Advanced Wireless & Communication Research Center

ACTIVITY REPORT 2025

The University of Electro-Communications

Director's Message

The year 2025 marks a significant milestone for the Advanced Wireless & Communication Research Center (AWCC), as we celebrate the twentieth anniversary of its establishment in 2005. It is a great honor for me to assume the role of Director in this commemorative year and embark on a new journey together with the members of AWCC.

Over the past two decades, AWCC has built a distinguished record through its participation in numerous national research programs and collaborative initiatives. In academic year 2025, the center continued this tradition through major projects, including JST CRONOS and other large-scale government-funded programs, producing outcomes of both academic significance and engineering impact. These achievements are possible only because of the outstanding efforts of our researchers. The accomplishments realized during the year clearly demonstrate the strength, dedication, and creativity of the AWCC community.

At the same time, academic year 2025 saw the departure of several highly accomplished researchers. While this inevitably affected the center's overall performance, I view it not only as a loss but also as a reflection of the role AWCC plays in cultivating talent. As researchers who have gained valuable experience at AWCC move on to new stages of their careers, they strengthen research networks throughout Japan and contribute to enhancing the nation's scientific and technological presence on the global stage. I sincerely hope that their future successes will further deepen these connections and create new opportunities for collaboration.

Meanwhile, the rapid progress of artificial intelligence (AI), highlighted by the emergence of generative AI as a transformative technology since late 2022, continues to reshape the landscape of science and engineering. This wave has also reached the field of wireless communications. Looking toward the 6G era, discussions have expanded beyond technologies such as integrated sensing and communications (ISAC) and non-terrestrial networks (NTN) to include the integration of AI into radio access technologies and, ultimately, AI-native networks in which intelligence is seamlessly embedded throughout the entire network architecture.

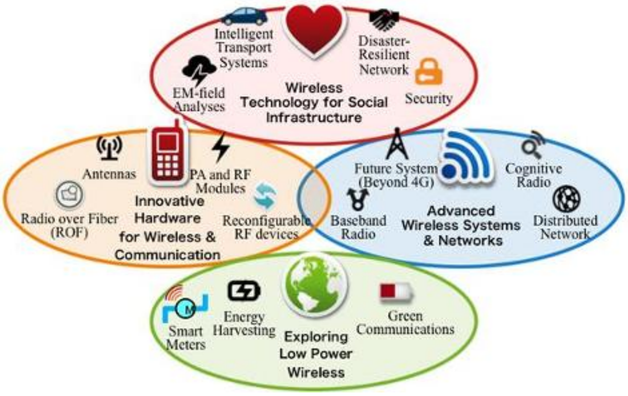
As this trend accelerates, understanding AI and learning how to effectively leverage it will become increasingly important. At the same time, leading universities around the world have begun to discuss the potential impact of AI on learning and intellectual development. We are entering an era in which institutions must carefully consider not only how AI can be utilized in research, but also how future researchers and engineers should be educated in the presence of increasingly powerful AI systems.

Against this backdrop, AWCC must continue to evolve. By embracing the opportunities presented by the AI-native era, we aim to cultivate the next generation of researchers and engineers while fostering a research environment that remains innovative, internationally visible, and intellectually vibrant. As we celebrate the twentieth anniversary of AWCC, we must also look beyond the present and prepare for the next decade and the decade that follows. Building upon the strong foundation established over the past twenty years, I look forward to working together with all members of AWCC to create the next chapter in the center's history.

Koji Ishibashi, Director of AWCC

１. ABOUT AWCC

1.1 OVERVIEW

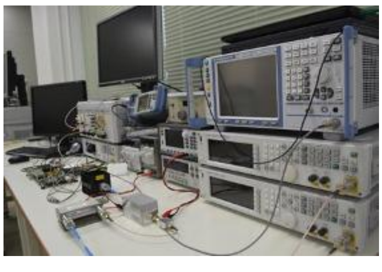


The Advanced Wireless Communication Research Center (AWCC) was launched in April 2005 with the aims of establishing a global hub for wireless communications; advancing education in wireless technology; industrial collaboration and technology transfer; and nurturing young engineers with strong emphasis on both theoretical and experimental aspects of wireless communications. In April 2015, the center was re-launched as the Advanced Wireless and Communication Research Center with the same abbreviation, AWCC, to enhance its remarkable range of activities over the previous ten years. With funding of approximately 1000 million yen over nine years, the center consists of 4 full time, 5 concurrent, 20 cooperative, and 6 visiting professors. In addition, there are 9 visiting professors from industry and more than 100 graduate students, post-doctoral and research fellows. The center actively contributes to academic societies and publishes more than 150 papers annually in top journals and proceedings of international conferences.

The AWCC organizes regular seminars and workshops with the highlight of 2014 being the "Tokyo Wireless Technology Summit" held in March 2014. The meeting focused on the next major phase of mobile telecommunications called 5th generation (5G) and attracted approximately 240 participants from all over the world.

1.2 FACILITIES

AWCC is located on the east-campus of the University of Electro-Communications in Chofu city, Tokyo near Shinjuku district in Japan. The center has opened with 10,441 square foot of modern research space containing a class room, two conference rooms, four research offices, and two experiment rooms with a wide range of instruments including FPGA development platforms, signal generators, vector network analyzers, spectrum analyzers, software defined radios, and so on. Also, it has extensive computer and network resources including high-speed workstations and personal computers which are integrated with resources of the Univeristy of Electro-Communications.



1.3 PEOPLE

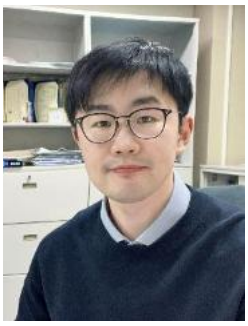
【Director, Full-time Prof. Koji Ishibashi】

Koji Ishibashi received the B.E. and M.E. degrees in engineering from The University of Electro-Communications, Tokyo, Japan, in 2002 and 2004, respectively, and the Ph.D. degree in engineering from Yokohama National University, Yokohama, Japan, in 2007. From 2007 to 2012, he was an Assistant Professor at the Department of Electrical and Electronic Engineering, Shizuoka University, Hamamatsu, Japan. Since April 2012, he has been with the Advanced Wireless Communication Research Center (AWCC), The University of Electro-Communications, Tokyo, Japan where he is currently an Associate Professor. From 2010 to 2012, he was a Visiting Scholar at the School of Engineering and Applied Sciences, Harvard University, Cambridge, MA. Prof. Ishibashi has contributed more than 100 articles to international journals and conference proceedings. His current research interests are grant-free access, non-orthogonal multiple access (NOMA), millimeter wave communications, ultra-low power communications, signal processing, and information theory. He is a senior member of IEEE and IEICE.

【Full-time Prof. Takeo Fujii】

Takeo Fujii was born in Tokyo, Japan, in 1974. He received the B.E., M.E. and Ph.D. degrees in electrical engineering from Keio University, Yokohama, Japan, in 1997, 1999 and 2002 respectively. From 2000 to 2002, he was a research associate in the Department of Information and Computer Science, Keio University. From 2002 to 2006, he was an assistant professor in the Department of Electrical and Electronic Engineering, Tokyo University of Agriculture and Technology. From 2006 to 2014, he has been an associate professor in Advanced Wireless Communication Research Center, The University of Electro-Communications. Currently, he is a professor in Advanced Wireless and Communication Research Center, The University of Electro-Communications. His current research interests are in cognitive radio and ad-hoc wireless networks. He received Best Paper Award in IEEE VTC 1999-Fall, 2001 Active Research Award in Radio Communication Systems from IEICE technical committee of RCS, 2001 Ericsson Young Scientist Award, Young Researcher's Award from the IEICE in 2004, The Young Researcher Study Encouragement Award from IEICE technical committee of AN in 2009, Best Paper Award in IEEE CCNC 2013, and IEICE Communication Society Best Paper Award in 2016. He is a senior member of IEEE and a fellow of IEICE.

【Full-time Associate Prof. Kun Li】



Kun Li received the B.E. degree in communication engineering from the Nanjing University of Posts and Telecommunications, Nanjing, China, in 2011, and the Ph.D. degree in electrical engineering from the University of Toyama, Toyama, Japan, in 2017. From 2017 to 2019, he was a Researcher with National Institute of Information and Communications Technology (NICT), Tokyo, Japan. From 2020 to 2023, he was an Assistant Professor with Kagawa University, Takamatsu, Japan. He was a Visiting Researcher with CNRS/IETR, University of Rennes 1, Rennes, France, from 2022 to 2023. Since 2023, he has been an Associate Professor with the Advanced Wireless and Communication Research Center (AWCC), The University of Electro-Communications (UEC), Tokyo, Japan. His research interests include wireless communication, radiofrequency electromagnetic field (RF-EMF) safety, over-the-air testing, MIMO systems, and bioelectromagnetics. Dr. Li received the Outstanding Associate Editor Award from IEEE Antennas and Wireless Propagation Letters in 2025 and 2026, where he served as an Associate/Guest Editor. He was also the recipient of the URSI Young Scientist Award in 2020. He currently serves as the Early Career Representative of URSI Commission K. He is a Senior Member of IEEE and URSI, and a Member of IEICE.

【Concurrent Prof. Koji Wada】

Koji Wada received the B.E. and M.E. degrees from Kinki University, Osaka, Japan, in 1991 and 1995, respectively, and the Doctorate degree from Yamaguchi University, Yamaguchi, Japan, in 1999. From 1999 to 2004, he was a Research Associate with the Department of Electrical Engineering and Electronics, Aoyama Gakuin University, Kanagawa, Japan. From 2004 to 2015, he worked as an Associate Professor at the Department of Electronic Engineering, the University of Electro-Communications, Tokyo, Japan and he is Currently a Professor at the Department of Computer and Network engineering, Graduate School of Informatics and Engineering, the University of Electro-Communications. His research interests include resonators, filters, multiplexers, multiband circuits, tunable circuits, periodic structure, and metamaterial circuits. Dr. Wada is a member of the Institute of Electronics, Information and Communication Engineers (IEICE), Japan, Institute of Electrical Engineers of Japan (IEEJ), and Japan Institute of Electronics Packaging (JIEP).

【Concurrent Prof. Motoharu Matsuura】

Motoharu Matsuura received the Ph.D. degree in electrical engineering from the University of Electro-Communications, Tokyo, Japan, in 2004. In 2007, he joined the Department of Information and Communication Engineering at the University of Electro-Communications as an Assistant Professor. From 2010 to 2011, on leave from the university, he joined the COBRA Research Institute, Eindhoven University of Technology, Eindhoven, The Netherlands, as a Visiting Researcher, where he studied ultrahigh-speed optical signal processing using semiconductor-based devices. He is currently a Professor with the Graduate School of Informatics and Engineering, Department of Communication Engineering and Informatics, University of Electro-Communications. His research interests include optical signal processing, photonic subsystems, and radio-over-fiber transmission systems. He is the author or coauthor of more than 180 papers published in international refereed journals and conferences. He received the Ericsson Young Scientist Award in 2008, the FUNAI Information Technology Award for Young Researcher in 2009, and the Telecommunication System Technology Award of the Telecommunications Advancement Foundation in 2011. He is a member of IEEE, OSA, and IEICE.

【Concurrent Prof. Ryo Ishikawa】

Ryo Ishikawa received the B.E., M.E., and D.E. degrees in electronic engineering from Tohoku University, Sendai, Japan, in 1996, 1998, and 2001, respectively. In 2001, he joined the Research Institute of Electrical Communication, Tohoku University, Sendai, Japan. In 2003, he joined the University of Electro-Communications, Tokyo, Japan. His research interest is the development of microwave compound semiconductor devices and related techniques. He was the recipient of the 1999 Young Scientist Award for the Presentation of an Excellent Paper of the Tohoku Chapter, Japan Society of Applied Physics.

【Concurrent Prof. Celimuge Wu】

Celimuge Wu received his PhD degree from The University of Electro-Communications, Japan, where he is currently a professor. His research interests include Vehicular Networks, Edge Computing, IoT, Intelligent Transport Systems, and AI for Wireless Networking and Computing. He serves as an associate editor of IEEE Transactions on Network Science and Engineering, IEEE Transactions on Green Communications and Networking, and IEEE Open Journal of the Computer Society. He is the Vice Chair (Asia Pacific) of IEEE ComSoC Technical Committee on Big Data (TCBD), and the chair of IEEE TCGCC Special Interest Group on Green Internet of Vehicles. He is a recipient of 2021 IEEE Communications Society Outstanding Paper Award, 2021 IEEE Internet of Things Journal Best Paper Award, IEEE Computer Society 2020 Best Paper Award and IEEE Computer Society 2019 Best Paper Award Runner-Up. He is a senior member of IEEE.

【Visiting Professors】

Prof. Yasushi Yamao, Ph.D.
Prof. Kazuhiko Honjo, Ph.D.
Prof. Yoichiro Takayama, Ph.D.
Prof. Akira Saito, Ph.D.
Prof. Masashi Hayakawa, Ph.D.
Prof. Hiroshi Suzuki, Ph.D.
Prof. Mitsuo Makimoto, Ph.D.
Prof. Giuseppe T. F. de Abreu, Ph.D.
Prof. Nobuo Nakajima, Ph.D.
Prof. Yukitsuna Furuya
Prof. Takayuki Inaba, Ph.D.
Prof. Tadashi Matsumoto, Ph.D.
Prof. Koichiro Ishibashi, Ph.D.

【Cooperative Professors】

Prof. Haruhisa Ichikawa, Ph.D.
Prof. Naoto Kishi, Ph.D.
Prof. Tetsuro Kirimoto, Ph.D.
Prof. Kazuo Sakiyama, Ph.D.
Prof. Fengchao Xiao, Ph.D.
Prof. Xi Zhang, Ph.D.
Prof. Cong-Kha Pham, Ph.D.
Prof. Suhua Tang, Ph.D.
Associate Prof. Manabu Akita, Ph.D.
Associate Prof. Yoshiaki Ando, Ph.D.
Associate Prof. Toshiharu Kojima, Ph.D.
Associate Prof. Hisa-Aki Tanaka, Ph.D.
Associate Prof. Kazuki Nishi, Ph.D.
Associate Prof. Hayato Yamaki, Ph.D.
Associate Prof. Zhi Liu

【Visiting Professors from Industry】

Prof. Kunio Uchiyama (AIST)
Prof. Takahiro Asai (NTT Docomo)
Prof. Yoji Kishi (KDDI Research Inc.)
Prof. Terunao Soneoka (NTT-AT)
Prof. Akinori Taira (Mitsubishi Research Institute Inc.)
Prof. Hiroyuki Tsuji (NICT)
Prof. Hideki Hayashi (Softbank Corp.)
Prof. Hiroyuki Seki (Fujitsu Laboratory Ltd.)
Prof. Kenji Yoshida (Intermedia Laboratory Inc.)

2.1 Division of Wireless Technologies as Social Infrastructure

2.1.1 Purpose of Research

Wireless technologies will have more importance in the society as the base of safe, secure and smart life for individuals and community. Various types of machine-to-machine communication such as sensors, IoT devices and vehicular communications will spread in the society taking little notice but support safety and secureness of society, as well as creating more comfortable and smarter life. In these days, done communications are also focused on new infrastructures such as flying car, logistics and flying base stations and communications supporting drone is one of the important issues. In this division, technologies for realizing reliable and high-capacity communication for supporting social infrastructure are developed.

2.1.2 Research Staffs and Their Specialties

Prof. Takeo Fujii (Division Leader, ITS, Radio Environment Recognition, Smart Infrastructure)

Prof. Koji Ishibashi (Wireless Security)

Associate Prof. Kun Li (Smart Infrastructure)

2.1.3 Major Research Outcomes in 2025

[Efficient spectrum sharing utilizing beamforming and power control in Private 5G] (Fujii Lab.)

Private 5G（P5G）is a proprietary network built and operated locally by companies and municipalities. In Japan, multiple operators use the same frequency to communicate in P5G. Therefore, mutual interference is avoided by providing a margin area outside each operator's coverage area. This operational adjustment narrows the area where P5G can be built and reduces geographic efficiency. This study proposes an efficient spectrum sharing approach using power control and beamforming to avoid mutual interference. In this method, resources are adaptively shared or isolated depending on whether mutual interference is present in the target area.

Fig. 2-1-1 shows the system model of the proposed method. In this system, the database divides all resource blocks (RBs) into either shared RBs or dedicated RBs and controls the RBs used by each operator. When the coverage areas of two P5G operators are in direct contact, the proposed method avoids mutual interference by utilizing beamforming and power control. Specifically, one operator performs beamforming to steer a null toward the other operator, while the other operator reduces its transmission power until it no longer causes mutual interference to its counterpart. In areas where sufficient received power is maintained under these conditions, resources can be shared while avoiding interference; therefore, shared RBs are allocated to these areas. Conversely, since it is also necessary to ensure communication in areas that fall outside the beamforming coverage, dedicated RBs are assigned to those specific areas.

Fig. 2-1-2 shows the comparison of the number of resource blocks effectively used for communication among different methods. When using the proposed method, the average demand increased by 27.5% compared to the conventional method, which simply divides resources into two equal parts for each operator, at the point where the demand fulfillment rate falls below 95%. Furthermore, the proposed method achieved a 27.5% increase in average demand even when compared to a case without power control, confirming that power control functions effectively in this system. Additionally, the performance gap caused by errors in demand forecasting was found to be 8.8%.

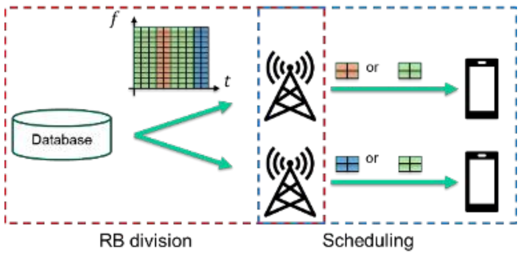


Fig. 2-1-1 System Model.

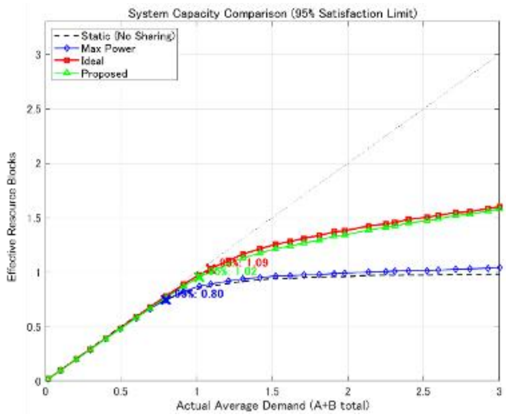


Fig. 2-1-2 Result of Simulation.

[Frequency Interpolation for Radio Map Using Cross-Band Frequency Correlation Characteristics] (Fujii Lab.)

To realize effective spectrum sharing, Radio Environment Maps (REMs) are essential for understanding radio utilization. However, terminal overhead and communication costs often lead to spatially and spectrally sparse measurement data. This study addresses this issue by proposing a method to interpolate and estimate shadowing values at unobserved locations and frequency bands using limited datasets. Figure 3 illustrates the system model of this study.

We analyzed shadowing correlation across the 920 MHz, 2.4 GHz, and 5 GHz bands, finding that significant correlation persists even with large frequency offsets. Based on this, the frequency correlation was modeled using an exponential function with a constant term. We then propose a two-dimensional Kriging method that extends spatial Kriging into the frequency domain by formulating the covariance function as a product kernel of spatial and frequency models. To evaluate the performance, we compared the proposed method with extended Inverse Distance Weighting (IDW) models using frequency correlation or frequency difference as the distance parameter.

Fig. 2-1-3 shows the estimation accuracy results under the condition where no measurement data is available for the target band. The horizontal axis represents the missing rate (the ratio of missing points to the total number of spatial meshes), while the vertical axis represents the

RMSE (Root Mean Square Error) between the ground truth and the estimated values. The results confirm that the proposed method achieves higher estimation accuracy across all missing rates compared to the benchmark methods.

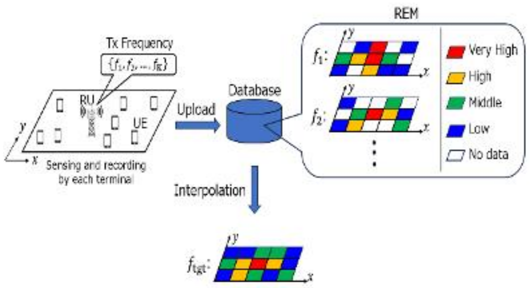


Fig. 2-1-3 System model.

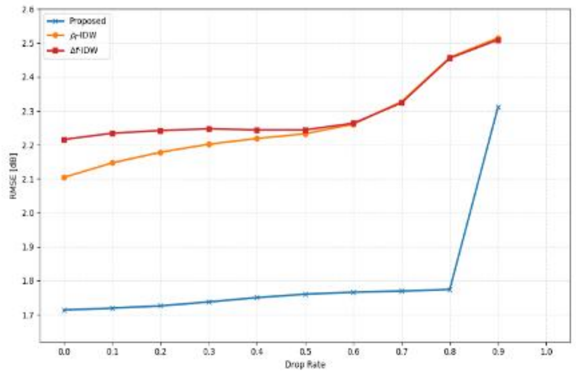


Fig. 2-1-4 Results on the Estimation Accuracy of Shadowing Values.

[E2E QoS Prediction Based on Wireless Environment Information] (Fujii Lab.)

As wireless communication is increasingly used for bandwidth-intensive services such as cross-reality, user concentration at specific places or times may cause bandwidth shortages and interference, resulting in degraded wireless communication quality and quality of service (QoS). Therefore, predicting end-to-end (E2E) communication quality in advance is important to prevent QoS degradation. Existing prediction methods often use machine-learning models that take historical time-series data of throughput as input. However, such methods require continuous measurement to obtain past values, which increases traffic load and may further degrade communication quality. Additionally, they cannot make such predictions until data transmission begins.

This study proposes a method for predicting communication quality without increasing traffic load by using wireless environment information that terminals can obtain during normal operation. In the proposed method, the E2E communication path is divided into the wireless access link between a terminal and an access point (AP) and the remaining AP-to-AP link. For the wireless access link, a Random Forest regression model is used to predict potential throughput based on wireless environment information such as received signal strength indicator (RSSI), modulation and coding scheme (MCS), and channel occupancy rate (COR). For the AP-to-AP link, where detailed state information cannot be directly obtained from terminals, the effects of congestion are captured through latency estimation based on round-trip time (RTT) and used for E2E QoS evaluation.

The prediction accuracy of E2E potential throughput was evaluated through measurement-based experiments. Fig. 2-1-5 shows the measurement setup, and Fig. 2-1-6 presents the relationship between the actual potential throughput and the mean absolute error. Across 600 samples, the proposed method achieved a mean absolute error (MAE) of 18 Mbps and a root mean square error (RMSE) of 23 Mbps. The mean absolute percentage error was 25%, and 70% and 80% of the samples had absolute errors within 21 Mbps and 27 Mbps, respectively.

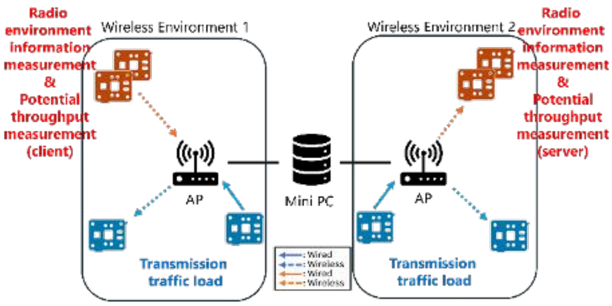


Fig. 2-1-5 Experimental setup.

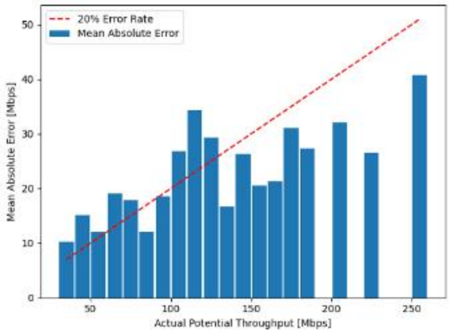


Fig. 2-1-6 Mean absolute error versus actual potential throughput.

[Smart Infrastructure Management System, "Automated Construction for Tunnel Blasting] (Kun Li Lab., Fujii Lab)

The remote control of various electronic devices using wireless communication technologies at construction sites is expected to improve operational efficiency and reduce safety risks for workers. However, achieving reliable wireless communication in underground environments, such as within bedrock or tunnels, presents significant technical challenges. Low-frequency (LF) bands are more suitable for underground wireless communication due to their superior propagation characteristics in bedrock compared to higher-frequency (MHz) bands. In this study, to establish a wireless link with electronic devices embedded in bedrock, the near-field strength distribution was investigated using a prototype system consisting of a circular loop antenna and a coil operating at 255 kHz. The received power of the LF-band wireless communication system was measured by varying the orientation of the loop antenna at several tunnel construction sites in Japan, and the resulting dataset was analyzed.

Fig. 2-1-7 illustrates the measurement system in a tunnel environment, where the propagation medium is rock. The average received power of a square-wave signal transmitted from the coil at a frequency of f = 255 kHz was measured using a spectrum analyzer connected to a circular loop antenna. The time-series pulse signal emitted from an underground electronic device was received by the loop antenna. Measurements were conducted over distances from x = 0 m to 10 m at regular intervals, and from y = 0 m to 5 m for cases where $\theta \neq 0^\circ$. However, characterizing LF-band underground communication requires a large amount of on-site measurement data, which is often impractical due to cost constraints, as well as measurement errors and uncertainties caused by varying tunnel environmental conditions.

To address these challenges, this study proposes methods targeting two key issues. First, ensuring predictive accuracy is difficult due to the limited availability of comprehensive datasets from tunnel environments. To overcome this limitation, principal component analysis (PCA) was employed to capture the overall trends in the data distribution. The results demonstrate that effective prediction of LF-band received power is possible even with a limited dataset, as shown in Fig. 2-1-8. Through dimensionality reduction, PCA enables visualization of essential data features, allowing for a comprehensive understanding without overlooking important characteristics. Second, it is difficult to visually distinguish data features and interpret overlapping datasets, particularly when identifying deviations from expected patterns, such as in the null directions of wireless communication. By applying PCA for dimensionality reduction, data trends and patterns become more interpretable, reducing the risk of missing critical features. To further enhance the robustness of the analysis, clustering techniques were also applied to complement the PCA results, thereby improving objectivity. By analyzing the distance-dependent path loss characteristics using PCA, it was found that the data points are distributed according to the positions of null directions, and that some regions exhibit null directions in locations different from those initially expected.

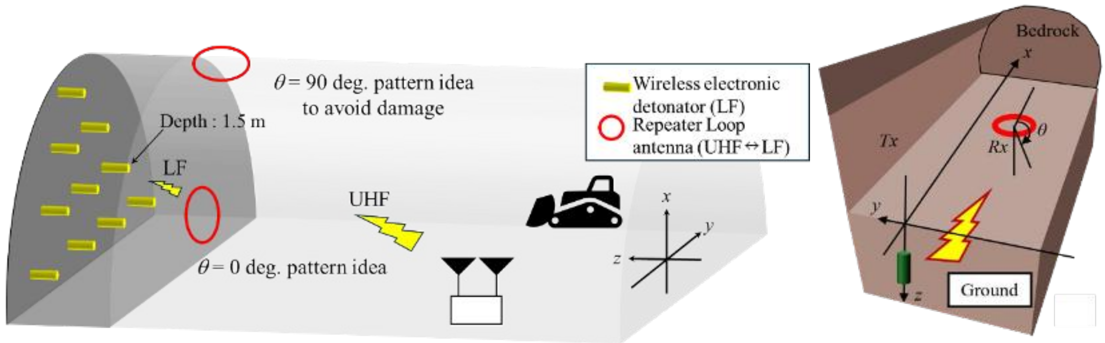


Fig. 2-1-7 LF-Band underground communication experiment at a tunnel construction site.

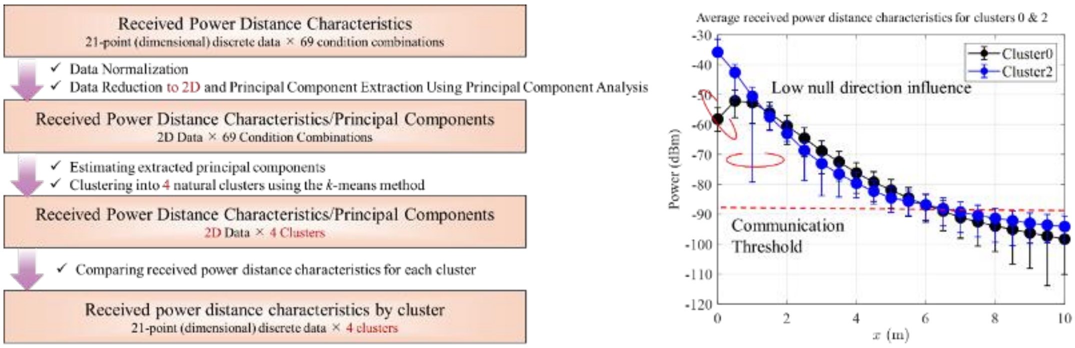


Fig. 2-1-8 PCA analysis based on LF received power in different tunnel constructions sites.

2.1.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research B "Wireless Environment Recognition using Three Dimensional

Hierarchical Wireless Sensing"

Takeo Fujii

【Commissioned Research】

1. SIP Smart Infrastructure Management System, "Automated Construction for Tunnel Blasting"

   Takeo Fujii, Kun Li
2. MIC "R&D on the Deployment of Mobile Communication Systems in the Millimeter wave Band and Other frequencies"

   Takeo Fujii
3. MIC FORWARD, "R&D of High-Efficiency Wireless Networks Using a Distributed Spectrum Management Database"

   Takeo Fujii

【Cooperative Research】

1. NEC Corp. Takeo Fujii
2. Softbank Corp., Katsuya Suto

2.2 Advanced Hardware Research Division

2.2.1 Purpose of Research

Research and development of wireless information/power transmission hardware for next generation mobile communication base stations and terminal devices

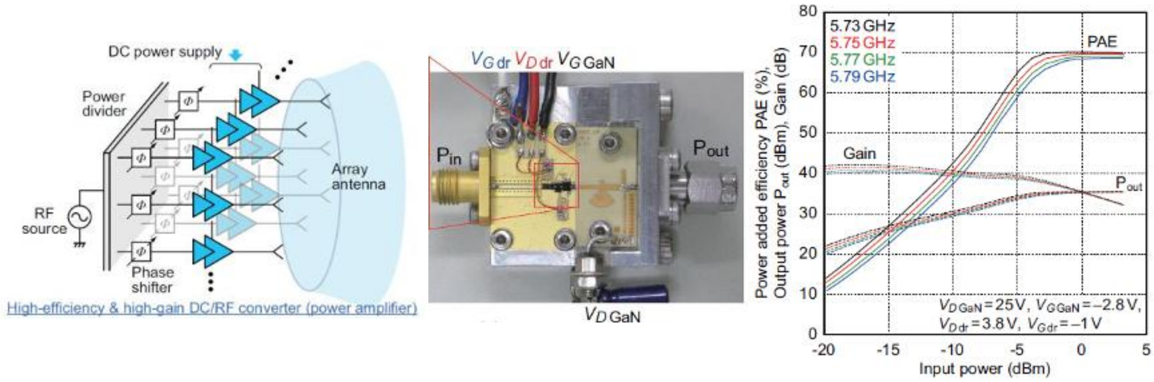
2.2.2 Research Staffs and Their Specialties

Prof. M. Matsuura	Wideband RoF Systems, Devices, Fibers and Integration
Prof. R. Ishikawa	Microwave/Millimeterwave Devices and Circuits
Prof. K. Wada	Microwave Filters and Their Applications
Prof. K. Li	Antenna, Radio Wave Propagation, Bioelectromagnetics
Visiting Prof. Y. Yamao	Reconfigurable RF Circuit, Nonlinear Compensation
Visiting Prof. K. Honjo	Microwave Engineering, Semiconductor Devices
Visiting Prof. Y. Takayama	Microwave Power Amplifier Systems
Visiting Prof. A. Saitou	Electro-Magnetic Wave Engineering, Antennas
Visiting Prof. Koichiro Ishibashi	Low Power RF Devices, Sensor Networks

2.2.3 Major Research Outcomes in 2025

[Multistage 5.75-GHz High-Efficiency and High-Gain Amplifier as DC-RF Power Converter for SSPS] (Ishikawa Lab.)

As one of the candidates for the next generation energy source, the space solar power system (SSPS) is being planned. In this system, it is assumed that electricity generated by solar power in space will be transmitted to the earth's surface by microwaves. One of the key devices for this system is a high-efficiency microwave power amplifier for DC/RF conversion. Fig. 2-2-1 (a) shows an example of the configuration of the power transmitter for a wireless power transmission system. The microwave amplifiers are arranged in an array just before each antenna element of the power transmission array antenna. Since the solar power density is roughly 3 W / (5 cm)2, a required output power is several-watt for each power amplifier. The amplifiers are required to have not only a high-efficiency performance but also a high-gain characteristic, in order to reduce the power consumption at the front signal processing system. In addition, since the amplifier is required for each element of the array antenna, a huge number of amplifiers are required. Therefore, they are required to be small and lightweight when launched into space. In our laboratory, a high-efficiency and high-gain power amplifier designed at 5.75 GHz has been developed. The fabricated multistage power amplifier exhibited a maximum power-added efficiency of of 69%, and a gain of 35.1 dB at 5.75 GHz (Fig. 2-2-1 (b)).



(a) (b)

Fig. 2-2-1 (a) An example of the configuration of the power transmitter for WPT system, and (b) Fabricated multistage power amplifier and its characteristic.

[Optically Powered Antenna Module Without Electric Power Amplifiers] (Matsuura Lab.)

As radio-frequency (RF) signals for mobile communications shift to higher frequencies, performance limitations are emerging in the frequency characteristics of RF circuits in remote radio heads (RRHs). Significant degradation is observed in output saturation power and power-added efficiency (PAE), particularly in downlink electrical power amplifiers (PAs), which account for the largest power consumption in RRHs. In recent years, high-power photodiodes (HPPDs) have advanced rapidly, with numerous reports demonstrating excellent performance in achieving higher operating frequencies and increased RF signal output power. Enhancing RF output power can eliminate the need for PAs in RRHs, thereby addressing both PA performance degradation and increased power consumption due to reduced PAE at higher RF frequencies. Owing to their ultra-low nonlinearity and high-power transmission capability, hollow-core fibers (HCFs) have attracted significant attention as a promising future optical link. Leveraging the ultra-low nonlinearity, we previously reported high-quality analog RoF (A-RoF) transmission with fiber input powers exceeding 30 dBm, and proposed that high-power A-RoF transmission using HCFs with HPPDs is effective for enhancing RF output power and eliminating PAs in RRHs.

This year experimentally demonstrate high-power A-RoF transmission of a 28 GHz 5G NR modulated signal using a 1 km HCF and a commercially available HPPD for the directly driven antenna. We also compare and optimize the modulation depth of the A-RoF signal to enhance 5G NR output power from the HPPD. As a result, we achieved high-quality 5G NR signal output power exceeding 10 dBm without PAs after 1 km HCF transmission.

Figure 2-2-2(a) shows the 5G NR output power as a function of the fiber input A-RoF signal power for conventional and high-power A-RoF transmissions. The red-marked conventional transmission achieved a significantly higher output power at the same input power compared with the blue-marked high-power transmission. However, in the conventional transmission, the input power limitation of the PD prevented us from achieving an output power exceeding –11.28 dBm. In contrast, we successfully obtained an output power of up to 11.38 dBm in the high-power transmission. Figure 2-2-2(b) shows the EVM as a function of the fiber input A-RoF signal power.

Overall, the EVM decreased as the input power increased. However, in the high-power transmission, the EVM began to rise when the input power exceeded 20 dBm. This behavior is attributed to output-power saturation based on the input-output characteristics of the HPPD. Unlike sinusoidal-wave signals, 5G NR signals exhibit transiently high PAPRs, which make the impact of output-power saturation more pronounced. Nevertheless, we achieved an output power exceeding 11 dBm with an EVM below 4% in the high-power transmission.

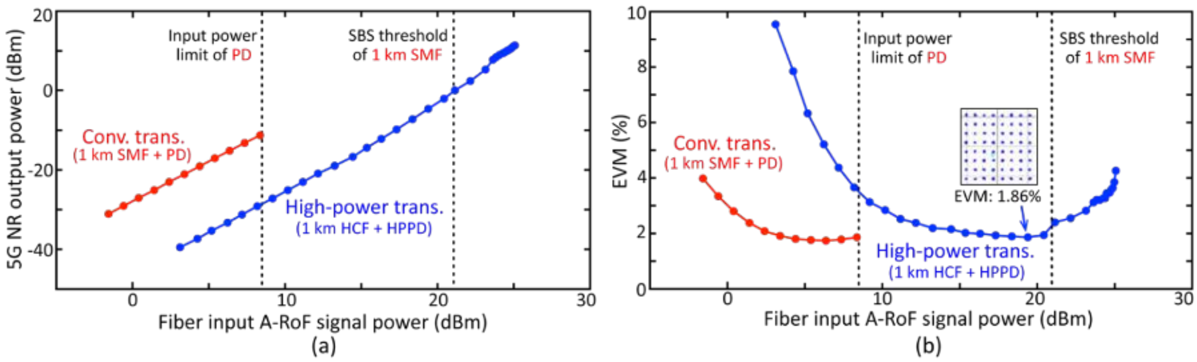


Fig. 2-2-2 (a) 5G NR output power and (b) EVM as a function of fiber input A-RoF signal power in conventional and high-power A-RoF transmissions. Dashed lines are input power limit of conventional PD and SBS threshold of 1 km SMF, respectively.

[Development of a FR3 band Near-field Electromagnetic Field Measurement System] (Kun Li Lab.)

With the practical deployment of Beyond 5G and 6G systems, human exposure safety assessment in the FR3 frequency band (7.125–24.25 GHz) has attracted significant attention. For frequencies between 6 GHz and 300 GHz, international exposure guidelines recommend absorbed power density (APD) as the basic restriction for protecting humans from excessive localized exposure. In this frequency range, electromagnetic energy is predominantly absorbed in superficial tissue layers, making thermal effects the primary biological interaction mechanism. However, direct measurement of APD on biological surfaces remains technically challenging. Therefore, establishing an accurate APD estimation methodology is essential for compliance assessment with exposure limits. Due to the shallow penetration depth of electromagnetic waves above 6 GHz, APD cannot be directly measured in the same manner as conventional specific absorption rate (SAR). To address this limitation, this study proposes a method to estimate the electromagnetic field at the phantom surface by inversely reconstructing it from the transmitted field measured at a position separated from the antenna using a low-loss phantom. As an initial step, a near-field electromagnetic measurement method for the FR3 frequency band was developed, as shown in Fig. 2-2-3. In a preliminary investigation, the xy-plane in the vicinity of the antenna was scanned, and the validity of the method was evaluated by comparing the incident power density (IPD) of a standard-gain horn antenna at 7 GHz. The results showed that the difference between simulation and measurement was within 0.1 dB, demonstrating the accuracy and reliability of the proposed measurement-based power density evaluation.

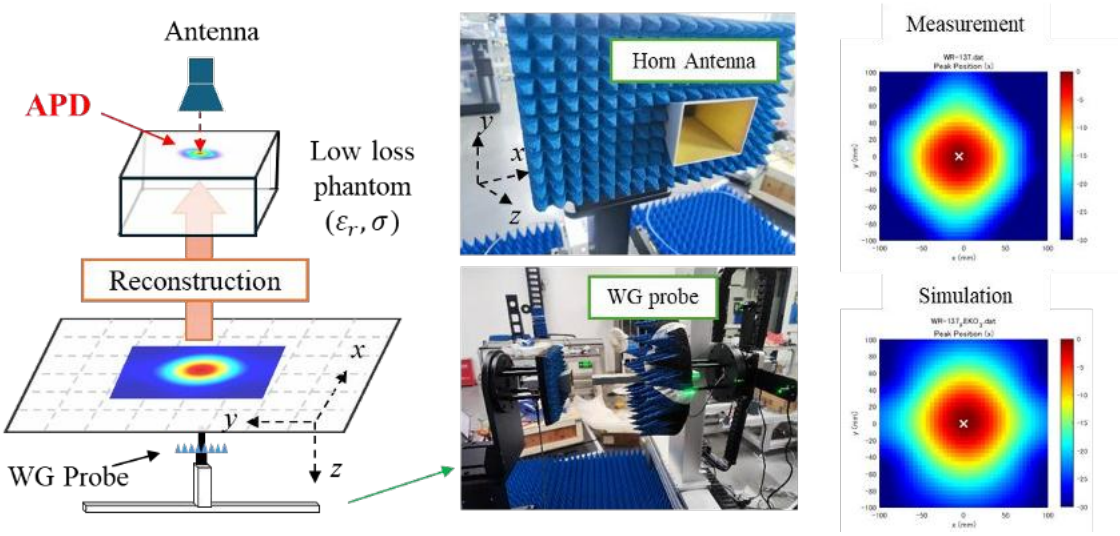


Fig. 2-2-3 Near-field measurement system for IPD and APD evaluation.

2.2.4 Funds

【Grants-in-Aid for Scientific Research】

1. Grant-in-Aid for Challenging Research (B) "Research on advanced power-over-fiber using pure-silica double-clad fibers" (M. Matsuura)
2. Grant-in-Aid for Challenging Research (C) "Development of a hybrid-operation RF power amplifier configuration for highly efficient amplification of next-generation wireless communication signals" (R. Ishikawa)

【Commissioned Research】

1. MIC, "Study on Thermal and Physiological Responses to Electromagnetic Waves Toward Beyond 5G" (T. Hikage, H. Masuda, A. Nagai, K. Li)

【Cooperative Research】

1. Toshiba Corp. "Study of design techniques for improving the performance of RF circuits" (R. Ishikawa)
2. Japan Space Systems. "Development of energy-related technology on the lunar surface (organization of technical issues related to electric power) Development and study of equipment, etc. for power transmission technology demonstration experiments from low-Earth orbit" (R. Ishikawa)
3. NEXCO-PI. "Research on the application of power-over-fiber systems to highway facilities" (M. Matsuura)

2.3 Division of Creating Advanced Wireless Systems

2.3.1 Purpose of Division

R&D of Advanced Wireless Systems and Networks contributing to development of society by sustainable technologies of wireless systems

2.3.2 Research Staffs and Their Specialties

Prof. Koji Ishibashi（Division Leader, Future NW, Distributed NW）

Prof. Takeo Fujii（Future NW, Cognitive Radio, Distributed NW）

Prof. Motoharu Matsuura（Future NW）

Prof. Celimuge Wu (Future NW, Distributed NW)

Associate Prof. Katsuya Suto (Future NW)

2.3.3 Major Research Results in 2025

[Predictive Multi-Band Traffic Steering Using Statistical Radio Environment Maps and Machine Learning for 5G Sub-6GHz/mmWave Networks] (Fujii Lab.)

Millimeter-wave (mmWave) bands are essential for boosting 5G capacity, yet their links can deteriorate sharply when vehicles or other obstacles block the line of sight. This makes conventional event-triggered mobility control, which relies on instantaneous measurements and time-to-trigger (TTT), fundamentally reactive and creates a trade-off between delayed response and excessive handovers. This study proposes a predictive multi-band traffic steering scheme for integrated Sub-6 GHz/mmWave networks using a statistical radio environment map (REM) and lightweight supervised learning to predict near-future link quality, as illustrated in Fig. 2.3-1. The REM stores, for each spatial grid and candidate cell, the mean and standard deviation of received signal quality, enabling the controller to capture both long-term channel quality and location-dependent uncertainty caused by dynamic blockage. Based on real-time user measurements and REM features at the predicted future position, two random-forest models estimate the probability of severe degradation and Signal-to-Interference-plus-Noise Ratio (SINR), from which future throughput is derived. A risk-threshold parameter controls the reliability-efficiency trade-off by filtering out cells with an excessively high predicted failure probability before throughput-based selection.

The proposed scheme follows an AI-RAN architecture in which REM construction and model training are performed offline, while an edge controller conducts near-real-time inference upon event-triggered measurement reports. Commercial 5G measurements in an urban area confirmed that, whereas vehicle blockage has a comparatively smaller impact on Sub-6 links, mmWave links suffer substantial degradation in RSRP, SINR, and throughput. System-level evaluation using the 3D ray-tracing scenario with dynamic vehicle blockage shown in Fig. 2.3-2 demonstrates strong predictive performance, with an AUC of 0.973 for degradation prediction and an R^2 of 0.82 for SINR estimation. Compared with a conventional TTT-based baseline, the proposed method reduces cumulative degradation time from 2.18 [s] to 0.45–0.66 [s], improves the 5th-percentile throughput from 32.33 [Mbps] to 40.10–40.64 [Mbps] under representative balanced and high-efficiency operating policies, and also reduces average latency and handover count.

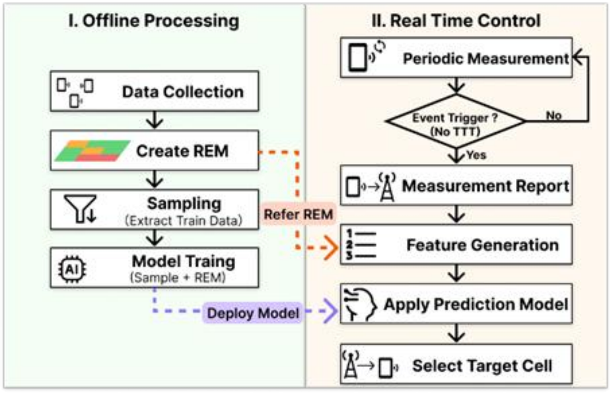


Fig. 2.3-1 Overview of the proposed method.

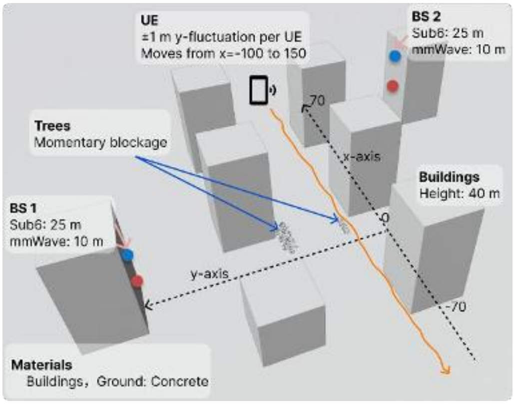


Fig. 2.3-2 Ray-tracing scenario.

[Joint QoS-Aware Satellite Selection and Interference Mitigation for Dynamic Spectrum Sharing in Multi-Layer NTNs] (Fujii Lab.)

Dynamic spectrum sharing across heterogeneous layers is a key enabler for future 6G non-terrestrial networks. In multi-layer LEO/MEO deployments operating over shared frequency bands, inefficient user association can cause traffic concentration and severe inter-layer interference, leading to underutilized spectrum resources within a service area. Conventional association strategies, such as maximum-elevation-based or longest-service-time-based schemes, do not explicitly consider system-wide spectrum efficiency and therefore fail to balance interference mitigation and load distribution.

This paper proposes a spectrum-efficient association framework for multi-layer non-terrestrial networks. The framework consists of two independent components. First, a utility-based mechanism governs user association and handover decisions by incorporating delay requirements, satellite load conditions, and handover penalties to stabilize connectivity and prevent traffic concentration. Second, interference suppression is achieved by grouping satellites that are in mutual interference relationships based on their positional information and partitioning the frequency bandwidth within each interference group.

Figures 2.3-3 and 2.3-4 illustrate the proposed system model and the cumulative distribution function (CDF) of the user throughput obtained through simulations, respectively. The curve for the proposed method, indicated in red, begins to rise at approximately 5 Mbps. This demonstrates a reduction in the number of users experiencing low throughput compared to the other comparative methods, confirming that fairness among users is well maintained. Furthermore, the proposed method achieves a lower number of handovers (HOs) and satisfies nearly 100% of the latency requirements, verifying its capability to simultaneously fulfill multiple Quality of Service (QoS) requirements at a high standard.

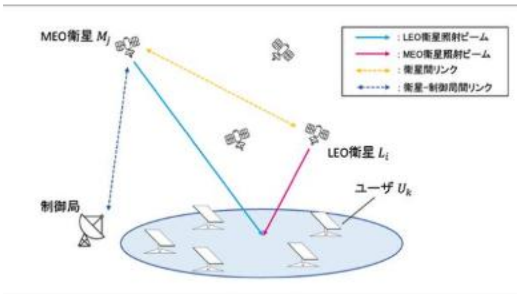


Fig. 2.3-3 System model.

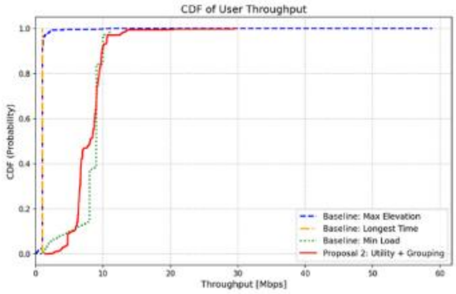


Fig. 2.3-4 Result of User Throughput.

[Semantic segmentation-based semantic communication system for image transmission] (Celimuge Wu Lab)

Motivated by the limitations of traditional communication systems that treat all image pixels equally and cannot efficiently handle bandwidth constraints, we study a semantic communication framework for image transmission that prioritizes task-relevant information. Specifically, we propose a semantic segmentation-based approach that distinguishes Regions of Interest (ROI) and Regions of Non-Interest (RONI), enabling differentiated transmission strategies. As illustrated in Fig. 2.3-5, our system consists of a transmitter, channel, and receiver: at the transmitter, semantic segmentation (e.g., U-Net) is first applied to split the image into ROI and RONI, which are then encoded using two semantic communication models with different bandwidth requirements (SC1 for lower bandwidth and SC2 for higher fidelity), followed by a sparse data compression scheme to reduce communication overhead; at the receiver, the transmitted data are reconstructed and combined to form the final image. Experimental results shown in Fig. 2.3-6 demonstrate that our method achieves consistently higher θPSNR than baseline schemes under different importance weights (θ), particularly when more emphasis is placed on ROI, indicating improved robustness and superior transmission quality in noisy environments.

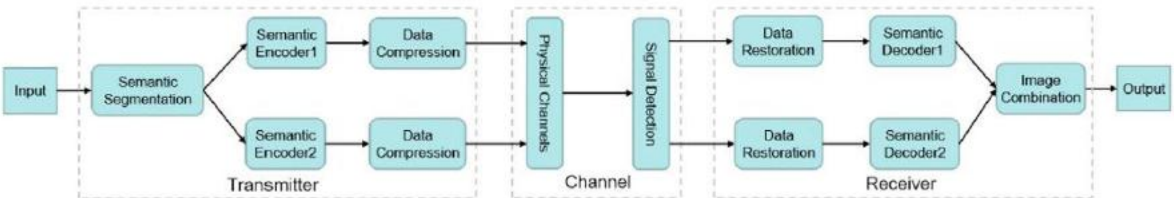


Fig. 2-3-5 The proposed system model.

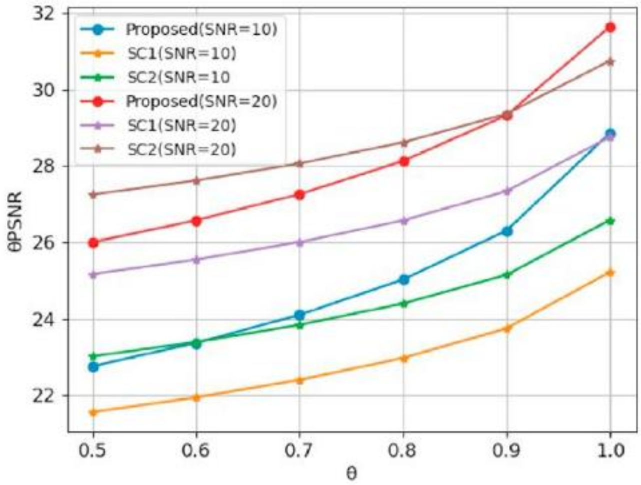


Fig. 2-3-6 The θPSNR under different values of θ over the AWGN channel.

[Grant-Free Access for Massive Users] (Koji Ishibashi Lab.)

Next-generation wireless communication systems are expected to serve a massive number of devices, as represented by internet of things (IoT). Moreover, some applications such as factory automation require both strict delay constraint and reliability. To satisfy these requirements, grant-free non-orthogonal multiple access (GF-NOMA) has been actively studied as one of the promising techniques. In GF-NOMA, the users are not exclusively assigned radio resources and each active user transmit pilot and data without handshaking procedure.

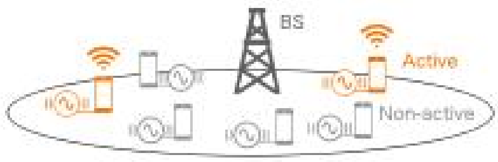


Fig. 2.3-7 GF-NOMA system

This academic year, to achieve a reliable GF-NOMA system, we proposed a receiver design that considers carrier frequency offset (CFO) and its extension to distributed MIMO architectures. We proposed a GF-NOMA scheme that integrates compressed sensing (CS)-based active user detection and channel estimation (AUD-CE) with a lightweight neural network (NN)-based CFO estimation. In this method, nonlinear hard decisions are handled by the NN, while the linear channel estimation is performed through the CS framework. This hybrid algorithm design allows for a smaller NN model while ensuring high estimation performance. Furthermore, we extended this approach to a distributed MIMO architecture, where not only users but also access points (APs) are affected by the CFO. The proposed receiver accounts for both user-side and AP-side CFO, compensating for these effects by iteratively estimating both parameters. Furthermore, by tracking the CFO using the demodulated data symbols, it is possible to suppress performance degradation caused by CFO estimation errors.

[Toward Practical Cell-Free Massive MIMO Systems] (Koji Ishibashi Lab.)

Cell-free massive multiple-input multiple-output (CF-mMIMO) systems have attracted for next-generation wireless communication systems. CF-mMIMO systems can provide uniform communication quality to all users in the service area by exploiting macro diversity from spatially distributed access points (APs) connected to central processing units (CPUs). Moreover, a network-assisted full-duplex (NAFD) architecture can further improve spectral efficiency (SE) by allowing simultaneous uplink and downlink transmissions through direction assignment of access points.

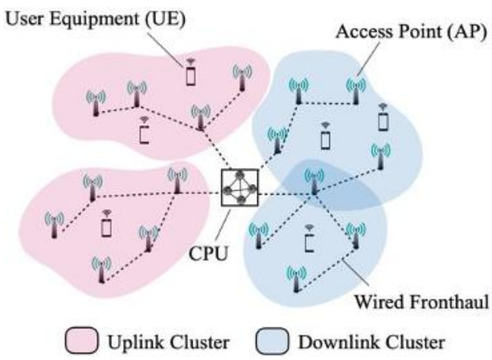


Fig. 2.3-8 NAFD cell-free MIMO

Even though CF-mMIMO systems can achieve superior performance to the conventional cellular systems, there are still practical open problems. To realize the CF-mMIMO system, in this academic year, we proposed (1) a beamforming design that does not require instantaneous channel state information (CSI), (2) a backhaul capacity limitation-aware AP clustering and signal detection method, (3) an energy-efficient joint AP clustering and beamforming design for NAFD CF-mMIMO system, and (4) genetic algorithm (GA)-based AP clustering and transmit power control for NAFD CF-mMIMO system to maximize both fairness and sum-rate of the system.

Regarding (1), we proposed a beamforming design based on the affine combination of spatial covariance eigenvectors. This approach achieves high SE comparable to instantaneous CSI-based beamforming while significantly reducing CSI acquisition overhead. Regarding (2), we proposed distortion-aware adaptive clustering (DAAC) combined with a two-stage detection method. By selecting APs less affected by distortion and employing two-stage detection to minimize backhaul load, the proposed method effectively mitigates the impact of backhaul capacity limitations.

Regarding (3), we developed a joint beamforming and clustering method for NAFD CF-mMIMO system to maximize energy efficiency (EE). By formulating the design as an optimization problem with a tunable weight parameter, the proposed method achieves a flexible trade-off between EE and SE. Regarding (4), we proposed a multi-stage GA-based clustering and power control method for scalable NAFD CF-mMIMO systems. This approach optimizes AP clustering and transmission directions simultaneously while satisfying system constraints. By maximizing the geometric mean of user SE, the method effectively balances total SE with user fairness.

[Advanced Signal Processing Technologies for Millimeter-Wave and Terahertz Channels] (Koji Ishibashi Lab.)

To improve spectral efficiency, it is vital to exploit higher frequency bands such as (1) millimeter-wave (mmWave) and (2) terahertz (THz) bands. While these high-frequency bands provide significantly wider bandwidths compared to conventional lower-frequency bands, they also exhibit distinct propagation characteristics that do not appear in traditional frequency bands. Therefore, it is necessary to address these challenges.

(1) In the mmWave band, diffraction and atmospheric absorption loss become more severe. Thus, beamforming is indispensable for compensating for these propagation losses. To form beams that are well aligned with time-varying channels, (1-1) channel estimation and (1-2) beam training and tracking techniques play a crucial role. Regarding (1-1), we proposed a channel estimation method that accounts for array imperfections such as mutual coupling and antenna spacing errors, which become particularly significant at high frequencies. Specifically, by introducing an alternating optimization framework based on compressed sensing and gradient descent, the proposed method enables accurate channel estimation with a small number of pilots even in the presence of array errors. Regarding (1-2), we proposed deep learning-based efficient beam tracking and beam optimization methods. Specifically, the proposed deep learning model accurately down-selects the beam candidates to reduce the training overhead and design the optimal analog beamformer to prevent the beam misalignment in dynamic mmWave environments.

(2) In the terahertz band, the impact of atmospheric absorption becomes even more pronounced. As the propagation distance increases, a unique phenomenon known as temporal broadening occurs, in which the effective signal bandwidth shrinks due to frequency-dependent attenuation. Furthermore, highly efficient power amplifiers have not yet been fully established for the THz band. Motivated by these challenges, we propose a transmission scheme tailored for THz communications. The proposed method adopts a hybrid transmission structure in which OFDM-based multicarrier transmission is applied to the outer-band subcarriers, while DFT-s-OFDM-based single-carrier transmission is applied to the inner-band subcarriers. This hybrid design mitigates the frequency selectivity induced by temporal broadening effects while simultaneously reducing the PAPR.

[Near-Field Signal Processing Technologies] (Koji Ishibashi Lab.)

Beamforming with large antenna arrays is a key enabler to meet diverse requirements in next-generation wireless communications systems. Large antenna arrays not only enable the exploitation of high-frequency bands by compensating for spreading loss but also expands the near-field region. Wave propagation with a spherical wavefront provides the capability of beam shaping in addition to that of beam steering. Therefore, a variety of beamforming designs and CSI acquisition for beamforming have been considered.

In particular, we propose robust beamforming to improve robustness against positioning errors, Bessel beam and curving beam designs to enhance robustness against random path blockage in high-frequency bands, and channel estimation to obtain full-dimensional channel matrices with a practical pilot length.

In the robust beamforming design, theoretical analysis and numerical results confirm that the proposed approach can maintain high spectral efficiency by jointly designing precoders and combiners based on ergodic capacity maximization. In Bessel and curving beam designs, the proposed approaches enable Bessel beam generation toward desired angles with antenna arrays, and trajectory designs of curving beams to reach a user while avoiding obstacles. As a result, those beams can overcome channel impairments by their unique propagation properties rather than specific signal processing.

The proposed channel estimation also facilitates full-dimensional CSI acquisition in multi-user scenarios by exploiting sparsity in the polar domain, thereby reducing the polynomial length required for channel estimation and the bit error rate (BER).

[High-Power WDM Transmission Using a Hollow-Core Fiber] (Matsuura Lab)

Dense WDM (DWDM) transmission systems with a channel spacing denser than 100 GHz can further increase the capacity of mobile data communications. In this case, higher-power transmission is required to increase the number of channels. On the other hand, when conventional silica-core optical fibers such as standard single-mode fiber (SMFs) are used as transmission lines, the channel crosstalk due to nonlinear effects such as stimulated Brillouin scattering (SBS) and four-wave mixing (FWM) is a serious problem. In our previous works, DWDM A-RoF transmission with a channel spacing of 50 GHz using a hollow-core finer (HCF) has been demonstrated. As a result, the nonlinear effects were clearly reduced, and the signal quality was significantly improved compared to SMF transmission. However, there is no detailed evaluation of the signal quality in HCF transmission with a channel spacing of less than 50 GHz, and the effects of changes in channel spacing and input optical power on signal quality. In this year, we experimentally evaluated the output spectrum and the signal quality of three-channel DWDM A-RoF transmission using a 1 km HCF while changing the channel spacing and input optical power. As a result, in HCF transmission, the output spectrum was almost unaffected by the nonlinear effect, and the high signal quality was obtained regardless of the channel spacing and input optical power. It was also shown that the high-quality signal transmission could preserve even when the channel spacing was narrowed to 12.5 GHz and the total input optical power was increased up to 29.6 dBm.

Figure 2.3-9 shows the EVM characteristics as a function of the channel spacing and input optical power in the (a) 1 km SMF and (b) HCF transmissions when the input optical power was 25.6 dBm, 27.6 dBm, and 29.6 dBm, respectively. The EVM values were measured by extracting only the center channel signal of the three-channel signals using a T-BPF. As shown in Fig. 2.3-9(a), when the channel spacing was narrowed from 100 GHz to 25 GHz, the EVM value increased. In addition, it was observed that the magnitude of the increase in the EVM strongly depended on the input optical power. Even when the channel spacing was narrowed, there was not much increase in the EVM value when the input optical power was less than 27.6 dBm. However, when the input optical power was 29.6 dBm, a rapid increase in the EVM value was observed at a channel spacing of 25 GHz. On the other hand, in the HCF transmission, we observed that a low

EVM value was maintained almost constant regardless of the channel spacing and the input optical power. We also measured the EVM of the other two channels, and observed that a low EVM value was maintained at a nearly constant level. From these results, we showed that it is possible to perform WDM transmission with a higher density than conventional silica-core fibers by using HCFs.

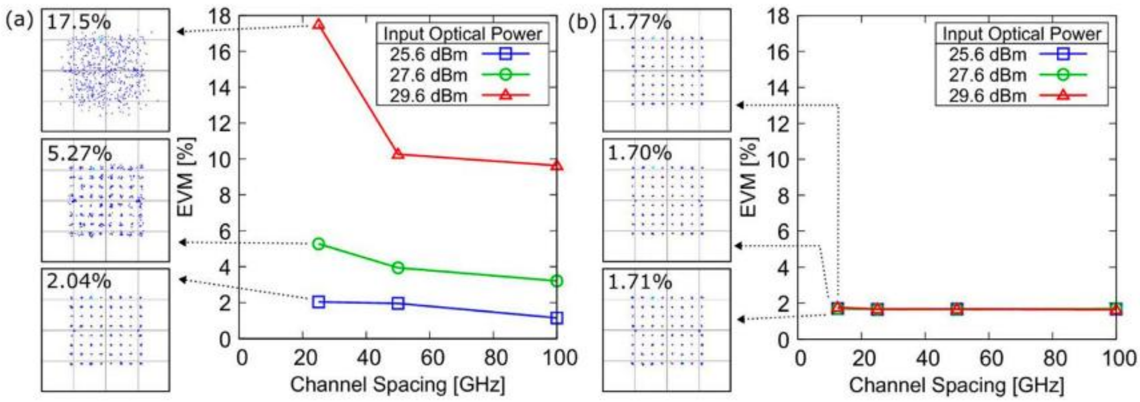


Fig. 2.3-9 EVM characteristics as a function of channel spacing (25 GHz, 50 GHz, 100 GHz) in (a) 1 km SMF and (b) 1 km HCF transmission when input optical power was 25.6 dBm, 27.6 dBm, and 29.6 dBm, respectively. Insets show constellation diagrams of received signals.

2.3.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research B “Establishment of Cell-Free Network Architecture for User-Centric Communications”
   Koji Ishibashi
2. Scientific Research Fostering Joint International Research Type B “Simultaneous Wireless Information and Power Transfer with Intelligent Reflecting Surface”
   Katsuya Suto
3. Scientific Research B “Frequency Spectrum Sharing based Digital Twin of Wireless Communication and AI for Cooperation and Distributed Extensions”
   Takeo Fujii (PI belongs to other organization)
4. Scientific Research B “Quantum Optimization Accelerating High-Speed, High-Capacity Wireless Communications”
   Koji Ishibashi (PI belongs to other organization)
5. Scientific Research B “Autonomous Control and Integrity Assurance for Large-scale Distributed Systems”
   Celimuge Wu (PI belongs to other organization)

【Commissioned Research】

1. JST CRONOS "Development of Ultimate Wireless Systems Beyond Classical Design"
   Koji Ishibashi
2. MIC SCOPE “Research and Development of Advanced Wireless Environmental Information Sharing Sensor Networks”
   Takeo Fujii (PI belongs to other organization)
3. JST ASPIRE “Open Digital Infrastructure through the Convergence of Telecommunications and AI”
   Celimuge Wu (PI belongs to other organization)
4. MIC “Research and development of advanced optical transmission technology that contributes to a green society”
   Motoharu Matsuura
5. NICT B5G “Construction of a highly efficient wireless communication system using high power radio-over-fiber transmission”
   Motoharu Matsuura
6. NICT JUNO3 “End-to-end network slicing and orchestration in future programmable converged wireless-optical networks”
   Motoharu Matsuura

【Cooperative Research】

1. NEC Corporation, Takeo Fujii
2. KDDI Research Inc., Koji Ishibashi
3. Ericsson AB, Koji Ishibashi
4. Softbank Corporation, Takeo Fujii
5. Toyota Motor Corporation, Celimuge Wu
6. Takenaka Corporation, Koji Ishibashi
7. Mitsubishi Electric Corp., Katsuya Suto
8. Mitsubishi Electric Corp., Koji Ishibashi

2.4 Division of Next Generation Wireless Networks

2.4.1 Purpose of Division

R&D of Next Generation Wireless Systems, Sensor Networks, and intelligent distributed Networks, contributing to development of society by empowering next generation intelligent network systems.

2.4.2 Research Staffs and Their Specialties

Prof. Celimuge Wu (Division Leader, Distributed NW)
Prof. Takeo Fujii（Cognitive Radio）
Prof. Koji Ishibashi（Distributed NW）

2.4.3 Major Research Results in 2025

[Federated Reinforcement Learning Framework for Mobile Robot Navigation Using ROS and Gazebo] (Celimuge Wu Lab.)

Deep reinforcement learning (DRL) offers a robust approach for mobile robot navigation without the need for pre-mapping, but these models often struggle with poor generalization in unseen environments due to a tendency to overfit specific training data. To address this challenge, we propose a Federated Reinforcement Learning (FRL) framework utilizing the Robot Operating System (ROS) and the Gazebo simulator, where local model training is conducted on ROS1 client machines and model aggregation is handled by a centralized ROS2 server. As illustrated in Fig. 2-4-1, this FRL concept enables heterogeneous mobile robots to interact and train within their distinct local environments, after which their local model updates are uploaded and aggregated on the centralized server to construct a more generalized global model. Finally, the training results presented in Fig. 2-4-2 demonstrate the average cumulative reward per episode, showing that both FRL and standalone RL models gradually converge and progress over time; importantly, the FRL-trained models achieve average rewards comparable to the standalone models, indicating that the collaborative FRL process effectively maintains navigation performance within individual training environments while aiming to enhance overall adaptability.

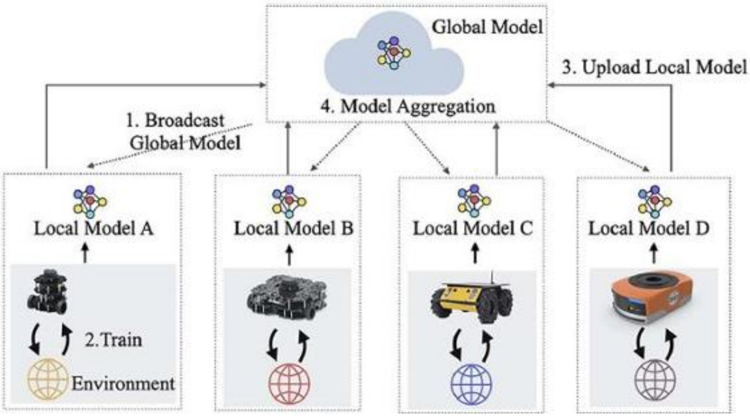


Fig. 2-4-1 The architecture of federated reinforcement learning.

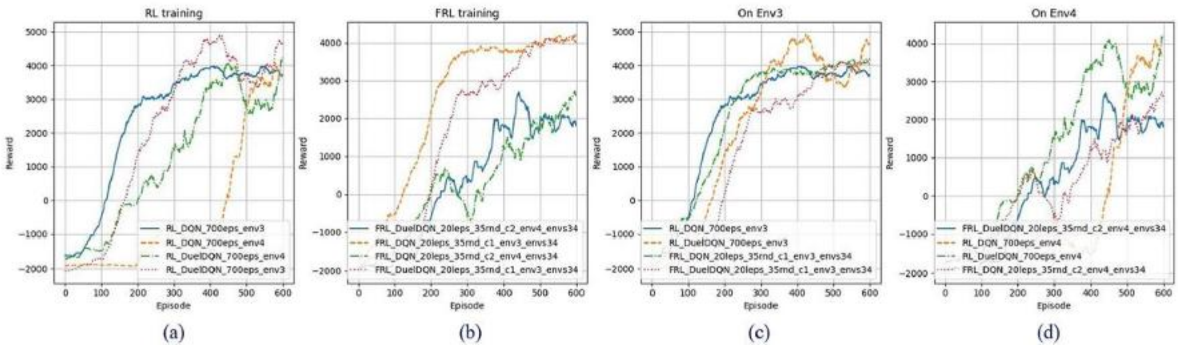


Fig. 2-4-2 Average cumulative reward plots.

[Efficient Communication Techniques for Wireless Sensor Networks] (Ishibashi Lab.)

Fig. 2-4-3 wireless sensor node powered solely by solar EH and implementing the proposed ZEN-MAC protocol.

Research on medium access control (MAC) protocols for wireless sensor networks powered by energy harvesting (EH) has been actively conducted to enable maintenance-free collection of environmental information. To realize long-lifetime sensor networks utilizing EH, communication schemes that simultaneously achieve high energy efficiency and robustness against temporary power depletion are essential. Consequently, many studies have focused on receiver-initiated MAC (RI-MAC) protocols, which enable asynchronous multihop communication. However, conventional RI-MAC protocols require long idle-listening periods to discover communication partners, and the power consumption during these periods has become a major obstacle to achieving low-power operation.

To address issues, we propose the Zero Excess Node MAC (ZEN-MAC), which achieves both high energy efficiency and reliable communication. ZEN-MAC identifies the intended communication partner while minimizing power consumption during idle listening through multi-stage beacons and repeated carrier sensing. In addition, we introduce a mechanism that predicts each node's communication load based on harvested energy and past successful transmissions, autonomously adjusting the intermittent interval to prevent battery depletion. We evaluate the power consumption and communication quality of each node under the proposed protocol through theoretical analysis and simulations. Simulation results under an EH model emulating realistic conditions demonstrate that ZEN-MAC improves communication quality and reduces power consumption compared with conventional methods, while preventing long-term battery depletion even when energy distribution among nodes is uneven. Furthermore, we conduct experimental evaluations using an actual implementation, as shown in Fig. 2-4-3.

[A Hierarchical Federated Continual Learning Framework for Dynamic and Heterogeneous IoV] (Celimuge Wu Lab.)

To address the challenges of data heterogeneity and catastrophic forgetting in dynamic Internet of Vehicles (IoV) environments, we propose a Hierarchical Federated Continual Learning (Hier-FCL) framework that incorporates optimized experience replay, meta-knowledge distillation, and dynamic client clustering. As illustrated in Fig. 2-4-4, our framework consists of a three-layer architecture including a cloud server, edge servers, and clients; the clients perform local continual learning using a data reservoir and a teacher model for meta-knowledge distillation, the edge servers dynamically cluster clients for local model aggregation, and the cloud server executes the global aggregation. Finally, the experimental results in Fig. 2-4-5 illustrate the Retained Accuracy (RA) curves of all tasks during the training process across different algorithms. The results clearly demonstrate that our Hier-FCL maintains a significant advantage in the retained accuracy across all tasks, effectively balancing the learning of new tasks and the retention of old ones, whereas most other baseline methods exhibit a downward trend in performance and obvious negative transfer when facing subsequent tasks with large differences.

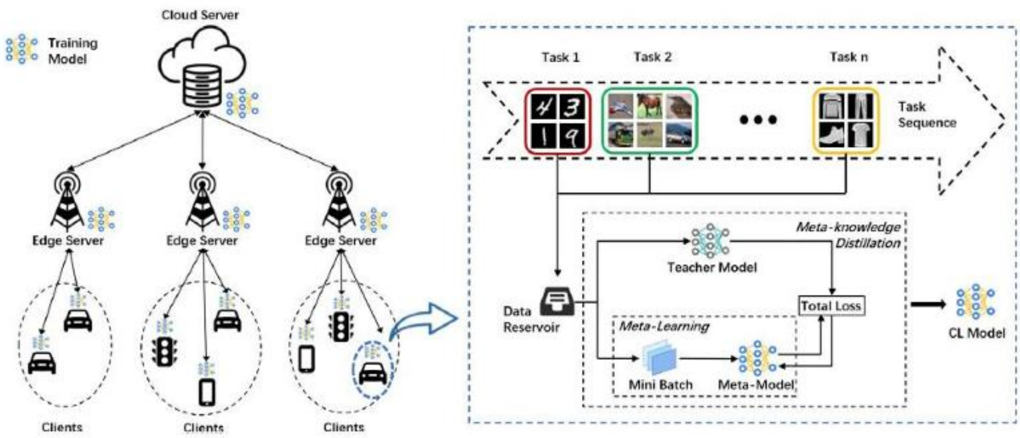


Fig. 2-4-4 Hier-FCL framework.

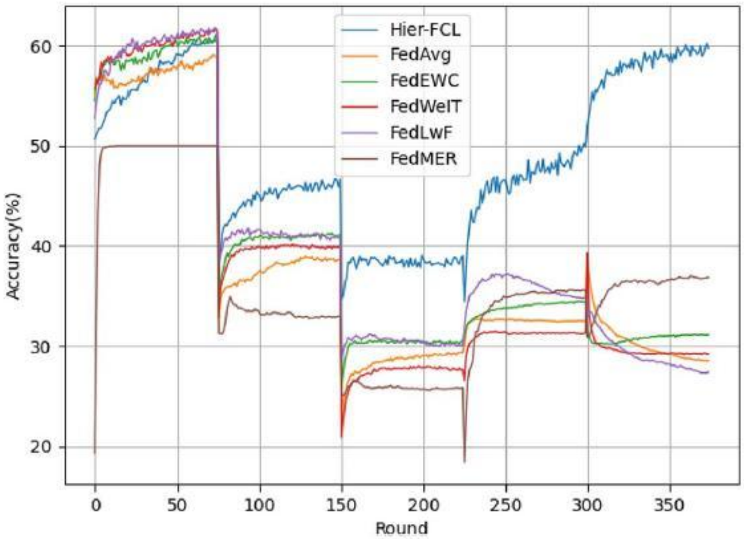


Fig. 2-4-5 Comparison of RA across different algorithms.

[Behavior Cloning With Fuzzy Logic for Accelerating Early-Stage DRL in Edge Offloading] (Celimuge Wu Lab)

To address the computationally intensive early-stage training and random initialization issues of Deep Reinforcement Learning (DRL) in edge computing task offloading, we propose leveraging fuzzy logic to improve the early-stage performance of DRL agents through behavior cloning. As illustrated in Fig. 2-4-6, our system models a multi-access edge computing environment involving multiple user devices and edge servers communicating over low-latency radio access networks to manage distributed task offloading. Finally, the experimental results presented in Fig. 2-4-7 compare the Average Task Completion Rate (ATCR) and Average Task Processing Time (ATPT) across training episodes. The results clearly demonstrate that all of our proposed behavior cloning strategies—with the exception of the static Only-BC approach—achieve a significantly higher initial ATCR and lower ATPT than the standard DRL baseline, ultimately leading to faster convergence and enhanced stability during the early learning stages.

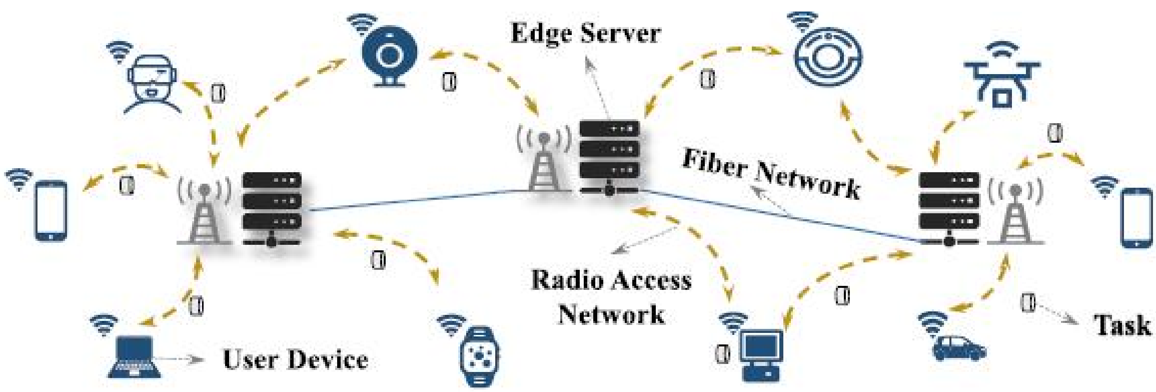


Fig. 2-4-6 System model of MEC task offloading environment.

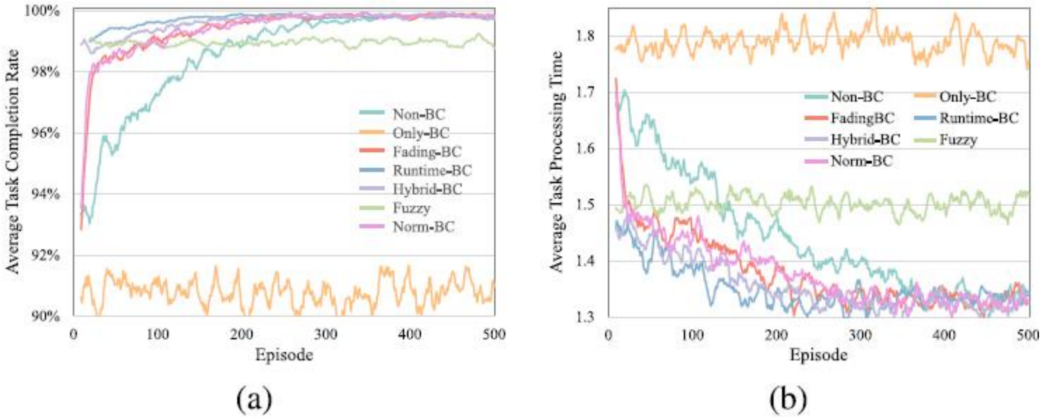


Fig. 2-4-7 Performance comparison for baselines and BC strategies in terms of (a)ATCR and (b)ATPT.

[Simulation and Implementation Evaluation of Variable Bandwidth LoRa for Interference Reduction with Superimposed Signals at the Same Spreading Factor] (Fujii Lab.)

LoRa enables simultaneous reception of signals with different spreading factors (SFs) due to its quasi-orthogonal property; however, signals using the same SF cannot be reliably received simultaneously. To address this limitation, Variable Bandwidth LoRa (VBW-LoRa) has been proposed, which enables the reception of signals with the same SF and identical power levels. VBW-LoRa generates signals by reducing the modulation bandwidth by a factor of $1/l$, where l represents the symbol length ratio. Although this makes the symbol length l times longer, the signal can be demodulated using conventional LoRa processing by sampling the signal at l times the conventional sampling length.

In this research, we evaluate the interference characteristics of VBW-LoRa through simulation and Software Defined Radio implementation. As shown in the experimental setup in Fig. 2-4-8, the desired and interference signals output from two ports of the transmitting Universal Software Radio Peripheral (USRP) are superimposed using variable attenuators and a combiner, and then demodulated by the receiving USRP. Figure 2-4-9 shows the experimental results, where l_{D} and l_{Int} represent the symbol length ratios of the desired and interference signals, respectively. These results confirm that the hardware implementation achieves performance equivalent to the simulation. Specifically, a packet error rate (PER) of 10^{-2} is achieved at signal-to-interference ratio (SIR) ≥ -5 dB when the desired signal's symbol length ratio is $l_{\mathrm{D}} = 1$, and at $\mathrm{SIR} \geq -6$ dB when $l_{\mathrm{D}} = 1.5$.

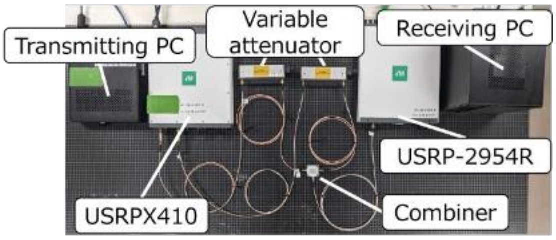


Fig. 2.4-8 Experimental setup

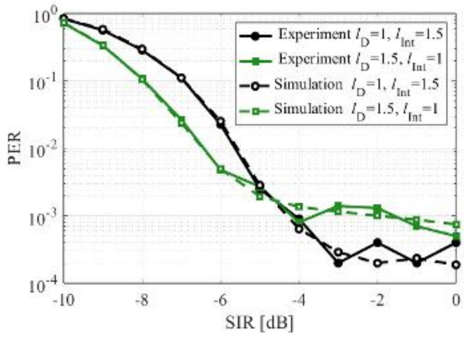


Fig. 2.4-9 PER versus SIR

2.4.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research A "Researches on Model-aided Learning Approaches for Reliable Realtime Control in Future Wireless Systems"
   Celimuge Wu (PI belongs to other organization)

【Commissioned Research】

1. JST AdCORP "Green IoT"
   Koji Ishibashi (PI belongs to other organization)

【Cooperative Research】

1. Toyota Motor Corporation, Celimuge Wu
2. TIS Inc., Celimuge Wu, Takeo Fujii, and Katsuya Suto
3. Tokyo Gas Co. Ltd., Koji Ishibashi and Takeo Fujii
4. Takenaka Corporation, Koji Ishibashi
5. HYTEC INTER Co., Ltd., Koichi Adachi

４．令和７年度　外部発表リスト

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シンポジウム講演

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その他の講演

【1】 Koji Ishibashi, "Enabling Near-Field Communications: Beam Shaping, Optimization, and Channel/Data Estimation," Keynote talk at Workshop on Near-Field Communications with KVA-JSPS Seminar, Stockholm, Sweden, May 2025.

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【3】 Koji Ishibashi, "Enabling Near-Field Communications: Beam Shaping, Optimization, and Channel/Data Estimation," Invited KVA-JSPS Seminar, Linköping University, May 2025.

【4】 Koji Ishibashi, "Enabling Near-Field Communications: Beam Shaping, Optimization, and Channel/Data Estimation," ELLIIT Distinguished Lecture, Lund University, May 2025.

【5】 Koji Ishibashi, "Beyond Beamforming: Robust Wavefront Design in the Near Field with Phased Arrays," Ericsson Research Day, Oct. 2025.

【6】 Koji Ishibashi, “Enabling Near-Field Communications: Beam Shaping, Optimization, and Channel/Data Estimation,” 2025 IEEE Global Communications Conference (IEEE GLOBECOM) Tutorial – Scalable 5G/6G ORAN, MIMO, and RIS Innovations for Commercial 5G/6G Communications, Taipei, Taiwan, Dec. 2025.

受賞

【1】 2025 年 4 月 OWPT 2025 Best Student Paper Award, Optical Wireless and Fiber Power Transmission Conference（OWPT）
【2】 2025 年 5 月 19 日 荒井甲 2024 年度 IEICE 無線通信システム（RCS）研究会活動奨励賞
【3】 2025 年 6 月 Kun Li, Outstanding Associate Editors, IEEE Antennas and Wireless Propagation Letters
【4】 2025 年 6 月 26 日 竹村和香奈 2025 年度 IEICE 無線通信システム（RCS）研究会「初めての研究会」優秀発表賞
【5】 July 2025 Masaki Hattori, Best Paper Award, SRIoT2025,
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【7】 2025 年 7 月 上田有真 電子情報通信学会 EMCJ 研究会若手研究者発表会 若手奨励賞
【8】 2025 年 8 月 5 日 荒井甲 情報理論とその応用シンポジウム若手研究者論文賞
【9】 2025 年 8 月 5 日 照井貫太 情報理論とその応用シンポジウム若手研究者論文賞
【10】 2025 年 10 月 21 日 宮本大哉 IEEE VTS Tokyo/Japan Chapter 2024 Young Researcher’s Encouragement Award
【11】 2025 年 11 月 Kun Li, Outstanding Contribution Award, IEICE ICETC 2025.
【12】 2025 年 11 月 松本拓真、2025 年電子情報通信学会 RISING 研究会優秀ポスター発表賞
【13】 2026 年 1 月 22 日 松木 淳一郎 回路とシステム研究会 学生優秀賞“積層構造と SIW 構造を用いたトリプレクサの設計に関する一検討”電子情報通信学会
【14】 2026 年 1 月 22 日 松木 淳一郎“積層構造と SIW 構造を用いたトリプレクサの設計に関する一検討”IEEE CAS Society Japan Joint Chapter Best Student Award
【15】 2026 年 3 月 松本拓真、2025 年電子情報通信学会スマート無線研究会研究奨励賞,
【16】 2026 年 3 月 脇田仁、藤井威生、2025 年電子情報通信学会スマート無線研究会論文賞,
【17】 2026 年 3 月 26 日 川口達広 第 41 回電気通信普及財団賞テレコムシステム技術学生賞

【18】 2026年3月，電子情報通信学会フォトニックネットワーク（PN）研究会 学生ワークショップ 優秀発表賞
【19】 2026年2月6日 神崎涼司 令和7年度 修士論文発表会 優秀発表賞
【20】 2026年2月6日 宮本大哉 令和7年度 修士論文発表会 優秀発表賞
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【22】 2026年2月6日 坂本 陽向 令和7年度 修士論文発表会 優秀発表賞
【23】 2026年2月6日 倪 楠 令和7年度 修士論文発表会 優秀発表賞
【24】 2026年2月6日 早坂 勇飛 令和7年度 修士論文発表会 優秀発表賞
【25】 2026年2月6日 湯澤 昂平 令和7年度 修士論文発表会 優秀発表賞
【26】 2026年2月6日 井上大樹 令和7年度 卒業研究発表会 優秀発表賞
【27】 2026年2月6日 執行彬良 令和7年度 卒業研究発表会 優秀発表賞
【28】 2026年2月6日 田中 成朋 令和7年度 卒業研究発表会 優秀発表賞
【29】 2026年2月6日 鐘ヶ江僚太 令和7年度 卒業研究発表会 優秀発表賞
【30】 2026年2月6日 加藤 涼 令和7年度 卒業研究発表会 優秀発表賞
【31】 2026年2月6日 松本 拓真 令和7年度 卒業研究発表会 優秀発表賞
【32】 2026年2月6日 新見 俊太朗 令和7年度 卒業研究発表会 優秀発表賞
【33】 2026年2月6日 服部 聖樹 令和7年度 卒業研究発表会 優秀発表賞
【34】 2026年2月6日 大井 朝陽 令和7年度 卒業研究発表会 優秀発表賞
【35】 2026年3月25日 神崎涼司 令和7年度 目黒会賞
【36】 2026年3月25日 後藤 樹 令和7年度 目黒会賞
【37】 2026年3月25日 鐘ヶ江僚太 令和7年度 目黒会賞
【38】 2026年3月25日 加藤 涼 令和7年度 目黒会賞
【39】 2026年3月25日 松本 拓真 令和7年度 目黒会賞
【40】 2026年3月25日 湯澤 昂平 令和7年度 目黒会賞
【41】 2026年3月25日 竹村和香奈 令和7年度 学生表彰
【42】 2026年3月25日 照井貫太 令和7年度 学生表彰
【43】 2026年3月25日 川口達広 令和7年度 学生表彰
【44】 2026年3月25日 荒井甲 令和7年度 学生表彰
【45】 2026年3月25日 内村颯汰 令和7年度 学生表彰
【46】 2026年3月25日 上田康平 令和7年度 学生表彰
【47】 2026年3月25日 宮本大哉 令和7年度 学生表彰
【48】 2026年3月25日 服部聖樹 令和7年度 学生表彰
【49】 2026年3月25日 松本拓真 令和7年度 学生表彰

特許

【1】 ネットワークノード、方法、端末及び通信システム，特願 2025-078216，鐘雷，邵校，策力木格，林楊菲，2025年5月8日出願。

【2】 ネットワークノード、方法、センシングエンティティ、端末及び通信システム，特願 2025-078215，鐘雷，邵校，策力木格，林楊菲，2025 年 5 月 8 日出願。

【3】 通信システム及び通信プログラム，特願 2025-077989，林楊菲，策力木格, 2025 年 5 月 8 日出願。

【4】 コアネットワーク装置、端末装置及び通信方法，特願 2025-135229,鐘雷,邵校，劉雨彤,策力木格,林楊菲，2025 年 8 月 14 日出願。

【5】 コアネットワーク装置、端末装置及び通信方法，特願 2025-135224，鐘雷,邵校,劉雨彤,策力木格,林楊菲，2025 年 8 月 14 日出願。

【6】 コアネットワーク装置、端末装置、及び通信方法，特願 2025-135242,鐘雷,邵校,策力木格,林楊菲，2025 年 8 月 14 日出願。

【7】 感知データ伝送方式,特願 2025-187377，鐘雷,邵校，劉雨彤,策力木格,林楊菲，2025 年 11 月 6 日出願。

【8】 感知状態の監視および感知データ報告のトリガ方式,特願 2025-187376，鐘雷,邵校，劉雨彤,策力木格,林楊菲，2025 年 11 月 6 日出願。

【9】 センシングデータレポート方式,特願 2026-12893，鐘雷,邵校，劉雨彤,策力木格,林楊菲，2026 年 1 月 29 日出願。

広報・報道発表

【1】 電波が「計算」する新時代へ ノイズを克服し、膨大な IoT データから瞬時に未来を予測，電通大ニュースリリース, 2026 年 3 月 13 日

【2】 障害物を「回り込み」信号を届ける！次世代通信６G の死角をなくす新技術 ～電波の「形」を最適化し、遮蔽物があっても途切れない通信を実現～，電通大ニュースリリース, 2026 年 3 月 17 日