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Development of Distributed Sensing Infrastructure and Flood Monitoring Systems

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Radar observations of precipitation have been successfully used to feed into various hydrometeorology models. Evaluation studies also found it important to incorporate high resolution precipitation data for small-scale severe weather events or in highly localized terrains. Recent development of radar technologies enables high resolution, accurate precipitation observations over wide areas. Yet the observation geometry of a single radar system has fundamental limitations, such as beam blockage due to earth curvature and decreasing resolution at long ranges. To address these limitations, a new networked sensing paradigm was developed to innovatively organize multiple radars over distributed computation and communication infrastructure in the NSF engineering research center for CASA (Collaborative Adaptive Sensing of the Atmosphere). Based on this concept, revolutionary distributed and adaptive end-to-end sensing systems have been engineered. In this paper, we will introduce the key sensing system attributes and the development of the supporting infrastructure and the comprehensive technologies infusing them together.

The new sensing paradigm is summarized as Distributed Collaborative Adaptive Sensing (DCAS). As a DCAS system, a dense network of short-range X-band radars is distributively deployed to provide a large coverage of interest and at the same time counter the range associated limitations. The neighboring radars have substantial overlapping coverage and are collaboratively steered to enhance the observations. The sensing resources in the network are adaptively configured to meet multi-user needs in ever-changing weather conditions. In this manner, a DCAS system operates as a closed-loop dynamic system, executing optimized scans.

A couple test-beds have been recently developed following the DCAS concept. The CASA center has developed and is operating a demonstration test-bed to integrate various innovations for DCAS technology. The National Research Institute for Earth Science and Disaster Prevention (NIED) in Japan is developing another test-bed in Tokyo Metropolitan area using a dense radar network (X-Net). In a typical networked system, apart from the state-of-the-art reconfigurable radar systems, the communication and computation infrastructure is vital to support DCAS operation and more importantly the communication and computation capabilities are infused into every subsystem of the network through distributed system architecture. The system along with its applications can be geologically deployed over a large part of continental US. It will be powered by a suite of real-time algorithms for detection and optimization as the MC&C (Meteorological Command and Control) subsystem.

By orchestrating sensing, communicating, and computing together, we achieved unprecedented capability in hazardous weather observations. Detection algorithms output the current weather condition from rich datasets of sensing observations, and MC&C consolidate all the user requirements and optimize the sensing subsystem for better observations. Within a short system update time, called a heartbeat, the new scan tasks are issued to the distributed radar nodes for the optimized scans. Case studies will be presented to demonstrate all the new capabilities. The DCAS test-bed is shown providing high quality rainfall observations which can be used to drive advanced hydrological models for flooding applications. A real-time short-term nowcasting system is experimentally operated to gain important lead time in severe weather events. The DCAS network of this kind can be flexibly installed in the highly occupied cities to avoid widely spread strong clutter and blockage and take advantage of high communication readiness. CASA and NIED scientists are leading a partnership to build an urban flood monitoring system using the networked sensing products.