Modeling and Measurement for Rapidly-Deployed Multi-Transmitter Networks

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Area of Interest: Cellular Strength Mapping in Disaster Environments

Capability Description:

Based on past experiments from JIFX 14-4 and JIFX 15-1, CMU has developed enhanced capability for real-time measurement of three-dimensional RF fields, interpolation, and visualization. At this JIFX, we propose to demonstrate this enhanced capability and to continue our experiments in coupling measurements with dynamically-evolved field models. It is our belief that such coupled measurement / model systems offer the possibility of rapidly-deployed multi-transmitter networks with better coverage than prior approaches.

Experiment Objective/Hypothesis:

Offline analysis of data from past field experiments and comparison to traditional models shows significant discrepancies. Traditional models are intended for a more-or-less two-dimensional view of the network, and individual models are applicable to specific situations (e.g, urban clutter, rural, open field, and open air). Real-world networks don't fit under any one model.

Our hypothesis is that only through a combination of real-time measurement and real-time modeling can a suitable model be constructed. Our contention is that data gathered in real time should inform the model and that the model should be able to distinguish between areas where its confidence is high from areas where its confidence is low. These low-confidence areas, in turn, can be used as input to flight-planning software for autonomously operated unmanned aerial vehicles, creating a coupled modeling and sensing system that uses model uncertainty to close the loop in data gathering. Focusing the data-gathering only in areas of uncertainty both shores up a weak model and reduces time-to-accurate-model.

Experiment Plan / Data Collection Plan:

We propose to set up our portable cellular base station and mobile RF lab at the CACTF and to fly autonomously-piloted quadcopters in and around the CACTF, collecting data and building a self-optimizing model. In addition, we will operate autonomous ground vehicles (model cars equipped with the same sensing and piloting equipment as our quadcopters) to gather radio data at ground level.

The quadcopters and the cars have been designed to make accurate aerial and ground RF measurements in the 900 MHz band using low power spread-spectrum radios (good proxies for sub-gigahertz LTE cellular radios). They relay telemetry in real time to the mobile RF lab where the model builds itself in real time. The basic approach was demonstrated and proven at JIFX 15-1.

We will experiment with a variety of model-building techniques including Bayesian networks and convolutional deep neural networks.

Measures of Performance & Effectiveness:

Through oversampling, we will build an accurate RF map of the CACTF and its surrounding area and use this as "ground truth". This will serve as the basis of comparison for the under-sampled machine learning system.

Performance will be assessed as a tradeoff between accuracy and time. The subsampled model should approach the ground truth model as more and more sorties are flown. Effectiveness will be assessed by demonstrating acceptable accuracy (within a few dB) using substantially less data-collection time than the ground truth case.

What new capability does this represent?

If successful, multi-transmitter networks with predictable coverage will be deployable more rapidly than is the case today. This has application to disaster situations in which the communications infrastructure has been rendered inoperable and in which time-to-restore basic service is of the essence.

Likewise, this approach would serve equally well in a battlefield environment to provide rapidly deployable networks with predictable coverage -- supporting both ground-based and airborne missions.

What capability gap does this address?

Multi-transmitter network deployment is a slow and tedious process, necessitating time-consuming measurement that is human intensive. It depends on modeling techniques that must be adapted manually to the terrain and built infrastructure. When changes happen (e.g., loss of a transmitter, change in foliage), the time-intensive process must be repeated.

Our approach automates most of the manual tasks, improves the quality of modeling, and operates more quickly -- allowing changes to be handled more rapidly.