Improving key management in wireless sensor networks

Filip Jurnečka

DTEDI

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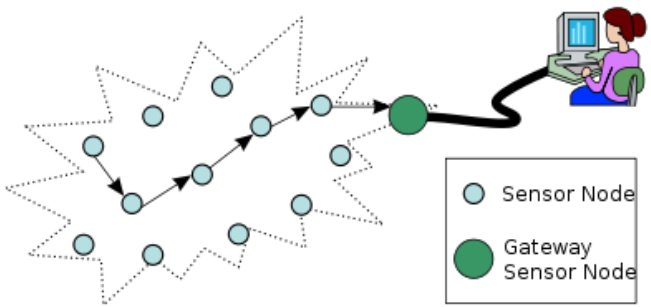
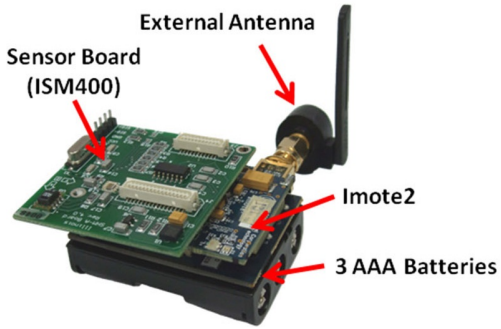
Wireless sensor network (WSN)



- A distributed (or hierarchical) multi-hop heterogenous network composed of a
  - large number of tiny low-end devices (motes, nodes...).
    - they are usually equipped with sensors and radio.
    - limited processing power, memory and energy.
  - one or a few powerful secured devices (base stations).
- The network is used to monitor some physical phenomena.
- Applied in various scenarios like battlefield management, monitoring wildfire, vibrations on an engine or pressure in car tires.

Wireless sensor network (WSN)

(a) TelosB mote

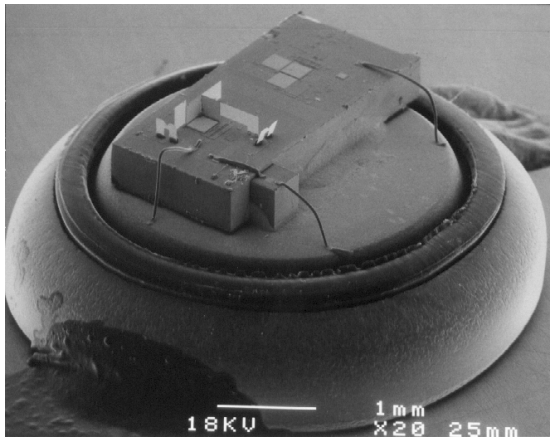


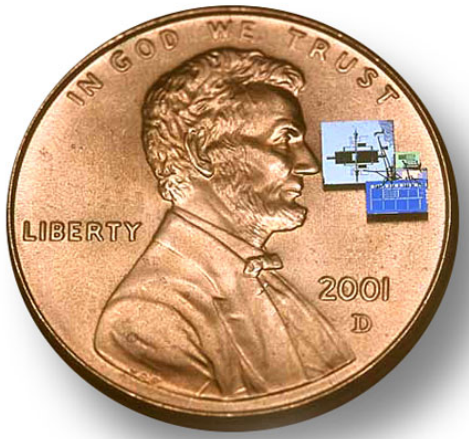
(b) Imote2 mote

- MICAz
  - 8-bit Atmel microcontroller ATmega128L operating at up to 16 MHz
  - 4kB RAM, 128kB program flash, 512kB Measurement Serial Flash
- TelosB
  - 16-bit Texas Instrument microcontroller MSP430 operating at 8 MHz
  - 10kB RAM, 48kB program flash, 1024kB Measurement Serial Flash
  - powered by two AA batteries
- Imote2
  - 32-bit processor Intel PXA271 operating at up to 416 MHz
  - 256kB SRAM, 32MB flash, 32MB SDRAM

Key management schemes' (KMS) properties

- Memory footprint
- Communication overhead
- Processing speed
- Network bootstrapping
- Network resilience
- Connectivity
  - Global connectivity
  - Local connectivity
  - Node connectivity
- Scalability
- Extensibility
- Energy





Existing taxonomies

Published taxonomies of key management schemes are based on:

- encryption key mechanism
  - Asymmetric cryptography
  - Symmetric cryptography
  - Other solutions
- characteristic
  - Self-enforcing schemes
  - Arbitrated schemes
  - Pre-distribution schemes
- characteristic, take 2
  - Key pool schemes
  - Mathematical schemes
  - Negotiation schemes
  - Public key schemes
- network structure
  - Centralized key schemes
  - Distributed key schemes
- probability of keying
  - Probabilistic key schemes
  - Deterministic key schemes

Existing solutions for key establishment

- Asymmetric cryptography
  - RSA
  - ECC
  - Identity-based key agreement scheme
- Symmetric cryptography
  - Master key based pre-distribution scheme
  - Base station participation scheme
  - Trusted third node based scheme
  - Pair-wise key pre-distribution scheme
  - Probabilistic key pre-distribution schemes
- Other solutions
  - Key infection scheme
  - Hybrid schemes

Many protocols lack reviews and thus might have previously unknown shortages.

Master key pre-distribution

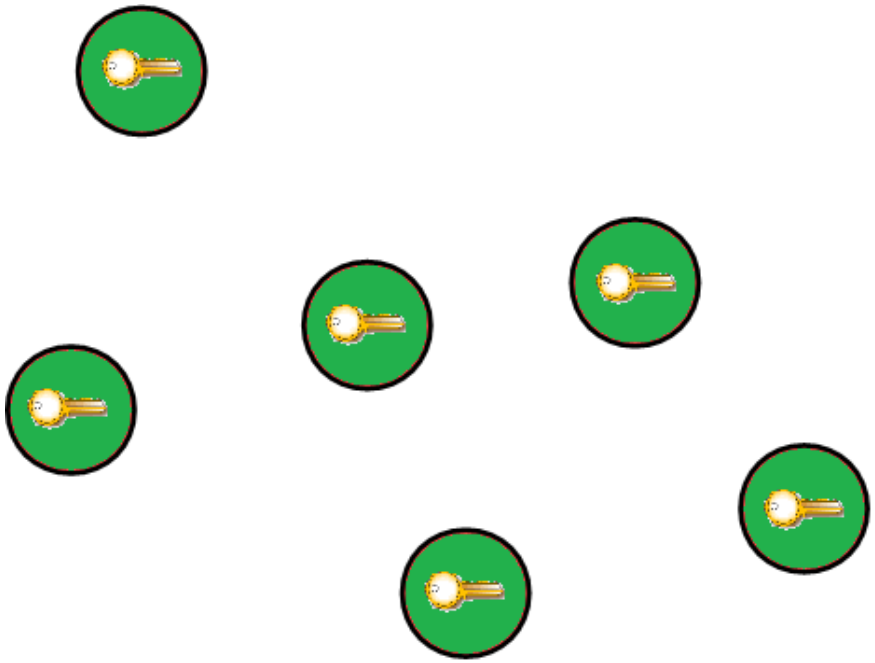


Figure : Same key shared by all nodes

- Perfect in terms of memory storage
- Completely fails with single node

Master key pre-distribution

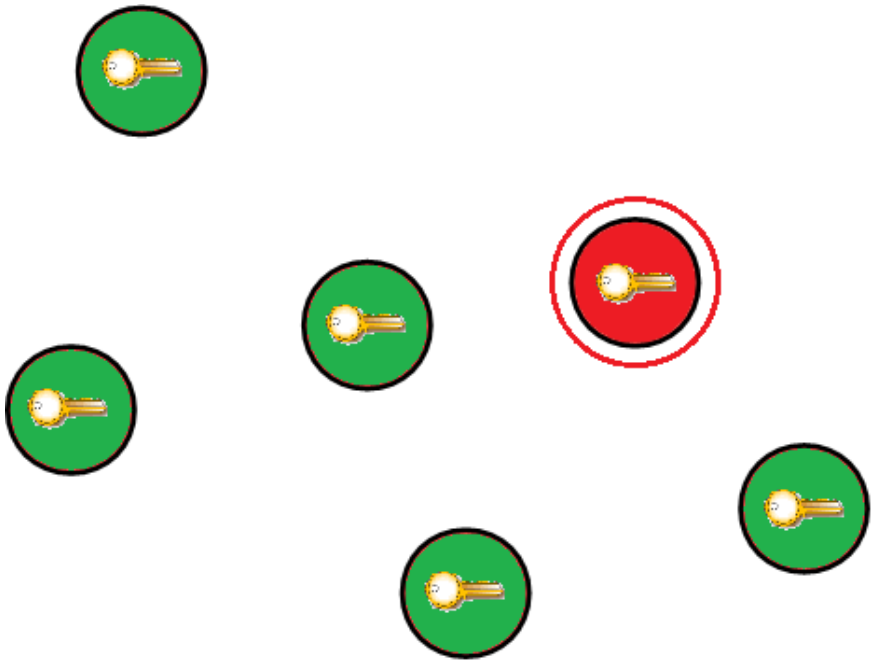


Figure : Capturing a single node implies capturing all keys

- Perfect in terms of memory storage
- Completely fails with single node

Master key pre-distribution

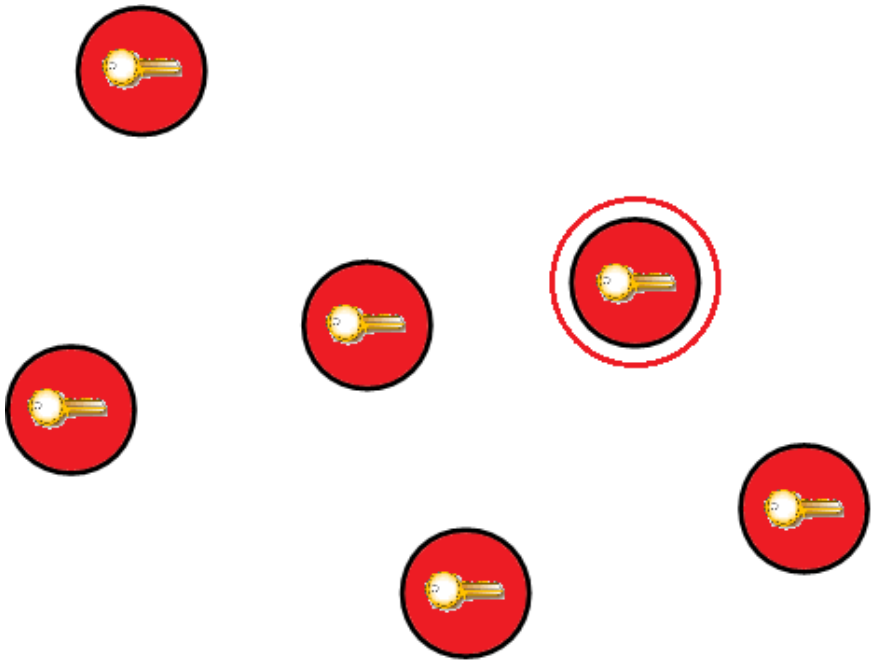


Figure : All communication is now exposed to the attacker

- Perfect in terms of memory storage
- Completely fails with single node

Eschenauer-Gligor (EG) probabilistic pre-distribution

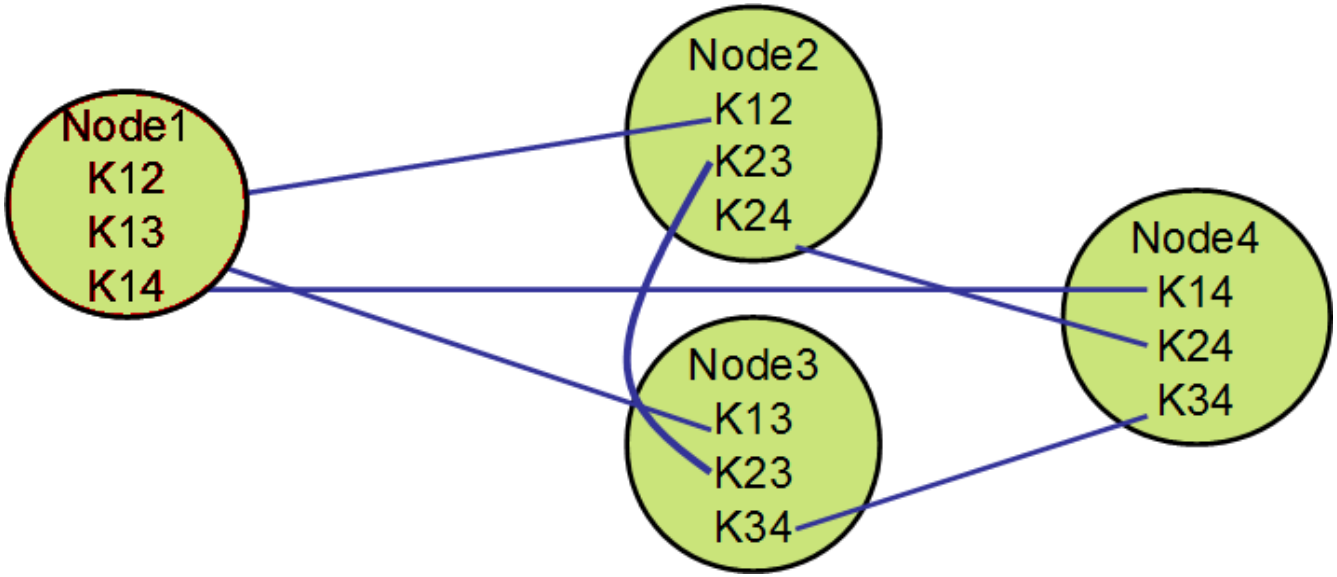


Figure : Each node loaded a random subset of keys

- Only links to captured node are compromised
- Not scalable in terms of memory storage
- Key from captured node can be used everywhere

Eschenauer-Gligor (EG) probabilistic pre-distribution

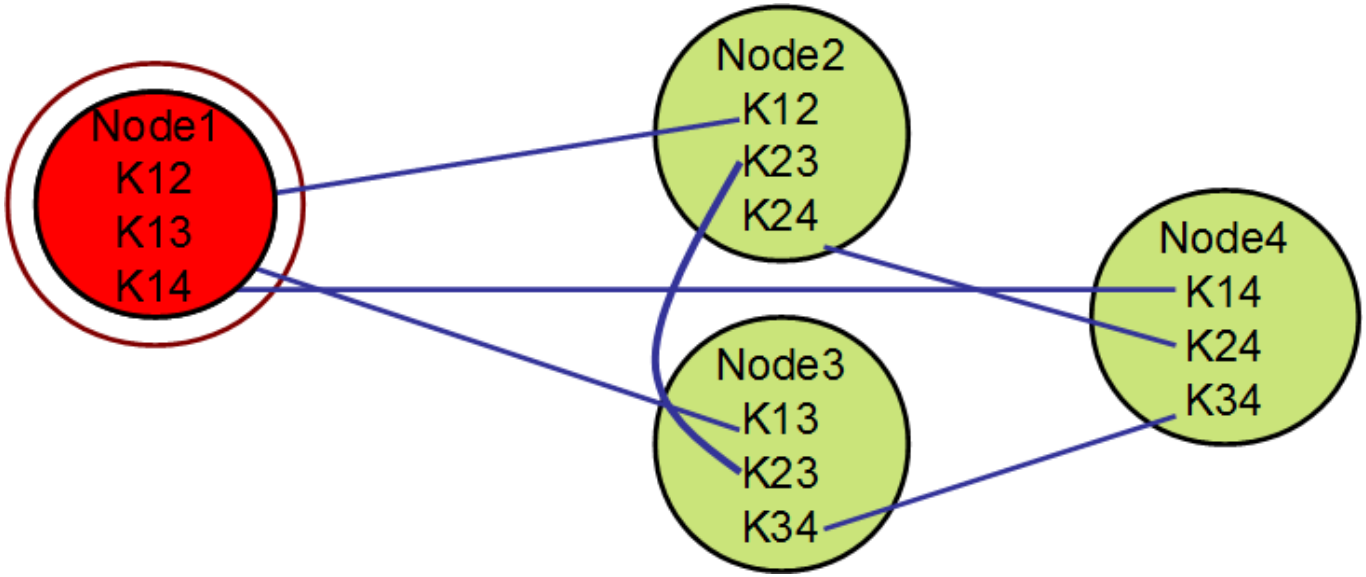


Figure : Capturing of single node reveals keys shared with neighbours

- Only links to captured node are compromised
- Not scalable in terms of memory storage
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Eschenauer-Gligor (EG) probabilistic pre-distribution

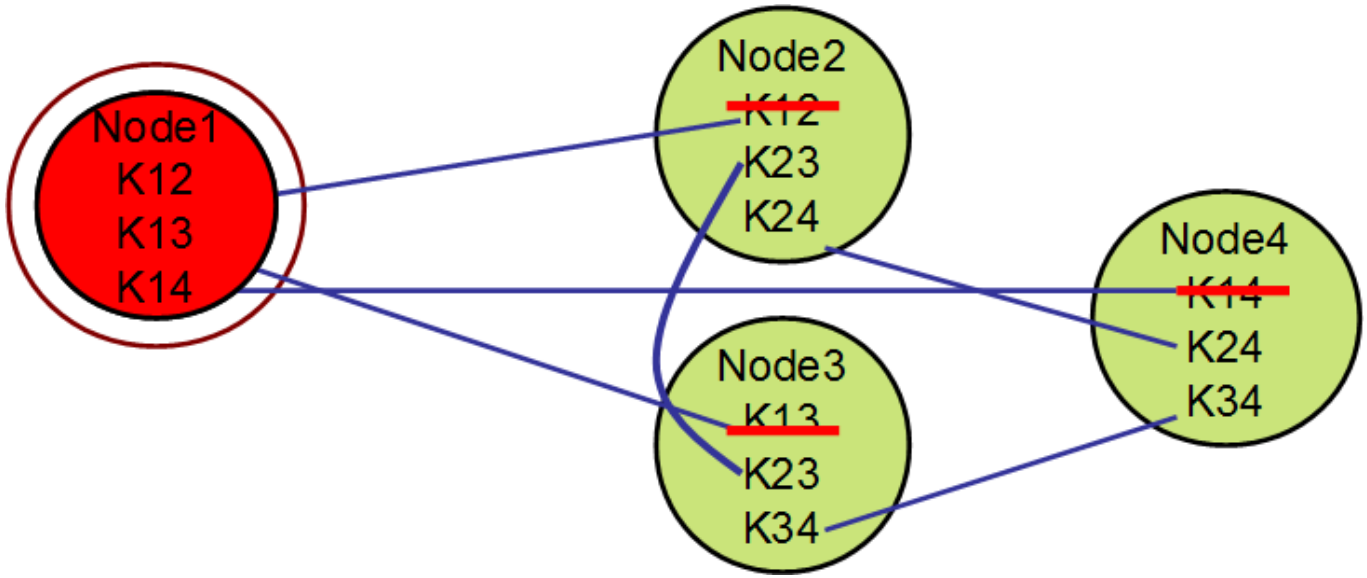

Figure : Capturing of single node reveals keys shared with neighbours

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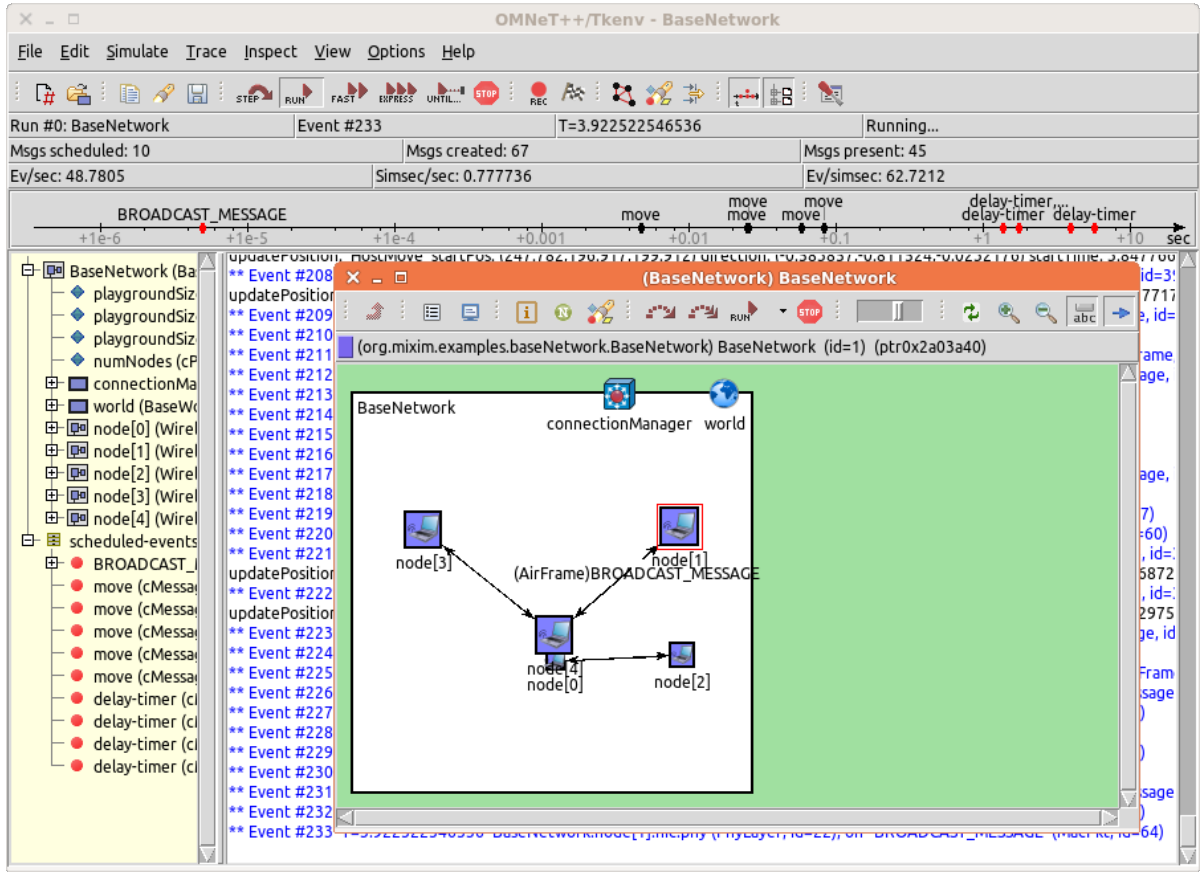
Motivation for simulating WSNs

- Building a WSN testbed is very expensive.
- The network management is time consuming.
- Simulations are repeatable.
- Simulations allow for large scale evaluations.
- Correctness of the simulation depends on the **model**.

Mainstream WSN simulators

- NS-2
- TOSSIM
- OMNeT++
  - **MiXiM**
  - Castalia
- J-Sim
- Cooja
- WSNet
- ATEMU
- Avrora
- SensorSim
- and many others



Simulation model

- Topology
- Radio propagation
- Energy consumption
- Networking stack
- Security model support
- Attacker model support
- Memory requirements model
- Computational complexity model

Attacker model

The **real world** attacker model from key infection scheme.

- Attacker can be present in the deployment area prior to the deployment, but only able to monitor a small portion of the communication during the initialization phase.
- Attacker can perform passive attacks during the initialization phase such as eavesdropping only.
- After the initialization phase, the attacker can become global and execute any attack, including a node capture.

Based on parameter settings, we could identify general classes of attackers.

The proposal

- Construct a unifying taxonomy of WSNs key management schemes.
  - Analysis of existing taxonomies.
  - Include the parameters of KMSs to the taxonomy.
  - Unification done probably by multi-dimensional or hierarchical taxonomy.
- Add a security model support and implement a representational subset of KMSs to the MiXiM simulator and TinyOS.
  - Review protocols during implementation.
  - Measure memory requirements of the protocols' infrastructure together with the stored keying material.
- Optionally introduce new KMSs for WSN.
- Add the attacker model support to the MiXiM simulator thus allowing to evaluate proposals from security point of view.
  - Generalize the definition of an attacker to WSN and define classes of common attackers to evaluate security of proposals against.

Are there any questions?

Thank you!

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