Self-Organizing Networks (SONets) with Application to Target Tracking

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Abstract The growing interest in large arrays of deployable sensors is not only the result of recent advances in technology that make cheap expendable sensors readily available, but is also due to the limitations of current large expensive assets in some applications of timely importance such as urban warfare and complex terrain surveillance. Large distributed arrays of deployable, configurable sensors, cooperating to achieve system-level goals, may provide the solution for such problems, whether acting as independent networks or as agents gathering localized information to aid large assets. The primary challenge of dynamic allocation of network assets (DANA) is the cost of computation and communication of global optimization and real-time configuration of individual sensors. Scaling of network size generally yields an exponential increase in optimization computation and a prohibitive need for communication bandwidth for scheduling of individual sensors – making such approaches of limited real-time use. This paper presents the novel methodology of Self-Organizing Networks (SONets) where small sensors with local decision capabilities and overall system performance knowledge yield an emergent behavior aimed at maximizing system information in a communication-constrained architecture, while eliminating (or reducing) the need for sensors to be actively scheduled. Preliminary results demonstrate promising performance in a multi-target/ multi-sensor environment. The SONets methodology is based on sensors making local decisions on which mode to operate in, including data collection, broadcast, etc. based on perceived value of expected return and thresholding, with the capability of adaptively self-organizing. Sensors update learning indices (adaptive weights) based on expected return and observation of overall system knowledge. The result is an emergent behavior that may be supervised and altered through general broadcasts from a centralized unit. This work presents the SONets methodology and shows how it addresses the problem of DANA for large networks of small sensors. The SONets performance is evaluated in a tracking scenario based on track accuracy and compared to baseline performance bounds for a stepwise optimal resource-scheduling algorithm.

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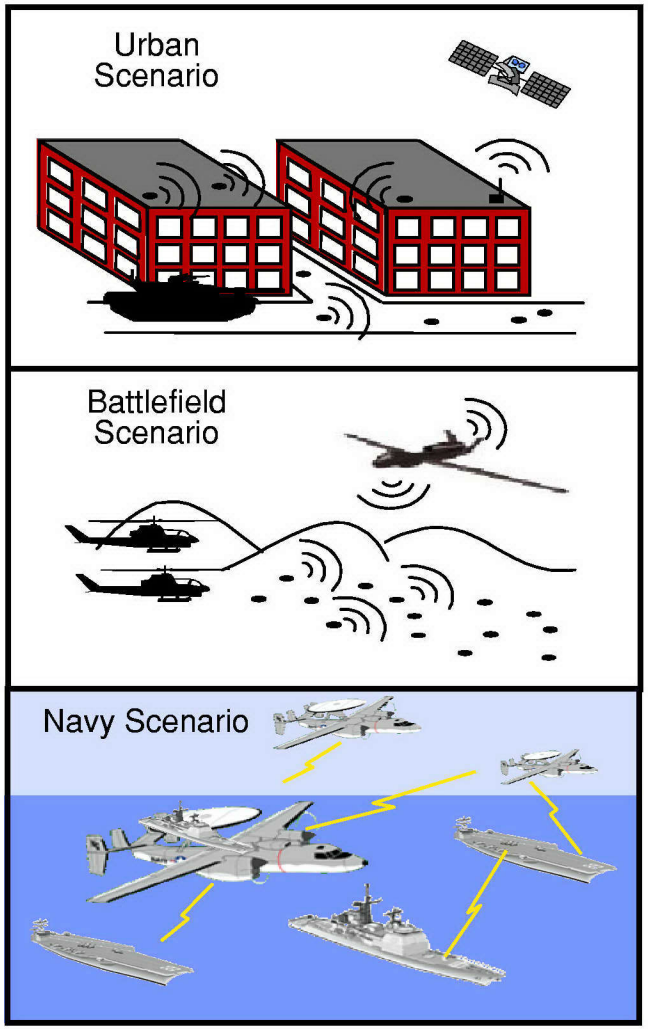
Sensor Networks: The Scalability Problem



Problem:

Current large expensive assets have performance limitations in some applications of timely importance.

Proposed Solution:

Use large arrays of small, deployable, and configurable sensors, cooperating to achieve system-level goals.

Challenges:

- Cost of computation and communication of global optimization
- Real-time configuration of individual sensors
- Scaling of network size

Approach:

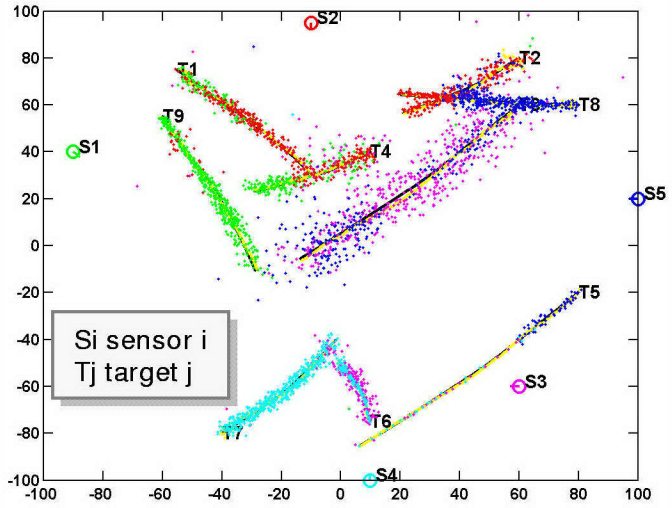
Move some or most of the management functions to the sensing nodes to achieve system-level goals through self-organization.

Information-Based Sensor Self-Configuration

Scalable Networks

Self-Organizing Networks (SONets):

Small sensors with local decision capabilities and overall system performance knowledge yield an emergent behavior aimed at maximizing system information in a communication constrained architecture.



Tracking Example

Key Contributions:

SONets respond to system level goals without centralized scheduling, and exhibit

- Autonomous task allocation with tuning and learning capabilities
- Robustness to changing environment and network sensing resources
- Network adaptability to changes in constraints including scalability