A Survey of Military Applications of Wireless Sensor Networks

M. Pejanović Đurišić[1], Z. Tafa[1,2],
G. Dimić[3], and V. Milutinović[2]
[1]Department of Electrical Engineering,
University of Podgorica, Montenegro,
[2]School of Electrical Engineering
and [3]Institute Mihajlo Pupin,
University of Belgrade, Serbia

Outline

- Military communications:
  requirements & scenarios
- Potential of WSNs in military applications
- Classification of military applications of WSNs
- Description of classified applications
- Research and engineering challenges:
  - Spatial Coverage in WSNs
  - Supercomputer Processing for WSNs
  - Data Mining in WSNs

Military Communications (1)

- In all aspects of military operations:

  distribution of commands, logistical info, intelligence, and data from sensors

- Requirements:

  - maintained where & when needed;

  - resistant to jamming, direction finding, and other electronic warfare threats

  - provide end-to-end message security

Military Communications (2)

- Military engagement scenarios:
  - battlefield: well-known, well-defined enemy;
  - operations in urban environments
  - other than war (OTW), e.g. peacekeeping, disaster relief
  - force protection (intersects previous three)

WSNs in Military Applications

- Sensors measuring: electromagnetic energy / signals, light, pressure, sound – explosions
- Also: chemical, biological and explosive vapor; presence of people or objects
- WSNs: cost-effective gathering of information about environment and actors
- Use of WSNs can reduce uncertainty: where enemy forces will be deployed; their role
- OTW: Areas at risk of natural disaster; location of population to be protected

*****

Classification of Military WSN Applications

- By types of military operations:

  battlefield, urban, OTW, force protection
- By sensor types:
  - presence/intrusion (IR+photoel.+laser+acoustic);
  - chemical, biological, radiological, nuclear and explosive (CBRNE) detectors;
  - ranging (e.g. radar, lidar, ultrasonic);
  - imaging (IR, ladar);
  - noise (acoustic sensor producing audio stream)
- Soldier-worn WSNs: track vital functions – considered for force protection and OTW (e.g., firefighters)

Classes of Military WSN Applications

Sensor types	Operation scenario			
	Battlefield	Urban	OTW	Force protection
Presence / Intrusion	SHLM, AAP, ASW	SDT		SHLM, AAP, SDT
CBRNE	RCS		VDM	VDM, RCS
Ranging	ASW	EARS, INS	BL, INS	EARS, BL, SDL, PP
Imaging		SDL, MCM	MCM	SDL, MCM, PP
Noise		ATS	ATS	ATS

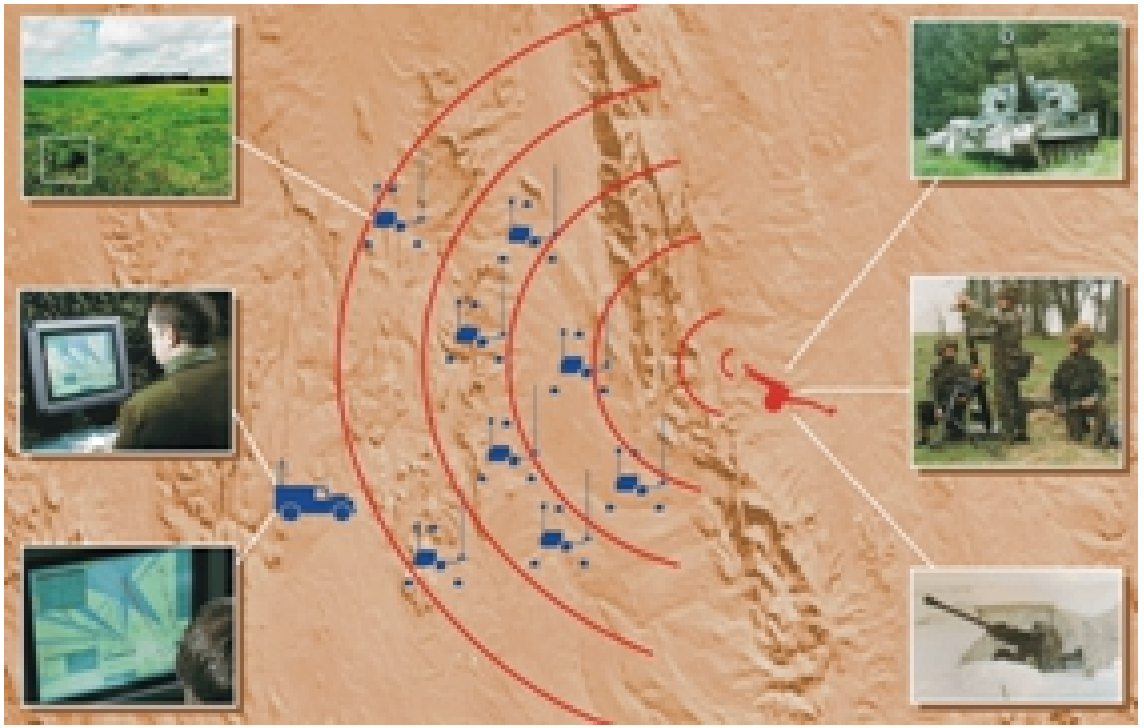
Major Sensing Approaches

- For Presence/Intrusion & Ranging:
- Sensor arrays for azimuth & elevation estimation → Direction of arrival (DOA), Time difference of arrival (TDOA)
- Mostly acoustic & seismic sensors
- Aided by cameras, IR cameras (Imaging); radars
- For CBRNE, multiple sensors for improved detectability/coverage, not for direction estimation

Description of Classified Apps (1)

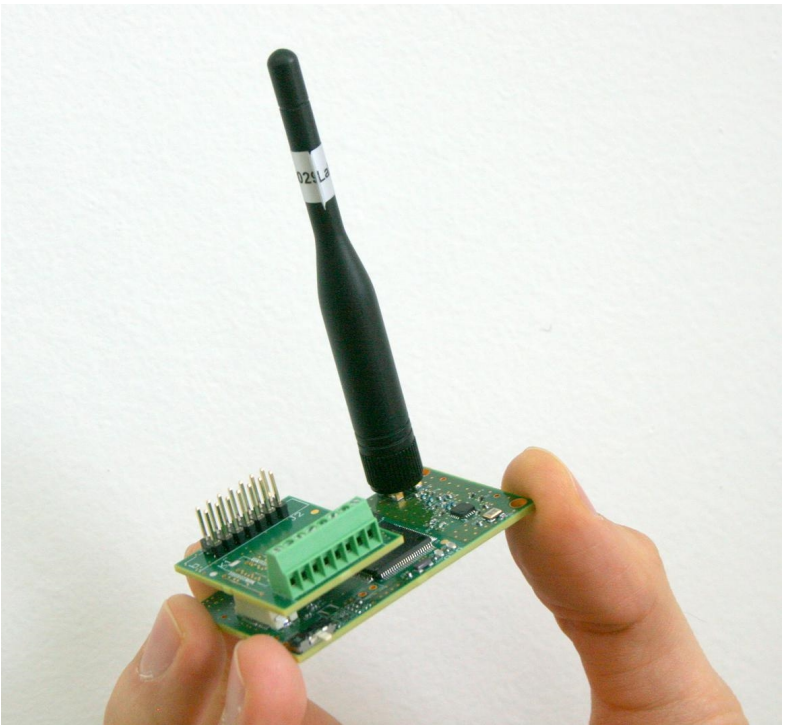
- Self-healing land mines (SHLM): BF&FP; each antitank mine senses threats, responds autonomously by moving; acoustic & accelerometer sensors
- Aerostat acoustic payload for transient detection (AAP): BF&FP; acoustic sensor arrays below tethered aerostats, detect & localize small arms fire (DOA), ground sensors augment AAP
- Soldier detection and tracking (SDT): U&FP; acoustic & seismic sensors survey specific points; daylight still cameras optional

Description of Classified Apps (2)



Navsea NSWC Dahlgren:

Ground Counter Fire Sensor



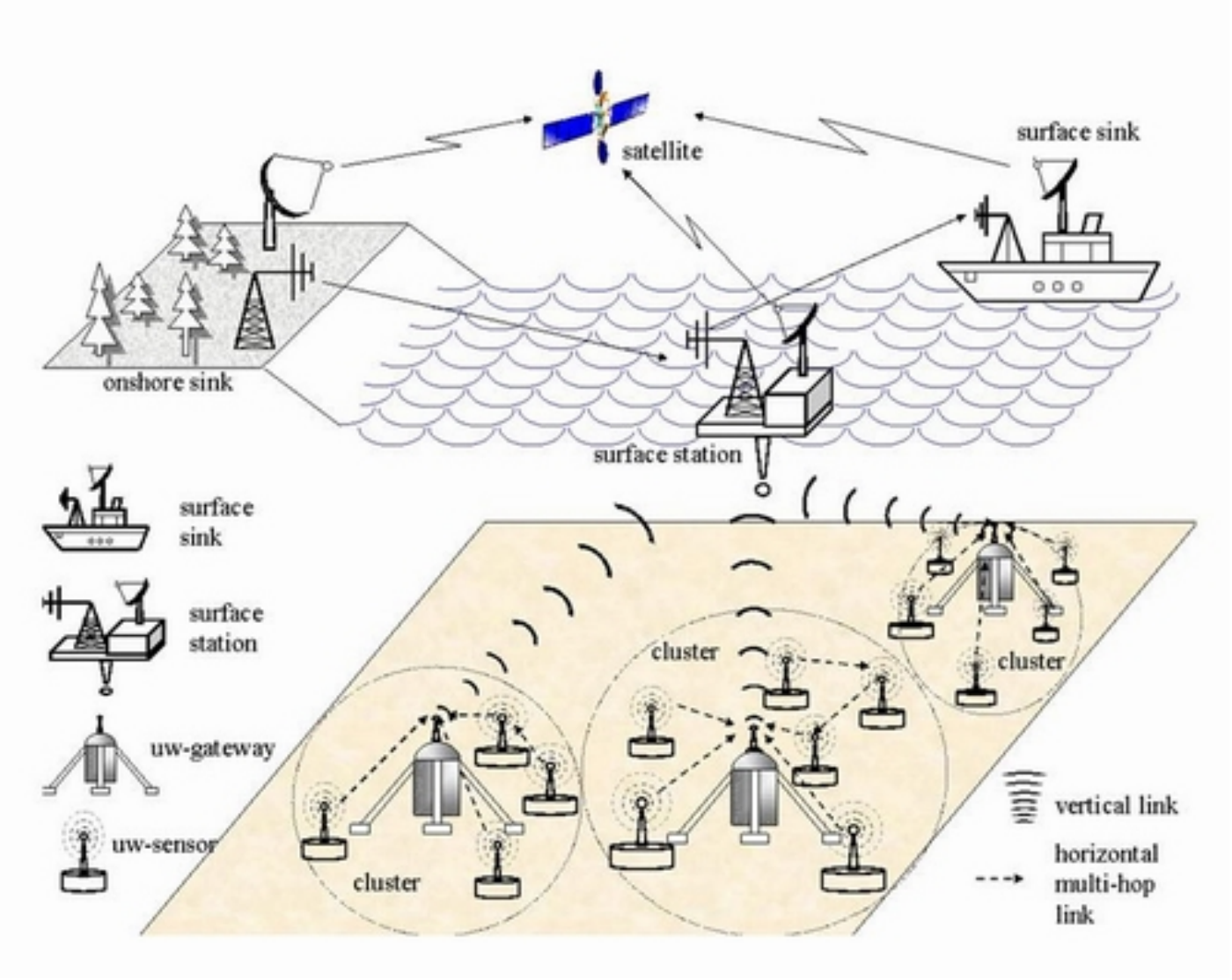
Institute Mihajlo Pupin

MOTE1

Description of Classified Apps (3)

- Low-cost acoustic sensors for littoral anti-submarine warfare (ASW): BF (FP); passive & active sonars to detect submarines operating on batteries; short detection range – robust to multipath
- Early attack reaction sensor (EARS): U & FP; man-wearable passive acoustic (microphone array) to detect gunshot – relative azimuth & range of the shot origin
- Sniper detection & localization (SDL): FP; two acoustic arrays & video camera (Imaging); triangulation & affirmative image of perpetrator

Description of Classified Apps (4)

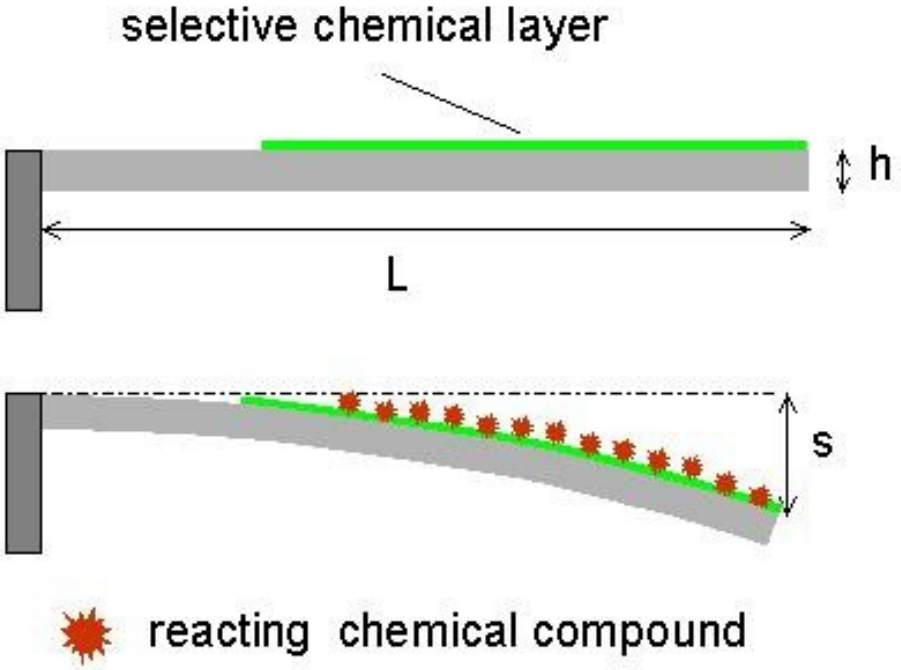


Description of Classified Apps (5)

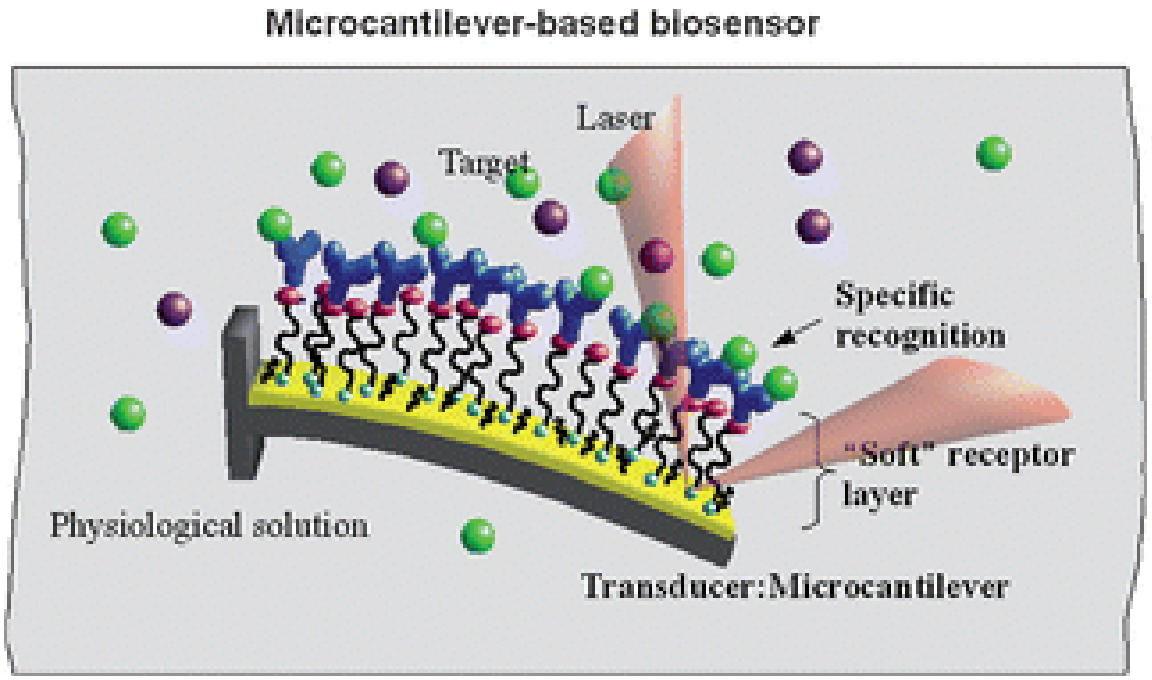
- Time difference of arrival blast localization (BU); OTW, FP; mesh network of 3-D TDOA acoustic localization; each sensor node self-configures
- Perimeter protection (PP); FP; multi-sensor daylight cameras, IR non-cooled thermal cameras (Imaging), mm-wave radars; intelligent data analysis & data fusion
- CBRNE: Vapor detection w/ micro cantilever array sensor (VDM); OTW & FP; measure trace concentrations of explosive, toxic chemicals, biological agents; electrical & thermal properties of vapor molecules
- Remote chemical sensor for UAV (RCS): B & FP; detect hazardous chemicals at alt 300m, at ~100km/h; unique IR absorption signatures & 3 color photodiodes

Description of Classified Apps (6)

F. Baldini, SPIE 2006 →



M. Alvarez & L. M. Lechuga,
Analyst, 2010, 135, 827



Description of Classified Apps (7)

- Optical sensor system for missile canisters continuous monitoring (MCM): U, FP, OTW; monitor shock & vibration in 3-D at high speed
- Inertial Navigation System (INS): U&OTW; TDOA from WSN;
  magnetometer data for vehicle heading & pitch improves orientation
- Noise: Acoustic threatening sound recognition system (ATS): U, FP, OTW;
  distributed & hierarchical architecture;
  collaboratively detect, classify & estimate location;
  reduce false alarms and latency

Review

- New military operational contexts:
  urban, OTW, force protection
  → various new WSN applications;
- Cost-effective, reduce uncertainty
- Type & capability of WSN depends on:
  sensors, wireless comm. architecture,
  coverage, information processing & fusion
- Classification of WSN military applications
- Survey of classified applications

Engineering & Research Challenges

- Requirements for future military-use of WSNs
- Physical size & weight not a major constraint
- Rapidly identify neighbors, configure network
- Reasonably static; coverage area 5-20 km^2
- Communication range of a node: 250-500m
- 2-way communication gateway-nodes
- Small EM emission
- # nodes mostly < 100; low-med data rates
- *Disruption-tolerant*

Engineering Challenges

- Identification of several simultaneous events & reliable correlation of information from neighboring nodes
- Classification of objects & events
- Improved integration of different sensor types
- Miniaturization & better robustness of sensors
- Common formats & standards for sensor data communication

Research Challenges

- Increase WSN usability, flexibility & security
- Security: reputation approaches
- Endurance: energy harvesting, efficiency
- Coverage & connectivity improvement:
  sensing & communication range
  (yet covert, small EM emission)
- Information processing, fusion & knowledge:
  related to coverage for reliable correlation
  of info across space & time
  to perform data mining, knowledge engineering

Major Challenges

- Spatial Coverage in WSNs
- Supercomputer Processing for WSNs
- Data Mining in WSNs

*****