Toward Stable Wireless Communications in Manufacturing Sites

—Verification Experiment for SRF Wireless Platform Ver. 2—

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1. Introduction

In addition to the spread of Wi-Fi and Bluetooth, the introduction of new wireless communication technologies such as 5G and local 5G (L5G) are raising expectations of wireless communication in manufacturing sites and other fields including medical care and logistics. Examples of applications using wireless communication in manufacturing sites include the automation of parts conveyance by automated guided vehicles (AGVs) and the collection and management of information related to tools such as torque wrenches. The introduction of manufacturing-oriented applications using wireless communication to improve productivity is progressing annually and is expected to increase even more in the years to come.

On the other hand, the quality of wireless communication can become unstable due to interference and shielding effects causing delays and throughput to deteriorate. If communication performance should worsen in this manner, AGVs may come to a stop or tool-related information may become unavailable causing the manufacturing line to shut down and productivity to drop. This article introduces the Flexible Factory Project (FFPJ) established by the National Institute of Information and Communications Technology (NICT) in 2015 to promote cross-barrier collaboration among a variety of companies and work sites with the aim of achieving the stable use of wireless communication in manufacturing sites. It also introduces the Smart Resource Flow (SRF) wireless platform as technology developed for the coordinated control of heterogeneous radio systems using the knowledge gained at FFPJ. Finally, it reports on the development of a wireless communication system supporting technical specifications Ver. 2 of the SRF wireless platform and on an experiment to verify the effectiveness of this system in an actual manufacturing site, all in collaboration with NEC Corporation, Tohoku University, and Toyota Motor East Japan.

2. FFPJ and FFPA

To promote the use of the Internet of Things (IoT) in manufacturing sites, NICT established FFPJ to achieve smart factories using wireless communication and it has been conducting a variety of wireless-communication performance evaluation experiments at working factories (Figure 1). The goal here is to achieve adaptive wireless control systems according to environment and application in manufacturing sites.

Launched in June 2015, the FFPJ currently consists of 23 participating companies, namely, NICT, OMRON Corporation, the Advanced Telecommunications Research Institute International (ATR), NEC Corporation, Fujitsu Limited, Sanritz Automation Co., Ltd., Murata Machinery, Ltd., Mobile Techno Corp., Panasonic System Networks R&D Lab. Co., Ltd., Internet Initiative Japan Inc., KOZO KEIKAKU ENGINEERING Inc., Silex Technology, Inc., Toyota Technical Development Corporation, PwC Consulting LLC, NTT Communications Corporation, Takenaka Corporation, KYOCERA Corporation, AK Radio Design Inc., FUKUDA DENSHI , Microwave Factory Co., Ltd., ANRITSU CORPORATION, Sekisui Chemical Company, Limited, and Nippon Telegraph and Telephone East Corporation. These companies have been involved in the development of new wireless platforms, the formulation of specifications for wireless communication standards, the publishing of various types of white papers on diverse topics including communication security in manufacturing sites, etc. These projects continue to this date, but to expand to other fields such as medical care, logistics, and infrastructure that have issues similar to those of manufacturing sites, activities expanded in 2020 to the Flexible Society Project (FSPJ) that aims to support society overall through wireless communication. Specifically, activities have been divided into the Flexible Care Project (FCPJ) targeting issues in medical care, Flexible Logistics Project (FLPJ) targeting issues in logistics, Flexible Infrastructure Project (FIPJ) targeting infrastructure, and Flexible Data Trading Project (FDTPJ) that aims to enable the use of data measured in locations and environments that differ from field to field. What has not changed in these activities since the launch of FFPJ is

Figure 1: Scene from an experiment in the Flexible Factory Project

how we proactively promote feedback from on-site personnel to research and development and conduct all sorts of surveys and experiments in relation to wireless communication in accordance with on-site needs.

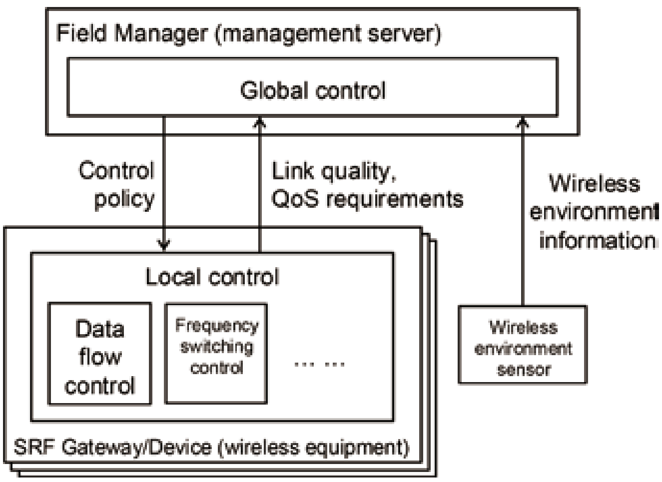
In addition, the Flexible Factory Partner Alliance (FFPA), a non-profit voluntary organization, was established in July 2017 by a group of FFPJ volunteers to promote adoption of the Internet of Things (IoT) in manufacturing sites. The plan is to achieve this through the formulation, standardization, and spread of the SRF wireless platform as coordination control technology for achieving stable communications in environments having multiple wireless systems. As of March 2025, member companies consisted of OMRON Corporation, Advanced Telecommunications Research Institute International (ATR), Sanritz Automation Co., Ltd., NICT, NEC Corporation, Fujitsu Limited, Murata Machinery, Ltd., Siemens K.K., and Telecom Engineering Center. Andreas Dengel (German Research Center for Artificial Intelligence) is chairperson of FFPA.

3. SRF wireless platform

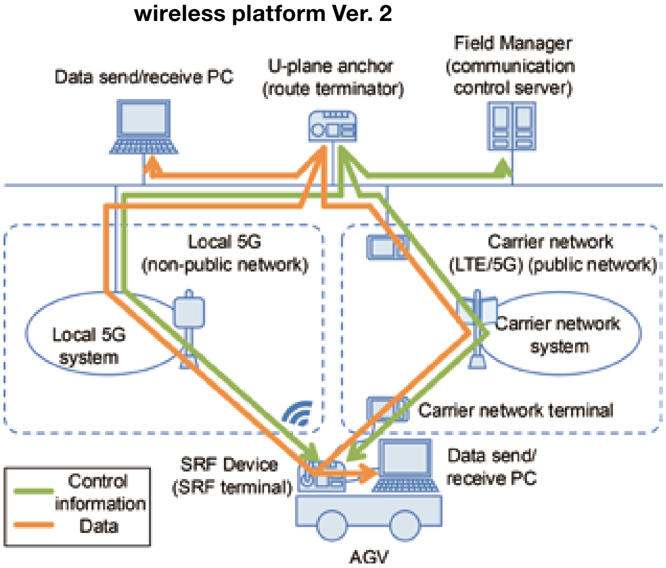
SRF is a system engineering strategy that uses multilayer system analysis proposed by NICT to smoothly manage the flow of manufacturing-related resources (such as people, facilities, equipment, materials, energy, and communications). The wireless control platform for implementing this system engineering strategy is the SRF wireless platform, which is a mechanism for connecting a wide variety of wireless devices and facilities and operating them in a stable manner. For example, the SRF wireless platform can be used to avoid interference in the radio interval and minimize communication delay by monitoring communication conditions of other applications running in the same space and adaptively controlling the communication channels and data speeds they are using. The technical specifications of the SRF wireless platform are formulated by FFPA, which released Ver. 1 in October 2021 and Ver. 2 in January 2023.

Within the SRF wireless platform, the Field Manager (management server) performs global control to coordinate resources among multiple wireless systems, and an SRF Gateway/Device (wireless equipment) performs local control to optimize communications within a single wireless system (Figure 2). Based on information obtained from the wireless environment sensor, this platform avoids interference in the radio interval and minimizes communication delay by coordinating global control and local control and adaptively controlling communication channels and data speeds according to the communication conditions of other applications. Technical specifications Ver. 2 of the SRF wireless platform used in system development enables the use of hybrid networks using LTE and 5G circuits in addition to wireless LAN targeted by Ver. 1. In this way, wireless communication quality can be stabilized even further by combining LTE and 5G, which can provide wireless communications over a wide area, with local 5G, which can provide wireless communications locally in places like factory buildings whose metallic frame might make it difficult for radio waves to arrive from the outside. NICT and NEC developed a wireless communication system supporting technical specifications Ver. 2 of this SRF wireless platform. Additionally, to verify the effectiveness of this system in an actual manufacturing site, we conducted an experiment at the Miyagi Ohira plant of Toyota Motor East Japan in the environment shown in Figure 3. Specifically, we tested for the first time in the Tohoku region the stability of wireless communication quality with a mobile vehicle by switching between the carrier network (LTE/5G) and local 5G.

■ Figure 2: Functional configuration of the SRF wireless platform



■ Figure 3: Experimental system using the developed SRF wireless platform Ver. 2



■ Figure 4: Mobile vehicle (AGV) mounting an SRF Device

4. Verification experiment in a working manufacturing site

To verify the effectiveness of this wireless communication system in a working manufacturing site, we conducted an experiment at the Miyagi Ohira plant of Toyota Motor East Japan to evaluate wireless communication quality with a mobile vehicle by switching between the carrier network and local 5G in the environment shown in Figure 3. In the experiment, we mounted an SRF Device on a mobile vehicle (AGV) operating in a manufacturing site as shown in Figure 4 and had the vehicle make a round trip between Plant-A and Plant-B situated approximately 163 m from each other. The local 5G frequency band used radio waves in the 4.8 GHz – 4.9 GHz range.

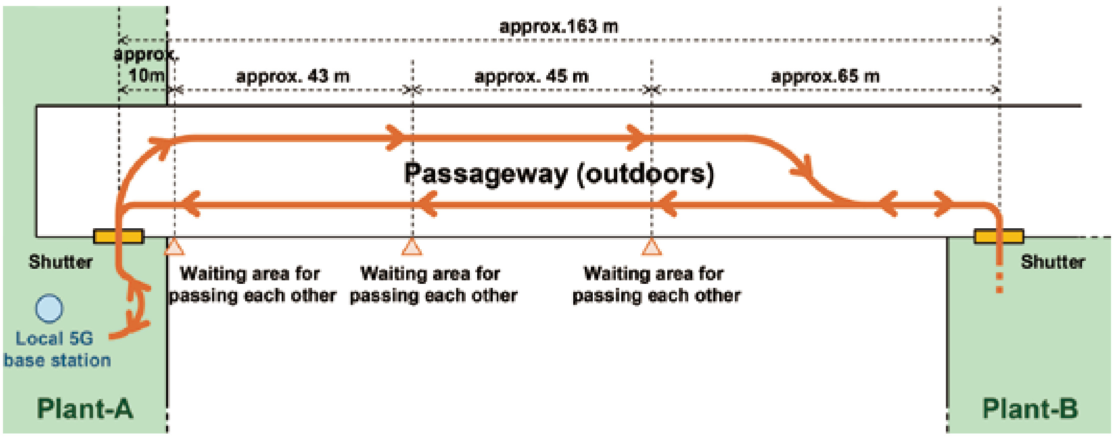
We performed this experiment in the environment shown in Figure 5. Here, Plant-A has a local 5G base station installed and the AGV mounting an SRF Device makes round trips between Plant-A and Plant-B. The shutters in these plants (AGV entrances/exits) were approximately 163 m away from each other connected by an outdoor passageway. The AGV moved in the direction indicated by the arrows in Figure 5. Waiting areas for passing each other were situated at three locations along the passageway to avoid congestion. Until bidirectional AGVs become available, the AGV that arrives first will wait in that waiting area.

While transmitting data by local 5G as indicated by the blue line in Figure 3, the AGV starts to move from Plant-A equipped with a local 5G base station toward Plant-B. At this time, local 5G communication quality deteriorates as the AGV moves away from Plant-A. However, the SRF wireless platform provides a backup path on the carrier network side as shown by the blue broken line on the right in Figure 3. Accordingly, if the SRF Device should determine that the carrier network is more suitable than local 5G for data transmission based on wireless quality information (receive signal strength, etc.), communication quality can be maintained by switching the data transmission path to the carrier network as shown by the green line in Figure 3. In this experiment, we tested whether switching between local 5G and the carrier network could be performed seamlessly and whether communications could continue in a stable manner.

Experimental results are shown in Figure 6. For the case of not using the SRF wireless platform as shown in Figure 6 (a), the AGV becomes out of range from local 5G immediately after entering Plant-B. As a result, communications are disconnected. Then, on searching for another transmission path, the AGV is switched to the carrier network and communications are reopened, but only after a communication cutoff of approximately 9.75 s. In addition, round-trip time (RTT) deteriorated significantly just before the local 5G communication cutoff reaching a maximum of approximately 1.01 s (see the enlarged view in Figure 6 (c) left).

However, for the case of using the SRF wireless platform as shown in Figure 6 (b), it was found that switching the data

■ Figure 5: Factory environment for this experiment



■ **Figure 6: Experimental results**

Figure 6(a): Case of not using the SRF wireless platform

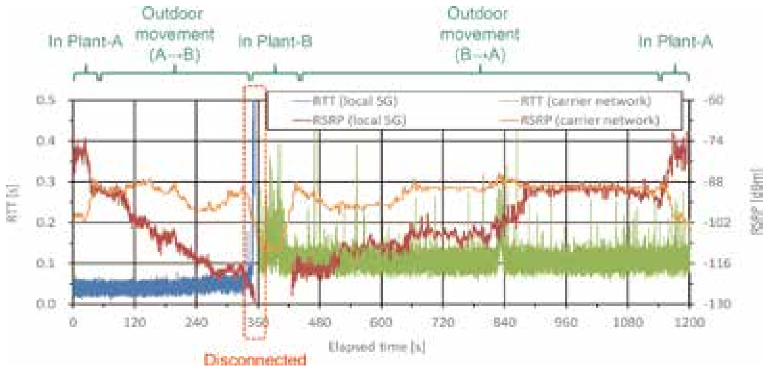


Figure 6(b): Case of using the SRF wireless platform

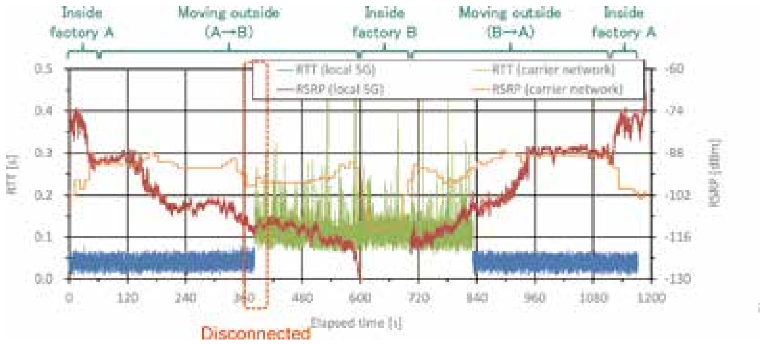
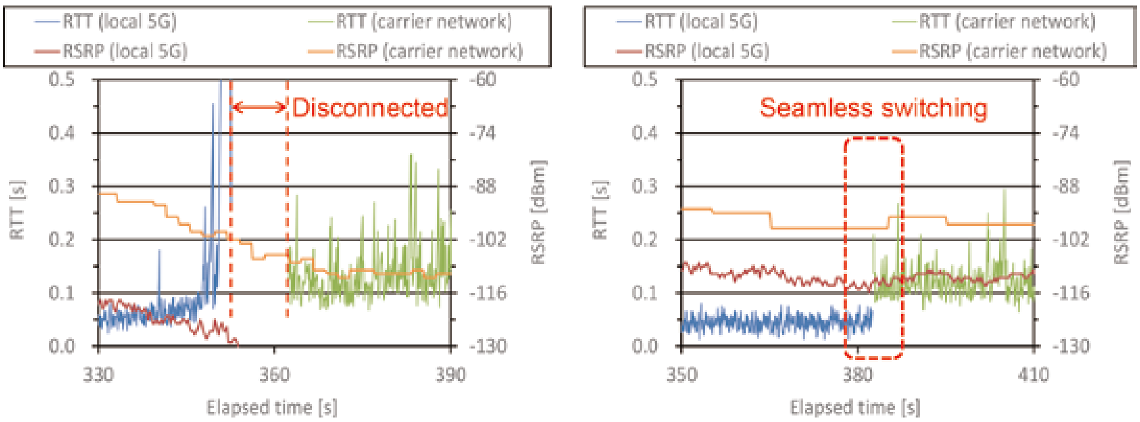


Figure 6(c): Enlarged views at switching time (left: SRF not used; right: SRF used)

Blue line: round-trip time (RTT) via local 5G; green line: round-trip time (RTT) via carrier network; red line: receive signal strength via local 5G; orange line: receive signal strength via carrier network



transmission path to the carrier network slightly before entering Plant-B shortened the communication cutoff time at the time of path switching to approximately 0.14 s. This result confirmed that application communications could continue in a stable manner through seamless switching (see the enlarged view in Figure 6 (c) right). Additionally, once the AGV leaves Plant-B and approaches Plant-A and the receive signal strength of local 5G improves, it was found that the SRF Device could switch back to local 5G and continue communications. In this way, we demonstrated as a world's first the effectiveness of the SRF wireless platform in achieving stable communications without interruption by using a hybrid network consisting of a carrier network and local 5G having different characteristics such as size of service area.

5. Conclusion

Going forward, we aim to apply the results of this verification experiment to the practical use of the SRF wireless platform to achieve stable wireless communication in factories. Finally, we would like to express our sincere appreciation to Toru Osuga of NEC and to all concerned at Toyota Motor East Japan and Tohoku University for their gracious assistance. This research and development work was commissioned in part by the SCOPE (International Standard Acquisition Type) JPJ000595 project of the Ministry of Internal Affairs and Communications (MIC).