Joint Demonstration Report

of the Local 5G Optimization Project

Ver 1.0

2025.2.25

All Participating Companies of the Local 5G Optimization Project

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1. Introduction

In November 2023, the "Local 5G Optimization Project" (hereinafter referred to as L5G Optimization Project) was launched, initiated by NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION, with participation from 18 companies, including domestic and international telecommunications equipment vendors. The project aims to promote the adoption and expansion of local 5G by reducing costs and enhancing convenience. It advances interconnection demonstrations of local 5G equipment and validates use cases. As of February 2025, over 300 combinations of joint demonstrations have been completed.

The vendor equipment that makes up the local 5G system is diverse, with each having different functionalities, performance characteristics, and pricing. When providing a local 5G system to users, combining equipment from different vendors based on user requirements can lead to proposals that are optimally tailored to meet those specific needs.

On the other hand, constructing a local 5G system using equipment from different vendors, can lead to higher integration costs due to the need for tuning configuration parameters and conducting operational verification tests. Consequently, systems are often built using equipment from the same vendor. However, a local 5G system composed of equipment from a single vendor, may sometimes offer functionalities or performance that exceed the requirements of specific use cases. To further reduce the costs of local 5G systems, it is considered effective to adopt an approach that minimizes integration costs during interconnection between different vendors, thereby broadening the range of equipment selection based on use case requirements.

This report presents successful combinations of vendors for interconnection, along with considerations to keep in mind during the interconnection process. It also discloses performance metrics such as throughput and latency associated with these combinations, as well as the operational results of security solutions available in the market. We believe this data will assist in the integration process during system construction, and hope that utilizing this report will contribute to reducing system integration costs associated with vendor equipment configurations.

Additionally, this report is the first version(Ver1.0), and we plan to continue publishing verification results and insights in the future. We hope that this report will contribute to accelerating the social implementation of local 5G, promoting industrial digital transformation (DX), and addressing regional challenges.

2. Regarding the Local 5G Optimization Project

This project is being conducted in collaboration with various companies that brought their verification equipment to the laboratory of NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION, based on three themes. This chapter provides an overview of each theme.

As of February 2025, the participating companies consist of 26 firms, as shown in Table 2-1. The local 5G equipment brought in by each company is illustrated in Figure 2-1.

Table 2-1 List of Participating Companies in the Project

No.	Company Name
1	Airspan Japan KK
2	ANRITSU Corporation
3	Askey Computer Corporation
4	Compal Electronics
5	CTOne Inc.
6	D-Link Japan K.K.
7	FLARE SYSTEMS Co., Ltd.
8	Hewlett Packard Japan, G.K.
9	HTC Corporation
10	HYTEC INTER Co., Ltd.
11	Industrial Technology Research Institute（ITRI）
12	KYOCERA Corporation
13	LITE-ON Japan ltd.
14	LITE-ON Technology Corporation
15	NEC Corporation
16	NEC Magnus Communications, Ltd.
17	NIPPON TELEGRAPH AND TELEPHONE EAST CORPORATION
18	Nokia Solutions and Networks Japan G.K.
19	NTT TechnoCross Corporation
20	Panasonic Connect Co., Ltd.
21	Pegatron Japan Inc.
22	Quanta Cloud Technology Incorporated
23	REIGN Technology Corporation
24	Saviah Technologies
25	Sumitomo Electric Industries, Ltd.
26	Trend Micro Inc.

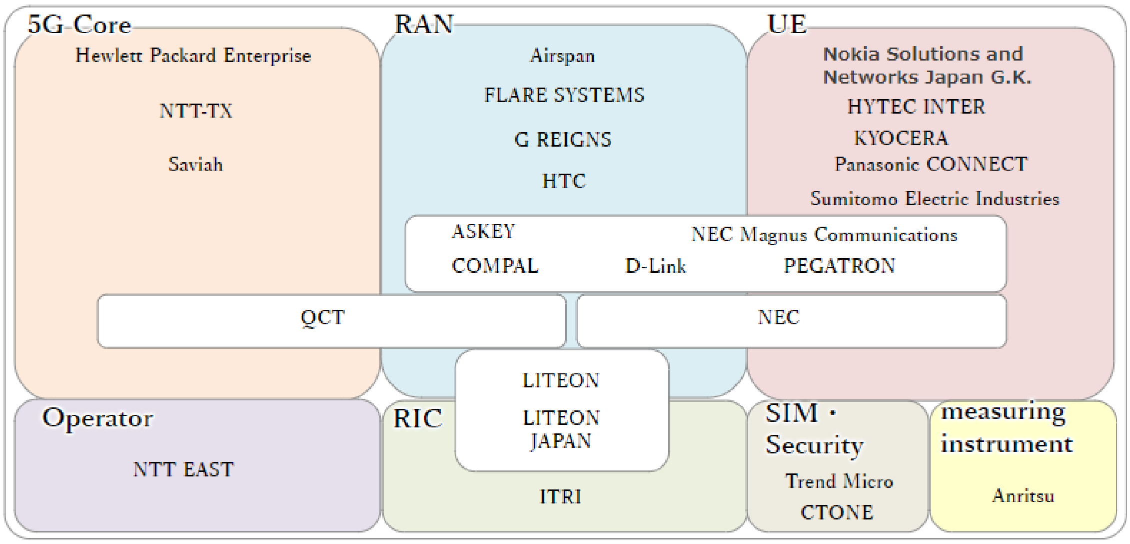

Figure 2-1 Local 5G Equipment Provided by Participating Companies

2.1. Overview of Theme 1 (Interconnection between Local 5G Devices)

In Theme 1, we are working on the interconnection verification between local 5G devices from different vendors.

When constructing a local 5G system using devices from different vendors (including the 5G core responsible for terminal authentication and network control, as well as the base stations (RAN) used for radio control), the integration costs associated with system construction, such as tuning of configuration parameters and operational verification tests between local 5G devices, are often higher compared to a configuration consisting of devices from the same vendor. As a result, it has become common to use local 5G devices from the same vendor.

However, in configurations using local 5G devices from the same vendor, there are cases where the functionality or performance may be excessive for certain use cases. To further reduce the costs of local 5G systems, it is considered effective to adopt an approach that minimizes integration costs during interconnection between multiple vendors, thereby broadening the selection of local 5G devices according to specific use cases.

Therefore, in Theme 1, we will evaluate communication performance in successful connection patterns and assess communication quality in use cases such as high-definition video transmission. Additionally, we will compile cases where connections were unsuccessful and clarify the points to consider during interconnection.

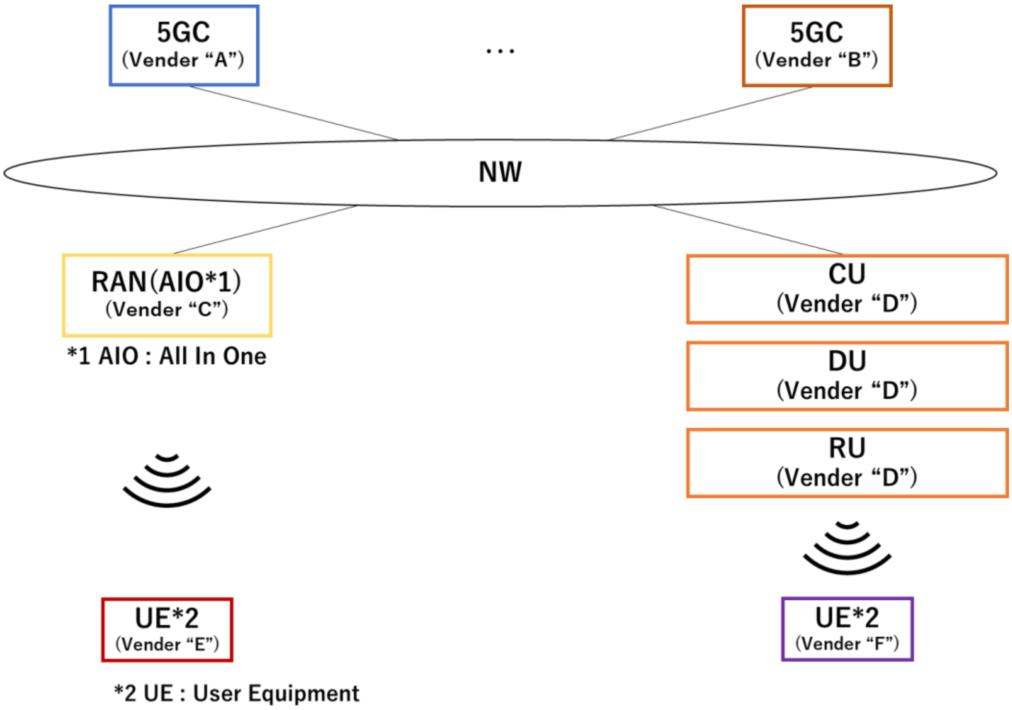

Figure 2-2 Overview of Theme 1

2.2. Overview of Theme 2 (Optimization of Local 5G Device Parameters)

In Theme 2, we will focus on the verification of parameter optimization for local 5G devices according to specific use cases.

In wide-area environments such as factories and logistics warehouses, it is common to have a mix of devices with various communication requirements installed. This necessitates support for a diverse range of use cases. For example, when making layout changes such as relocating installed local 5G devices in a customer environment, the parameters must be adjusted every time during device handovers to meet the communication requirements of each terminal. Therefore, there is an expectation for the realization of autonomous and automatic control of local 5G device parameters, which would eliminate the need for complex operations by the customer.

In Theme 2, the aim is to enhance usability by expanding use cases and providing a high-quality local 5G environment tailored to those use cases. This includes addressing various communication requirements in environments where critical communications, such as high-definition real-time video transmission and robot operation, must not be interrupted. The goal is to clarify the optimal values for local 5G device parameters, such as handover parameters, that correspond to technologies controlling service quality, including priority control and bandwidth management.

Additionally, with an eye on utilizing the RAN Intelligent Controller (RIC) as defined by the O-RAN ALLIANCE, the goal is to establish a system that enables autonomous and automatic parameter control even when the environment changes due to layout modifications in factories or logistics warehouses. This approach aims to ensure the continuous provision of high-quality local 5G communication.

The results of this theme's demonstration will be reported in the next report and will not be included in this document.

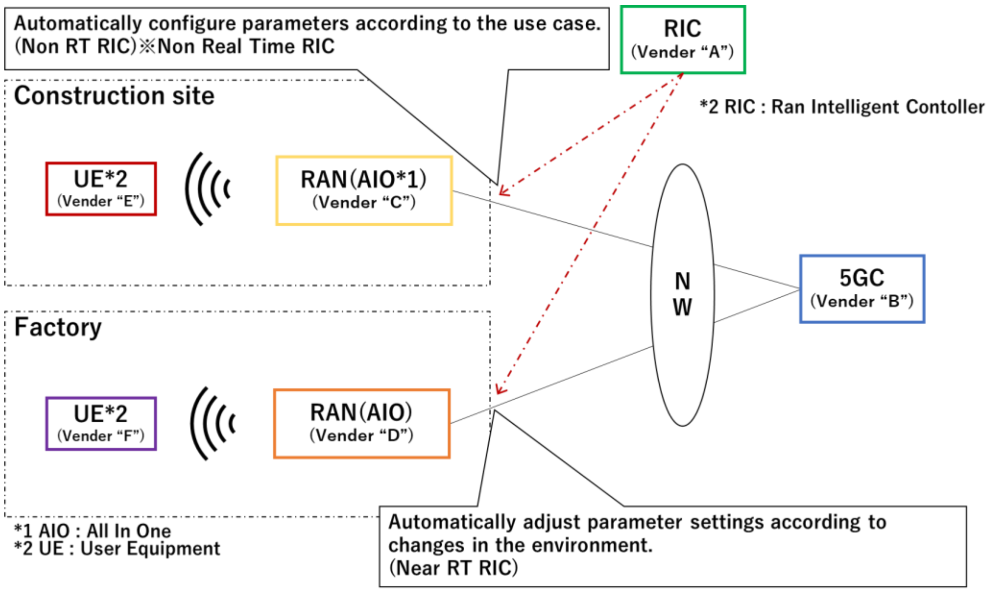

Figure 2-3 Overview of Theme 2

2.3. Overview of Theme 3 (Enhancement of Security Measures for Local 5G Utilization Environment)

In Theme 3, we will focus on enhancement of security measures for the local 5G utilization environment. Furthermore, this theme was established as a new initiative based on discussions among project members since the project's inception.

While local 5G is expected to enhance security through strict subscriber management and robust key management via SIM cards, there are many devices, such as IoT devices, that cannot implement traditional agent-based endpoint security measures.

Additionally, in environments such as factories and medical settings, there is a need to continue using older devices, making it difficult to upgrade the operating systems or related software. As a result, there are cases where devices must be operated with known vulnerabilities.

In a completely closed network where the introduction or removal of devices is not permitted, the use of such terminals and devices would not pose any issues. However, with the increasing opportunities for connection to external networks due to IoT and smart technology, there is growing concern that terminals and devices lacking adequate security measures may be exposed to threats.

Therefore, in Theme 3, we aim to enhance security measures in various local 5G device utilization environments by leveraging the TMMNS solution provided by Trend Micro and CTOne. This will involve the integration of security SIM cards with network security features to create a more robust security framework.

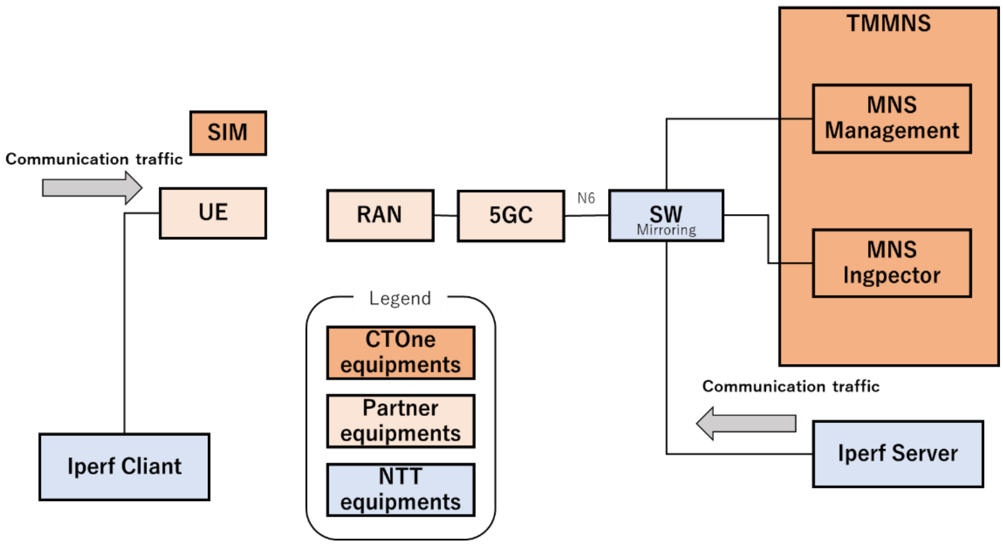

Figure 2-4 Overview of Theme 3

3. Theme 1 Demonstration (Interconnection between Local 5G Devices)

Theme 1 will conduct interconnection tests between local 5G equipment from different vendors. The specific details of the demonstration are shown in Table 3-1.

Table 3-1 Theme 1 Demonstration Content

No.	Demonstration Content
3.1 Interconnection Testing	· Evaluate the feasibility of interconnection. · Summarize insights on interconnection through examples of failed interconnections.
3.2 Throughput Testing	· Evaluation of communication quality in combinations that allow interconnection.
3.3 4K Video Transmission Delay Testing	· Evaluation of delay characteristics during 4K video transmission as a specific use case for communication quality.

3.1. Interconnection Testing

3.1.1. Test Configuration

The test configuration is illustrated in Figure 3-1 and Figure 3-2. The RAN and UE will be deployed within a shielded box or a shielded tent.

Data communication after the UE connection is established will occur between the UE itself or a Client PC connected to the UE, and the N6 Server located at the N6 interface.

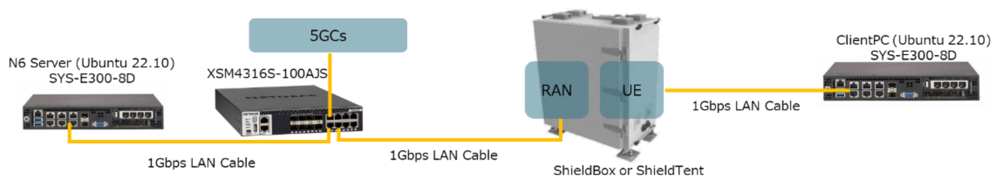

Figure 3-1 Interconnection Testing Configuration

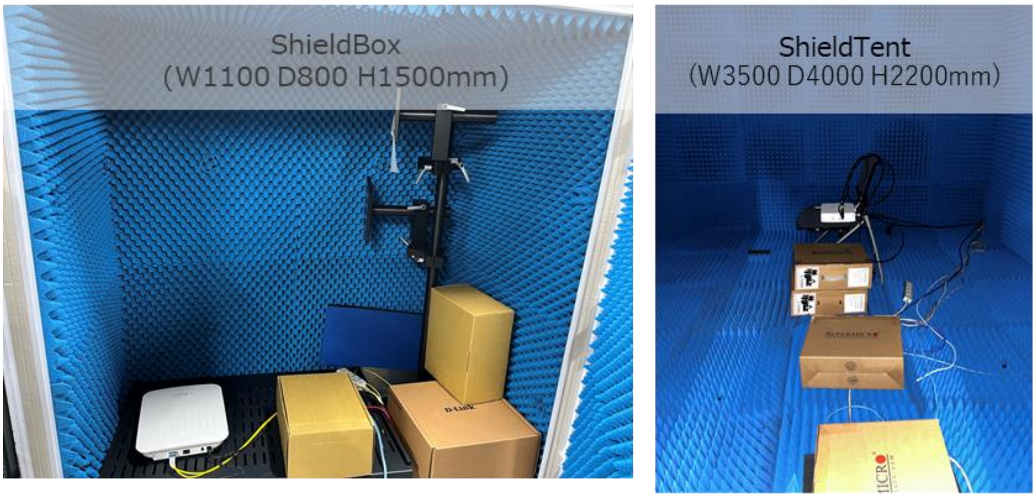

Figure 3-2 Shielded Box and Shielded Tent

To minimize the impact of environmental differences on the test results, the output power of the RAN and the placement of the UE were adjusted to achieve an RSRP value of approximately -70 dBm for the UE. The sizes of the shielded box and shielded tent, along with their effective field strengths, are shown in Table 3-2.

Table 3-2 Specifications of the Shielded Box and Shielded Tent

Product Name	Size(W×D×H)【mm】
Shielded Box	1,100×800×1,500
Shielded Tent	3,500×4,000×2,200

3.1.2. List of Test Equipment

The names and model numbers of the local 5G equipment used in this test are shown in Table 3-3, and the specifications of the local 5G equipment are presented in Table 3-4.

Table 3-3 Local 5G Devices Used in Interconnection Testing: Product Names and Model Numbers

Company Name	Abbreviation	Classification	Product Name/Model Number
Hewlett Packard Japan, G.K.	HPE	5GC	HPE Aruba Networking Private 5G Core
NTT TechnoCross Corporation	NTT-TX	5GC	-
Quanta Cloud Technology Incorporated	QCT	5GC	OmniCore
Saviah Technologies	Saviah	5GC	-
Airspan Japan KK	Airspan	RAN	Airspeed 1900
Askey Computer Corporation	Askey	RAN	NR xCell 80156C
Compal Electronics	Compal	RAN	Integrated Small Cell "Cedar"
FLARE SYSTEMS Co., Ltd.	FLARE SYSTEMS	RAN	-
HTC Corporation REIGN Technology Corporation	HTC G REIGNS	RAN	HPFG-0-0101
LITE-ON Technology Corporation	LITE-ON	RAN	FlexFi 5G Small cell ORAN-RU/FF-RFI079I04
NEC Corporation	NEC	RAN	RV1200
NEC Magnus Communications, Ltd.	NEC Magnus	RAN	FB2000SS
Pegatron Japan Inc.	Pegatron	RAN	5G ORAN Station/PG5200, Indoor RU 4T4R
Quanta Cloud Technology Incorporated	QCT	RAN	OmniRAN
Askey Computer Corporation	Askey	UE	NUQ3000M
Compal Electronics	Compal	UE	RAKU/91ZX533007A
D-Link Japan K.K.	D-Link	UE	DWP-1010W
HYTEC INTER Co., Ltd.	HYTECINTER	UE	HW5G-3100-SSD
NEC Corporation	NEC	UE	VersaPro/VJV50G-B
NEC Magnus Communications, Ltd.	NEC Magnus	UE	FG900CS
Nokia Solutions and Networks Japan G.K.	Nokia	UE	Industrial 5G Fieldrouter FRRO501c
Panasonic Connect Co., Ltd.	PCO	UE	XC-WN930J-01
Pegatron Japan Inc.	Pegatron	UE	Raptor V2/MG54AX
KYOCERA Corporation	KYOCERA	UE	K5G-C-100A
Sumitomo Electric Industries, Ltd.	SEI	UE	industrial 5G terminals/IGW5111

Table 3-4 Specifications of Local 5G Devices Used in Interconnection Testing

Abbreviation	Classification	3GPP Rel Ver	Embedded CPU/SoC,modem	Layer (UL×DL)	Max QAM UL	Max QAM DL
HPE	5GC	Release16	Confidential	-	-	-
NTT-TX	5GC	Release16	Intel based CPU	-	-	-
QCT	5GC	Release15	Intel based CPU	-	-	-
Saviah	5GC	Release16	Confidential	-	-	-
Airspan	RAN	Release15	Confidential	Confidential	Confidential	Confidential
Askey	RAN	Release15	FSM10056	2×2	256	256
Compal	RAN	Release16	NXP LX2160A NXP LA1238	2×4	256	256
FLARE SYSTEMS	RAN	Release17	Confidential	2×4	256	256
HTC G REIGNS	RAN	Release15	Intel based CPU	2×4	64	64
LITE-ON	RAN	Release15	NXP LX2160	2×4	64	256
NEC	RAN	Release15	Confidential	Confidential	Confidential	Confidential
NEC Magnus	RAN	Confidential	Intel Icelake＋FPGA	2×4	256	256
Pegatron	RAN	Release15	Intel Icelake＋ FPGA(BBU) Intel Arria 10 FPGA(RU)	2×4	Confidential	Confidential
QCT	RAN	Release15	Intel based CPU	2×4	64	256
Askey	UE	Release16	Snapdragon X65 5G Modem-RF System	2×4	256	256
Compal	UE	Release15	Snapdragon X55 5G Modem-RF System	2×4	256	256
D-Link	UE	Confidential	Confidential	Confidential	Confidential	Confidential
HYTECINTER	UE	Release16	Snapdragon X55 5G Modem-RF System	2×4	256	256
NEC	UE	Confidential	Confidential	Confidential	Confidential	Confidential
NEC Magnus	UE	Confidential	Snapdragon X55 5G Modem-RF System	2×4	256	256
Nokia	UE	Release15	Qualcomm IPQ6010 Quectel RM505Q-AE with SDX55	Confidential	Confidential	Confidential
PCO	UE	Release15	Confidential	1×4	64	256
Pegatron	UE	Release16	Snapdragon X62 RM520N-GL	Confidential	Confidential	Confidential
KYOCERA	UE	Release15	Snapdragon X55 5G Modem-RF System	2×4	256	256
SEI	UE	Release16	Snapdragon X65 5G Modem-RF System	2×4	256	256

3.1.3. Configuration Items

The configuration items required for each local 5G device (node) in the interconnection testing are presented in Table 3-5. In this project, uniform configuration values were set for each local 5G device, and tests were conducted under consistent conditions.

Table 3-5 List of Configuration Items

Configuration Item	Per-Node Configuration Item	Configuration Format	5GC	RAN (AIO)	RAN (CU)	RAN (DU)	RAN (RU)	UE
IP Address	5GC N2 IP address	-	○	-	-	-	-	-
	5GC N3 IP address	-	○	-	-	-	-	-
	5GC N4 IP address	-	○	-	-	-	-	-
	5GC N6 IP address	-	○	-	-	-	-	-
	RAN CU IP address	-	-	○	○	-	-	-
	RAN DU IP address	-	-	○	-	○	-	-
	RAN RU IP address	-	-	○	-	-	○	-
	5GC Management IP address	-	○	-	-	-	-	-
	RAN Management IP address		-	○	○	○	○	-
	UE Management IP address		-	-	-	-	-	○
VLAN	N2 VLAN	-	○	○	○	-	-	-
	N3 VLAN	-	○	○	-	○	-	-
RAN SW Mode	-	-	-	○	-	-	-	-
UE Pool IP Address	-	-	○	-	-	-	-	-
PLMN	-	6-digits	○	○	○	-	-	-
TAC/TAI	-	6-digits	○	○	-	○	-	-
SST	-	2-digits	○	○	-	○	-	--
SD	-	1to4-digits	○	○	-	○	-	-
DNN	-	Arbitrary string	○	○	○	-	-	○
5QI	-	1to3-digits	○	○	○	-	-	-
gNB-ID-Length	-	Any number	○	○	○	-	-	-
gNB-ID	-	Hexadecimal 6 digits	○	○	-	○	-	-

3.1.4. Test Items

The test items for this examination are presented in Table 3-6.

Table 3-6 Test Items in Interconnection Testing

No.	Test Item	Test Objective	Test Pass Criteria
1	Registration・PDU Procedure	Verify the connection operation of the UE under normal conditions.	Power on the UE after the 5GC and RAN have been initiated. Confirm that the registration is completed and that a PDU session can be established.
2	1Call test	Confirm data communication of the UE under normal conditions.	After the PDU session is established, confirm that it is possible to ping the server located at the N6 interface.
3	RF Power OFF/ON	Assuming a RAN shutdown and verify that the UE can successfully connect and enable data communication after the RAN is restarted.	After the PDU session is established, disable the RAN. When the RAN is re-enabled, confirm that the UE can successfully establish the PDU session again.
4	UE Power OFF/ON	Assuming user-initiated power OFF/ON operations for the UE and confirm that the UE can successfully connect and enable data communication after it is powered on.	After the PDU session is established, turn off the power of the UE. When the power is turned back on, confirm that the UE can successfully establish the PDU session again.
5	Airplane mode OFF/ON	Assuming user-initiated airplane mode ON/OFF operations and verify that the UE can successfully connect and enable data communication after airplane mode is disabled.	After the PDU session is established, enable the airplane mode on the UE. When airplane mode is disabled, confirm that the UE can successfully establish the PDU session again.

3.1.5. Test Procedures

In this test, we will verify the interconnection and data communication based on the signals specified in items 1 to 5 of the 3GPP specifications [1][2]. Each signal will be confirmed using packet capture.

1. Registration and PDU Procedure Verification
2. Verification of Data Communication Availability After UE Connection
3. Verification of Connection Availability and Procedures Between 5GC and UE After RAN Shutdown and Restart
4. Verification of Connection Availability and Procedures After UE Shutdown and

Restart

5. Verification of Connection Availability and Procedures After Disabling Airplane Mode on UE

In the event that a connection failure occurs or signals outside of the 3GPP specifications are detected during testing, all parties will collaborate to analyze the root cause and work on improvements. If the cause is not identified within the testing period, a retest will be scheduled for the future.

3.1.6. Test Results and Discussion

The combinations that were confirmed to be interconnectable in this test are shown in Table 3-7. UEs labeled with 'OK' are those that have passed all test items. Regarding the UEs manufactured by Sumitomo Electric Industries (SEI), some combinations have not been tested due to their late participation in this project.

Table 3-7 Interconnection Test Results

5 GC	RAN	UE										
		Askey	Compal	D-Link	HYTECINTER	NEC	NEC Magnus	Nokia	PCO	Pegatron	KYOCERA	SEI
HPE	Askey	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
HPE	LITE-ON	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
NTT-TX	Askey	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
NTT-TX	LITE-ON	OK	OK	*1	OK	OK	OK	OK	OK	OK	OK	-
HPE	NEC	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
NTT-TX	NEC Magnus	*1	OK	OK	*1	OK	OK	OK	OK	*1	OK	-
NTT-TX	Airspan	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
Saviah	Pegatron	*1	OK	*1	OK	OK	OK	OK	OK	OK	OK	-
HPE	Compal	*1	OK	OK	OK	OK	OK	*1	OK	OK	OK	-
Saviah	Aiaspan	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-
Saviah	HTC G REIGNS	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
HPE	NEC Magnus	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Saviah	FLARESYST EMS	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
HPE	HTC G REIGNS	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
NTT-TX	FLARESYST EMS	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
HPE	Pegatron	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
QCT	FLARESYST EMS	OK	OK	*1	OK	*1	OK	*1	OK	OK	OK	OK
QCT	Airspan	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Saviah	NEC	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
QCT	Askey	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
NTT-TX	HTC G REIGNS	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
QCT	NEC Magnus	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
NTT-TX	Pegatron	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
QCT	NEC	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Saviah	QCT	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

*1: The combinations that are either not connectable or scheduled for retesting due to one of the connection failure events shown in Table 3-8. The cause analysis information for each combination will not be disclosed in this report.

The results of all 265 combinations that have been processed by February 2025 are shown in Figure 3-3. There are 254 connectable combinations, with a pass rate of 95.8% for the mutual connection tests.

The breakdown of the 11 combinations that were not connectable is shown in Table 3-8. Out of the 11 combinations that were not connectable, 5 have had their causes identified and the issues resolved, while the causes of the remaining 6 are still under investigation.

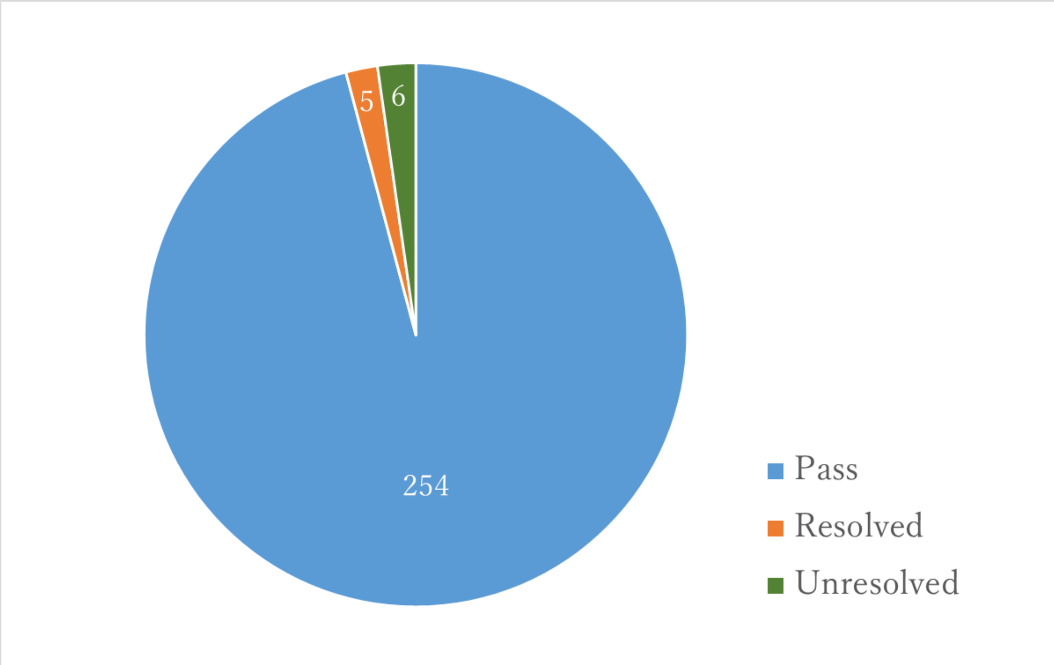

Figure 3-3 Interconnection Test Results

Table 3-8 Interconnection Test Issues

Status	Number of Issues (11)	Issue
Resolved	5	An issue has occurred where the registration procedure is not completed.
Unresolved	1	An issue has occurred where the PDU session establishment has failed.
	2	An issue has occurred where data communication fails after the PDU session is established.
	1	An issue has occurred where the PDU session is repeatedly released and reconnected after reconnection.
	1	An issue has occurred where the PDU session cannot be established after the RAN is powered off and then back on; however, reconnection is possible after restarting the UE.
	1	An issue has occurred where registration fails after the UE is restarted.

3.1.7. Considerations for Compliance in Interconnection and Specific Examples of Connection Failures

The local 5G equipment used in this test has been developed in accordance with 3GPP specifications, and no exchanges of non-standard signals have been observed. On the other hand, while a connection success rate of 95.8% was achieved, there were instances where certain combinations initially failed to connect. However, through troubleshooting, it became possible to establish a connection in those cases. Through this troubleshooting process, the considerations for compliance in interconnection have been summarized as shown in Table 3-9. In addition, this section will introduce specific examples of connection failures.

Table 3-9 Points to Consider for Compliance in Interconnection

Target			Points to Consider
5 GC	RAN	UE	
-	✓	✓	Confirm that the RAN can process the packet size sent by the UE, as the acceptable size of the UE Capability Information packet transmitted by the UE may vary in the RAN.
✓	✓	✓	Be aware of the versions of the 3GPP releases supported by the 5GC, RAN, and UE to avoid inconsistencies caused by unsupported signaling messages exchanged by the local 5G equipment.
✓	✓	-	Some UEs may retain VoIP APN information, so ensure that the 5GC is configured to accept the APN.
✓	-	✓	During setup, verify the necessity of VLAN configuration and implement the appropriate VLAN settings (for N2 and N3 segment configurations).
✓	✓	-	Ensure that the 5QI values for the DNN are mutually supported by both the 5GC and RAN.

・**Case Study 1: Connection failure due to the RAN node discarding the UE Capability Information signal.**

There were UE devices that could not remain in the coverage area with a specific combination of 5GC and RAN. However, by analyzing the N2 packet capture and RAN logs obtained during the test, the cause was identified, and the issue was resolved through a software modification of the RAN.

An excerpt of the packet capture obtained during the occurrence of the issue is shown in Figure 3-4.

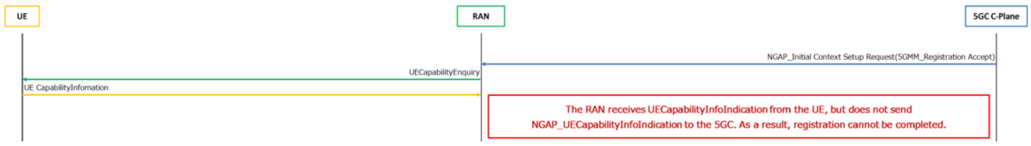

Figure 3-4 Case Study 1 Overview

According to the 3GPP specifications, when the RAN receives the 5GMM_Registration Accept from the 5GC, it is supposed to return the NGAP_UECapabilityInfoIndication to the 5GC. However, the RAN did not return this signal.

Analysis of the RAN system logs during the occurrence of the issue revealed that there was a failure in processing the UE Capability Information received from the UE, which led to its discard.

The UE Capability Information contains technical information, protocol information, security details, and other network function information supported by the UE. It was found that the UE experiencing the issue had a large amount of this information, resulting in an oversized packet that the RAN could not process.

Therefore, in this project, it was determined that the issue was due to a malfunction in the internal processing of the RAN, and not a problem arising from the combination of local 5G equipment. The RAN vendor implemented a software modification, and the resolution of the issue was confirmed. Since then, no occurrences of the same or similar issues have been observed.

・Case Study 2 : Connection Failures Due to Differences in Supported 3GPP Release Versions

There were User Equipments (UEs) that could not remain in coverage with a specific combination of 5G Core(5GC) and Radio Access Network(RAN). The signaling exchanges between local 5G devices captured during the occurrence of the issue are illustrated in Figure 3-5.

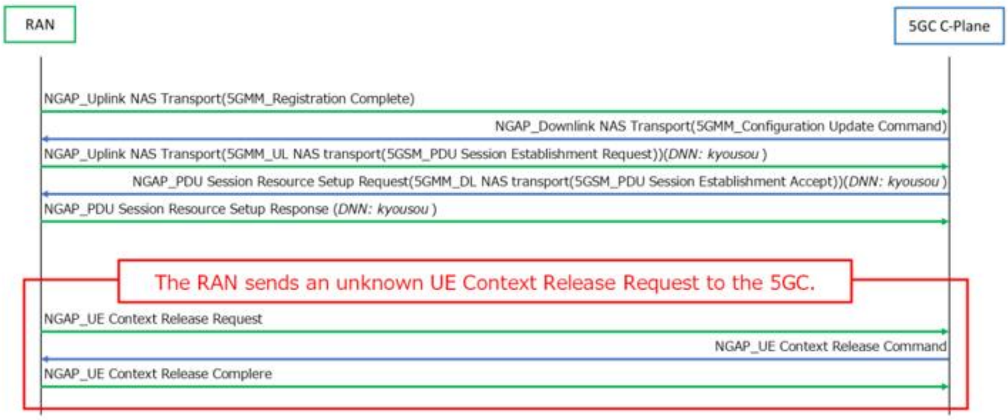

Figure 3-5 Case Study 2 Overview

Immediately after the PDU session was established, an unknown NGAP_UE Context Release Request was sent from the RAN to the 5GC. Analysis of the NGAP_PDU Session Establishment Request signal from the UE, along with the examination of the RAN system logs, revealed that the signals from the UE experiencing the issue contained messages from 3GPP Release 16 [3]. Additionally, it was determined that the RAN in use was not compliant with 3GPP Release 16.

After the RAN vendor implemented a software modification to skip the processing of Release 16 messages within the signaling, the issue was resolved. Since then, no similar issues have been observed.

・Case Study 3：Connection Failure Due to Rejection of Voice APN

There were UEs that could not remain in coverage with a specific combination of 5GC and RAN. Through packet analysis during the occurrence of the issue, we were able to identify the root cause and resolve the problem. An excerpt of the packets during the occurrence of the issue is shown in Figure 3-6.

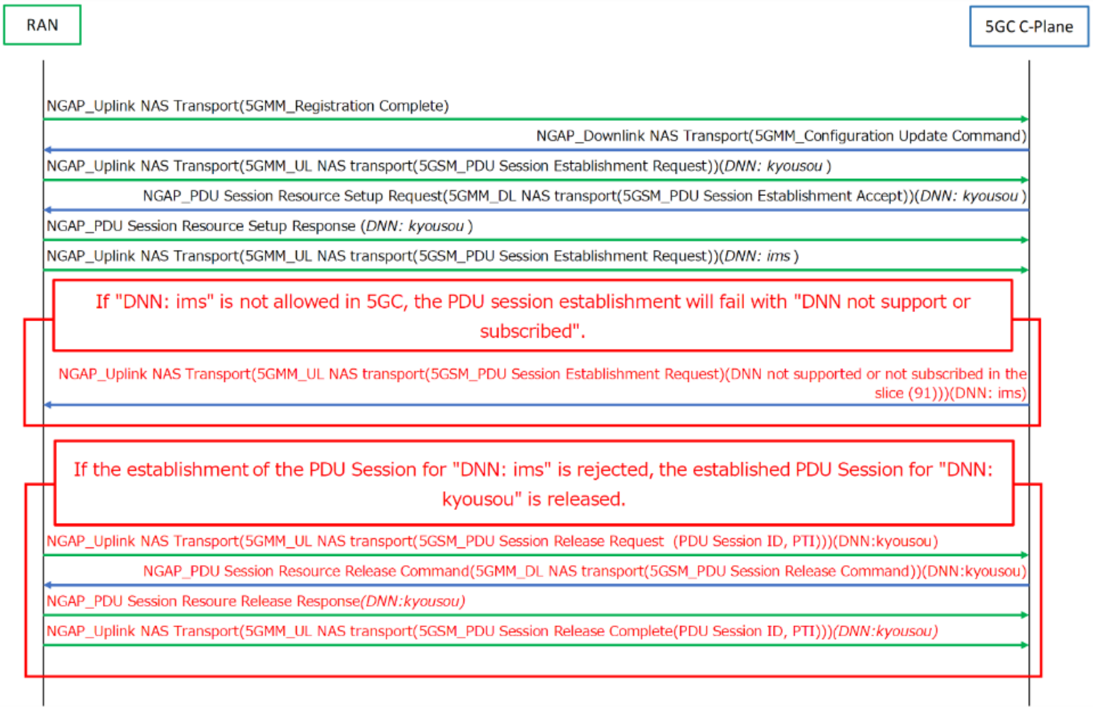

Figure 3-6 Case Study 3 Overview

In this project, we are conducting connection tests using the DNN "kyousou". Additionally, there were UEs attempting to establish a PDU session using the DNN "ims".

Since the 5GC did not have the DNN "ims" configured, it sent a PDU Session Release Command in response to the PDU session establishment request for "ims", thereby rejecting the connection establishment. Subsequently, there were UEs that, after the failure of the PDU session establishment for "ims", also disconnected the established PDU session for data.

According to the 3GPP specifications, the issue arises when UEs with an internal DNN of "ims" establishes a PDU session while the 5GC supports IMS_VoPS.

An example of the 5GMM_Registration_Accept signal[4] is shown in Figure 3-7.

```
⌄ 5GS network feature support
    Element ID: 0x21
    Length: 1
    0... .... = MPS indicator (MPSI): Access identity 1 not valid in RPLMN or equivalent PLMN
    .0.. .... = Interworking without N26 (IWK N26): Not supported
    ..00 .... = Emergency service fallback indicator (EMF): Emergency services fallback not supported (0)
    .... 00.. = Emergency service support indicator (EMC): Emergency services not supported (0)
    .... ..0. = IMS voice over PS session over non-3GPP access indicator (IMS-VoPS-N3GPP): Not supported
    .... ...1 = IMS voice over PS session indicator (IMS VoPS): Supported
```

Figure 3-7 Example of NGAP Registration Accept Signal for 5GC Supporting IMS_VoPS

When the IMS VoPS bit is set, the UEs with an internal DNN of "ims" requests the establishment of PDU sessions using both the "kyousou" and "ims" DNNs.

The failure of connection establishment using the "ims" DNN can be avoided by either configuring the 5GC to allow the "ims" DNN or by ensuring that the 5GC does not support IMS_VoPS.

・Case Study 4：Connection failures due to misconfigurations in the local 5G network settings.

A problem occurred where all UEs were unable to remain in coverage with a specific combination of 5GC and RAN, or if they were able to connect, they would be immediately disconnected. However, by analyzing the N2 and N3 packet captures obtained during the verification tests, along with network monitoring from the RAN, we were able to identify the root cause. The issue was resolved by modifying the configuration of the network switch.

The excerpt of the packet capture obtained during the issue is shown in Figure 3-8.

It was confirmed that a PDU Session Establishment Reject was returned from the 5GC immediately after the registration was completed.

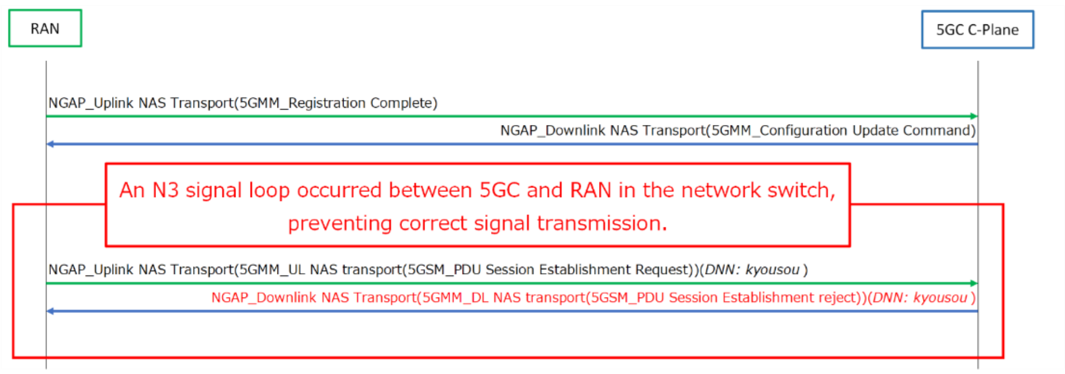

Figure 3-8 Case Study 4 Overview

Based on the information from the packet capture, we checked the system logs of the 5GC and RAN, as well as packet monitoring, and found that packets sent from the N3 port of the 5GC were reaching the N2 port of the RAN. This indicated that the packets were not arriving at the correct port.

The 5GC and RAN that experienced the issue required VLAN configuration on the network switch in the operating environment. Although the VLAN settings had been implemented, a configuration error led to packet mixing.

In the introduction of local 5G equipment that includes VLAN in the operational requirements, it is essential to create a network diagram in alignment with all parties involved and to carefully consider and construct the test environment to prevent configuration errors.

・Case Study 5：Connection failure due to differences in the 5QI supported by the 5GC and RAN

There was a UE that could not remain in the coverage area with a specific combination of 5GC and RAN. However, by correlating the N2 packet capture obtained during testing with the RAN specifications, we identified and resolved the root cause of the issue. An excerpt of the packet capture obtained during the occurrence of the issue is shown in Figure 3-9.

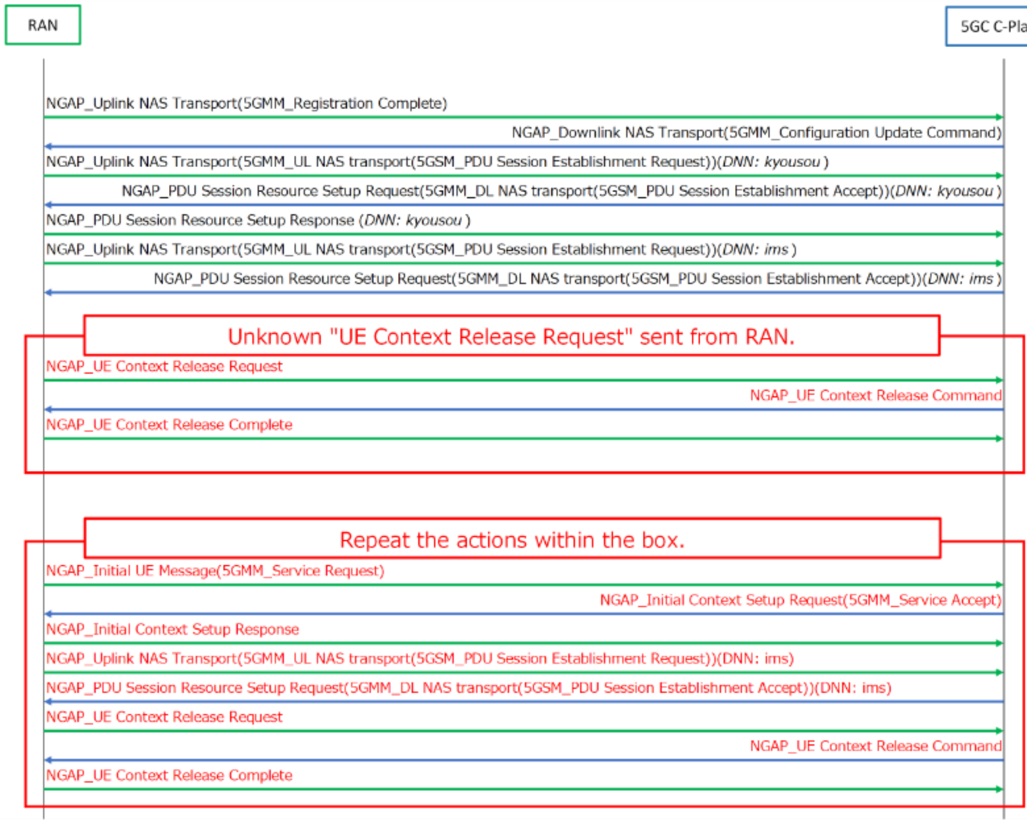

Figure 3-9 Case Study 5 Overview

When establishing a PDU session for the IMS DNN, the RAN was sending an unknown UE Context Release Command to the 5GC. Upon analysis, it was found that the 5QI parameter within the NGAP_PDU Session Establishment Accept signal from the 5GC for the IMS DNN was set to '4', which is a parameter not supported by the RAN.

The 5QI parameter within the PDU Session Establishment Accept signal [4], which was the cause of the issue, is illustrated in Figure 3-10. Please note that while the problematic behavior occurred during the PDU session establishment for the IMS DNN in this project, it is not limited to this specific DNN.

```
˅ QoS flow description 1 - 5QI - GFBR uplink - GFBR downlink - MFBR uplink - MFBR downlink
    ..00 0001 = Qos flow identifier: 1
    001. .... = Operation code: Create new QoS flow description (1)
    .1.. .... = E bit: 1
    ..00 0101 = Number of parameters: 5
  ˅ Parameter 1
      Parameter identifier: 5QI (1)
      Length: 1
      5QI: 4
```

Figure 3-10 Example of PDU Session Establishment Accept Signal for 5QI=4

When the 5GC adjusted the 5QI parameter for the IMS DNN to a value acceptable by the RAN, the problematic behavior was resolved, and no further occurrences have been observed since. In interconnection testing and during commercial deployment, it is essential to verify the support information for 5QI and ensure appropriate configurations for the combination of 5GC and RAN.

3.2. Throughput Testing

3.2.1. Test Configuration

The configuration of this test is illustrated in Figure 3-11.The RAN and UE will be deployed within a shielded box or a shielded tent.

Similar to the interconnection testing, to minimize the impact of environmental differences on the test results, the output power of the RAN and the placement of the UE were adjusted to achieve an RSRP value of approximately -70 dBm for the UE.

Since the information regarding the shielded box and shielded tent is similar to that presented in Table 3-2, this section will be omitted.

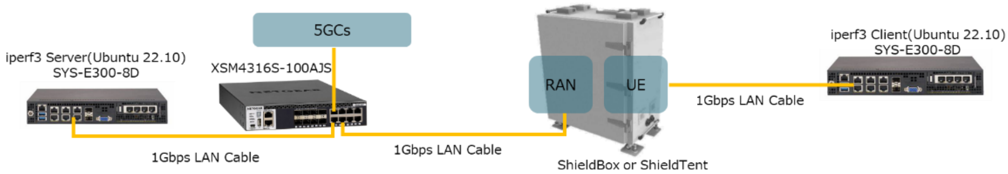

Figure 3-11 Throughput Test Configuration

3.2.2. List of Test Equipment

The names and specifications of the test equipment used in this trial are similar to the information presented in Table 3-3; therefore, this section will be omitted.

3.2.3. Test Items

The items for throughput measurement are shown in Table 3-10.

The transmission throughput for interconnectable combinations will be measured for both synchronous (TDD) and semi-synchronous (TDD1) modes, specifically for UDP and TCP in both uplink (UL) and downlink (DL) scenarios.

Additionally, we will verify that the throughput when the RAN is configured to semi-synchronous (TDD1) mode is consistent with the expected rates based on the configuration.

The tool used for the tests was iperf3.

Table 3-10 Throughput Test Items

No.	Sync (TDD)/Semi-sync(TDD1)	Protocol	Direction
1	Synchronous(TDD)	UDP	UL
2			DL
3		TCP	UL
4			DL
5	Semi-Synchronous(TDD1)	UDP	UL
6			DL
7		TCP	UL
8			DL

3.2.4. Test Procedures

The options and parameters for the iperf3 command to be executed were determined in agreement with all participating companies in the project, ensuring that no advantages or disadvantages arise for any local 5G devices.

The execution command and option parameters are detailed below. The downlink throughput test will be conducted using iperf3 in Reverse Mode, without implementing any routing configurations on the local 5G devices.

Furthermore, if sufficient performance is not confirmed, a re-test will be conducted within the testing period after analyzing the causes, using 70% of the nominal throughput values provided by each company as a guideline. Cases where the root cause cannot be identified will not be included in the discussion of this report.

・Synchronous(TDD) UDP

UP Link: iperf3 -u -c ***iperf3Server Addr*** -l 1300 -b 75M -P 10 -O 10 -t 60

Down Link: iperf3 -u -c ***iperf3Server Addr*** -l 1300 -b 75M -P 10 -O 10 -t 60 -R

・Semi-Synchronous(TDD1) UDP

UP Link: iperf3 -u -c ***iperf3Server Addr*** -l 1300 -b 49M -P 10 -O 10 -t 60

Down Link: iperf3 -u -c ***iperf3Server Addr*** -l 1300 -b 49M -P 10 -O 10 -t 60 -R

・Synchronous(TDD) / Semi-Synchronous (TDD1) TCP

UP Link: iperf3 -c ***iperf3Server Addr*** -l 1300 -P 10 -O 10 -t 60

Down Link: iperf3 -c ***iperf3Server Addr*** -l 1300 -P 10 -O 10 -t 60 -R

3.2.5. Test Results and Discussion

3.2.5.1. Test Results Compared to Target Values

The distribution chart shown in Figure 3-12 illustrates the percentage of throughput obtained from the test results compared to the nominal throughput values of each RAN device.

Since the test environments for each RAN device vary by vendor, it is expected that the results may not align perfectly with the nominal values. However, the fact that 80% of the results fell within the range of 100% ± 30% of the published values indicates that the test environment is considered appropriate for evaluating the performance of local 5G devices from different vendors.

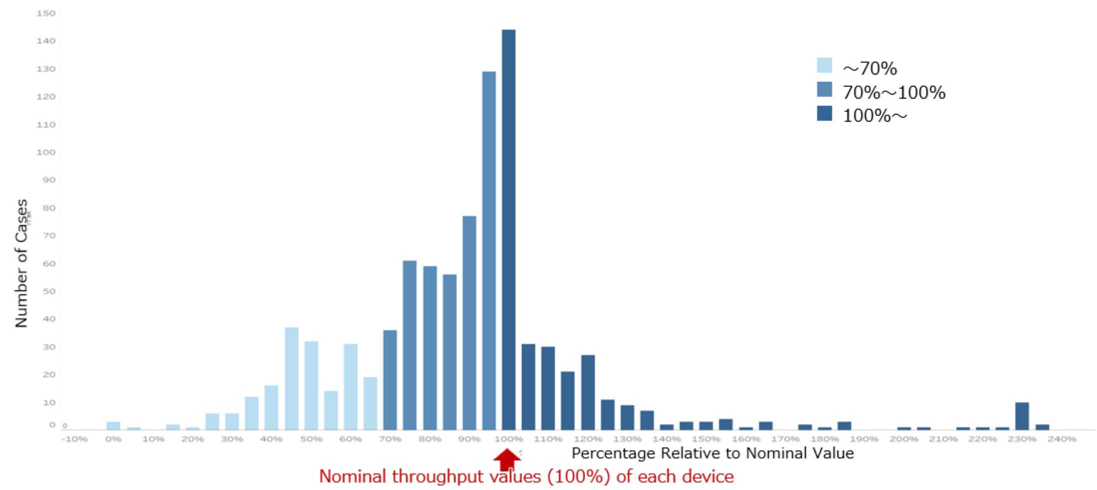

Figure 3-12 Nominal Value Achievement Rate and Pattern Count

3.2.5.2. Test Results from the Perspective of RAN and UE Performance

The throughput test results are presented in Figure 3-13 to Figure 3-32.

Differences in the test results were observed due to the supported QAM (Quadrature Amplitude Modulation) levels by the RAN and the number of antennas equipped on the RAN.

Based on Table 3-4, a grouping table categorizing the RAN used for measurements according to the QAM levels and the number of antennas equipped has been presented in Table 3-11.

The aggregation and analysis of the throughput test results will be conducted for each group.

Table 3-11 Groups divided by the number of UL antennas (QAM) x DL antennas (QAM) in the RAN

Group Number	RAN Specification
1	1(64)×2(256)
2	2(256)×2(256)
3	2(64)×4(64)
4	2(64)×4(256)
5	2(256)×4(256)

・**Group 1: UL Antenna Count 1 (64QAM) x DL Antenna Count 2 (256QAM)**

UL： The throughput speed remained almost the same regardless of the number of UL antennas in the UE(1 to 2). This is likely because the number of UL antennas in the RAN is 1, which means that variations in the number of UL antennas in the UE do not affect the throughput values.

In addition, in the semi-synchronous mode (TDD1), the proportion of UL communication is higher than in the synchronous mode (TDD). As a result, differences in throughput characteristics between the two modes were observed for both TCP and UDP.

DL：The throughput speeds yielded almost identical results, clustering within approximately 70% of the optimal throughput value.

Furthermore, in the semi-synchronous mode (TDD1), the proportion of DL communication is lower than in the synchronous mode (TDD). Consequently, differences in throughput characteristics between the two modes were observed for both TCP and UDP.

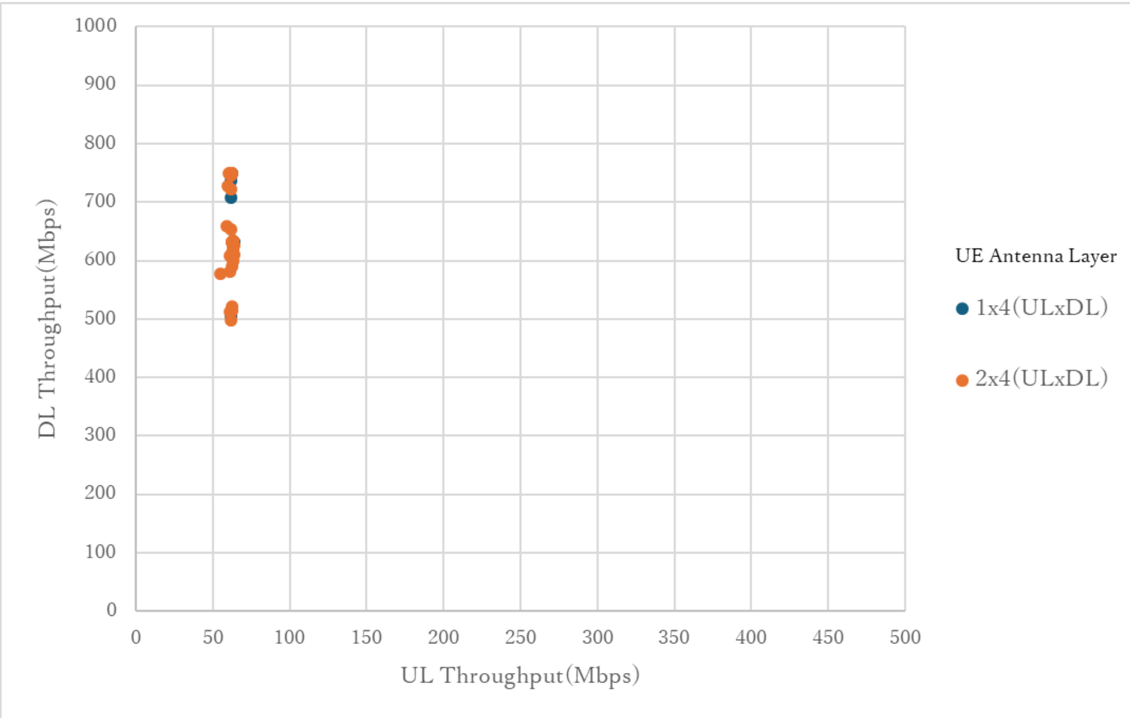

Figure 3-13 Synchronous UDP Throughput Test Results (Group 1)

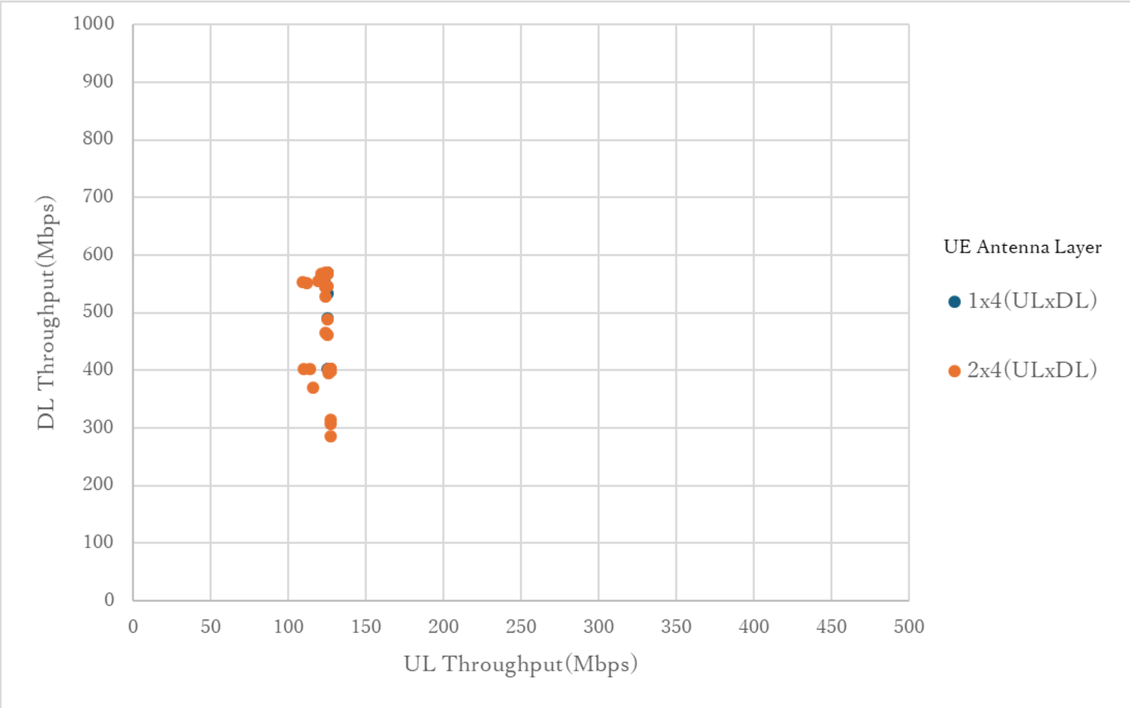

Figure 3-14 Semi-Synchronous UDP Throughput Test Results (Group 1)

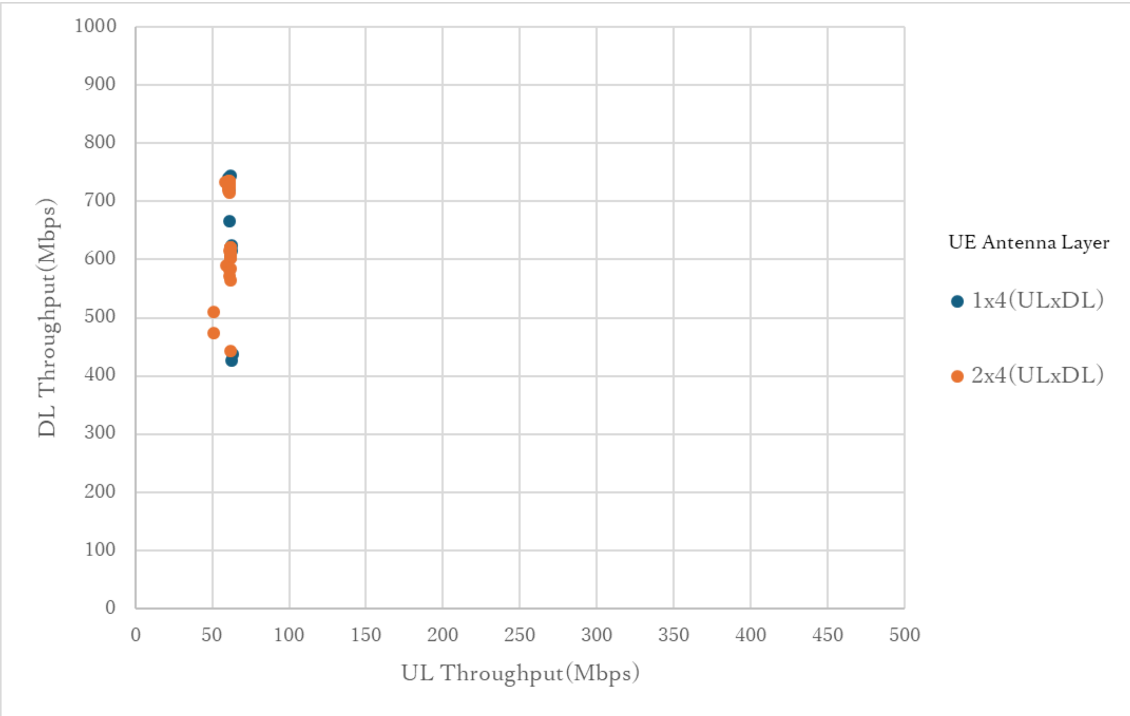

Figure 3-15 Synchronous TCP Throughput Test Results (Group 1)

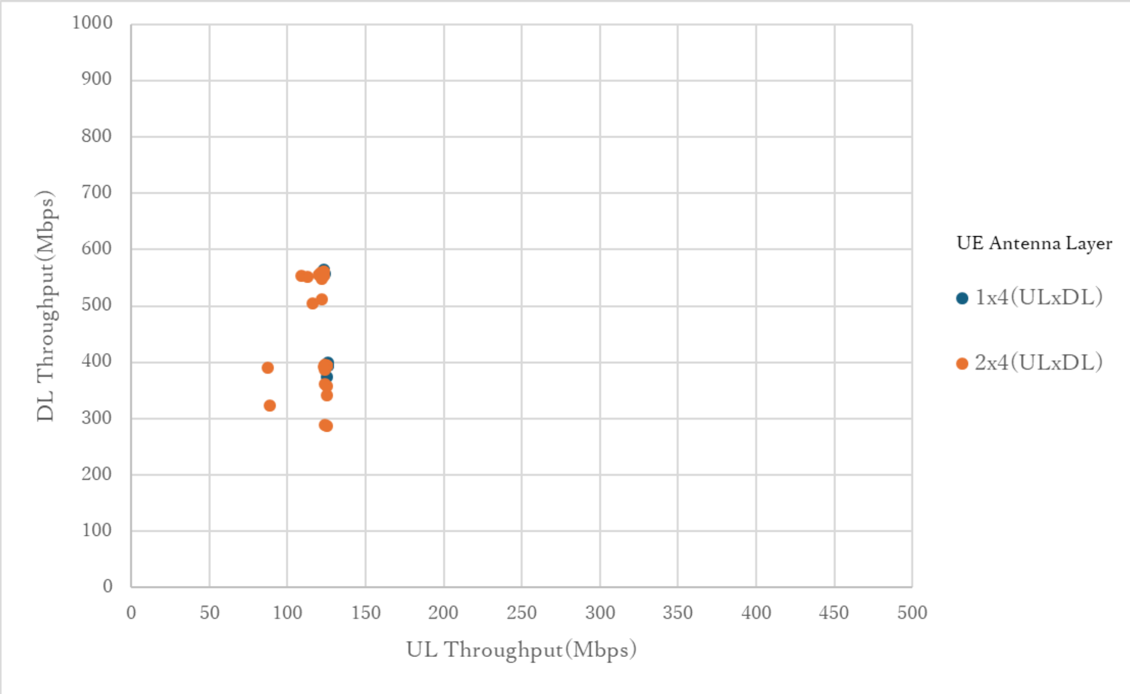

Figure 3-16 Semi-Synchronous TCP Throughput Test Results (Group 1)

・**Group 2: UL Antenna Count 2 (256 QAM) x DL Antenna Count 2 (256 QAM)**

UL：When comparing the optimal throughput values of UE with 1 UL antenna and 2 UL antennas, it is observed that the throughput speed with 2 UL antennas is approximately twice that of the configuration with 1 UL antenna.
This difference is likely attributed to the fact that the RAN has 2 UL antennas, which affects the number of antennas used by the UE for UL communication.
Additionally, in the semi-synchronous mode (TDD1), the proportion of UL communication is higher than in the synchronous mode (TDD). This resulted in observable differences in throughput characteristics between the two modes for both TCP and UDP.

DL：Throughput speeds were nearly identical, clustering within approximately 70% of the optimal throughput value. Additionally, in the semi-synchronous mode (TDD1), the proportion of DL communication is lower than in the synchronous mode (TDD), leading to observable differences in throughput characteristics between the two modes for both TCP and UDP. It was measured that both TCP and UDP exhibited better throughput in the synchronous mode compared to the semi-synchronous mode (TDD1).

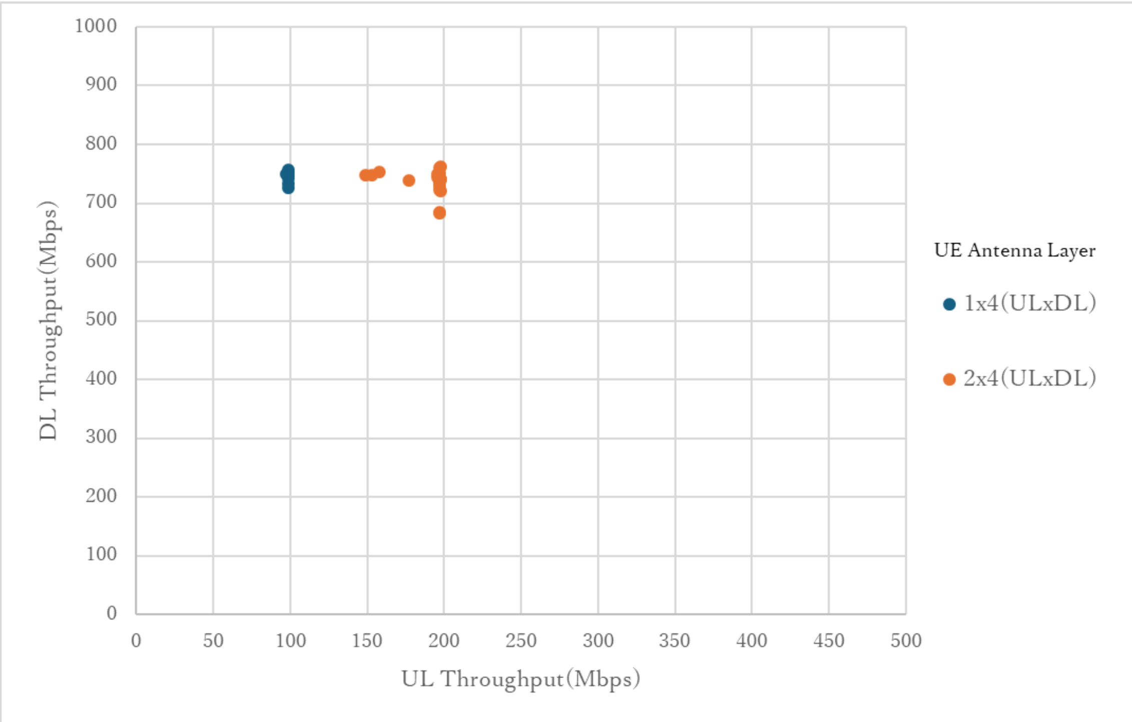

Figure 3-17 Synchronous UDP Throughput Test Results (Group 2)

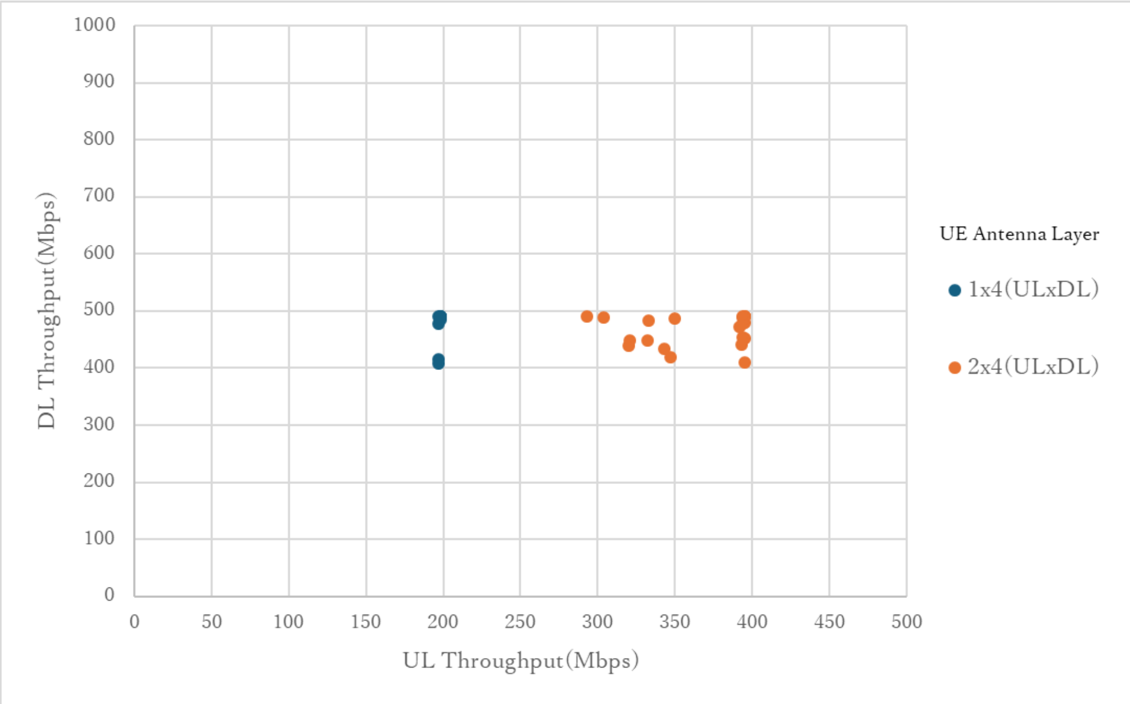

Figure 3-18 Semi-Synchronous UDP Throughput Test Results (Group 2)

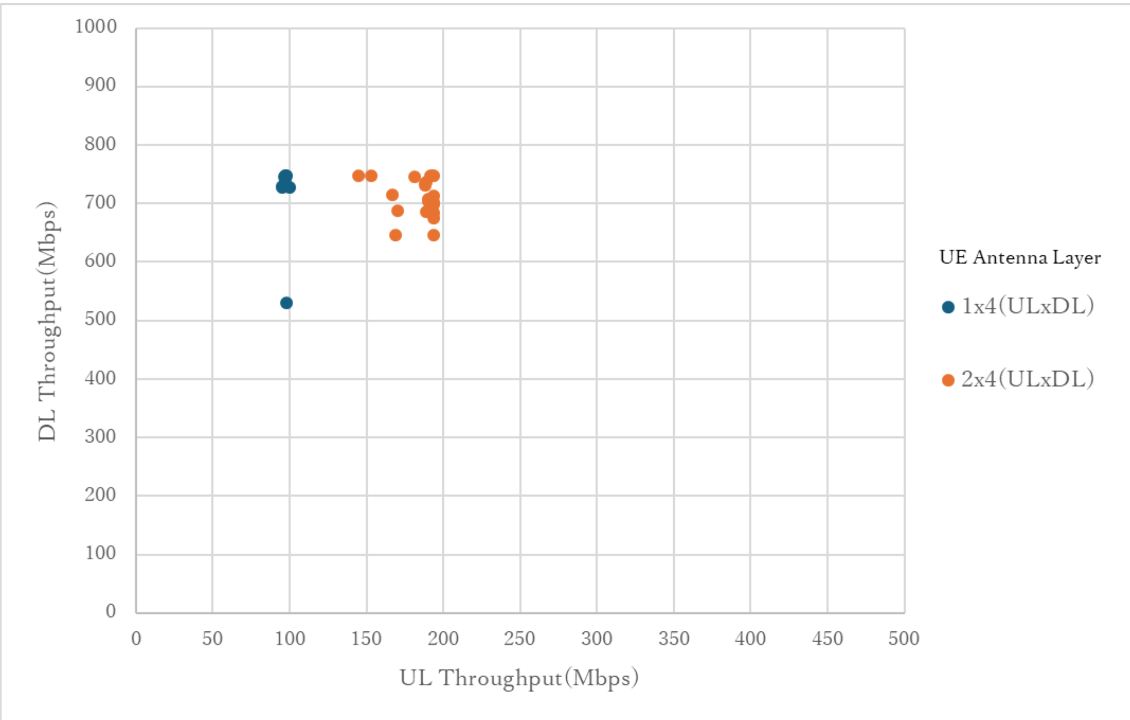

Figure 3-19 Synchronous TCP Throughput Test Results (Group 2)

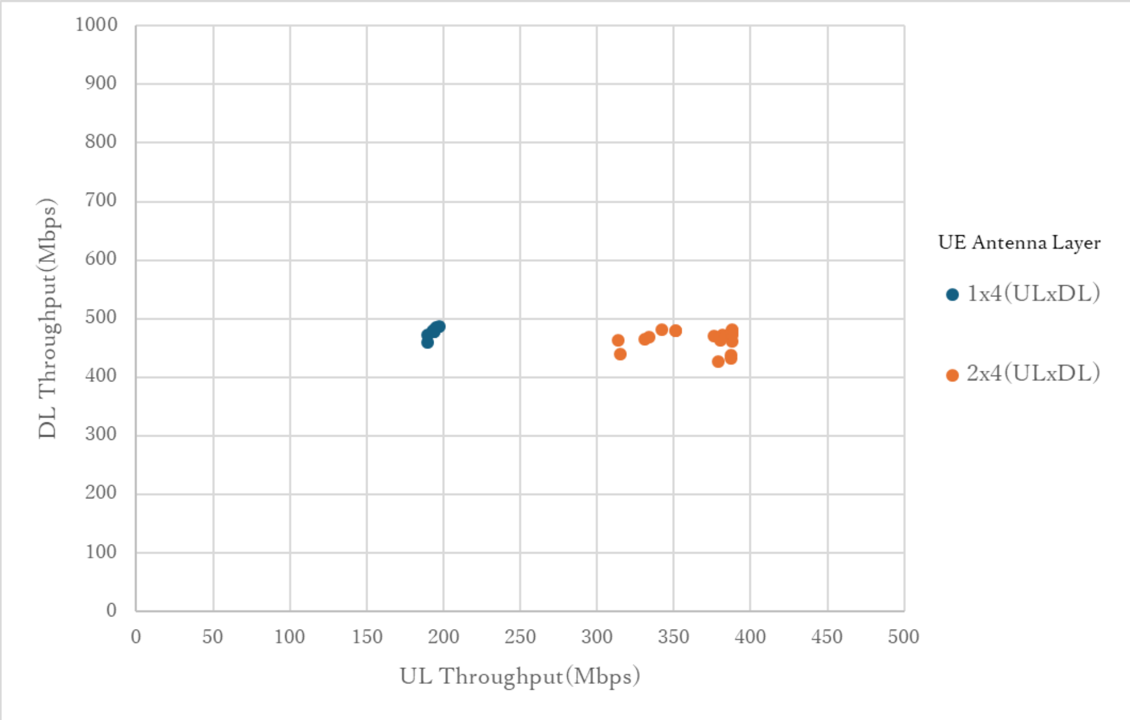

Figure 3-20 Semi-Synchronous TCP Throughput Test Results (Group 2)

・Group 3: UL Antenna Count 2 (64 QAM) x DL Antenna Count 4 (64 QAM)

UL： When comparing the best throughput values for UE with 1 UL antenna versus 2 UL antennas, it is observed that the throughput for 2 UL antennas is approximately twice that of the configuration with 1 UL antenna.

Additionally, in the semi-synchronous mode (TDD1), the proportion of UL communication is higher than in the synchronous mode (TDD), which allowed for the observation of differences in throughput characteristics between TCP and UDP.

DL：The throughput speeds are nearly identical, with the values clustering within approximately 70% of the best throughput value.

Furthermore, in the semi-synchronous mode (TDD1), the proportion of DL communication is lower than in the synchronous mode (TDD), which allowed for the identification of differences in throughput characteristics between TCP and UDP.

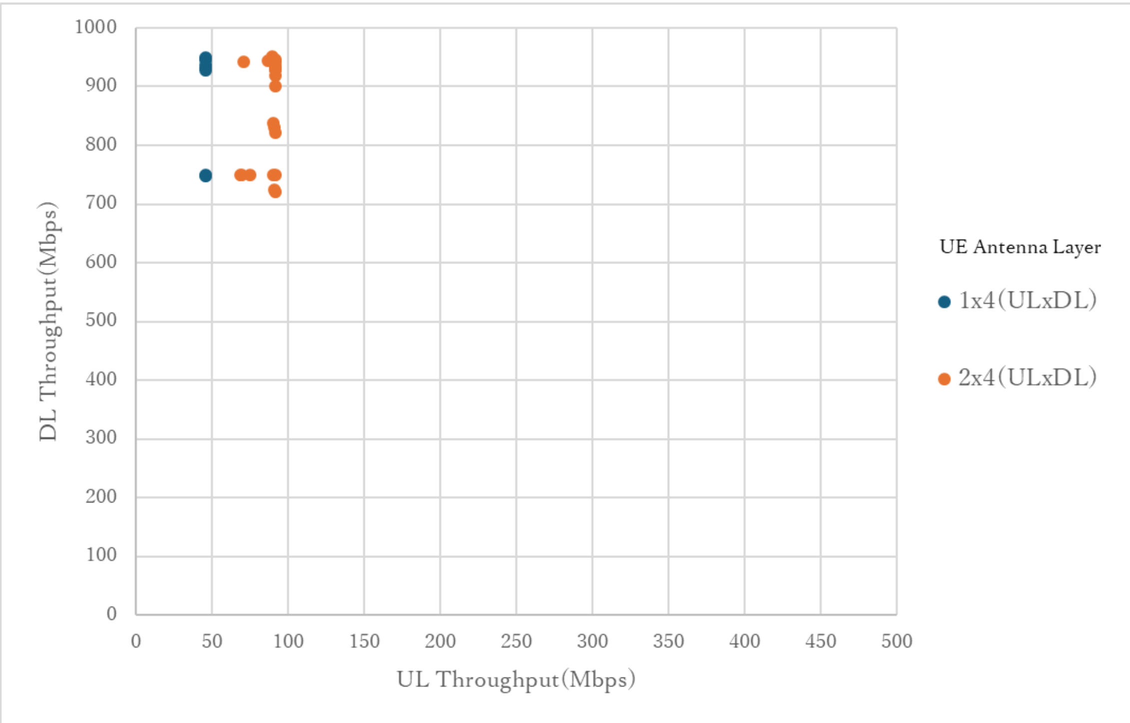

Figure 3-21 Synchronous UDP Throughput Test Results (Group 3)

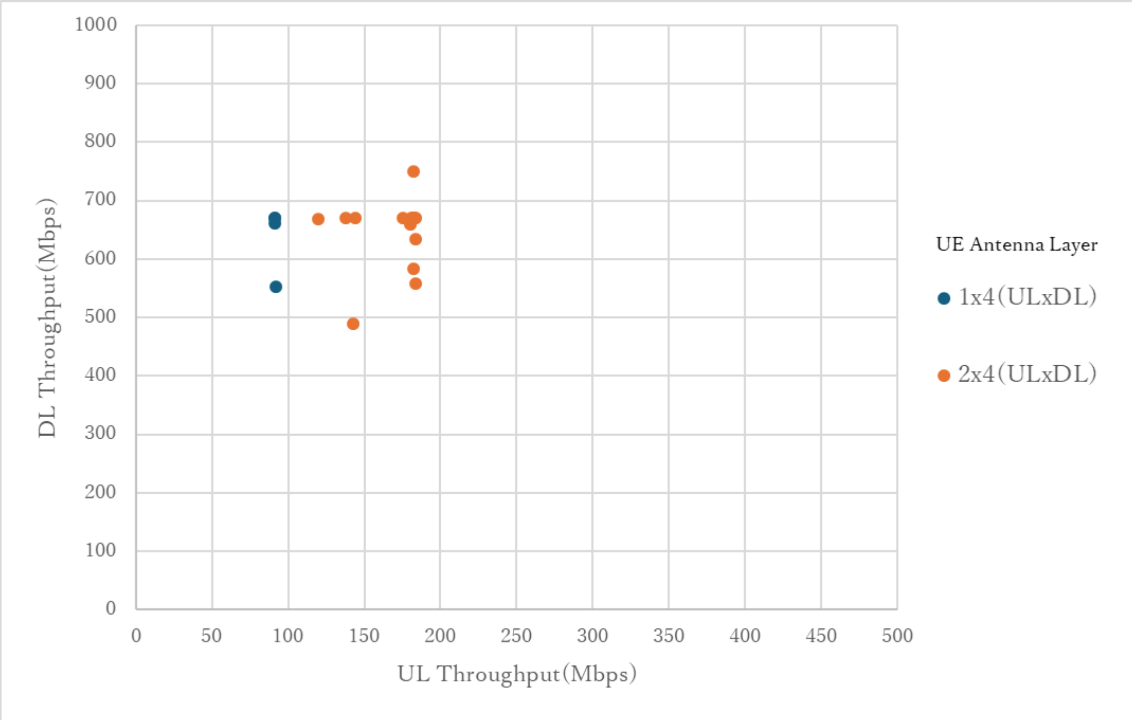

Figure 3-22 Semi-Synchronous UDP Throughput Test Results (Group 3)

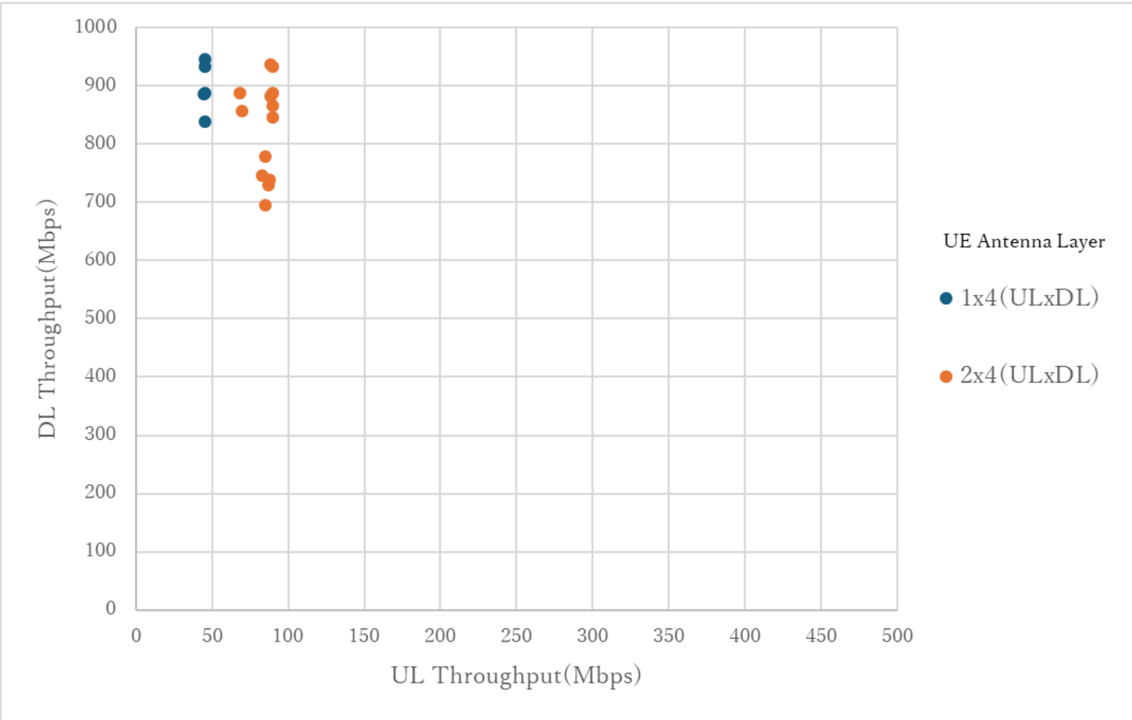

Figure 3-23 Synchronous TCP Throughput Test Results (Group 3)

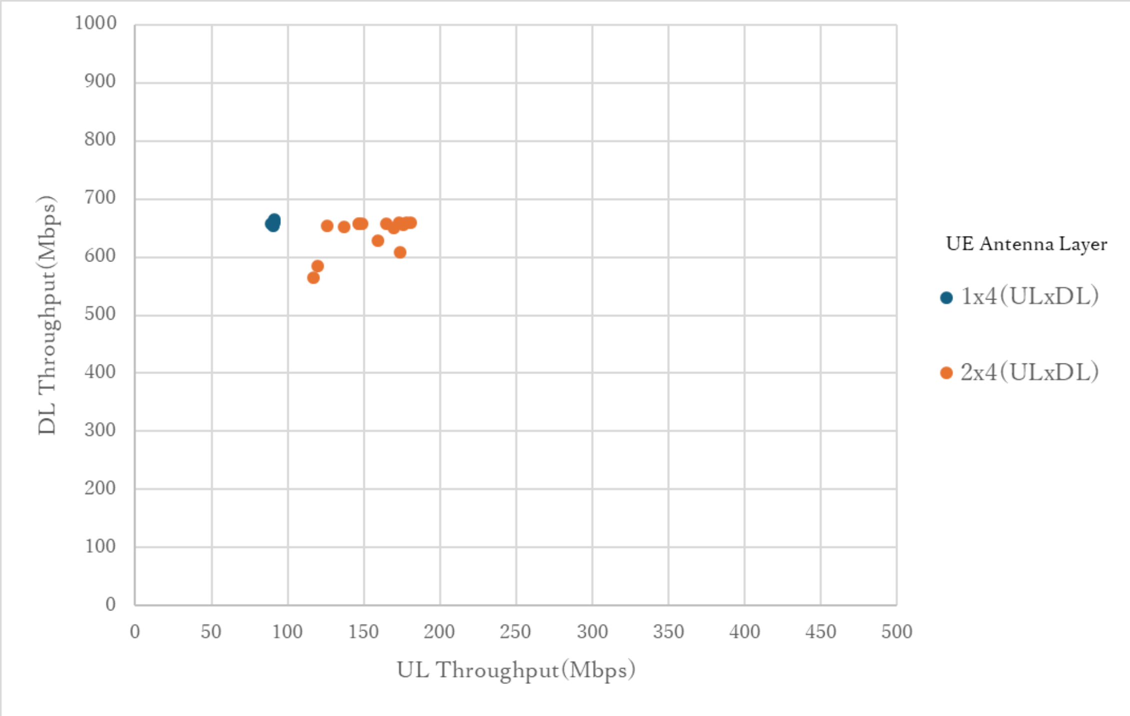

Figure 3-24 Semi-Synchronous TCP Throughput Test Results (Group 3)

・Group 4: UL Antenna Count 2 (64 QAM) x DL Antenna Count 4 (256 QAM)

UL：Due to the large number of RAN/UEs being measured, the results show some variability. When comparing the optimal throughput values for UE with 1 UL antenna and those with 2 UL antennas, it is observed that the throughput speeds for UE with 2 UL antennas are approximately twice that of the UE with 1 UL antenna.

Additionally, in the semi-synchronous mode (TDD1), the proportion of UL communication is higher than in the synchronous mode (TD), which allowed for the observation of differences in throughput characteristics between the two modes for both TCP and UDP.

DL：Due to the large number of RAN/UEs being measured, the results show variability. The DL throughput exceeded 350 Mbps, regardless of the differences between synchronous (TDD) and semi-synchronous (TDD1) modes, as well as between UDP and TCP.

Additionally, in the semi-synchronous mode (TDD1), the proportion of DL communication is lower than in the synchronous mode (TDD), which allowed for the observation of differences in throughput characteristics between the two modes for both TCP and UDP.

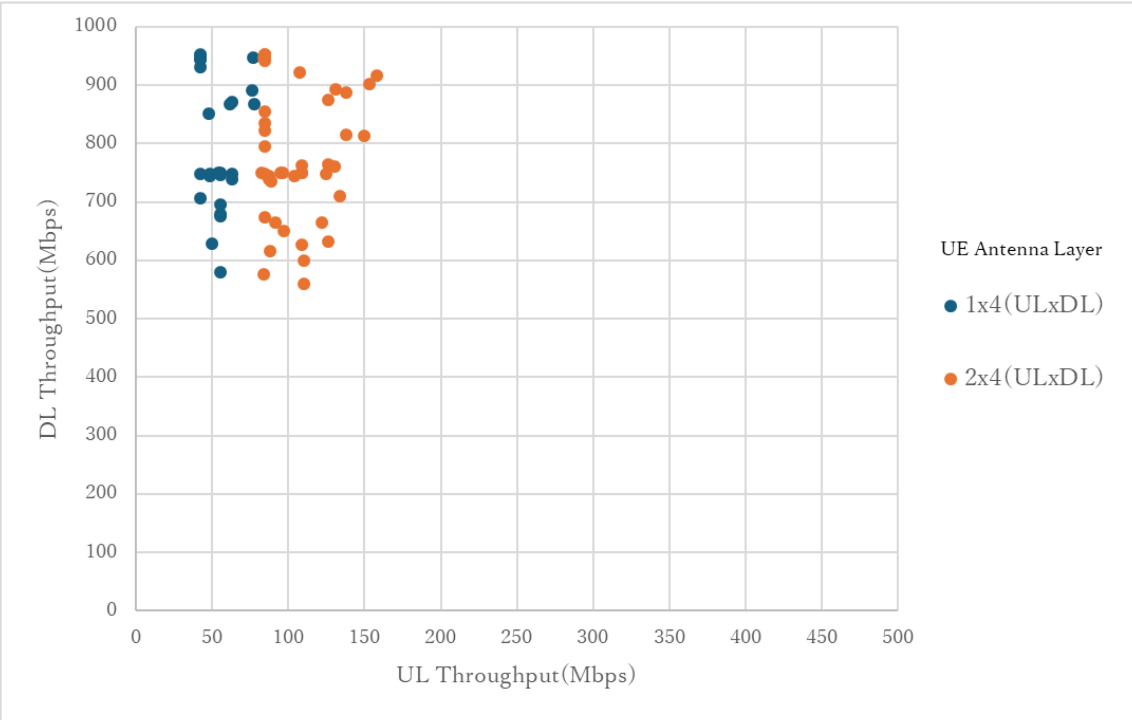

Figure 3-25 Synchronous UDP Throughput Test Results (Group 4)

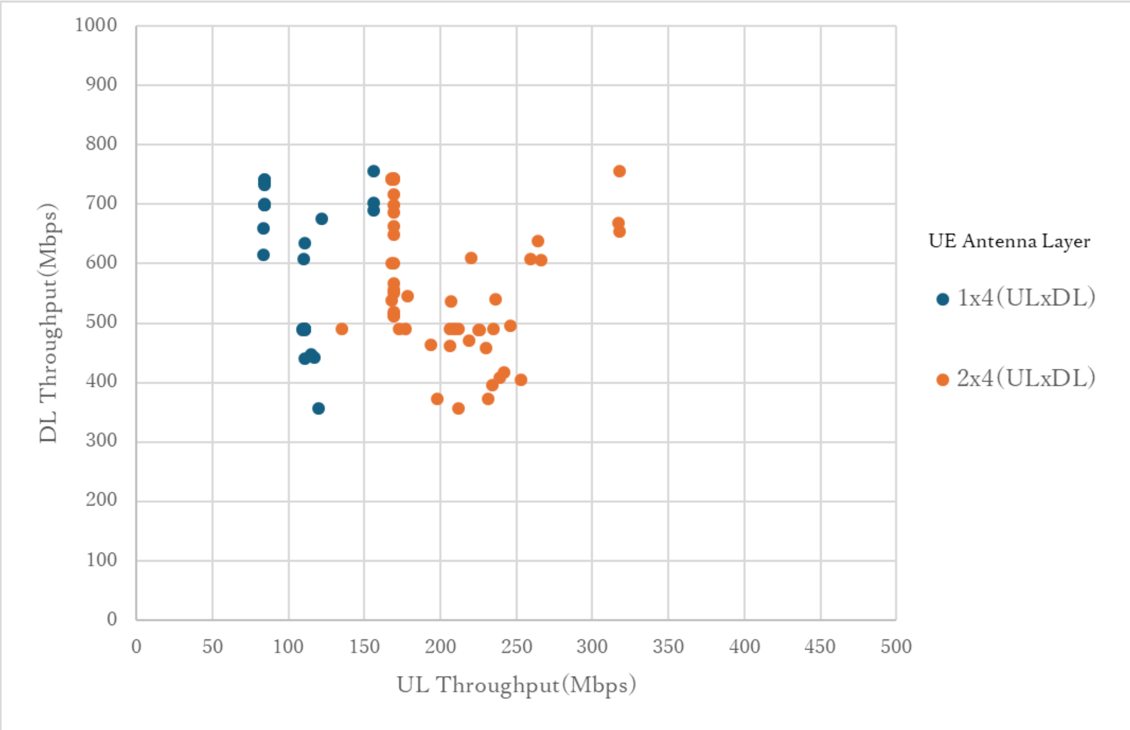

Figure 3-26 Semi-Synchronous UDP Throughput Test Results (Group 4)

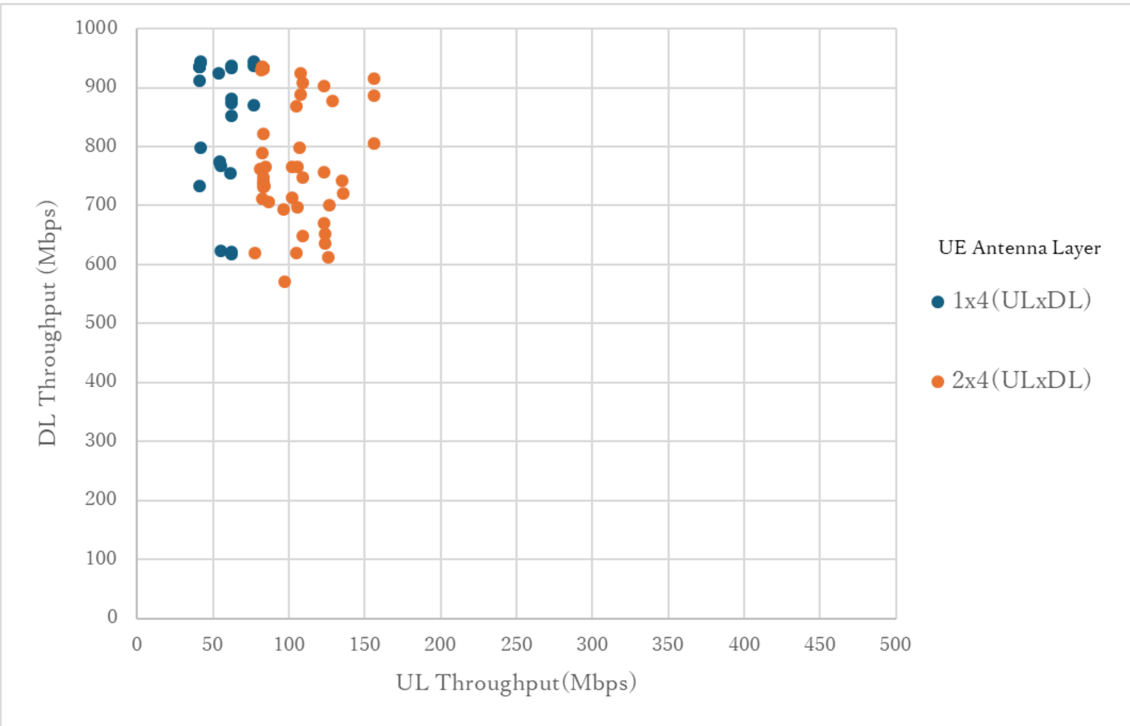

Figure 3-27 Synchronous TCP Throughput Test Results (Group 4)

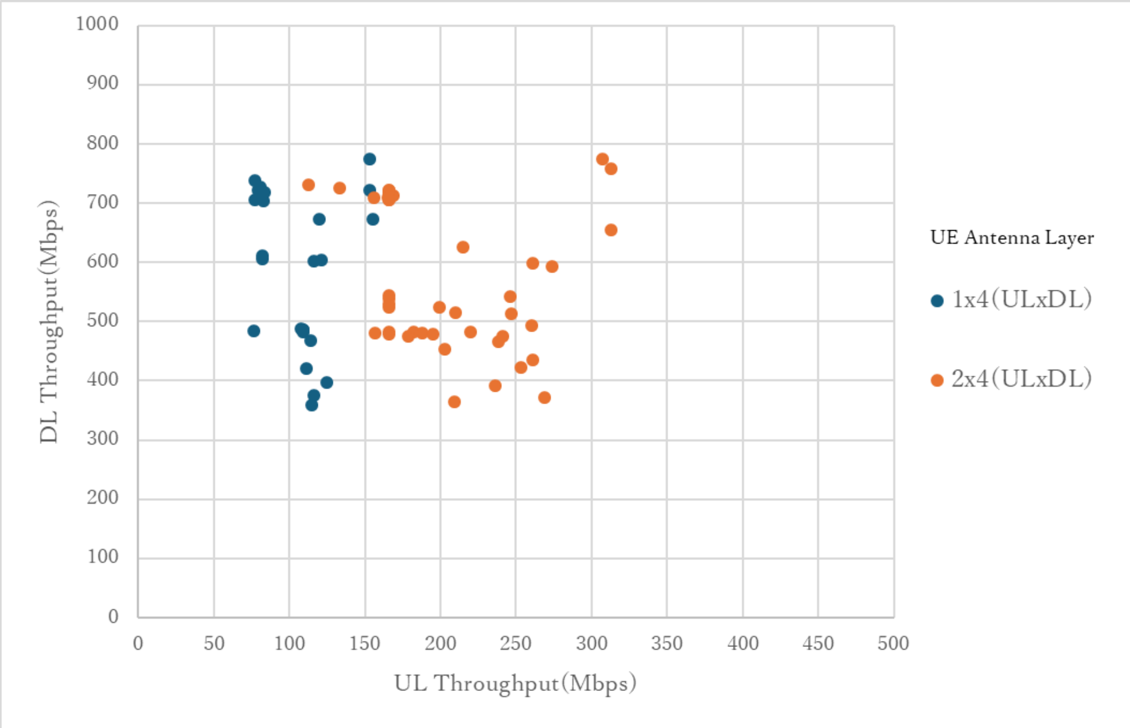

Figure 3-28 Semi-Synchronous TCP Throughput Test Results (Group 4)

・Group 5: UL Antenna Count 2 (256 QAM) x DL Antenna Count 4 (256 QAM)

UL：Due to the large number of RAN/UEs being measured, the measurement results are exhibit variability.

When comparing the best throughput values for UE with 1 UL antenna versus those with 2 UL antennas, it is observed that the throughput for 2 UL antennas is approximately twice that of the configuration with 1 UL antenna.

Additionally, in the semi-synchronous mode (TDD1), the proportion of UL communication is higher than in the synchronous mode (TDD), which allowed for the observation of differences in throughput characteristics between the two modes for both TCP and UDP.

DL：Due to the large number of RAN/UEs being measured, the measurement results are exhibit variability.

The DL throughput exceeded 500 Mbps, regardless of the differences between synchronous (TDD) and semi-synchronous (TDD1) modes, as well as between UDP and TCP.

Furthermore, in the semi-synchronous mode (TDD1), the proportion of DL communication is lower than in the synchronous mode (TDD), which allowed for the identification of differences in throughput characteristics between the two modes for both TCP and UDP.

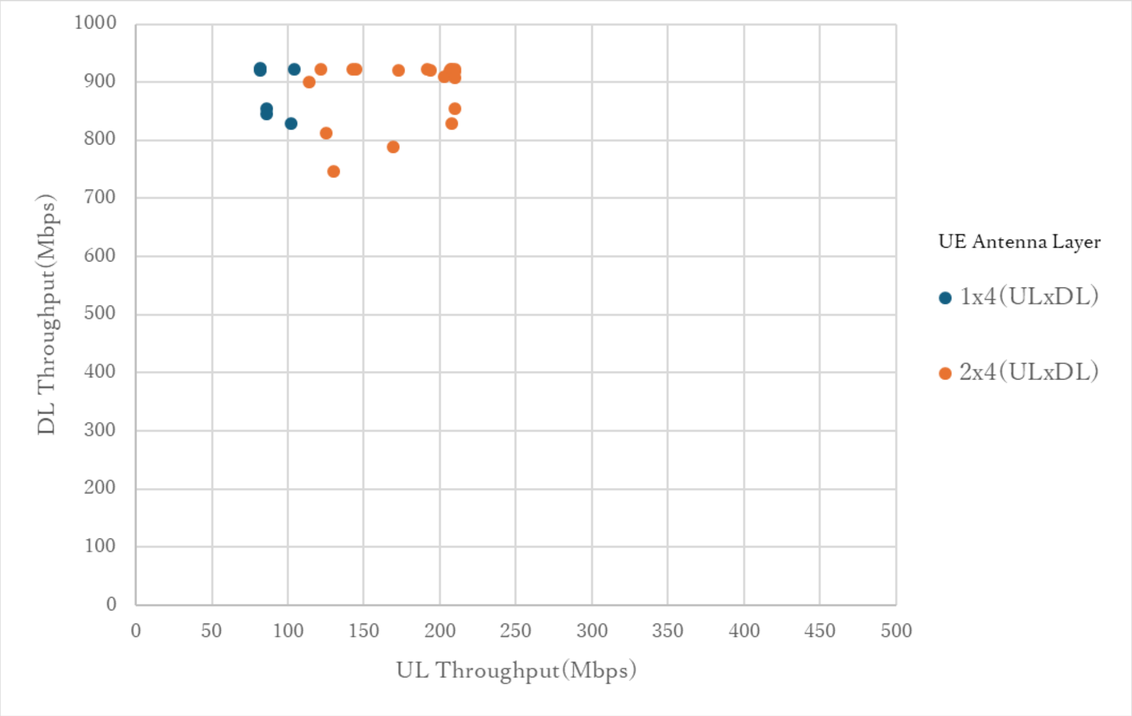

Figure 3-29 Synchronous UDP Throughput Test Results (Group 5)

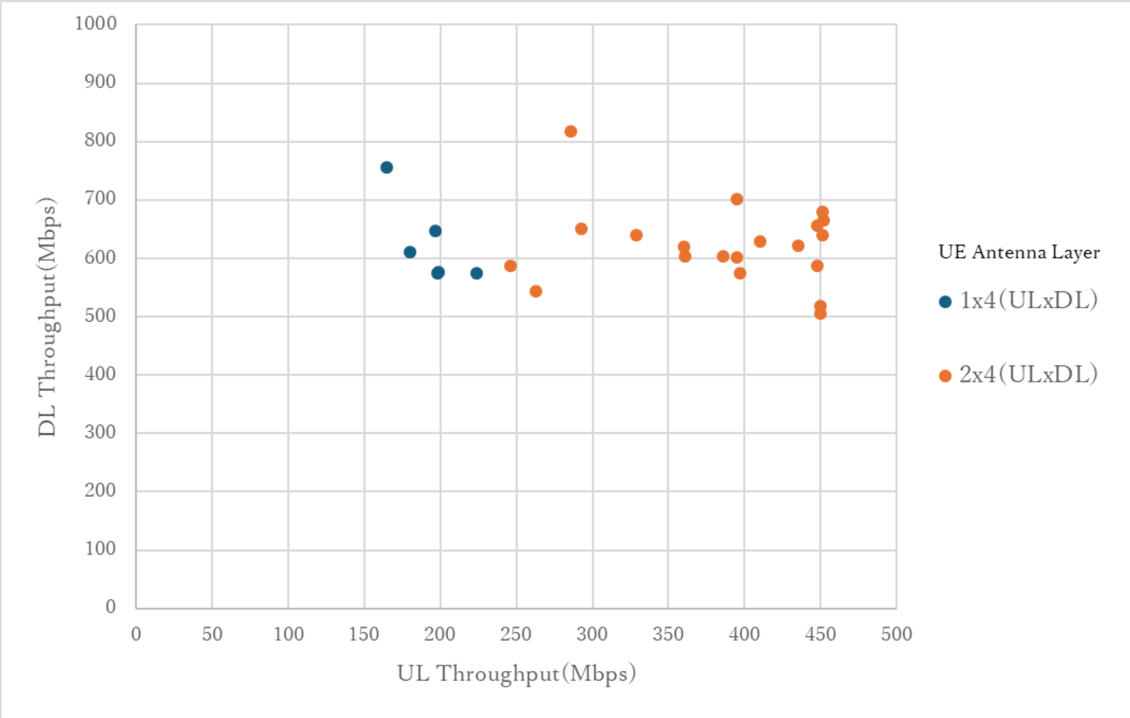

Figure 3-30 Semi-Synchronous UDP Throughput Test Results (Group 5)

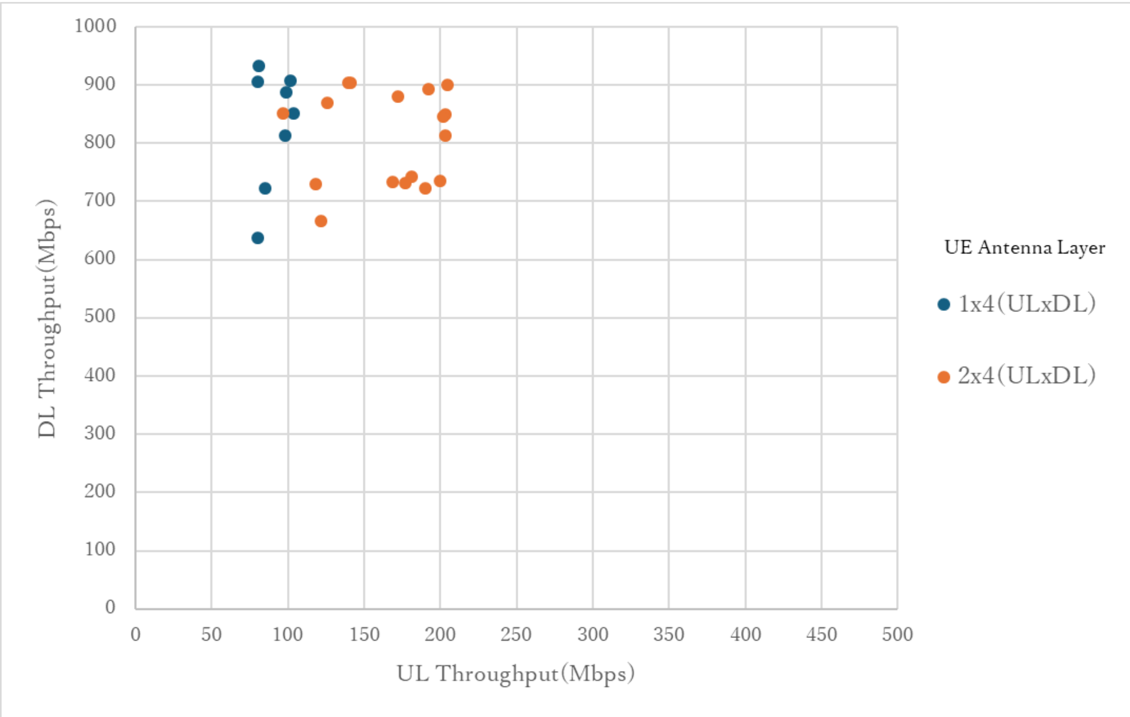

Figure 3-31 Synchronous TCP Throughput Test Results (Group 5)

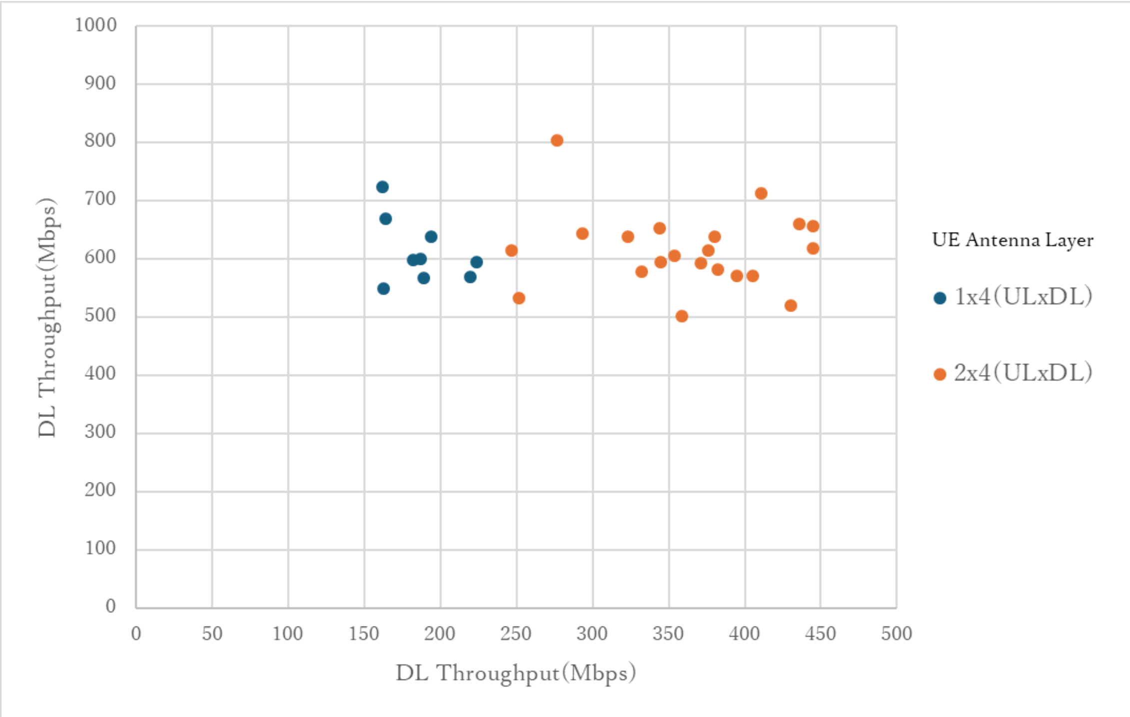

Figure 3-32 Semi-Synchronous TCP Throughput Test Results (Group 5)

The best throughput test results for each combination of the number of antennas equipped on the RAN and UE, along with the supported QAM(Table 3-11), are presented in Table 3-12 and Table 3-13.

Table 3-12 Group(UL 64QAM RAN) Test Results Best Values Summary

Group number	Number of UE Antenna Layers	Sync				Semi-Sync (TDD1)			
		UDP		TCP		UDP		TCP	
		UL	DL	UL	DL	UL	DL	UL	DL
Group1	1×4	63.7	749	63.1	744	127	569	126	565
	2×4	63.7	749	62.7	736	127	569	125	560
Group3	1×4	62.9	952	62.4	945	122	742	125	738
	2×4	138	952	136	937	266	750	274	731
Group4	1×4	77.2	947	77.3	945	156	755	155	774
	2×4	161	952	156	933	318	802	313	837

Note:

・Unit: Mbps

・n×m：**n** represents the number of uplink antenna layers, and **m** represents the number of downlink antenna layers

Table 3-13 Group(UL 256QAM RAN) Test Results Best Values Summary

Group Number	Number of UE Antenna Layers	Sync				Semi-Sync (TDD1)			
		UDP		TCP		UDP		TCP	
		UL	DL	UL	DL	UL	DL	UL	DL
Group2	1×4	98.8	757	99.8	747	198	490	197	486
	2×4	198	762	194	748	395	491	479	482
Group5	1×4	105	922	104	907	226	647	224	638
	2×4	210	922	205	901	452	702	445	713

Note:

・Unit: Mbps

・n×m：**n** represents the number of uplink antenna layers, and **m** represents the number of downlink antenna layers

3.3. Results of 4K Video Transmission Delay Tests

3.3.1. Test Configuration

The environment used for the tests is shown in Figure 3-33.

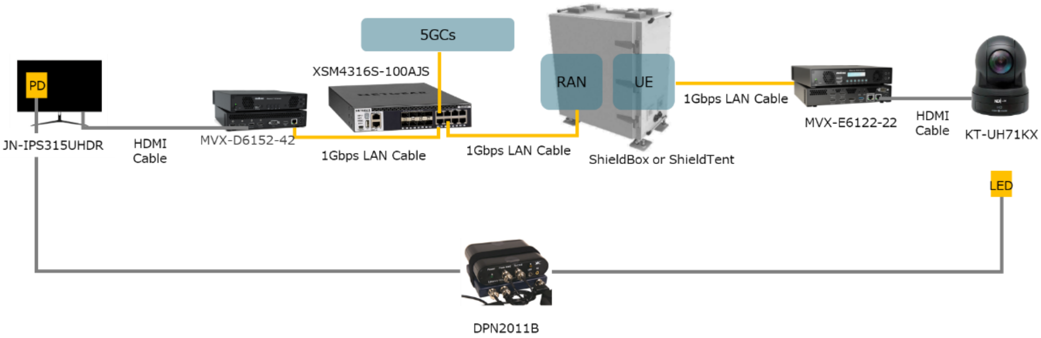

Figure 3-33 4K Video Transmission Delay Test Configuration

The RAN and UE are deployed within a shielded box or shielded tent. A video encoder and a 4K camera are connected under the UE, while a decoder and a 4K monitor are connected to N6.

The optical path delay measurement device (LED section) is placed in front of the 4K camera, while the optical path delay measurement device (PD section) is attached to the 4K monitor. The time difference between the video captured by the 4K camera and the video displayed on the monitor is measured as the delay.

To minimize the impact of environmental differences on the test results, similar to the interconnection tests and throughput tests, the output values of the RAN and the placement of the UE were adjusted to ensure that the RSRP value of the UE was approximately -70 dBm.

The information regarding the shielded box and shielded tent is similar to that presented in Table 3-2; therefore, it will be omitted in this section.

3.3.2. List of Test Equipment

The names and specifications of the test equipment used in this trial are similar to the information presented in Table 3-3; therefore, this section will be omitted.

A list of the test equipment used in the trial is presented in Table 3-14.

Table 3-14 List of Testing and Verification Equipment Used in the Test

Product name	Model number
4K camera	KT-UH71KTN
Encoder	MVX-E6122-22
Decoder	MVX-D6152-4
Optical path delay measurement device	PicoScope 2205AMSO

3.3.3. Test Items

The test items for this trial are presented in Table 3-15.

Table 3-15 Test Items for 4K Video Transmission Delay Testing

No	Test Item	Test Pass Criteria
1	Delay time	Confirm that the network latency in the local 5G network segment is below 50 msec.
2	Block noise	Confirm that there is no block noise being output.

3.3.4. Test Procedures

A web camera, video encoder, and decoder are connected to the local 5G test environment to transmit 4K video at 60 frames per second (fps) at a rate of 15 Mbits/sec. The transmission of the captured video is confirmed to be free of noise on the monitor screen through visual inspection. Additionally, a light path delay measurement device is used to measure the network delay time within the local 5G network.

The network delay time is calculated by subtracting the delay time measured when the video encoder and decoder are directly connected from the delay time measured with the light path measurement device.

In cases where the network delay time is significantly greater than 50 ms or where screen noise persists, a root cause analysis is conducted during the testing period, followed by a retest.

3.3.5. Test Results and Discussion

Out of the 224 combinations tested, 90% were able to transmit 4K video with network delay times of 200 ms or less, demonstrating that 4K video transmission via interconnection is feasible without issues.

Furthermore, 80% of those combinations recorded network delay times of 50 ms or less, with a distribution observed in the range of 10 ms to 40 ms.

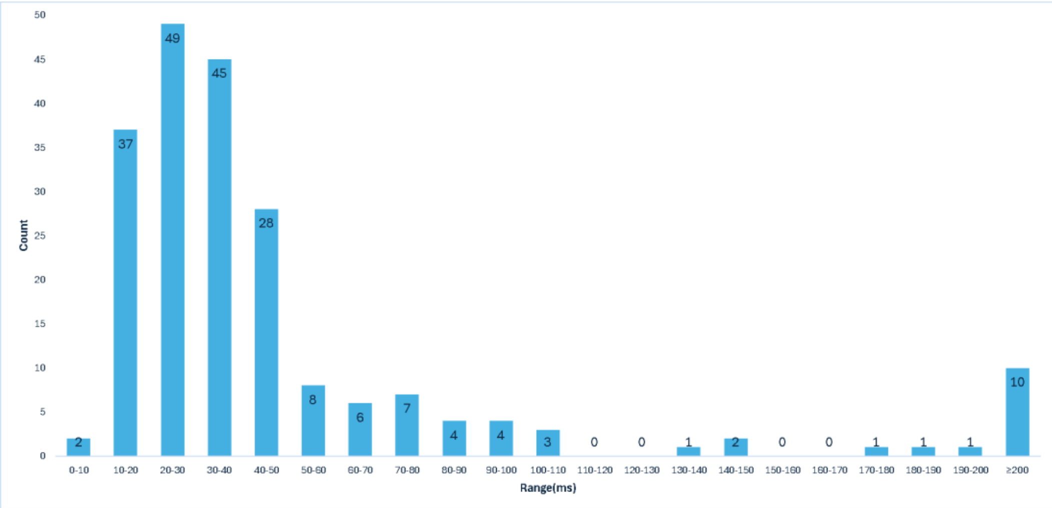

Figure 3-34 Delay Time and Number of Instances

The following insights were gained from this test.

1. The impact of the supported 3GPP Release versions of each local 5G device on the test results was not observed.
2. Due to the network conditions during the testing, packet fragmentation of the transmitted video was observed. The issue was resolved by adjusting the MTU size that the 5GC notifies to the UE to match the network conditions of the testing environment.

4. Theme 3 Demonstration (Enhancement of Security Measures in Local 5G Utilization Environments)

4.1. Security Test

4.1.1. Test Configuration

The test configuration for this examination is illustrated in Figure 4-1. In this test, Trend Micro Mobile Network Security (hereinafter referred to as TMMNS), provided by Trend Micro and CTOne, will be used as the security solution in the urban environment.

Based on the specifications of TMMNS, it is assumed that there will be no operational differences due to variations in RAN equipment. Therefore, connection tests will be conducted based on the combinations of the 5GC and User Equipment UE. The UE will be equipped with a dedicated SIM card that includes security features specifically designed for integration with TMMNS.

The RAN and UE will be deployed within a shielded box or a shielded tent. Similar to the connection tests in Theme 1, adjustments were made to the RAN output power and the placement of the UE to ensure that the RSRP value of the UE is approximately -70 dBm, thereby minimizing the impact of environmental differences on the test results.

The details regarding the shielded box and shielded tent are similar to the information presented in Table 3-2, and therefore, will be omitted in this section.

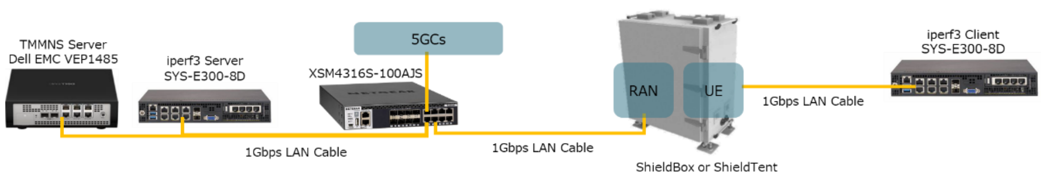

Figure 4-1 Security Test Configuration

4.1.2. List of Test Equipment

The names and specifications of the test equipment for this trial are similar to the information presented in Table 3-3, and therefore, will be omitted in this section.

4.1.3. Test Items

The test items for this trial are shown in Table 4-1. Basic operation tests of TMMNS and security threat scenario tests will be conducted. Assuming security threats such as device virus infection and SIM swapping, check the operation of functions to detect and quarantine them.

Table 4-1 Security Test Items

No	Test Item		Test Pass Criteria
1	Basic operation confirmation	Confirmation of UE display availability	Confirm that the IMEI of the UE and the IMSI of the SIM card are displayed in the TMMNS after the UE is in coverage.
2		Confirmation of UE control availability	Manually send a disconnect signal from the TMMNS server to the UE and confirm that the UE is forcibly disconnected.
3		Confirmation of UE information update interval	Verify that the information update signal is being sent from the UE to the TMMNS server, and check the sending interval.
4		Confirmation of traffic volume display	Confirm that the communication traffic volume of the test UE is displayed on the management screen of the TMMNS server.
5	Security threat scenario testing	Unauthorized access prevention	Execute the test scenario to detect unauthorized access and confirm that the test UE is forcibly disconnected by the TMMNS.
6		SIM swap prevention	Execute the test scenario to detect SIM swap and confirm that the test UE is forcibly disconnected by the TMMNS.

4.1.4. Security Threat Scenarios

4.1.4.1. Unauthorized Access Prevention Test Scenarios

Among the security threat scenario tests, the unauthorized access defense test scenario is illustrated in Figure 4-2. This test scenario aims to verify the defensive actions taken during unauthorized access incidents within the local 5G network. The specific scenario is as follows:

① Using nmap (a port scanning tool), simulate unauthorized access by sending pseudo-communication from the UE to the PC located at N6.

② The TMMNS server detects the unauthorized access and sends a disconnection signal to the UE.

③ The UE is forcibly disconnected, and subsequent data communication becomes impossible.

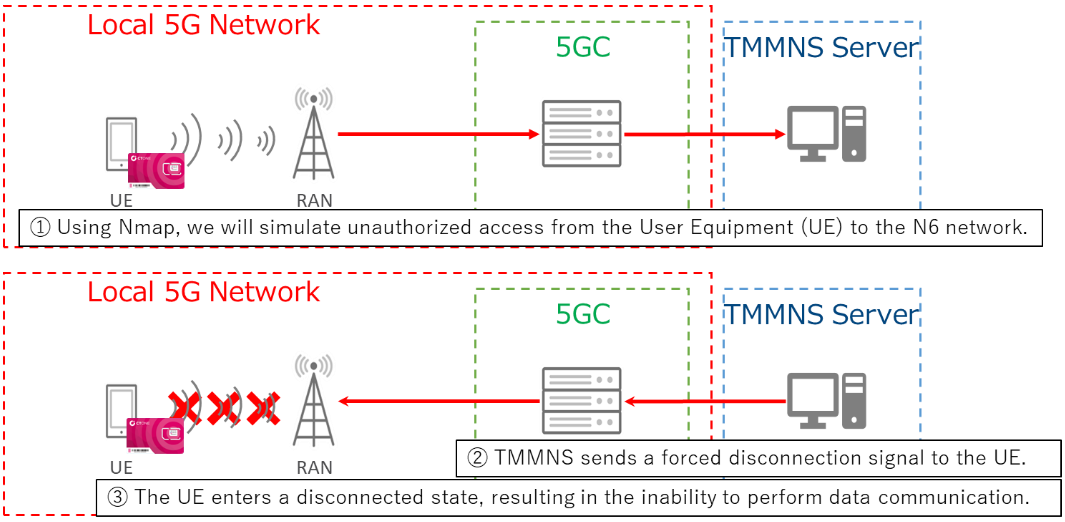

Figure 4-2 Unauthorized Access Prevention Test Scenarios

4.1.4.2. SIM Swap Defense Test Scenario

Among the security threat scenario tests, the SIM swap defense test scenario is illustrated in Figure 4-3. This test scenario aims to verify the defensive actions taken during SIM swap incidents within the local 5G network. The specific scenario is as follows:

① Insert the SIM card currently in UE(A) into UE(B).

② The TMMNS server detects the SIM swap and sends a disconnection signal to UE(B).

③ UE(B) is forcibly disconnected, and subsequent data communication becomes impossible.

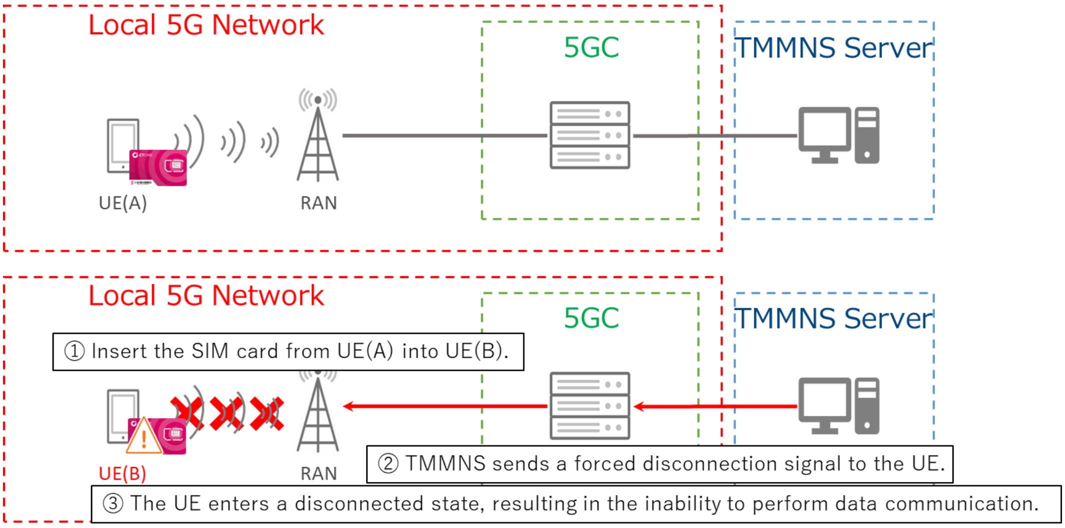

Figure 4-3 SIM Swap Prevention Test Scenarios

4.1.5. Test Results and Discussion

As of February 2025, the results of all 44 combinations that have been processed are shown in Table 4-2. Approximately 90% of the combinations resulted in normal operation of the TMMNS; however, for a specific model of UE, the UE information did not appear on the TMMNS management screen, resulting in a test failure (NG). The analysis revealed that the reason for the issue was that the necessary functions for integration with the TMMNS were disabled at the software level on the UE side. Currently, improvements to the operation of the affected UE are under consideration.

Table 4-2 Security Test Results

5 GC	Basic operation confirmation	Security threat scenario testing
HPE	pass(10) Retest Required(1)	pass(10) Retest Required(1)
NTT-TX	pass(10) Retest Required(1)	pass(10) Retest Required(1)
Saviah	pass(10) Retest Required(1)	pass(10) Retest Required(1)
QCT	pass(10) Retest Required(1)	pass(10) Retest Required(1)

In the security testing, as shown in Figure 4-4, out of all 44 combinations processed as of February 2025, 40 combinations were found to be connectable, resulting in a pass rate of 90.9%.

The breakdown of the combinations that could not be connected is shown in Table 4-3.

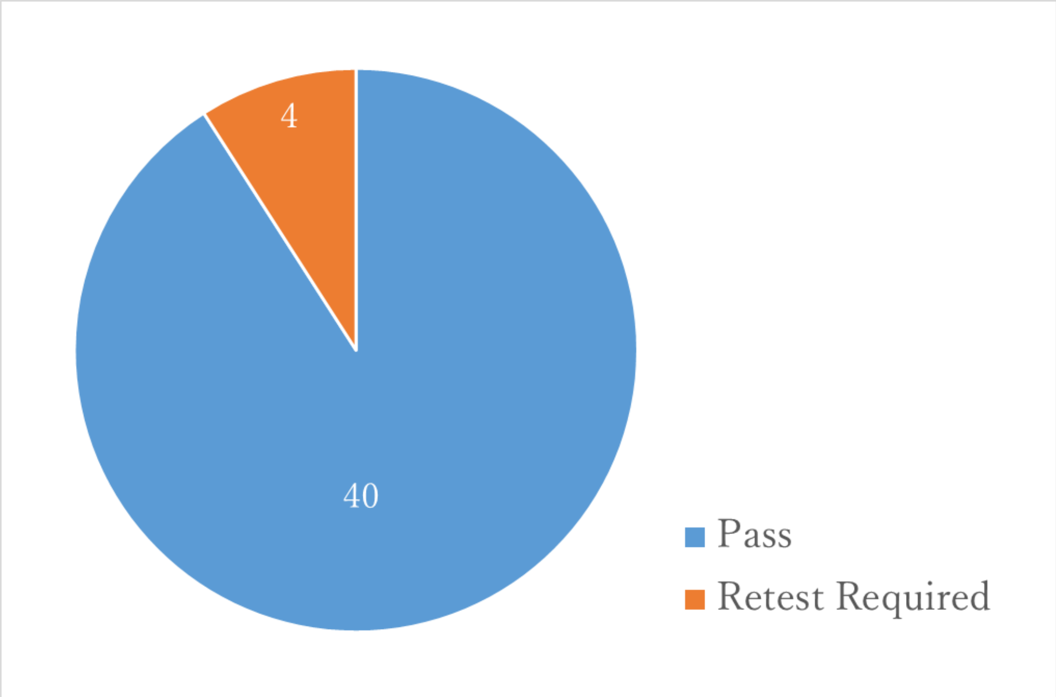

Figure 4-4 Security Test Results

Table 4-3 Security Threat Scenario Test Execution Failures

Status	Number of Issues(4)	Issue
Unresolved	4	An issue has occurred where a specific UE cannot be displayed on the TMMNS management screen.

4.1.6. Considerations to be Observed in TMMNS Connections

The considerations that must be adhered to for TMMNS connectivity,as identified through troubleshooting and confirmation with the UE vendor, are presented in Table 4-4.

Table 4-4 TMMNS Connection Compliance Considerations

Target			Points to Consider
TMMNS	5GC	UE	
✓	-	✓	To ensure integration with the TMMNS, it is necessary to equip the UE with a SIM card that has a dedicated security feature (applet). When connecting to the TMMNS, use a UE that is compatible with the applet on the SIM card.

5. Conclusion

In this report, the results of Theme 1, "Interconnection between Local 5G devices," and Theme 3, "Enhancement of security measures for Local 5G utilization environment," were shown respectively.

In Theme 1, the combination of products on the market that were successfully interconnected across vendor boundaries, points to keep in mind when interconnecting, and performance such as throughput and 4K video transmission delay due to the combination were shown. It is hoped that this will dispel the negative image of "no interconnection" and "poor performance" in the market.

In Theme 3, demonstration results were shown that security in the local 5G environment can be enhanced by linking security SIM cards and network security functions.

By utilizing this report, we expect that integration costs for different vendor equipment configurations will be reduced and the range of equipment selection according to use cases will be expanded. On the other hand, one of the factors that increases integration costs in different vendor equipment configurations is the tuning of parameters between devices according to use cases. For this reason, we are currently working on optimizing the parameters of local 5G devices as Theme 2, and plan to publish the results of this effort in our next report.

The demonstration results and insights gained from new combinations will be compiled into reports and shared widely, not only domestically but also internationally. Through the achievements of this project and co-creation with participating companies, we aim to accelerate the societal implementation of local 5G, promote industrial DX, and contribute to solving social issues.

Finally, we would appreciate any comments or feedback from readers of this report.

6. References

[1] 3GPP TS23.501："System architecture for the 5G System (5GS)"

[2] 3GPP TS23.502："Procedures for the 5G System (5GS)"

[3] 3GPP TS38.331："NR;Radio Resource Control(RRC) Protocol specification"

[4] 3GPP TS24.501："Non-Access-Stratum (NAS) protocol for 5G System (5GS)"