Title: Open AI Cellular (OAIC): An Open-Source Platform for Prototyping and Testing AI-Enabled O-RAN for 5G/6G IIoT Networks

Abstract

Since first conceptualized and proposed, the Open Radio Access Network (O-RAN) has aimed for openness, intelligence and flexibility. To fulfill the objectives, various network components and interfaces will have been virtualized and disaggregated. Meanwhile, O-RAN based networks will incorporate artificial intelligence (AI) into the deployment, operation, and maintenance of the network. AI can optimize parameters in a large search space, easily scale up and scale down networks in new situations, as well as satisfy requirements of ultra-low low latency and high reliability in industrial IoT networks. This tutorial will introduce the open-source software platform Open AI Cellular (OAIC), a community research infrastructure project enabling 5G/6G wireless research and experiments. OAIC enables prototyping and testing of next generation AI-based cellular radio access networks (RANs). We will introduce how to design and integrate AI-based controllers into network, such as user/resource scheduling, performance monitor and network slicing. The tutorial will also highlight methodologies for developing open-source tools and services for AI-enabled O-RAN management and experimentation with software-defined radios (SDRs) along with an AI-enhanced RAN testing framework for 6G research. Attendees will obtain substantial knowledge and experience with O-RAN fundamentals and the emerging OAIC research platform and how to use it for wireless research and development, including 5G/6G access network, IoT network and so on.

Objectives and Motivations

1. O-RAN has been proposed as a practical next-generation RAN solution embracing intelligence, virtualization and flexibility. It disaggregate the original components in conventional RAN and introduced RAN Intelligent Controllers (RICs). The O-RAN Alliance defines open interfaces and an open architecture for innovation at all layers. Since there is increasing interest yet insufficient understanding, the first objective of this tutorial is to educate on the key O-RAN principles and concepts, such as architecture, interfaces, algorithms.
2. Realizing a cellular network is a challenging task due to its scale and complexity. However, by taking advantage of open-source 5G, we are prototyping AI-enhanced RAN controllers, or xApps. Through sample projects, we will show the methodology for developing xApps and AI controllers using the open-source software tools that OAIC provides and that enable rapid prototyping and testing.
3. While AI models are enablers to achieve intelligent wireless networks, the inability of the current theory to explain or prevent failures in the AI models emphasizes on the necessity of having a framework and appropriate environment for testing AI models deployed as cellular RAN

controllers. An AI testing framework has been developed as part of OAIC and we will demonstrate how to use it to support automated, multitasking, and distributed testing for O-RAN.

Presenters with their Bio-sketches:

1)Vuk Marojevic received the M.S. degree in electrical engineering from the University of Hannover, Germany, and the Ph.D. degree in electrical engineering from UPC-Barcelona Tech. He was assistant professor at UPC, research faculty at Wireless @ Virginia Tech and is currently an Associate Professor with the Department of Electrical and Computer Engineering at Mississippi State University. His research interests are in software-defined radio, spectrum sharing, vehicular communications, resource management with application to commercial and mission-critical cellular networks and unmanned aircraft systems. He is a PI of the NSF-sponsored AERPAW and Open AI Cellular (OAIC) projects. He serves as an Associate Editor of the IEEE Trans. on Vehicular Technology and the IEEE Vehicular Technology Magazine. He has given tutorials about software radio frameworks, open-source LTE and cellular communications security at major conferences and workshops, such as IEEE MILCOM (2018), NEWSDR (2019) and SDR-WInnComm (2013). He has presented a tutorial about OAIC at IEEE CCNC 2023.

2) Minglong Zhang received his M.S degree in electronic engineering from the Peking University, P.R. China and PhD degree in electrical and electronic engineering from Auckland University of Technology, New Zealand. He was a lecturer and research associate at Auckland University of Technology. He is a postdoctoral research associate at Mississippi State University. His research interests include 5G/6G V2X communications, software-defined radios, AI-enabled ORAN. He will give a tutorial about OAIC at IEEE CCNC 2023. Dr. Zhang has attended and organized multiple relevant conferences, such as IEEE ICC, 2020 WCNC, 2018 EIA SARTGIFT and 2017 PIMRC. He made presentations in the conferences and the topics were wireless networks, V2X communications and networking. He has been a tutorial presenter at IEEE CCNC 2023 and present OAIC.

3) Bo Tang received the M.S. degree in information processing from Chinese Academy of Sciences and Ph.D. degree in electrical engineering from University of Rhode Island. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering at Mississippi State University. His research interests are machine learning, edge AI, and AI security, as well as their applications in wireless networks. He is the recipient of NSF CAREER Award (2021) and NIJ New Investigator/Early Career Award (2019). He is a Senior Member of IEEE and servers as an Associate Editor of the IEEE Trans. on Neural Networks and Learning Systems. He has given a tutorial about OAIC at IEEE CCNC 2023.

4) **Vijay K. Shah** is an Assistant Professor in the Cybersecurity Engineering (CYSE) Department at George Mason University (GMU). He is also a faculty member of Commonwealth Cyber Initiative (CCI), a

Virginia state-wide initiative to foster 5G wireless, autonomous systems, data and cybersecurity research. His research interests include 5G/Next-G wireless, O-RAN architecture, AI/ML for communications and wireless testbed development and prototyping. He serves as a co-chair for IEEE workshop on next-generation radio access networks (co-located with IEEE GLOBECOM 2022). He has organized many IEEE and ACM workshops collocated with leading wireless communication and networking conferences, such as, IEEE GLOBECOM, ACM MobiCom, and ACM ICDCN.

Intended Audience

The tutorial is intended for junior and senior researchers in cellular/wireless communications and networks, educators, practitioners, and people working in government, on standardization and regulation.

Description

The advent of O-RAN, which is deemed as an industry-driven open architecture and interfaces for next generation network is drawing increasing attention. However, despite the increasing interests from both academia and industry, researchers and practitioners are still desperate for an open platform that they can conduct studies, prototyping and testing of 6G networks. OAIC provides an open platform[1] (software architecture, library, and toolset) for prototyping and testing artificial intelligence-based radio access network (RAN) controllers enabling next generation wireless networks. The tutorial will shed light on prototyping AI-enabled 6G cellular network with ORAN, which is composed of AI-enabled RAN controllers and a co-developed testing system. More precisely, the tutorial will demonstrate open-source tools and services for creating an AI-enabled O-RAN network with software-defined radios (SDRs) along with an AI-enabled RAN testing framework for 6G research. While showing how to prototype 6G research tool and experiments, the attendees will gain an understanding of how the software architecture needs to be designed to accommodate issues such as varying timescales of AI adaptation and how to apply and partition the AI processing to achieve the needed performance while considering the cross-interactions that result from modularized AI engines. We will also address the principles for validating that the AI is performing to expectations when placed in the network by leveraging properties of cellular networks and AI approaches. We provide the software as open-source code that can be downloaded and used with all dependencies met. It leverages wireless community research testbeds, Virginia Tech's CORNET and the Platforms for Advanced Wireless Research (PAWR), which provide remote access to modern SDRs. The methodology and tools enable research with minimal infrastructure costs.

Tutorial Outline

[1] Refer to two websites: https://www.openaicellular.org/ and https://github.com/openaicellular.

All presenters are familiar with all sections and the speaker for the different blocks will be determined to provide a seamless flow, time management, and to engage the audience. Every section will have a buffer for discussion or short breaks. Q&A and focused discussions are encouraged during the presentation, and time will be accounted for it in the final schedule. We will conduct both fundamental and expert-level discussions, including general topics, specific research activities in O-RAN processes and design, and demonstrations.

- O-RAN Fundamentals, Resources, and How to Build an O-RAN System (~20 minutes)

  Introduction of O-RAN, including its fundamental architecture, functionality, interfaces, specifications, and resources, and how it fits in the context of current and next-generations cellular network standards and protocols established by the Third Generation Partnership Project (3GPP). The key components of O-RAN, including the interfaces and the RAN Intelligent Controllers (RICs), as well as the roles, specifications, and options of these will be explained. In parallel, we discuss the deployment of an O-RAN system leveraging the available community resources: the O-RAN specifications, compilers, community software. We will guide the audience on the integration of the O-RAN architecture with open-source cellular software and SDRs hardware. This will introduce the Open AI Cellular (OAIC) platform that enables prototyping and testing AI-based RAN controllers as part of to subprojects: Open AI-enabled Cellular RAN Controllers (OAIC-C) and Open AI-enabled Cellular RAN Testing (OAIC-T).

- AI Controllers—OAIC-C (~30 minutes)

  We focus on the design, development and integration of AI controllers for NextG RANs, particularly, on the physical and medium access control layers. Such AI-controlled RAN functionality may be integrated as xApp in near-RT RIC, rApp in non-RT RIC or newly envisioned dApp/zApp in the ms/sub-ms real-time RIC in central unit (CU)/distributed unit (DU). Representative examples of include AI-controller for scheduling and AI controller for spectrum sharing.

- AI Testing Framework—OAIC-T (~20 minutes)

  Introduction of OAIC-T, an AI-enabled testing platform to help optimize the evaluation of AI controlled O-RAN systems under variations of the input data in realistic and, possibly, changing conditions. This platform supports automated and distributed testing by managing a number of test actors which are able to transmit testing signals in parallel. Given the large input

space of an AI-controlled system, it may be impossible to exhaustively and comprehensively test the performance of AI models without the help of AI. Our framework integrates AI-enabled testing methods to explore the decision space of AI models as cellular RAN controllers. In this part, we will discuss the design of OAIC-T framework, the modules, interfaces, features, functionality, examples, and its future extensions.

- Research Demonstrations and Interactive Discussions (~30 minutes)

  We will conduct live demonstrations of the developed O-RAN platform on a testbed to illustrate the software development, integration, testing and research experiment cycles. The audience will be able to interact with the presenters and gain hands-on experience. Discussion with the audience on other research problems and projects to advance practical AI-enhanced wireless research, development, and prototyping will be part of this session.

Materials

We provide attendees with lecture and online material and other resources for onboarding them to OAIC and SDRs. This will include slides, list of recommended readings, source code, development platform, and community testbed resources and how to build one.