A Sensor-cyber Network Testbed for Plume Detection, Identification, and Tracking

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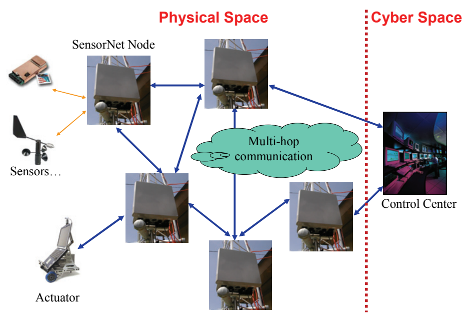
Introduction

- Under a national SensorNet initiative, we have carried out prototype deployments of **d**etection, **i**dentification, and **t**racking **s**ensor-**c**yber **n**etworks (DITSCN) at diverse sites (including Washington D.C., Port of Memphis, etc) to detect chemical, radiation, and biological releases and attacks.
- DITSCN combines various modalities of sensors and cyber networks
  - Sensors network provides information about the physical space
  - Cyber network provides storage and computational resources to predict plume propagation based on realistic dispersion models
  - Decisions regarding future sensing and communications are made in cyber network and carried out in the physical space

DITSCN Architecture



Research Tasks

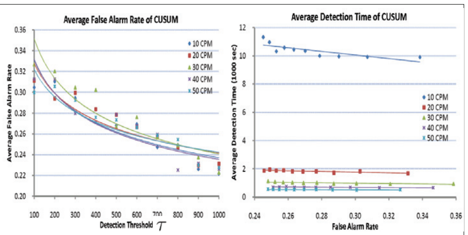
1. **Convergence** between physical and cyber spaces
   - Effectively gather information about the physical space
   - Communicate most useful data to the cyber space given bandwidth, delay and signal attenuation constraints
   - Enable the cyber space to task and activate sensors to collect high-quality data
2. Acknowledge the **existence of uncertainty** and enable decision making processes to deal with uncertainty in a robust fashion
   - Corporate physical environment: terrain elevation, land cover, and meteorological conditions
   - adequate modeling of physical phenomena (e.g., plumes with respect to the absorption, propagation, and dispersion coefficients).
3. Support for **deeply embedded operations**
   - Ability to integrate system components in an open, ***plug-and-play*** manner, through the use of open data, control and communication interfaces

CUSUM statistic CS_t at time t:

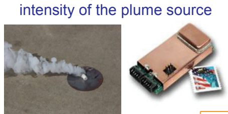
$$CS_t = \sum_{i=1}^{t} (sample_i - E[Backg])$$

Alarm if CS_t exceeds a threshold τ

Detection time $t_d = \inf_t \{CS_t \ge \tau\}$



RFTrax RAD Sensor to detect the presence and intensity of the plume source

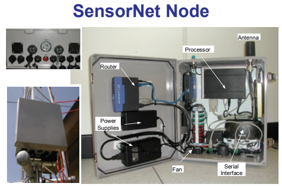


Plume Source

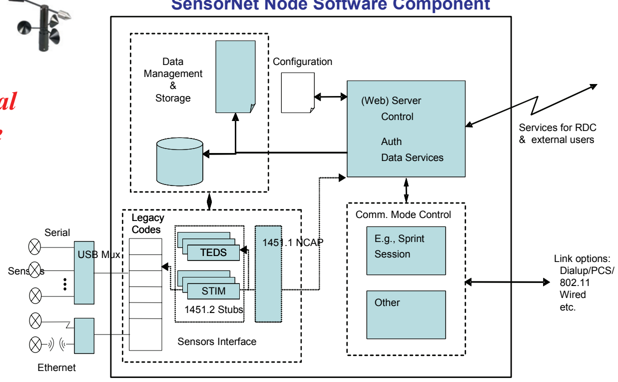
WMS Wind Sensor to monitor the wind speed and direction

- Sensor data communicated through RS-485 or 802.11x interfaces to the Sensor-Net Node
- Adapted *IEEE 1451* interface to configure sensor at runtime.

SensorNet Node



SensorNet Node Software Component



Physical Space

- Multi-hop communication over 802.11x wireless network
- AODV routing

	1Hop w/o obstacle	1 Hop w/ obstacle	2 Hop2 w/ obstacle
Signal (dBm)	-75.35	-88.25	-87.91
Loss Rate	0.008	0.024	0.799
RTT (ms)	2.79	3.41	474.9
TCP (Mbps)	8.011	2.444	0
UDP (Mbps)	9.548	3.124	0.0142

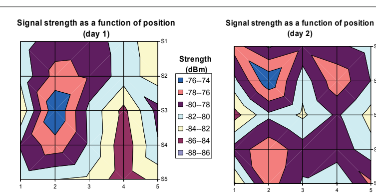
Experiments are carried out in Oak Ridge National Lab. Each hop is about 120 feet, and buildings are used as obstacles.

Cyber Space

- Realistic **SCIPUFF** plume dispersion model support for analysis and rendering of plume propagation in a real terrain
- Dynamically update plume propagation with variations in wind speed or direction
- Dynamically update the topology and routes in the multi-hop wireless sensor network
- **Tasking** mobile sensors (ER-1 robots) to collect high-quality and relevant data
- Dynamically update the positions of ER-1 robots

- **ER-1 Robots** supporting autonomous and programmable movement are guided by the cyber space, using commands sent over 802.11x wireless network.
- **Tasking** enables sensor mobility to increase the coverage of a high-risk location.
- Mobility affects the performance of wireless links

ER-1 Robots



Two wireless nodes are separated by 120 feet. One node moves in a limited space, divided into grids (1*1 foot). We observe that a small position change can have a large effect on the received signal strength, and it is NOT consistent over time.

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