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Wireless Research Customer Stories

5th Edition

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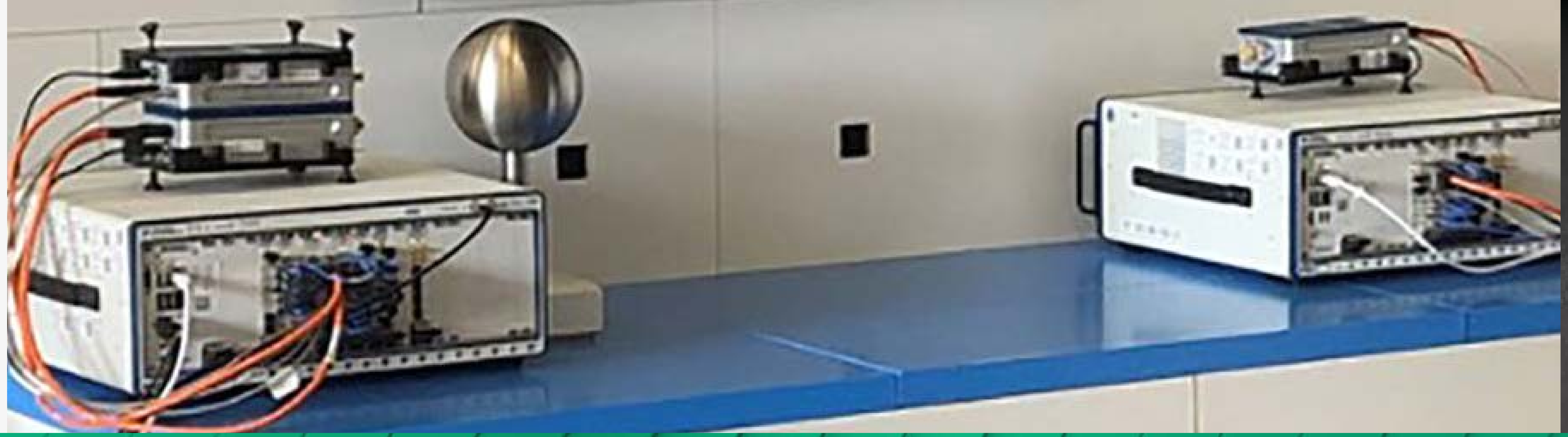
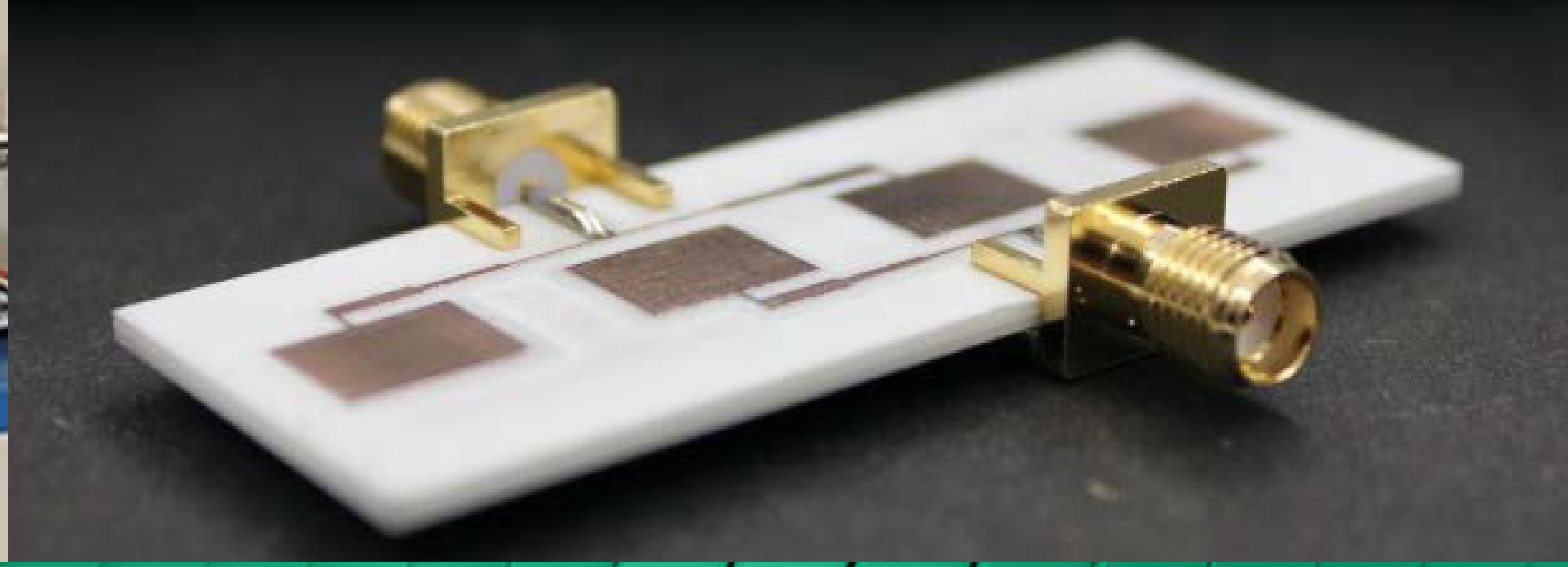




> “Using this setup, we can validate diverse research on mmWave antennas and signal-processing algorithms with real-world signals. Seamlessly, we have the entire Python ecosystem at hand, including link-level simulators such as HermesPy.”
>
> **Dr. Maximilian Matthé**
> Barkhausen Institut, Dresden, Germany

Millimeter Wave System for Research on Joint Communication and Sensing (JCAS)

Hardware-in-the-loop algorithm development for mmWave radar and communication systems.

MAXIMILIAN MATTHÉ, PADMANAVA SEN, JAN ADLER, AND MERVE TASCIOGLU YALCINKAYA,
BARKHAUSEN INSTITUT, DRESDEN, GERMANY

THE CHALLENGE

JCAS research cannot stop at algorithms or simulations— algorithms need to be tested with real hardware in realistic environments. This is particularly difficult in mmWave domains, with evolving applications demanding wider bandwidths.

Because real-time implementations demand significant FPGA skillsets and development efforts, we need to test algorithms with real-world data from realistic environments offline. Using our system, researchers quickly can evaluate digital signal processing algorithms in the mmWave domain with 2 GHz of bandwidth and seamlessly switch between simulated and real hardware.

THE SOLUTION

The setup comprises two units, where “system A” is equipped with a transmitter and receiver and acts as the radar/communication emitter and receiver. “System B” performs reception only; hence, it acts as the communication receiver.

The setup allows transmission/reception at cmWave (X band) and mmWave (71-76 GHz) frequencies. A user generates transmitter IQ samples offline and uploads these over the network into the JCAS emitter. The transmitter emits these samples with a rate of 3.072 GHz and, simultaneously, the receivers of both systems A and B record the received signals. Afterward, you can download recorded samples via the network for further processing offline. The setup includes a Python library that interacts with the setup remotely and transfers IQ samples back/forth. This way, you can develop signal-processing algorithms with the entire Python ecosystem at hand, including link-level simulators such as HermesPy (developed at BI).

NEXT STEPS

In the future, we seamlessly will integrate the mmWave system into the HermesPy link-level simulator. Moreover, we'll use the system for channel measurements and custom hardware evaluation, such as mmWave antennas and front-ends.

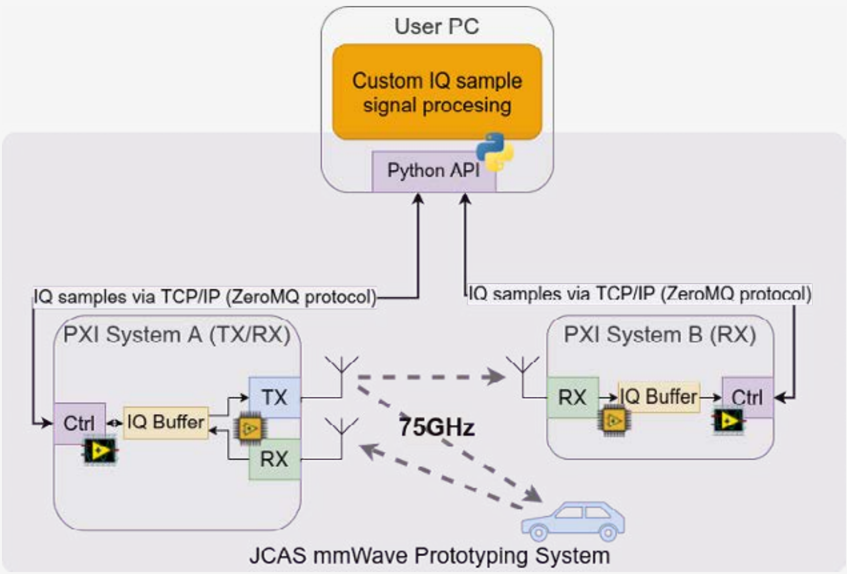


FIGURE 1. SETUP STRUCTURE AND SIGNAL FLOW

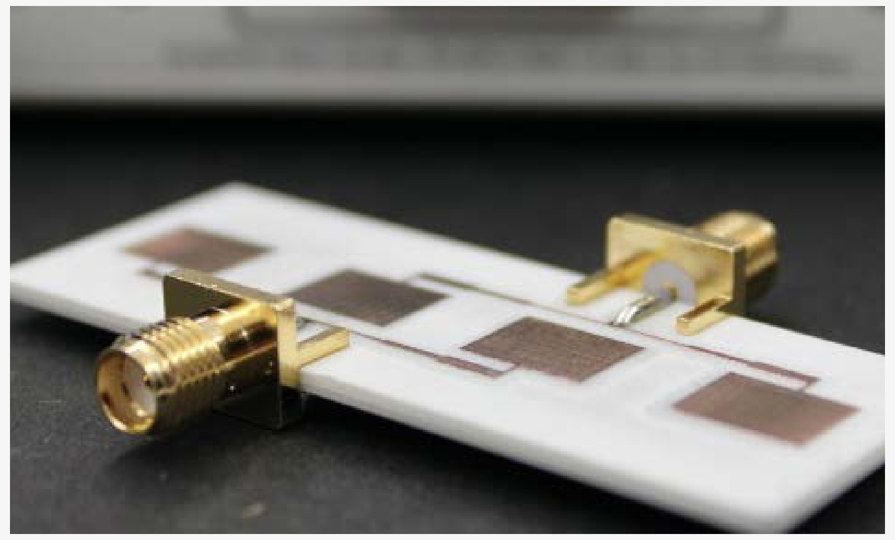


FIGURE 2. A 10 GHZ PATCH ANTENNA EVALUATED USING THE MMWAVE SYSTEM'S IF MODE

KU LEUVEN

O-RAN and Massive MIMO Cell-Free Exploration

vRU and vDU Signal Processing.

DR. SOFIE POLLIN, ANDREA P. GUEVARA, AND ROBBERT BEERTEN, NETWORKED SYSTEMS GROUP, KU LEUVEN

> “By disaggregating the functionalities in multiple virtual units at the Distributed KU Leuven Massive MIMO testbed, we will benefit from the flexibility of the O-RAN architecture and the capacity increase of the cell-free massive MIMO system.”
>
> **Dr. Sofie Pollin**
> Networked Systems Group, KU Leuven

THE CHALLENGE

O-RAN’s vision is the disaggregation of the RAN into different functional nodes—centralized unit (O-CU), distributed unit (O-DU), and radio unit (O-RU). While multiple vendors provide these nodes, their functionalities are integrated seamlessly and securely.

In parallel, scalable cell-free massive MIMO architectures are expected to improve the transmission rate via distributed, cooperative signal-processing techniques. Cell-free and O-RAN integration is starting to get attention, but so far, there is a lack of experimental results.

THE SOLUTION

Using the flexible NI KU Leuven Massive MIMO testbed, you can distribute the antenna elements. It can emulate virtual DUs (vDU) and virtual RUs (vRU) by applying different precoding matrices to selections of the antennas. In addition, you can deploy the testbed’s 64-patch antennas and distribute them into multiple arrays to emulate small cell-free scenarios.

During the first attempt to virtually integrate O-RAN and cell-free systems, we considered the study case of splitting the decoder across a single vDU or two vRUs, where the vRU coherently combines the signal of eight antennas. As seen in Figure 1, during uplink data transmission, the symbols were estimated locally in each vRU or centrally at the vDU. In Figure 2, the DU has a larger gain and hence, a larger signal amplitude.

NEXT STEPS

These initial results show that real-time experiments to validate several O-RAN splits and control API are possible. The next step is to build the relevant building blocks for scaling up O-RAN cell-free experiments with more RU and higher frequencies and bandwidths. The planned project is called the Horizon Europe 6G-BRICKS.

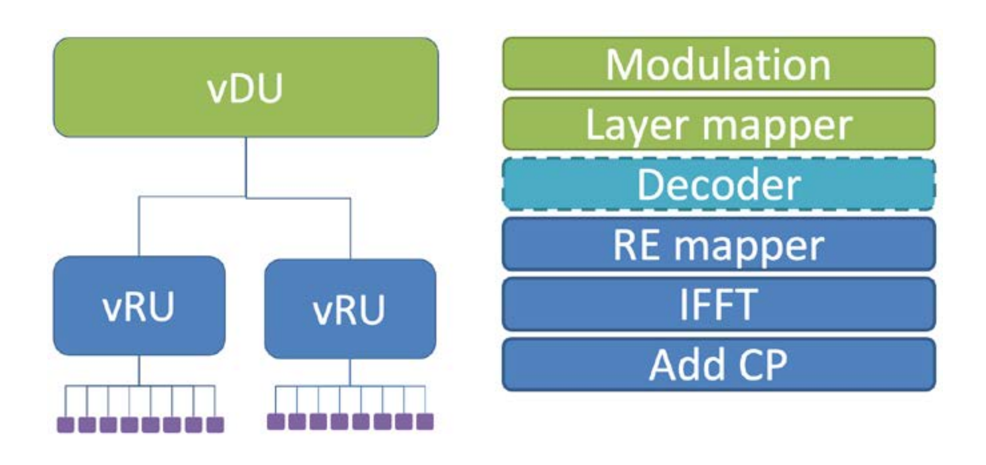


FIGURE 1. VIRTUAL FUNCTIONALITY IMPLEMENTED IN THE KU LEUVEN MASSIVE MIMO FOR UPLINK DATA TRANSMISSION

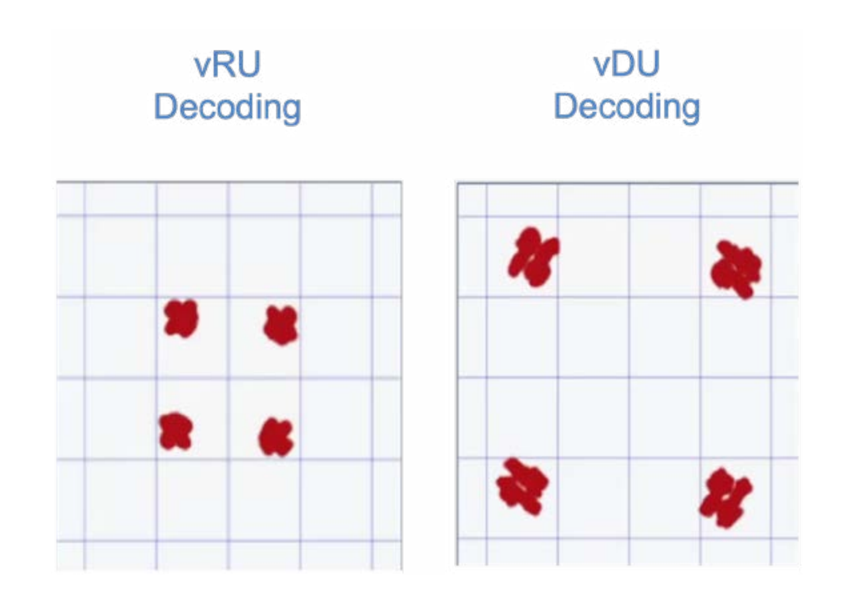
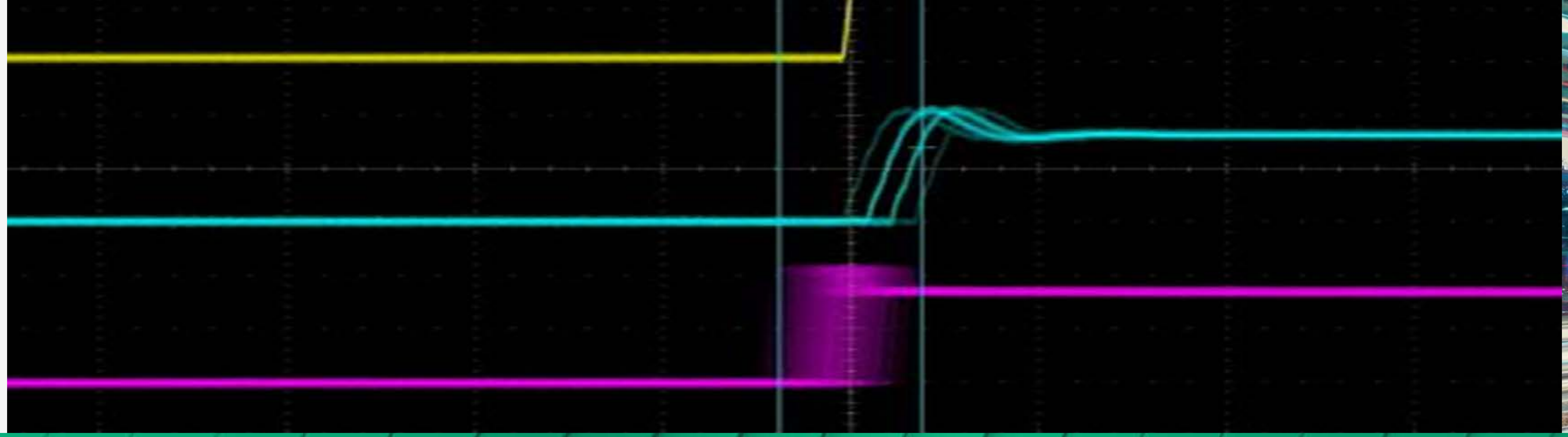


FIGURE 2. OFDM SYMBOL AT THE VRU AND VDU



> “Extending TSN time synchronization standards over wireless networks is more difficult due to the less deterministic nature of both the wireless propagation environment and existing wireless communication.”
>
> **Chin Ming Pang**
> A Star

Wired-to-Wireless TSN Time-Synchronization Extension and Data Acquisition Demonstrator

Prototype system built using NI’s USRP (Universal Software Radio Peripheral) and CompactRIO devices to demonstrate synchronized analog signal capture by a wired and wireless node in a time-sensitive networking (TSN) network.

CHIN MING PANG, RAYMOND JAYABAL, LEE KEE GOH, AND BO JIN, INSTITUTE FOR INFOCOMM RESEARCH (I²R), A*STAR, SINGAPORE

THE CHALLENGE

A core feature of the TSN standard is accurate time synchronization among distributed devices. However, TSN time synchronization standards were mainly developed for wired networks. Extending this highly accurate time synchronization over wireless networks is more difficult due to the less deterministic nature of both the wireless propagation environment and existing wireless communication protocols.

THE SOLUTION

To extend the time synchronization established on the wired TSN network to devices in the wireless network, we built an experimental system using NI’s CompactRIO industrial controller and USRP software defined radio (SDR) platforms (Figure 1). A key component in this system is the Transmission Gating Time Hyperchannel (TGT-HC) medium access control (MAC) (Figure 2), which provides highly deterministic and timestamped packet transfer and a highly accurate clock drift compensation algorithm based on easing functions. With these, we were able to demonstrate a capture of an analog signal by a wired and a wirelessly connected CompactRIO controller synchronized to within 100 ns within a lab environment (Figures 3 and 4).

NEXT STEPS

Future R&D plans include a timing advance feature to compensate for propagation delays for longer distances between devices. We also will deploy this solution in AI for critical industrial process data or indoor positioning in smart manufacturing, accurate time-aligned data processing of large sensor networks in critical infrastructures and built environments, and synchronizing autonomous systems for simultaneous operations.

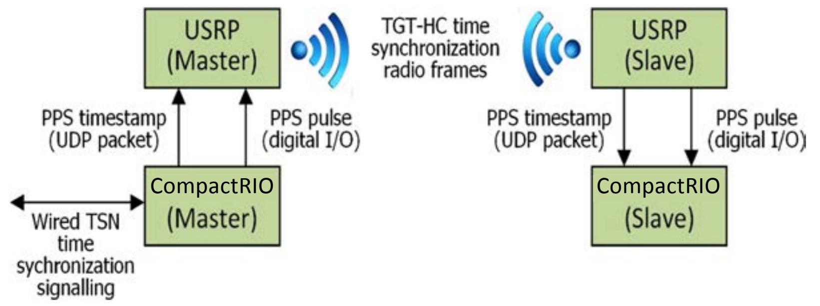


FIGURE 1. WIRED-TO-WIRELESS TIME SYNCHRONIZATION SCHEME

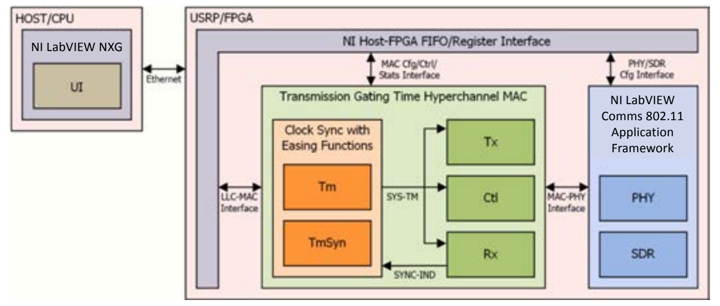


FIGURE 2. TGT-HC IMPLEMENTATION ARCHITECTURE

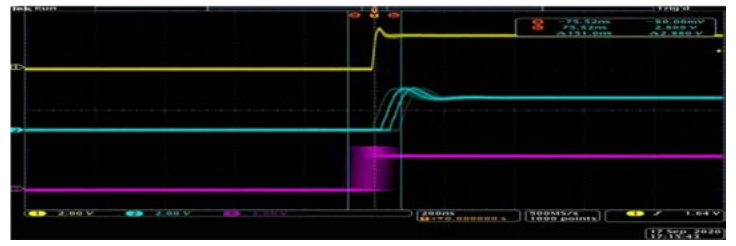


FIGURE 3. THE DISTANCE BETWEEN PPS PULSES FROM BOTH USRPS IS WITHIN 75 NS.

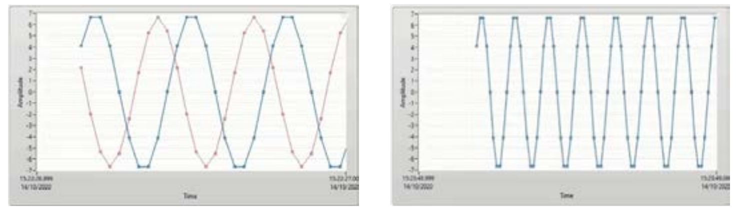


FIGURE 4. COMPARISON OF THE SAMPLE DATA GRAPHS FROM BOTH COMPACTDAQ DEVICES, WITHOUT AND WITH OUR TIME-SYNCHRONIZATION ENABLED

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

Wireless Digital Twin for Vehicular Communication Scenario Testing

Combining SDR-based wireless channel measurements, modeling, and emulation to develop novel testing tools.

STEFAN ZELENBABA, BENJAMIN RAINER, MARKUS HOFER, AND THOMAS ZEMEN, CENTER FOR DIGITAL SAFETY & SECURITY, AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

> “Affordable SDR tools for repeatable performance testing are a key enabler for boosting V2X adoption and unleashing its full potential.”
>
> **Stefan Zelenbaba**
> PhD Researcher, AIT

THE CHALLENGE

Developing and testing highly reliable wireless systems for time-sensitive and safety-critical use cases, such as vehicle-to-everything communications (V2X), demands tremendous resources. By deploying wireless propagation channel digital twins, we can drastically reduce system design costs and enable new services, such as collision avoidance and intelligent navigation.

THE SOLUTION

Using an NI USRP-2954R device, we built a multinode wireless channel sounder that can measure wireless impulse responses between more than two sounding nodes simultaneously. Each node is controlled by LabVIEW and is installed in an NI PXIe-8135 chassis. We use the measurement data to calibrate a realistic geometry-based stochastic channel model that simulates the measured scenario. Finally, we feed compressed channel coefficients to our hardware-in-the-loop (HIL) setup that uses a USRP-2954R device for real-time channel emulation. The HIL setup emulates the wireless channel between two commercial modems, meaning that we can measure their packet error rates in realistic conditions within a lab environment. The error rates obtained from the simulated channel show a good match with the error rates obtained from the measured channel.

NEXT STEPS

Our future work includes extending our digital twin framework to railway communication, drones, and industry automation, as well as future 6G physical layer technologies (mmWave).

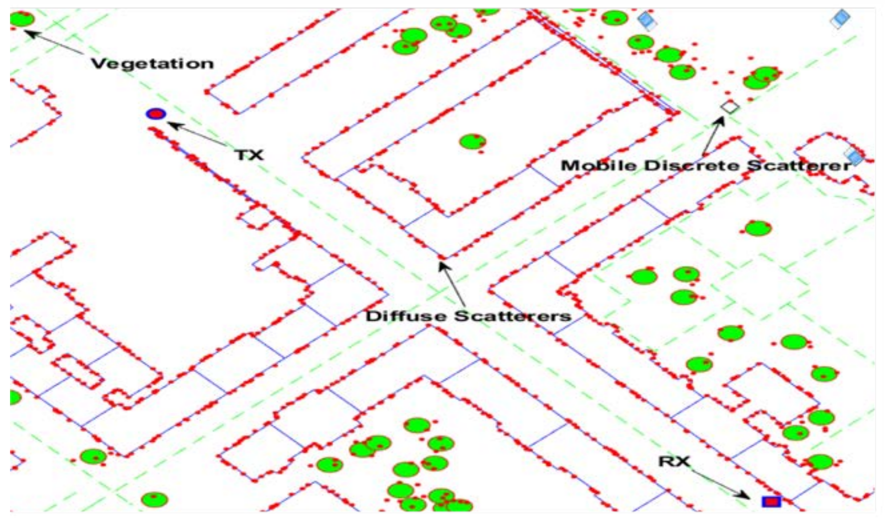


FIGURE 1. CHANNEL MODEL GEOMETRY

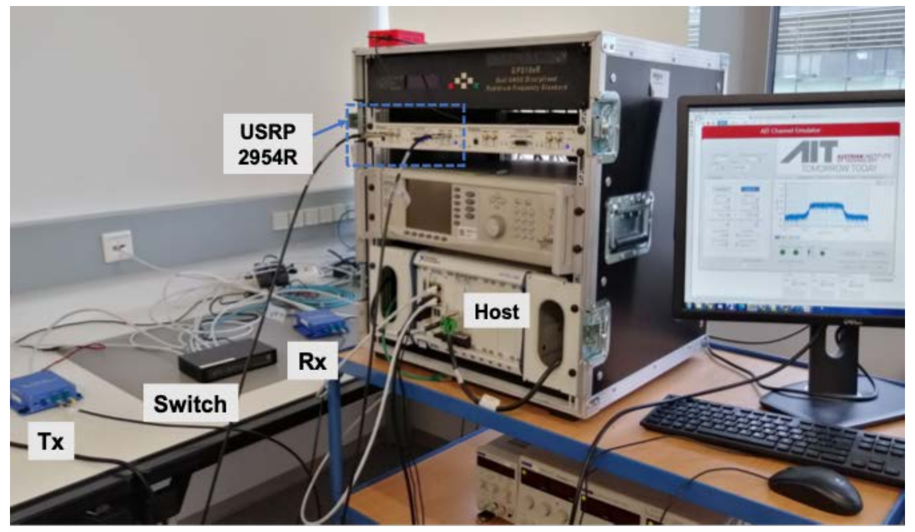
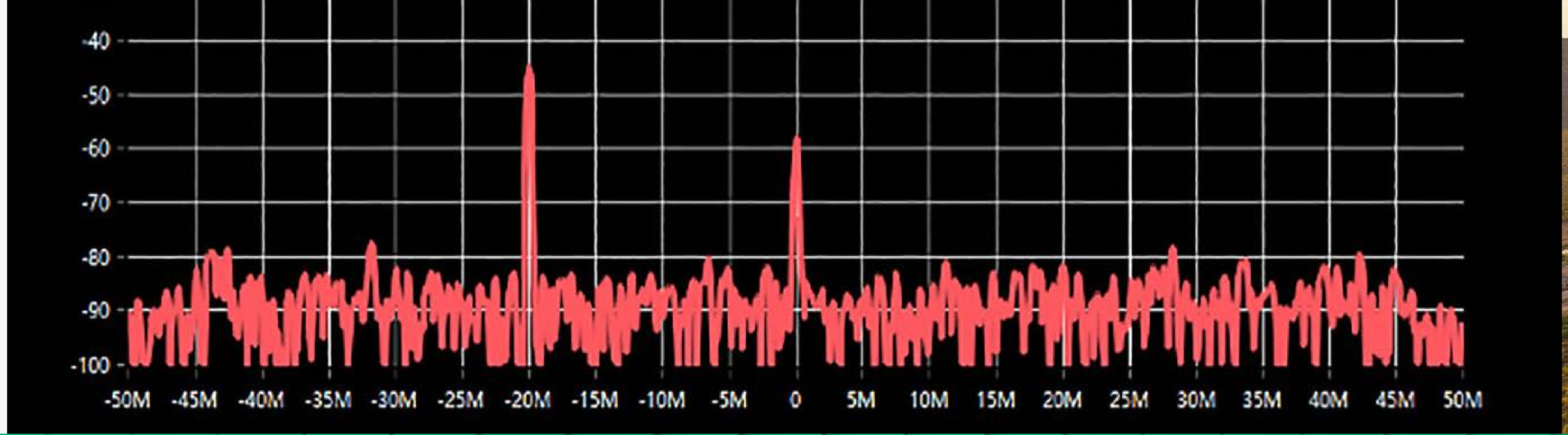


FIGURE 2. HARDWARE-IN-THE-LOOP SETUP USING THE AIT



> “Extracting differentiated features of the channel, and modeling the channel scenario data to accurately identify wireless channels, is a challenge.”
>
> **Jian Xiong, Ph.D.**
> Shanghai Jiao Tong University

Channel Identification in Wireless Communication Based on an LTE System

An intelligent channel identification method which uses two NI USRP-2942R devices to recognize broadband communication channels based on a long-term evolution (LTE) system.

PROFESSOR JIAN XIONG, DEPARTMENT OF ELECTRONIC ENGINEERING, SHANGHAI JIAO TONG UNIVERSITY, SHANGHAI, CHINA

THE CHALLENGE

While a communication system’s wireless channel environment is complex and changeable, the transmission path is affected by the receiver’s physical environment and location. Extracting differentiated features of the channel and modeling the channel scenario data to accurately identify wireless channels is a challenge.

Taking the channel feature as the label corresponding to the communication scenario can optimize the communication system’s design and improve its performance.

THE SOLUTION

We developed 18 MHz-bandwidth SC-FDMA communication based on an LTE system using LabVIEW and an NI PXIe-5645 vector signal transceiver as a channel emulator, as well as two NI USRP-2942R devices as a base station and user equipment (UE). The downlink user receiver feeds back the channel information identified by the machine learning algorithm to the uplink base station to form a wireless channel identification system. A PXIe-5645 channel simulator can configure the attenuation and delay parameters of each channel. We can generate different channel types and signal-to-noise ratios (SNRs) by adjusting the channel simulator’s parameters. To obtain channel characteristics, we correlate the pseudorandom noise sequence at the receiving end. The machine learning algorithm extracts further channel features based on FPGA code, and finally, the system obtains the classification result to identify the wireless channel.

NEXT STEPS

We’ll conduct research on USRPs (Universal Software Radio Peripherals) equipped with a neural network and deep learning algorithms to improve channel identification in low SNR scenarios. In the future, we’ll use USRP equipment that works independently and mount it on platforms such as unmanned aerial vehicles to identify wireless channels in the air in real time.

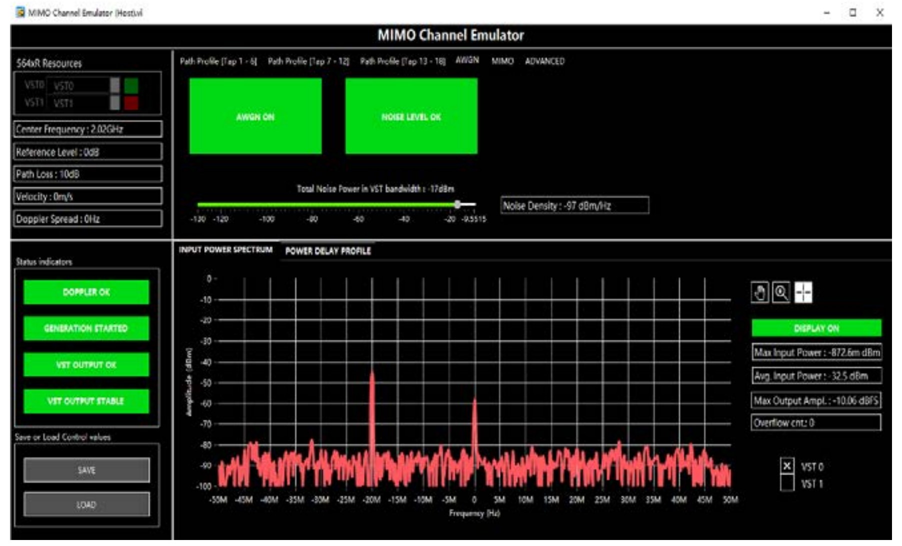


FIGURE 1. CHANNEL SIMULATION AND NOISE ADDITION MODULE

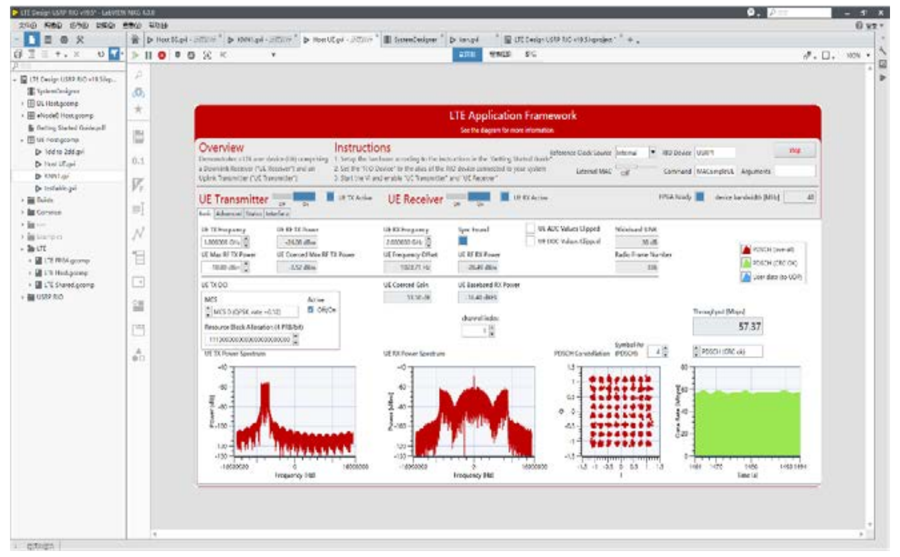
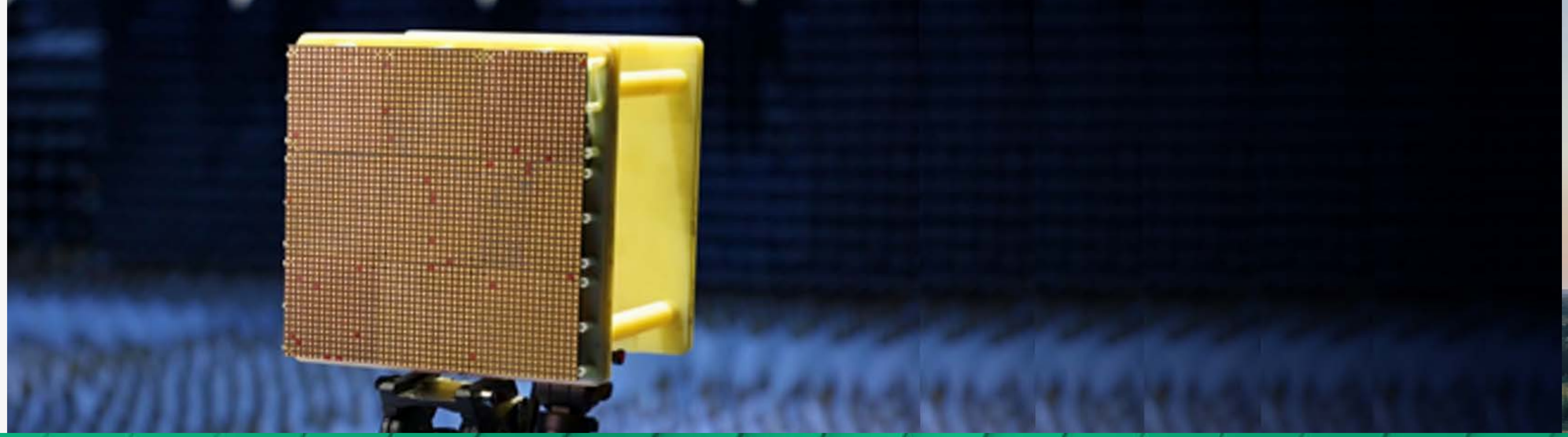


FIGURE 2. DESIGN INTERFACE OF CHANNEL IDENTIFICATION SYSTEM BASED ON LTE SYSTEM



Low-Power Communications Based on RIS and AI for 6G

A low-power communication system based on an NI mmWave Transceiver System which integrates RIS and AI to reduce power consumption.

MINGYAO CUI, ZIDONG WU, YUHAO CHEN, SHENHENG XU, FAN YANG, AND LINGLONG DAI, DEPARTMENT OF ELECTRONIC ENGINEERING, TSINGHUA UNIVERSITY, BEIJING, CHINA

CHALLENGE

Massive multiple-input-multiple-output (MIMO) is one of the most important 5G techniques, using hundreds of antennas to achieve a several-Gb/s data rate. Because 6G might require a tenfold increase in data rate, massive MIMO is evolving to ultramassive MIMO (UM-MIMO), using thousands of antennas or even more.

However, with that increase comes unaffordable power consumption requirements. Existing UM-MIMO systems usually employ phased arrays that require many transceiver modules and phased shifters, resulting in very high hardware power consumption. Furthermore, increasing the number of antennas and required data rate increases computing power consumption.

SOLUTION

By jointly optimizing the hardware and software, we developed a low-power communication system based on RIS and AI for 6G:

- For hardware, we replaced the power-hungry phased array with a low-power RIS. Unlike phased-array, which uses separated phase shifters and antennas, RIS integrates the phase shifters and the antenna module. It consists of thousands of low-power subwavelength metamaterials. In our system, an RIS with 256 elements at the base station replaces the phased array. Moreover, an RIS with 2,304 elements acts as a relay to assist the communication with reduced transmit power.
- For software, we developed an AI-based transmission to reduce computing power consumption. A single neural-network-based signal-processing module replaces traditional complex signal-processing modules, including modulation, demodulation, channel coding, and decoding.

We implemented these hardware and software solutions on NI's mmWave communication platform.

NEXT STEPS

In the future, we will focus on lower-power communications with extremely large- scale antenna array (ELAA) while considering near-field propagation. Specifically, we will design and implement near-field transmission techniques for ELAA with more than 1,000 antennas.

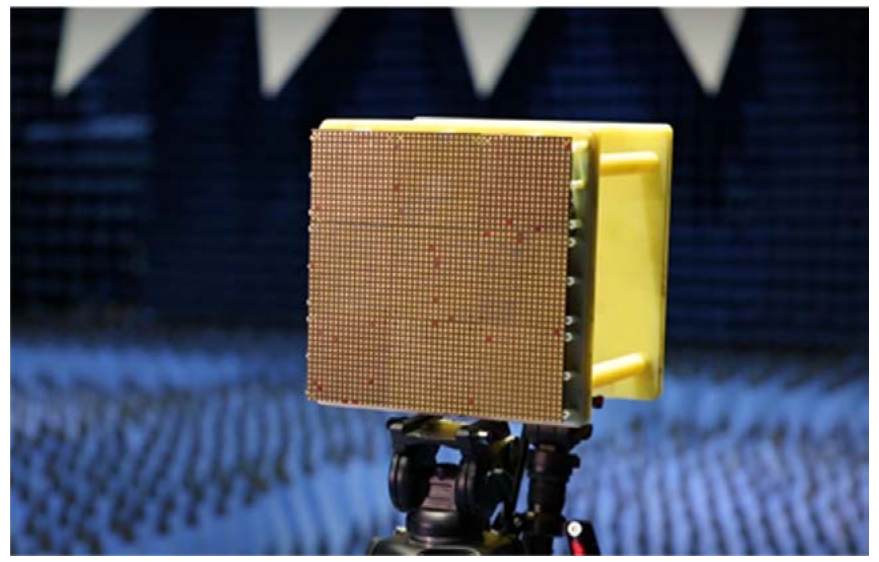
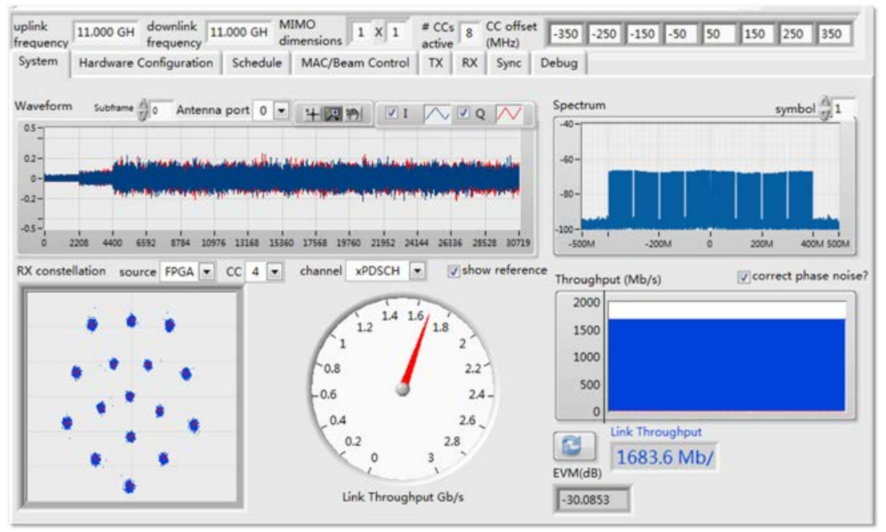
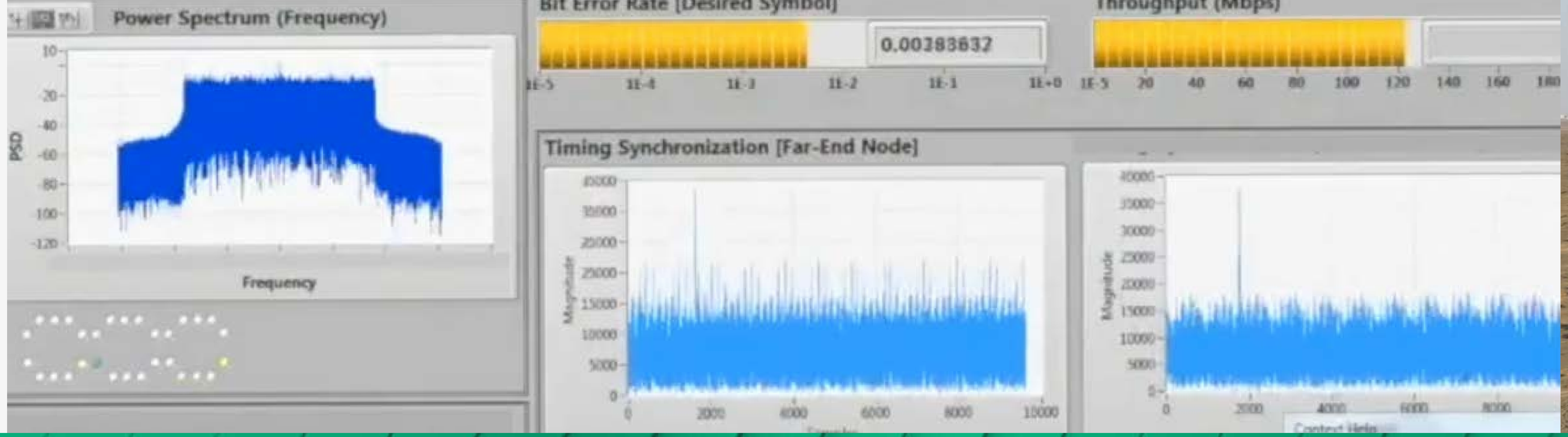


FIGURE 1. 2304-ELEMENT RIS AT THE RELAY SIDE



uplink frequency 11.000 GH
downlink frequency 11.000 GH
MIMO dimensions 1 X 1
CCs active 8
CC offset (MHz) -350 -250 -150 -50 50 150 250 350
Subframe 0
Antenna port 0
symbol 1
RX constellation source FPGA
CC 4
channel xPDSCH
☑ show reference
☑ correct phase noise?
Link Throughput 1683.6 Mb/
EVM(dB) -30.0853

FIGURE 2. CONSTELLATION OF AI-BASED COMMUNICATIONS



FSO Communications for 6G Wireless Networks: SDR-Based Feasibility Validation

Investigating, for the first time, the feasibility of a long-distance NI SDR-based FSO link of up to 20 km in 6G networks.

HONG-BAE JEON, SOO-MIN KIM, HYUNG-JOO MOON, JOON-WOO LEE, SANG-KOOK HAN, AND CHAN-BYOUNG CHAE,
SCHOOL OF INTEGRATED TECHNOLOGY, DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING, YONSEI UNIVERSITY,
SEOUL, SOUTH KOREA

> “After many years of spectrum-range enhancements, it is time to take FSO communications research to the next level. Yonsei University and NI’s software-defined-radio platform presents the design and validation of real-time video-signal communication and networking solutions for FSO networks with extreme link distance.”
>
> **Professor Chan-Byoung Chae**
> Yonsei University, South Korea

THE CHALLENGE

The enormous length of an FSO link, which can be up to 20 km, increases vulnerability to atmospheric turbulence and other losses. As a result, researchers have been working to develop the necessary technologies for a robust FSO link. Due to the enormous link distance, measuring the exact feasibility of the FSO link is difficult, limiting researchers to analytical expressions and simulations.

THE SOLUTION

We conducted a real-time video signal transmission prototype to solve this problem and assess the feasibility of the FSO network for 6G. The FSO channel emulator and the FPGA-based SDR platform were integrated in the prototype. The channel emulator models a time-varying atmospheric channel with power attenuation via absorption and scattering, as well as models turbulence with scintillation. The FPGA-based SDR platform is implemented for video-signal generation and encoding/decoding. Moreover, we apply various link-quality enhancement techniques to enhance the received video signal quality, including the selective noise filtering and the sampling-based pointing-loss compensation technology.

NEXT STEPS

We believe that, through our demonstration, we have conveyed a promising insight into the benefits of implementing long-distance FSO links, which can provide an extremely high data rate for future wireless networks. For future work, we will focus on robust distortion removal techniques in high-turbulence scenarios using a retroreflector and RF lens antenna.

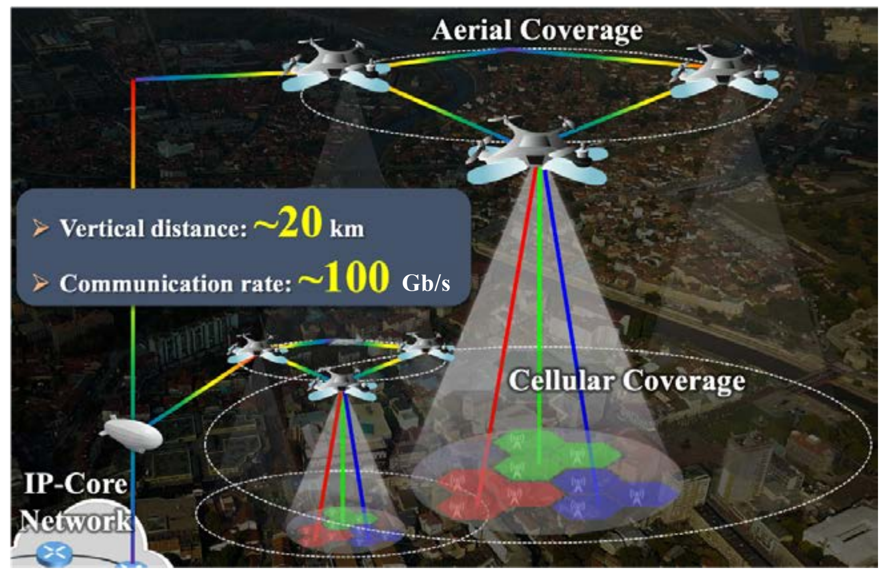


FIGURE 1. FSO NETWORK FOR 6G: SYSTEM MODEL

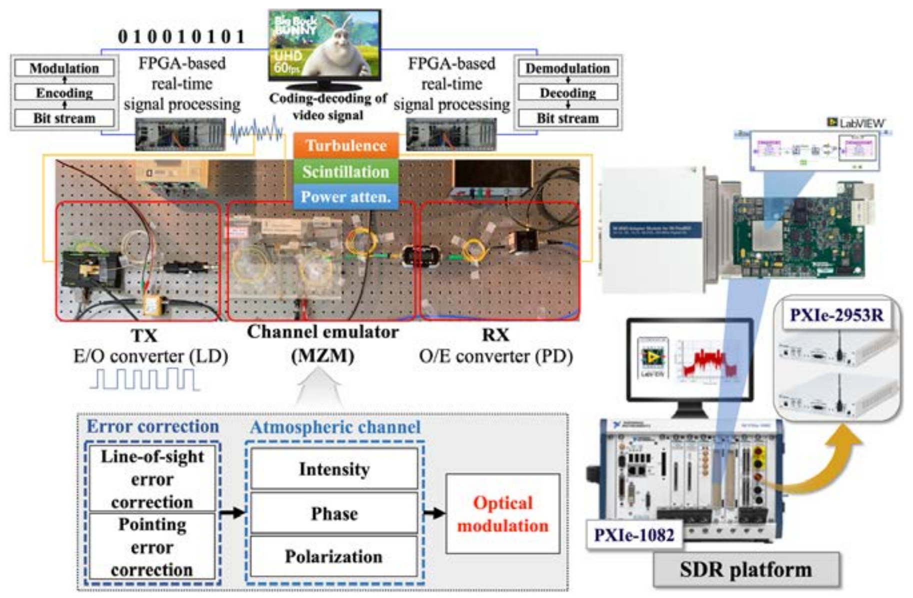


FIGURE 2. FSO NETWORK FOR 6G: PROTOTYPE VALIDATION

> “Many thanks to the Air Force Research Lab, Dr. Thomas Ketseoglou (CPP ECE), and Dr. Subodh Bhandari (CPP ARO) for their support, with recognition of CPP ECE students for their hard work on developing and implementing the system.”
>
> **Tamer Omar**
> Assistant Professor, Cal Poly Pomona

Deployable Just-in-Time Communication System for Emergency Networks

Providing wireless coverage during disaster situations using software defined radios.

TAMER OMAR, ASSISTANT PROFESSOR, ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT, CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA

THE CHALLENGE

This research aims at presenting a potential solution to the lack of connectivity available for individuals located in a disaster-impacted region. The project explores construction of a mobile base transceiver station that equips an unmanned aerial vehicle (UAV) with SDR. It uses Universal Software Radio Peripheral (USRP) to create virtual interfaces required for backup communication systems. The USRPs are programmed to create the required relay stations to restore the wireless networks in case of disaster.

THE SOLUTION

The objective of the deployable communication system is to provide a vehicular ad-hoc network (VANET) for just-in-time communication. The VANET connects a UAV and unmanned ground vehicle (UGV) fleet (together, a UXV) with the UXV operations center (OC) and the VANET traffic command and control (C&C) center. The deployable communication system utilizes state-of-the-art SDRs, vehicle routers, system on chip (SoC), and a controller area network (CAN) bus. The proposed system will help emergency crews reestablish their communication network when the existing communication infrastructure is affected by natural disasters, such as wildfires.

NEXT STEPS

Attaching the SDR system (USRP E320) to a UAV is possible and practical. In the future, the team is willing to fly the design and test at what altitudes and distances the transmission would work. After this test, we will investigate the viability of working in emergency conditions.

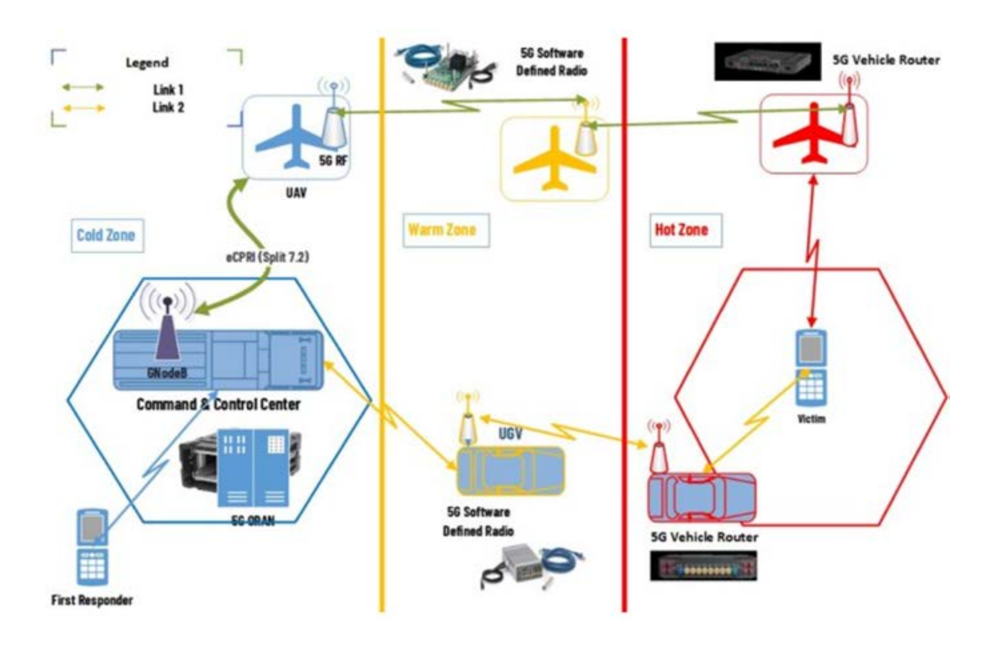
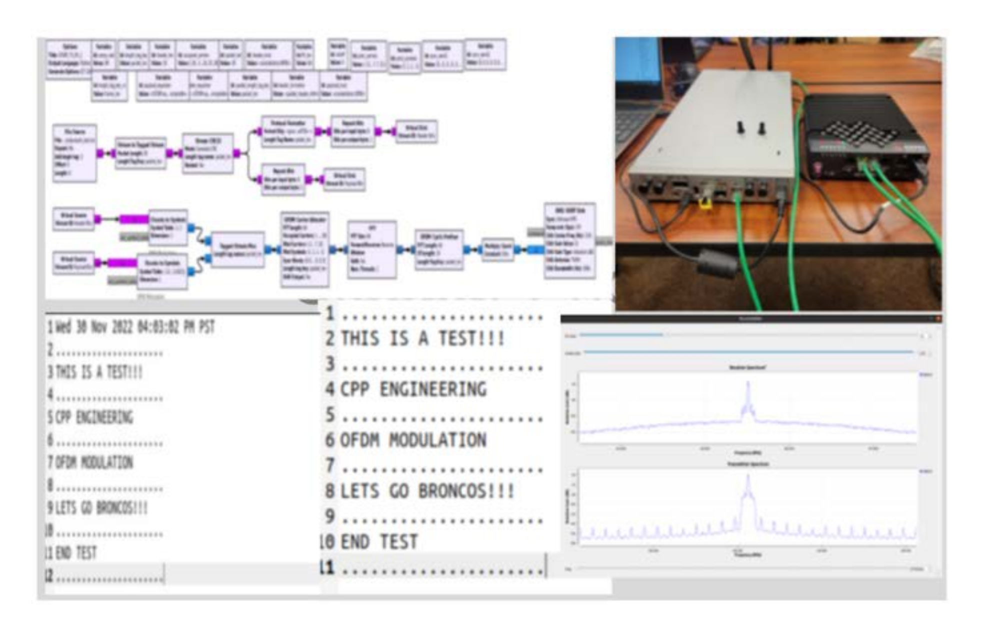


FIGURE 1. NETWORK ARCHITECTURE



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1 Wed 30 Nov 2022 04:03:02 PM PST
2 ....................
3 THIS IS A TEST!!!
4 ....................
5 CPP ENGINEERING
6 ....................
7 OFDM MODULATION
8 ....................
9 LETS GO BRONCOS!!!
10 ....................
11 END TEST
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1 ....................
2 THIS IS A TEST!!!
3 ....................
4 CPP ENGINEERING
5 ....................
6 OFDM MODULATION
7 ....................
8 LETS GO BRONCOS!!!
9 ....................
10 END TEST
11 ....................
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FIGURE 2. SYSTEM TESTING USING USRP N321

> “As a groundbreaking testbed, the CCI xG Testbed has enabled end-to-end, SDR-based, O-RAN closed-loop experimentation, deploying and showcasing the key O-RAN components development and commercial interoperability into the testbed’s capabilities.”

Dr. Aloizio P. Da Silva
CCI XG Testbed Director and Research Faculty,
Commonwealth Cyber Initiative, Virginia Tech

CCI xG Testbed: SDR-Based Radio Ceiling Platform for End-to-End O-RAN Closed-Loop Experimentation

Introducing a complete, end-to-end, O-RAN-compliant experimental network comprised of SDR and open-source components, bringing together the key components of the O-RAN ecosystem (RICs, rApp, xApp, RAN, and O1, A1, and E2 interfaces).

ALOIZIO P. DA SILVA, CCI XG TESTBED DIRECTOR, COMMONWEALTH CYBER INITIATIVE, VIRGINIA TECH

THE CHALLENGE

Wireless network communications are progressing in an unprecedented way. The overall network ecosystem is more complex—a multitude of devices and virtual/physical components can interact with each other and autonomously respond to increasing demand. Real-time orchestration and dynamic adaptation of such components requires new approaches from the application to the physical layers. We must have an end-to-end open-source platform to achieve R&D in different layers in order to validate, test, and integrate these components and new mechanisms into the next-generation ecosystem.

THE SOLUTION

CCI xG Testbed is an open-access, end-to-end, O-RAN-based wireless platform comprised of 72 USRP (Universal Software Radio Peripheral) devices, a missmatch of X310, N310, and X410, synchronized by 10 OctoClocks connected to an external GPS antenna. The indoor testbed is deployed on the ceiling and capable of operating at sub-6 GHz (with an FCC experimental license). It is fully programmable, AI/ML-powered, and interoperable with commercial equipment. With powerful servers, full-stack storage, and a groundbreaking petaFLOPS system, it offers network softwarization and virtualization via O-RAN principles and, for the first time, SDR-based end-to-end O-RAN experimentation. As such, CCI xG Testbed is a one-of-a-kind end-to-end, open-source, SDR- and O-RAN-based platform.

NEXT STEPS

CCI xG Testbed began with the idea of creating an open, programmable, and reproducible research platform. As it evolves, we are reshaping it to go beyond and serve as an O-RAN interoperability and testing platform. It will include both indoor and outdoor components such that academia, government, and industry can innovate with it. We foresee it going beyond an experimentation platform and serving as a workforce-development catalyzer.

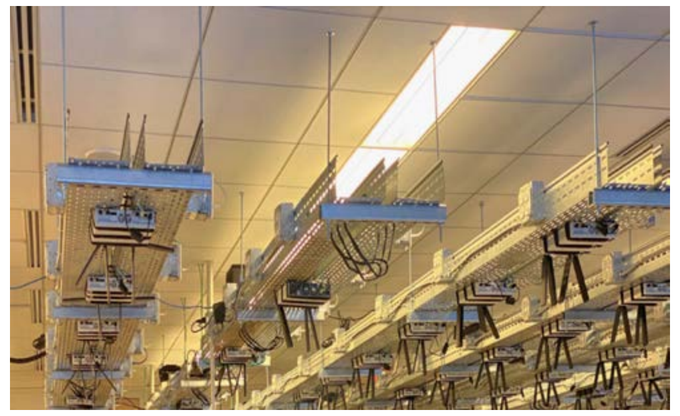


FIGURE 1. CCI XG TESTBED RADIO CEILING NETWORK

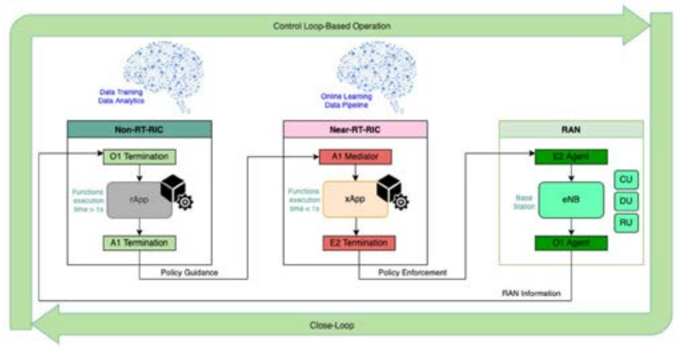


FIGURE 2. CCI XG TESTBED O-RAN CLOSED-LOOP SYSTEM

FIGURE 3. O-RAN CLOSED-LOOP SETUP USING X310S FOR eNB AND UE

Software-Defined Millimeter Wave Initial Access

Enabling Experimental Research on Next-Generation mmWave Initial Access Using Software Defined Radios.

JOAO F. SANTOS, EFAT FATHALLA, ALOIZIO P. DA SILVA, LUIZ A. DASILVA, JACEK KIBILDA,
COMMONWEALTH CYBER INITIATIVE, VIRGINIA TECH

> “Our platform allows researchers to build software defined radio mmWave experiments where the beam directionality can be dynamically controlled from the software radio, which is also great for automatically capturing datasets that can be used for training machine-learning-based solutions for mmWave communication and networking.”
>
> **Joao F. Santos**
> Commonwealth Cyber Initiative, Virginia Tech

THE CHALLENGE

Communication in the millimeter-wave (mmWave) spectrum and above requires beam management strategies for identifying and updating transmission and reception directions. Current-generation mobile standards and, as a consequence, commercial mmWave platforms, include an initial access procedure that statically probes the link quality in all directions for a fixed duration, incurring high overhead. However, the lack of flexible mmWave platforms that support the customization of their standard-compliant initial access procedures hinders the experimental evaluation of different design parameters or adaptive algorithms.

THE SOLUTION

To successfully experiment with and evaluate design choices and performance trade-offs for next-generation initial access procedures, Virginia Tech combined the flexibility of software defined radios with the directionality of mmWave front ends to create a software-defined mmWave framework at the CCI xG Testbed. We leveraged GNU Radio to implement a complete initial access control loop with programmable baseband processing and beam management. With our platform, experimenters initially can access mmWave over arbitrary beam sequences with custom durations, collect different performance metrics and report them with arbitrary cadence, and employ different decision algorithms to select the best beam pair for data transmission. We validated and demonstrated our software-defined mmWave framework using NI's software defined radios that send and receive intermediate frequency communication signals to and from commercial mmWave radio front ends operating in the 28 GHz spectrum band and control their beam management plane through the general-purpose input/output (GPIO) interface.

NEXT STEPS

We are investigating solutions for optimizing mmWave initial access parameters—including beam sweep sequences, beam duration, and payload duration—for different services and applications, and exposing the beam management plane to the Open Radio Access Network ecosystem through a bespoke E2.

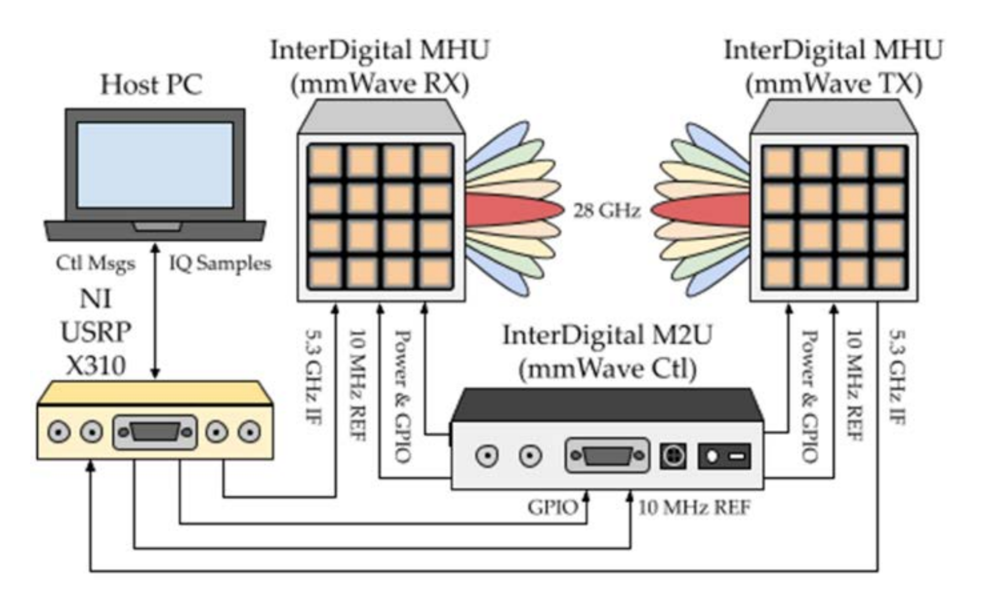


FIGURE 1. EXPERIMENTAL SETUP SYSTEM DESIGN

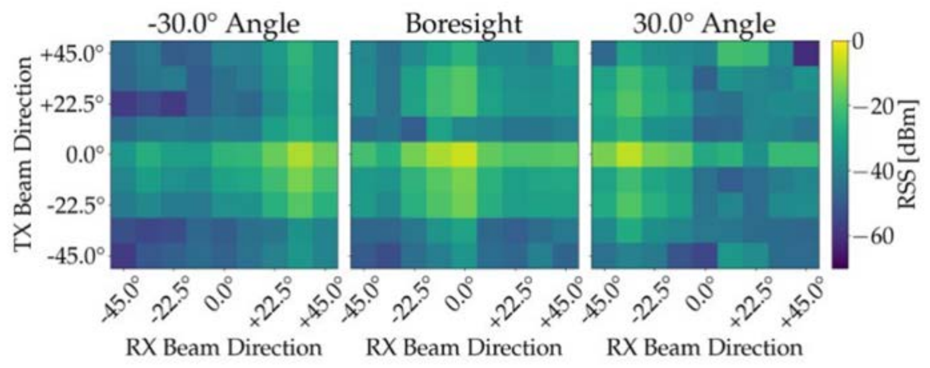
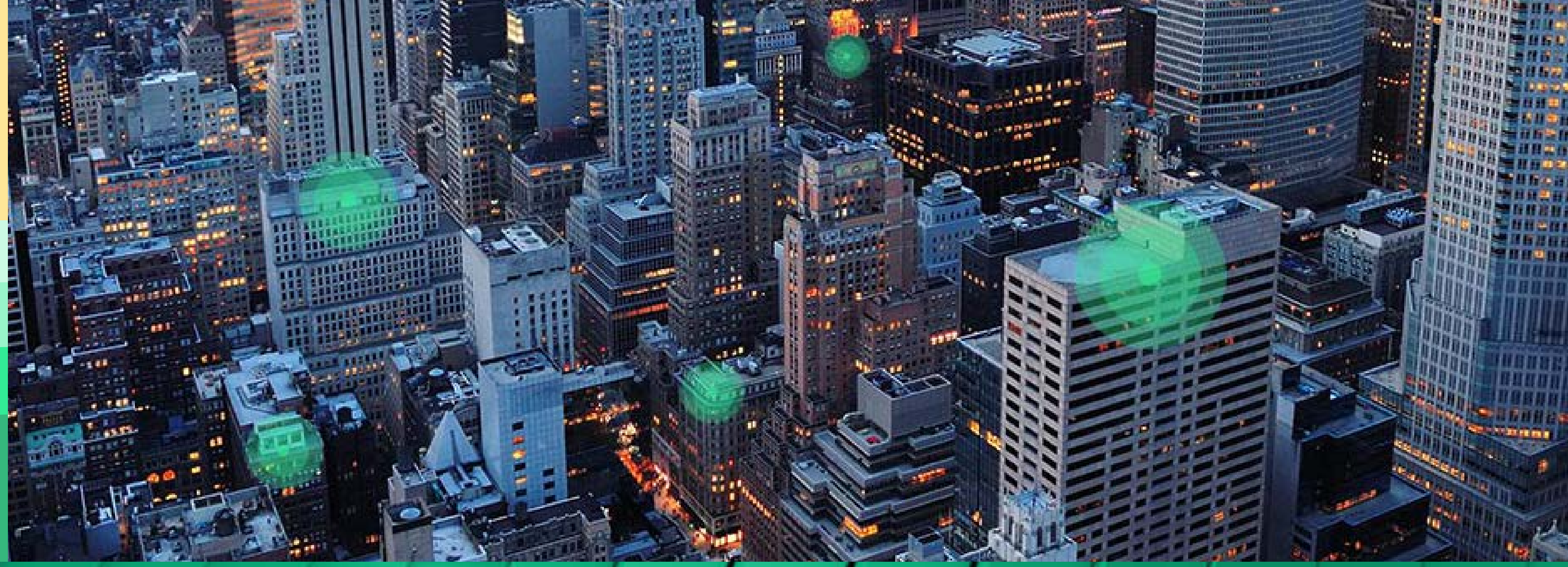


FIGURE 2. IDENTIFYING THE BEST COMMUNICATION DIRECTION



> “This work received financial support from the Science Foundation Ireland (SFI) via grants 18/CRT/6224 (SFI Centre for Research Training in Digitally-Enhanced Reality), 16/SP/3804 (Enable), and 12/RC/2289 P2 (Insight).”
>
> **Bharat Agarwal**
> School of Electronic Engineering, DCU

QoE-Driven Optimization in 5G O-RAN-Enabled HetNets for Enhanced Video Service Quality

A novel Quality-of-Experience (QoE) enhancement function xApp.

BHARAT AGARWAL, DUBLIN CITY UNIVERSITY (DCU); MOHAMMED AMINE TOGOU, DCU; MARCO RUFFINI, TRINITY COLLEGE DUBLIN; GABRIEL MIRO MUNTEAN, DCU

THE CHALLENGE

The mobile industry is about to reach a turning point. Video traffic currently makes up 66 percent of all mobile data traffic, and by 2026, that is expected to increase to 77 percent. Upgrading network capacity until 2024 paves the way for connected consumer wearables, higher-quality video services, Augmented Reality/Virtual Reality (AR/VR) and cloud gaming. On the other hand, some applications demand real-time data processing and low latency. As a result, supporting a wide range of applications, each with unique requirements, requires a flexible network that effectively uses resource provisioning strategies. However, because current radio access networks (RANs) don't provide for this, we need network upgrades.

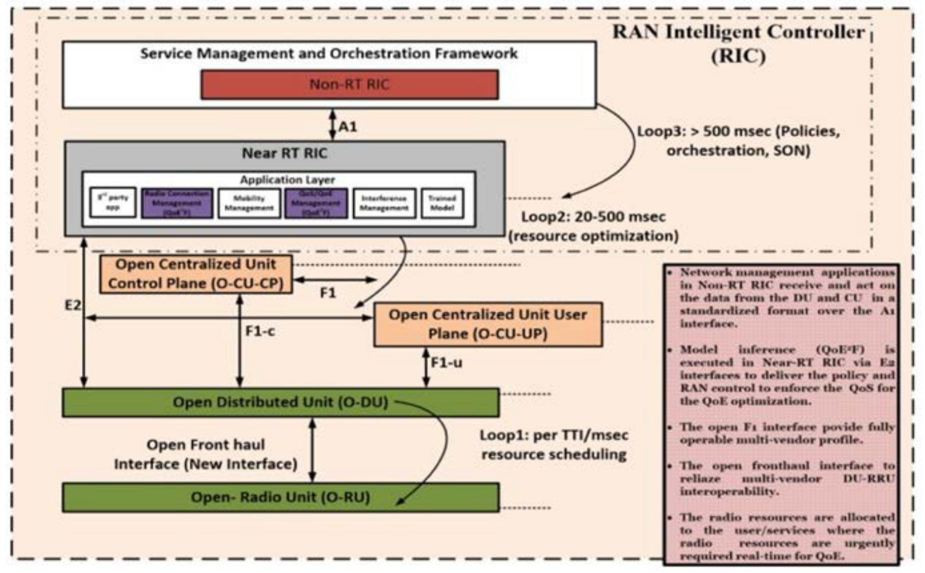
THE SOLUTION

We designed and integrated the QoE Enhancement Function (QoE2F) application within the Open-RAN architecture to improve QoE with video services. The QoE2F application solves the user association-resource allocation-power allocation (UA-RA-PA) problem with a novel adaptive genetic algorithm (AGA) as a dual '0/1' multiple knapsack problem (MKP).

NEXT STEPS

We plan to continue researching the QoE2F xApp's ability to achieve:

- Real-time control—O-RAN optimization and control comes with a coarse timescale (greater than 10 milliseconds). Future evolutions of O-RAN need to integrate specific real-time components, such as dApps, for dynamic real-time data-driven control and optimization. These elements can collaborate with xApps to use data that cannot be transported from the RAN to RIC for analysis (e.g., in-phase and quadrature samples or fine-grained channel data).
- Effective AI/ML algorithm design, testing, and deployment—The AI/ML workflow puts O-RAN in a position to serve as a framework for using ML solutions in the RAN. While this process is being standardized, there are still a number of difficulties stemming from both the need to gather, train, and test heterogeneous datasets that are indicative of large-scale deployments, and to test and improve data-driven solutions through online training.



- Network management applications in Non-RT RIC receive and act on the data from the DU and CU in a standardized format over the A1 interface.
- Model inference (QoE²F) is executed in Near-RT RIC via E2 interfaces to deliver the policy and RAN control to enforce the QoS for the QoE optimization.
- The open F1 interface povide fully operable multi-vendor profile.
- The open fronthaul interface to reliaze multi-vendor DU-RRU interoperability.
- The radio resources are allocated to the user/services where the radio resources are urgently required real-time for QoE.

FIGURE 1. QoE2F INTEGRATION WITH O-RAN

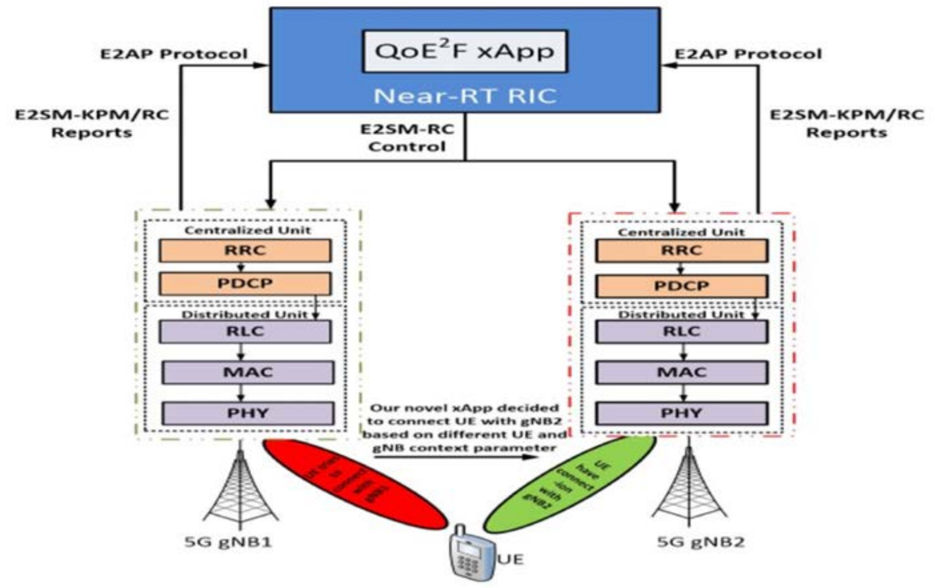


FIGURE 2. QoE2F xAPP BASED ON E2AP

> “OAIC provides an open platform (including software architecture, library, and toolset) for prototyping and testing AI-based radio access network (RAN) controllers, enabling 6G cellular research.”
>
> **Vijay K. Shah**
> NextG Wireless Lab, George Mason University

Next-Generation O-RAN Research Testbeds with NI SDR Platform

Open AI Cellular (OAIC): Prototyping Artificial Intelligence-Enabled Control and Testing Systems for Cellular Communications Research.

PROFESSOR VIJAY K. SHAH, GEORGE MASON UNIVERSITY, NEXTG WIRELESS LAB

THE CHALLENGE

Open Radio Access Network (O-RAN) is an emerging, transformative cellular RAN architecture for 5G and future 6G networks based on openness, virtualization, and standardized interfaces. Artificial intelligence (AI) offers promising tools to intelligently deploy, operate, and manage these networks. However, comprehensive AI performance testing is cumbersome and, in many cases, nonexistent.

THE SOLUTION

We built an NI software defined radio (SDR) testbed featuring an open-source 5G cellular system that interacts with the near-real-time RAN intelligent controller (near-RT RIC) of the O-RAN architecture through standard interfaces known as the Open AI Cellular (OAIC) platform. OAIC serves as a foundational platform for prototyping and testing AI-based RAN controllers enabling 6G cellular networks. For example, two RAN controllers, xApps in near-RT RIC, namely, KPIMON xApp and RAN Slicing xApp, in the OAIC platform. The OAIC code base, library, documentation, and toolset are publicly available for research, development, and experimentation. Read more about OAIC at openaicellular.org.

NEXT STEPS

Moving forward, our focus is on building AI-driven RAN controllers in the PHY and MAC layers (as xApps in near-RT RIC) on top of our OAIC platform. Furthermore, we will enhance the OAIC platform with non-RT RIC and newly developed RT RIC capability. Finally, we will integrate the AI testing framework to evaluate various AI-driven RAN controllers (and the 5G O-RAN system as well).

FIGURE 1. AN OAIC TESTBED PLATFORM AT GMU PROVIDES A 5G O-RAN SYSTEM WITH ONE BS AND FIVE UES (ONE SDR-BASED UE AND FOUR COTS UES).

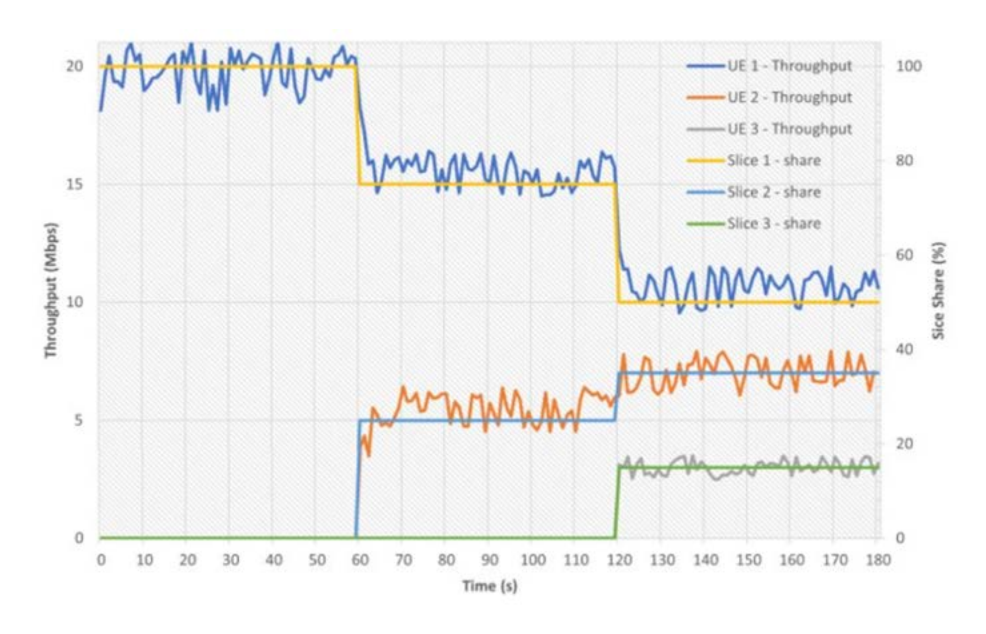


FIGURE 2. THE RAN SLICING XAPP SHOWS THE UE BANDWIDTH VARIATION WHEN ASSOCIATED WITH DIFFERENT SLICES (RAN SLICING XAPP CODE BASE ORIGINALLY DEVELOPED BY POWDER).

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