COLLABORATIVE SENSOR SIGNAL PROCESSING FOR TARGET DETECTION, LOCALIZATION, AND TRACKING

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I. INTRODUCTION

Wireless ad hoc sensor network is an emerging information technology that promises great potential for both military and civilian applications. Such a network can be used to monitor environment, detect, classify, and locate objects and then track them over a specified region. The sensor network is expected to deploy varying number of sensor nodes that can sense the environment using different modalities such as acoustic, seismic, and infrared. The sensors also have the capabilities to communicate and interact with neighboring sensors via wireless channels as well as process the information. It is expected that these components can be integrated into a tightly packaged, low cost sensor nodes, ready for massive deployment. For military applications these low-cost, integrated wireless sensor nodes can be rapidly deployed by air over remote regions to monitor vehicles and personnel movements, and to relay the findings back to the command center on a real-time basis.

SensIT is a Defense Advanced Research Projects Agency (DARPA) sponsored research programs on sensor networks with the goal of developing system and application level software for potential military applications [1]. Under this program the University of Wisconsin, Madison research team is developing a collaborative signal processing (CSP) application for detecting, locating, and tracking ground vehicles traversing a sensor network. In this paper, we briefly describe our approach, called *Location-centric computing,* for this application. We also briefly describe the underlying CSP algorithms.

II. LOCATION-CENTRIC COMPUTING

The location-centric computing approach is based on the observation that detection, location, and tracking requires collaboration among devices in a certain area or region and not among an arbitrarily specified set of devices. This is fundamentally different from the conventional node-centric approaches in which the information exchange and collaboration is between a set of devices and the collaboration typically continues between the same set of devices even if they move. In contrast, in the location-centric approach, a device ceases (begins) to participate in an ongoing collaboration if it leaves (enters) the corresponding defining region.

To efficiently support this approach we proposed a network application programmers interface called UW-API [2,3,4]. In UW-API, geographic regions play the role of a node in the traditional network interface. In particular, the nodes/devices are not individually addressable in UW-API. Instead, the programmer creates entities called *regions*, which are then addressable in the communication primitives.

A region in UW-API represents a rectangular geographic area. We assume that each device is aware of its geographic location and the regions to which it belongs. Within each region, an area is designated as a *manager sub-region*. A region is typically tasked with one or more CSP activities. Devices in a region participate in the information exchange and collaboration signal processing activities of that region. The devices in the manager sub-region coordinate information exchange activities needed for the CSP.

In addition to primitives for creating and deleting regions, UW-API has primitives for sending task and information to regions, receiving task and information from regions, and aggregating information within a region. These primitives are supported by an underlying location-aware routing scheme called UW-routing [1,2,3]. The routing scheme is bandwidth efficient in delivering information from one region to another. We have developed and written the CSP application for detection, localization, and tracking using UW-API. In the following section we describe the target tracking application.

III. TARGET TRACKING APPLICATION

Regions are first created around potential target entry area. Only devices in these initial regions are active. All other devices passively wait to be activated by initial regions. Within a region the following software modules are used to detect, classify, and track a target of interest.

- *NodeDet*: Devices run a Constant False Alarm Rate Energy Detector for detecting the presence of a target. The devices in a region relay their decisions to the manager sub-region.
- *DetFus*: The devices in the manager sub-region run a robust fusion algorithm to combine the detection decisions of the devices in the region to arrive at consensus detection decision for the region.
- *NodeClass*: When *NodeDet* in a device decides a target is present, it invokes a classifier to determine whether the target is of the desired type. The classification result is relayed to the manager sub-region.
- *ClassFus*: When *DetFus* decides that a target is present it invokes a robust fusion algorithm to combine the classification decisions of the devices in the region to determine whether the target is of the desired type.
- *TarLoc*: When *ClassFus* decides that the target is of the desired type, it invokes a localization algorithm to estimate the target's location.
- *TarTrak*: Devices in the manager sub-region estimate target parameters such as speed and direction and use it to predict the near-term target locations. If the predicted target locations lie outside the region, additional regions are created and tasked with the application.

IV. EXPERIMENTAL RESULTS

A preliminary implementation of the above target tracking application was field tested at 29 Palms Marine Base in November 2001. The sensor network for the field test consisted of 70 WINS2.0 devices from Sensoria Corporation. Each device was equipped with three sensing modalities: acoustic, passive infrared, and seismic. The network was used to track military vehicles such as AAV, DW, LAV, and HMVVV. During the field test sensing data was also collected for later use.

Since the field test, we refined the underlying algorithms in the above application. We also developed a mechanism to playback the data collected during the field test. Using the timestamps in the collected data, the playback mechanism emulates the field test on a sensor network test bed at BBN Technologies. That is, an application running on the BBN test bed completely emulates the performance at the 29 Palms field test. We evaluated our target tracking application using this playback mechanism on the BBN test bed. The results of this evaluation are presented in the associated poster. They can also be found at the project website http://www.ece.wisc.edu/~sensit.

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