Aerial Experimentation and Research Platform for Advanced Wireless (AERPAW)

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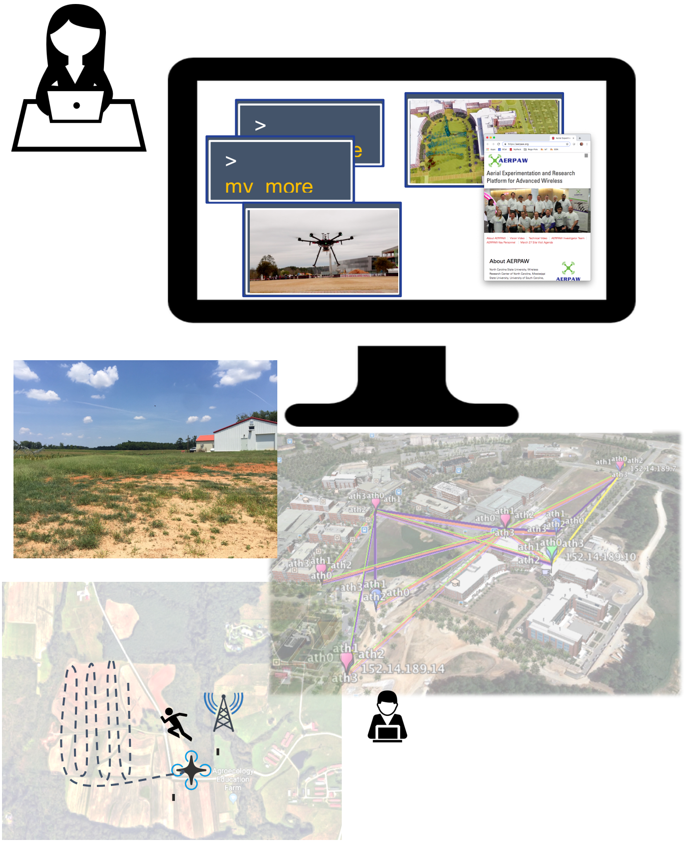
AERPAW is a testbed for proving research in the emerging intersection of advanced wireless communication technologies, wireless protocols, and 3D mobility of autonomous agents. It has been funded as the third PAWR platform by the US National Science Foundation's PAWR program. New use cases for advanced wireless technologies, once thought to be science fiction, are recently emerging in the unmanned aerial systems (UAS) spaces. According to Goldman Sachs, a $100 billion market opportunity exists for UAS in commercial, civil government, and military sectors between now and 2020. Multiple applications of UAS have attracted major attention, e.g. by Amazon, Google, Uber, Boeing, Zipline, Flytrex, and Matternet. While most UAS operations presently require visual line-of-sight (VLOS) between a pilot and the drone, cellular networks with advanced wireless technology will enable the emergence of beyond VLOS (BVLOS) and autonomous UAS operations, unleashing 3D mobility.

As far as we know, AERPAW will be the first-of-its-kind aerial wireless experimentation platform, developed in partnership by NC State University, Wireless Research Center of North Carolina, Mississippi State University and Renaissance Computing Institute (RENCI) at the University of North Carolina at Chapel Hill; additional partners include Town of Cary, City of Raleigh, North Carolina Department of Transportation, Purdue University, University of South Carolina, and many other academic, industry and municipal partners.

A unique feature of AERPAW is that support of mobile radio endpoints, both ground and airborne, is considered a primary design determinant. Wireless communication is largely driven by the need to be "untethered", and mobility is the root driver of many of the most difficult intellectual challenges in wireless theory and technology, from coarse-grained concerns such as handover to fine-grained ones such as beam-steering to track mobile nodes. AERPAW is unique in its combination of being embedded in real outdoor spaces, of a variety of radio terrain ranging from agricultural to urban, and with native support of wireless mobility in experiments. Further aspects of the technical architecture are driven by the paramount need for operational safety of airborne mobile nodes, the reproducibility of experiments, and the requirement to onboard users easily onto this unique environment on an ongoing basis.

A representative small experiment on the testbed is envisioned as follows. In designing this experiment, the user (researcher) plans to focus on a single wireless link and has chosen an available fixed location offered by AERPAW for one endpoint and an aerial mobile node for the other. They have chosen to use an SDR at each endpoint node. Finally, they intend to study link characteristics as the mobile endpoint of the link traverses a specific three-dimensional trajectory over the surrounding geography. We assume that the exact space-time trajectory of the UAV, as well as the exact sequence of SDR transmissions, are not known in advance even to the experimenter, but are decided at run-time by the experimental code implemented on the two endpoint nodes. From this, we can see that the basic need of the researcher is to be able to program computers with advanced wireless interfaces attached to them. Naturally, an experimenter may choose multiple fixed and mobile nodes and radios of various types. We also



allow the user to include pure compute nodes in an experiment, such as to represent edge-compute nodes or the Cloud. All nodes can run user-developed code, and it is a legitimate expectation that these distributed pieces of code will be able to coordinate their execution at run-time, and do so without compromising the integrity of the spectrum being used by the experimental wireless channels. In other words, the testbed needs to provide a back-channel to let the various pieces of experimenter code coordinate "out-of-band".

In addition to SDRs, AERPAW will have a variety of advanced wireless equipment available for its nodes, including commercial 5G radios (mmWave and sub-6), LoRa and Sigfox IoT, and UWB. Planned allocations of these radios to the fixed and mobile nodes are provided in a supplementary document with budget details. Assignments will change over time in normal testbed operation, and AERPAW's technical architecture is designed to be general enough to handle any assignment.

We will use virtualization techniques extensively in AERPAW, but by the very nature of the testbed, sharing space or spectrum to co-locate multiple experiments in the same location at the same time is only possible to a certain extent without curtailing experimenter freedom to write adaptive code in terms of positioning mobile nodes, varying radio frequencies, and iterating over scenarios. It follows then that experiments must be defined when they are developed to have boundaries in time, space, and spectrum. Violating any of these boundaries must cause the experiment to be terminated in an automatic and responsive manner.

The coming deluge of 3D wireless autonomous nodes is certainly not unique to the US. We envision that many other wireless testbeds focusing on autonomous airborne agents will be designed and built, and that the design and operations of such testbeds, as well as the research challenges they will accommodate, will be a fruitful area of future cooperation between the US and European researchers in the general areas of wireless, networking, and mobile computing.