication system is the ability to achieve a significantly larger number of simultaneous connections. In the IoT (Internet of Things) era, the number of mobile connected things will increase and all sorts of things will be connected to the Internet. Mobile communication systems will therefore have to provide a social infrastructure that achieves larger numbers of simultaneous connections.

It is expected that the simultaneous connection capabilities of 5G will allow it to accommodate a million terminals per square kilometer[1]. This goal needs to be evaluated together with realistic assumed applications in order to clarify the usage scenarios that can be implemented with 5G. Therefore, in this article we report on the results of demonstrations based on two different use cases: the use of 5G in disaster-proof warehouses during disaster situations, and the use of 5G in smart offices to support future working styles [2].

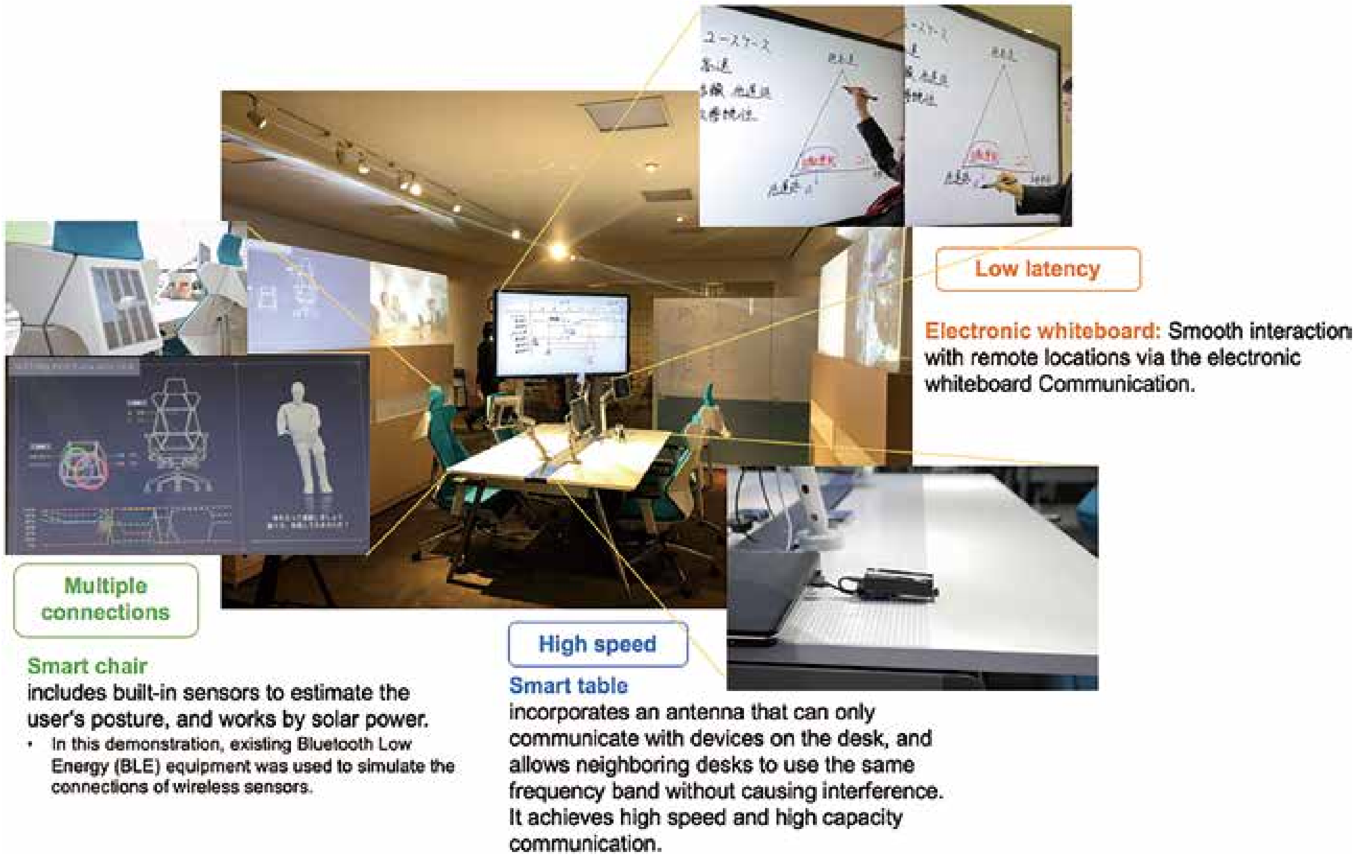
## 2. Disaster-proof warehouse use case

In a disaster, it is important to manage very large numbers of resources and ascertain the circumstances of many people. The purpose of a disaster-proof warehouse is to stockpile reserves in normal situations so they can be used or consumed in the event of an emergency. However, considering the circumstances that arose during disasters in recent years, it can be seen that it was not possible to accurately ascertain the positions of warehouses with a surplus of goods and warehouses where problems had arisen due to

**Figure 1: Demonstration of a disaster-proof warehouse use case**



■ **Figure 2: Demonstration of a smart office use case**




shortages. In addition, it may be unrealistic to expect that accurate warehouse records will continue to be kept when accepting and dispensing aid during an emergency. Efforts are therefore being made to implement a system whereby goods are labeled with RF tags that can be scanned to generate information that is sent via 5G to a city hall or the like, where it can be centrally analyzed to identify shortages and ensure that aid supplies are directed to where they are most needed. Furthermore, wearable devices that can measure the wearer's position and vital signs would be provided to people who need particular care, such as children, the elderly and infirm. This information can be collected via 5G and used to request the assistance of doctors or volunteers when abnormal values are detected (Figure 1).

The wireless communication needed to implement this system is realized using a Grant-Free system that is being studied for 5G [3,4]. In conventional communication systems like LTE, a communication channel must be established before any data communication starts. This process places a heavy load on the communication system, and gives rise to limitations on the number of terminals that can be connected. However, in the Grant-Free system, data can be transmitted straight away without having to set up a communication channel. This system is suitable for situations where small quantities of data such as sensor outputs are sporadically transmitted from large numbers of terminals. For this demonstration, we developed a prototype device that implements this method. We also developed a test device capable of simulating 20,000 terminals and generating wireless communication connections in the same way. By combining these devices, we constructed a demonstration environment where up to 20,000 terminals are transmitting signals in the Grant-Free system while transmitting information from wearable devices to a base station.

For this demonstration, we used a wireless system with a bandwidth of 10 MHz, with each terminal transmitting information at five second intervals. The base station regards a terminal as having communicated successfully if it receives information within ten seconds. The results of this test confirmed that the 5G system is capable of receiving data from all 20,000 terminals in 70 seconds when the terminals are set up to transmit data every 5 seconds. We also confirmed that in an environment with 20,000 wireless terminals, it is still possible for the server management screen to produce a graphical display of stock tag information and pulse information from wearable terminals.

## 3. Smart office use case

In the future it is expected flexible work patterns will become more commonplace, increasing the demand for office environments that are customized to individual needs. People also expect to have greater opportunities to work efficiently in remote businesses anywhere using a nearby shared office. We will therefore implement smart office environments by developing office tools that combine not only the multiple simultaneous connection capabilities of 5G, but also other desirable performance attributes such as ultra-high speed and ultra-low latency (Figure 2).

As examples of tools, the smart table incorporates a planar antenna in the desktop for near-field communication, and is connected to a base station operating in the 3.7 GHz band. For this demonstration, we used an LTE base station with a bandwidth of 20 MHz, and we aimed to conduct an evaluation in terms of the system configuration and radio wave interference. This planar antenna only allows terminals to communicate when they are on the desk, and suppresses radio wave interference to the space further away from the desktop surface. Therefore, even if there are several smart tables installed in the same conference room, they can use radio waves of the same frequency band without causing interference between desks. This facilitates effective use of frequency resources, and makes it possible to achieve a large overall network communication capacity. Video from an omnidirectional camera and audio from a microphone capable of estimating direction of audio sources are communicated by smart tables to a server, which automatically creates the minutes of the meeting by recognizing what is being said and by who. In addition, when the system estimates that the discussion has stalled (e.g., at a break in the conversation), the system searches for current news relating to keywords extracted from the most recent spoken content, and displays it on a large-sized wall-mounted display to contribute ideas for brainstorming.

The smart chair has six pressure sensors on the seat and back panel. Information from these sensors is transmitted to the server via multiple simultaneous connections so that the posture of the person sitting on the chair can be identified (e.g., leaning forward, leaning back, or shifted to one side). In the future, by gathering information from every chair in the room, the system could recommend breaks or control the air conditioning to prevent fatigue and drowsiness among the conference participants. In this demonstration, these chair pressure sensors are powered entirely by photovoltaic panels installed on the rear side, so there is no need to replace batteries. Other forms of chair sensor that are being developed can detect a person's heart rate and/or breathing when a person simply sits down, and in the future this can be expected to be used for health management and fine-grained control of the office environment. Since the 5G wireless system for chairs is still on the drawing board, we used existing Bluetooth Low Energy equipment for connections of wireless sensors.

The electronic whiteboard uses ultra-low latency communication in the 28 GHz band to provide a real-time display that updates in synchronization with other whiteboards at remote locations. Most current videoconferencing systems share only video and audio signals, but by also sharing the pen strokes drawn on a whiteboard in real time, it is possible to share the same whiteboard between multiple conference rooms, resulting in greater work efficiency and smoother discussions. Here, the writing on the electronic whiteboard from multiple locations is managed by a 5G edge server directly connected to the base station. This not only reduces the radio access latency, but can also reduce the latency in higher layers.

## 4. Summary

We have presented the results of a demonstration to examine the performance of 5G simultaneous multiple connections in two usage scenarios. This demonstration confirmed that it is possible to improve the terminal connectivity required in disaster situations, and to develop a new office environment. The function and performance of 5G are being strongly led from the viewpoint of services, and we hope that the results of this verification will be useful for future 5G applications and 3GPP standard reviews. In addition, we are studying methods for distributed micro-cell technologies in mobile communication systems [5], and we expect this can be effectively applied to smart offices where there is limited communication range.

**Acknowledgments**

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References

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[3] 3GPP R1-166403,"Grant-free Multiple Access Schemes for mMTC".
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## *Cover Art*

**Onoe Kikugoro (Picture of kabuki actor Onoe Kikugoro III. It is said that he is playing the role of Ushiwakamaru (1838).)**

Utagawa Kunisada (1786–1865)

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