Empowering Education with ARA

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AraFest'25

ARA Platform Overview

- The ARA living lab is mainly used for research
- It can also be used for education "by default"
- Instructors can utilize any ARA experiment from our user manual to be used in their classrooms/labs
- We decided to go one step further

- **Open-Source NextG**
  - Transmitting, Receiving, and Visualizing Waveforms using UHD and GNURadio
  - Indoor/Sandbox Over-the-Air OpenAirInterface5g Experiment using USRPs
  - Outdoor Over-The-Air (OTA) OpenAirInterface 5G SA Experiment
  - Basic srsRAN Experiment in Sandbox using USRPs
  - srsRAN Outdoor 5G SA Experiment with COTS UE

ARA EXPERIMENTS

"Hello World!" Experiment

AraRAN Experiments

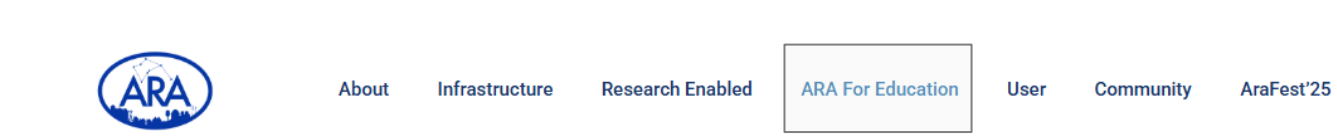
AraHaul Experiments

Additional Experiments

Instructor Resources

- Dedicated "ARA For Education" webpage
  - https://arawireless.org/ara-in-education/
- Customized experiments for the classroom
  - Variety of labs for different courses (Wireless Networks, Wireless Security)
  - Lab templates (in editable format – instructors can customize)
  - Lab report solution for instructors (not shared on our website)
- We provide technical support for instructors and TAs
- Students' Feedback

ARA Education Webpage



ARA For Education

The ARA wireless living lab offers rich opportunities for enhancing higher education, particularly in undergraduate and graduate courses related to networking and wireless networks. ARA can be seamlessly integrated into curriculums worldwide, providing students with hands-on experience and exposure to cutting-edge wireless technologies. For instance, ARA's focus on research and innovation in rural wireless and applications (e.g., precision agriculture) and its at-scale deployment across central Iowa's rural communities over 500 square kilometers provide students with a real-world living lab for developing and testing new technologies, empowering students to experience firsthand how theoretical concepts are applied to solve practical problems.

Integration into Undergraduate Courses

For undergraduate courses, particularly those focusing on the fundamentals of networking and wireless communications, ARA offers a unique, real-world laboratory setting. Students can engage with low-UHF massive MIMO systems, mmWave wireless access, advanced wireless x-haul, low-earth-orbit (LEO) satellite communications, as well as edge and cloud computing supported end-to-end in ARA. This practical exposure helps bridge the gap between theoretical knowledge and real-world applications. For instance, students can experiment with software-defined-radio (SDR) and programmable commercial-off-the-shelf (COTS) platforms, gaining valuable insights into how these technologies function and are deployed in rural settings.

Enhancing Graduate Studies

Graduate courses and research in wireless networks, especially those focusing on rural connectivity and advanced wireless research, can greatly benefit from ARA. Graduate students can utilize ARA's deeply programmable infrastructure to conduct rigorous scientific studies and applications. ARA's extensive coverage allows for comprehensive research on the performance and optimization of wireless networks. AraSoft, the software system of ARA, enables reproducible experimentation and the creation of software-defined virtual infrastructures. This capability is particularly valuable for research in wireless communications and networking, as it supports a wide range of applications from sensing and control to extended reality (XR) and streaming technologies.

https://arawireless.org/ara-in-education/

Experimental Exploration of 5G and Rural Broadband Systems Using ARA

This section provides access to comprehensive documentation designed for in-depth exploration of advanced wireless systems and rural broadband. The documentation covers the following modules:

- Module 0: Introduction to 5G
- Module 1: Modulation and Communication Techniques
- Module 2: Signal Processing and Analysis
- Module 3: Data Encoding and Packet Communication
- Module 4: Fundamental Concepts of SDRs
- Module 5: OpenAirInterface (OAI) and 5G Technologies
- Module 6: Advanced Signal Processing Techniques for 5G: Synchronization, Beamforming, and DOA Estimation

These modules offer a deep dive into the technical aspects of modern wireless communication systems, making them an invaluable resource for students and instructors. The set of modules can be accessed here.

https://arawireless.org/ara-in-education/

Module 5: OpenAirInterface(OAI) and 5G Technologies

- Background and History of OpenAirInterface (OAI)
  - Introduction
  - Why OAI was Created
  - OAI Implementation
  - Unique Aspects
  - OAI Community and Future
  - Conclusion
- How OpenAirInterface (OAI) Works and Its Advantages/Disadvantages
  - How Does OAI Work?
  - Disadvantages of OAI
  - Conclusion
- Setting Up a 5G Network Using OpenAirInterface (OAI)
  - Overview
  - Hardware and Software Requirements
  - Radio Access Network (RAN) Setup
  - Core Network (CN) Setup
  - Deployment Using Docker-Compose
  - Configuration and Testing
  - User Registration and Traffic Exchange
  - Monitoring and Optimization
  - Conclusion
- How OAI Uses and Establishes Configuration Files

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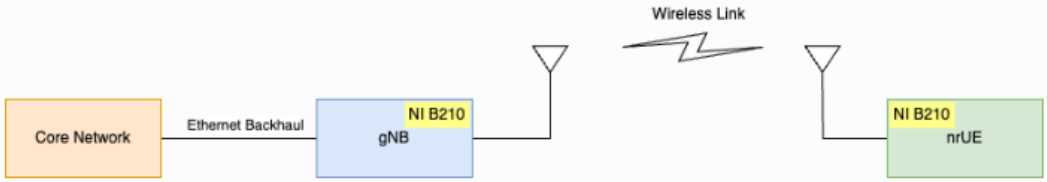
  - How OpenAirInterface (OAI) Works and Its Advantages/Disadvantages
  - Setting Up a 5G Network Using OpenAirInterface (OAI)
  - How OAI Uses and Establishes Configuration Files
  - Creating an IP Route Between gNB and NRUE Using SDRs
  - Quiz 1
  - Quiz 2
  - Indoor/Sanbox OpenAirInterface5g Experiments Using USRPs
  - Lab 2: 4G LTE Network Emulation and Throughput Testing Utilizing ARA

Indoor/Sanbox OpenAirInterface5g Experiments Using USRPs

Lab1: Setup, Ping, and Throughput measurement with iperf

Detailed Description: This experiment features a 5G network deployment using containerized 5G software components of OpenAirInterface5g, i.e., a containerized gNB, a containerized UE, and containerized core network deployed on Intel x86 servers. Both gNB and nrUE containers run on general purpose Intel x86 servers which are connected to USRP B210 SDRs via a USB 3.0 cable. The gNB is connected to a 5G core network via a high-speed backhaul link. The following figure shows the 5G BS-UE link created from the experiment.



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- **Module 5: OpenAirInterface(OAI) and 5G Technologies**
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Quiz 1

Quiz on OpenAirInterface (OAI)

6. What is the role of Software Defined Radios (SDRs) in the context of OpenAirInterface (OAI)?

- a. SDRs are used to implement the physical layer of the Radio Access Network (RAN).
- b. SDRs are used to create an IP route between gNB and NRUE.
- c. SDRs are used to test the connectivity between gNB and NRUE.
- d. SDRs are used to set up the Core Network (CN).

List of Courses that uses ARA at ISU

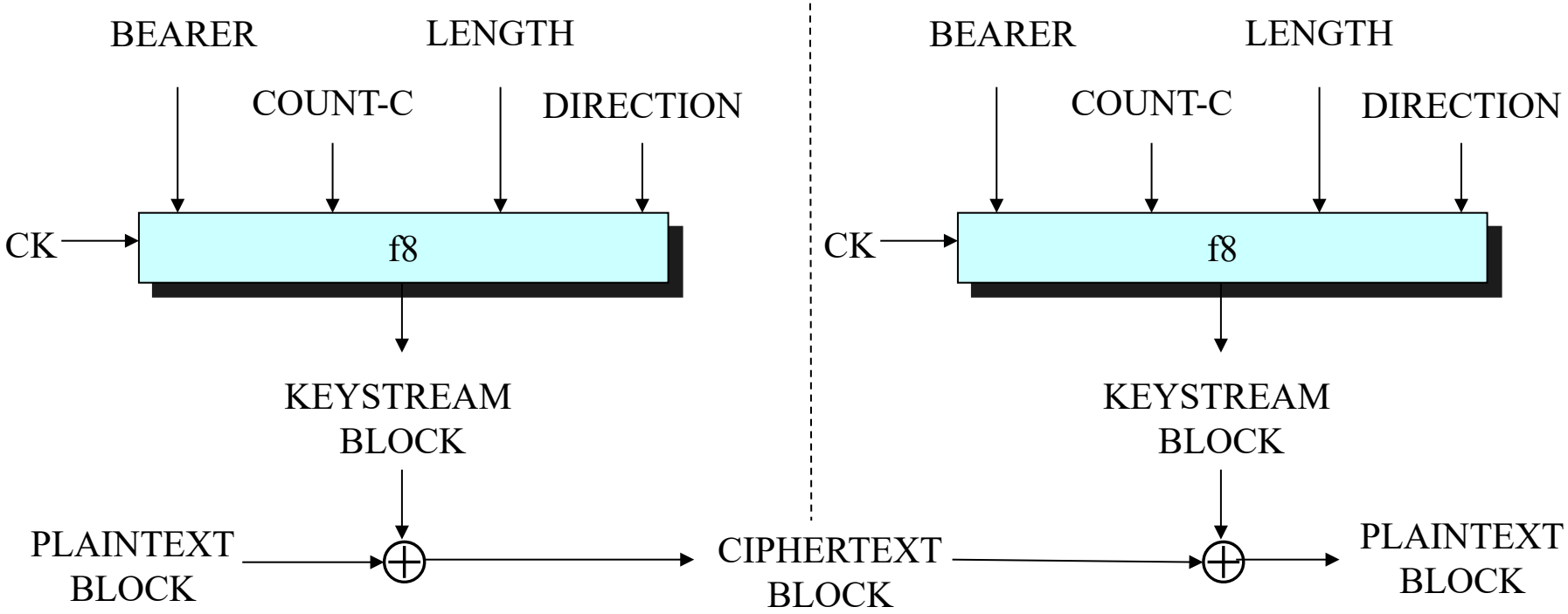
Spring 2024 – Fall 2025

- CPR E 4890: **Computer Networking and Data Communications**
- CPR E 5370: **Wireless Network Security (Graduate Course)**
- CPR E 4370: **Introduction to Wireless Security (Undergraduate)**

Technical Concepts (MCC, MNC, IMSI, etc)

- **IMSI** Stored in SIM, not more than 15 digits
  - 3 digits for Mobile Country Code (MCC)
  - 2 or 3 digits for Mobile Network Code (MNC)
    - ✓ It uniquely identifies the home network of the mobile subscriber.
  - <= 10 digits for National Mobile Station Identity (MSIN)

Technical Concepts (MCC, MNC, IMSI, etc)



Sender
(Mobile Station or
Radio Network Controller)

Receiver
(Radio Network Controller
or Mobile Station)

Students' Lab Report

From the EPC terminal, record:

- IMSI number: 001010123456789
- Allocated IP: 172.16.0.2
- Bearer QCI: 7

4) Starting the UE - Connection Process

After starting srsue, record:

a. Cell found - What's the PCI and PRB count?

PCI is the physical cell identity and it is an identifier for the cell at the PHY level.

PRB is the physical resource blocks and it counts the number of subcarriers × slots available in the downlink/uplink grid.

b. PLMN found - Does it match the network configured in EPC?

Yes it does. ID = 00101 = MCC + MNC. TAC 7 is also in both.

Example Lab Report Template

Visualizing SDR Data Lab

Institution:

Course:

Student Name: _____

Partner(s): _____

Date: _____

Instructor: _____

Procedure

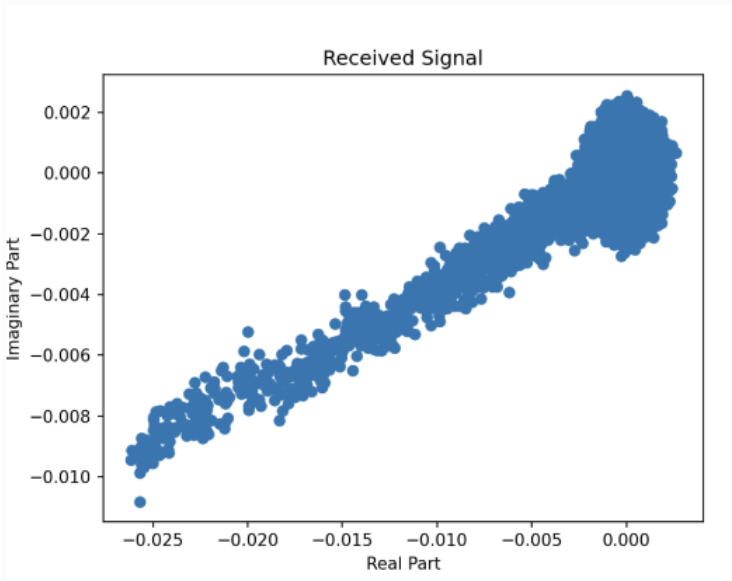
1. Received Signal Plot
   [Insert a screenshot here after running the code and generating the plot of Received signal (Imaginary Part vs Real Part)

Lab Report Solution for Instructors

Visualizing SDR Data Lab Answer Key

Procedure

1. Received Signal Plot
   [Insert a screenshot here after running the code and generating the plot of Received signal (Imaginary Part vs Real Part)



Example Final Project Report

Final Project Report
Team 04

Title: Simulating and Detecting Jamming Attacks on Cellular Networks using the ARA Platform

1. Overview of the Project

This report outlines our efforts to simulate and analyze a wireless network security vulnerability, specifically a jamming attack on a 4G LTE cellular communication system. We used the ARA Wireless Living Lab's indoor sandbox testbed to carry out this project [1]. The setup involved three main nodes: a base station (BS), a user equipment (UE), and a jamming node (JN). Each node was provisioned through ARA's portal.

Our objective was to successfully establish LTE communication between the BS and UE using OpenAirInterface (OAI), then launch a jamming attack using the third node to disrupt this communication. Throughout the process, we used tools like *ping* and *iPerf* to measure packet loss, latency, and throughput. Ultimately, this project helped us understand how targeted jamming works in a real environment and how we can detect and potentially defend against such attacks.

Example Final Project Report

4. How To Set Up and Execute the Attack

Step 1: Reserving ARA Resources

Begin by reserving three nodes on the ARA testbed – one each for the base station (eNB), user equipment (UE), and jamming node (JN). The ARA testbed allows flexible deployment of software-defined radio (SDR) environments with custom configurations [1]. Node reservations were made through the ARA portal, which can be seen in Figure 2. For the execution of the project, three nodes in close proximity were selected to ensure the UE would attach with ease [1]. Experiments conducted by our team showed that nodes further apart had slower network attachment times. The nodes used are node 020 for the JN, node 018 for the UE, and node 017 for the eNB. Figure 1 below shows which three nodes were reserved and their proximity to one another.

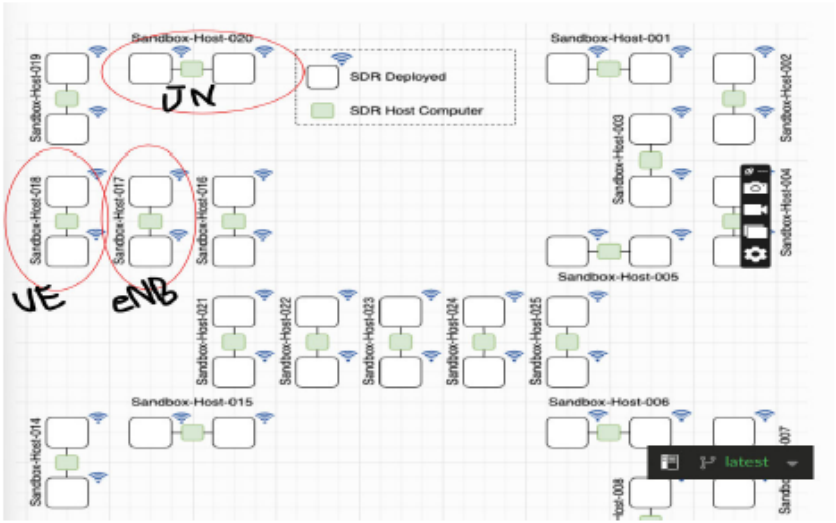


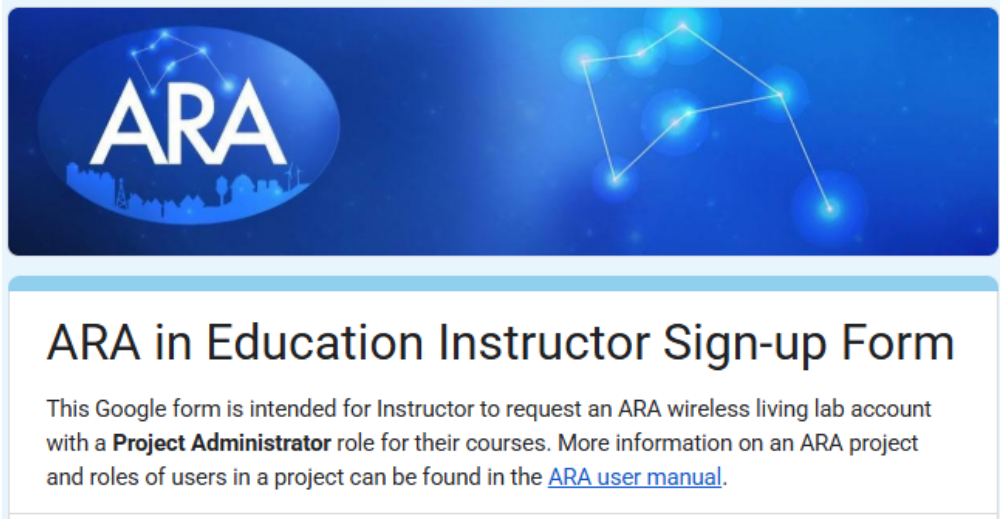
Figure 1

Students' Feedback

- I think that the emphasis on hands-on labs was useful and well done in this course. The labs and homework / reports also gave me an opportunity to explore wireless security topics on my own with provided direction.
- Having direct involvement in the various components through labs and other kinds of hands-on experiments helped promote learning
- The interactive hands-on labs and prompt instructor feedback reinforced my understanding by allowing me to immediately apply concepts to realistic scenarios. Additionally, clear explanations of complex security protocols helped me grasp challenging topics more effectively. The labs! They were very helpful at solidifying information presented in the lecture.

How to Use ARA For Education

- https://forms.gle/nchWZKjLXBHnJmUQ6



Questions

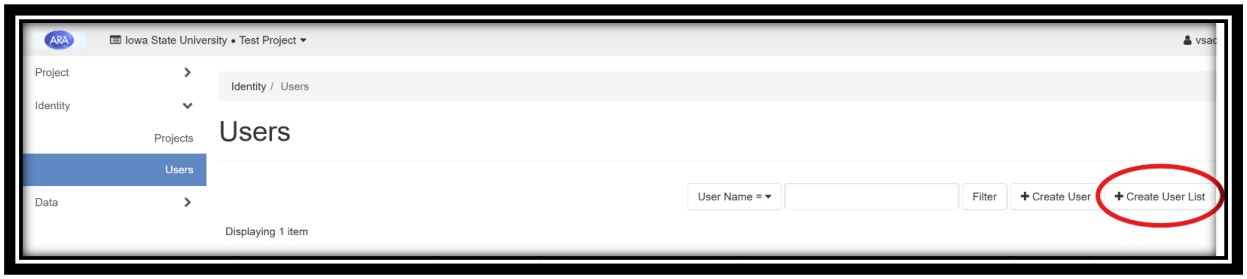
arawireless.org

wici.iastate.edu

Contact: Mohamed Selim, myoussef@iastate.edu, +1 515 294 2143

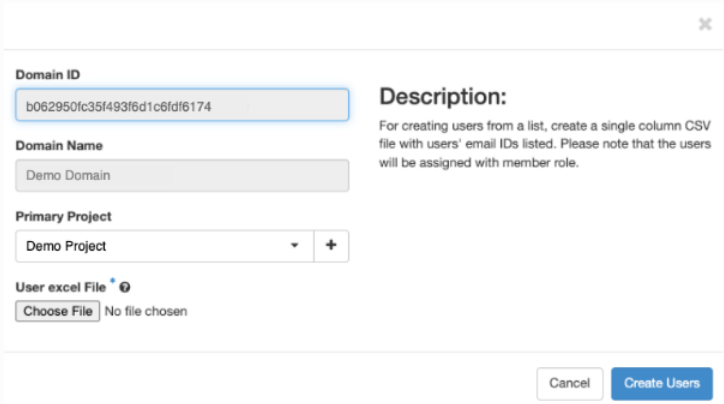
Adding Your Students to ARA Portal

- We recently adapted bulk addition of students using csv files



Adding Users from a List

If you want to add a list of users in a single click, navigate to the *Identity -> Users* tab in the dashboard. Then, click the **Create User List** button in the top-right corner of the page to open the following form:



The fields **Domain ID** and **Domain Name** are automatically populated. The drop-down menu under **Primary Project** lists the projects where you have an admin role. From the list, select the project to which you want to add users. Next, click the **Choose File** button to upload a CSV file containing user information in the following format:

Bulk Registration of Students

	A	B
1	username	role
2	test1@iastate.edu	member
3	test2@iastate.edu	member
4	prof@iastate.edu	admin

Displaying 4 items

User Name	Description	Email	User ID	Enabled	Domain Name	Actions
vsadvani@iastate.edu	-	vsadvani@iastate.edu	29e78396e8cd44198ad53b4d093583a9	Yes	Iowa State University	Edit
test1@iastate.edu	-	test1@iastate.edu	77377eccc6b849e7b3c57d4fe89d3c5e	Yes	Iowa State University	Edit
test2@iastate.edu	-	test2@iastate.edu	5dba70b831c440859cb83b10e2081038	Yes	Iowa State University	Edit
prof@iastate.edu	-	prof@iastate.edu	9de22c179a7e4ee1a77d899706b39986	Yes	Iowa State University	Edit

Displaying 4 items

Questions

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