AWCC
Advanced Wireless and Communication Research Center

Advanced Wireless & Communication Research Center

ACTIVITY REPORT 2024

UEC TOKYO The University of Electro-Communications

Message from the Director, Prof. Takeo Fujii

The year 2024 marked the resumption of active research activities with the end of the COVID-19 pandemic. The presentation in international conferences and domestic workshops by members of AWCC returned to pre-pandemic levels. The publication of journal papers also remained at a high level in 2023. Additionally, we are engaged in several national projects, including beyond 5G/6G, low power sensor networks, cooperative autonomous vehicles, and smart infrastructure.

For the years, Advanced Wireless & Communication Research Center (AWCC) has been aiming and conducting four missions that are;

- Dedication to advanced research on wireless communications; offering more unique results.
- Education in graduate school for cultivating specialty in engineering; specialized and universal education in the area.
- Active collaboration / joint research with industries and government; transferring the outcomes to the society.
- Constant acquisition of competitive research funds; for self-supported operation.

The current vision of AWCC is “Ambient Wireless in Connected Community (AWCC).” AWCC intends to cover broader research area including not only wireless communications but also any promising aspects of “wireless” and “communications”. As an academic institute, it is our mission to pursue basic research in science and technology. Toward the goals, AWCC will enhance its force and strengthen its presence in the world.

We are focusing the following four research sectors.

(1) Wireless Technology as Social Infrastructure

Wireless technologies will have more importance in the society as the base of safe, secure and smart life for the individual and the community. Intelligent Transport System (ITS) is one of the focused topics, anticipating the great demand for automated driving.

(2) Innovative Hardware for Wireless & Communication

Demands for broadband and high-capacity mobile communication systems are very strong, and 5G and beyond system is being developed in the world. The 5G and beyond system introduces new usage of frequency spectra called multi-band multi-access, which requires innovation in RF hardware to achieve higher-accuracy signal transmission with flexibility. Also, wireless power transfer is another hot and important topic.

(3) Advanced Wireless System & Networks

We have developed many fundamental technologies such as distributed dynamic multi-hop network, cognitive radio, fault-tolerant network operation, and radio environment-aware communications. From now on, we integrate the technologies and establish an ultimate wireless network design.

(4) Exploring Low Power Wireless

By reducing power consumption of wireless system dramatically, applications of wireless communications will spread wider than now. It will make all things connected in the world, realizing the word "IoT". Innovative low-power technologies are necessary to realize such a world.

As the open research center to the society, AWCC would like to think together with people and contribute much in research and education of “wireless” and “communications”. We hope your kind help and great understanding to AWCC.

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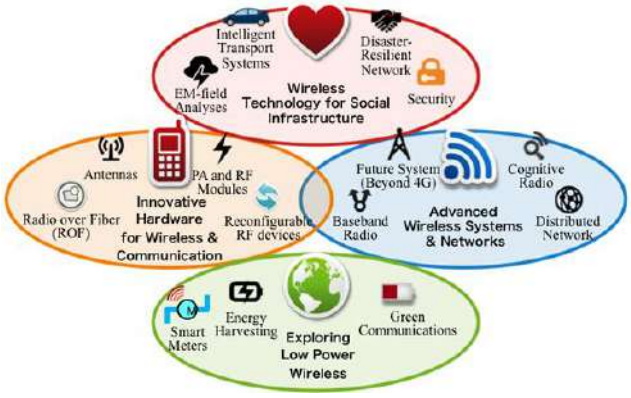
1 . ABOUT AWCC

1.1 OVERVIEW

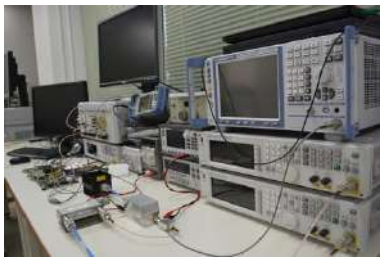


The Advanced Wireless Communication Research Center (AWCC) was launched in April 2005 with the aims of establishing a global hub for wireless communications; advancing education in wireless technology; industrial collaboration and technology transfer; and nurturing young engineers with strong emphasis 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

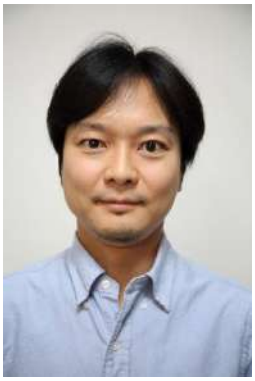
【Director, Full-time Prof. Takeo Fujii】

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 Prof. Koji Ishibashi】

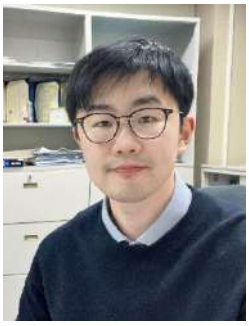
Koji Ishibashi received the B.E. and M.E. degrees in engineering from The University of Electro-Communications, Tokyo, Japan, in 2002 and 2004, respectively, and the Ph.D. degree in engineering from Yokohama National University, Yokohama, Japan, in 2007. From 2007 to 2012, he was an Assistant Professor 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 Associate Prof. Koichi Adachi】



Koichi Adachi received the B.E., M.E., and Ph.D. degrees in engineering from Keio University, Japan, in 2005, 2007, and 2009 respectively. His research interests include cooperative communications and energy efficient communication technologies. From 2007 to 2010, he was a Japan Society for the Promotion of Science (JSPS) research fellow. He was the visiting researcher at City University of Hong Kong in April 2009 and the visiting research fellow at University of Kent from June to Aug 2009. From May 2010 to May 2016, he was with the Institute for Infocomm Research, A*STAR, in Singapore. Currently, he is an associate professor at The University of Electro-Communications, Japan. He was an Associate Editor IEEE Wireless Communications Letters since 2016 to 2022, IEEE Transactions on Vehicular Technology between 2016 – 2018, IEEE Transactions on Green Communications and Networking between 2016 - 2022, IEEE Open Journal of Vehicular Technology since 2019, IEEE Transactions on Wireless Communications since 2023, and IEEE Communications Surveys & Tutorials since 2023. He is a senior member of IEEE and a member IEICE. He was recognized as the Exemplary Reviewer from IEEE Wireless Communications Letters in 2012, 2013, 2014, and 2015. He was awarded excellent editor award from IEEE ComSoc MMTC in 2013. He is a coauthor of WPMC2020 Best Student Paper Award and Best Student Paper Award and ICUFN'22.

【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 the Electromagnetic Compatibility Laboratory, National Institute of Information and Communications Technology, Tokyo, Japan. From 2020 to 2023, he was an Assistant Professor with the Faculty of Engineering and Design, Kagawa University, Takamatsu, Japan. He was a Visiting Researcher with the CNRS/IETR, University of Rennes 1, Rennes, France, from 2022 to 2023. In 2023, he joined the Advanced Wireless and Communication Research Center, The University of Electro-Communications, Tokyo, Japan, where he is currently an Associate Professor. His research interests include electromagnetic computation and measurement for radiation safety by human exposure to electromagnetic fields in radio frequencies, antenna design, and measurement techniques for wireless communication systems. Dr. Li was the recipient of the Young Scientist Award of the URSI, in 2020, the Risaburo Sato Award of EMC Sapporo & AMPEC, in 2019, the IEEE AP-S Japan Student Award in 2015, and the IEICE Best Letter Award in 2017. He is also an Associate Editor of IEEE Antennas and Wireless Propagation Letters, the Early Career Representative of URSI Commission K, and the Co-Chair of Working

Group under Subcommittee 6, the IEEE International Committee on Electromagnetic Safety (ICES) TC-95. He is a Senior Member of 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.

【Concurrent Associate Prof. Katsuya Suto】

Katsuya Suto received the B.Sc. degree in computer engineering from Iwate University, Morioka, Japan, in 2011, and the M.Sc. and Ph.D. degrees in information science from Tohoku University, Sendai, Japan, in 2013 and 2016, respectively. He has worked as a Postdoctoral Fellow for Research Abroad, Japan Society for the Promotion of Science, in the Broadband Communications Research Lab., University of Waterloo, ON, Canada, from 2016 to 2018. He is an Associate Professor with the Graduate School of Informatics and Engineering, the University of Electro-Communications, Tokyo, Japan. His research interests

include semantic communications, radio propagation, deep learning, and graph representation. He received the Best Paper Award at the IEEE VTC2013-spring, the IEEE/CIC ICCC2015, the IEEE ICC2016, and the IEEE Transactions on Computers in 2018. He is currently the Associate Editor of the International Journal of Computers and Applications. He is a member of IEEE and IEICE.

【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.

【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.
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. Satoshi Ono, Ph.D.
Associate Prof. Suhua Tang, 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. Koichi Adachi (Drone)
Associate Prof. Katsuya Suto (ITS)
Associate Prof. Kun Li (Smart Infrastructure)

2.1.3 Major Research Outcomes in 2024

[Interference Environment Estimation from Ground to Satellites by Using Measurement Satellite Signals at Mobile Devices for Spectrum Sharing in FR3] (Fujii Lab.)

Frequency Range 3 (FR3) has been defined as a new frequency band for next-generation mobile communication systems, such as 6G, and interest in its utilization is growing. However, since FR3 is already occupied by existing services, effective spectrum sharing techniques are required to mitigate interference. This study proposes a method for estimating the interference environment from the ground to satellites to aid in determining spectrum-sharing strategies. The propagation path information is classified through clustering based on received signal information from satellites observed by mobile devices. Specifically, we classify propagation paths as obstructed or non-obstructed using GNSS reception data, which can be easily obtained from consumer devices.

In the proposed method, the first step is to obtain the Carrier-to-Noise Ratio (CNR), satellite identifier, elevation, and azimuth from the GNSS satellite information received by the device. Next, based on the obtained information, the satellite positions are converted from celestial coordinates to three-dimensional coordinates, followed by clustering using CNR and the three-dimensional coordinates as inputs. The clustering is performed using the k-means method, with

the number of clusters set to two, and the clusters are labeled as "obstructed" and "non-obstructed" based on the CNR values of the cluster centers.

Figs. 2-1-1 and 2-1-2 show the measurement environment and classification results obtained by receiving actual GNSS signals and performing propagation path classification based on the dataset. The blue dots indicate non-obstructed points, while the orange dots represent obstructed points, where the silhouettes of buildings can be observed. In the environment shown in Figs. 2-1-1 and 2-1-2, when determining the obstruction direction, the estimation accuracy improves from 50.73% to 76.15% compared to using a simple threshold (CNR ≥ 20 dB).

Fig. 2-1-1 Measurement Environment.

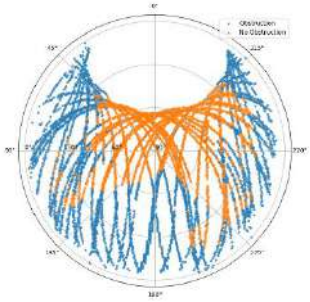


Fig. 2-1-2 Result of Environment Estimation.

[Efficient spectrum sharing utilizing beamforming in Local 5G] (Fujii Lab.)

Local 5G（L5G）is a proprietary network built and operated locally by companies and municipalities. In Japan, multiple operators use the same frequency to communicate in L5G. Therefore, mutual interference is avoided by providing a margin area outside each operator's coverage area. This operational adjustment narrows the area where L5G can be built and reduces geographic efficiency. In such cases, directivity control by beamforming is effective in reducing mutual interference between multiple operators. Therefore, this study proposes a method for efficient spectrum sharing utilizing a database and directivity control by beamforming.

Fig. 2-1-3. shows the system model. In our proposed system, we set up a database that collects data from multiple L5G operators and adjusts parameters. The database estimates mutual interference between operators based on measurements returned by operators. Then, the database allocates resource blocks to each operator based on the results of this mutual interference estimation. Resource blocks are divided into each operator's dedicated resources and shared resources. Dedicated resources are used in areas where there is interference between operators, and shared resources are used in areas where there is no mutual interference. When shared resources are used, beamforming is used to reduce mutual interference. When dedicated resources are used, isotropic antenna is used to ensure communication of users in the interference area.

To evaluate the proposed method, computer simulations were executed. Figure 2-1-4 shows the area design with beamforming when shared resources are used. From this area design, resource allocation by area was conducted and the amount of resource blocks was calculated. The amount of resource blocks that could be used increased by 72% compared to the case where the resource block was completely divided into two dedicated parts. Therefore, the superiority of beamforming in spectrum sharing appears.

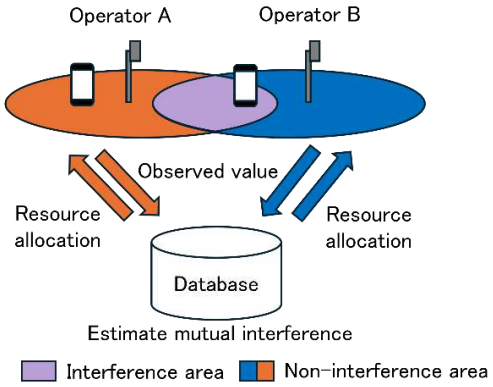


Fig. 2-1-3 System model.

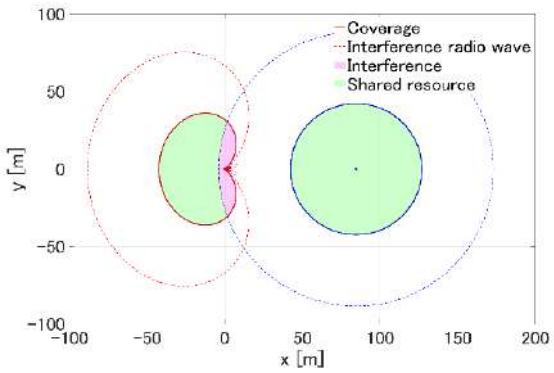


Fig. 2-1-4 Area design for shared resource use.

[Impact of UAV Wobble on Directivity in UAV-Assisted Communications] (Fujii Lab.)

Unmanned aerial vehicles (UAVs) are used in a wide range of applications. Recently, there has been a trend to use UAVs as aerial base stations (ABS). ABS attract attention as a practical solution to meet requirements due to using high frequency because they offer deployment flexibility by floating in the air and provide high-probability line-of-sight (LOS) communication links via air-to-ground channels. The primary advantage of using UAVs in high frequency bands like mmWave is that it solves the payload capacity issue. The utilization of high frequency bands enables the mounting of many antenna elements, despite the limited payload capacity of UAVs. This enables beamforming to compensate for millimeter-wave-band issues. Compared to omnidirectional antennas, this approach also improves spectral efficiency. However, because UAVs are not fixed, they can experience UAV's wobble due to external disturbances like strong wind gusts, resulting in beam misalignment.

Fig. 2-1-5 shows the system model. A hovering UAV provides communications using beamforming to a UE located directly below it. At this time, the UAV is subjected to UAV's wobble due to wind gust, which causes beam misalignment.

To evaluate the impact of UAV's wobble on communications quality, we conducted computer simulation using MATLAB. Fig. 2-1-6 shows the impact of UAV's wobble as the number of elements increases. When the rotation angle exceeds 8 degree, the average directivity tends to decrease with an increasing number of elements, resulting in significant degradation. This is because, although increasing the number of elements generally raises the average directivity, it also results in a narrower beamwidth. In other words, when the magnitude of UAV's wobble is

considered, increasing the number of elements to boost directivity does not necessarily improve communications quality.

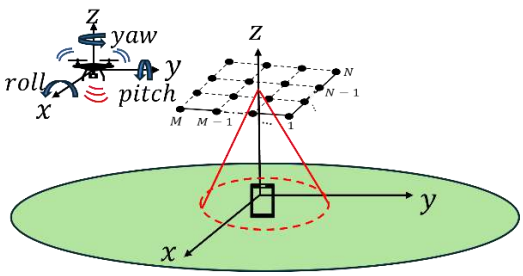


Fig. 2-1-5 System model.

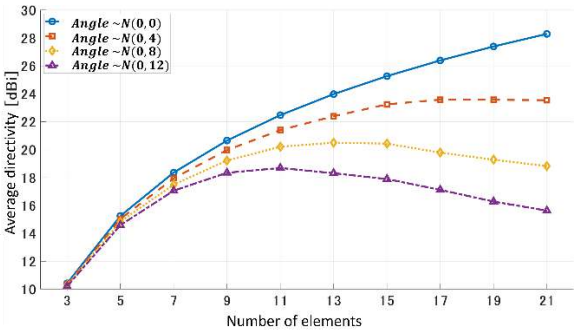


Fig. 2-1-6 Average directivity.

【Visually Secure Deep Joint Source-Channel Coding】(Suto Lab.)

In wireless image transmission, traditional methods based on separate source-channel coding (SSCC) struggle under time-varying channel conditions, suffering from phenomena such as the cliff effect and requiring long block lengths. Deep Joint Source-Channel Coding (DJSCC) has recently emerged as an attractive alternative, offering robustness and high performance, particularly in low-SNR and bandwidth-limited scenarios by directly optimizing compression and transmission through deep learning. However, ensuring security in DJSCC remains a critical challenge, as conventional encryption methods are incompatible with its pseudo-analog characteristics. Moreover, deep known-plaintext attacks (Deep KPA), where attackers leverage machine learning to break encrypted communications, pose a significant threat.

In this academic year, we proposed DJSCC with Chaotic Map encryption (DJSCC-CM), a novel secure DJSCC framework based on piecewise linear chaotic map (PWLCM) encryption applied to the latent space. Fig. 2.1-7 presents a visual comparison of reconstructed images at the legitimate receiver (Bob) and the eavesdropper (Eve) for both DJSCC-CM and DJSCC-LWE under harsh channel conditions (SNRTrain = 25 dB, SNRTest = 5 dB). At Bob's side, DJSCC-CM successfully reconstructs high-quality images that preserve critical visual features, achieving performance close to the standard DJSCC-OFDM baseline without encryption. In contrast, at Eve's side, when using DJSCC-CM, the reconstructed images are completely unrecognizable, and no meaningful information can be extracted. This result demonstrates the strong robustness of DJSCC-CM against Deep KPA attacks.

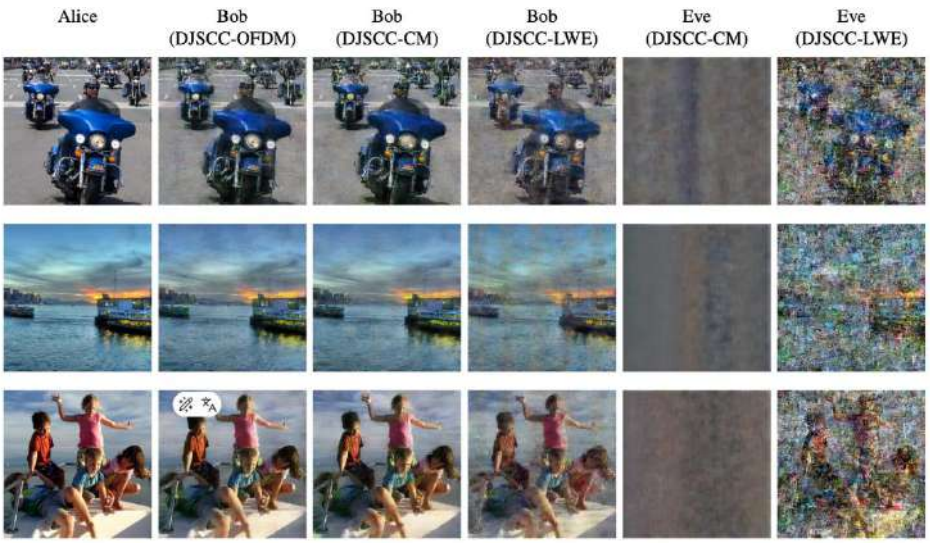


Fig. 2.1-7 Quality of reconstructed images with SNRTrain = 25 dB, SNRTest = 5 dB. The reconstructed image in DJSCC-CM cannot be recognized any meaningful information while we can roughly recognize the object in DJSCC-LWE.

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

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. In particular, reliable wireless communication in underground environments—such as inside 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 MHz bands. In this study, we investigate the near-field strength distribution of a circular loop antenna operating at 255 kHz to establish a wireless link with electronic devices embedded in bedrock. To address these challenges, we measured the received power of an LF-band wireless communication system by varying the angle of the loop antenna at different tunnel construction sites in Japan and analyzed the resulting dataset. A square-wave signal at 255 kHz was emitted from a coil, and the average received power was measured using a spectrum analyzer connected to a circular loop antenna. The pulse signal emitted by the underground electronic device was received by the loop antenna, and measurements were taken along the x-axis from 0 m to 10 m in regular increments, and along the y-axis from 0 m to 5 m for angles other than $\theta = 0°$. As shown in Fig. 2-1-8, the results showed that the null point in the magnetic field strength distribution consistently occurred at a depth of $z = 1.5$ m, where the electronic devices are planned to be placed, regardless of whether the measurements were taken in free space or tunnel environments.

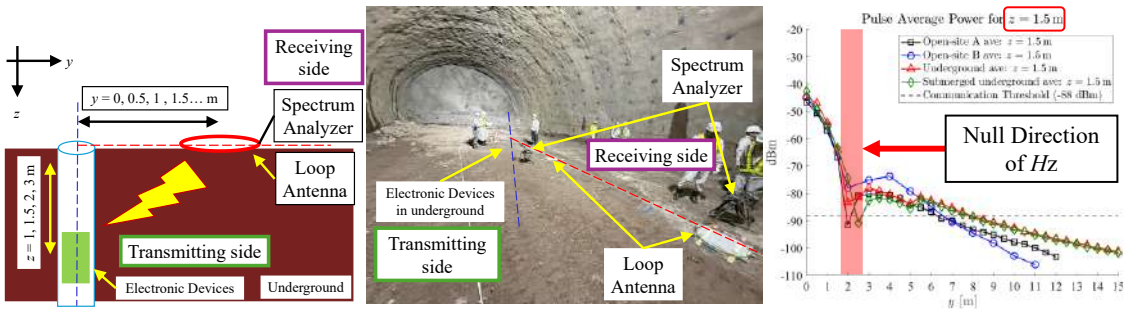


Fig. 2-1-8 LF-Band underground communication experiment at a tunnel construction site.

[Direction-of-Arrival Estimation using Beamforming in Local 5G] (Adachi Lab.)

Local 5G allows various entities such as companies and municipalities to build their own independent 5G systems within their premises. It is anticipated that multiple local 5G base stations (BSs) operated by different operators will be deployed within a vicinity in the future. Since different operators will share the same frequency bands, it is essential to suppress and avoid interference with existing local 5G systems in the vicinity when deploying a new local 5G system. Since adjacent BSs belong to different operators, close cooperation and coordinated control between them are difficult. Therefore, it is desirable for each operator to autonomously perform interference suppression and avoidance in a distributed way.

In this research, we proposed a method for estimating the direction of arrival (DoA) of interference signals in adjacent local 5G systems. This method generates frequency-dependent beams and estimates the DoA of interference signals by comparing received power at each frequency, thereby reducing the overhead associated with conventional direction of arrival estimation, as shown in Fig. 2-1-9. Under assumption with a simplified environment where interference waves from an adjacent local 5G system arrive from a single direction and without considering signal power or noise, we developed an algorithm for estimating the DoA using frequency-dependent beamforming. As shown in Figure 2-1-10, at a cumulative distribution function value of 0.9, the estimation error is approximately 0.68 degrees, and we confirmed the accuracy of the absolute error with a maximum error of approximately 1.45 degrees. Furthermore, the number of beam patterns required for the conventional beamformer method to achieve the same level of estimation accuracy as the proposed method is 26. Therefore, we confirmed that the proposed method can reduce the overhead associated with conventional direction of arrival estimation to 1/26th.

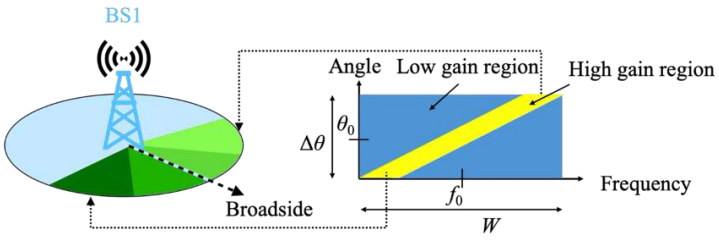


Fig. 2-1-9 Concept of the proposed DoA estimation method.

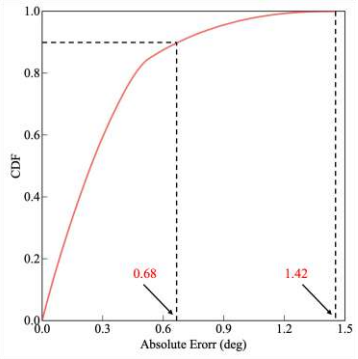


Fig. 2-1-10 Estimation error performance

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, Koichi Adachi

3. JST Aspire, “Resilient Cyberspace Generative Framework with Communication, Sensing and Learning Integration"

   Katsuya Suto

【Cooperative Research】

1. TIS Inc., Celimuge Wu, Takeo Fujii, Katsuya Suto
2. NEC Corp. Takeo Fujii
3. 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 2024

[A 4.7-GHz-band GaN HEMT Doherty-outphasing power amplifier with a miniature combiner](Ishikawa Lab.)

In recent years, the greater sophistication and diversity in wireless communication systems have become remarkable, hence further improvements in performance of wireless transmitters in the base stations are required. Power amplifiers are an important device, which greatly affect distortions for signals and power consumption. A peak-to-average power ratio (PAPR) of recent digital wireless signals is large as more than 6 dB. A PAPR of 9 dB is often considered in 4G and 5G OFDM (Orthogonal Frequency Division Multiplexing) / QAM (Quadrature Amplitude Modulation) systems. In such systems, power efficiency at large output power back off levels dominates a total power consumption of the amplifiers than that in saturation levels. Thus, high efficiency characteristics are required for wide dynamic range in the amplifiers, where a special attention should be paid on the efficiency at large output back-off (OBO) power level.

For this issue, a GaN HEMT Doherty-outphasing hybrid power amplifier with a miniature outphasing combiner has been developed at the 4.7 GHz band. An outphasing combiner for a series load-compensation scheme was constructed without using long transmission lines, to reduce the circuit size. The amplifier was designed based on a 3-power-level design technique to maximize the drain efficiency at different output power back-off levels. The fabricated Doherty-outphasing power amplifier exhibited a peak drain efficiency of 59.5% and a saturated output power of 42.3 dBm at 4.6 GHz. Furthermore, a drain efficiency above 50% was maintained within a deep output power back-off of 10.3 dB (Fig. 2.2.1).

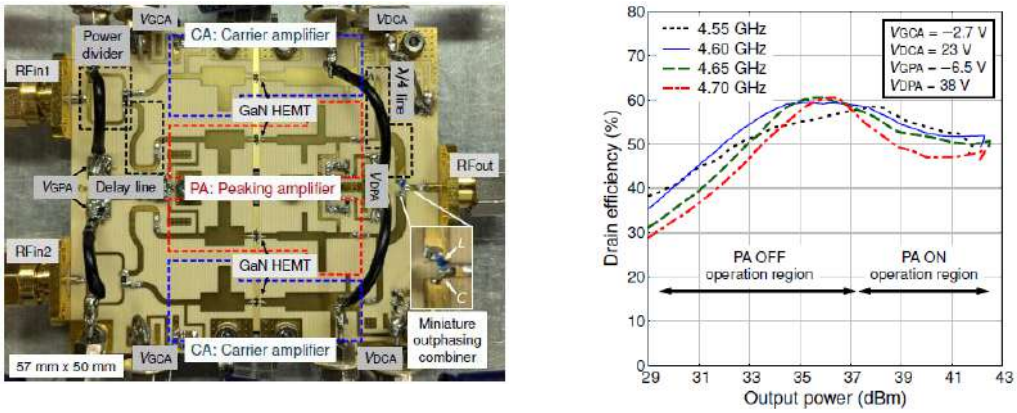
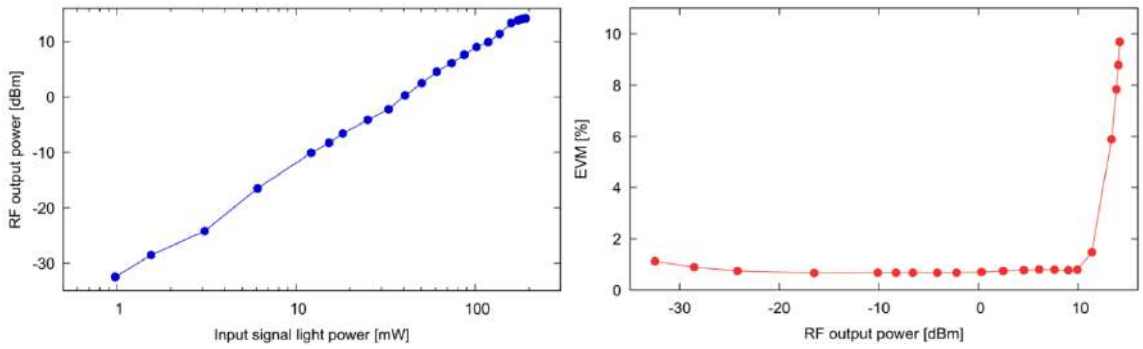


Fig. 2.2.1 Fabricated GaN HEMT Doherty-outphasing power amplifier, and its characteristics

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

Mobile data traffic has increased with the spread of 5G communications. Higher carrier frequency of radio-frequency (RF) signals is required for the higher speed and higher capacity of wireless communication systems. On the other hand, the higher carrier frequency increases the propagation loss and causes smaller cell size of remote antenna units (RAUs). Therefore, as a large number of RAUs will be required in near future, it is important to provide lower cost and simpler configuration of RAUs. Radio-over-fiber (RoF) systems, which transmit RF signals using optical fibers between control office (CO) and RAUs, provide low loss and broadband RF signal transmission. Also, power-over-fiber (PWoF), which delivers electric power using optical fibers and photovoltaic power converters (PPCs), has attracted much attention. PWoF systems simultaneously transmits data signals and feed lights over optical fibers. As PWoF enables to drive RAUs using only optical fibers without electrical wires, PWoF is expected to reduce the cost and simplify the configuration of RAUs.

In this year, we present an optically powered antenna without electrical power amplifiers to simplify configuration of RAUs. In downlink RoF transmission, the received RF signals are amplified using electrical power amplifiers. However, as the carrier frequency becomes higher, the RF output signal power and power added efficiency of electrical power amplifiers are significantly reduced. On the other hand, if optical data signal power can be increased and converted into RF signal using high-power photodiodes (HPPDs), it is possible to increase the output RF signal power without electrical power amplifiers. To install simple RAUs, it is one of the attractive ways that optically powered antenna with HPPDs does not require electrical power amplifiers for downlink. We also show an optically powered antenna module consisting of a HPPD and PPCs and a DC-DC converter (DDC), which enables to output high-power RF signals without electrical power amplifiers for downlink. We experimentally evaluate the performance of the optically powered antenna module in detail, and show the feasibility of the optically powered antenna.



(a) (b)

Fig. 2.2.2 (a) RF output power while changing A-RoF data signal power input to HPPD and (b) EVM characteristics of RF output signals as a function of RF output power.

Fig. 2.2.2 (a) shows the RF output power while changing the A-RoF data signal power input to the HPPD. The total feed light power input to the 4 PPCs was fixed to 2 W. The RF power increased linearly as the input signal power increased. The maximum RF output power was 14.18 dBm with input signal power of approximately 200 mW. The low modulation depth for good RF output signal quality was the cause of low conversion efficiency of the HPPD. It should be noted that the RF output power will be further increased if the modulation depth is improved. Fig. 2.2.2 (b) shows the EVM characteristic of the RF output signals as a function of the RF output power. The feed light power was fixed to 2 W. The average EVM was 0.72 % in the RF power range of −25 dBm to 9 dBm. The EVM values were rapidly increased as the RF output power increased above 10 dBm. The input signal pow-er saturation of the HPPD was the cause of bad signal quality. The maximum RF output power in the range of EVM values of less than 5.4% was 11.37 dBm and then input signal power was 137.1 mW.

[Dosimetry Modeling based on a Millimeter-Wave Exposure Equipment] (Kun Li Lab.)

A millimeter-wave dosimetry evaluation technology based on a spatially synthetic exposure system for real animal experiments has been developed. The exposure system comprises two lens antennas operating at 60 GHz, generating a focused radiation beam with an area of approximately 1 cm² at the skin surface of the exposure target. The spatially averaged absorbed power density (sAPD) at the skin surface was calculated using the FDTD method with a high-resolution rat voxel model, where the beam was directed toward the dorsal side of the rat. To account for potential misalignment of the exposure beam in realistic experimental settings, the deviation in sAPD due to shifts in the focal beam location was analyzed. Compared to the variation caused by changes in the separation distance between the antenna and the skin surface, it is known that the misalignment of the synthetic beam center on the exposed area may have a greater impact on the calculated sAPD. This is likely due to slight changes in the averaging area of the sAPD on the uneven skin surface. These findings are valuable for assessing the influencing factors in experimental dosimetry involving laboratory animals or human volunteers.

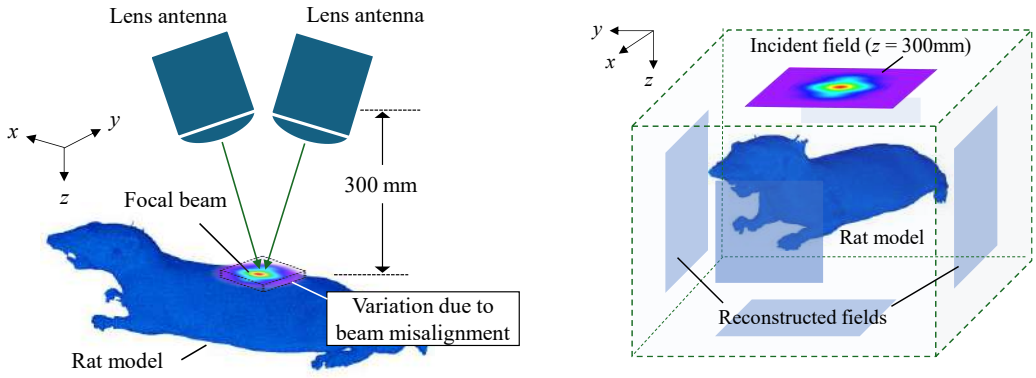


Fig. 2.2.3 Hybrid numerical simulation method using reconstructed incident E-fields for dosimetry analysis based on animal exposure experiment.

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 the biological effects on thermal physiology and cellular functions during millimeter-wave exposure" (T. Hikage, H. Masuda, A. Nagai, K. Li)

【Cooperative Research】

1. SoftBank Group Corp. "Low power consumption amplifier" (R. Ishikawa)
2. Toshiba Corp. "Study of design techniques for improving the performance of RF circuits" (R. Ishikawa)
3. Japan Space Systems. "Technical evaluation of high-efficiency power transfer section related to "Research and development project for high efficiency wireless power transfer in space solar power systems" (R. Ishikawa)
4. 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)
5. Japan Space Systems. "Study of RF amplifier for wireless power transmission in lunar orbit solar power generation system" (R. Ishikawa)
6. 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. Koichi Adachi (Future NW)
Associate Prof. Katsuya Suto (Future NW)

2.3.3 Major Research Results in 2024

[Indoor Positioning using BLE Beacons and User Equipmentns in Factory Environment] (Fujii Lab.)

A method using signals of BLE beacons has been investigated as method for estimating the location of user equipment (UE) indoors, and a trilateration using received signal strength indicator (RSSI) from BLE beacons has been proposed. Trilateration using beacons calculate the distance between each beacon and the UE using RSSI from three beacons with known locations. The intersection of three circles with the calculated distance as the radius and each beacon as the center is the estimated location of the UE. In the Trilateration, to improve position accuracy, it is necessary to install more beacons and increase the number of beacons in the line-of-sight (LOS). In factory environment where there are many metallic objects, the multipath effect is greater, so more beacons need to be installed. However, installing a huge number of beacons in Factory and knowing the location of all beacons is time-consuming and costly. This paper proposed a method the utilizes not only beacons, whose locations are known, but also UEs whose locations are unknown.

Fig. 2.3-1 shows the system model of the proposed method. In this study, the beacon only transmits BLE signals, while the UE both transmits and receives BLE signals. First, the location of the UEs with unknown location is estimated by Trilateration using beacons with known location. Next, the position of the UE to be located is estimated using both beacons and the UE that was located in the first step.

To evaluate the performance of the proposed method, observation experiments were conducted at the factory, and position estimation was performed based on the observed values. The number of beacons used for positioning was 21, 11, and 5, respectively, and the number of unknown terminals (UEs) used was 10. The results were compared between the conventional method using

only known beacons and the proposed method utilizing unknown UEs. The cumulative distribution function of the positioning error at each observation point is shown in Fig. 2.3-2. As a result, it can be confirmed that the proposed method reduces the positioning error more than the conventional method under all beacon configurations.

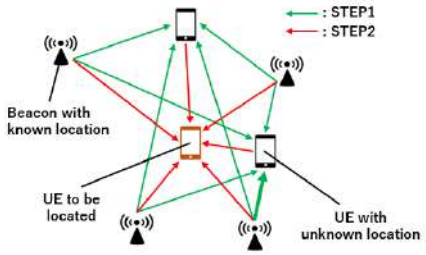


Fig. 2.3-1 System model.

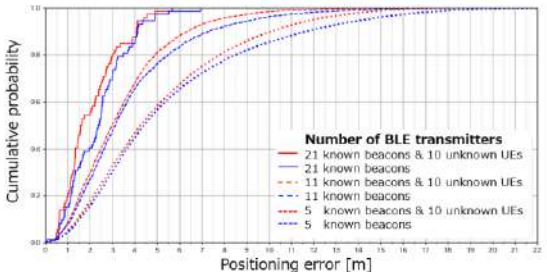


Fig. 2.3-2 Cumulative distribution function of positioning error with and without unknown UEs.

[Study of power control method using Variable Bandwidth LoRa] (Fujii Lab.)

Low Power Wide Area Networks (LPWAN) has features such as low power consumption and long-range communication. One type of LPWAN is Long Range Wide Area Network (LoRaWAN). LoRa modulation is LoRaWAN physical layer technology. LoRa modulation can adjust the transmission distance and data rate according to the purpose by combining parameters such as spreading factor (SF), bandwidth and coding rate. Signals modulated by same SF have quasi-orthogonality property. However, signals modulated by different SF are not quasi-orthogonality. Variable Bandwidth LoRa (VBW-LoRa) was proposed as a solution to this problem. VBW-LoRa change bandwidth and symbol length according to a parameter that is called symbol length rate. Nevertheless, a near-far problem occurred even when VBW-LoRa is used. Signals transmitted by end nodes close to a gateway (GW) may prevent demodulation of signals transmitted by end nodes far from the GW. One potential solution is power control. Therefore, this study proposes a method to power control with using VBW-LoRa.

Fig. 2.3-3 shows the system model. We assumed a circular cell centered at GW. The end nodes are uniformly distributed over the cell and transmit the packets according to a Poisson process. GW measures the Received Signal Strength Indicator (RSSI) of each packet. To close the RSSI values of packets received at GW, we decided on the transmission powers of each node based on the measured RSSI values.

To verify the proposed method, computer simulations were executed. In Fig. 2.3-4, Comparison from two perspectives, which are whether power control is used or not and whether the half of all nodes using VBW-LoRa or all nodes using conventional LoRa. Fig. 2.3-4 shows that throughput using both VBW-LoRa and power control improves average throughput per device when the number of end nodes is thirty or more. This is because the success rate of simultaneous reception improves by reducing the impact of interference from signals of the same SF.

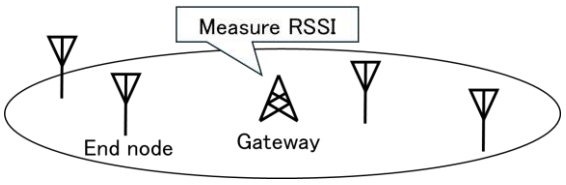


Fig. 2.3-3 System model.

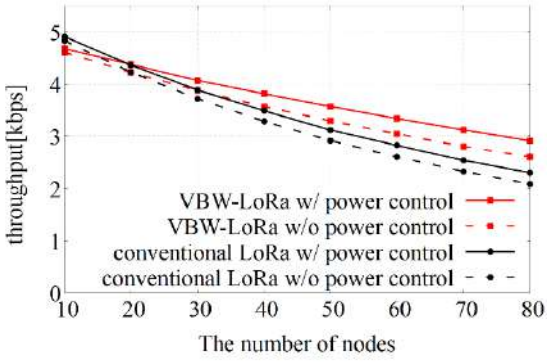


Fig. 2.3-4 The number of devices vs. average throughput per device.

[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 IoT applications such as telemedical require both strict delay constraint and privacy preserving. 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 base station (BS) does not exclusively assign radio resources to active users and each active user transmit pilot and data without handshaking procedure.

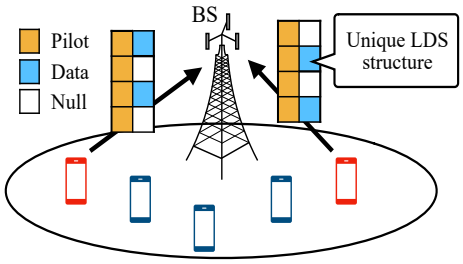


Fig. 2.3-5 GF-NOMA system based on LDS-OFDM

This academic year, to achieve robust and secure GF-NOMA system, we have proposed GF-NOMA schemes (1) plug-and-play (PnP)-based receiver design considering carrier frequency offset (CFO), (2) physical-layer authentication (PLA) utilizing estimated CFOs.

For (1), we have proposed a GF-NOMA scheme based on low-density signature orthogonal frequency division multiplexing (LDS-OFDM), as shown in Fig. 2.3-5. In this scheme, each user is allocated a unique LDS sequence corresponding to the low-density subcarrier allocation for data transmission. A multi-antenna BS exploits the LDS structure via machine learning as a side information (SI) and utilize the exploited SI via proposed SI-aided approximate message passing (AMP) to improve activity and channel estimation accuracy. Moreover, our proposed method can estimate CFOs of active users by performing iterative process between SI-aided AMP and expectation-maximization (EM) algorithm.

For (2), we have proposed a PLA method utilizing estimated CFO. In this scheme, a user is authenticated based on channel estimation error caused by the difference of CFOs between legitimate user (LU) and malicious user (MU). The optimal authentication threshold is designed by analyzing channel statistics to maximize MU detection probability. Incorporating estimated

CFOs for PLA, the BS is able to detect a spoofing attack by the MU with high accuracy, even when the channels coefficients of the LU and MU are highly correlated.

[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 user equipment (UE) in the service area, through joint baseband signal processing at central processing unit (CPU) that connect distributed access points (APs) via fronthaul links. Even though CF-mMIMO systems can theoretically achieve superior performance compared to conventional cellular systems, there are still practical open problems. The major two aspects for CF-mMIMO systems to be addressed for their implementation are a) to improve area spectral efficiency (SE) and energy efficiency (EE), and b) to address the carrier frequency offsets (CFOs).

For a), we have proposed signal processing methods using convex optimization, and integer program, based on a network-assisted full-duplex (NAFD) CF-mMIMO systems, as shown in Fig. 2.3-6. NAFD CF-mMIMO is one of the superior duplexing schemes that improve area SE compared to conventional time division duplex (TDD) schemes, and it is a method that allocates each AP exclusively to uplink and downlink according to the communication requirements of UEs. The AP clustering and beamforming design is essential for NAFD systems to deal with cross-interference signals. Therefore, we have proposed a signal processing methods that joint designs AP clustering and beamforming based on convex optimization, and have shown that it achieves high SE and EE compared classical CF-mMIMO schemes. Furthermore, we proposed a method that shows high performance even when the fronthaul capacity is limited, and a more practical method that reduces the computational complexity of signal processing, which has superior performance compared to conventional CF-mMIMO.

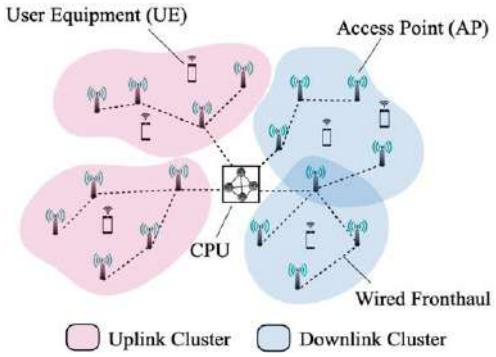


Fig. 2.3-6 System model of scalable network-assisted full-duplex cell-free

For b), we have proposed a joint estimation method of user-activity, channel coefficients, UE-side and AP-side CFOs. In contrast to conventional cellular systems, CF-mMIMO systems have independent oscillators in both UEs and APs. As a result, frequency synchronization becomes problematic, leading to CFOs that degrade communication quality. This is a significant implementation challenge for CF-mMIMO. Furthermore, to achieve high-quality and low-latency communication, it is essential to estimate active UEs and channel coefficients using pilot signals. Therefore, we have proposed an algorithm that combines compressed sensing-based activity and channel coefficients estimation with a CFO estimation scheme, and have shown that it achieves active detection accuracy, channel estimation accuracy, a bit error rate (BER) performance close

to that of the perfectly known CFO scenario.

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

Millimeter-wave (mmWave) communications are expected to be foundations of beyond 5G and 6G wireless architectures. However, **beam misalignment caused by (1) sudden blockages and (2) user mobility** poses significant challenges that degrade communication quality (see Fig. 2.3-7).

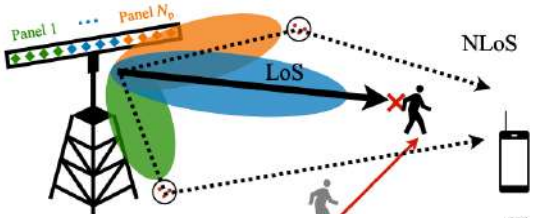


Fig. 2.3-7 System model of P2P mmWave downlink communications under random

To address the **challenge (1) : the impact of blockages**, we reconsidered the conventional beamforming design and proposed beamforming designs that enables stable communication by generating multi-beams with multiple main lobes, leveraging the characteristics of multi-panel arrays. By applying approximations to propagation path blockage and beamforming, we analytically derived the cumulative distribution function of spectral efficiency. Based on this, we formulated an outage probability minimization problem and proposed multi-beam design algorithms to solve it. The proposed methods achieved spatial diversity and demonstrated that it enabled more stable communication than conventional single-sharp-beam designs. In addition, we derived a closed-form expression for the blockage loss averaged over randomly positioned blocker using the extended METIS model, a knife-edge diffraction model for computing blockage loss analytically. The proposed model enables calculation of the beamwidth that maximizes the received power under stochastic blockage environments, without numerical computing.

To overcome **challenge (2): misalignment due to user mobility**, we developed a **deep learning-based beam tracking method** for uplink MIMO channels, which enables efficient codebook-based tracking with significantly reduced overhead compared to traditional model-based or exhaustive search approaches. Furthermore, we proposed a **codebook-free deep learning-aided receive beam design**, improving the UE achievable rate under dynamic user conditions.

[Terahertz communications systems] (Koji Ishibashi Lab.)

Terahertz (THz) communications systems, using spectrum resources ranging from 0.1 [THz] to 10 [THz], have attracted significant attention as technologies to meet further increasing demands for high data rates. However, signals at such high-frequency bands are more attenuated than millimeter-wave signals due to larger spreading losses, molecular absorption losses, and random path blockages. In addition, in THz bands, highly efficient transmitters are still lacking in terms of sampling capability and power amplifiers (PAs) due to an ultra-wide bandwidth and peculiar electromagnetic properties of THz signals.

From the above, to compensate for the received signal power considering the current limitation of transceivers, we propose waveform designs, namely, a joint allocation method of transmit power and spectrum to divides the available spectrum into non-overlapped sub-bands while

avoiding molecular absorption loss peaks and minimizing outage probabilities of throughput, and single-carrier systems whose equalizer and hybrid beamformers are designed jointly to maintain low peak-to-average power ration (PAPR) .

In the joint transmit power and spectrum allocation, the resource allocation is formulated as a sum-of-outage probability minimization problem with outage probabilities of instantaneous throughput for each UE by exploiting the statistical knowledge of random path blockages. Numerical results show that the proposed approaches can achieve lower outage probabilities and higher total system throughput than conventional approaches.

In the study of single-carrier transmissions, the joint design of liner equalizer and hybrid beamformers is formulated as a minimum mean square error problem for data symbol estimation to achieve lower BER and PAPR than orthogonal frequency division multiplexing (OFDM). Numerical results confirm that the proposed scheme achieves better BER performance than and OFDM transmissions, and reveal that the proposed transmit beamformer does not degrade the power amplifier efficiencies in terms of PAPR properties.

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

To achieve the high spectral efficiency required for 6G, it is vital to use the mid- and high-frequency bands, including mmWave and sub-THz. Since these bands suffer from severe path loss, beamforming with large antenna arrays becomes crucial. However, as the antenna aperture increases, near-field effects become significant and can no longer be neglected.

Large antenna array systems require a substantial pilot overhead to obtain accurate channel state information (CSI). To address this challenge, we proposed (1) an efficient near-field channel estimation with non-orthogonal pilot sequences and (2) a joint channel and data estimation (JCDE) approach.

In the proposed method (1), we exploit the angle-distance sparsity known as polar sparsity, which is near-field specific property. The use of this sparsity enables efficiently multiuser channel estimation with non-orthogonal pilot sequences with low computational complexity. However, the reduction in complexity and pilot overhead comes at the cost of limited channel estimation performance compared to schemes using orthogonal pilot sequences.

In the proposed method (2), to further accurately estimate near-field channel, not only pilot sequences but also estimated data symbols are utilized as pilot replicas. The channel estimation and data detection are alternately performed, leading to accurate joint estimation even with non-orthogonal pilot sequences. In addition, by exploiting the array model structure in the near-field region, the channel can be effectively estimated considering polar sparsity, leading to improved data detection performance.

[High-Power PON for Higher Split Ratio Using a Hollow-Core Fiber （Matsuura Lab）]

In optical access networks, passive optical networks (PONs) have become a popular solution not only for subscriber networks, but also for various communication services such as mobile communications and Internet of Things (IoT). In such networks based on radio-over-fiber (RoF) transmission, the number of optical network units (ONUs) is expected to increase dramatically in the future, and PONs with higher split ratio will be needed. In downstream PON transmission, inserting optical amplifiers at an input of splitters is an effective way to extend the power budget. However, this makes the structure more complex and requires the power to be supplied to the amplifiers. Hollow-core fibers (HCFs) have the ultra-low nonlinearity and latency, which are difficult to achieve with conventional silica-core optical fibers, and there have been many reports demonstrating these features. The ultra-low nonlinearity enables high-power data signal transmission.

In this year, we demonstrated high-power PON using a combination of a 1 km HCF and 256 single-mode fiber (SMF)-based branches. We successfully achieved not only high-power analog RoF (A-RoF) signal transmission with input power exceeding 36 dBm for increasing the split ratio.

To demonstrate the effectiveness of HCFs as a high-power link in PONs, we evaluated the high-power transmission characteristics of A-RoF signals using the 1 km HCF. The result is shown in Fig. 2.3-8 (a). In the SMF transmission, when the input power to the fiber exceeded 22 dBm, the EVM value increased sharply due to the fiber output power limitation by stimulated Brillouin scattering (SBS) in the fiber. Although the power threshold is dependent on the linewidth of the signal light source, it is a significant issue not only for higher split ratio PONs, but also for use of muti-level modulation signals for digital coherent transmission. On the other hand, in the HCF transmission, the EVM value remained constant even when the input power to the fiber exceeded 36 dBm. This means that SBS was well suppressed due to the ultra-low nonlinearity of the HCF, and high transmission characteristics were achieved even in high-power signal transmission. Note that the maximum input power of 36 dBm to the fiber was not a limit on the input power to the HCF, but a limit imposed by the equipment used in the experiment, such as the EDFA and BPF. We also calculated the actual PON configuration that could be assumed from the result. The calculated available number of branches as a function of fiber input signal power is shown in Fig. 2.3-8 (b). In PON using the 1 km SMF, a maximum of 128 branches can be constructed due to the input power limit to the fiber based on the result of Fig. 2.3-8 (a). However, in the high-power signal transmission using the 1 km HCF for the link before the splitter, a maximum of 1024 branches can be constructed. Note that the loss of the HCF was much higher than that of the SMF in this calculation. If a low-loss HCF equivalent to the SMF is introduced, the number of branches will be further improved.

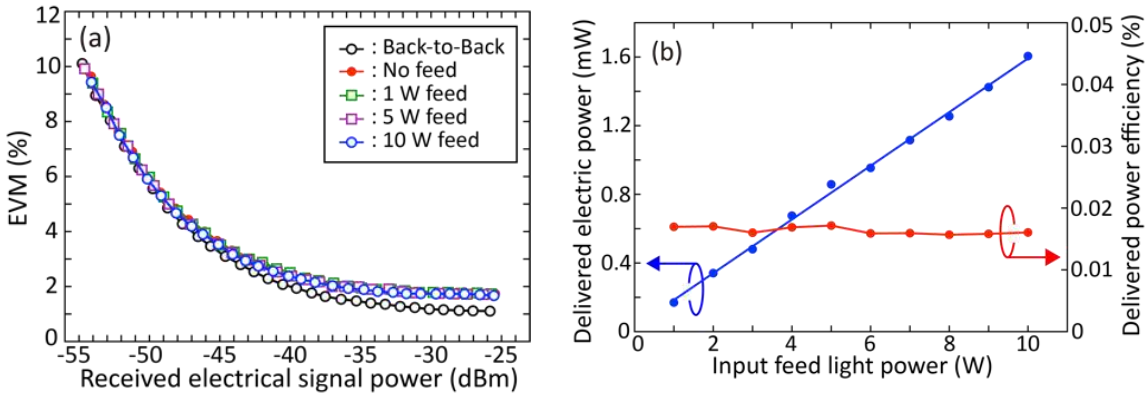


Fig. 2.3-8 (a) EVM characteristics as a function of fiber input signal power. (b) Available number of branches as a function of fiber input signal power.

[DQN-Based Adaptive Local Training for Hierarchical Federated Learning in Vehicular Networks] (Celimuge Lab.)

To address the challenges of communication constraints and dynamic conditions in vehicular networks, we proposed a DQN-based adaptive local training strategy integrated into a hierarchical federated learning (HFL) framework. The system is structured into three tiers: vehicle clients, roadside units (RSUs), and a cloud server. Each vehicle dynamically determines its number of local training epochs based on real-time training feedback and network conditions by formulating the local training control problem as a Markov Decision Process (MDP) and leveraging DQN for policy learning. This design enables distributed, context-aware adaptive training, improving convergence speed while reducing communication overhead, especially in non-IID vehicular environments. The overall architecture and integration of the DQN agent into HFL are illustrated in Fig. 2.3-9.

Through extensive simulations on a non-IID CIFAR-10 dataset, the effectiveness of the proposed method was verified. The convergence curve of the DQN agent demonstrated stable learning behavior under heterogeneous network conditions (Fig. 2.3-10). Compared with baseline strategies using fixed local epoch settings, the DQN-based adaptive training method achieved superior performance, improving final model accuracy by over 2% and significantly reducing the total training time. These results confirmed that adaptive local training not only enhances model convergence but also optimally balances communication cost and training efficiency in hierarchical federated vehicular systems.

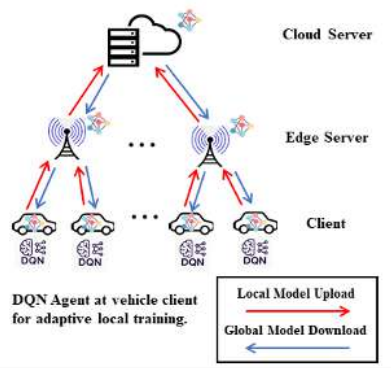


Fig. 2.3-9 The proposed DQN-based training control mechanism in HFL.

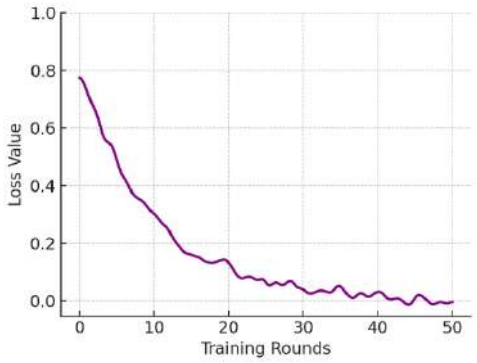


Fig. 2.3-10 Convergence of DQN agent during training.

[Node Clustering with Zero-overhead Information Exchange for Wireless Sensor Networks] (Adachi Lab.)

This research investigated zero-overhead radio environment information (inter-device sensing relationships) estimation for long-range wide area network (LoRaWAN), applying the principles of packet-level index modulation (PLIM). To validate the proposed method, experiments were conducted. In LoRaWAN, the wide coverage often leads to significant packet collisions between hidden nodes. Furthermore, the use of unlicensed bands imposes duty-cycle (DC) restrictions on transmission time. Consequently, gathering radio environment information from sensor nodes using uplink packets is impractical due to potential delays or inability to transmit essential data. Therefore, a low-overhead method for collecting radio environment information to facilitate resource allocation for packet collision mitigation is crucial. This study proposed a zero-overhead radio environment information estimation method to reduce packet collisions caused by the hidden node problem, along with clustering and resource allocation based on this estimated information. The proposed method leverages the fact that PLIM determines the transmission frequency channel and time slot. The gateway (GW) can infer that a node backed off its transmission by detecting a subsequently transmitted packet. Using PLIM's packet mapping, the GW can then estimate the originally intended frequency channel and time slot of the backed-off node. This allows the GW to estimate the radio environment information with the node that would have communicated using those resources. By further employing this estimated information for clustering and resource allocation, the hidden node problem is mitigated, reducing packet collision rates. Experiments using commercially available nodes (Fig. 2.3-11) demonstrated an approximately 18% improvement in packet delivery ratio (PDR), reaching 99.9%, compared to a traditional periodic transmission model by using the radio environment information estimated with the proposed zero-overhead method for resource allocation. These results confirm the feasibility of improving communication quality in LoRaWAN by utilizing radio environment information estimated with zero overhead.

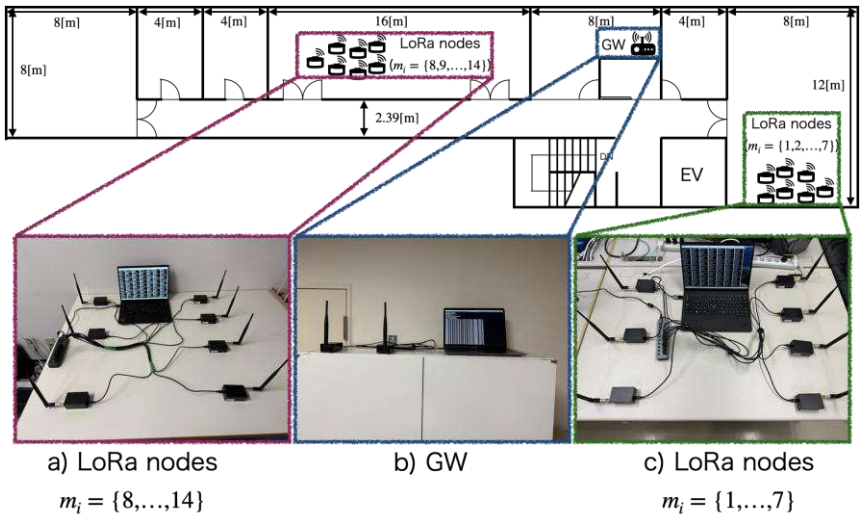


Fig. 2.3-11 Experimental setup.

[Decentralized Packet Collision Avoidance for LPWAN] (Adachi Lab.)

This research addresses the growing issue of out-of-system interference in long-range wide area network (LoRaWAN), a popular low power wide area network (LPWAN) technology operating in unlicensed bands. To mitigate the negative impacts of this interference on both uplink transmissions and gateway reception, we proposed a distributed detection and avoidance method. This approach leverages the unique characteristics of LoRa modulation, specifically the dechirping and Discrete Fourier Transform (DFT) processes at the receiver. By analyzing the DFT output of the received signal with and without dechirping, distinct features are extracted (average power, spectral entropy, and kurtosis) and fed into a decision tree machine learning algorithm at the node (Fig. 2.3-12). This allows the node to classify the received signal into four categories: own system, other system interference, noise, and mixed signals. Upon detecting out-of-system interference, the node autonomously switches to a different frequency channel to avoid it. Simulation results demonstrate that this proposed method significantly improves the packet delivery ratio (PDR) in the presence of interference compared to existing approaches, effectively achieving performance levels close to those experienced in interference-free scenarios with limited channel availability (Fig. 2.3-13).

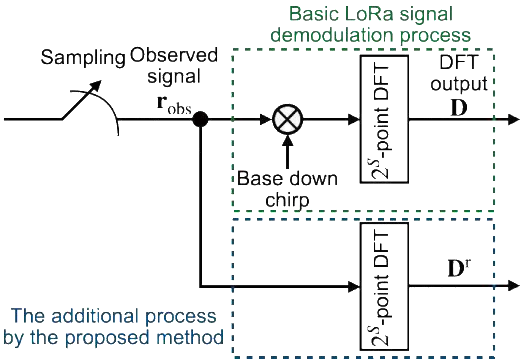


Fig. 2.3-12 Receiver structure of the proposed method.

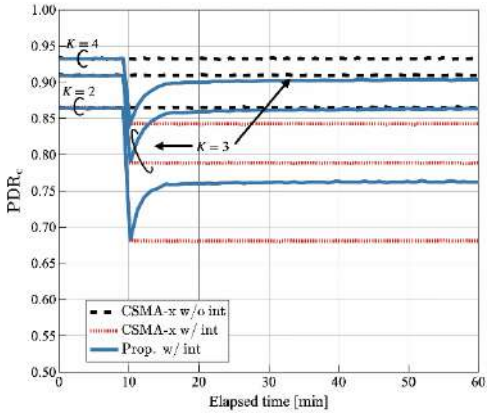


Fig. 2.3-13 PDR performance as a function of time.

[Fractional Spreading Factor (FSF)-LoRa] (Adachi Lab.)

The communication range and noise immunity of long-range wide area network (LoRaWAN) are typically managed by the integer Spreading Factor (SF), but this can lead to demodulation issues with same-SF interference and reduced data rates with higher SFs. To address these limitations, we proposed fractional spreading factor (FSF)-LoRa, allowing for more precise, sub-integer SF control. FSF is implemented by extending the symbol length while keeping the bandwidth consistent with standard LoRa, creating signals that can coexist with existing LoRa transmissions, as shown in Fig. 2.3-14. Simulations comparing FSF-LoRa to conventional LoRa show that FSF offers intermediate SER performance between integer SF values. Furthermore, by providing a wider range of data rates and reducing the likelihood of collisions among devices using the same fractional SF, FSF-LoRa demonstrates the potential to improve overall system throughput by up to 6% in dense networks as shown in Fig. 2.3-15. This suggests that fine-grained control of the spreading factor can be a significant advantage in optimizing LoRaWAN performance.

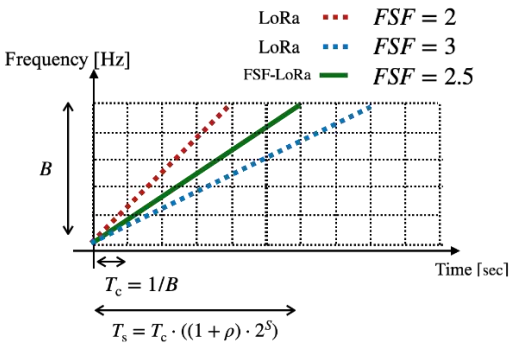


Fig. 2.3-14 Conceptual illustration of FSF.

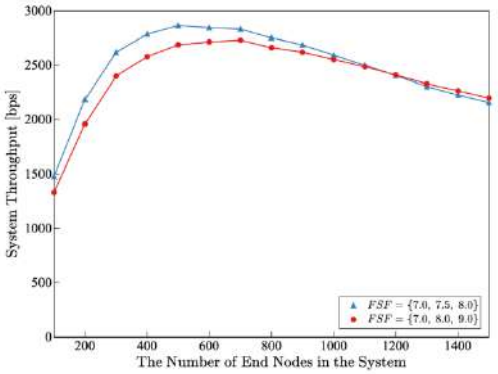


Fig. 2.3-15 Throughput performance.

[Vision-aided Intelligent Reflecting Surface] (Suto Lab.)

Intelligent Reflecting Surfaces (IRS) are a promising technology that can significantly enhance the performance of wireless communications by intelligently controlling radio propagation paths. In particular, IRS is highly effective in improving signal strength in non-line-of-sight (NLOS) areas; however, dynamic control of the reflected signal remains a challenge due to the lack of onboard signal processing capabilities at the IRS.

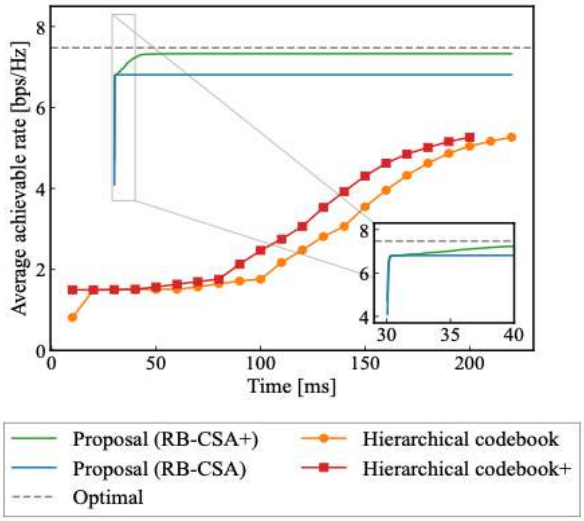


Fig. 2.3-16 Average achievable rate over elapsed time.

This year, we investigated a fast reflective beamforming method for IRS-assisted communication systems by leveraging situational awareness obtained through computer vision (CV). In the proposed system, the IRS is equipped with a vision sensor that recognizes and predicts user positions, forming what we term Clustered Situational Awareness (CSA). Based on CSA, the system clusters users and optimizes a reflective beam to uniformly cover users within the same cluster.

The proposed RB-CSA method utilizes gradient descent-based optimization to rapidly adjust the IRS beam direction towards the center of a user cluster. Furthermore, RB-CSA+ improves upon RB-CSA by introducing a hierarchical search process after gradient descent to further refine the beam direction.

As illustrated in Fig. 2.3-16, the proposed methods significantly reduce beamforming overhead compared to traditional hierarchical codebook-based beam alignment methods, which require extensive pilot signaling and exhaustive search. Simulation results demonstrate that the proposed methods achieve higher achievable rates with lower control latency, particularly in high-mobility scenarios.

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 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”
   Koichi Adachi, Takeo Fujii UPI belongs to other organization)
3. NICT B5G “Research and Development of Integrated Information and Power Transfer Systems for Private B5G/6G in Indoor Environments”
   Koichi Adachi, Takeo Fujii
4. MIC SCOPE “Communication Cost Reduction and Reliability Improvement for AMR Autonomous Driving”
   Celimuge Wu (PI belongs to other organization)
5. JST ASPIRE “Open Digital Infrastructure through the Convergence of Telecommunications and AI”
   Celimuge Wu (PI belongs to other organization)
6. MIC “Research and development of advanced optical transmission technology that contributes to a green society”
   Motoharu Matsuura
7. NICT B5G “Construction of a highly efficient wireless communication system using high power radio-over-fiber transmission”
   Motoharu Matsuura
8. NICT JUNO3 “End-to-end network slicing and orchestration in future programmable converged wireless-optical networks”
   Motoharu Matsuura

【Cooperative Research】

1. Hakusan Corporation, Motoharu Matsuura
2. NEC Corporation, Takeo Fujii
3. KDDI Research Inc., Koji Ishibashi
4. Ericsson AB, Koji Ishibashi
5. Softbank Corporation, Takeo Fujii

6. Toyota Motor Corporation, Celimuge Wu
7. Takenaka Corporation, Koji Ishibashi
8. Mitsubishi Electric Corp., Katsuya Suto

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）
Associate Prof. Koichi Adachi (Future NW)
Associate Prof. Katsuya Suto (Future NW)

2.3.3 Major Research Results in 2024

[HDFL: A Hierarchical Decentralized Federated Learning Framework for Dynamic and Heterogeneous IoV Environments] (Celimuge Lab.)

We proposed a Hierarchical Decentralized Federated Learning (HDFL) framework to address the challenges of dynamic and heterogeneous Internet of Vehicles (IoV) environments, where frequent node mobility, unstable communication links, and highly non-IID data significantly impact model consistency and convergence.

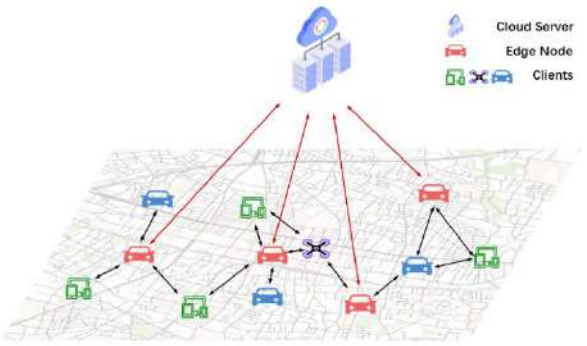


Fig. 2.4-1 Framework of HDFL.

HDFL adopted a three-layer architecture consisting of a cloud server, edge nodes, and clients. The proposed framework is illustrated in Fig. 2.4-1. It combines centralized and decentralized federated learning by enabling edge nodes to perform centralized aggregation with the cloud server, while clients asynchronously exchange and aggregate models through a weighted aggregation mechanism based on immediate and historical model performance.

To further mitigate model drift and enhance stability, HDFL introduced a local fine-tuning strategy based on knowledge distillation, where neighbor models serve as teacher models for personalized local updates. This approach effectively balances global consistency and local adaptability, achieving robust performance even under highly dynamic conditions.

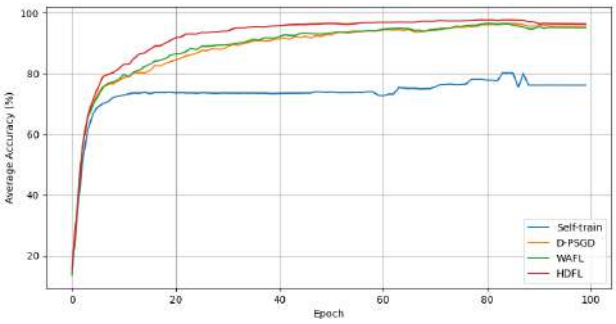


Fig. 2.4-2 Comparison of average accuracy across different methods

Simulation results using an integrated SUMO-OMNeT++-Python platform demonstrated that HDFL achieves up to 2.3% higher average accuracy and 30% faster convergence speed compared to state-of-the-art decentralized federated learning methods such as D-PSGD and WAFL, as shown in Fig. 2.4-2.

[Highly Efficient Communication Techniques in Wireless Sensor Networks] (Koji Ishibashi Lab.)

Wireless sensor networks (WSNs) have to meet low-power consumption and private data security via encryption. To satisfy these requirements, encryption-then-compression (EtC) has been studied. We focuses on block-wise redundancy fluctuations caused by the data format of packets and proposes an adaptive EtC method based on cyclic redundancy check (CRC)-aided polar codes. The method divides the encrypted packet into multiple blocks with different redundancies and efficiently compresses each block with the corresponding compression rate. Numerical results demonstrate that the proposed method exhibits lower decoding error rates than the conventional method, which compresses encrypted packets using a single compression rate by averaging the redundancies (see Fig. 2.4-3).

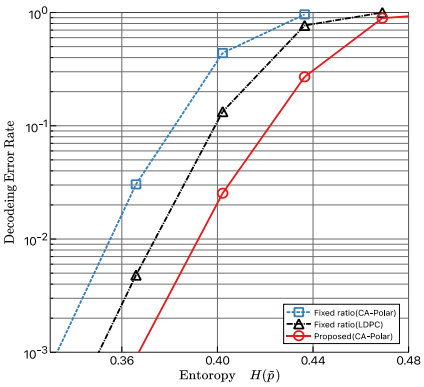


Fig. 2.4-3 Decoding performance

[Robust and Efficient Generative Semantic Image Transmission] (Celimuge Lab.)

Semantic communication offers efficiency for modern data-intensive applications like image transmission, but existing generative approaches often struggle with visual fidelity at high compression ratios or lack universality. To address these limitations, we developed the low-rank guided diffusion (LRGD) framework, leveraging compressed sensing and guided diffusion models for robust and high-fidelity image reconstruction.

Our framework transmits explicit, interpretable semantic information: saliency-adaptive sparse image samples, edge contours, and textual descriptions generated by a large language model (LLM). This achieves significant data compression (down to 6.0% of original size) and enhances cross-model compatibility as no model sharing or joint training is required. At the

receiver, we introduced a novel low-rank guidance mechanism within a pre-trained Stable Diffusion model. This mechanism uses a low-quality image derived from the sparse samples to guide the reconstruction process in the latent space, effectively restoring visual details without additional training. As shown in Fig. 2.4-4, edge and text information further condition the generation via ControlNet. Extensive experiments demonstrated that LRGD achieves robust and superior image reconstruction across various datasets and noisy environments, outperforming the baseline methods, especially at high compression ratios. Visual comparisons showcasing this performance are presented in Fig. 2.4-5.

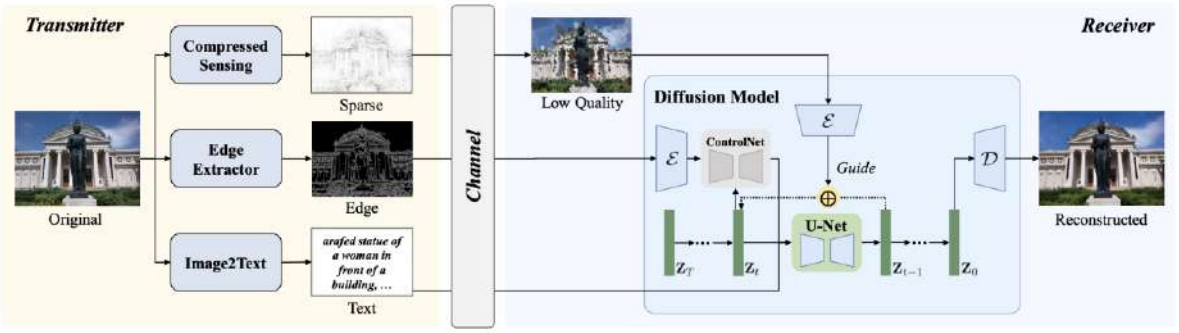


Fig. 2.4-4 Illustration of the proposed framework.

Fig. 2.4-5 Visual comparison results.

[Multi-Hop Communications by Multi-Antenna Beamforming in IRDT Protocol] (Fujii Lab.)

Wireless sensor networks (WSNs) collect data packets containing environmental measured information from sensor nodes (SNs) to concentrators. In WSNs, a large number of SNs may be placed in a large communication area for sensing. However, deploying many concentrators to cover a large area is not realistic due to the high installation cost. Beamforming and multi-hop communication are useful methods to address this issue. Beamforming is a technique that extends the communication distance by increasing the antenna gain of concentrators and suppresses interference power by controlling directivity. Multi-hop communication is also a technique that enables SNs to forward data packets, allowing the concentrator to collect packets from SNs that cannot communicate directly. Also, since SNs in WSNs are often battery-powered. Hence, reducing their power consumption is essential. Intermittent communication, such as the IRDT protocol, is one effective method for reducing power consumption. This study proposes a packet collection system that integrates digital beamforming and multi-hop communication in the IRDT protocol.

Fig. 2.4-6 shows the system model. In our proposed system, the concentrator collects data packets through single-hop or multi-hop communications and is equipped with a uniform circular array (UCA) for digital beamforming. Concentrators transmit request number (RNO) packets, which indicate the start of communication in the IRDT protocol, using digital beamforming to extend the communication range. Furthermore, during uplink communication, multiple beam patterns are used in parallel through digital signal processing to enable simultaneous reception of multiple packets.

Computer simulations in C language were performed to evaluate the proposed system, where 800 SNs were randomly deployed within a circular area with a radius of 1000 [m]. Fig. 2.4-7 shows the PDR, averaged every 10 [m], as a function of the distance from the concentrator. The red and black lines represent the proposed system and the previous system using an omnidirectional antenna at the concentrator, respectively. From Fig. 2.4-7, the proposed system improves the PDR regardless of the position. This is because digital beamforming improves the collection performance of the concentrator by suppressing interference and enabling simultaneous reception. Furthermore, the proposed system achieves a PDR close to 1 through multi-hop communication, even at locations more than 900 [m] away from the concentrator where direct communication is not possible. Therefore, the proposed system allows the concentrator to increase the communication distance while improving the collection performance.

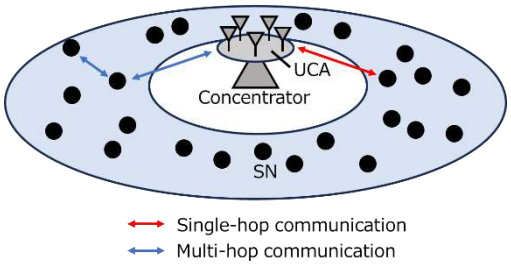


Fig. 2.4-6 System model.

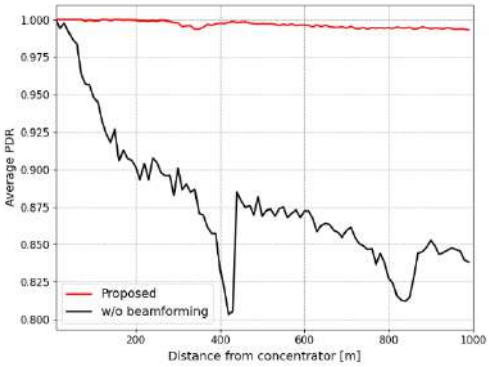


Fig. 2.4-7 Average PDR.

[WLAN Potential Throughput Prediction Using Channel Occupancy Rate] (Fujii Lab.)

As 5G and Wi-Fi6 become more prevalent, more and more users are using them for large traffic applications. However, the quality of wireless communication is highly influenced by the surrounding environment and the number of users, which can reduce the quality of such services. Prediction of wireless communication quality is a useful method to deal with this problem. A method has been proposed to avoid the degradation of quality of service by predicting throughput using time-series data of throughput, which is one of the indicators of wireless communication quality. However, existing methods need constant measurement of throughput, leading to increased traffic load and making it impossible to predict throughput before data transmission. In this research, we propose a method for predicting wireless communication quality without traffic load for measuring throughput.

The proposed method utilizes a random forest model that takes received signal strength indicator (RSSI), channel occupancy rate (COR), and modulation and coding scheme (MCS) as inputs to predict the throughput Th_p that can be potentially transmitted from a node with a new connection. As shown in Fig. 2.4-8, Th_p is obtained by subtracting the virtual throughput Th_v from the saturated throughput Th_s. Th_s is the target node's maximum throughput achievable in the absence of other nodes, and Th_v is the throughput that the target node could have achieved in the time that other nodes are active. Th_s is estimated from RSSI, while Th_v is estimated from RSSI, COR, and MCS.

Through experimental evaluation, we created a potential throughput prediction model and confirmed its accuracy. According to Fig. 2.4-9, in areas where RSSI is at least −60 [dBm], the potential throughput prediction achieves a mean absolute error of approximately 45 [Mbps] and a mean absolute percentage error of about 16%.

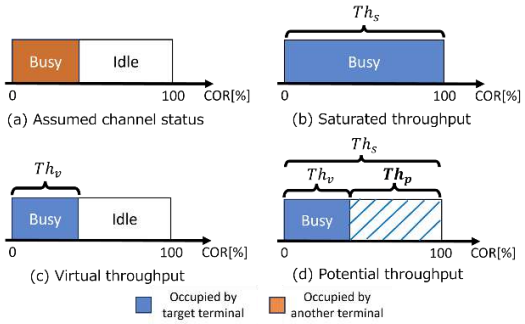


Fig. 2.4-8 COR and throughput.

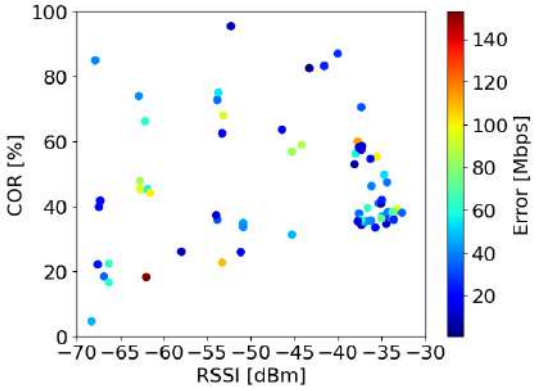


Fig. 2.4-9 Distribution of absolute error for RSSI and COR.

[LoRa System Data Rate Improvement with Chirp Index Partitioning] (Adachi Lab.)

The rapid growth of Internet-of-Things (IoT) technologies has long fueled demand for low-power wide-area networks (LPWANs). LoRaWAN, known for its low-power, long-distance communication, has gained prominence. While LoRaWAN excels in this, its data rate is limited. Most research focuses on boosting individual device data rates. However, for LPWAN applications, supporting numerous low-data-rate devices is key. We introduced chirp index space partitioning (CISP)-LoRa, where the chirp index space is divided into orthogonal subspaces, each for a device, enabling multiple access. CISP-LoRa improves system throughput in high SNR conditions. However, in low SNR, its throughput is lower than conventional LoRa due to inaccurate reception timing difference estimation. As devices are asynchronous, signal arrival times at the gateway (GW) vary. This timing difference causes signal leakage, leading to potential index misdetection despite orthogonality in the chirp index space. This year, we proposed a simple yet effective method for reception timing difference detection to enhance low SNR throughput. Our method uses the DFT outputs of received preambles from each device, summing them for detection. Figure 2.4-10 shows the proposed method's superior average SER performance across all SNR regions compared to the previous method and conventional single-device LoRa. Notably, around -15 dB SNR, we see an approximate 2 dB improvement. LoRa struggles to separate simultaneous transmissions, causing significant SER degradation. Figure 2.4-11 demonstrates our method's consistently higher throughput than conventional LoRa across all SNR, attributed to improved reception timing difference detection accuracy in low SNR.

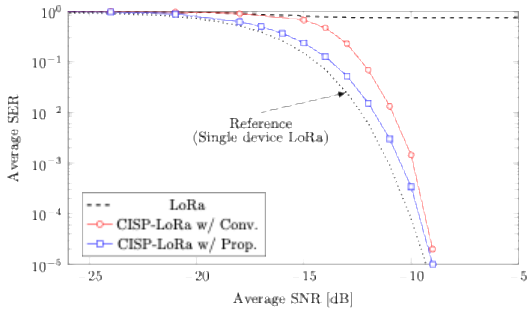


Fig. 2.4-10 Average SER performance.

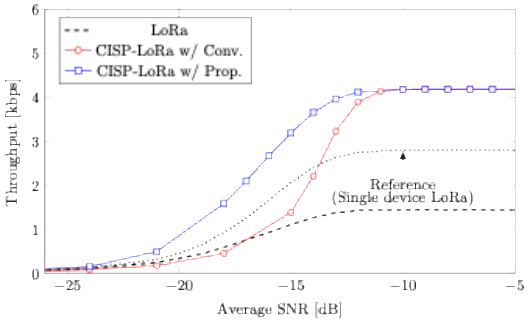


Fig. 2.4-11 Average throughput performance.

[Practical Deep Joint Source-Channel Coding] (Suto Lab.)

In recent years, efficient image transmission systems have become crucial for emerging applications such as real-time digital twins and remote monitoring. These applications demand wide coverage, low power consumption, and robust performance in low-SNR environments. Deep Joint Source-Channel Coding (DJSCC) has emerged as a promising solution, optimizing the encoding and decoding processes end-to-end using deep learning, and demonstrating strong performance even under noisy conditions. However, for DJSCC to be practically deployed, it must be integrated with encryption to protect private data and with modulation techniques to enable effective wireless transmission. Conventional encryption schemes and standard digital modulation approaches are not well-suited for DJSCC's pseudo-analog characteristics, creating a need for novel and compatible solutions.

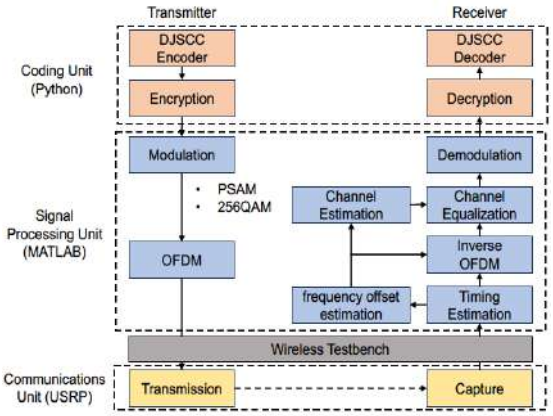


Fig. 2.4-12 Diagram of our implemented DJSCC system

In this fiscal year, as shown in Fig. 2.4-12, we have developed a practical DJSCC platform that allows flexible programming of coding, encryption, and signal processing functions using MATLAB. This platform enables easy evaluation of DJSCC performance under real-world wireless environments.

2.3.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research B “Autonomous Control and Integrity Assurance for Large-scale Distributed Systems”
   Celimuge Wu (PI belongs to other organization)

2. Scientific Research C “Chirp Index Partitioning for Efficient Data Gathering in IoT”
Koichi Adachi (PI)

【Commissioned Research】

1. MIC SCOPE “Communication Cost Reduction and Reliability Improvement for AMR Autonomous Driving”
Celimuge Wu (PI belongs to other organization)
2. JST ASPIERE “Open Digital Infrastructure through the Convergence of Telecommunications and AI”
Celimuge Wu (PI belongs to other organization)
3. JST AdCORP “Green IoT”
Koji Ishibashi (PI belongs to other organization)
4. JST Aspire, “Resilient Cyberspace Generative Framework with Communication, Sensing and Learning Integration"
Katsuya Suto

【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

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なし

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その他の講演

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【2】 Koji Ishibashi, "[invited talk] Rethinking Cell and PHY: New Approaches for Dependable Wireless Systems", at Northeastern University, Boston, MA, USA, Nov. 2024.

受賞

【1】 OWPT 2024 Paper Award（S. Sugiura, K. Murakami, H. Yamaji, M. Matsuura, T. Takagi, K. Mukasa）「Evaluation of nonlinear effects in hollow-core fibers for high-power transmission」Optical Wireless and Fiber Power Transmission Conference（OWPT）, 2024 年 4 月

【2】 OWPT 2024 Student Paper Award（H. Yamaji）「Simultaneous data and power transmission using a hollow-core fiber for passive optical network」Optical Wireless and Fiber Power Transmission Conference（OWPT）, 2024 年 4 月

【3】 藤井 威生, 電子情報通信学会通信ソサイエティ活動功労賞, Sept. 2024.

【4】 Best Paper Award, ACM 2024 International Conference on Intelligent Computing and its Emerging Applications (ICEA), for paper entitled “A TimeSync: GAN-Driven Temporal Feature Synchronization for Robust Collaborative Perception in Autonomous Driving”

【5】 Best Paper Award, 14th EAI International Conference on Wireless and Satellite Systems, for paper entitled “Sensing-Assisted Channel Estimation in ISAC Systems”

【6】 2024 年 5 月 8 日 上田康平 2023 年度 IEICE 無線通信システム（RCS）研究会活動奨励賞

【7】 2024 年 6 月 21 日 照井貫太 2024 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

【8】 2024 年 10 月 17 日 照井貫太 IEEE VTS Tokyo/Japan Chapter 2024 Young Researcher’s Encouragement Award

【9】 2025 年 2 月 4 日 奥井滉史 令和 6 年度 修士論文発表会 優秀発表賞

【10】 2025 年 2 月 4 日 照井貫太 令和 6 年度 修士論文発表会 優秀発表賞

【11】 2025 年 3 月 25 日 奥井滉史 令和 6 年度 目黒会賞
【12】 2025 年 3 月 25 日 照井貫太 令和 6 年度 目黒会賞
【13】 2025 年 3 月 25 日 内村颯汰 令和 6 年度 学生表彰
【14】 2025 年 3 月 25 日 上田康平 令和 6 年度 学生表彰
【15】 2025 年 3 月 25 日 照井貫太 令和 6 年度 学生表彰
【16】 2025 年 3 月 25 日 移川春音 令和 6 年度 学生表彰
【17】 上田恭平，目黒会賞（学部），2024 年度
【18】 蕪木碧仁，学生表彰，2024 年度
【19】 中田祥太郎 2024 年度回路とシステム研究会学生優秀賞 ，2025 年 1 月（和田研学生・博士前期課程修了学生）
【20】 松浦弘樹 2024 年度回路とシステム研究会学生優秀賞 ，2025 年 1 月（和田研学生・博士後期課程学生）
【21】 塩竹明人 2024 年度回路とシステム研究会学生優秀賞 ，2025 年 1 月（和田研学生・博士後期課程学生）
【22】 天津瑠斐 第 30 回電子情報通信学会東京支部学生大会東京支部学生奨励賞 ，2025 年 3 月（和田研学生・博士前期課程学生）
【23】 2025 年 3 月 25 日 松浦弘樹 令和 6 年度 学生表彰
【24】 2025 年 3 月 25 日 塩竹明人 令和 6 年度 学生表彰
【25】 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 優秀賞（杉浦 宗弥）「空孔コアファイバを用いた光給電型アンテナのためのビームフォーミング伝送」電子情報通信学会 フォトニックネットワーク（PN）研究会, 2025 年 3 月
【26】 白石悠大, 2024 年度電子情報通信学会マイクロ波研究会 学生研究優秀発表賞
【27】 石川亮，電子情報通信学会エレクトロニクスソサイエティ活動功労賞

特許

【1】 三宅久之助，斉藤昭，本城和彦，石川亮, “アンテナシステムおよびアンテナ,”日本国，登録番号：特許第 7508078 号, 21 May 2024.
【2】 齊藤稜弥, 安達宏一,「通信システム，通信方法及び通信プログラム」, 特願 2024-104136，2024 年 6 月 27 日
【3】 更屋貴大, 安達宏一,「通信システム，通信方法及び通信プログラム」, 特願 2024-142675，2024 年 8 月 23 日
【4】 藤井威生，李鯤,「構造物及びそれを用いた電波抑制方法」，特願 2024-149911，2024 年 8 月 30 日
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【7】 安達宏一，藤井威生，鷺見康平，角田真一朗，蕪木碧仁,「情報伝送システム，

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広報・報道発表

なし