

# Netted Sensors for Persistent Surveillance

Jeffrey T. Correia

781-271-2208 • [jcorreia@mitre.org](mailto:jcorreia@mitre.org)

Dr. Garry M. Jacyna

703-983-6972 • [gjacyna@mitre.org](mailto:gjacyna@mitre.org)

MITRE Sponsored Research

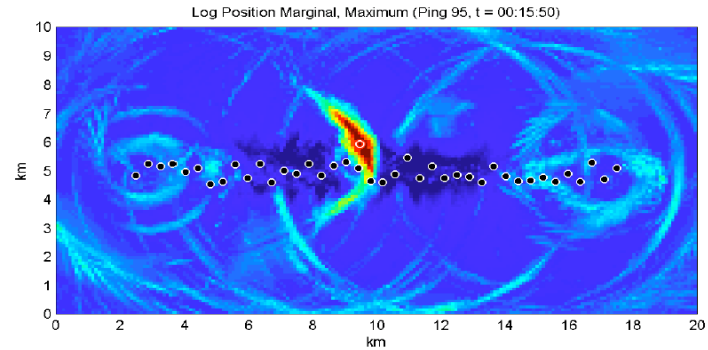
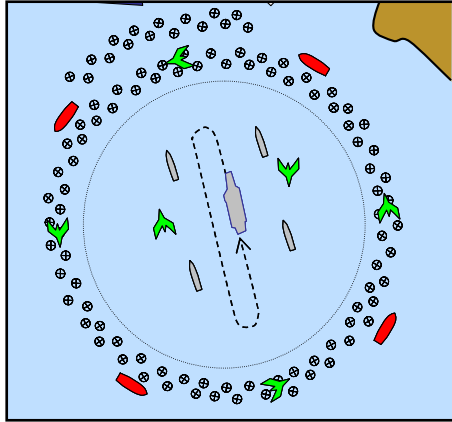


# Problem: Scalability of Control Aspects of Sensor Networks

- **The scalability of sensor networks is currently an obstacle to deploying large-scale sensor fields**
  - **Control**
  - **Communications**
  - **Networking**
  - **Etc.**
- **This research addresses improving the network control aspect of scalability**

# Background

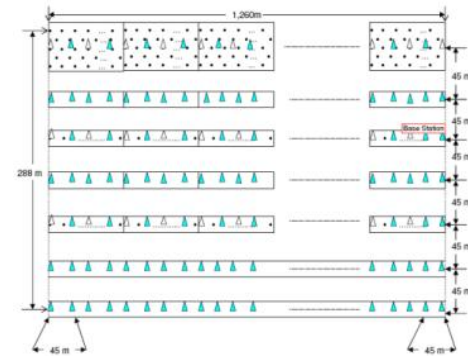
## Applications Are Emerging for Large Sensor Fields



## Network-Enabled Anti-Submarine Warfare (ASW)



1.3 km by 300m  
Sensor grid



## DARPA Networked Embedded Systems Technology (NEST) Program

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# Objective

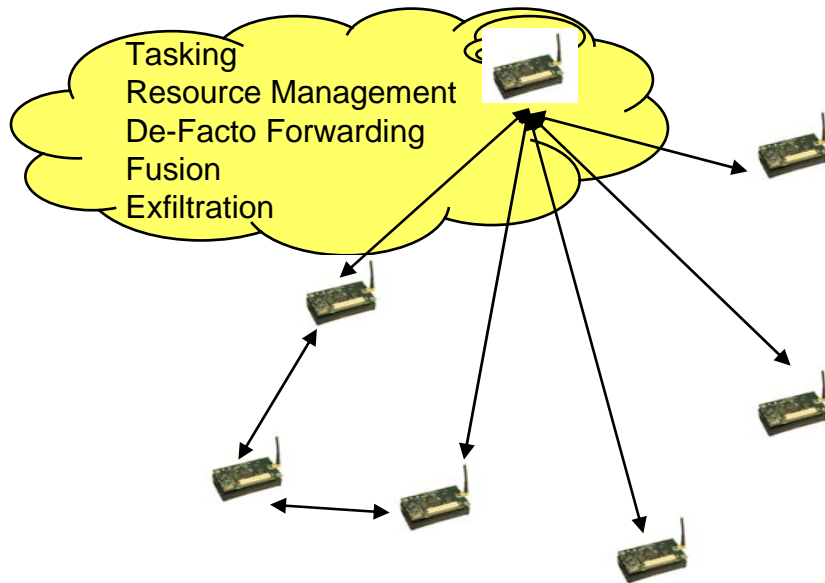
- **Develop a scheme by which sensor nodes determine their own (resource managed) operations based upon estimating the state and policy of other nodes, given only partial information about other nodes**
- **Compare the performance of this network to networks that use centralized paradigms for resource management and control**
- **Demonstrate the adaptivity, controllability, and flexibility of this approach**

# Activities

- **Develop overall mathematical framework**
  - Partially Observed (PO) Markov Decision Process (MDP)
- **Postulate node architecture for distributed control**
- **Implement sensor network simulations in MITRE Netted Sensor Toolbox (Matlab)**
  - I. Unconstrained resource utilization & centralized control
  - II. Constrained resource utilization & centralized control
  - III. Constrained resource utilization & distributed control
- **Develop and test algorithms for neighbor state and policy estimation**
- **Interface simulations with ISR Forensics Toolkit for network visualization**

# Highlight: MDP

## Centralized Network Control



**Determine Optimal Policy**

$$\max_{\text{Policies}} \langle R_{\infty} \rangle = [I - \beta T^{(\text{Policy})}]^{-1} R_1^{(\text{Policy})}$$

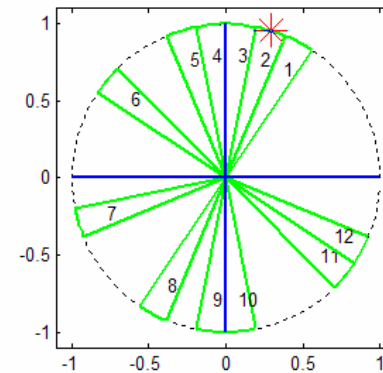
$\langle R_{\infty} \rangle$  - Value of adopting an overall particular policy

$R_1^{(\text{Policy})}$  - A set of rewards for taking particular actions

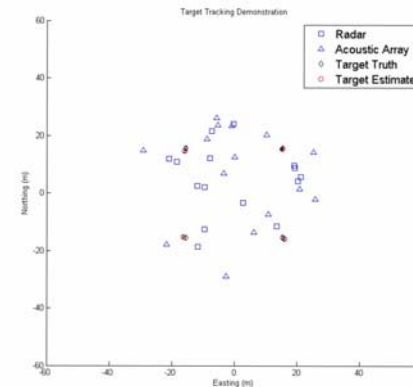
$\beta$  - Discount Factor

$T^{(\text{Policy})}$  - State Transition matrix

Target (red), Sensors (green) and Tasks (blue)



**1-Dimensional Tracking Demonstration**

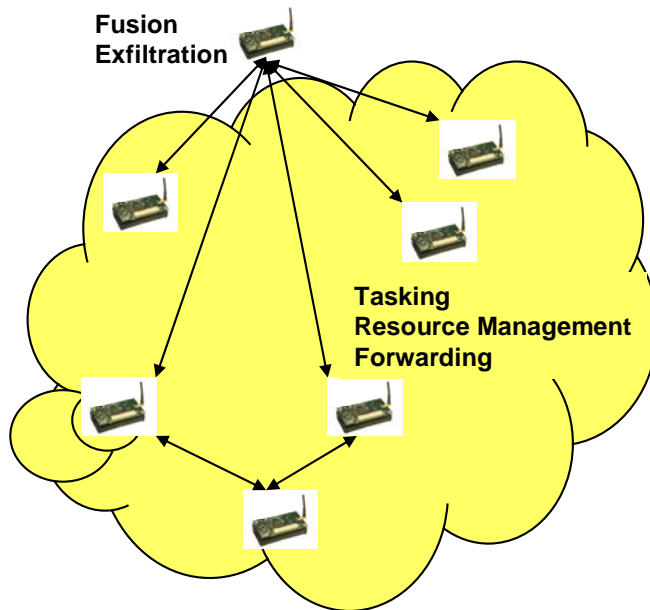


**2-Dimensional Tracking Demonstration**

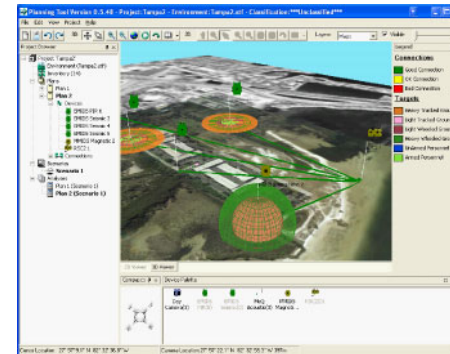
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# Highlight: POMDP Distributed Network Control



Network Visualization Demonstration

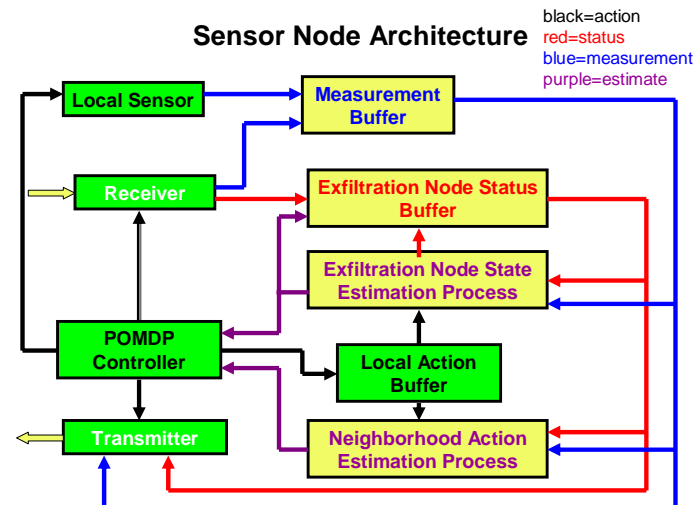


$$\max_{Policies} \langle R_{\infty} \rangle = [I - \beta T^{(Policy)}]^{-1} R_1^{(Policy)}$$

$T^{(Policy)}$  - Estimated rather than deterministic

Neighbor states and policies estimated from partially observed information

Sensor Node Architecture

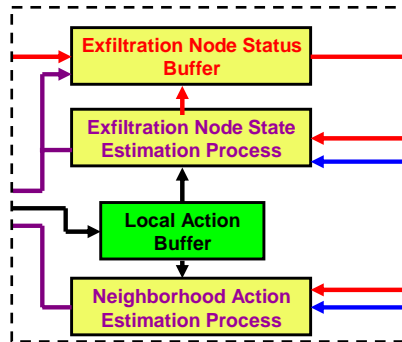


# Impact

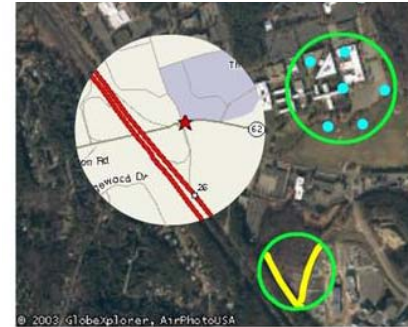
- ***A new level of sensor network control:***  
dramatically change the function of a sensor network by simply downloading new optimization parameters
- ***A new level of sensor network operation:***  
seamlessly adapt to non-functioning or newly inserted nodes
- **Improvement to scalability of network control**
- **Improved controllability of network**
- **Built-in resource management**

# Future Plans

## Continue to Refine Estimation Algorithms



## Refine Visualization and Control ISR Forensics with Semantic Lens



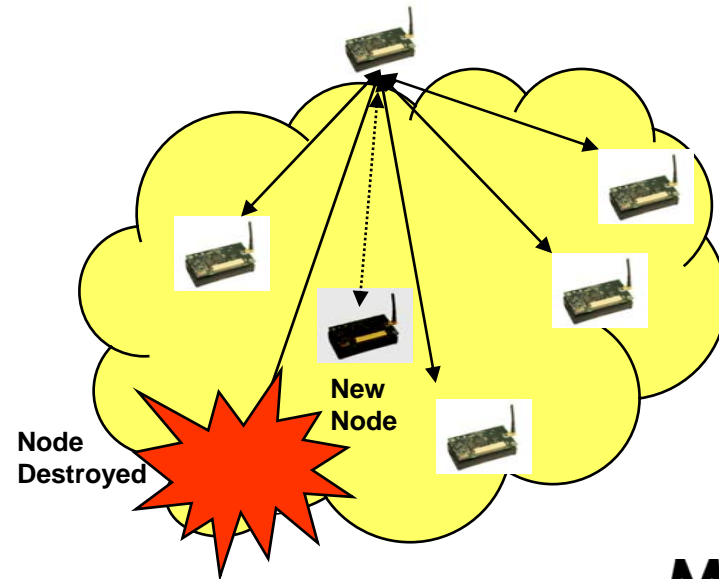
## Demonstrate Network Control



### Configure Network for ...

- Max Operating Life
- Max Information Now
- Improved Info Here
- ...

## Demonstrate Network Adaptivity



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