Demo: Mobile and Wireless Research on the POWDER Platform

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ABSTRACT

POWDER is a highly flexible, deeply programmable, and city-scale scientific instrument that enables cutting-edge research in wireless technologies. Researchers interact with the POWDER platform via the Internet to conduct their experiments, with zero penalty for remote access. In this two-part demonstration, the POWDER implementers show how to use the platform. First, they present the workflow that researchers follow to conduct experiments. Second, they highlight some of the hardware and software building blocks available through POWDER, including components related to over-the-air wireless and mobile networking, 5G, and massive MIMO.

CCS CONCEPTS

• **Networks → Wireless access points, base stations and infrastructure**.

1 INTRODUCTION

The evolution of mobile and wireless networking is being driven by several key trends including the "softwarization" of network functionality (e.g., SDN, NFV, and "open RAN"); the scarcity of usable spectrum in the face of increasing demand; the application of machine learning for analysis, management, and prediction; and emerging application areas such as "extended reality" (XR), volumetric video streaming, and high-precision localization. These trends present unique opportunities for research and innovation. However, the inherent complexity of the mobile and wireless ecosystem means that major advancements cannot be obtained by making only small adjustments at the edges of existing networks. To drive the science of wireless networking forward, researchers need platforms designed *specifically for experimentation:* networks at scale, in real environments, with end-to-end control, and with visibility at all layers from the radio to the application.

This is the purpose of POWDER, the Platform for Open Wireless Data-driven Experimental Research [1], currently being deployed in Salt Lake City, Utah, USA. POWDER is a *highly flexible, deeply programmable, and city-scale scientific instrument that enables research at the cutting edge of wireless technology.* Researchers access POWDER via the Internet to allocate resources and carry out their experiments (§2). The POWDER demonstration at MobiSys '21 illustrates the workflow of POWDER-based experiments and showcases some of the hardware and software components available to researchers in the platform (§3). POWDER is one of the platforms being developed as part of the National Science Foundation (NSF) Platforms for Advanced Wireless Research (PAWR) program.

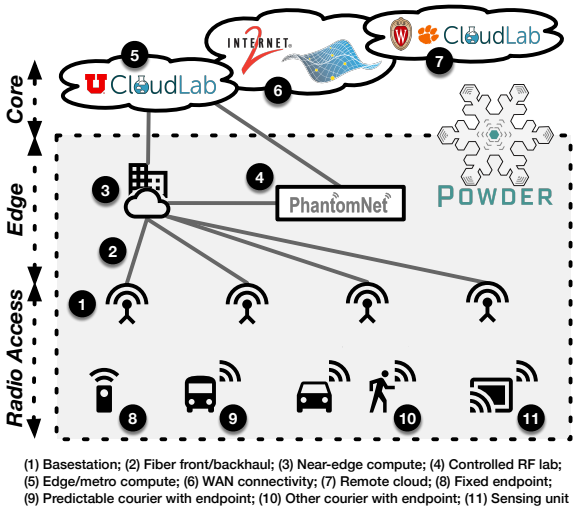

Figure 1: POWDER physical infrastructure overview

2 POWDER OVERVIEW

The POWDER platform consists of a physical *infrastructure*, depicted in Figure 1, that offers programmable *functionality* to researchers. The infrastructure includes a variety of radios, antennas, environments, and mobility patterns. General-purpose and specialized equipment coexist in the infrastructure, and new devices can be incorporated for specific experiments. Fixed-location and mobile devices—e.g., rooftop basestations and campus shuttle endpoints—are deployed across the University of Utah campus. More will be deployed in the near future, including a "dense deployment" of street-level devices. The functionality of all these devices is exposed to platform users—enabling end-to-end, deep programmability—to maximize the devices' utility and the platform's research impact. POWDER connects to Internet2 and other research platforms, notably CloudLab [3] and FABRIC [2].

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MobiSys '21, June 24–July 2, 2021, Virtual, WI, USA

ACM ISBN 978-1-4503-8443-8/21/06.
https://doi.org/10.1145/3458864.3466915

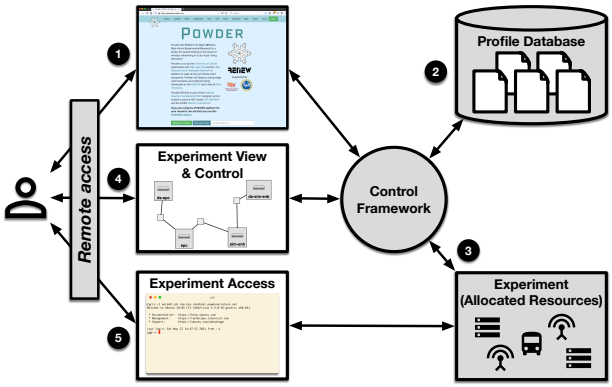

Figure 2: Workflow of an experiment on POWDER

POWDER is managed by a control framework that provides *remote access for zero penalty:* its goal is to enable physically remote researchers to work as effectively as they could if they were on site. The framework provides a web portal (https://powderwireless.net/), allocates resources to users for their experiments, and allows many people to use different "slices" of the platform concurrently.

Figure 2 illustrates the steps that a researcher typically follows to carry out an experiment on POWDER. The user starts by visiting POWDER's web portal ❶, logging in, and selecting the *profile* of the experiment that he or she would like to perform. A profile lists the hardware resources that must be allocated to an experiment, as well as the software required for the experiment. These are the "building blocks" that POWDER combines to set up a research environment for the user. POWDER provides a database of profiles ❷, and users can create their own. POWDER's control framework *instantiates* ❸ the user's chosen profile by allocating physical resources (devices, network, spectrum) and configuring them for the user, e.g., by loading software onto the devices. The set of configured resources is called an *experiment*. The researcher can view and control the experiment via the POWDER portal ❹, but more interestingly, he or she can access and control the allocated devices directly via standard tools and protocols ❺, e.g., SSH. The researcher has administrative ("root"), low-level access to the devices while the experiment is in progress. When the researcher is finished, he or she terminates the experiment. The experiment's resources are deallocated and made available to other users of the POWDER platform.

3 DEMONSTRATION

POWDER is designed to support physically remote users, and as such, it is straightforward to demonstrate POWDER to an online audience via virtual conferencing software. Using live screen sharing and recorded video segments, members of the POWDER development team show how researchers can use the platform for wireless experiments. The demonstration is presented into two parts. The first focuses on the workflow of typical POWDER experiments, and the second showcases some of the hardware and software building blocks that POWDER makes available within the platform.

Experiment workflow. The demonstrators step through the POWDER workflow described in §2 and illustrated in Figure 2. They show how users can:

- *Access the POWDER portal* and select a profile from the POWDER profile database to instantiate an experiment.
- *View and control* their experiments. This includes general activities such as determining the states of the devices in an experiment, rebooting the devices within an experiment, terminating or extending the lifetime of an experiment, and so on.
- *Access the devices* in an experiment. This includes low-level access to compute and radio resources on compute clusters, rooftop devices, and fixed and mobile endpoints.

Hardware and software building blocks. Using POWDER's example profiles, the demonstrators exercise some of the available building blocks for experiments in specific areas and environments:

- *Over-the-air, end-to-end, software-defined mobile networking.* A key capability of POWDER is over-the-air (OTA) experimentation in a real-world environment. The demonstrators show this functionality using POWDER rooftop and fixed-endpoint nodes, combined with the srsRAN open-source mobile networking stack [9].
- *Fully programmable CBRS/BRS massive MIMO (mMIMO).* Another key feature of POWDER is its fully programmable mMIMO capabilities. The demonstrators show an experiment that uses POWDER's rooftop-deployed Skylark [8] equipment, combined with the mMIMO software being developed in the RENEW project [7].
- *Open-source 5G non-standalone (NSA), standalone (SA), and core network (CN).* Open-source 5G functionality is rapidly emerging. The POWDER team demonstrates 5G NSA/SA functionality using COTS UEs and SDR-based eNodeBs/gNBs (hardware) with OpenAirInterface open-source software [6], as well as open-source 5G CN functionality from Open5GS [5].
- *RF transmission/reception from fully programmable mobile endpoints.* POWDER's remotely accessible, fully programmable, mobile endpoints provide unique functionality for mobility-related experiments. The demonstrators present this capability using SDRs available in the mobile endpoints and rooftop nodes, combined with the GNU Radio software [4].

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant Number 1827940. We thank the PAWR Project Office, the PAWR Industry Consortium, and our partners at the University of Utah and in Salt Lake City for their support.

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