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Special Feature

Satellite-5G Network Demonstration Utilizing Flexible Dynamic Routing and Quality Control

Research and Development of Satellite-Terrestrial Integration Technology in Beyond 5G

Demonstration and Evaluation of Local 5G with GEO/LEO Backhaul: Implementing High Reliability and High Capacity

Enhancing Local 5G Resilience through Satellite-Terrestrial Integrated Backhaul and Adaptive Resource Control

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C O N T E N T S

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Research and Development of Satellite-Terrestrial Integration Technology in Beyond 5G

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In "Beyond 5G" (i.e., the future generation of wireless technology that will succeed the current 5G networks), "Non-Terrestrial Networks" (NTN) are attracting attention from the perspective of scalability and wide coverage. An NTN connects different spaces—including space, air, and sea—through a multi-layered, diverse communication infrastructure consisting of satellites, high-altitude platform stations (HAPS), drones, and other equipment. Each component of the communication infrastructure that composes the NTN has different communication characteristics in terms of latency and stability, and it is expected that flexible communication links will be established according to the application. Moreover, standardization of NTNs has gained pace at the 3rd Generation Partnership Project (3GPP); in particular, the initial NTN specifications in Release 17 have been completed, and the further improvements from Release 18 onwards are being considered. In accord with these trends, efforts toward the commercialization of integrated satellite links and 5G/Beyond 5G networks are intensifying both domestically and internationally.

In 2019, the National Institute of Information and Communications Technology (NICT) established the "Study Group on the Collaboration between Satellite Communications and 5G/Beyond 5G." Including a wide range of organizations, including domestic satellite operators, terrestrial mobile operators, satellite-related manufacturers, universities, research institutions, and standardization organizations, this study group focused on effective use cases, technical challenges and solutions, evaluation and demonstration, and standardization related to the collaboration between satellite communications and 5G/Beyond 5G[1].

Moreover, with the aim of strengthening Japan-Europe cooperation in the NTN field, NICT has signed a Letter of Intent (LoI) with the European Space Agency (ESA) and is promoting research and development of NTN technology from a global perspective and continuing efforts toward implementing communication infrastructure.

Under these circumstances, NICT launched the research project "Research and Development of Satellite-Terrestrial Integration Technology in Beyond 5G" under its commissioned research and development program for advanced communications and broadcasting, and it promoted the project from 2020 to 2024 in collaboration with Japan Radio Co., Ltd., SKY Perfect JSAT Corporation, and The University of Tokyo[2]. In this project, under a Japan-Europe cooperation framework based on the aforementioned LoI with the ESA, the Japanese and European partners collaborated on the demonstration experiments described below.

In the first phase of the project, Phase 1 (FY2020-FY2021), a Japan-Europe joint experiment on integrated satellite-5G control, including a geostationary (GEO) satellite link—Japan's first such experiment—was conducted from January to February 2022 [3][4]. In this experiment, a Japan-Europe joint trial testbed was constructed and used to demonstrate the transmission of 4K video and Internet of Things (IoT) data. Specifically, the experiment demonstrated that communication sessions could be established by using control signals between the customer-premises equipment (CPE, i.e., 5G-enabled gateway) in Japan and the 5G core in Europe even under the influence of delays associated with long-distance transmission using satellite links and Japan-Europe terrestrial links. It also confirmed that data acquired by 4K cameras and IoT sensors on the Japanese side could be transmitted to laptops and data servers on the European side, and the operability of the satellite-5G network was evaluated by measurements of network quality in each transmission section.

In the second phase of the project, Phase 2 (FY2022-FY2024), following up on the basic demonstrations performed in Phase 1, a disaster use case connecting a GEO satellite link, low Earth orbit (LEO) satellite links, and local 5G was demonstrated. To evaluate the interoperability of satellites and 5G-control technology, a proof-of-concept experiment using path control, satellite Quality of Service (QoS) control, and slicing technology was conducted, and the results of the experiment demonstrate that dynamic backhaul-path switching and QoS control were successful[5].

This special feature details the results obtained from the demonstration experiments conducted in Phase 2 of this commissioned research project. SKY Perfect JSAT will provide an explanation titled “Demonstration and Evaluation of Local 5G with GEO/LEO Backhaul: Implementing High Reliability and High Capacity,” and the University of Tokyo will explain “Enhancing Local 5G Resilience through Satellite-Terrestrial Integrated Backhaul and Adaptive Resource Control.”

Aiming to Implement a three-dimensional network that connects land, sea, air, and space in a multi-layered manner, NICT will further deepen its collaborations with domestic and international companies, universities, and research institutions to promote the research, development, and implementation of satellite-to-terrestrial integration technology and NTN technology in the Beyond 5G era from a global perspective.

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[4] Keisuke Saito et al., “Evaluation of Network Performance for 4K Video Streaming with Satellite and 5G interconnection in Japan-Europe Joint Experiment,” 39th International Communications Satellite Systems Conference (ICSSC2022), 2022.
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Cover Art

The Pride of Tokyo's Twelve Months: June, Morning Glories at Iriya

Tsukioka Yoshitoshi (1839-1892)

Source: National Diet Library, NDL Image Bank (https://ndlsearch.ndl.go.jp/imagebank)

Demonstration and Evaluation of Local 5G with GEO/LEO Backhaul: Implementing High Reliability and High Capacity

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1. Introduction

Satellite communications technology has advanced rapidly in recent years, including advances with Low Earth Orbit (LEO) constellations. This is leading to advances in the communications infrastructure being deployed by satellite communications operators, such as multi-orbit configurations.

On the other hand, Local 5G is getting organized domestically in Japan, making it possible to build independent 5G Networks within particular geographic areas or facilities. 5G is capable of high-speed, high-capacity and low-latency communications as well as large numbers of simultaneous connections, so it is highly anticipated for use in a wide range of fields, such as manufacturing, agriculture, disaster response and remote medicine.

By integrating satellite communications technology and 5G communications technology, we hope to create new value and contribute to solving societal issues. In commissioned research conducted by NICT, titled "Research and Development of Satellite-Terrestrial Integration Technology in Beyond 5G (No. 21901)," a network environment combining dynamic routing with Quality of Service (QoS) control was built, utilizing satellite communications as the Local 5G backhaul, with multiple orbits having different communications characteristics. This showed the effectiveness of dynamic control based on channel conditions. The demonstration confirmed that both stable communications and increased throughput can be achieved by combining LEO satellites for high-capacity data transport with Geostationary Earth Orbit (GEO) satellites for guaranteeing stable bandwidth.

This article introduces anticipated use cases, the 5G control technologies, and an overview of the demonstration and results. This is followed by discussion of how the results will be used and business prospects for the future.

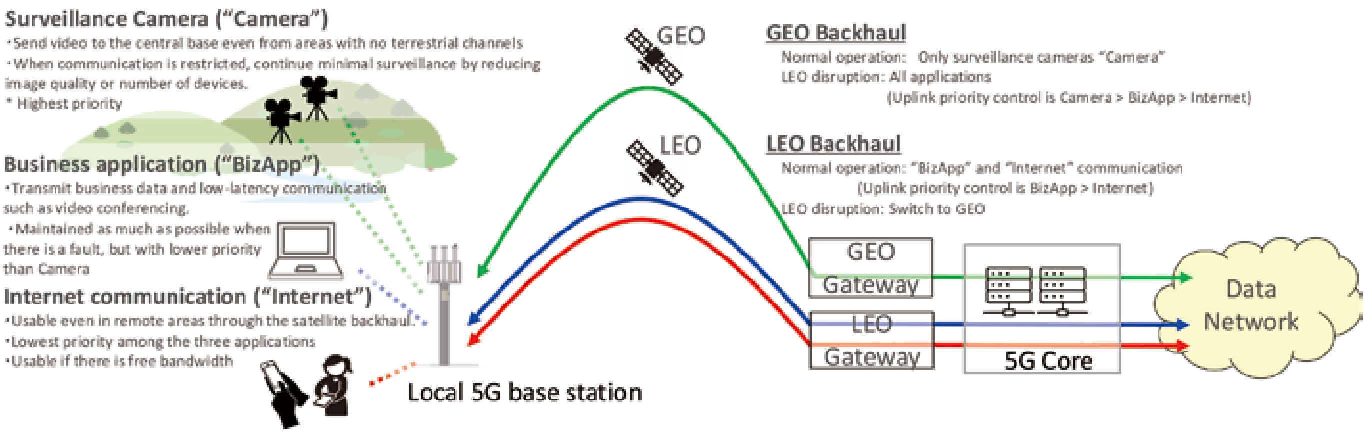
2. Local 5G and multi-orbit satellite communications use cases

A use case for multi-orbit satellite communications as the backhaul of Local 5G systems is in deployment of Local 5G base stations in regions where installation of fixed or mobile networks is difficult, such as on islands or in the mountains. The use case and applications (Camera, BizApp and Internet) are shown in Figure 1. GEO satellites and LEO satellites were used as the Local 5G backhaul for these use cases. With an understanding of the communications characteristics of both GEO and LEO satellites, we studied methods for utilizing the strengths of both types of satellite. Characteristics of each type of satellite communications are given below.

GEO satellites

GEO satellites have a stationary orbit at an altitude of approximately 36,000 km and their position relative to the earth's surface does not change, so it is easy to maintain line-of-site between an earth station and the satellite. A single satellite can provide communications over a wide area, so there is a wide range of choices for locating earth station equipment, and it can achieve stable transmission capacity and round-trip time (RTT).

Figure 1: Use case overview



LEO satellite

LEO satellites orbit at altitudes between hundreds and thousands of kilometers, and their position relative to the earth's surface is always changing. They are relatively small, and many are used to form mega-constellations that enable the whole system to achieve high capacity. Earth stations must track the satellites and perform handover between satellites as necessary. They are able to implement communication that is relatively high-speed and low latency.

Three types of application were envisioned for this use case. Among the three types, surveillance cameras, which require the highest level of communication priority and stability, always use the GEO satellite backhaul. The business application and internet communications are lower priority than the surveillance camera video, but require low latency and high capacity, so they normally use the LEO satellite backhaul. Interruptions in LEO satellite communication were anticipated (e.g. temporary interruption due to insufficient number of operating satellites, longer interruptions due to infrastructure faults, etc.), and GEO satellites were used to maintain the minimum communication when the LEO satellite communications were interrupted. Communication was switched back as soon as the LEO satellites recovered. QoS control was applied to adjust bandwidth for each application dynamically, even when channels were switched and traffic became concentrated on GEO satellite links. This control enabled communication continuity and stability to be maintained.

3. 5G Control technologies

Advanced technologies in 5G were used to implement the use cases described in Section 2. The main technologies: "dynamic routing" and "QoS control" are described below.

■ Dynamic routing

Dynamic routing involves many technologies for each domain (i.e.: access network and core network) and for each protocol layer. In this article, we describe the method for dynamic routing using protocols specified for the 5G core network. The Session Management Function (SMF) handles configuring and managing communication routes. In the User Plane Function (UPF), which handles packet routing and transport, transport rules are delivered using the Packet Forwarding Control Protocol (PFCP). In gNodeB (gNB: base stations) communications configuration is delivered using the Next Generation Application Protocol (NGAP) through the Access and Mobility Management Function (AMF). These functions are performed when a Protocol Data Unit (PDU) session is established, but the same control is also performed when a fault such as a communications interruption is detected, which makes automatic route switching possible.

■ QoS control

5G QoS control is done in units of QoS Flow, of which there are two types: Guaranteed Bit Rate (GBR) QoS Flows, which provide a guaranteed bit rate, and Non-GBR QoS Flows, which do not. 3GPP standardized multiple Quality of Service class identifier (5QI) values, defining QoS characteristics such as latency, packet loss, and priority level for each 5QI. A GBR QoS Flow controls bit rates in terms of a Guaranteed Flow Bit Rate (GFBR) and a Maximum Flow Bit Rate (MFBR).

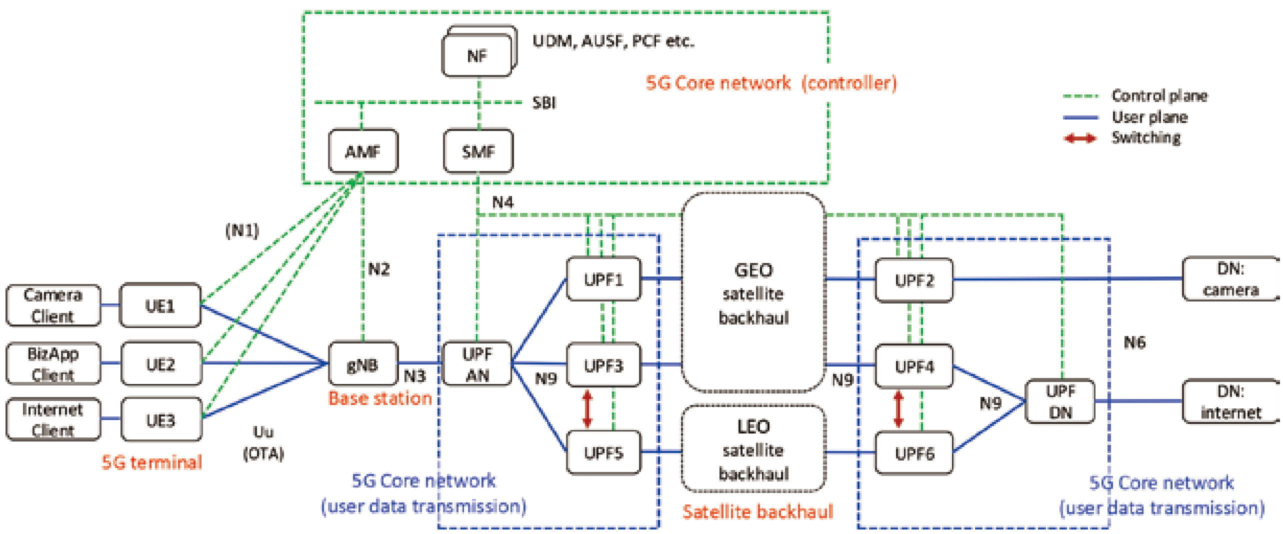
In this demonstration QoS control was performed by setting the priority level, GBR or Non-GBR, and GFBR/MFBR values for each application according to the network environment.

4. Test overview

Here we describe the demonstration performed using GEO and LEO multi-orbit satellite communications as the backhaul for Local 5G, based on the use case described in Section 2.

A summary of the system architecture is shown in Figure 2. The 5G core network UPF used in this demonstration had not

■ **Figure 2: System configuration**



■ **Table 1: QoS design (normal operation)**

Application	5QI	Priority Level	GBR	GFBR (Mbps)	MFBR (Mbps)	Backhaul
Camera	4	50	GBR	15	29	GEO
BizApp	6	60	Non-GBR	--	--	LEO
Internet	9	90	Non-GBR	--	--	LEO

■ **Table 2: QoS design (when LEO interrupted)**

Application	5QI	Priority Level	GBR	GFBR (Mbps)	MFBR (Mbps)	Backhaul
Camera	4	50	GBR	15	15	GEO
BizApp	4	50	GBR	8	10	GEO
Internet	4	50	GBR	3	4	GEO

implemented QoS control functions, so QoS evaluation for down-link communication was not possible. However, the gNB did implement QoS control functions for up-link communications, so QoS control was applied to the Local 5G radio segments (Radio Access Network, RAN).

For GEO backhaul channels, we built an environment emulating the 30 Mbps up-link throughput, while the LEO backhaul channels used real Starlink connections. Note that the GEO emulation environment was validated in preliminary testing with real GEO channels, confirming that there was no practical difference for indices such as throughput, jitter and RTT.

In this use case, we designed two QoS configurations: normal operation and when the LEO channel is interrupted; and enabled switching between them. The QoS designs for the demonstration are shown Table 1 and Table 2.

During normal operation, only the 5G control signals and Camera, which are high priority and require a stable connection, use the GEO channels. When a LEO channel is interrupted, BizApp and Internet also use the GEO channel. According to the QoS design, the upper limit for Camera is halved, maintaining the minimum quality it requires, while enabling BizApp and Internet to continue.

5. Test results and discussion

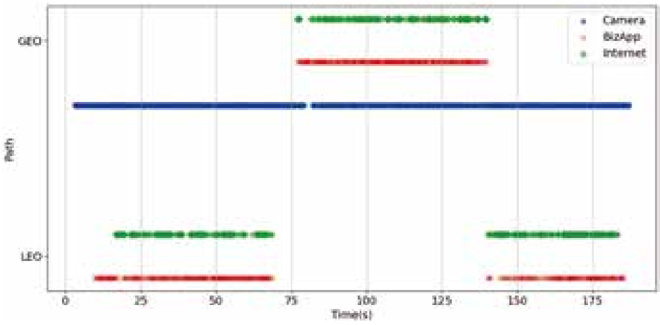
Route switching results

Figure 3 shows results of which backhaul each application is using, GEO satellite or LEO satellite, over time.

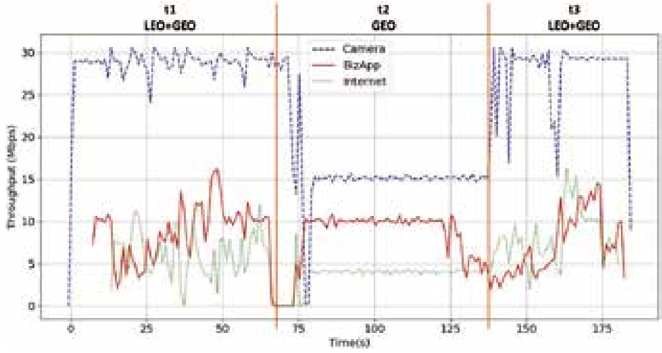
Camera (● symbol) uses the GEO satellite for communication all of the time, as designed. The ● symbol in a fixed position across the entire timeline shows continuous and stable communication.

The BizApp (× symbol) and Internet (◆ symbol) applications were designed to communicate by LEO satellite channel under normal operation. The × and ◆ symbols in the figure show the GEO satellite being used only when the LEO channel is interrupted, indicating that communication continuity is maintained by using the LEO satellites when they are available, and using the GEO satellite when they are not.

■ **Figure 3: Backhaul classification**



■ **Figure 4: UDP throughput fluctuation**



QoS control results

We measured the up-link throughput from User Equipment (UE) to the server on the Data Network (DN), and verified effectiveness of the QoS control. Results of UDP throughput measurements are shown in Figure 4. In the graph, the vertical axis shows throughput and the horizontal axis shows elapsed time. The horizontal axis can be divided into three main time periods:

t1. Using both GEO and LEO channels simultaneously
t2. Using only GEO channels (when LEO channels are not available)
t3. Using both GEO and LEO channels simultaneously (after LEO channels have recovered)

During the t1 and t3 segments, GEO and LEO channels are both being used, achieving high overall throughput. Camera uses GEO channel exclusively, so it does not compete for resources. On the other hand, although “BizApp” was higher priority than “Internet”, priority control had no apparent effect on throughput. This is because the up-link bandwidth on the LEO channel is narrower than between gNB and UE, so QoS control on the backhaul is essential. Throughput on the LEO channel also fluctuates more, so the trade-off between guaranteed bandwidth and wide-band utilization must be considered in QoS control at the IP layer and higher.

In the t2 segment, throughput was stable, and bandwidth restrictions were shown to be operating appropriately for the three applications when using the GEO channels. Resource competition was minimized between the applications and communication quality was shown to be maintained for each application.

Note that interruption did occur for three to five seconds when switching channels. The switching time includes detecting the interruption, recovery and changing the route, and this can be adjusted by configuring the interval and frequency of detection.

6. Conclusion and future prospects

In this research, we studied a new use case using multi-orbit satellite communications for a Local 5G backhaul and showed that it is possible to increase throughput and achieve stable communications by using 5G QoS control and dynamic routing according to the network environment. These results suggest that multi-orbit satellite linked with 5G communications can provide high-speed, stable communications infrastructure in areas where terrestrial infrastructure is insufficient or during disaster.

A result of this demonstration is that satellite channels can be used in a service providing backhaul for Local 5G networks, but also that satellite communications can be applied in 5G NTN services expanded to the RAN segment in 5G (see Figure 5).

SKY Perfect JSAT Corporation is also considering applications for Universal NTN. Universal NTN is a multilayer network based on 3GPP standard technology, combining geostationary satellites, non-geostationary satellites, high-altitude platform (HAPS) and other technologies. This will function as communications infrastructure where terrestrial networks do not reach, such as at sea, in the mountains and during disaster and aim to implement a "Society without dead zones"[1].

Realizing Universal NTN will involve many issues beyond flexible routing and QoS control technologies used in this demonstration, such as improving performance of NTN infrastructure, network connection technology (ISL technology), development of multi-access/multi-band terminals and integrated control systems. For now, we will continue linking SKY Perfect JSAT Corporation's satellite infrastructure and terrestrial communications systems using the results of this demonstration, and expand functionality in stages, as 3GPP extension specifications spread. From the state of NTN standardization and external trends, we expect to implement multi-layered networks composed of multiple NTN infrastructures and terrestrial communications systems by around 2030. SKY Perfect JSAT Corporation plans to take leadership with these technologies and business models and create the future of sustainable communications infrastructure.

Acknowledgements

This research was conducted by NICT as part of the commissioned research, "Research and Development of Satellite-Terrestrial Integration Technology in Beyond 5G" (No. 21901).

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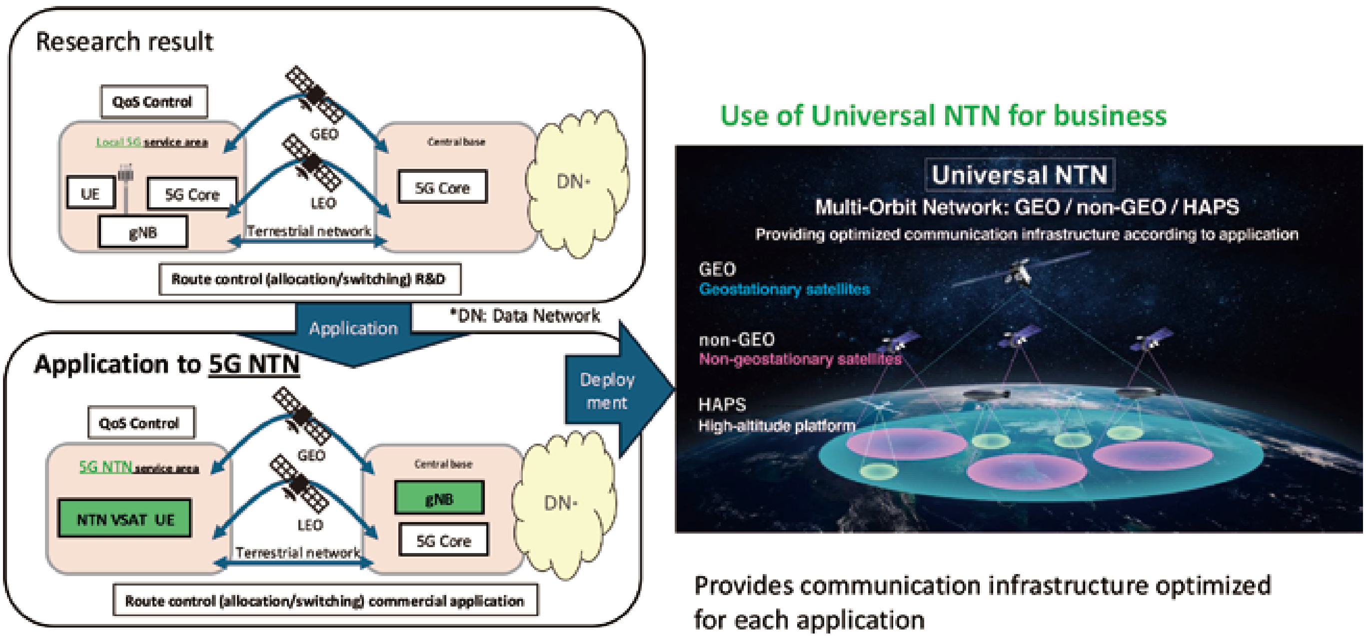
Figure 5: Using results of this demonstration and business prospects



Enhancing Local 5G Resilience through Satellite-Terrestrial Integrated Backhaul and Adaptive Resource Control

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1. Introduction

As Beyond 5G evolves, interest in non-terrestrial networks (NTNs) grows because they extend coverage and strengthen communication systems against terrestrial infrastructure failures. Within NTNs, satellite communication provides wide-area coverage and an independent backhaul path for Local 5G systems.

In this article, Local 5G resilience means the ability to maintain or rapidly restore essential connectivity and service quality when terrestrial backhaul fails, access demand rises sharply, or available network capacity becomes constrained. Satellite backhaul improves path diversity, but a backup path alone does not guarantee service continuity. Satellite links generally provide less bandwidth and higher latency than terrestrial links, so traffic that moves to the satellite path can create congestion and degrade critical applications.

This study therefore combines satellite-terrestrial integrated backhaul with adaptive control in the 5G Core (5GC), the user plane, and the network-slicing management layer. The approach addresses three complementary aspects of resilience: connection-establishment resilience during simultaneous access, priority-data resilience under user-plane contention, and application-service resilience under constrained backhaul capacity.

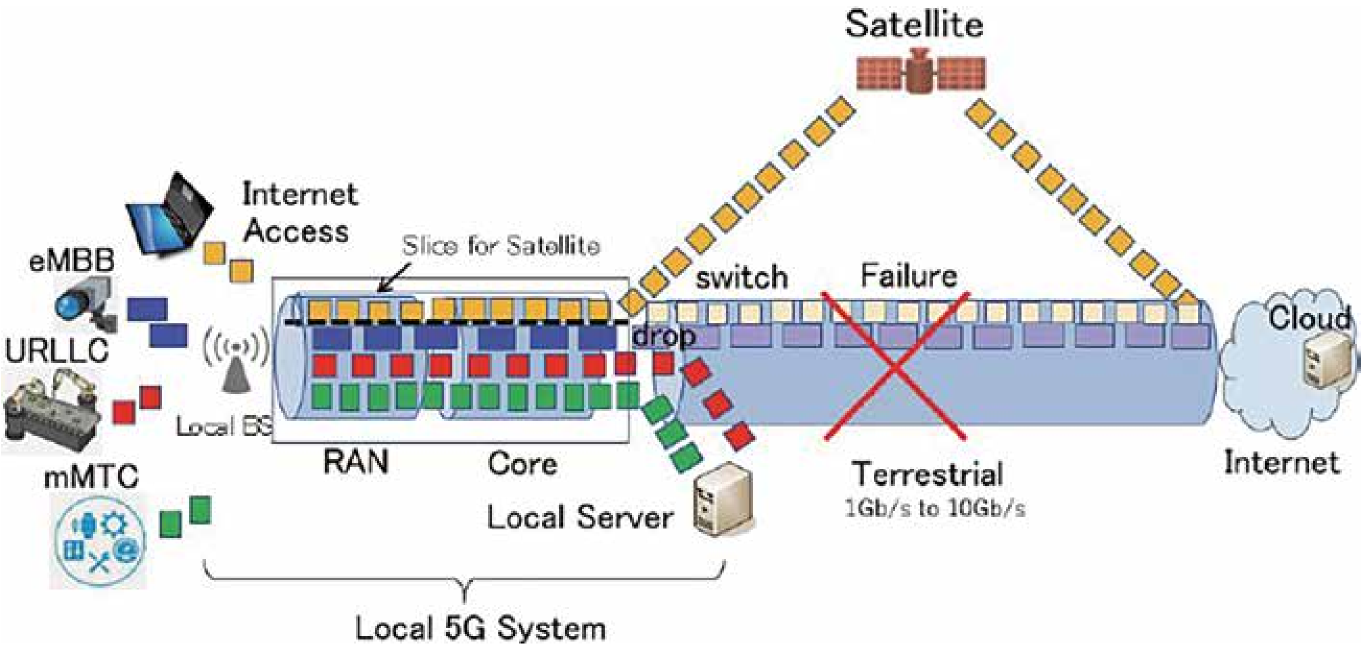
The University of Tokyo conducts this work under the NICT-commissioned project “Research and Development of Satellite-Terrestrial Integration Technology for Beyond 5G” (No. 21901). The project develops Local 5G backhaul technologies that use satellite communication as an alternative path when terrestrial connectivity becomes unavailable or insufficient.

2. Local 5G Resilience Framework

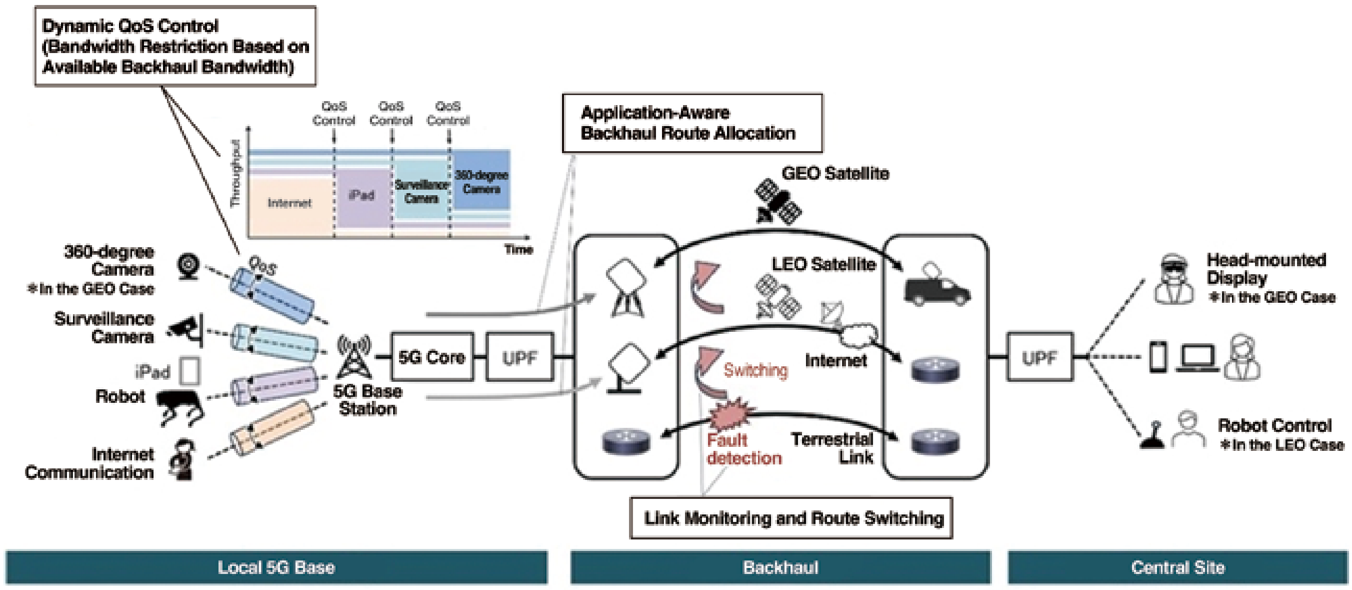
Figure 1 illustrates the basic resilience concept. A Local 5G system normally uses a terrestrial backhaul path and switches essential traffic to a satellite path when the terrestrial path fails. This path diversity preserves connectivity, while network slicing and adaptive resource control determine which services continue to receive resources when the backup path has limited capacity.

Figure 2 shows the integrated testbed and the resilience-control sequence. The system monitors available links, detects a fault, switches the backhaul route, allocates routes according to application requirements, and adjusts QoS according to the available backhaul capacity. Together, these functions form a resilience loop that detects a change, adapts the network, and

■ **Figure 1: Satellite backup path for resilient Local 5G**



■ **Figure 2 : Resilience architecture for satellite-terrestrial integrated Local 5G**



protects priority services.

To make the purpose and evaluation directly correspond, this study defines the following three resilience objectives:

Objective	Resilience objective	Control mechanism	Evaluation focus
Objective 1	Connection-establishment resilience	Prioritize 5GC control-plane network functions during simultaneous UE access.	Average number of UEs that establish a connection.
Objective 2	Priority-data resilience	Allocate user-plane processing resources to critical IoT slices under competing traffic.	Number of MQTT messages transmitted by each sensor class.
Objective 3	Application-service resilience	Apply dynamic 5QI, GFBR, and MFBR control when backhaul capacity is constrained.	Continuity and quality of the priority camera service.

The integrated testbed includes terrestrial and real satellite links. The results below focus on the control and resource-management mechanisms that sustain essential services after network conditions change. End-to-end failover metrics, such as switchover time and service-interruption duration, remain outside the present evaluation scope.

3. Resilience Technologies and Evaluation

3.1 Control-Plane Resilience during Simultaneous Access

A disaster or backhaul outage can cause many devices to reconnect at nearly the same time. The resulting signaling surge can congest the 5GC control plane before user equipment (UE) establishes a Packet Data Unit (PDU) session. This congestion prevents devices from regaining network access precisely when communication becomes most important.

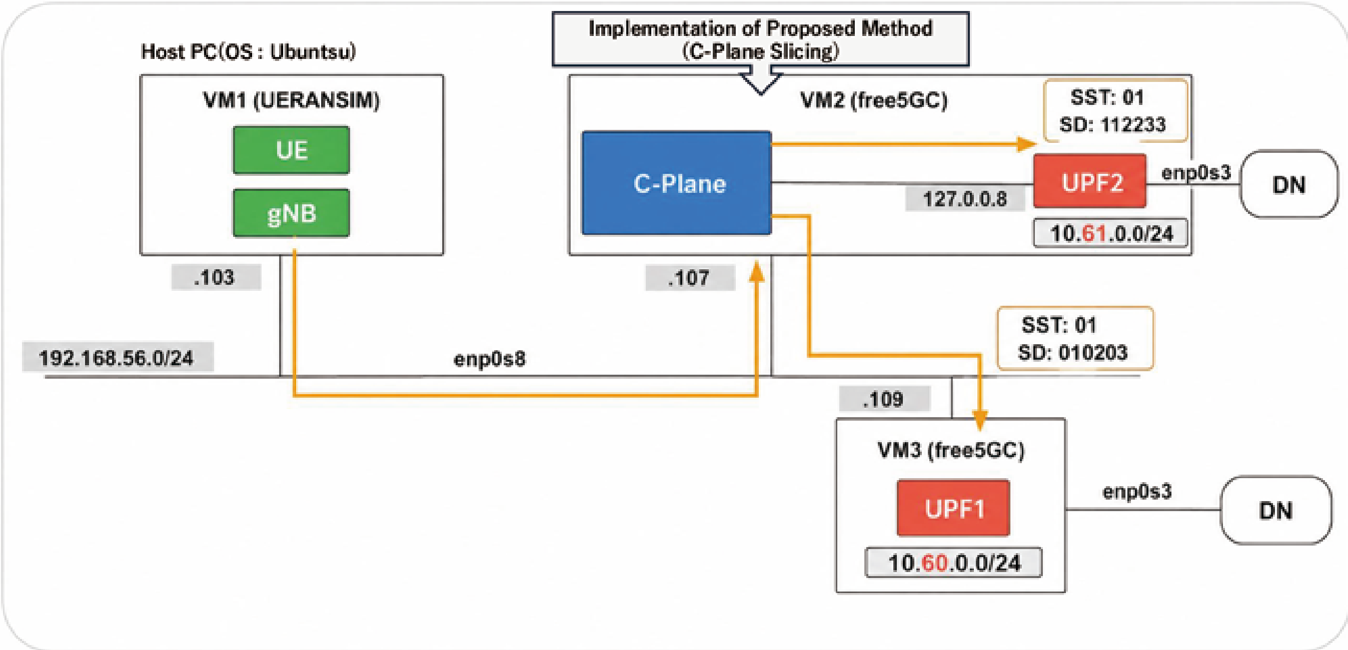
To improve connection-establishment resilience, we apply a control-plane resource-prioritization method, referred to here as control-plane slicing, to selected 5GC network functions (NFs). The method assigns different CPU scheduling priorities to the Network Repository Function (NRF) and the Access and Mobility Management Function (AMF), where signaling processing can become a bottleneck. Figure 3 shows the evaluation environment based on free5GC and UERANSIM.

The evaluation activates 70 UEs simultaneously and compares the average number of successful connections under different NF priority settings. The Linux nice command controls CPU scheduling priority. Nice values range from -20 to 19, and a lower value gives a process a higher scheduling priority.

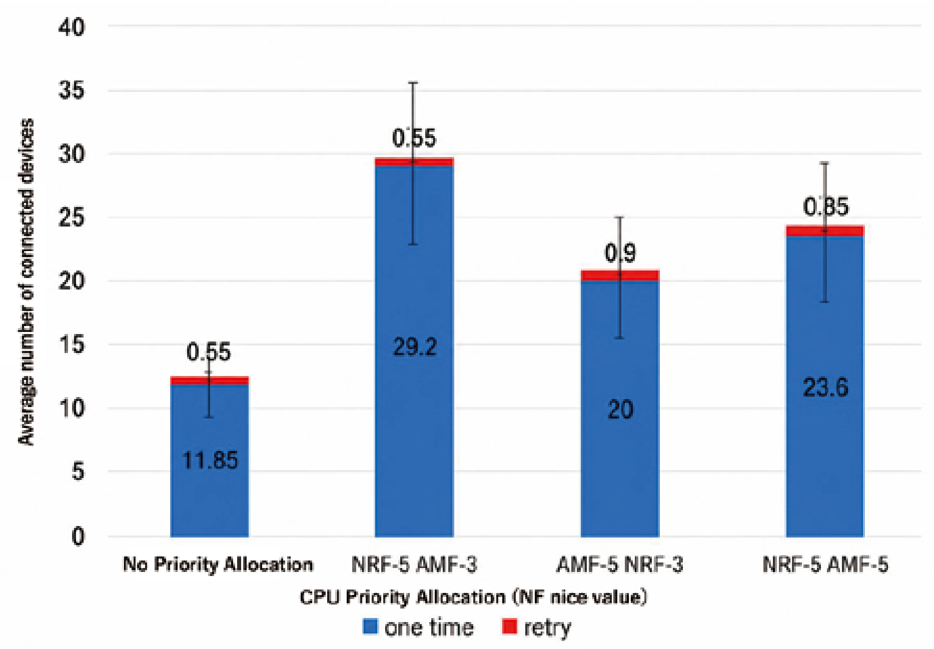
Without priority allocation, an average of 12.4 UEs establishes a connection. The average rises to 29.75 when the NRF receives higher priority, 20.9 when the AMF receives higher priority, and 24.45 when the NRF and AMF receive equal priority. NRF prioritization produces the best result and reaches approximately 2.4 times the baseline.

These results show that targeted control-plane resource allocation improves the ability of Local 5G to absorb a simultaneous-access surge and reconnect more devices. The best configuration does not connect all 70 UEs within the measurement interval, so the result represents a component-level resilience improvement rather than complete recovery. Further evaluation examines scaling behavior, connection-completion time, and the interaction among additional control-plane NFs.

■ **Figure 3: Evaluation environment for control-plane resilience using free5GC and UERANSIM**



■ **Figure 4: Average number of connected UEs under different NF CPU-priority configurations**

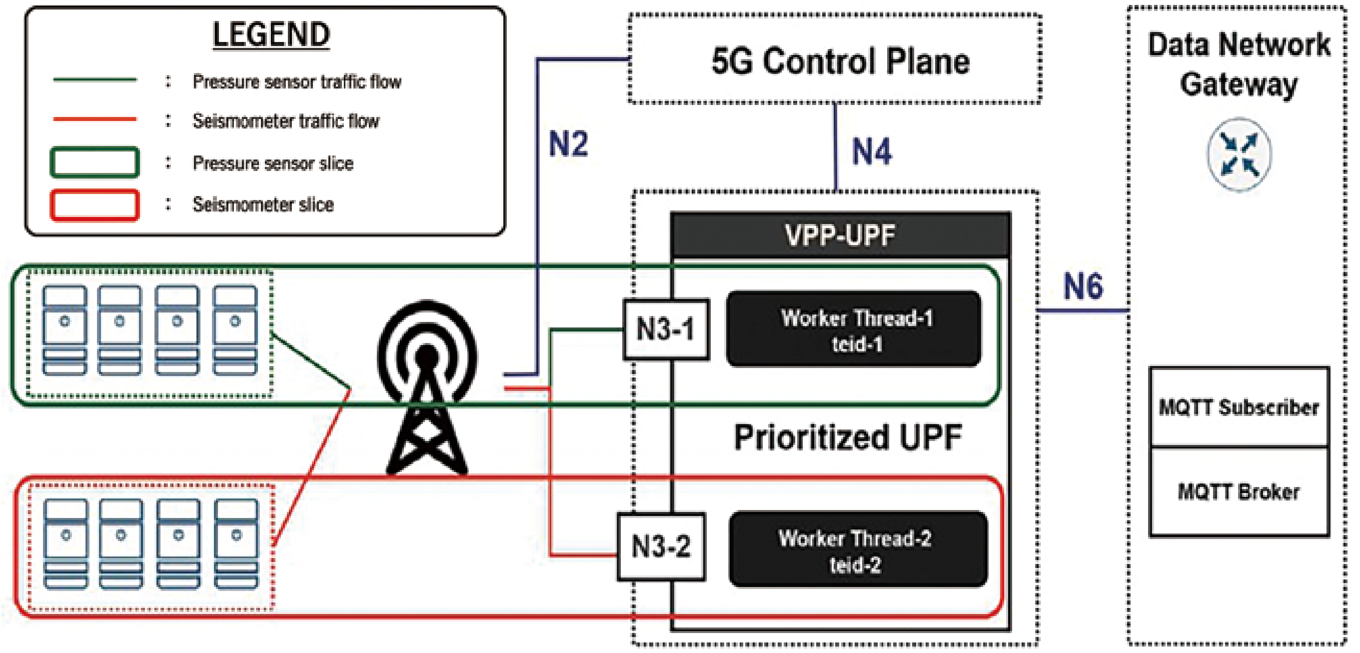


3.2 User-Plane Resilience for Priority IoT Traffic

After devices establish a connection, Local 5G resilience also depends on the continued delivery of critical data. Disaster-monitoring systems commonly use Message Queuing Telemetry Transport (MQTT), a lightweight messaging protocol for IoT applications. When multiple sensor classes share the same user-plane resources, high-volume or non-critical traffic can reduce the processing capacity available to urgent monitoring data.

The proposed network-slicing method assigns separate user-plane processing resources to pressure-sensor and seismometer

Figure 5: Slice-aware UPF resource allocation for resilient MQTT communication

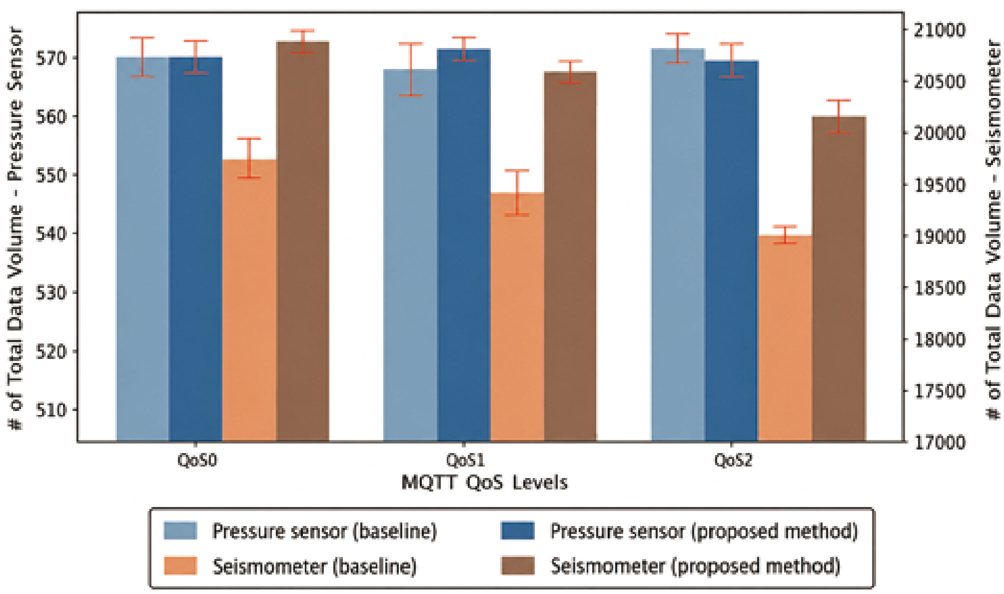


traffic and gives the critical seismometer slice higher processing priority in the User Plane Function (UPF). Figure 5 illustrates the slice-aware UPF configuration, and Figure 6 compares the baseline and proposed methods at MQTT QoS levels 0, 1, and 2.

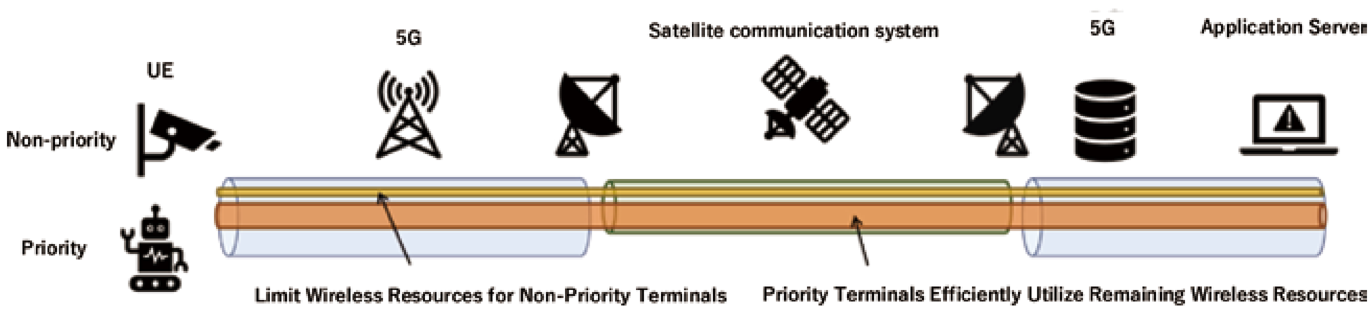
In the demonstration, seismometers transmit data at a high rate. At every MQTT QoS level, the proposed method increases the number of transmitted seismometer messages by more than 1,000 relative to the baseline while preserving the pressure-sensor service. This result indicates that slice-aware user-plane resource allocation helps sustain priority-data throughput under contention.

The present evaluation focuses on throughput. Mission-critical resilience also depends on end-to-end delivery ratio, latency, jitter, and duplicate-message behavior, particularly at MQTT QoS levels 1 and 2. The next evaluation stage measures these indicators and

Figure 6: Total number of MQTT messages transmitted with the baseline and proposed methods



■ Figure 7: Dynamic QoS control for priority-service continuity under constrained backhaul



examines whether the method maintains stable performance when satellite-link delay and loss vary.

3.3 Application-Service Resilience under Constrained Backhaul

When traffic moves to a bandwidth-constrained backhaul path, priority applications can still experience video degradation or freezing even though basic connectivity remains available. Application-service resilience therefore requires the network to adapt resource allocation according to the importance of each service and the currently available capacity.

The proposed management method uses network slicing and 5G QoS control. Each application receives a Single Network Slice Selection Assistance Information (S-NSSAI) value and a 5G QoS Identifier (5QI). QoS flows use either a Guaranteed Bit Rate (GBR) or non-GBR resource type. GBR flows include a Guaranteed Flow Bit Rate (GFBR) and a Maximum Flow Bit Rate (MFBR), which allow the controller to set explicit bandwidth parameters.

When a user designates a camera as a priority application, the controller applies a GBR-type QoS profile with configured GFBR and MFBR limits to non-priority traffic. This control restricts the bandwidth used by non-priority slices and preserves capacity for the priority camera. Figure 7 shows the resulting resource-control concept across the Local 5G and satellite-communication path.

In the remote disaster-monitoring demonstration, the controller responds to an on-demand request for a camera with guaranteed quality. The evaluation observes less image degradation and shorter freezing intervals after dynamic bandwidth control is applied. Because the present result is qualitative, further evaluation quantifies freeze duration, frame loss, video bitrate, latency, and objective image-quality indicators.

Operational resilience also requires timely and repeatable control. The next implementation stage automatically selects and applies network-slice policies according to application state, user priority, and measured backhaul capacity. This automation reduces dependence on manual operation and lowers the risk of human error during an emergency.

4. Conclusion

This article frames satellite-terrestrial integration as a Local 5G resilience architecture rather than as a backup-link function alone. Satellite backhaul provides path diversity, while control-plane prioritization, slice-aware user-plane processing, and dynamic QoS management help the system use limited backup capacity effectively.

The component evaluations address three directly corresponding resilience objectives. Control-plane prioritization raises the average number of connected UEs from 12.4 to 29.75 in the best configuration in our testbed. This result shows our proof of concept for control-plane slicing, but we plan to extend our idea to a larger scale experiment. Slice-aware UPF resource allocation increases transmitted seismometer messages by more than 1,000 at each MQTT QoS level. Dynamic QoS control preserves capacity for a priority camera and reduces observed image degradation and freezing intervals.

Taken together, these results support the component-level feasibility of a Local 5G system that absorbs access surges, sustains critical IoT traffic, and protects priority services when backhaul capacity becomes constrained. The current evaluation does not yet provide a complete end-to-end resilience assessment because it does not quantify route-switchover time, service-interruption duration, satellite-link latency, jitter, or packet loss.

Further work integrates automatic policy control with link monitoring and route switching and evaluates the complete resilience sequence under repeatable failure and congestion conditions. The resulting architecture provides a practical basis for robust Local 5G deployments in disaster monitoring and other environments where terrestrial connectivity is unavailable, damaged, or insufficient.

Supporting Disaster-Resilient Digital Infrastructure in Asia-Pacific Region

Dr. Cosmas Luckyson Zavazava
Director, BDT

In disaster prone regions as across the Asia-Pacific, resilient digital infrastructure is essential to ensure that lifesaving warnings reach people in time. This was the central focus of the Regional Workshop on Resilient Infrastructure for Effective Early Warning Dissemination, convened in September 2025 by the International Telecommunication Union (ITU) and the International Research Institute of Disaster Science (IRIDeS), Tohoku University, with the support of Japan's Ministry of Internal Affairs and Communications (MIC), in Sendai, Japan.

Sendai carries profound relevance for disaster risk reduction. The city was one of those severely impacted by the 2011 Great East Japan Earthquake and tsunami, making it a powerful setting to reflect on how technology, policy, and preparedness translate into real-world resilience.

The workshop brought together policymakers, regulators, disaster management agencies, network operators, and technical experts from across the Asia-Pacific region. Discussions focused on how robust, redundant, and interoperable ICT networks can support early warning systems. The workshop also illustrated how Japan's experience is being translated into structured regional cooperation through a long-standing partnership between MIC Japan and ITU on resilient ICT infrastructure in Asia and the Pacific.

Japan's national experience was highlighted as a practical reference. The J-Alert system demonstrated how automated, multi-channel warning dissemination—using satellite and

Figure 1: Participants at the International Research Institute of Disaster Science (IRIDeS), Tohoku University.

terrestrial networks—can deliver alerts directly to the public without manual intervention, even outside working hours. Advances such as impact-based tsunami forecasting showed how warnings can evolve from simple alerts into actionable information for emergency response.

These operational lessons are being translated into regional cooperation through the long-standing partnership between MIC Japan and ITU. The collaboration has strengthened policy frameworks, institutional capacity, and national abilities to deploy resilient ICT infrastructure and early warning communications, directly contributing to the Early Warnings for All initiative.

An early warning system combines hazard monitoring, risk analysis, communication networks, and public preparedness so that timely and understandable alerts reach people at risk. A key emphasis of the workshop was ensuring that warnings are delivered reliably, rapidly, and inclusively.

Cell Broadcast was highlighted as a critical tool to achieve this objective. Unlike SMS, Cell Broadcast enables authorities to send area-specific alerts simultaneously to all mobile phones connected to nearby base stations, including during periods of network congestion. Participants emphasized that appropriate policy and regulatory support is essential for its effective implementation.

Hands-on learning was reinforced through study tours and site visits, allowing participants to observe resilience measures in practice. These included visits to the National Institute of Information and Communications Technology, NTT DOCOMO's disaster-recovery facilities in Sendai, drone-based early warning demonstrations along the coast, and the Arahama Elementary School preserved as a site of remembrance from the 2011 tsunami.

Participants consistently highlighted that no single technology can guarantee complete coverage. Countries emphasized the importance of hybrid approaches that combine mobile networks, broadcasting, satellite systems, and community based channels, alongside strong policy mandates, regional cooperation, and capacity building for officials and communities.

Figure 2: Emergency response coordination room of NTT

Figure 3: Knowledge sharing by experts from NTT DOCOMO

Figure 4: Knowledge sharing by experts from NTT DOCOMO

■ **Figure 5: A scene from Arahama Elementary School, a reminder of the 2011 tsunami's impact and the community's recovery.**

The workshop ended with a study tour to Arahama Elementary School, located near the Pacific coast, which was struck by the 2011 tsunami and accommodated more than 300 local residents. It was followed by a demonstration of automated disaster-alert drone system of Sendai City.

■ **Figure 6: A diorama model of earthquake remains at Arahama Elementary school.**

Held in Sendai—a city shaped by disaster and recovery—the workshop reinforced a shared regional commitment to building resilient, inclusive, and standards-based digital infrastructure so that early warnings reach everyone, everywhere.

■ **Figure 7: Group Picture during visit to NICT Sendai Center**

Figures: To be credited to ITU

= A Serial Introduction Part 4 =
Winners of ITU-AJ Encouragement Awards 2025

In May every year, The ITU Association of Japan (ITU-AJ) proudly presents ITU-AJ Encouragement Awards to people who have made outstanding contributions in the field of international standardization and have helped in the ongoing development of ICT.
These Awards are also an embodiment of our sincere desire to encourage further contributions from these individuals in the future.
If you happen to run into these winners at another meeting in the future, please say hello to them.
But first, as part of the introductory series of Award Winners, allow us to introduce some of those remarkable winners.

Takashi Matsui

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Fields of activity: ITU-T SG15, IEC TC86

Collaboration Between ITU-T and IEC: Paving the Way for New Recommendations on optical fiber for space-division multiplexing

I would like to express sincere appreciation upon receiving this ITU-AJ Encouragement Award. I would also like to express my sincere gratitude to all those involved in ITU-T SG15 activities.

I have participated in standardization activities with IEC TC86 (Fiber Optics) since 2009, engaged mainly in the standardization of existing optical fiber and test methods. and with IEC SC86A (Optical Fiber Cables), in standardization of high-density optical cables. Since 2022, I have participated in ITU-T SG15, engaged in discussions toward revision of existing optical fiber recommendations and standardization of Space Division Multiplexing (SDM) optical fiber, which is attracting attention as a next-generation optical fiber.

ITU-T SG15 and IEC TC86 promote discussions in cooperation with each other. At ITU-T SG15, a technical report on SDM optical fiber technology was published in 2022, and a supplement document, G Suppl. 87, which summarizes the mandatory parameters and frameworks for establishing standards for SDM optical fiber and cooperation with other standardization organizations, was agreed upon and published in 2025. This supplement describes that the first Recommendation specifies a weakly coupled multi-core fiber (WC-MCF), and specifically targets WC-MCF, which has a standard cladding diameter (125 µm) and is optically compatible with existing G. 65x single-mode fibers.

Based on this supplementary document, Japan proposed development of new Recommendations for WC-MCF and establishment of related test methods, which were approved in March 2025. At the same time, IEC TC86 also agreed to start standardization discussions related to WC-MCF, and discussions are proceeding in close cooperation through a liaison. We will continue to contribute to standardization activities for optical fiber cable technology, including the new standardization of MCF technology, while serving as a bridge between ITU-T and IEC.

Yukinobu Miyatake

KDDI Foundation
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Fields of activity: Support for education in developing countries

Expanding access to educational opportunities in Nepal through e-learning and robotics programming

I am deeply honored to receive this Encouragement Award from the ITU Association Japan. I would like to express my sincere gratitude to the Association, and everyone who has worked with me.

With its slogan, “Bridging Worlds, Creating Futures,” the KDDI Foundation aims to share the benefits of ICT globally. Below, I introduce our educational support activities in Nepal, which I have been involved in since the early stages of my work at the Foundation.

One major challenge I encountered in Nepal was the significant gap in educational opportunities. Even within compulsory education, some children were unable to attend school due to family circumstances. Education often relied heavily on individual teachers’ skills, children with visual or hearing impairments faced delays in learning, and ICT infrastructure remained insufficient. These conditions highlighted the urgent need for comprehensive educational support.

Under such circumstances, cooperating with the Mayor of Lalitpur, local education authorities, and the NGO OLE Nepal, we launched an e-learning platform and a robotics programming initiative in public basic and secondary schools. These initiatives helped parents of economically disadvantaged families to better understand the importance of education, leading to improved school attendance. They also enabled students to study independently outside regular class hours, thereby expanding learning opportunities.

In parallel, we developed digital learning materials, including Nepali-language e-books and Nepali sign-language content, and implemented them in special needs schools for children with visual or hearing impairments. Although geographically limited, our support has expanded to girls' schools and schools in remote areas. To address challenges such as limited ICT skills among teachers and curriculum revisions by the government, we collaborated with OLE Nepal to update e-learning materials and provide local educators with training.

As a result, students' motivation improved, and STEAM-oriented education was initiated at girls' schools. Since 2023, we have organized an annual robotics competition in Lalitpur, and enthusiastic student participation has reaffirmed the significance of our efforts

Going forward, we seek to deepen collaboration with local stakeholders to establish a sustainable, locally driven education support model. We will continue working toward this ideal.

Kanta Yamamoto

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Fields of activity: O-RAN WG2, WG10 standardization

Standardization Activities for Resolving Policy Conflicts concerning Wireless Base Stations

I am truly grateful to receive the prestigious Japan ITU Association Encouragement Award. I would like to express my sincere gratitude to everyone at the Japan ITU Association and all those who participated in the activities aimed at resolving the A1 policy conflicts in the O-RAN WG2.

The O-RAN has a mechanism for conveying RAN control policies, called "A1 Policies," from SMO/Non-RT RIC to Near-RT RICs. However, it has not sufficiently discussed or studied situations in which multiple A1 Policies are implemented simultaneously and, consequently, might contradict or conflict with each other. This A1 Policy conflict has raised concerns that if such contradictions are not resolved at higher-layer entities (e.g., SMO and Non-RT RIC), complex conflict handlings will be required at lower-layer entities (e.g., O-CU, O-DU, and O-RU), and the complexity of development of lower-layer entities could be increased in a way that makes openness and multi-vendor interoperability of the open fronthaul interface more difficult. Recognizing the importance of resolving A1 Policy conflicts at higher layers, as a rapporteur for the Work Item (WI) of WG2, I have decided to promote the study of resolving these technical issues.

The technical report describes methods for detecting overlapping scopes of A1 Policies, determining the presence of conflict and/or inconsistency scenarios within those overlapping scopes, and arbitrating conflicts between A1 Policies. It also proposes some examples of practical algorithms for detecting such conflicts and necessary procedures from the viewpoint of service-based architecture.

From now on, I will promote activities to reflect the contents of this technical report in the O-RAN standard specification, and I would like to utilize my experience to contribute to the realization of "real open" wireless base stations.

Shohei Yoshioka

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Fields of activity: 3GPP TSG RAN WG1

Specification of 3GPP standards for creation of 5G industry and collaborative solutions

I am deeply honored to receive the prestigious Japan ITU Association Encouragement Award. I would like to express my sincere gratitude to everyone at the Japan ITU Association and to all those involved who provided tremendous support in my standardization activities leading up to this award.

Since 2017, I have been participating in 3GPP, in which I have been focusing on development of physical control channels for 5G as well as standard specifications—which are the key to industrial creation and solution co-creation—for V2X/terminal-to-terminal communication and NTNs (non-terrestrial networks). As for V2X communication, I approached discussions with "achieving high reliability" as my key focus; however, coordinating with various companies that prioritized other aspects, such as simplifying terminal operation, was not easy. Nevertheless, I continued to make proposals with conviction, and through persistent dialogue, I was able to build agreement and incorporate many high-reliability features into the specifications.

As for NTNs, I played a key role in coordinating discussions regarding ensuring uplink connectivity. Amid the conflicting interests of numerous companies, leading the discussions while gaining trust as an impartial facilitator and reaching a consensus was an invaluable, irreplaceable experience. I am proud to say that by deeply understanding the intentions of each company, assessing the validity of their arguments, and taking firm action when necessary, I was able to contribute to improving quality of NTNs. After approximately 10 years of discussions on 5G, the standardization of 6G is finally about to begin in earnest. I intend to continue working wholeheartedly on standardization activities to promote the development of the industry and realize a world full of dreams.

58th Celebration of World Telecommunication and Information Society Day

The ITU Association of Japan

On May 15, the "58th Celebration of World Telecommunication and Information Society Day," hosted by the ITU Association of Japan (ITU-AJ), was held at the Keio Plaza Hotel in Nishi-Shinjuku (Shinjuku-ward, Tokyo). Approximately 140 participants from the Japanese government and the telecommunications and broadcasting industries attended the event. A celebratory reception followed the ceremony. May 17 marks the anniversary of the signing of the International Telegraph Convention in 1865, which laid the foundation for the International Telecommunication Union (ITU). In conjunction with the global observance of World Telecommunication and Information Society Day (WTISD) by the ITU and its member countries, ITU-AJ holds this annual commemorative ceremony in Japan. During the ceremony, the MIC Minister's Award and the ITU-AJ Awards, both of which have a distinguished history and were presented for the 54th time this year, were awarded in recognition of individuals who have made outstanding contributions to the fields of international standardization, international cooperation, and the broader information, communications, and broadcasting sectors.

In her remarks as a guest of honor, Noriko Horiuchi, State Minister for Internal Affairs and Communications, noted that the widespread adoption of AI is ushering information and communications into a new era. She highlighted Japan's efforts to develop and standardize All-Photonics Networks as a key infrastructure for an AI-driven society, emphasized the important role of the ITU in bridging the digital divide, and expressed Japan's continued commitment to actively contributing to ITU activities, including support for the re-election of Seizo Onoe as Director of the Telecommunication Standardization Bureau. Remarks were also delivered by Ryo Nakamura, Director-General and Assistant Minister (Ambassador) for Global Issues at the Ministry of Foreign Affairs of Japan (MOFA), who stressed the importance of the ITU's role in ensuring that people around the world have access to information and communication technologies. He further noted that Japan should continue to play a leading role within the ITU in promoting the development of telecommunications and stated that Japan would continue its outreach efforts to relevant countries in advance of upcoming elections. Hiroyuki Morikawa, Chairman of the Selection Committee for the ITU-AJ Awards, presented a report on this year's award selection process.

The award presentation ceremony then took place, during which the MIC Minister's Award and the ITU-AJ Awards were conferred. The MIC Minister's Award was presented to Satoshi Miyaji of KDDI Corporation. Mr. Miyaji served as Chair of ITU-T Study Group 9 (SG9) from 2016 to 2024, during which he promoted the standardization of Japanese proposals, including IP cable broadcasting technologies and fifth-generation cable modem systems. He contributed significantly to the smooth management of SG9 meetings and the revitalization of the group's activities. In addition, at the World Telecommunication Standardization Assembly 2024 (WTSA-24), he played a leading role in the integration of SG9 and SG16 and, as Chair of Committee 3, guided consensus-building efforts. Through these achievements, he made outstanding contributions to the advancement of telecommunications technologies and to enhancing Japan's presence in the international arena. The ITU-AJ Special Award was presented to Dots for Inc. and Okayama Broadcasting Co., Ltd. Dots for Inc. was recognized for establishing low-cost communications infrastructure powered by solar panels and other technologies in rural regions of Africa that previously lacked connectivity, thereby creating sustainable digital access environments. The company has also leveraged the resulting connectivity and data to support a range of initiatives, including installment-based sales services, vocational training, advertising businesses, and remote work opportunities such as AI annotation. By integrating communications infrastructure development, data utilization, and employment creation, Dots for has made a significant contribution to local economic transformation. Okayama Broadcasting was honored for its more than 30 years of efforts to expand the possibilities of sign-language broadcasting and improve information accessibility. The company pioneered Sign Language Commentary 2.0, in which deaf individuals themselves provide live sign-language commentary, and has broadened opportunities for visually accessible sports viewing through practical applications in sporting events and Deaflympics-related programming. Through these initiatives, it has contributed to the realization of a more inclusive society through broadcasting. In addition, recognition was given to five individuals who received the ITU-AJ Special Achievement Award, thirteen individuals who received the ITU-AJ Accomplishment Award, and twenty individuals and one team who received the ITU-AJ Encouragement Award. These awards honored contributions to the activities of the ITU and related ITU initiatives in Japan, the implementation of the principles and action plans of the World Summit on the Information Society, international cooperation in the fields of telecommunications, broadcasting, and postal services, and other internationally significant activities related to information and communications or broadcasting.

Following the award ceremony, commemorative lectures were delivered by the recipients of the ITU-AJ Special Award. Representing Dots for, Mr. Carlos Oba presented a lecture entitled "Technology, Ideas, and Passion to Bridge the Digital Divide for 3.5 Billion People Worldwide" Representing Okayama Broadcasting, Mr. Yoshio Shinoda delivered a presentation entitled "Thirty Years of Sign Language Broadcasting Built Together with the Deaf Community — Pursuing Information Accessibility for All"

The Association is grateful that it was once again able to present the MIC Minister's Award and the ITU-AJ Awards at this year's ceremony. We extend our sincere congratulations to all award recipients and wish them continued success and good health. We would also like to express our appreciation to the nominating organizations and to all those whose support made this event possible. A recording and photos from the ceremony are posted on the ITU-AJ web site.

https://ituaj.jp/?p=43552

58th Celebration of World Telecommunication and Information Society Day

15 May 2026 at the KEIO PLAZA HOTEL

The ITU Association of Japan

通巻百五十一号

MIC Minister's Award Winner
State Minister for Internal Affairs and Communications
HORIUCHI Noriko (left) and
MIYAJI Satoshi of KDDI (right)

ITU-AJ Special Award Winner
SHINODA Yoshio of
Okayama Broadcasting Co., Ltd. (right)

ITU-AJ Special Award Winner
OBA Carlos of Dots for Inc. (right)

Recipients of the ITU-AJ Special Achievement Award

Recipients of the MIC Minister's Award and the 54th ITU-AJ Awards

(Listed in Japanese alphabetical order; honorifics omitted. Affiliations are those at the time of nomination.)

MIC Minister's Award

MIYAJI Satoshi KDDI CORPORATION

ITU-AJ Special Award

Okayama Broadcasting Co., Ltd.
Dots for Inc.

ITU-AJ Special Achievement Award

ABE Muneo Formerly at Mitsubishi Electric Corporation
KAWASUMI Yasuhiko Formerly at KDDI CORPORATION
TSUGAWA Seiichi Formerly at KDDI CORPORATION
MAEDA Yoichi Formerly at NTT, Inc.
YAMASHITA Makoto BHN Association

ITU-AJ Accomplishment Award

ONO Koji KDDI CORPORATION
KANEKO Toshihiro KDDI Foundation
KUMAKI Kenji KDDI CORPORATION
KENYOSHI Kaoru National Institute of Information and Communications Technology
KONOMA Kazuhisa BHN Association
SAWADA Hirokazu National Institute of Information and Communications Technology
SHIBAGAKI Nobuhiko KOKUSAI DENKI Electric Inc.,
TAKECHI Hiroshi NEC Corporation
TSUJI Hiroyuki National Institute of Information and Communications Technology
NAKAZATO Hidenori Waseda University
NAKAMURA Takauyuki NTT DOCOMO SOLUTIONS, INC.
MASUDA Masafumi NTT DOCOMO, INC.
YASUKAWA Masaki NEC Magnus Communications, Ltd.

ITU-AJ Encouragement Award

INOUE Shoki NEC Corporation
UEMURA Katsunari 1FINITY Inc.
EMA Arisa The University of Tokyo
KAWAMOTO Makio Mitsubishi Electric Corporation
SHIBAIKE Naoya NTT DOCOMO, INC.
TAKAHASHI Masaki Japan Broadcasting Corporation
TAKEI Shigenori SCSK Security Corporation
TAKETSUGU Masanori NEC Corporation
TANIGUCHI Kosuke NTT DOCOMO, INC.
TOJO Yasuhide KDDI Foundation
NAKANO Yuto KDDI Research, Inc.
NAMBU Naoaki Yachiyo Engineering Co., Ltd.
HIRAMATSU Masaaki National Astronomical Observatory of Japan, National Institutes of Natural Sciences
HIROYA Nanami The Japan Aerospace Exploration Agency
FUKUMOTO Norihiro KDDI Research, Inc.
HONDA Mariko National Institute of Information and Communications Technology
MATSUO Yoichi NTT, Inc.
MUNEKATA Takehito KDDI CORPORATION
LIU Juan National Institute of Information and Communications Technology
WAKAYAMA Toshiyasu KDDI CORPORATION
O-RAN Standardization Project Team for O-RU Energy Saving Specification NEC Corporation

定価 一冊 一、六五〇円（本体価格 一、五〇〇円、消費税 一五〇円） 年間購読料 六、六〇〇円（本体価格 六、〇〇〇円、消費税 六〇〇円）