ARA PAWR: Wireless Living Lab for Smart and Connected Rural Communities

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ABSTRACT

As the Platform for Advanced Wireless Research (PAWR) in rural broadband, the ARA wireless living lab features the deployment of first-of-its-kind wireless access and backhaul platforms in real-world agriculture and rural settings, and preliminary experiments have demonstrated very promising results, e.g., up to 3.2 Gbps wireless access throughput and more than 10 Gbps throughput across a wireless backhaul link of over 10 km. ARA is expected to be publicly released for broad community use starting in September 2023. Through this demo, we plan to share, for the first time, with the wireless research community the transformative research experiments enabled by ARA. To stimulate discussion and community participation, we will demonstrate a few example experiments ranging from MU-MIMO in TV White Space (TVWS) bands to long-range mmWave and microwave backhaul communications, as well as open-source 5G NR protocol stacks such as srsRAN and OpenAirInterface.

KEYWORDS

ARA, Rural Wireless, 5G and beyond, Precision Agriculture

1 ARA OVERVIEW

Lack of broadband Internet access in rural regions is a major societal challenge today, and addressing the challenge requires rural-focused broadband technology innovation [1]. To this end, we develop the ARA [1] wireless living lab as the U.S. Platform for Advanced Wireless Research (PAWR) in rural broadband. ARA embraces the unique community, application, economic, and operational contexts of rural wireless systems, and it features first-of-its-kind deployment of advanced wireless access and backhaul platforms in real-world agriculture and rural settings.

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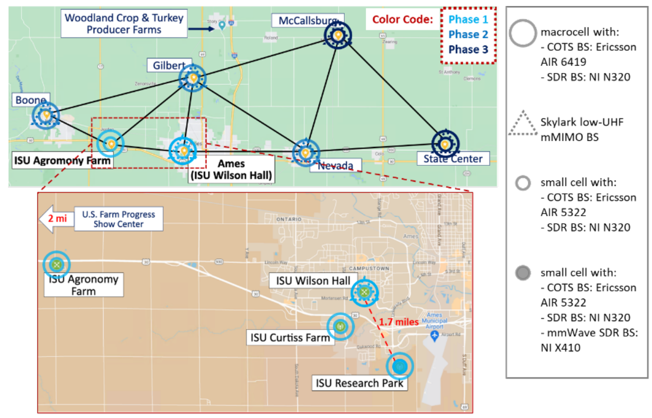

Figure 1: ARA deployment in central Iowa, U.S.A.

Table 1: Heterogeneous radio platforms in ARA

	Radio Platforms	Frequency Range	Bandwidth
AraRAN	Skylark mMIMO	470–710 MHz	up to 40 MHz
	NI X410	1 MHz–7.2 GHz	400 MHz
	InterDigital	26.5–29.5 GHz	500 MHz
	NI N320	3–6000 MHz	200 MHz
	NI B210	70–6000 MHz	56 MHz
	Ericsson FR1	3.4–3.6 GHz	200 MHz
	Ericsson FR2	24.25–27.50 GHz	325 MHz
AraHaul	Aviat 11 GHz	10.6–11.5 GHz	100 MHz
	Aviat 80 GHz	71–86 GHz	2 GHz
	AraOptical	194THz	5 GHz
	LEO satcom	12–40 GHz	2 GHz

Specifically, Figure 1 shows the ARA deployment in central Iowa, U.S.A. The top subfigure shows the long-distance, high-capacity wireless backhaul mesh network *AraHaul* spanning the City of Ames, where Iowa State University (ISU) resides, and surrounding agriculture farms and rural towns, with each AraHaul site equipped with heterogeneous platforms of the ARA wireless access network *AraRAN*. The bottom subfigure shows the additional AraRAN sites in the City of Ames. As summarized in Table 1, AraRAN includes both Software-Defined Radios (SDRs) and Commercial Off-The-Shelf (COTS) platforms that operate at frequencies ranging from low-UHF to mmWave bands. AraHaul consists of long-distance, high-capacity free space optical, mmWave, and microwave wireless backhaul links. ARA enables a wide range of research in advanced rural wireless and applications, with some examples shown in Table 2.

Table 2: Example research areas supported by ARA

Domain	Research area
Modeling	• Real-world rural wireless channel characterization • Physical dynamics and mobility characterization
Architecture	• Long-distance, high-capacity wireless backhaul • Cellular networks with massive MIMO and D2D links • Mobile networking of agricultural vehicles and robots • Integrated wireless access and backhaul • Integrated wireless, fiber, and edge computing
Technology & Service	• Ultra-reliable low-latency communications (URLLC) • Massive MIMO, beamforming, and beam tracking • Fixed and mobile mmWave networking • Massive machine type communication (mMTC) • Dynamic spectrum sharing • Green wireless networking
Application	• AR/VR based tele-operation of ag vehicles and robots • Real-time collaborative machine learning • AR/VR-based crop phenotyping • Animal health monitoring and Ag education

To transform the at-scale field-deployed ARA infrastructure into a wireless living lab supporting reproducible scientific experiments in advanced wireless and applications, we develop the ARA control framework *AraSoft*. AraSoft builds upon the open-source infrastructure management platforms OpenStack and CHI-in-a-Box [2], leveraging their computing and networking management solutions and extending them by developing solutions for managing wireless infrastructure resources and integrating wireless with computing and wired networking resources.

2 DEMO

ARA has completed its Phase-1 deployment with four Base Station (BS) sites at the ISU Wilson Hall, Agronomy Farm, Curtiss Farm, and Research Park, one AraHaul link between the Wilson Hall and Ag Farm sites, as well as nine User Equipment (UE) sites with 11 more UEs to be deployed by the end of September 2023. The fixed UEs are deployed in crop and livestock farms and city facilities, while mobile UEs are deployed on ag-vehicles, city buses, and pubic safety vehicles. As an example, Figure 2 shows the east sector radio deployment at the rooftop of Wilson Hall. With AraSoft, all the ARA infrastructure resources are accessible online by the broad communities to conduct cutting-edge experiments.

2.1 Demo Experiments

To demonstrate the scientific experiment workflow of ARA as well as ARA-enabled research, we will present three representative demo experiments: 1) Measurement and analysis of rural TVWS multi-user MIMO (MU-MIMO) systems using the programmable production-quality many-antenna MIMO

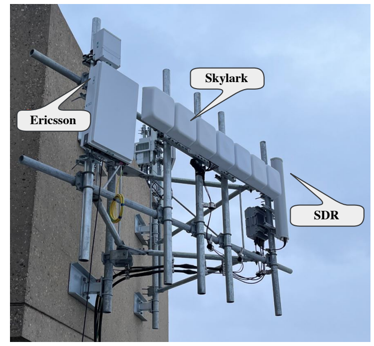

Figure 2: East sector deployment at Wilson Hall

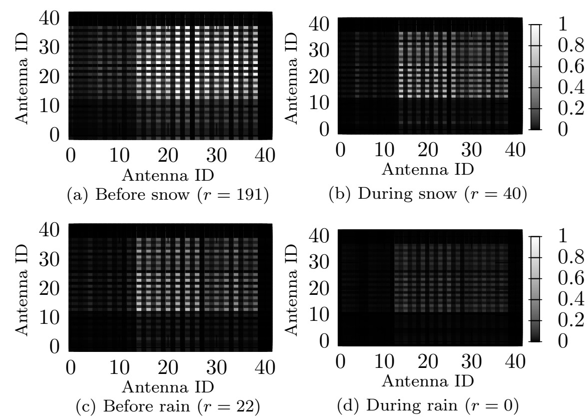

Figure 3: Channel correlation between antenna pairs

(mMIMO) system by Skylark Wireless. 2) End-to-end over-the-air 5G NR experiments using open-source 5G stacks srsRAN and OpenAirInterface as well as the USRP N320 and B210 SDRs; and 3) Experimental study of multi-modal, long-distance, and high-capacity mmWave and microwave wireless backhaul links using Aviat Networks radios. These demo experiments and the interactions with conference attendees will help the attendees understand the types of experiments uniquely enabled by ARA, as well as the unique research data and insight that can be derived from such experiments. For instance, in the rural TVWS MU-MIMO experiment, we can measure ground-truth CSI, capacity, latency, user grouping, and received signal strength, through which we can gain insight into the system spectral efficiency, capacity, latency, and channel correlation. Figure 3 shows one such example, demonstrating that rain and snow add additional randomness to wireless channels that can be leveraged in a mMIMO system to compensate for the additional path loss introduced by rain/snow.

2.2 Resources needed for Demo

This demo only requires Internet connectivity (to access the ARA web portal) and a desk with a large computer monitor.

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