Advanced Wireless & Communication
Research Center

ACTIVITY REPORT 2023

The University of Electro-Communications

Message from the Director, Prof. Takeo Fujii

The year 2023 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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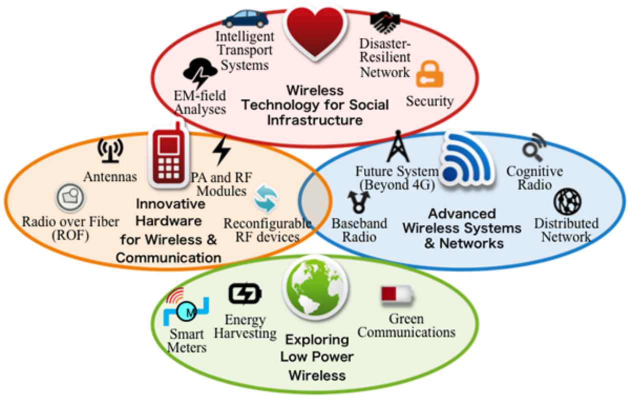
1 . ABOUT AWCC

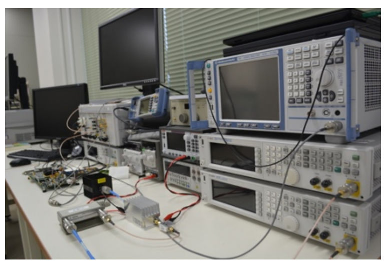
1.1 OVERVIEW



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

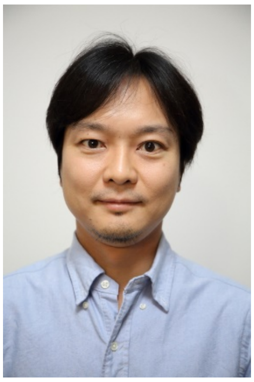
【Director, Full-time Prof. Takeo Fujii】

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 M.E. and Ph.D. degrees in electrical engineering from the University of Toyama, Toyama, Japan, in 2014 and 2017, respectively.

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 working as 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 body area network system. 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 a member of IEEE International Committee on Electromagnetic Safety TC95 and Co-Chair of Working Group

7 under Subcommittee 6 EMF Dosimetry Modeling established to study average schemes and assessment methods of absorbed power density. He is a senior member of URSI and a member of IEEE and 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 2023

[Observation Data and 3D Map-based Radio Environmental Recognition with Area Crassification] (Fujii Lab.)

In the next-generation mobile communication system, unmanned aerial vehicles (UAVs) are attracting attention. Especially drones are expected to become a new means of delivery and mobility. Since drones are controlled wirelessly, the safety of their communications must be assured. For this purpose, estimating the radio environment in a 3D space is necessary. Conventionally, radio maps have been proposed as a method for predicting the radio environment in 2D space, and kriging is effective for interpolation. In the 3D space, the map construction requires the division of the area because the surrounding environment differs greatly in the direction of altitude. In this study, we proposed a method for classifying propagation conditions based on 3D maps that record the topography and building geometry, and then interpolating and estimating the received power from the observed data based on these classifications. The system model of the estimation method is shown in Fig. 2.1-1. The UAV observes the radio environment in a portion of the flight area, and the database server performs interpolation estimation based on these observations.

From the result of the measurement campaign for the LTE base station, the proposed method reduced the RMSE (Root Mean Squared Error) between estimated values and observed values. Figure 2.1-2 shows the cumulative distribution function (CDF) of the RMSE when observations are randomly sampled from within the area to be estimated and kriging interpolation is performed. The 'all' and 'divide' in the legend indicate the case where kriging was performed over the entire range and the case where area division was performed, respectively. The numbers that follow indicate the number of sampled data (the total number of data in the estimated area is 120). When the number of data was 8, area dividing resulted in RMSE of 5.50[dB] or less in 90% of cases, an improvement of 1.59[dB] compared to 7.09[dB] in the case without dividing.

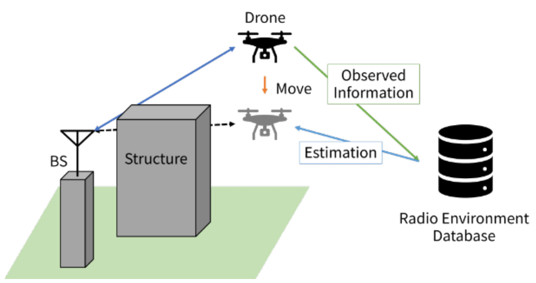


Fig. 2.1-1 System model.

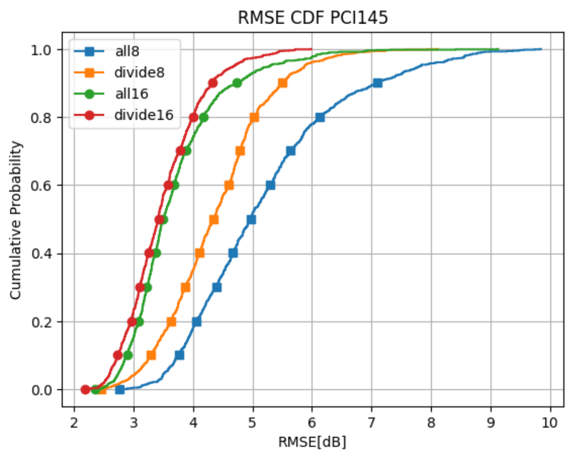


Fig. 2.1-2 RMSE distribution after 1,000 times interpolation iterations

[Throughput Prediction Using Channel Occupancy Rate and Communication Logs] (Fujii Lab.)

With the spread of 5G and Wi-Fi6, the demand of high speed high capacity communication using 5G and Wi-Fi6 increases. However, the increase in the number of wireless users leads to bandwidth shortage and radio frequency interference, which can significantly decrease their quality of service. Prediction of the wireless communication quality is important to avoid the decrease in their quality of service. It is known that the throughput value is useful as an evaluation index of wireless communication quality. Although there are some methods for predicting future throughput using past throughput values, these methods require constant measurement of throughput, which increases the traffic load and may reduce the quality of communication. Therefore, the method for predicting throughput without traffic load is required.

In this research, we estimate the throughput from communication logs of wireless terminals in wireless LAN communications. Specifically, we estimate throughput using the COR (Channel Occupancy Rate) and RSSI (Received Signal Strength Indicator) of the user's communication environment. Usually, as throughput increases, the amount of traffic through the channel increases, and COR becomes higher. The relation between the traffic through the channel and the COR is shown in Figure 2.1-4 and 2.1-4. We can understand that as traffic increases, the COR increases. The COR for each traffic is higher when the RSSI is -60 dBm than when the RSSI is -35 dBm. These results confirm the possibility that COR and RSSI can be used for throughput estimation in wireless LAN communications.

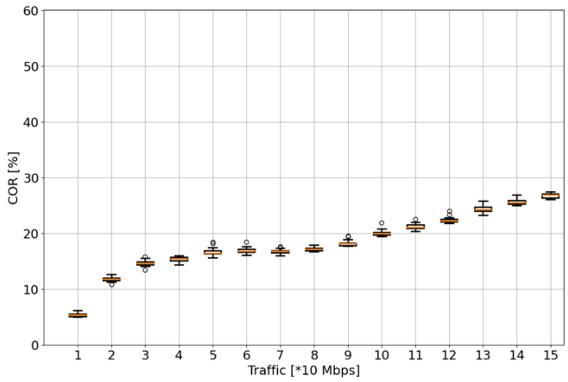


Fig.2.1-3 Relation between traffic and COR (Wi-Fi5, RSSI=-35 dBm).

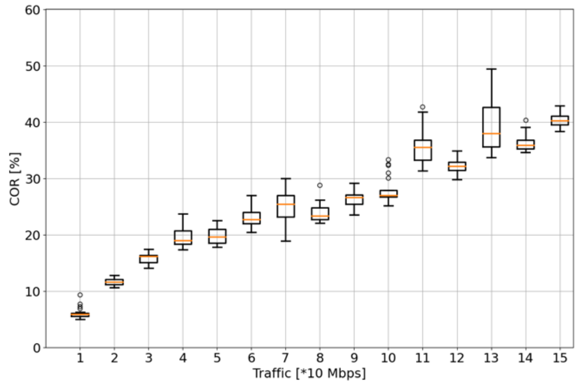


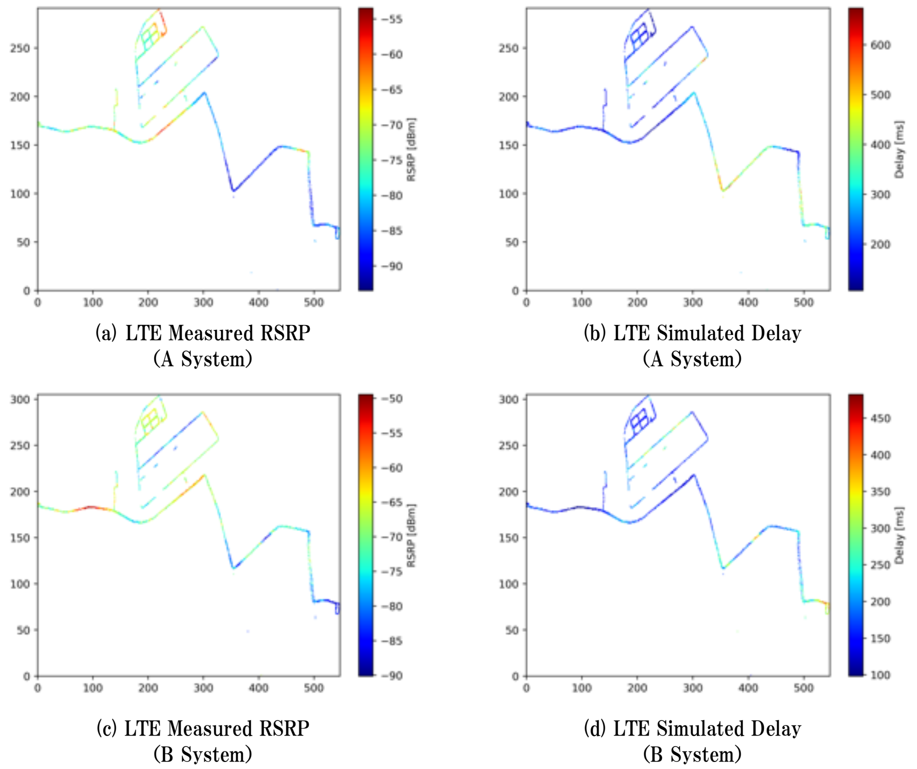
Fig.2.1-4 Relation between traffic and COR (Wi-Fi5, RSSI=-60 dBm).

【Cyber-Physical Integrated Emulator for Cooperative Automated Driving】(Suto Lab.)

Cooperative automated driving using vehicle-to-everything (V2X) communications is a promising solution for future transportation systems because it can improve the safety of driving by cooperative perception, i.e., collection of surrounding information that cannot be obtained by self-equipped sensors. However, the performance and accuracy of cooperative perception are affected by the quality of service (QoS) of V2X communications. Toward the promising transportation system, we developed a network emulator that accurately evaluates QoS using physical information collected from the real world. Specifically, our developed emulator has the following features:

1. Multi-modal traffic simulator is integrated into the network simulator to analyze the interdependency between vehicle mobility and V2X QoS.
2. Actual measurement data in the real world is incorporated to emulate site-specific wireless environments.
3. Any applications using V2X communications can be developed in the platform to emulator cooperative automated driving services, i.e., behavior arbitration, speed advisory, etc.

In this academic year, we developed the simulation platform that integrates the simulation of urban mobility (SUMO) and NS3. As shown Fig. Fig. 2.1-5, the simulator visualizes the spatial Statistics of V2X QoS such as delay and throughput by considering simulated vehicle traffic (corresponding data traffic). Further, by inputting physical radio environment information such as location of BS, channel knowledge and handover data, the simulator accurately estimates the V2X QoS.



(a) LTE Measured RSRP (A System)

(b) LTE Simulated Delay (A System)

(c) LTE Measured RSRP (B System)

(d) LTE Simulated Delay (B System)

Fig. 2.1-5 V2X performance simulated by integrated transportation and network simulators with measurement radio environment information.

【Deep Joint Source-Channel Coding for UAV Communications】(Suto Lab.)

Unmanned aerial vehicle (UAV) image transmission system is a key technology to support the future aerial social infrastructure such as logistics, measurement, construction, etc. Compared to the well-developed terrestrial network that support variety of applications, the UAV communications system can be designed by considering the use case of UAV. From the perspective, we design joint source-channel coding (JSCC) using deep neural network. By constructing source coding and channel coding in learning manner, the encoder can achieve more compression performance than the traditional communication system.

In this academic year, we addressed the specific challenge of UAV communications with physical limitation consideration, i.e., the reduction of peak to average power ratio (PAPR), robustness against frequency-selective and time-selective fading. As for PAPR issue, we designed a latent-feature-based semantic (LF-Semantic) filter that eliminates the zero-closed latent feature value to compress the baseband signal while reducing the PAPR. Based on the LF-Semantic filter, we further investigated the optimization of compression ratio to maximize the image quality under frequency-selective and time-selective fading effect. Fig. 2.1-6 shows the examples of image transmission with conventional deep JSCC and our proposal. Obviously, our proposal successfully decodes the accurate image compared to the conventional method.

Fig. 2.1-6 Example of image transmission, 1st row: conventional deep JSCC, 2nd row: proposal, 1st column: original image, 2nd column: SNR=5, 3rd column: SNR=15, 4th column: SNR=25.

[Physical Layer Security for Future IoT Systems] (Koji Ishibashi Lab.)

To protect information privacy in future IoT systems, several physical layer security (PLS) technologies have been proposed. During this academic year, we proposed an authentication method based on channel statistics and a rate splitting multiple access (RSMA) for secure communications.

Our proposed authentication method exploits spatio-temporal correlation features of multiple-input multiple-output (MIMO) channels. Particularly, spatial correlation and channel aging between two legitimate nodes are captured by the covariance matrix of consecutive channel estimates and then incorporated in the *Mahalanobis* distance allowing the detection of the impersonator's spoofing attack. Fig. 2.1-7 shows receiver operation characteristic (ROC). It can be observed that Mahalanobis distance has a higher detection probability than Euclidean distance (conventional) even when a lower false alarm probability is imposed.

We further proposed a precoder design for rate splitting multiple access (RSMA) downlink communication in the presence of both malicious users and an eavesdropper (Eve). While the conventional secure precoder designs for RSMA consider only malicious users or Eve, we proposed a novel precoder design against both Eve and malicious users. Fig. 2.1-8 shows the cumulative distribution functions (CDFs) of the mean data rates of users. The results confirm that the proposed approach achieves a higher feasible probability with at worst the same throughput as the conventional approach.

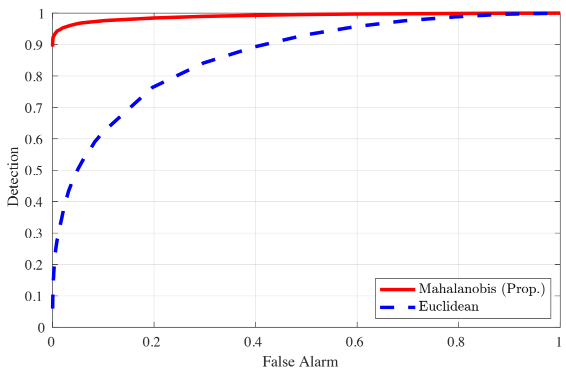


Fig. 2.1-7 ROC curves.

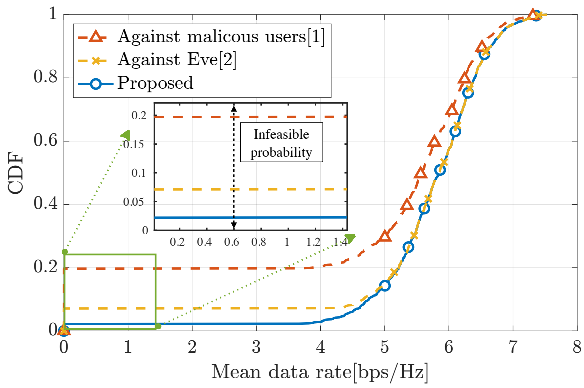


Fig. 2.1-8 CDFs of the mean data rates.

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

In order to reliably detonate the wireless electronic detonators embedded in the tunnel face within the specified delay time, a highly reliable communication link with the blasting device is essential. The wireless electronic detonator, currently being developed by NOF, uses the UHF band (920 MHz) from the operating device to the repeater, and from the repeater installed near the tunnel face to the detonators embedded in the bedrock, the LF band (250 kHz) wireless communication has been used. This ensures connectivity, delivers charging instructions, and transmits blasting information. Fig. 2.1-9 presents an example of measurement results from a mock blasting test in a mine shaft environment. At a certain separation distance between the LF-band loop antenna and the tunnel face, responses from all the wireless electronic detonators inside the rock were confirmed successfully. However, significant degradation in signal level has been observed when altering the detonator depth, which warrants further investigation through numerical simulation. Additionally, pulse signals at 920 MHz transmitted by the blasting device were detected at various repeater positions. The effects of repeater position, polarization, and line-of-sight (LoS) conditions have been analyzed. Subsequent empirical testing in actual tunnels has been carried out, including examining the high noise levels caused by heavy machinery such as high-power dust collectors and drilling equipment.

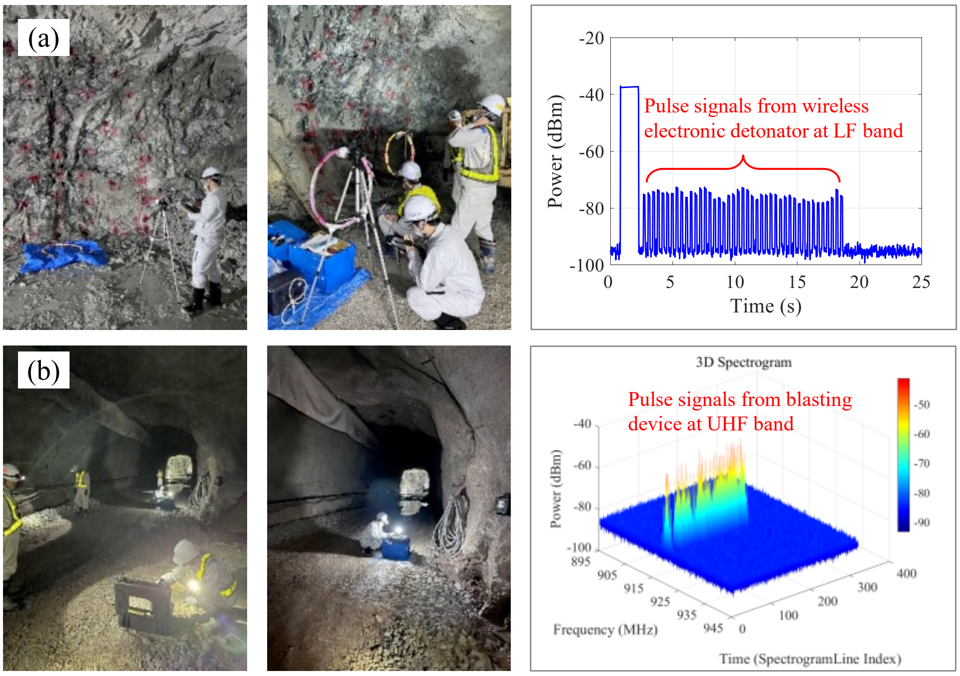


Fig. 2.1-9 LF and UHF band signals of wireless electronic detonator in mock blasting test.

2.1.4 Funds

【Commissioned Research】

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

   Takeo Fujii, Kun Li

2. METI Project on Research, Development, Demonstration and Deployment (RDD&D) of Autonomous Driving toward the Level 4 and its Enhanced Mobility Services (RoAD to the L4), "Harmonization and interoperability of V2V and V2P for deployment of L4 in mixed traffic environment

   Takeo Fujii, Katsuya Suto

3. JST EIG CONCERT Japan, "Organically Resilient and Secure Wireless Networks for Next-Generation IoT Technologies (ORACLE)"

   Koji Ishibashi

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

   Katsuya Suto

5. MIC SCOPE, "R&D on Digital-Twin Construction with mmWave UAV Mesh Networks"

   Katsuya Suto

【Cooperative Research】

1. TIS Inc., Celimuge Wu, Takeo Fujii, Katsuya Suto
2. NEC Corp. Takeo Fujii
3. Softbank Corp., Katsuya Suto
4. TOPPAN Holdings Inc., Takeo Fujii
5. Mitsubishi Research Institute Inc., Takeo Fujii

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

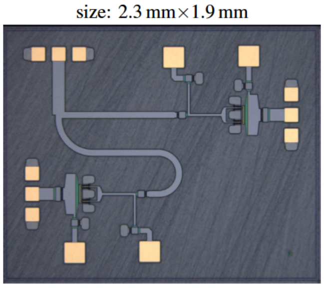
2.2.3 Major Research Outcomes in 2023

(A) [A 28-GHz-band Wide-dynamic-range GaN HEMT MMIC Outphasing Amplifier](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 fully integrated GaN HEMT outphasing amplifier has been developed at the 28-GHz band. Since the circuit configuration of an outphasing amplifier is usually complicated, in order to deal with load modulation, the efficiency characteristic is degraded by circuit insertion loss, especially at the millimeter-wave region. Thus, the circuit was carefully designed based on impedance optimization at both low- and high-output-power levels, considering the circuit loss by using a loss map created on a Smith chart. The fabricated GaN HEMT outphasing amplifier MMIC exhibited a maximum drain efficiency of 45% and a drain efficiency of 22% at 5 dB backoff at 28.5 GHz(Fig. 2.2.1).

size: 2.3 mm×1.9 mm



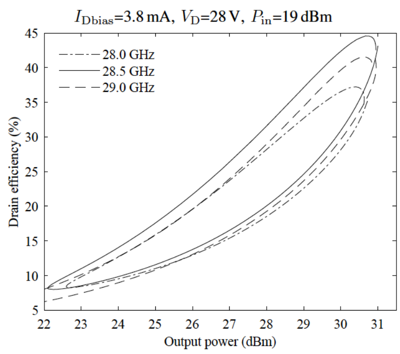


Fig. 2.2.1 Fabricated GaN HEMT outphasing power amplifier MMIC, and its characteristics

(B) [OAM Long-range Communication via Dielectric Lens Repeater] (Ishikawa Lab.)

We have demonstrated that the electro-magnetic wave propagation occurs with a single orbital angular momentum (OAM) mode when a current distribution of the azimuth angle ϕ-direction for a circular loop antenna conductor contains only one Fourier expansion coefficient. This condition almost retains at the loop-antenna conductor length of $n\lambda$ (n is the integer). As a common issue for the OAM communication, the directivity of the OAM waves is wide, especially for the loop antenna that has a small antenna aperture. Therefore, for a long-range communication, paraboloid reflectors are utilized for focusing the OAM waves.

Here, we have tried to extend the transmission distance by using a dielectric lens as a repeater. The location of the dielectric lens was investigated with simulated electric fields of each mode. From the investigation, for a dielectric lens with a diameter of 30 cm, the distance between the array and the lens was ideally estimated to be less than 90 cm. A 4-channel OAM multiplexing long-range communication test via lens in the 24 GHz band was carried out. As a result, the signal transmission and signal-to-interference ratio values for all modes were achieved as more than −22.6 dB and more than 21.2 dB, respectively, with a communication distance of 155 cm (Fig. 2.2.2).

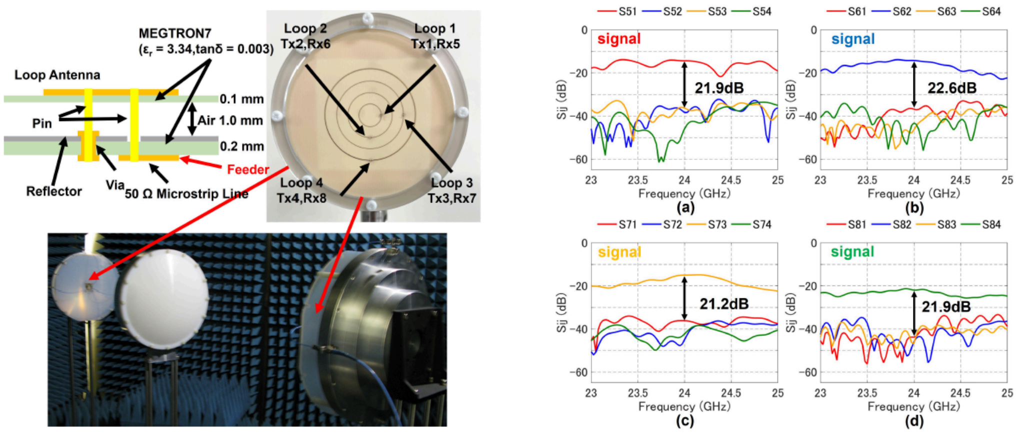


Fig. 2.2.2 Fabricated roop antenna system for 4-channel OAM multiplexing communication via lens, and its characteristics

(C) Photonic Digital to Analog Conversion Using Frequency Chirp in Semiconductor Optical Amplifiers (Matsuura Lab.)

In recent years, the development of communication technology has required more sophisticated data signal processing techniques. In particular, the demand for analog-to-digital conversions (ADCs) and digital-to-analog conversions (DACs) with higher operating speeds and resolutions has been rapidly increasing. However, it is currently difficult for electrical ADCs and DACs to achieve higher operating speed, because the performance is greatly limited by jitter limitation and resistive-capacitive delay of the electrical components. To overcome this problem, photonic ADCs and DACs, which achieve signal conversion in the optical domain, have attracted much attention. The use of semiconductor optical amplifiers (SOAs) provides numerous advantages such as a small footprint and monolithic integration ability for optical signal processing. In addition, compared to the conventional SOAs, quantum-dot SOAs (QD-SOAs) provide a faster gain recovery time and broader gain bandwidth, and improves the performance of optical signal processing applications.

In this year, we demonstrate a 4-bit, 40 Gb/s PDAC using frequency chirp in a QD-SOA, by optimizing the wavelength and power of the input binary data and clock signals, as well as the configuration of the PDAC for 40 Gb/s operation. We also evaluated the conversion performance in terms of differential and integral nonlinearities. To the best of our knowledge, this is the first experimental demonstration of 4-bit PDAC with high conversion performance at a bit rate of 40 Gb/s.

Fig. 2.2.3 (a) shows an example of the pulse train of the 40 Gb/s input binary data signal and converted 16-level (analog) data signal. It can be observed that the 20 Gb/s converted signal consists of a pulse train with each different pulse peak power corresponding to each 16-level data determined by the input binary data pattern, as shown in Fig. 2.2.3 (b). This indicates that a 4-bit conversion of 40 Gb/s was successfully achieved. Fig. 2.2.3 (c) shows the ideal (blue dotted line), actual (red solid line) step functions for the PDAC. The output pulse peak amplitude was normalized in 16 steps, and each one step corresponded to the smallest increment step of the PDAC output between two adjacent levels. Here, the ideal PDAC step is defined as 1 least significant bit (LSB). In this case, the function was close to the ideal step. The obtained results showed that the 4-bit, 40_Gb/s PDAC using blue frequency chirp had higher performance.

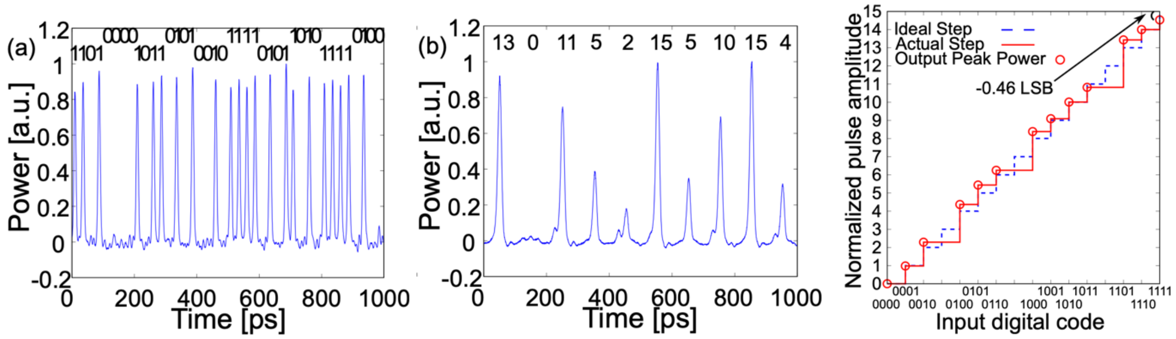


Fig. 2.2.3 Example of pulse train of 40 Gbit/s (a) input binary data signal and (b) converted 16-level data signal. (c) ideal and actual step function of PADC.

(C) [Wearable MIMO Antenna Design with High and Stable Channel Capacity] (Kun Li Lab.)

We developed a compact wearable multiple-input multiple-output (MIMO) antenna in collaboration with the University of Toyama and Jinlin University. This antenna maintains a high and stable channel capacity of over 20 bits/s/Hz in dynamic human off-body channels. The MIMO array comprises 4 miniaturized antenna elements, each operating at 2.45 GHz. The antenna element is connected to a compact microwave coupler, giving a wide power-tunable range exceeding 25 dB and a phase difference near 90 degrees. The design of the antenna and coupler facilitates optimal weighted-polarization power control, which effectively mitigates polarization mismatch due to variations in the cross-polarization power ratio (XPR) of incoming waves and the antenna's inclination angle during human arm-swing motion. The antenna radiation pattern concerning polarization control was measured in an anechoic chamber. In addition, a 4 × 4 MIMO channel capacity experiment was conducted using a 3D fading emulator with an arm-swinging human phantom. The measured results agree well with the simulated outcomes, both with and without the influence of the human body effects. These findings demonstrate that the proposed wearable antenna systems are well-integrated and consistently achieve a high and stable MIMO channel capacity of over 20 bits/s/Hz in a typical dynamic off-body channel.

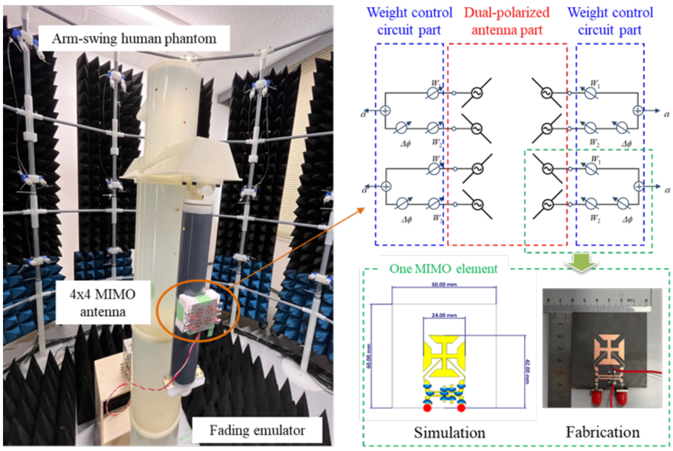


Fig. 2.2.4 Wearable MIMO antenna evaluation by OTA apparatus with a human phantom.

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

【Commissioned Research】

1. MIC, SCOPE, "Research and development of reconfigurable OAM spatial multiplexing antenna technology for massive multiple access wireless networks"
   R. Ishikawa, K. Honjo, A. Saitou

【Cooperative Research】

1. SoftBank Group Corp. "Low power consumption amplifier", R. Ishikawa
2. ROHM Co., Ltd. "High frequency measurement technique for GaN-HEMT", 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

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 Wireless Environment Visualization for Smart Factories] (Fujii Lab.)

To realize a smart factory that operates with a stable power supply and a cyber-physical system (CPS), wireless power transfer (WPT) and data transmission for the CPS must be performed simultaneously without interference. For the design of these simultaneous transmissions, it is important to accurately recognize the wireless environment. One of the methods for recognizing the environment is a radio environment map (REM), which visualizes the statistical results of measured received power and communication quality by linking them to location information. In this paper, we propose measuring the received power of local 5G (L5G) in a smart factory and constructing an indoor spectrum database. REMs were created from the constructed database and their accuracy was evaluated.

To construct an indoor spectrum database, we measured the reference signal received power (RSRP) of L5G in the factory environment. The REM created using the constructed indoor spectrum database is shown in Fig. 2.3-1. The average RSRP was used as the representative value for each mesh of the REM; the observation area in the LF is a 1[m]×1[m] mesh, and the BS of the L5G is located below the (15,3) mesh.

To verify the accuracy of the REM, the root mean square error (RMSE) was derived for each mesh and the entire REM. The RMSE for the entire REM was 1.26 [dB]. Fig. 2 shows the RMSE at each mesh. From Fig. 2.3-2, it can be seen that even at the worst value, the RMSE is kept below 3 [dB]. Thus, by constructing a REM, the wireless environment can be accurately determined even in a complex environment such as a factory.

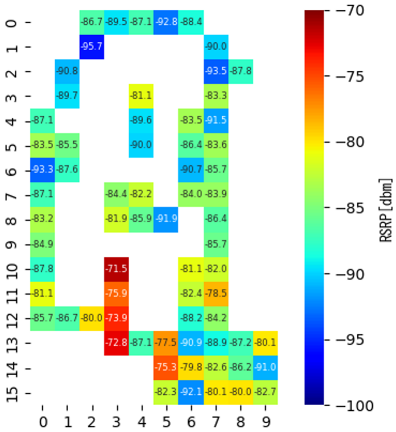


Fig. 2.3-1 RSRP Map of L5G.

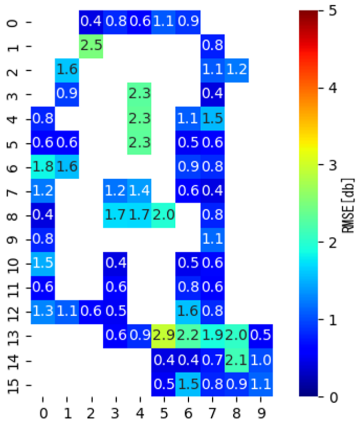


Fig. 2.3-2 RMSE of RSRP in each mesh.

[Indoor Positioning using BLE Beacons 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 proposes a method utilizes not only beacons, whose locations are known, but also the signals from UE whose locations are unknown.

Fig. 2.3-3 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 UE 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 are conducted at the factory, and position estimation is performed based on the observed values. The number of known beacons is 21 and the number of unknown UEs is 4. The results are compared between a method using 21 known beacons and 4 unknown UEs. The cumulative distribution function of the positioning error at each observation point is shown in Fig. 2.3-4. As a result, it can be confirmed that the proposed method reduces the positioning error.

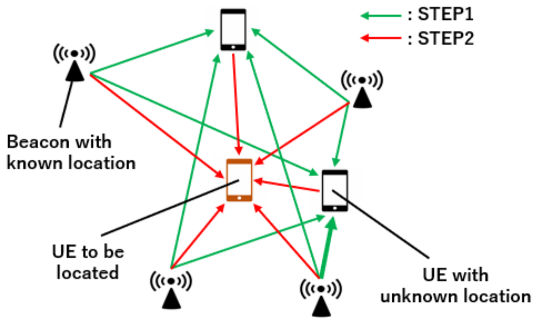


Fig. 2.3-3 System model.

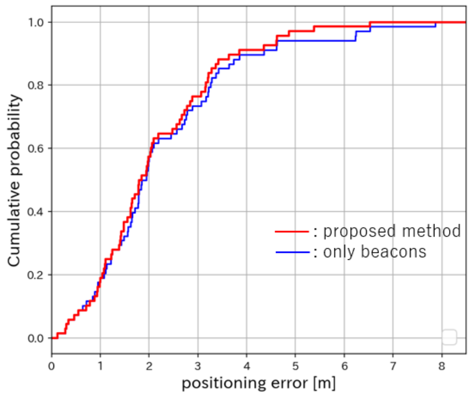
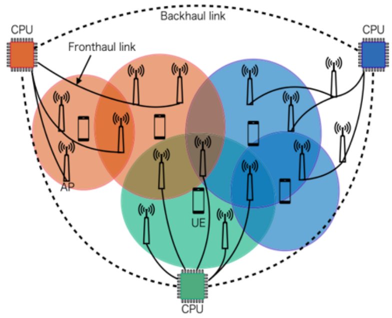


Fig. 2.3-4 positioni



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

Next-generation wireless communication systems *i.e.* Beyond 5G and 6G, are expected to accommodate a massive number of devices. To the end of realizing low-latency data transmission in the presence of a massive number of devices, designing multiple access schemes is crucial. As one of the promising techniques, grant-free non-orthogonal multiple access (GF-NOMA) has been actively studied. In GF-NOMA, the base station (BS) does not exclusively assign radio resources to active users for data transmission.

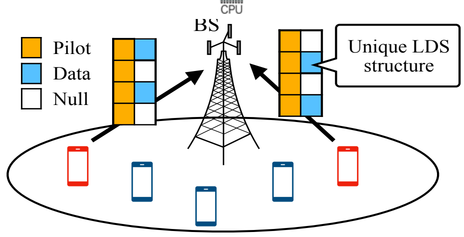
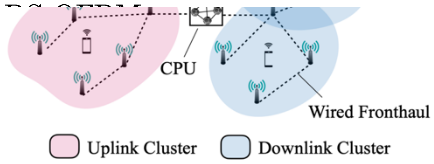


Fig. 2.3-5 GF-NOMA system based on



This academic year, 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 utilizes the LDS structure to improve the estimation accuracy of the active users, channel coefficients, and transmitted data. In this process, the LDS structure is exploited as the side information (SI) and utilized in the proposed SI-aided multiple measurement vector approximate message passing (MMV-AMP). Computer simulation confirms that our proposed scheme achieves better bit error rate performance than the conventional GF-NOMA system.

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

Cell-free massive multiple-input multiple-output (CF-mMIMO) system has attracted the research community and practitioners' attention as a potential key architecture for next-generation wireless communication systems such as beyond 5G and 6G. CF-mMIMO system can provide uniform quality of communication to all users' equipment (UEs) in the service area, through

Fig. 2.3.6 System model of multiple CPUs cell-free massive MIMO joint baseband signal processing at central processing units (CPUs) that connect distributed access points (APs) via fronthaul links. However, the implementation of CF-mMIMO faces serious challenges such as scalability and hardware limitations. It is in this regard that we present the following contributions.

First, we proposed joint design of beamformers and clusters for multiple-CPU CF-mMIMO under severe quantization noise due to backhaul link capacity limitation. The proposed joint design enhances the performance by leveraging the benefits of cooperation among CPUs (*see* Fig. 2.3.6). Likewise, we also proposed a low-complexity clustering and beamforming design for CF-mMIMO. The superiority of our proposed design method is illustrated through its comparison with conventional cellular systems.

Second, we proposed scalable network-assisted full-duplex (NAFD) CF-mMIMO system (*see* Fig. 2.3.7) that achieves high spectral efficiency (SE) while reducing the fronthaul load by forming exclusive AP-clusters for uplink and downlink based on each UE's requirements. We proposed clustering techniques based on convex optimization and Hungarian algorithm, along with downlink power control. Our proposed design outperforms conventional time division duplex (TDD) CF-mMIMO and dynamic TDD small cell system.

Fig. 2.3.7 System model of scalable network-assisted full-duplex cell-free

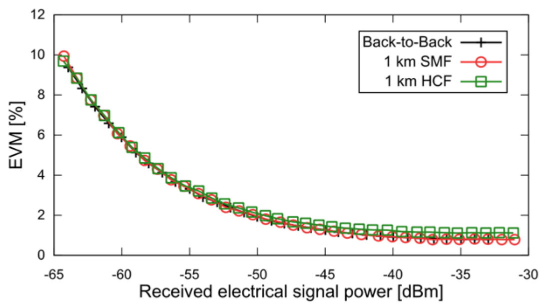
[Advanced Signal Processing Technologies for Millimeter-Wave Channels] (Koji Ishibashi Lab.)

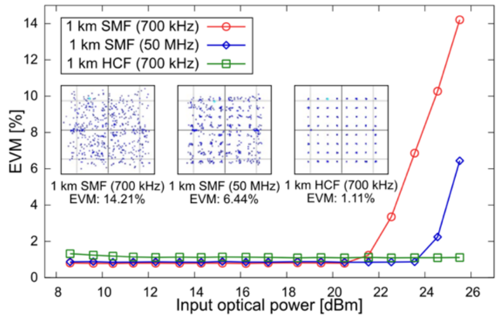
Millimeter-wave (mmWave) communications are expected to be foundations of beyond 5G and 6G wireless architectures. (1) Channel estimation, (2) channel tracking, and (3) beamforming techniques are necessary to compensate for severe signal attenuation by sharp beams based on channel state information (CSI) to focus the power to specific regions.

- For (1) channel estimation: conventional model-based approaches are adversely affected by array model errors such as mutual coupling, antenna gain/phase errors, and antenna spacing errors. To address this problem, we proposed a channel estimation algorithm that requires a small amount of pilot overheads thanks to the exploitation of arrays' error structures.
- For (2) channel tracking: the particle filter can update CSI accurately with few training overheads, leading to high spectral efficiencies. However, this approach requires a tremendous computational complexity for the Monte Carlo sampling process. To avoid Monte Carlo sampling, we proposed compressive-sensing-based channel tracking that exploits angle-domain sparsity in mmWave channels.
- For (3) beamforming: the corporative beamforming scheme overcomes random path blockages while minimizing sum-of-outage probability for channel capacity over mmWave-coordinated multi-point (CoMP) transmissions. However, this scheme considers the sum-of-outage probability only, leading to a significant sum data rate loss. Therefore, we proposed a new beamformer design based on regularized sum-of-outage minimization allowing a joint outage minimization and date rate maximization. The numerical results confirm that the proposed approach achieves higher sum data rates than the conventional one while maintaining comparable outage probabilities.

[High-Power Analog RoF Transmission Using Hollow-Core Fiber for Mobile Communications] (Matsuura Lab)

In optical fiber transmission systems, the transmission characteristics and applied technologies are significantly influenced by optical fibers. Silica-core optical fibers have played a crucial role in these systems. However, high-power optical signal transmission, particularly in single-mode fibers (SMFs), faces challenges due to nonlinear effects and power density limitations in the small core area. Hollow-core fibers (HCFs) feature an air core, providing various advantages such as ultra-low nonlinearity and low latency over conventional silica-core optical fibers. Although some results have been published on single-channel, digital transmission experiments using HCFs, no reports exist on high-power, multichannel transmission experiments involving actual A-RoF data signals, to the best of our knowledge. In this year, we demonstrate single- and four-channel transmissions with the A-RoF signal power exceeding 32 dBm using a 1-km HCF. To highlight its effectiveness, we conduct a comparative evaluation of transmission characteristics using conventional silica-core optical fibers with the same length. Our results show that both single-channel A-RoF transmission using the HCF achieve high transmission characteristics, even when the A-RoF signal power input to the HCF exceeds 25 dBm.





(a) (b) Fig. 2.3.8 (a) EVM characteristics as a function of (a) received electrical signal power and (b) input optical power in 1 km SMF and HCF transmissions.

Fig. 2.3.8(a) illustrates the EVM characteristics of one of the A-RoF signals of four-channel SMF and HCF transmissions as a function of received electrical signal power. In this experiment, the input A-RoF signal power to the test fibers and the PD was 20.03 dBm and 5.5 dBm, respectively. As the attenuation was reduced, and the received electrical signal power was increased, the EVM decreased in all cases. However, slightly larger EVMs were observed overall in the HCF link compared to the EVMs in the back-to-back and the SMF link at high electrical signal power levels. We attribute this to the higher chromatic dispersion and transmission loss of the HCF link. Figure 2.3.8(b) displays the EVM characteristics of the 1 km SMF and HCF transmissions while changing the input A-RoF signal power. The EVM of the SMF link rapidly increased when the input signal power surpassed 21 dBm, surpassing the SBS threshold of the SMF link. Subsequently, the EVM rose due to insufficient transmission power in the SMF link and increased ASE noise from the two-stage EDFA as the input power to the SMF link increased. In contrast, the HCF link maintained a small EVM, even at an input signal power of more than 25 dBm, indicating sustained high transmission characteristics without SBS during high-power A-RoF signal transmission. These findings suggest that the HCF link maintains high transmission characteristics in high-power A-RoF signal transmission.

[Hier-FedMeta: A Hierarchical Federated Meta-Learning Framework for Personalized and Efficient IoV Systems] (Celimuge Wu Lab)

The Internet of Vehicles (IoV) enhances smart city functionalities by interconnecting diverse components, yet it introduces significant challenges in terms of user privacy, communication efficiency, and energy consumption. Traditional federated learning frameworks, while adept at addressing these concerns, fall short in personalization due to heterogeneous data distributions among clients. To overcome this, we introduce Hier-FedMeta, a novel framework that combines hierarchical federated learning with meta-learning to provide tailored and efficient solutions. Hier-FedMeta contains a three-layer structure (Fig. 2.3.9 left), and its multi-layer architecture is very suitable for complex scenarios of multi-layer communications. Furthermore, we perform an in-depth analysis of the aggregation parameters, providing valuable insights into the optimization of hierarchical federated meta-learning architectures. As shown in the experimental results (Fig. 2.3.9 right), Hier-FedMeta achieves enhanced performance with minimal computational overhead as compared with exisitng baselines.

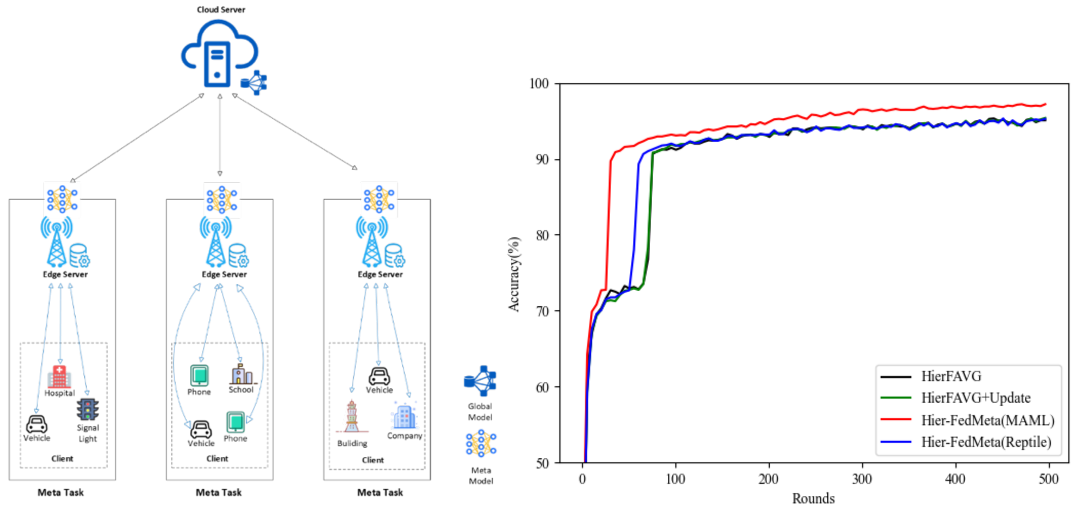


Fig. 2.3.9 Hier-FedMeta Framework and Experimental Results (left: three-layer structure of Hier-FedMeta; right: accuracy of four different algorithms trained for 500 rounds).

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

Low power wide area networks (LPWANs), including long-range wide area network (LoRaWAN), that enable long-distance communication with low-power consumption have been attracting attention along with the development of the Internet-of-Things (IoT). Carrier sensing (CS) is mandated before packet transmission in some regions and countries. However, the hidden node problem becomes more serious as the communication area becomes larger. Packet-level index modulation (PLIM) assigns indexes to the frequency channel and time slot of packet transmission to increase throughput. This study proposes a PLIM-based method to enable the gateway (GW) to obtain the sensing relationships among nodes without explicit signaling. The obtained information can be used for node clustering and resource allocation to alleviate the hidden terminal problem. Fig. 2.3.10 shows example of the spectral clustering results that the nodes in proximity are clustered in the same cluster, even though the location information of the node is unknown in the GW. For each simulation run, the shape of a cluster and the number of nodes within each cluster differ. However, the nodes close to each other are in the same cluster. Fig. 2.3.10 shows the computer simulation result of the Packet delivery rate (PDR) performance by up to 13% compared to the conventional method using PLIM. And can achieve a similar PDR performance as the situation where the inter-node distance is ideally known.

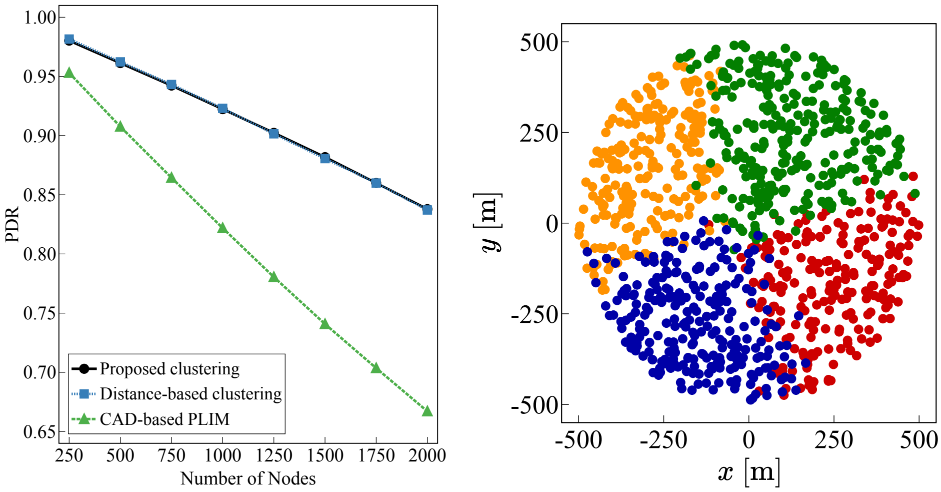


Fig. 2.3.10 PDR improvement of the proposed method against the conventional method and the results of clustering.

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

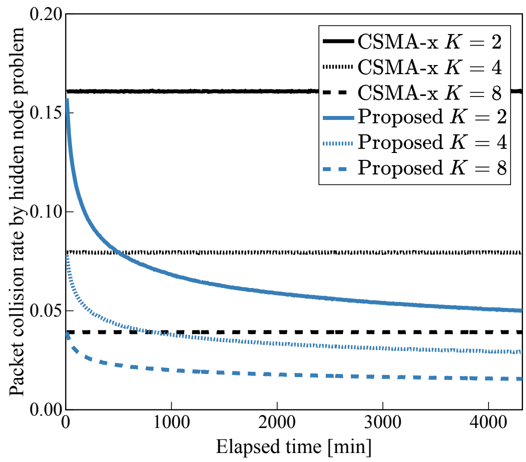


Figure 2.3.11. Packet collision rate by hidden node problem per number of frequency channels

Low-power wide-area networks (LPWANs) have recently attracted much attention from both industry and academia. In some LPWAN applications, periodic uplink (UL) traffic dominates the network traffic. Since LPWANs adopt pure ALOHA, continuous packet collisions may occur in the periodic UL traffic. Because of this background, listen-before-talk (LBT) based medium access control (MAC) has been studied as an alternative to ALOHA. The LBT scheme changes transmission timing based on the carrier sense (CS) result. When a node detects the signal by CS, the node can avoid radio resource conflict by probabilistically backoff the transmission timing. However, packet collisions frequently occur in LPWANs with large communication areas due to the hidden node problem.

Thus, this study proposes an autonomous distributed resource allocation scheme that utilizes the CS and UL traffic periodicity for the purpose of reducing packet collision rate by hidden node problem. In the proposed scheme, each node detects hidden nodes based on DL signals from the GW to cope with the hidden node problem. Since the DL signal from the GW generally reaches all nodes, the DL signal to the hidden node is more likely to be detected by the CS. If a node detects a DL signal by the CS, the node may be able to avoid packet collisions with hidden nodes by changing the wireless resources to be used. As shown in Fig. 2.3.11, the computer simulation results, the proposed scheme can reduce the packet collision rate by hidden node problem performance by up to about 15% compared to conventional LBT-based scheme (called CSMA-x).

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

Recently, low power wide area network) technology is expected to be applied to environmental monitoring and smart agriculture because it provides low power consumption and long-distance communications, compared to short-distance wireless communications technology like Zigbee, Bluetooth. However, LPWAN technology has its merits, it is also known to have characteristic of low data rate. We focused on LoRaWAN,it is one of the LPWAN technology, which has open source MAC layer and uses unlicensed bandwidth, and studied for LoRa PHY. The LoRa signal characterize the spreading factor (SF) as the carried amount of bits by one LoRa symbol. SF is an integer value, typically between 7 and 12. The signals with different SF are semi-orthogonal. We introduced fractional coefficient $0 \leq \rho < 1$ to increase the symbol length by the fractional coefficient, and studied the fractional spreading factor (FSF) used it. This new LoRa is named FSF-LoRa, and FSF-LoRa enables an increase in the number of usable channels, thereby increasing the overall throughput of the system. A demodulator for FSF-LoRa was designed and evaluated by computer simulation. In the simulations, we compared the throughput in the AWGN environment for the following three pairs: the pair used LoRa with SF=7 and FSF-LoRa with fractional coefficient $\rho = 0.25$ ($S_1 = \{(7, \rho = 0.25), 7\}$), the pair used normally system ($S_2 = \{7,8\}$), the same SF pair ($S_3 = \{7,7\}$). Fig. 2.3.12 shows improving throughput up to about 14% by multiplexing FSF-LoRa signal when the signal-to-noise-ratio (SNR) higher than -10[dB].

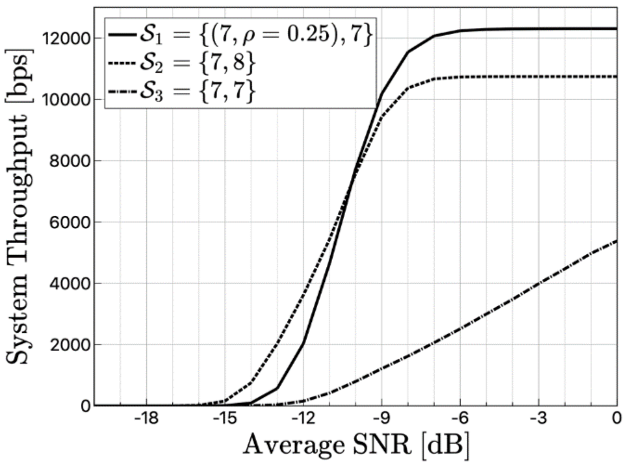


Fig.2.3.12. Throughput performance of the proposed FSF-LoRa

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

Intelligent reflecting surface (IRS) is a promising technology that can significantly improve the performance of wireless communications, by smartly control radio propagation path. Specifically, it is effective to improve the signal strength to non-line-of-sight (NLOS) area; however, the dynamic control of reflected signal is challenge due to the lack of signal processing at IRS. Therefore, we focus on vision-aided intelligent reflecting surface (Fig. 2.3-X). In the system, IRS detects the low-SNR area from vision information and create the optimal reflect path with phase shift control. As a first step, we develop a mathematical model to evaluate the achievable rate of vision-aided IRS under Rician fading environment with different IRS design, i.e., gain, spatial correlation between element, element density, etc (Fig. 2.3-13).

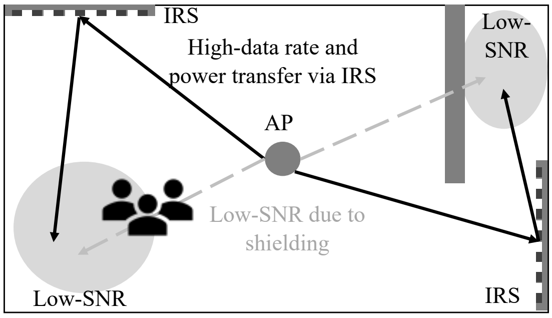


Fig. 2.3-13 Vision-aided IRS system, where IRS control phase-shift based on vision

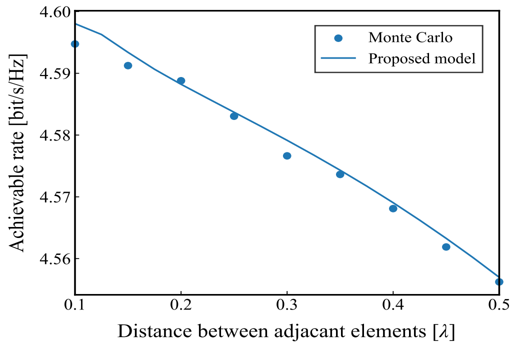


Fig. 2.3-13 The impact of element design on the achievable rate

2.3.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research B "Establishment of Cell-Free Network Architecture for User-Centric Communications"
   Koji Ishibashi
2. Scientific Research Fostering Joint International Research Type B "Simultaneous Wireless Information and Power Transfer with Intelligent Reflecting Surface"
   Katsuya Suto
3. Scientific Research B "Sensor Networks with High Speed Environmental Adaptation by Recognition of Synthesizing Wave"
   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 "Collaborative information processing platform for vehicular IoT based on federated learning"
   Celimuge Wu

【Commissioned Research】

1. MIC SCOPE "Research and Development of Advanced Wireless Environmental Information Sharing Sensor Networks"
   Koichi Adachi, Takeo Fujii (PI belongs to other organization)
2. NICT B5G "Research and Development of Integrated Information and Power Transfer

Systems for Private B5G/6G in Indoor Environments"
Koichi Adachi, Takeo Fujii

3. MIC "Research and development of advanced optical transmission technology that contributes to a green society"
Motoharu Matsuura
4. NICT B5G "Construction of a highly efficient wireless communication system using high power radio-over-fiber transmission"
Motoharu Matsuura
5. NICT JUNO3 "End-to-end network slicing and orchestration in future programmable converged wireless-optical networks"
Motoharu Matsuura
6. MIC SCOPE "Communication Cost Reduction and Reliability Improvement for AMR Autonomous Driving"
Celimuge Wu (PI belongs to other organization)
7. JST ASPIERE "Open Digital Infrastructure through the Convergence of Telecommunications and AI"
Celimuge Wu (PI belongs to other organization)

【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

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)

2.4.3 Major Research Results in 2023

[Fuzzy Logic-Enhanced Edge Server Selection Method for Hierarchical Federated Learning] (Celimuge Wu Lab.)

In the complex landscape of hierarchical federated learning (HFL) within the vehicular networks, ensuring efficient edge server selection is important due to the uncertain network conditions and server capabilities. Selecting the most suitable edge servers is critical for managing the computational demands and optimizing resource allocation in HFL tasks. To address this challenge, we introduce a fuzzy logic based approach for intelligent edge server selection, aimed at enhancing the overall efficiency and performance of the HFL system. By integrating this approach with our previously developed client selection scheme, we first select the optimal edge servers and then the appropriate clients, forming a complete and efficient architecture for HFL. The proposed method evaluates edge servers based on criteria such as Available Throughput (AT), Device Load (DL), and Computational Capability (CC), utilizing fuzzy logic to accommodate the unpredictable network environments. Our prototype system (Fig. 2.4-1 left) employs a setup with Raspberry Pis, mini PCs and laptops as federated learning clients, demonstrating the practical application of our method. Experimental results (Fig. 2.4-1 right) reveal the method's effectiveness in improving HFL accuracy compared to baseline methods. The proposed fuzzy logic based selection scheme thus exhibits a marked superiority, optimizing federated learning in IoT scenarios by intelligently navigating the challenges of edge server and client selection.

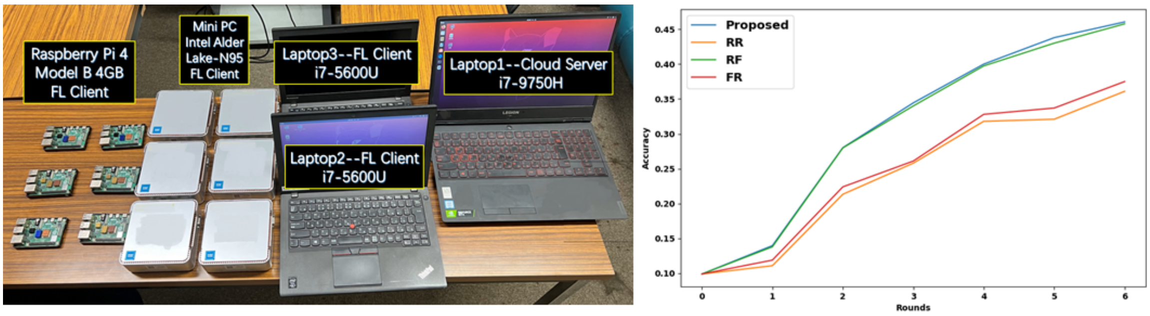


Fig. 2.4-1 Client Selection for FL (left: prototype system; right:. accuracy comparison between the proposed scheme and other baselines).

[Semantic Communication for Efficient Image Transmission Tasks based on Masked Autoencoders] (Celimuge Wu Lab.)

Semantic communication is emerging as a critical technology for 6G mobile communications due to its promise for high reliability, high spectrum efficiency, and its ability to meet the complex demands of future communication networks. This innovative approach focuses on extracting and transmitting the semantic features of information sources, offering a new paradigm that goes beyond the conventional methods guided by classical information theory. However, existing studies tend to focus more on image reconstruction rather than accurately transmitting semantic information at the pixel level. We design a semantic communication system for efficient image transmission tasks based on Masked Autoencoders. The proposed system compresses local information into low-dimensional latent vectors which can improve system efficiency. We also design a selective module for enhanced image reconstruction (Fig. 2.4-2 left) and implement Noise Adversarial Training to increase the system's resilience to channel noise. Experimental results (Fig. 2.4-2 right) show that our method effectively improves downstream tasks while preserving image quality.

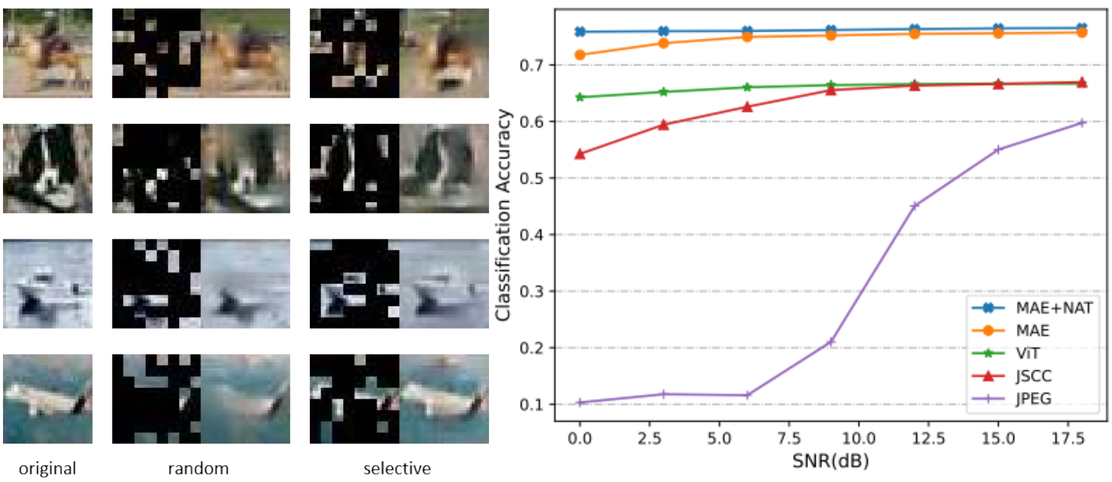


Fig. 2.4-2 Simulation Results (left: Reconstructed images versus mask sampling strategies; right: The classification accuracy between the proposed system and other baselines).

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

The abnormalities caused by disasters such as earthquakes tend to be localized. With this in mind, our proposed method assigns IDs with close Hamming distances to neighboring sensors. Each sensor transmits its ID to a gateway upon detecting an anomaly. The gateway then tries to detect multiple IDs from the collided received signals. Our proposed method demonstrates efficient detection by incorporating a total variation regularizer into Boolean compressed sensing.

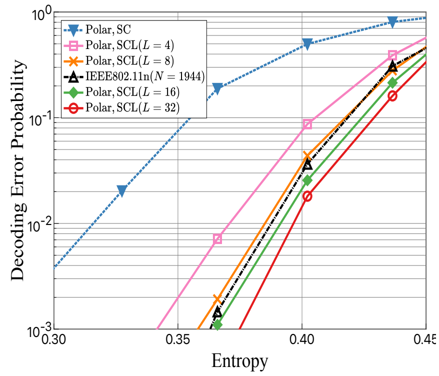


Fig. 2.4-3 Decoding performance

This fiscal year, we further discussed the design of polar codes for the Encryption-then-Compression (EtC) technique using density evolution. Figure 2.4-3 shows the decoding performance of the proposed EtC scheme with different list sizes. These results show that our proposed method exhibits lower decoding performance than conventional methods with LDPC codes design for IEEE802.11.

[Decentralized Learning Techniques for Pervasive Network Intelligence] (Suto Lab.)

Pervasive network intelligence is a concept that aims to distribute intelligence model throughout a network in order to autonomously, adaptability, efficiently recognize its state and make optimal decisions. In the system, artificial intelligence and machine learning for recoginition and decsion are also gradually trained to fit the network state. Therefore, we need to develop stable and decentralized learning tecniques.

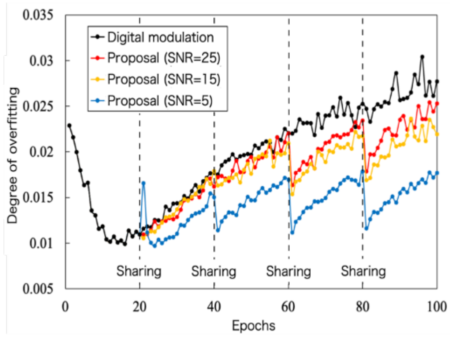


Fig. 2.4-4 Overfitting progress

In this academic year, we desing a novel distibuted federated learning techniques that utilizes the deep joint-source channel coding for model sharing. Deep joint-source channel coding has benn recoginized as efficient communicaiton system for image transfer; however, it can not provide bit-level accurate communications due to the impact of channel noise. Our proposal focus on the characteristic of channel noise. Assuming the channel noise follows the gaussian distribution, the noise make the AI model robust to overfitting. As shown in Figure 2.4-4, we confirm that the proposal ahicves high stability on overfitting.

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

The rapid development and popularization of Internet-of-Things (IoT) technologies have driven demand for low-power wide-area networks (LPWANs) for years. Long range wide area network (LoRaWAN), which enables long-distance communications with low power consumption, has increased in recent years. Although LoRaWAN is capable of low-power long-distance communication, its data rate is low. Most existing research works focus on increasing the data rate of a single device. However, from the viewpoint of LPWAN applications, it is desirable to accommodate a number of devices with a low data rate. This study aims to increase the system data rate by dividing the chirp index space into orthogonal subspaces and allocating nonoverlapping subspaces to multiple devices, enabling simultaneous transmission from multiple devices. Set the chirp index used by the terminal as shown in Fig. 2.4-5. With the allocation shown in this figure, each device in each group can transmit 2 SF-5 bits in one symbol time. Each signal is orthogonal and can be demodulated. In addition, in order to demodulate the multiple signals transmitted on the distinct chirp index subspace, it is necessary to understand the receive timing difference between the multiple signals received at GW. In this study, we also propose a method to estimate the receive timing difference at GW using the preamble sent by LoRa devices. We confirmed the usefulness of the proposed method by computer simulation. Figure 2.4-6 shows the throughput performance of the proposed method and conventional LoRa modulation. The proposed method randomly selects the arrival timing difference between two signals from $\tau \in \{-31, \cdots, 31\}$. For performance evaluation, the throughput performance of the conventional LoRa with a single device is plotted. The figure shows that the proposed method improves the system data rate by up to 175% compared to the conventional LoRa system.

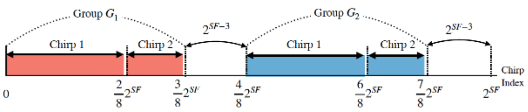


Fig. 2.4-5. Example of chirp index partitioning for two users.

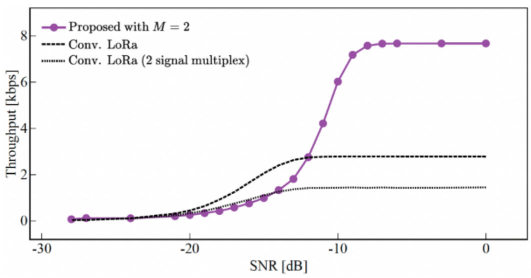


Fig. 2.4-6. Throughput performance of the proposed method compared to the conventional LoRa.

[Packet Reception Utilizing Multi-Antenna Beamforming in IRDT Protocol] (Fujii Lab.)

Wireless sensor networks (WSNs) are utilized to collect data packets containing environmental information from sensor nodes (SNs) to aggregation stations like concentrators. Low Power Wide Area (LPWA) is often utilized in WSNs to reduce the power consumption of SNs. LPWA enables low-power and long-range communications. However, even with LPWA networks, the deployment of more concentrators to receive data packets from enormous SNs placed in a large area is unavoidable, resulting in a high deployment cost. In that case, beamforming would be a useful method, which provides array gain and suppresses interference power by directional signal transmission or reception. Besides the use of beamforming, reducing the power consumption of SNs is a critical concern. One potential solution is intermittent communication, such as the intermittent receiver-driven data transmission (IRDT) protocol. Therefore, this study proposes a packet reception method utilizing digital beamforming based on the IRDT protocol.

Fig. 2.4-7 shows the system model. In our proposed system, we deploy a concentrator equipped with an array antenna for digital beamforming, which employs beam sweeping during downlink beacon called request number (RNO) transmission to mitigate collisions of send request (SREQ) packets from SNs. Furthermore, we utilize multiple digital reception beams in parallel, allowing for the simultaneous decoding of multiple packets in uplink transmission.

To evaluate the proposed method, computer simulations were executed using the C language. In Fig. 2.4-8, "Omnidirectional" is a previous method using an omnidirectional antenna at the concentrator. Fig. 2.4-8 shows that the proposed method achieved better PDR than the previous method. This is because interference due to hidden SNs is suppressed and simultaneous reception is achieved by the parallel processing. Therefore, the superiority of digital beamforming appears.

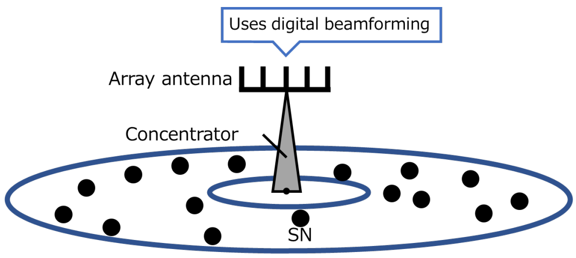


Fig. 2.4-7 System model.

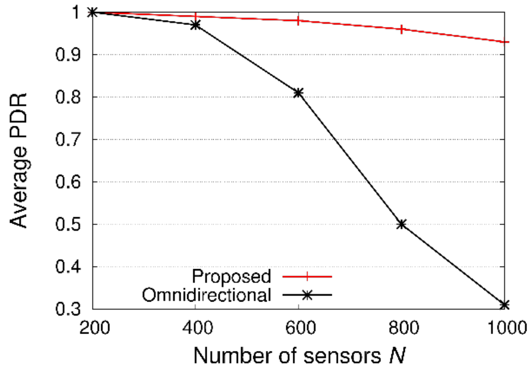


Fig. 2.4-8 Average PDR.

2.4.4 Funds

【Grants-in-Aid for Scientific Research】

1. Scientific Research C "Chirp Index Partitioning for Efficient Data Gathering in IoT",
   Koichi Adachi (PI)
2. Scientific Research A "Researches on Model-aided Learning Approaches for Reliable Realtime Control in Future Wireless Systems"
   Celimuge Wu (PI belongs to other organization)

【Commissioned Research】

1. JST AdCORP "Green IoT"
   Koji Ishibashi (PI belongs to other organization)
2. JST Aspire, "Resilient Cyberspace Generative Framework with Communication, Sensing and Learning Integration"
   Katsuya Suto (PI)
3. MIC SCOPE, "Ultra Wide Area and Interference Tolerance Sub-GHz Wireless Sensor Network on Mixed Environment of Multiple Systems"

Takeo Fujii

4. MIC SCOPE, “Layer-integrated Communication Control for Efficient Spectrum Utilizations”

   Takeo Fujii

【Cooperative Research】

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

４．令和５年度　外部発表リスト

著書

なし

査読付き一般論文

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【2】 Jiantao Yuan、Zheyi Wu、Rui Yin、Guangzhe Zhao、Xianfu Chen、and Celimuge Wu、“An Optimal Distributed Energy-Efficient Resource Scheduling for D2D-U Enabled Cellular Networks”、IEEE Trans. Cogn. Commun. Netw.、vol.9、no.4、pp.1053-1066、Apr. 2023.

【3】 Yuma Katsuki、Giuseppe Thadeu Freitas de Abreu、Koji Ishibashi and Naoki Ishikawa、“Noncoherent Massive MIMO With Embedded One-Way Function Physical Layer Security”、IEEE Trans. Inf. Forensics and Secur.、vol. 18、pp. 3158-3170、May 2023.

【4】 Takumi Takahashi、Hiroki Iimori、Keigo Ando、Koji Ishibashi、Shinsuke Ibi、and Giuseppe Thadeu Freitas de Abreu、“Bayesian Receiver Design via Bilinear Inference for Cell-Free Massive MIMO with Low-Resolution ADCs”、IEEE Trans. Wireless Commun.、vol. 22、no. 7、pp. 4756-4772、Jul. 2023.

【5】 Shusuke Narieda and Takeo Fujii、“Energy Detection Based Carrier Sense in LPWAN”、IEEE Access、vol.11、pp.79105-79119、Jul. 2023.、doi: 10.1109/ACCESS.2023.3299219.

【6】 Sota Uchimura、Hiroki Iimori、Giuseppe Thadeu Freitas de Abreu and Koji Ishibashi、“Outage-Minimization Coordinated Multi-Point for Millimeter-Wave OFDM with Random Blockages”、IEEE Trans. Veh. Technol.、vol. 72、no. 7、pp. 8783-8796、Jul. 2023.

【7】 Yangfei Lin、Celimuge Wu、Jiale Wu、Lei Zhong、Xianfu Chen、and Yusheng Ji、“Meta-Networking: Beyond the Shannon Limit with Multi-faceted Information”、IEEE Network、vol.37、no.4、pp.256-264、Jul./Aug. 2023.

【8】 Kosei Tanii and Koji Wada、“Planar Quadruplexer with Adjacent Passbands Using BandpassFilters Based on Dual-path Hairpin Resonators”、Transactions of The Japan Institute of Electronics Packaging、16、pp. E22-006-1-E22-006-8、Aug. 2023.

【9】 Weiyu Zhou、Koji Wada、and Kenichi Ohta、“The Design Method of Compact

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【10】 Ying Ju、Guoxue Zou、Haowen Bai、Lei Liu、Qingqi Pei、Celimuge Wu、and Sattam Al Otaibi、“Random Beam Switching: A Physical Layer Key Generation Approach to Safeguard mmWave Electronic Devices”、IEEE Trans. Consum. Electron.、vol.69、no.3、pp.594-607、Aug. 2023.

【11】 Rui Yin、Xiao Lu、Chao Chen、Xianfu Chen、and Celimuge Wu、“Distributed Resource Management in Unlicensed Assisted Mobile Edge Computing”、IEEE Internet Things J.、vol.10、no.23、pp.20662-20674、Aug. 2023.

【12】 Ryota Kumada and Koichi Adachi、“Interference Cancellation for Coexistence of LoRaWAN with Wireless Power Transfer”、IEEE Internet Things J.、vol.10、no.15、pp.13109-13122、Aug. 2023、DOI: 10.1109/JIOT.2023.3259472.

【13】 Etsuko Ijima、Kun Li、Takashi Hikage、Akiko Nagai、Murakami Yasutaka、Arima Takuji、Ishitake Tatsuya、and Hiroshi Masuda、“Intensity-dependent temperature rise induced by local exposure to 26.5 GHz quasi-millimeter-wave in rat”、in vivo、vol.37、no.5、pp.2092-2099、Sep. 2023.

【14】 Weiyu Zhou and Koji Wada、“A New SIDGS-Based Tunable BPF Design Method with Controllable Bandwidth”、IEICE Trans. Electron.、vol.E106-C、no.10、pp.614-622、Oct. 2023.

【15】 Kun Li、Takashi Hikage、Hiroshi Masuda、Etsuko Ijima、Akiko Nagai、and Kenji Taguchi、“Parameter variation effects on millimeter wave dosimetry based on precise skin thickness in real rats”、Scientific Reports、vol.13、Oct. 2023、Art. no. 17397.

【16】 Ming Yao、Stanislav Stefanov Zhekov、Bo Xu、Kun Li、and Shuai Zhang、“A Study on Exposure to Electromagnetic Fields From User Equipment Antennas above 100 GHz”、IEEE Trans. Electromagn. Compat、vol.65、no.5、pp.1292-1299、Oct. 2023.

【17】 Shuo Yang、Xiaolong Wang、Lei Zhu、Xin Gao、Kun Li、Valerii Shulga、and Geyu Lu、“A Novel Ring Type Power Divider With Arbitrary Power Division、Arbitrary Phase Difference and Controllable Bandwidths”、AEU - International Journal of Electronics and Communications、vol.170、no.7、pp.154773、Oct. 2023.

【18】 Jingjing Bao、Celimuge Wu、Yangfei Lin、Lei Zhong、Xianfu Chen、and Rui Yin、“A scalable approach to optimize traffic signal control with federated reinforcement learning”、Scientific Reports、vol.13、Article number:19184、https://doi.org/10.1038/s41598-023-46074-3、Nov. 2023.

【19】 Guangji Chen、Qingqing Wu、Celimuge Wu、Mengnan Jian、Yijian Chen、Wen、"Static IRS Meets Distributed MIMO: A New Architecture for Dynamic Beamforming"、IEEE Wireless Commun. Lett.、vol.12、no.11、pp.1866-1870、Nov. 2023.

【20】 Jie Feng、Liu Lei、Xiangwang Hou、Qingqi Pei、and Celimuge Wu、"QoE Fairness Resource Allocation in Digital Twin-Enabled Wireless Virtual Reality Systems"、IEEE J. Sel. Areas Commun.、vol.41、no.11、pp.3355-3368、Nov. 2023.

【21】 Bin Li、Zhen Qian、Lei Liu、Yuan Wu、Dapeng Lan、and Celimuge Wu、"Computation Offloading for Edge Computing in RIS-Assisted Symbiotic Radio Systems"、 IEEE Trans. Netw. Sci. Eng.、vol.10、no.6、pp.4033-4045、Nov.-Dec. 2023.

【22】 Masaaki Ito、Shuto Fukue、Keigo Ando、Issei Kanno、Kosuke Yamazaki、and Koji Ishibashi、"Clustering and Beamforming for User-Centric Cell-Free Massive MIMO With Backhaul Capacity Limitation"、IEEE Access、vol. 12、pp. 382-395、Dec. 2023.

【23】 Jingwei Liu、Yue Fan、Rong Sun、Lei Liu、Celimuge Wu、Shahid Mumtaz、"Blockchain-Aided Privacy-Preserving Medical Data Sharing Scheme for E-Healthcare System"、IEEE Internet Things J.、vol.10、no.24、pp.21377-21388、Dec. 2023.

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【26】 Kun Li、Sachiko Kodera、Dragan Poljak、Yinliang Diao、Kensuke Sasaki、Shuai Zhang、Ming Yao、Ante Lojic Kapetanovic、Congsheng Li、Tongning Wu、Thorsten Liebig、Winfried Simon、and Akimasa Hirata、"Spatially Averaged Epithelial/Absorbed Power Density for Non-Planar Skin Models Exposed to Antenna at 10–90 GHz"、IEEE Access、vol. 12、pp. 15379-15389、Jan. 2024.

【27】 Yujie Song、Yue Cao、Yingzhe Hou、Bo Cai、Celimuge Wu、and Zhili Sun、"A Channel Perceiving-based Handover Management in Space-ground Integrated Information Network"、IEEE Trans. Netw. Serv. Manag.、vol.21、 no.1、pp.882-896、Feb. 2024.

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査読付き国際会議プロシーディングス等

【1】 Yuya Yaguchi、Suguru Fujita、Shih-Chun Lin、Suresh Subramaniam、Hiroshi Hasegawa、Motoharu Matsuura、“Evaluation of response time of power-over-fiber for dynamic power control of remote antenna units in mobile networks”、in Proc. The 5th Optical Wireless and Fiber Power Transmission Conference (OWPT 2023)、OWPTp-01、Yokohama、Apr. 2023.

【2】 Jiaxin Song、Ying Ju、Lei Liu、Qingqi Pei、Celimuge Wu、Mian Ahmad Jan、and Shahid Mumtaz、“Trustworthy and Load-Balancing Routing Scheme for Satellite Services with Multi-Agent DRL”、in Proc. IEEE INFOCOM 2023 Workshop on AI-Driven Trustworthy、Secure、and Privacy-Preserving Computing (AidTSP 2023)、6 pages、New York area、USA、May 2023.

【3】 Zhenyu Wang、Tianheng Xu、Xianfu Chen、Ting Zhou、Honglin Hu、and Celimuge Wu、“Enhance Detection of SSVEPs through a Sinusoidal-Referenced Task-Related Component Analysis Method”、in Proc. IEEE INFOCOM 2023 Workshop on Pervasive Network Intelligence for 6G Networks (PerAI-6G)、6 pages、New York area、USA、May 2023.

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【6】 Kaito Sugimura、Takashi Hikage、Hiroshi Masuda、Tatsuya Ishitake、Kun Li、and Akiko Nagai、“Development of a 60 GHz Band Lens Antenna for The Study of Thermo- physiological and Cellular Function Changes Induced by Millimeter-wave Exposure”、The Joint Annual Meeting of The Bioelectromagnetics Society and the European BioElectromagnetics Association (BioEM2023)、Oxford、England、Jun. 2023.

【7】 Masaaki Miura、Katsuya Suto、Koya Sato、and Onel Luis Alcaraz López、“Performance Analysis for IRS-Assisted SWIPT with Optimal Phase Shift under Spatially Correlated Fading Channels”、in Proc. IEEE 97th Vehicular

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シンポジウム講演

【1】 石川亮、“準ミリ波帯動作アウトフェージング増幅器の研究開発”、Microwave Workshops & Exhibition (MWE 2023)、TH6A-1、2023 年 11 月

【2】 稲田仁美、伊地智幸一、北畠秀俊、柳幸喜、鹿志村修、藤野義之、三谷友彦、小嶋浩嗣、栗田怜、石川亮、石村康生、熊本篤志、宮崎康行、阿部琢美、田中孝治、“超長距離無線送電のための宇宙実験に関するミッション検討”、第 9 回宇宙太陽発電(SSPS)シンポジウム、2023 年 12 月

その他の講演

【1】 石橋功至、"Beyond 5G/6G に向けたミリ波通信設計"、KKE 無線通信セミナー、2023 年 7 月

【1】 和田光司、"広帯域フィルタとその分波器への応用"、MWE2023 ワークショッププログラム　広帯域マイクロ波フィルタの設計入門基礎講座 MWE2023 WE6B-1、2023 年 11 月 29 日

【2】 李鯤、"電波ばく露評価方法に関する研究"、IEICE 東京支部学生会講演会, 2023 年 12 月 2 日

【3】 Katsuya Suto、"Deep Learning and Its Applications to Radio Map Construction (Keynote)"、The 5th ASEAN – UEC Workshop on Informatics and Engineering、2023 年 9 月

受賞

【1】 Exemplary Editor of the IEEE Transactions on Green Communications & Networking、IEEE Communications Society、May 2023.

【2】 2023 年 5 月 26 日 内村颯汰 2022 年度 IEICE 無線通信システム（RCS）研究会活動奨励賞

【3】 2023 年 6 月 16 日 奥井滉史 2023 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

【4】 2023 年 9 月 5 日 内村颯汰 情報理論とその応用サブソサイエティ若手研究者論文賞

【5】 2023 年 9 月 13 日 石橋功至 電子情報通信学会通信ソサイエティ活動功労賞

【6】 2023 年 9 月 13 日 石橋功至 電子情報通信学会基礎・境界ソサイエティ 編集活動感謝状

【7】 2023 年度 PN 研学生奨励賞(杉浦宗弥、村上夏尉、松浦基晴、高木武史、武笠和則、"空孔コアファイバにおける非線形光学現象の観測、"信学ソ大、B-12-14、2023 年.)

【8】 2023 年度 PN 研学生奨励賞(久野拓真、落合匠郎、樋口怜治、佐竹風人、森洋二郎、Shih-Chun Lin、松浦基晴、Suresh Subramaniam、長谷川浩、"4.71Pbps スループットを実現する空間・波長ハイブリッド型光クロスコネクトのマルチバンド伝送実験、"信学ソ大、B-12-8、2023 年)

【9】 2023 年 9 月 26 日 石橋功至 KDDI Foundation Award 2023 業績賞

【10】 2023 年 10 月 10 日 奥井滉史 IEEE VTS Tokyo/Japan Chapter 2023 Young Researcher's Encouragement Award

【11】 2023 年 10 月 10 日 荒井甲 IEEE VTS Tokyo/Japan Chapter 2023 Student Paper Award

【12】 2023 年 11 月 7 日 石橋功至 電子情報通信学会 信号処理研究専門委員会 信号処理特別功労賞

【13】 2023 年 11 月 21 日 三輪健太 WPMC2023 Student Travel Grant

【14】 2023 年 11 月 21 日 三輪健太，安藤研吾，アブレウ・ジュゼッペ，石橋功至 WPMC2023 Best Paper Award

【15】 成島章太 2023 年度回路とシステム研究会学生優秀賞 ，2024 年 1 月（和田研学生・博士前期課程学生）

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【17】 2024 年 8 月 棚木拓海 IEEE APWCS 2024 IEEE VTS Japan/Tokyo Chapter Young Researcher's Encouragement Award

【18】 2024年1月 坂本陽向 電子情報通信学会無線通信システム研究専門委員会「初年度発表者コンペティション」優秀発表賞

【19】 2024 年 3 月 5 日 燕木碧仁 電子情報通信学会 学術奨励賞

【20】 2024 年 2 月 13 日 上田康平 令和 5 年度 修士論文発表会 優秀発表賞

【21】 2024 年 2 月 19 日 見戸悠弥 令和 5 年度 卒業研究発表会 優秀発表賞

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【23】 2024 年 3 月 21 日 内村颯汰 第 39 回電気通信普及財団賞テレコムシステム技術学生賞

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【25】 2024 年 3 月 25 日 三輪健太 令和 5 年度 学生表彰

【26】 2024 年 3 月 25 日 奥井滉史 令和 5 年度 学生表彰

【27】 2024 年 3 月 25 日 内村颯汰 令和 5 年度 学生表彰

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【29】 小林大輝、2023 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

【30】 2023 年度 PN 若手研究賞(村上夏尉、杉浦宗弥、松浦基晴、高木武史、武笠和則、"空孔コアファイバを使用したマルチチャネル大電力 A-RoF 伝送、"電子情報通信学会フォトニックネットワーク研究会、PN2023-72、2023 年.)

【31】 谷井竜義，令和 5 年度卒業論文優秀発表賞，2024 年 3 月（和田研・学域生）

【32】 根本重法，令和 5 年度卒業論文優秀発表賞，2024 年 3 月（和田研・学域生）

特許

【1】 JP Patent 特願 2023-171051、通信システム、コンセントレータおよび通信方法、齋藤慶悟、藤井威生、石橋功至、柴田悠宇、遠藤秀樹、土岐爽真、2023 年 10 月 2 日

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【3】 高山洋一郎、本城和彦、石川亮、“マルチバンド増幅器およびデュアルバンド増幅器”、韓国、登録番号：10-2602394、2023 年 11 月 10 日

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【5】 K. Arai、K. Ishibashi、H. Iimori、P. Klaine and S. Malomsoky、No. PCT/EP2024/051728、Jan. 25、2024.

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【9】 齊藤稜弥、安達宏一、藤井威生、「復調器、復調方法及び復調プログラム」、日本国、特願 2024-053888、2024 年 3 月 28 日

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【3】 世界初！Beyond 5G/6G に向けて、ミリ波帯での多数同時接続と超低遅延の同時実現に成功、時事ドットコム、2023 年 5 月 25 日

【4】 構造計画研究所と電気通信大学、ミリ波帯での多数同時接続と超低遅延の同時実現に成功、IoT News、2023 年 5 月 25 日

【5】 構造計画研究所と電通大がミリ波帯の新通信技術を実証、ロボット制御に活用、日経クロステック、2023 年 6 月 7 日

【6】 構造計画研究所、ミリ波帯の新通信技術　ロボ制御に、日経テックフォーサイト、2023 年 6 月 7 日

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