Application-Aware In-Network Service Deployment for Collaborative Adaptive Sensing of the Atmosphere (CASA)

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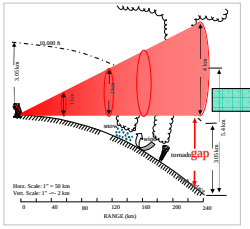
Abstract

An Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) funded by the National Science Foundation, seeks to revolutionize the way we detect, monitor and predict atmospheric phenomena by creating a dense network of small, low-cost, low-power radars that could collaboratively and adaptively sense the lower atmosphere. Such a network is expected to provide more timely and accurate forecasts for tornadoes, flash floods, and other hazardous weathers. In addition, the networked radars can offer improved accuracies and more specific inferences that could not be achieved by the use of a single long-range radar. In CASA, multiple end users may be present that have distinct sensing, communication and computation requirements for their operations. In addition, the underlying network infrastructure may itself be subjected to adverse conditions due to severe weather and link degradation/outage along wired and wireless links.

We use overlay networking to provide acceptable quality of service (QoS) and robust data transport service for the CASA end-users. At CSU, we have developed an AWON (Application-aWare Overlay Networks) architecture for deploying application-aware services in an overlay network to best meet the end-users' QoS requirements over the available networking infrastructure; based on this, we have implemented an application-aware multicast service for CASA. We also present a multi-sensor fusion framework which can provide a mechanism for selecting a set of data for data fusion considering application-specific needs, and a distributed processing scheme to minimize the execution time required for processing data per integration algorithm.

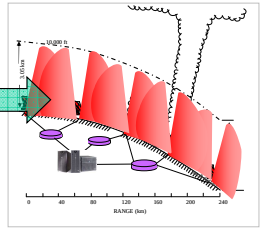
CASA: Collaborative Adaptive Sensing of the Atmosphere

Current State of the Art



- Sparse, high-power radar
- Sensing gap: Earth curvature effects prevent 72% of the troposphere below 1 km from being observed

CASA Vision

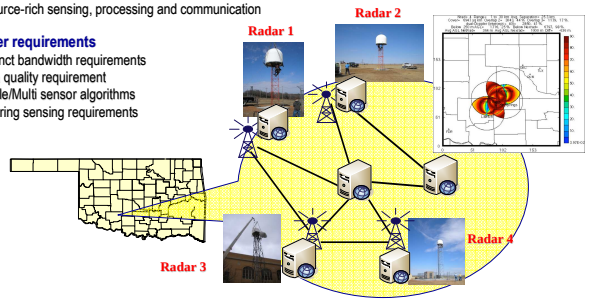


- *Collaborating* radars:
  - improved sensing
  - improved detection, prediction
- Responsive to multiple *end-user needs*

CASA Oklahoma Test-bed

System Environment
- Initial 4-nodes test-bed (Sensor network can be extended to tens of nodes)
- Wired/wireless TCP/IP communication
- Resource-rich sensing, processing and communication

End user requirements
- Distinct bandwidth requirements
- Data quality requirement
- Single/Multi sensor algorithms
- Differing sensing requirements

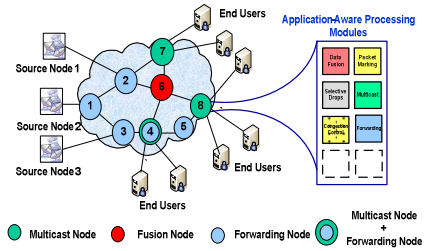


Goals

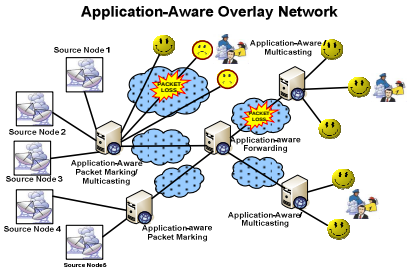
Develop networking protocols for emerging distributed collaborative adaptive sensing systems such as CASA:

- Develop an architecture for application-aware data dissemination
- Design and develop application-aware protocols
- Develop application programming interface(API) for application-aware overlay deployment
- Develop a multi-sensor data fusion framework for CASA radar data fusion algorithms

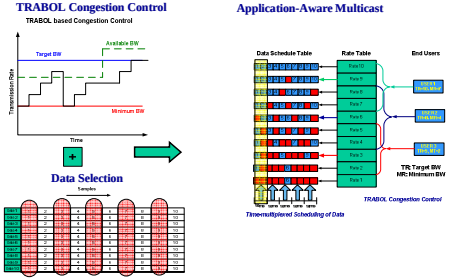
Application-Aware Overlay Network



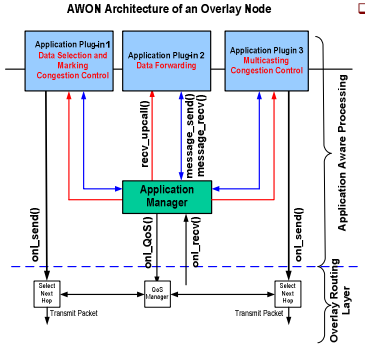
Application-Aware Multicast



Application-Aware Multicast Protocol

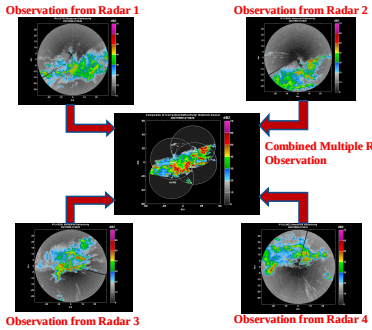


AWON (Application aWare Overlay Network) Node Architecture:



CASA Data Fusion

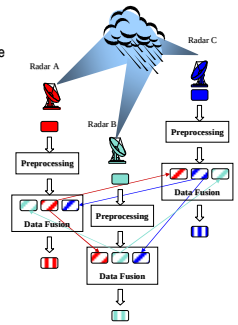
Network-based Reflectivity Retrieval:
- Set of observations from multiple radars
- Improve sensing accuracy by combining data from multiple radars



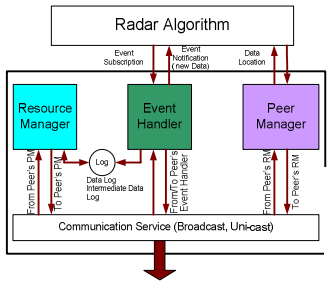
Multi-Sensor Data Fusion: Challenges

Resource-intensive Applications:
- High-bandwidth data generation:
  - several Mbps to tens of Mbps per node
- Vast amount of computation resources
- Client-Server architecture may not be appropriate:
  - Scalability Issue
  - Single-point of failure

Peer-to-Peer Processing:
- P2P for multi-sensor fusion
  - Better resource utilization by sharing
  - Coordinated processing
  - Better fault tolerance
- Coordinate peers to minimize response time

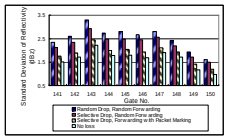


Fusion Node Architecture

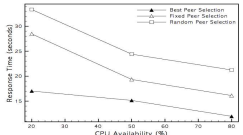


Performance Evaluation

Application-aware Multicast



Data Fusion Response time



Variable System Load Condition

Summary and Future Work

Application-aware processing paradigm using overlay networks for meeting QoS requirements of heterogeneous end users in CASA networks
- AWON architecture for deployment of application-aware functionality in overlay networks
- Application-aware congestion control and in-network processing enhance the QoS under dynamic network conditions

Multi-sensor data fusion framework for CASA and other emerging distributed collaborative adaptive sensing systems
- Deployment of multi-sensor data fusion service in CASA network
- Data fusion framework reduces the execution time required for data fusion processing
- Implement a prototype of multi-sensor data fusion framework and test it in a real test-bed environment.
- Develop an analytical model for data fusion response time considering the impact of network dynamics such as network delay and loss

Publications

P. Lee, T. Banka, A. P. Jayasumana, V. Chandrasekar, "Content-based Packet Marking for Application-aware Processing in Overlay Networks," Proc. of IEEE Local Computer Networks LCN 2006, pp. 123-131, Tampa, FL, Nov. 2006

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P. Lee, A. P. Jayasumana, S. Lim and V. Chandrasekar, "A Peer-to-Peer Collaboration Framework for Multisensor Data Fusion," Proc. International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 2007), Bridgeport, CT, Dec. 2007.

S. Lim, V. Chandrasekar, P. Lee, A. P. Jayasumana, "Reflectivity Retrieval in a networked radar environment: Demonstration from the CASA IP-1 radar network," Proceedings of IGARSS07, Barcelona, Spain

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