CERIAS

Distributed Detection, Identification, and Tracking in Sensor-cyber Networks

Laboratory for Advanced Networking Systems
Department of Computer Science, Purdue University

Project Background

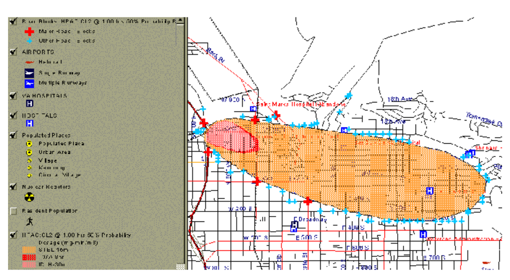
- ***Sensor-cyber project in national defense***
  - ➢Near real-time detection, tracking, and analysis of plumes (nuclear, chemical, biological, …)
- ***Multi-university partnership funded by Oak Ridge National Lab***
  - ➢Sensor testbed design and implementation
  - ➢Research team: Purdue, UIUC, LSU, U of Florida, Syracuse
- ***Partnership with SensorNet Initiative http://www.sensornet.gov***

Purdue Personnel

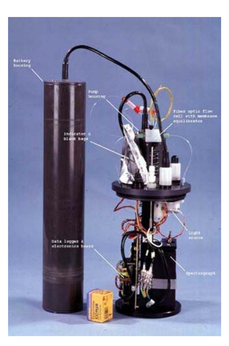
Principal investigator: David K. Y. Yau

Ph.D. students: Yu Dong, J. C. Chin, Chris Ma

SensorNet Initiative*



analysis, modeling, and prediction



chemical

radiational

biological

The SensorNet project is chartered to build a comprehensive incident management system for the near-real-time detection, identification, and assessment of chemical, biological, radiological, nuclear, and explosive (CBRNE) threats. The goal is to bring together and coordinate all necessary knowledge and response information quickly and effectively. This will be done by providing a common data highway for the processing and dissemination of data from CBRNE, meteorological, video and other sensors in order to provide near-real-time information to emergency management decision makers and first responders

*Information credit: Oak Ridge National Lab

Sensor Network Design in physical space

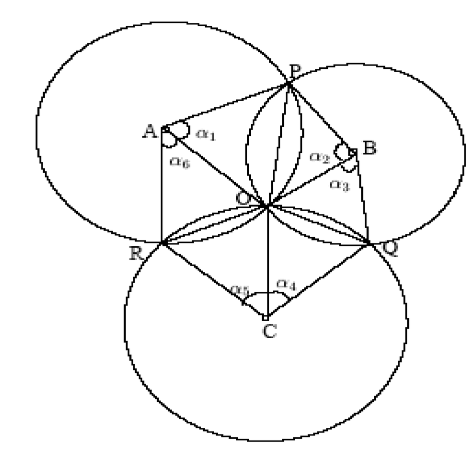
- ***Sensor placement and density for required quality of monitoring (QoM)***
  - ➢Under given false positive / negative probability constraints
- ***Dynamic tracking support for inverse and forward algorithms***
  - ➢Cluster formation, data report, in-network digest computation, tasking of sensors by inverse / forward algorithms

Sensor Modalities

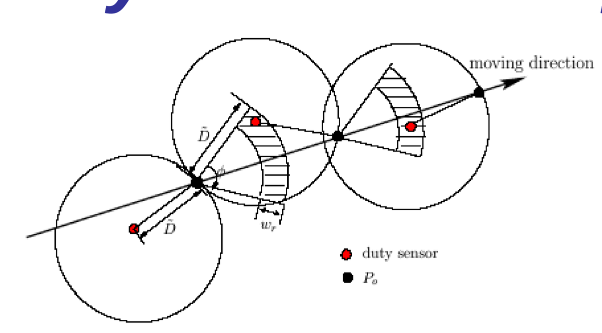
Sensor type	Sensor description	Baseline range measures	Sensitivity measures	Spatial / environmental effects	Approximate data rates
A. Radiation	RFTrax; mote-scale form factor; 600 microA at 3.6 V full power; reduced power mode available	1cm – 3 m	0.1 – 1000 milliREM /hour	Impact likelihood decreases according to inverse square; count aggregates determine reading	1KB/reading, 1 second/reading, 1-3 second stabilization
	NucSafe (mobile / handheld)	50 cm	Single Panel – 10 gms of Pu at 50 cm; P(detection) = 99%	Variable Interference	10 KB / reading / second
	NucSafe stationary	1 m	Per 0.25m square panel - 5 gms Pu	Effectiveness proportional to area of detector; inverse square for detection	100 KB / reading; 10 seconds / reading
B. Hyper-spectral	Axis PTZ cameras; 12 V DC	100+ m	Image - 25/30 fps. Image frame from 160x120 to 704x480 (NTSC)	Day-night and I/R capability, pan (+/- 170 deg), Tilt –30/90 deg), zoom 12-18x	Motion JPEG, MPEG-4, pan speed (max 100 deg/sec), Tilt (90 deg/sec)
C. Acoustic	Acoustic sensor array (Mote-based [Led05])	100 m (shooter)	O(10%) at 100 m, 50 sensors	3D-triangulation	O(1 kSPS, 12 bps) (on board A/D)
	Vibration sensor (terrain commander)	25 m -human 500 m -light truck			
D. Chemical	Smiths detection (APD 2000 mobile / handheld) – 9-18 V DC	Requires particulate ingestion	4 – 500 ppb	Plume effects apply; 4 ppb – 30 seconds; 200 ppb – 15 seconds	10 KB/sample
	Centurian (stationary; 110/220 V)	Requires particulate ingestion			50 KB/sample (includes spectrum)

Sensor Coverage Problem

- ***Cover crossing point O***
- ***Minimize overlap***
- ***Probabilistic overage***
  - ➢Relaxed perfect disk assumption (imperfect wireless communication)
  - ➢K-coverage for inverse/forward algorithms

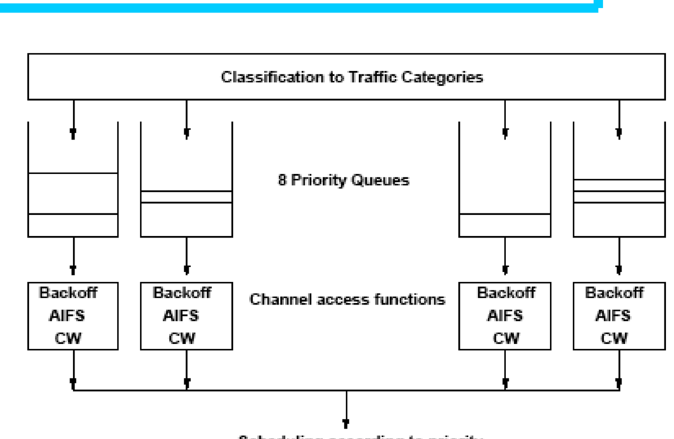


Duty Sensor Relay for Continuous Checking



- ***Handoff of duty sensor in relay area defined by parameters***
- ***Handoff along tracking path***

QoS Provisioning in IEEE 802.11e



- ***802.11e defines enhanced distributed channel access for contention based communication***
- ***Parameter selection: AIFS, CWmin, CWmax, TXOP, …***
- ***Implementation: MadWifi driver on Atheros chipset***

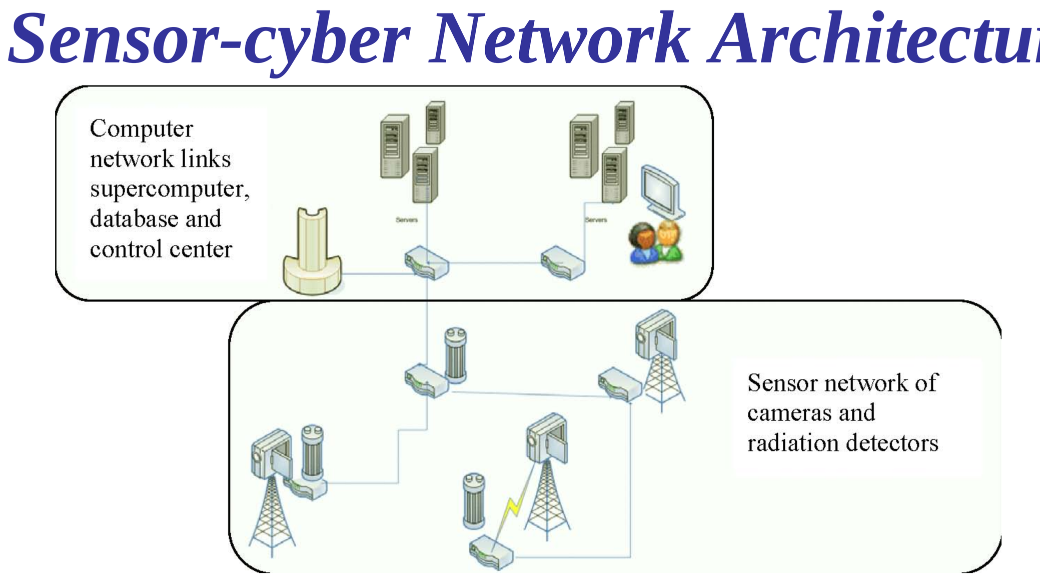
Cyber-sensor Network Coordination

- ***Uncertainty management***
  - ➢Adaptive tasking of sensors by cyber center control
  - ➢Temporal and spatial uncertainty under noise
- ***Temporal QoS in 802.11e networks***
  - ➢DCF, PCF, and HCF media access
  - ➢Contention resolution and service differentiation
- ***Data QoS from lower to higher tier sensor network***
  - ➢Dynamic cluster formation
  - ➢Adaptive timeout protocol
    - ✓Distributed, minimize signal interference, prefer strong signal and suppress weak signal
  - ➢Block based scheduling

System Architecture

- ***Two-tiered sensor network in physical space***
  - ➢Plume detection by first-tier capable sensors
  - ➢Continuous plume tracking by second-tier lightweight mote-like sensors
- ***High-performance computational grid in cyber space***
  - ➢Plume analysis and extrapolation (inverse and forward algorithms under uncertainty)
- ***Interactions (data and control) between sensor and cyber networks***

Sensor-cyber Network Architecture



Project Features

- ***Timely project in critical domain***
  - ➢Address of national security issues
  - ➢Research results will be implemented, deployed, and evaluated
  - ➢Close collaboration with ONR/ORNL (including summer internships for students)
  - ➢Experience has broader applications beyond national defense
    - ✓Wireless protocols, sensor network architecture, motes/TinyOS, sensor-cyber network interactions

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