D6: Application Aware Overlay Network Based Data Fusion Framework for Distributed Collaborative Adaptive Sensing

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Abstract

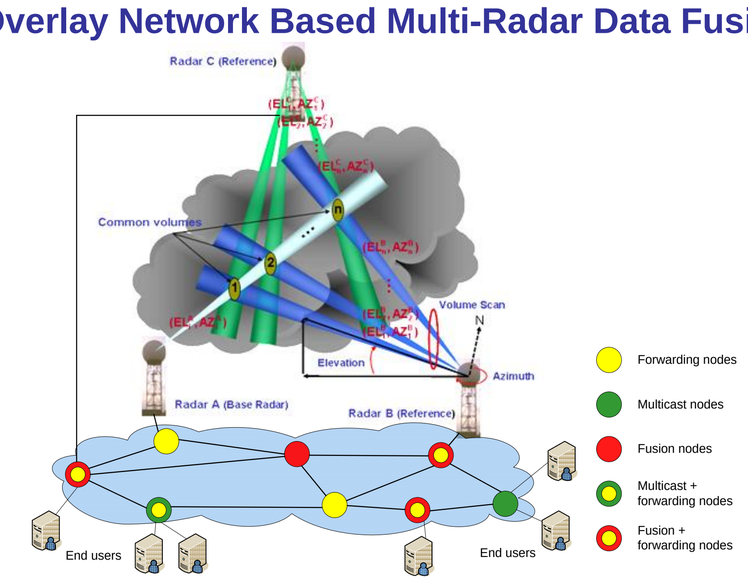
Many emerging Distributed Collaborative Adaptive Sensing (DCAS) systems rely on sensing, processing, and storage nodes interconnected via the Internet. Such systems require timely exchange of large volumes of sensor data among geographically distributed end-users under resource-constrained network conditions. We have developed and implemented an architecture, Application-aWare Overlay Networks (AWON), for deploying application-aware services in an overlay network to best meet the QoS requirements of DCAS systems.

Here we focus on a data fusion framework for such Application Aware overlay networks. We first present an architectural framework for real-time implementation of CASA multi-radar data fusion. We then extend it to a distributed, peer-to-peer based collaboration framework that aggregates and utilizes unused processing, storage, and communication resources in other peers. The fusion framework combines data in such a manner that real-time requirement of the sensor application is met. An analytical model is presented that predicts data fusion latency. The fusion framework further utilizes an application specific mechanism to select subsets of data, from multiple radars, to increase the desired accuracy of the results. A dynamic peer-selection algorithm, Best Peer Selection (BPS), is used to choose a set of peers based on their computation and communication capabilities to minimize data fusion time. Simulation results show the ability of the proposed framework to satisfy CASA data fusion requirements.

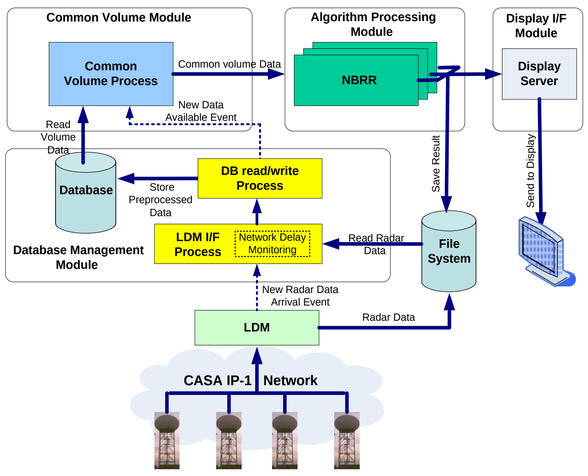
Research Objectives

- Develop a multi-sensor radar data fusion framework that utilizes our Application Aware Overlay Network (AWON) architecture [6]
- Develop an analytical model to predict data fusion latency in DCAS systems

Overlay Network Based Multi-Radar Data Fusion



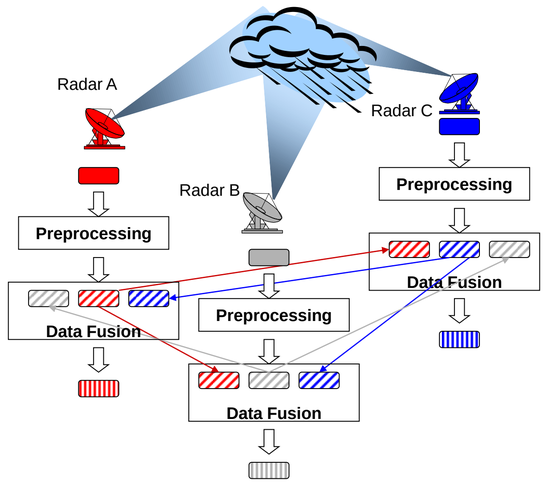
Architecture Of Data Fusion Nodes [3]



Software architecture

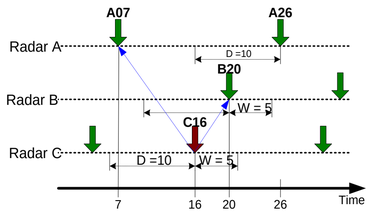
- Selection of correlated data
- Parallel execution of Network-Based Reflectivity Retrieval (NBRR) algorithm

P2P Collaboration Framework For Data Fusion [2 – 4]

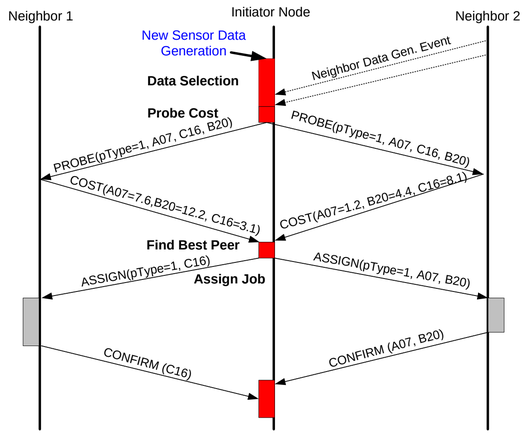


Collaborative and adaptive radar operation for data fusion

- Aggregate and utilize unused processing, storage, and communication resources
- Locating peers with desired data



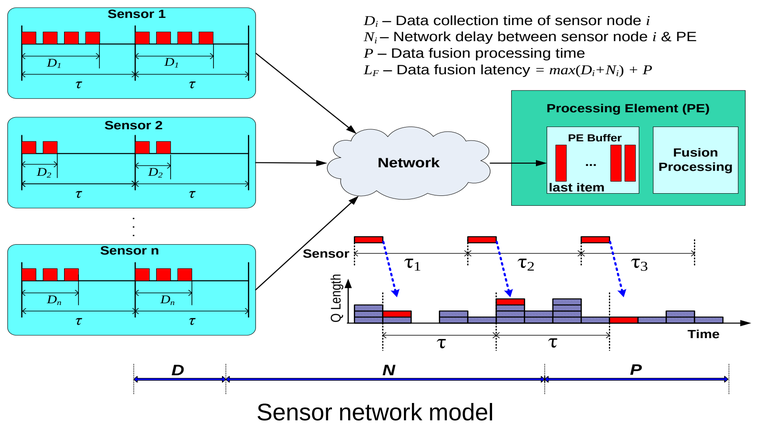
Data synchronization timing



Best peer selection

- Timely selection of data for fusion
- Selection of best peers that can minimize overall fusion latency

Analytical Model For Data Fusion Latency [1, 3]



D_i – Data collection time of sensor node i
N_i – Network delay between sensor node i & PE
P – Data fusion processing time
L_F – Data fusion latency = $max(D_i+N_i) + P$

Sensor network model

- We are interested in $P\{L_F > z\} < \varepsilon$
- N_i is affected by self-similar cross traffic
- Queue size formed in a period τ

$$Q(\tau) = A(\tau) - \alpha C\tau,\ 0 < \alpha \le 1$$

  - C – Link capacity
  - $A(\tau)$ – Amount cross traffic arrival within τ
- Queue length distribution

$$P\{Q(\tau) > x\} = P\{A(\tau) - \alpha C\tau > x\}$$
$$= P\{m\tau + \sqrt{am}Z(\tau) - \alpha C\tau > x\}$$
$$= 1 - \Phi\left(\frac{x + \alpha C\tau - m\tau}{\sqrt{am}\tau^{H}}\right)$$

- Probability that single-hop delay exceeds y

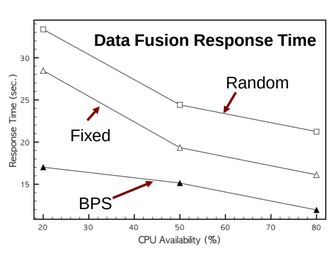
$$p(y) = P\{D + \frac{(m+s)\tau + \sqrt{am}Z(\tau) - \alpha C\tau}{C} + d > y\}$$

Future Work

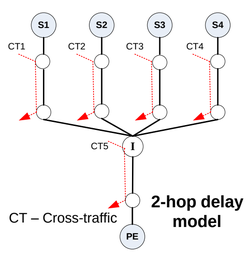
- Design and develop enhanced mechanisms for Application Aware overlay network based data fusion
  - Efficient data and resource discovery through structured P2P
  - On-demand ray-by-ray data transfer to reduce fusion latency
  - In-network caching to enable reuse of preprocessed/fused data
- Evaluate the performance and scalability of AWON based data fusion for small and large-scale CASA systems

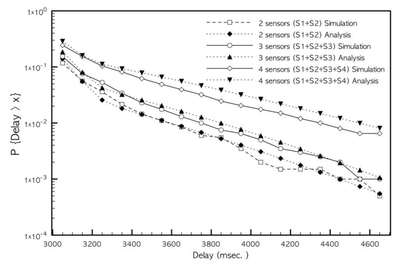
Performance Evaluation [1 – 4]

- Case 1 – Isolated convective storm (06/10/2007)
- Case 2 – Isolated storm (06/16/2007)
- Case 3 – Several severe storms (05/07/2008)
- Case 4 – Cluster of storms (05/27/2008)
- Case 5 – Isolated super cell (06/01/2008)



- Best peer selection reduce response time
- System does not overflow





- Model provides a good estimation of L_F
- Coordinated processing is effective

Publications

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