Secure Embedded Wireless Networks

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Product/Service

- Communication and reprogramming protocol that can fit within the constraints of embedded wireless devices
- Secure ⇒ No eavesdropping, no masquerading, no compromised nodes

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Advantages

- Based on Advanced Encryption Standard (AES) protocol already widely used and National Security Agency (NSA) approved
- Fastest AES encryption method available
- Provides secure communication; even when a node has been compromised (local monitoring)
- Science novelty:
  - Software optimizations, including compiler
  - Distributed software requiring no central controller
- Cost effective and easily modified since it is software-based

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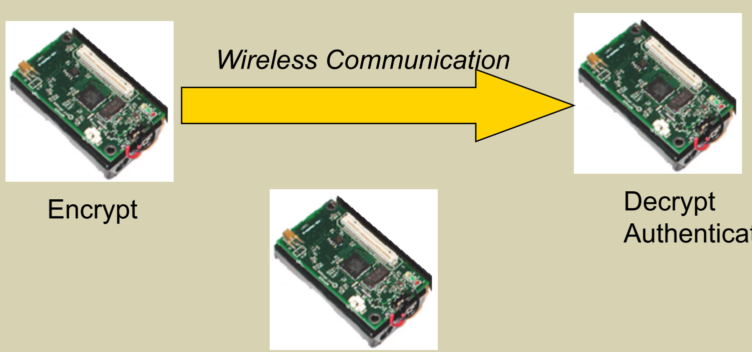
Schematic of Solution



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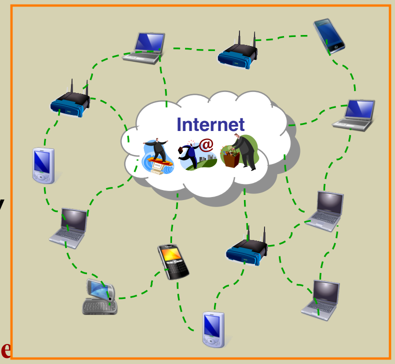
Ad Hoc Wireless Networks (AHWN)



- Consist of a number of nodes that communicate with each other over a wireless channel
  - Each node operates not only as a host but also as a router
- Are easily deployable, decentralized, and self-configured
- Suitable for a variety of applications that avoid infrastructure because
  - **Establishing infrastructure is impossible**
    - **E.g., battlefield, natural-disaster areas, natural habitat, etc.**
  - **Establishing infrastructure is not cost-effective**
    - **E.g., rural areas, temporary events such as a sport match or a conference**

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Security Vulnerability of AHWN

- Adversary can physically capture and tamper with ad hoc nodes
  - Ad hoc nodes are often deployed in insecure locations
    - Mesh routers are deployed on rooftops or attached to streetlights
    - Nodes may be deployed in a hostile environment, e.g., in a battlefield
  - Ad hoc nodes are typically low-cost devices with a lack of strong hardware protection (e.g., anti-tamper hardware)
- Compromised nodes can be exploited to launch a variety of attacks
  - Deny the network protocols such as the back-off rule at MAC layer or packet-relaying duty, etc.
  - Inject malicious traffic, e.g. worms, into networks

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Motivation

- Behavior-based Detection
  - Nodes overhear communications in their neighborhood
  - Then, determine if the behaviors of the neighbors are legitimate
- Use of Multiple Channels and Multiple Radios
  - Nodes are equipped with multiple radios tuned on different non-overlapping channels
  - Can significantly increase the capacity of AHWNs
- Question that arises:

In order to execute the behavior-based detection, on which channel does a node overhear?

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Problem Statement

- Framework for behavior-based detection in multi-channel AHWNs
  - We use a set of trusted nodes (called monitoring nodes) to execute the behavior detection for monitoring the network
    - Monitoring nodes can be dedicated nodes for security purposes or reliable system nodes
- Optimal placement of monitoring nodes and selection of channels

Where to place a given number of monitoring nodes among several possible locations in the network and which channels to tune their radios to, in order to maximize the detection coverage?

Equivalently, given a set of monitoring nodes deployed in the network,

How to choose a subset of monitoring nodes to be activated and the channels for the chosen monitoring nodes, in order to maximize the detection coverage?

Contributions

MCSC	GR-MCSC (existing work) AR: 1-1/e		
MCMC Centralized	GR-MCMC AR: 0.5	PRA AR: 1-1/e, Probabilistically	DRA AR: 1-1/e, Deterministically
MCMC Distributed	DGR-MCMC AR: 0.5	DPRA AR: $\alpha \cdot$(1-1/e), Probabilistically	DDRA AR: $\alpha \cdot$(1-1/e), Deterministically

- Best approximation ratio for MCSC: 1-1/e
- Best approximation ratio for MCMC: 1-1/e
- α is an accuracy parameter that can be set to $\in (0, 1)$

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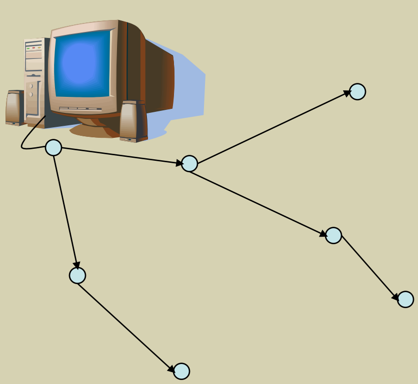
Sensor Network Reprogramming

- Uploading new software while the nodes are *in situ*, embedded in their sensing environment



- **Fix software bugs**
- **Adapt to changing user needs and environmental conditions in which the network is deployed**
- **Shorten software development phase**
- **Make software robust**
- **Fine-tune algorithms**
- **Complete application replacement**

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Requirements of Network Reprogramming

- For correctness, all nodes in the network should receive the code completely
  - Reliable dissemination using unreliable wireless channels is challenging
- For performance, code upload should minimize
  - *reprogramming time* so that sensor nodes can quickly resume their normal function
  - *reprogramming energy* spent in disseminating code through the network since sensor nodes have limited energy
- For security, malicious nodes should be unable to insert code
- Solution should fit within computation, memory, and bandwidth constraints of sensor nodes

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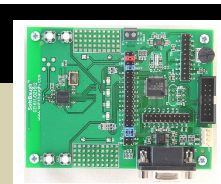

Experiment

- Softbaugh DZ1611 Zigbee Demo Board
- ROM (Code) Size
  - msp430-objdump
- RAM (Memory) Usage
  - msp430-gdb printing stack pointer
- Execution Time
  - Set I/O line on start, clear on end
  - Measure on oscilloscope

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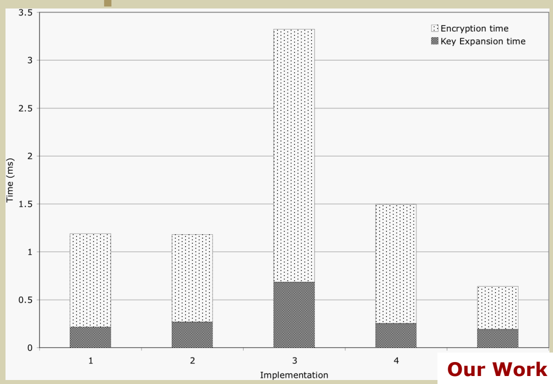
AES Comparison

- Improved both speed and code size (RAM unknown)
- Note that our measurements seem to have varied significantly from published numbers in some cases



Implementation	Reference paper	Measured ROM Usage	Published ROM Usage
1	[6]	5968 bytes	n/a
2	[12]	6780 bytes	12616 bytes
3	[14]	6848 bytes	3322 bytes
4	[10]	n/a	n/a
5	Our implementation	5160 bytes	n/a

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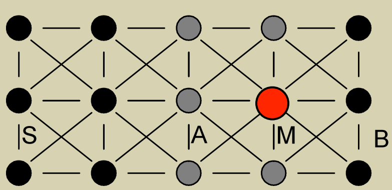
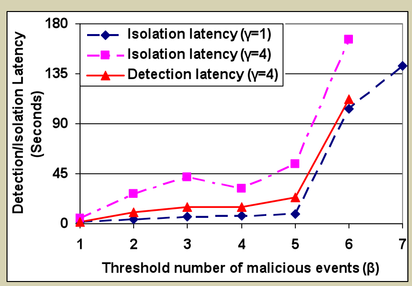
Internal Malicious Node Detection





- Malicious node *M* – has all the cryptographic keys – thwarting communication to base node *B*

Applications

- Military/Homeland Security
  - Secure ad-hoc networking
  - Secure wide area networking
  - Emergency/disaster communications
- Corporate entities where secure wireless communication is a concern
- Hospitals/pharmacies
- E-commerce

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Team

- Faculty principal investigator:
  Prof. Saurabh Bagchi
- Technical staff: Aaron Ault
- Students: Shammi Didla (undergraduate), DongHoon Shin, Matthew Tan Creti
- Alumni students: Rajesh Panta

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Next Steps

- Patent issued
- Development timelines:
  - Prototype developed & tested, including comparative evaluation
  - Commercial viability = ~1 man year
- Future plans for development
  - Software for the two parts (secure communication, detection of compromised nodes) needs to be ported to a common platform

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Summary

- Secure communication between nodes using AES that is faster than the wireless network speed
- Detection and isolation of internal compromised node through decentralized protocol

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Opportunity

- Licensing or start-up opportunity
  - Contact Hilton Turner, Technology Manager
  - 765-496-7539
  - haturner@prf.org