Radar Networking in Collaborative Adaptive Sensing of the Atmosphere (CASA):
State of the Art & Research Challenges

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Collaborative Adaptive Sensing of the Atmosphere (CASA)

- Collaborating & adapting radars
  - Improved sensing, detection, & forecasting
- Aggregates distributed groups of resources as & when needed
  - 10,000 radars to cover U.S.
  - High data rate – 800 Mbps
  - Heterogeneous, dynamic, & distributed
  - Real-time – 30 sec heart beat
CASA Test Beds

- **Oklahoma test bed**
  - 7,000 km² · 40 km range, 30 km spacing
  - Connected to the Internet
  - Data pull – 30 sec heart beat
  - Being moved to Dallas-Fort Worth

- **Puerto Rico student test bed**
  - Solar powered
  - Wireless connections
### CASA Applications & End Users

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>No of Radars</th>
<th>Data Type(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectivity</td>
<td>Reflectivity of clouds</td>
<td>1</td>
<td>Reflectivity</td>
</tr>
<tr>
<td>Velocity</td>
<td>Wind velocity</td>
<td>2-3</td>
<td>Doppler velocity, reflectivity</td>
</tr>
<tr>
<td>Network-Based Reflectivity</td>
<td>Reflectivity of clouds detected using multiple radars</td>
<td>3+</td>
<td>Reflectivity</td>
</tr>
<tr>
<td>Retrieval (NBRR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nowcasting</td>
<td>Short term (10-30 min) high resolution forecasts of active weather events</td>
<td>1-3</td>
<td>Reflectivity</td>
</tr>
<tr>
<td>Tornado tracking</td>
<td>Detect &amp; track a tornado as it forms &amp; moves</td>
<td>2+</td>
<td>Doppler velocity, reflectivity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>End user</th>
<th>Description</th>
<th>Applications</th>
<th>Rule Trigger</th>
<th>AOI</th>
<th>Sampling Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Weather Service (NWS)</td>
<td>Responsible for issuing warnings</td>
<td>Reflectivity</td>
<td>Periodic</td>
<td>Counties under jurisdiction</td>
<td>1 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Velocity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NBRR, nowcasting, QPE</td>
<td>High reflectivity</td>
<td>Area of active weather</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tornado tracking</td>
<td>Rotating wind, ground spotters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency Managers (EMs)</td>
<td>Siren blowing, helping first responders, act as spotters</td>
<td>Reflectivity</td>
<td>Periodic</td>
<td>Counties under jurisdiction</td>
<td>1 min</td>
</tr>
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<td></td>
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<td>Velocity</td>
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<td></td>
<td>1 min</td>
</tr>
<tr>
<td>Researchers</td>
<td>To understand physical properties of weather events, test new algorithms</td>
<td>Reflectivity</td>
<td>Periodic</td>
<td>Area of active weather</td>
<td>1 min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Velocity</td>
<td>High wind</td>
<td></td>
<td>30 sec</td>
</tr>
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<td></td>
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<td>NBRR, nowcasting, QPE</td>
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- Same data accessed by multiple applications & end users
Data Transfer & Fusion

Data Transfer & Data Fusion

Streaming
- TRABOL – End-to-end
- AWON – Multicasting
- Modeling data fusion latency
- Integrating Other Sensors

Pull
- Sensor-specific names
  - Proxy-based
  - P2P-based
  - Data Intensive Clouds
- Data-specific names
  - NDN-based

Archive
Streaming – TCP friendly Rate Adaptation Based On Loss (TRABOL)

- **Target Rate (TR)**
  - Users prefer to receive all relevant data
- **Minimum Rate (MR)**
  - Most important data
- **TCP & UDP inadequate**
- **TRABOL**
  - Application-layer solution
  - Application-aware packet drop
  - Enhance quality of received data

Multicasting – Application-Aware Overlay Networks (AWON)

- API for application-aware service deployment
  - Application-aware
    - Packet marking
    - Data delivery under varying network conditions


Measurements on PlanetLab

60% reduction in link capacity
Data Fusion – Peer-to-Peer Collaboration Framework

- Radars depend on each other’s data to correct/detect errors
  - Subscribe to neighbors
- Best peer selection
  - Peers with relevant data
  - Peers with lowest data delivery time
    - Computation + transmission


40% cross traffic
Data Fusion – Data Intensive (DI) Clouds

- Infrequent peak demands
- Cloud computing is a good fit
- Enable data-intensive experiments/workflows from start to finish
  - Radars, weather stations, & cameras
    - Virtualized access to sensors
    - Developed under GENI ViSE project
  - Processing & storing in Amazon cloud

Data Fusion – Integrating Infrasound Sensors

- Tornados & their precursors produce infrasound (< 20 Hz)
- Increase accuracy of detection, warning time, & localization

### Geographic location & weather event specific names
- Content dependent names
  - `/Anaheim/Reflectivity/10:30/`

### Decouple data, security, & access from sensor
- Decouple identity, security, & access from end point

### Load balancing, resilience, & security
- Better reliability & security

### Pull based
- Users determine how resources are used
- On demand data generation

### High temporal & spatial locality
- Exploit temporal & spatial locality

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**Diagram:**
- **AOI**
- **r**
- **R**

/`AOI/application/time`

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**Graph:**
- Data pulled from a radar within 6 min (MB)
- Cache size (MB)
- LFU
- LRU
- Oldest
Research Opportunities & Challenges

• Integrating diverse sensors
  – CASA, solid state, long-range, special purpose, & mobile radars
  – Micro weather stations, pressure sensors, wind profilers, etc.
  – How to transfer & process?
    • Different data types, generation patterns, processing, & bandwidth requirements

• Aggregating distributed groups of resources
  – As & when needed
  – Heterogeneous, distributed, dynamic, & multi-attribute resources
  – Real time & distributed resource matching, binding, & compensation

• Data intensive clouds
  – Transferring data in/out of clouds
    • On demand virtual networks across ISPs
  – Rapid resource deployment
  – Cloud-based processing strategies for weather data
    • Models to understand performance & cost benefits
Questions/Comments

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www.cnrl.colostate.edu/Projects/