# A Distributed Acoustic Localization System using Clusters of Microphones.

**Introduction**

As hardware technology advances, both the dimension and cost of wireless sensor nodes are dramatically decreasing. These technological developments open up new opportunities for collaborative and distributed signal processing. New research challenges consist of solving traditional signal processing problem via distributed, scalable and power-efficient algorithms.

Acoustic localization with microphone arrays has been an active research area for many years [1]. While there are systems that can locate acoustic sources by analyzing the time difference of arrival (TDOA) between pairs of sensors [2], these systems rely on a centralized unit to process the information. It is still a challenging task to develop efficient algorithms that approach the performance of standard methods but perform the data processing in a distributed, robust and scalable way. [3][4]

**Thesis**

We aim to develop an algorithm that solves the localization problem in a distributed manner. Many clusters of microphones are located in a domain containing an acoustic source. The source location estimate is transmitted from cluster to cluster, and each cluster successively refines the estimate using the TDOA measurement performed locally. The algorithm we aim to develop is characterized by very low complexity and can be used for quickly providing a rough estimate of the source location. The computational complexity is suitable for use in real-time application, where data collection in a central node may be infeasible. The distributed approach we utilize is scalable, since the localization error decreases with the number of nodes in the network, while the computation requirement at each sensor node remains constant. Thus, this approach is well suited for performing acoustic localization in large scale wireless networks.

**Method**

The proposed project plan is divided into four phases.
First, we plan to review the available literature on this topic and to familiarize with signal processing techniques such as time-difference estimation and beamforming. We expect this phase of the project to take approximately 40 to 50 hours.

As a second step, we plan to implement and test in MATLAB our localization algorithm. We will need to write functions which perform geometric operations and the TDOA analysis. We will use these functions to build a simulator, which will be used to test the effectiveness of the algorithm. We expect this second phase of the project to take approximately 60 to 70 hours.

In the third phase, we plan to implement and test out localization algorithm in a wireless sensor network test bed. The test bed will consist of several Windows-based laptops equipped with microphones and wireless cards. We will write MATLAB code that will allow each laptop to receive data from the microphones, calculate the TDOA, and compute a source location estimator.

We will then connect the laptops through an ad-hoc 802.11a wireless network, and test our distributed algorithm in a real environment. As part of our experiment, we will compare the performance of our distributive method to that of centralized algorithms. The brunt of the work will be here, and we will need MATLAB to record both the raw data and our calculated data over multiple trials with various

configurations of the system. We will use the data to ascertain the optimal number and placement of the microphone nodes. We expect this third phase of the project take approximately 150 hours. Finally, we plan to document and interpret our experimental results. This final phase of the project will take approximately 30 hours.

**Extensions**

Extensions to this project include making the system more robust to function in a noisy environment, as well as localizing multiple signals at the same time. Applications of this system can range from videoconferencing to search-and-rescue and security systems, where localization is important to the functionality of the system.

**Calit2's Mission**

This project is very much in the spirit of Calit2's mission. Much of the institution's success stems from taking advantage of networks to provide unprecedented levels of collaboration and unconventional problem solving to research teams. It is our hope that by extending this revolutionary style of researching to the research itself that we can unlock new possibilities in both localization and collaborative computing as a whole.

[1] J.C. Chen, Kung Yao and R.E. Hudson, "Source localization and beamforming", in IEEE Signal Processing Magazine, vol. 19, no. 2, pp.30-39, Mar 2002.
[2] C.H. Knapp and G.C. Carter. "The generalized correlation method for estimation of time delay," IEEE Transactions on ASSP, vol 24, no. 4, pp.
320-327, Aug 1976.
[3] M.G. Rabbat and R.D. Nowak, "Decentralized source localization and tracking wireless sensor networks," Proceedings of IEEE ICASSP 200404,
vol.3 , pp. 921-924, May 2004.
[4] A. O. Hero and D. Blatt. "Sensor network source localization via projection onto convex sets (POCS)." Proceedings of IEEE ICASSP, March 2005.