Demo: Arena: A 64-antenna SDR-based Ceiling Grid Testbed for Sub-6 GHz Radio Spectrum Research

Lorenzo Bertizzolo, Leonardo Bonati, Emrecan Demirors, Tommaso Melodia
Institute for the Wireless Internet of Things, Northeastern University, Boston, MA 02115, USA
Email: {bertizzolo.l, bonati.l, edemirors, melodia}@northeastern.edu

ABSTRACT

Arena is an open-access wireless testing platform based on a grid of antennas mounted on the ceiling of a 2240 square feet office-space environment. Each antenna is connected to programmable software-defined radios enabling sub-6 GHz 5G-and-beyond spectrum research. With 12 computational servers, 24 software defined radios synchronized at the symbol level, and a total of 64 antennas, Arena provides the computational power and the scale to foster new technology development in some of the most crowded spectrum bands, ensuring a reconfigurable, scalable, and repeatable real-time experimental evaluation in a real wireless indoor environment. We demonstrate some of the many possible capabilities of Arena in three cases: MIMO Capabilities, Ad Hoc Network, and Cognitive Radio Network.

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1 INTRODUCTION

The evolution of wireless networked systems continues to be a crucial commercial, strategic, and geopolitical matter. It is expected that by 2020, over 50 billion devices will be absorbed into the Internet, generating a global network of "things" of dimensions never seen before. Industrial automation, smart cities, and distributed robotic systems will increasingly rely on large-scale wireless networked systems. In addition to their commercial strategic need, 5G and IoT have been identified as critical technologies for national security.

It is therefore surprising that the wireless research community is still lacking experimental facilities to support rigorous and repeatable experimental evaluation of wireless networked systems. The recent NSF Platforms for Advanced Wireless Research (PAWR) program is addressing this issue by developing four city-scale platforms for advanced wireless research to experiment with new wireless systems in outdoor environments [5]. Following the same trend, Colosseum [3] will provide a *shared* wireless network emulation facility to experiment *at scale*, in a fully *controlled and observable environment*. While the availability of PAWR platforms and Colosseum represents a major stepping stone towards open rigorous experimentation with shared facilities, the community is still lacking a platform to test at scale medium- and short-range radio technologies in the sub-6 GHz radio bands in an indoor realistic environment guaranteeing high-fidelity, scale, and repeatability of experiments. This is crucial for sub-6 GHz testing indoor deployments such as offices, malls, and airports that are characterized by fast-varying environment, spatially and time-varying interference, significant multi-path effect, and continuous mobility of surrounding objects. We make an effort to address this need by designing Arena [1], a remotely-accessible wireless testing platform based on an indoor 64-antenna ceiling grid connected to programmable SDRs for sub-6 GHz 5G spectrum research, and present its live demonstration capabilities in this work.

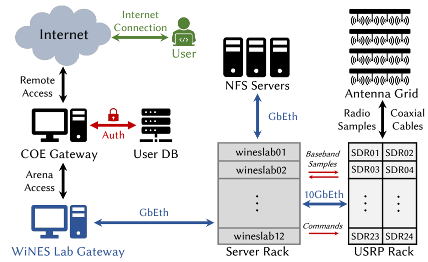

Figure 1: Arena access system diagram.

2 ARENA DESIGN

Arena is an open upon-grant platform, which any academic or industry researcher can access upon receiving a Northeastern University COE sponsored account. Arena is based on a three-tiered architecture, the server rack, the radio rack, and the antenna grid as illustrated in Fig. 1.

Server Rack. The server rack is composed of 12 servers, a gateway, and a switch. The servers are Dell PowerEdge R340 machines with an Intel Xeon E-2186G processor, and drive the 24 SDRs (see Figure 2). Each server is equipped with an Intel X520 Dual 10 Gigabit DA/SFP+ network card and can reach an aggregate data-rate of 20 Gbit/s, ensuring low-latency radio control and communication. A set of

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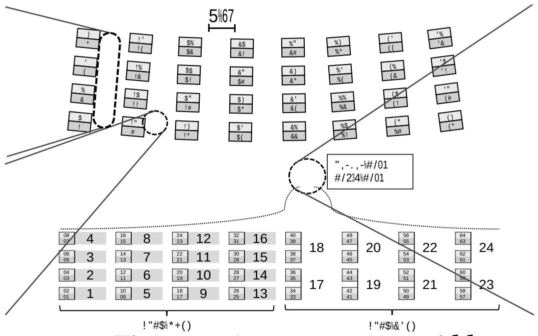

Figure 2: Arena antenna grid layout.

open-source software tools (e.g., GNU Radio, srsLTE, UHD, Python, etc.) is present on the servers to communicate with the SDRs. A Gigabit Ethernet interface connects each server to the gateway enabling remote user access through a Gigabit Ethernet switch. To protect the servers from power spikes and surges, and give them emergency power in case of outages, the power supply system is based on two APC Rack Power Distribution Units AP7811B and a Dell 5000 VA 208 V Smart Uninterruptible Power Supply (UPS).

Radio Rack The radio rack houses 24 Ettus Research SDRs (16 USRPs N210 and 8 USRPs X310), along with 4 OctoClock clock distributors, and two 10 Gigabit switches (see Figure 2). USRPs are experimental hardware radio platforms completely controllable through software programs and are particularly suitable to design, test, prototype, and deploy wireless radio communication systems and protocols. The USRP N210 is a networked device with high-bandwidth and dynamic range processing. The USRP X310, instead, is a high-performance scalable device embedding two daughterboard slots as well as a user-programmable FPGA. The USRP N210 and X310 embed one and two daughterboard slots, respectively, allowing for bi-directional wireless communication. These devices are controllable via software through a Gigabit Ethernet interface, and two 200 MS/s aggregate SFP+ slots, respectively. Multiple USRPs N210 and USRPs X310 are externally synchronized at the symbol level through 4 OctoClock clock distributors. Finally, USRPs N210 and X310 mount one and two CBX daughterboards, respectively, which allow USRPs to operate in the 1.2-6 GHz frequency range with up to 120 MHz instantaneous bandwidth [6].

Antenna Grid Arena 64-antenna ceiling grid concerns an 8×8 array covering an overall area of 2240 ft^2, where each antenna point is cabled to the radio rack. Arena is based on 64 same-length American Wire Gauge (AWG) RG8-CMP low-attenuation cables designed for indoor applications connecting the antennas to the SDRs. The same-length cables ensure equal delays all over the testbed, making it possible to test schemes such as MIMO, where a different antenna connector length might compromise the transmission synchronization. For over-the-air communications, Arena is equipped with omnidirectional dualband VERT2450 antennas for transmission and reception (see Figure 2) optimized to work in the 2.4-2.5 GHz and 4.9-5.9 GHz operating frequency bands. The 64 antennas are mounted on eight 15 ft rails hung to the ceiling, which also permit an easy antenna relocation.

3 DEMONSTRATION

The live demonstration of remote experiments on Arena envisions: *MIMO Capabilities, Ad Hoc Networks,* and *Cognitive Radio Networks.*

MIMO Capabilities: Its full-testbed symbol-level synchronization enables distributed MIMO transmission schemes implementations, aimed at increasing the SINR of a wireless communication link by instantiating a 4-MISO transmitter employing maximum ratio transmission beamforming, compared to single antenna transmission.

Ad Hoc Networks: Arena can seamlessly implement hoc wireless networks such as an instance of WNOS [4]. This is a wireless network operating system for ad hoc networks that provides automated network control, interfacing the network designer with a simple control interface. We demonstrate a 14-nodes WNOS prototype on Arena, where two source nodes intend to deliver data to two destinations through 12 relay nodes, in a wireless multi-hop fashion. Specifically, we employ WNOS to dictate two different network behaviors, namely *max-rate* and *min-power* (see [4] for details).

Cognitive Radio Networks: Finally, we employ Arena to demonstrate spectrum-sensing-based solutions such as cognitive radios to gather information about Wi-Fi activity in the surroundings. Specifically, we leverage an IEEE 802.11 GNU Radio implementation [2] to instantiate SDR-based Wi-Fi receivers and sense the environmental Wi-Fi activity.

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