14R.2 CASA'S FIRST TEST BED: INTEGRATIVE PROJECT #1

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1. INTRODUCTION

The Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is a ten-year National Science Foundation Engineering Research Center (ERC) established in the fall of 2003. The goal of CASA is to develop a low-cost, low-power network of solid-state, phased-array radars that will dynamically and adaptively sample the lower troposphere (0 – 3 km AGL). CASA will utilize a networked approach to sensing, known as distributed collaborative adaptive sensing (DCAS), to overcome the limitations associated with low-cost, low-power radars (e.g., attenuation and limited range).

During the ten years of the center, CASA will utilize a series of five test beds, known as integrative projects (IPs), to develop, experiment, and demonstrate the enabling technologies. The first integrative project, IP1, will consist of four radars and be located in southwestern Oklahoma. IP1 will focus on sensing low-level wind hazards and associated severe weather. IP2 will be located in Houston, Texas, and will aim to improve the detection and prediction of urban flooding. A third test bed, IP3, will be located in Puerto Rico and will be used to study tropical rain in complex terrain that can lead to flooding and landslides. A fourth test bed, known as CLEAR, will focus upon the measurement of winds in the non-precipitating atmosphere to improve forecasts of convective initiation and pollutant transport. The fifth test bed will be a second generation IP1 test bed using research and technology developed during the course of the CASA project.

Integrative Project #1 is designed as an end-to-end system, meaning that IP1 is being built to collect data, transmit, process and archive that data, and make that data available to end-users in real-time. A schematic showing the flow of data within the IP1 system is shown in Figure 1. This architecture exemplifies an end-to-end system, with the radar-to-end-user-to-radar data loop being completed every 30 seconds.

IP1 has been designed to enable six very specific capabilities: 1. Tornado detection; 2. Tornado pinpointing; 3. Tornado anticipation; 4. Data assimilation; 5. Nowcasting; and 6. End-user integration.

IP1 is an example of a dynamic, data-driven application system (DDDAS; Darema 2004). The data collected by the radars are processed by either human end-users (e.g., NWS forecasters and local emergency managers) or by numerical forecast models and algorithms (e.g., WDSS-II and WRF). This processed information is then used to determine how, when and where the next data should be collected by the system. In other words, each end-user will be able to provide input back to the observing system for targeted data collection.

This paper will focus upon the architecture, deployment, and operation of IP1.

2. NETWORK OVERVIEW

IP1 will consist of four radar nodes located in southwestern Oklahoma, spaced nearly equidistantly at 25 km apart (Fig. 2). Each radar will be installed on a tower, equipped with wireless DS-3 microwave communication capability. An existing communications network in Oklahoma, known as OneNet, provides the base tower and communications infrastructure for IP1. Three OneNet towers, near the towns of Chickasha, Lawton, and Rush Springs, will be used for IP1. A fourth tower will be built near the town of Cyril to complete the necessary network configuration, and this tower will be integrated into the OneNet communication system.

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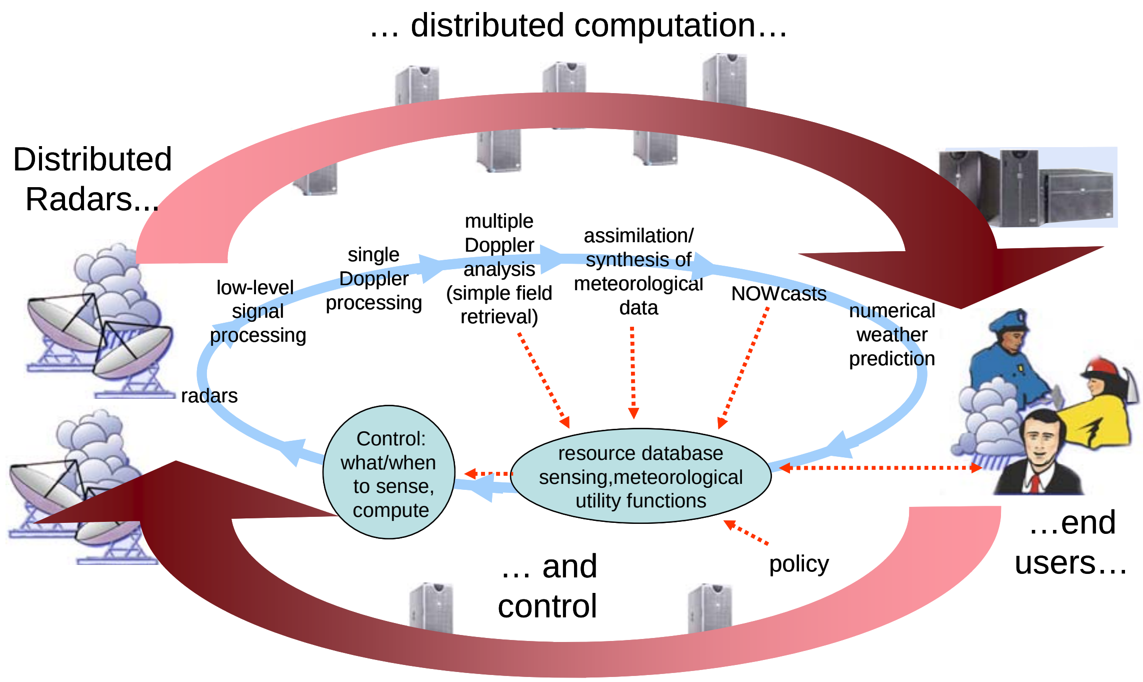

Fig. 1: A schematic showing the flow of data in IP1. Figure courtesy of Dr. J. Kurose.

The network location, network configuration and node spacing were determined by a number of factors (Brewster et al. 2005). The general philosophy for deployment of the test bed was to site the network in an area of "tornado alley" ideally upstream from a major metropolitan area. In addition, the network should be located in an area far from existing NEXRAD radars to best supplement existing radar coverage. The IP1 network was sited between 25 km and 50 km to the southwest of Oklahoma City, midway between WSR-88D radars located at Twin Lakes (NE of Norman), and Fredrick (west of Lawton). Approximately 98% of the lowest elevation angle of NetRad scans below the height of the lowest elevation scan from the two WSR-88D radars.

The network configuration and station spacing was determined by a series of numerical experiments (Brewster et al. 2005). Dual-Doppler area is maximized with a mean station spacing of 20 - 25 km for radars with a maximum range of 30 km. The network configuration is optimal for maximizing dual-Doppler winds when the stations are separated equidistantly, with a mean angle between sites of 40° – 60°.

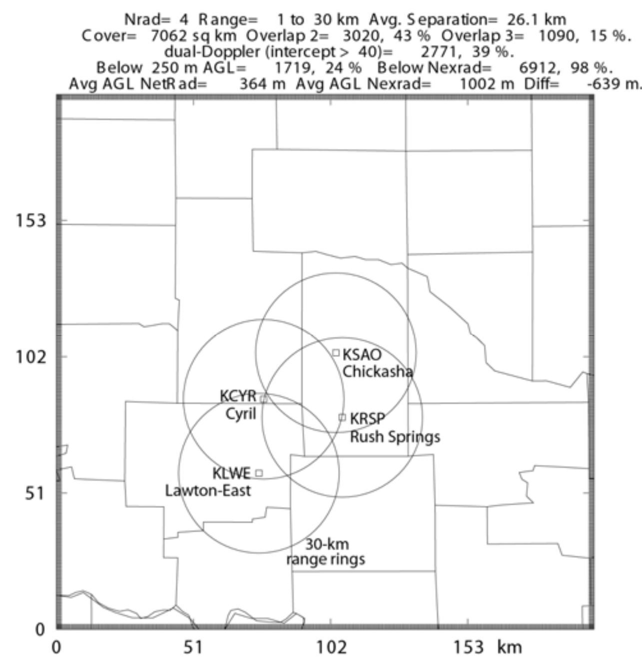

Fig. 2: The IP1 test bed.

Three OneNet towers were selected that were near the ideal spacing from the numerical experiments. Based on the location of those sites, the fourth site, near Cyril was chosen to approach the best dual-Doppler coverage while taking into account local terrain and other practical siting considerations.

3. RADARS

The four radars of IP1 are 3-cm (X-band), magnetron, mechanically scanning in the azimuth and elevation. Each radar has a nominal maximum range for precipitation signal detection of 30 km, a range resolution of 100 m, and beamwidth of 2 degrees. Each radar is also equipped with dual polarization capability. A summary of radar specifications are listed in Table 1. The IP1 radars were equipped with rapid rotation pedestals to enable testing ahead of later generations of test beds that will employ solid-state technology with electronically steered beams. The radars will nominally scan at a rate of 24°/sec.

TABLE 1. Radar specifications for Integrative Project #1

System Parameters	Value
Operating frequency	9.3 GHz
Wavelength	3 cm
Antenna diameter	1.5 m
Antenna bandwidth	2.0 deg
Maximum range	30 km
Effective transmitter power	12.5 kw
Average transmitter power	25 W
Pulse repetition frequency	3000 Hz
Range resolution	100 m

4. DATA QC, SIGNAL PROCESSING, AND DETECTION ALGORITHMS

The spectral (Tier I) data produced by the radars are processed by an off-the-shelf Linux server at the base of each radar tower site. Each radar is equipped with a single server and RAID storage system; each RAID system stores the Tier I data for up to 24 hours, where the data can be downloaded manually if needed. At this stage, quality control is applied to the Tier I data, and a combination of random phase coding and dual PRF are applied to the data to mitigate range-velocity ambiguity. Next, the signal processing estimates the moment (Tier II) data and writes the data into NetCDF formatted files. NetCDF files from each of the four radars are transmitted in real-time using UNIDATA Internet Data Delivery (IDD, a TCP-IP protocol) on OneNet, an existing high-speed communications network for the Oklahoma higher education system. OneNet utilizes DS-3 microwave technology to transfer data to a central location known as the System Operations Control Center (SOCC) located at the University of Oklahoma in Norman.

Once the data are ingested at the SOCC, additional quality control is then applied to the real-time data stream. The real-time data are then used by a suite of detection algorithms, which “mine” the data in search of hazardous weather and other features of interest.

At this stage, all CASA radar data are merged with WSR-88D radar data, geostationary satellite data, numerical forecast model output and upper-air and surface observations to produce the best estimate of the current state of the atmosphere as possible. The National Severe Storm Laboratory’s Warning Decision Support System – Integrated Information (WDSS-II; Hondl 2003) provides the platform for the feature detection software and merging of the CASA radar data. The merged, 3D-gridded (Tier III) data set is combined with output from the detection algorithms within the “Feature Repository”, a library data base. Tier II and Tier III data are made available to CASA end-users in real-time via IRaDS (Integrated Radar Data Services, Droegemeier et al. 2005).

5. END USER INTEGRATION

One key measure of success for IP1 will be its ability to integrate end-users into the dynamic data flow of the system. End-users are expected to be able to access data in real-time, as well as have the ability to provide real-time input to the radar system control. End-users include human customers, such as emergency managers, media outlets, research scientists, and private industry, as well as automated data mining algorithms and numerical models, such as the Weather Research Forecast (WRF) model and the Advanced Regional Prediction System (ARPS). How each end-user interacts within the IP1 data flow architecture is described below.

5.1 Direct Human Interaction

CASA presents a new paradigm to meteorology. Until now, data flowed in one direction, from the observations to the end-user. Data were "pushed" to the end-user. IP1 is designed to integrate the end-user into the data flow by allowing the end-user the option to request specific, targeted information.

There are several ways in which the human end-user will be able to interact with the system. First, *a priori* specifications will be provided by each end-user to the optimization/resource allocation system. These specifications will likely be made in tabular form or code, with each end-user assigning weights to weather features and scanning patterns. This ensures that the overall operation of the system reflects the needs of that individual end-user. Second, an interactive GUI system will be developed that will allow end-users the ability to dynamically and selectively submit requests to the optimization system in real-time. For example, a NWS forecaster, using the GUI system, could simply draw a polygon outline highlighting the storm region that she would like to see scanned. This information would be fed to the radar optimization system for consideration in scan priority for the next radar scanning cycle.

5.2 Numerical Model Interaction

Several numerical models and a suite of detection and data mining tools will act as end-users of CASA data as they ingest the radar data in real-time. An ensemble Kalman filter will be used to ingest the data into the ARPS Data Analysis System (ADAS; Brewster 1996) and WRF model. A suite of detection algorithms from WDSS-II are being designed to work with CASA data. These include adaptations of the rotation detection algorithms used in the operational WSR-88D system, as well as new algorithms that take advantage of the unique properties of the CASA data (Hondl et al., 2005). The latter set of algorithms include a Linear Least-Squared Derivative (LLSD) method for detecting areas of shear, a multi-Doppler wind vector calculation and a dual-polarametric debris signature technique. Output from these models will be used to provide information to the optimization and resource allocation module in targeting the next areas to be scanned.

6. OPTIMIZATION AND RESOURCE ALLOCATION

The Tier III gridded radar output, numerical model output, human input to the system (via a priori tables, weighting functions, and GUI input), as well as signal-to-noise ratio (attenuation) data, are combined in a combinatorial auction for resource allocation of the radar scanning strategy for the next sampling cycle.

7. OPERATION OF THE TEST BED

The IP1 test bed will be operated in accordance with the recommendations as set forth by the CASA Executive Committee. The implementation phase of IP1, designated IP1a, will end once all hardware and software are stable and operating properly. The second phase of IP1, designated IP1b, is expected to begin April 1st, 2006, and will mark the research and experimentation phase of the test bed.

All Tier II and Tier III data collected during IP1b will be archived on tape. Data will be stored on-line for up to two weeks. Real-time data will be made available to CASA partners only; however, archived data will be made available upon request as resources permit.

8. SUMMARY

CASA's Integrative Project #1 is the first of five test beds to be developed as part of the CASA project. This first test bed is expected to remain operational for another 3 – 5 years. The test bed will initially have four radars, and additional money from the University of Oklahoma has been made available explicitly to expand the number of radar nodes within the operational period.

CASA's IP1 will be among the first observing systems that will utilize a distributed, collaborative, and dynamically adaptive and data-driven approach to atmospheric sampling. With this system, new research methods for feature detection, tracking, and anticipation are expected to be developed and demonstrated. By integrating the needs of the end-user in the planning, design and real-time scan optimization, it is expected that such a network will be adopted quickly by weather sensitive interests in the private and public sectors.

9. REFERENCES

Brewster, K., 1996: Application of a Bratseth analysis scheme including Doppler radar data. Preprints, *15th Conf. on Weather Analysis and Forecasting*, Norfolk, VA, Amer. Meteor. Soc., 92-95.

Brewster, K., L. White, B. Johnson, and J. Brotzge, 2005: Selecting the Sites for CASA NetRad, a Collaborative Radar Network. Preprints, *Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, Amer. Meteor. Soc., San Diego, CA.

Darema, F., 2004: Dynamic Data Driven Application Systems: A new paradigm for application simulations and measurements. M. Bubak, G. van Albada, P. Sloot, and J. Dongarra, (Eds.), ICCS 2004, LNCS 2038, Springer-Verlag, Berlin, pp 662-669.

Droegemeier, K., J. D. Martin, C. Sinclair, and S. Hill, 2005: An Internet-Based Top-Tier Service for the Distribution of Streaming NEXRAD Level II Data: CRAFT Becomes an Operational System. Preprint, *21st Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*. Amer. Meteor. Soc., San Diego, CA.

Hondl, K., 2003: Capabilities and Components of the Warning Decision Support System - Integrated Information (WDSS-II). Preprint, *19th Conference on IIPS*, Amer. Meteor. Soc., Long Beach, CA.

Hondl, K., T. Smith, K. Manross and V. Lakshmanan, 2005: Tornado detection techniques for a network of Doppler radars. Preprints, *Ninth Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS),* Amer. Meteor. Soc., San Diego, CA.