Source Location Privacy Considerations in WSNs

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Wireless Sensor Networks

- WSNs can be used in applications where sensors are unobtrusively embedded into systems, involving operations like:
  - Monitoring
  - Tracking
  - Detecting
  - Collecting
  - Reporting

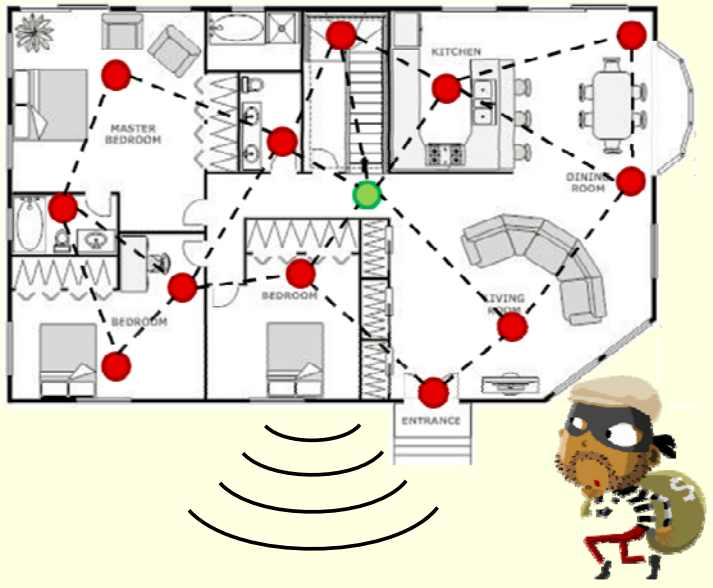



source: http://www.libelium.com

- WSNs enable the AmI paradigm

The Privacy Problem

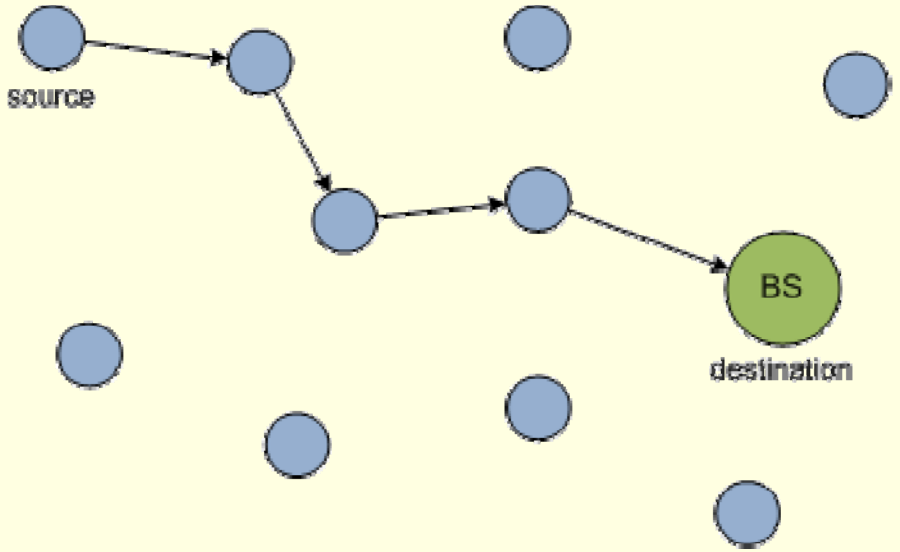
- The integration of WSNs will not only bring benefits but also serious privacy risks
- Simple observation of network traffic can reveal information about the network itself and the events being monitored, even if messages are cryptographically protected
- Home Sensor Network
  - Empty house
  - Appliances in use
  - Unethical in-house behaviour
  - ...



source: http://pleaserobme.com/

The Location Privacy Problem

- The path followed by messages expose both the source and destination
  - Source Location Privacy
  - Receiver Location Privacy



- Important since it gives the attacker the ability to determine where some events of interest to him are taking place

Talk Outline

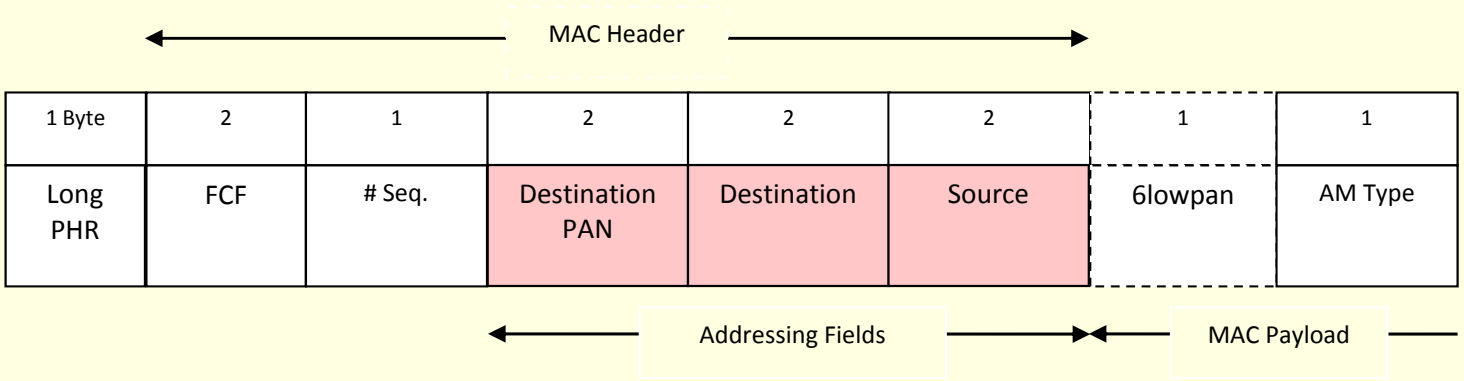
- Introduction

- Source Location Privacy
  - *Node Identity Protection*
  - Traffic Pattern Protection

- Conclusions

Nodes Identity Protection

- The first step is to hide nodes identities from being eavesdropped
- The adversary can create a map of the network
- Packet headers contain information in order to route the packets through the network



TinyOS 2.x MAC Header

Pseudonyms

- A pseudonym is a name or identifier that can be used instead of a real name
- Using fixed pseudonyms eventually provides no protection because the attacker relates a pseudonym to a node
- Several schemes have been proposed to create dynamic pseudonyms
  - Pool of pseudonyms (memory)
    - Simple Anonymity Scheme
  - Cryptographic schemes (computation)
    - Cryptographic Anonymity Scheme
    - Hashing-based ID Randomization (HIR) and Reverse HIR

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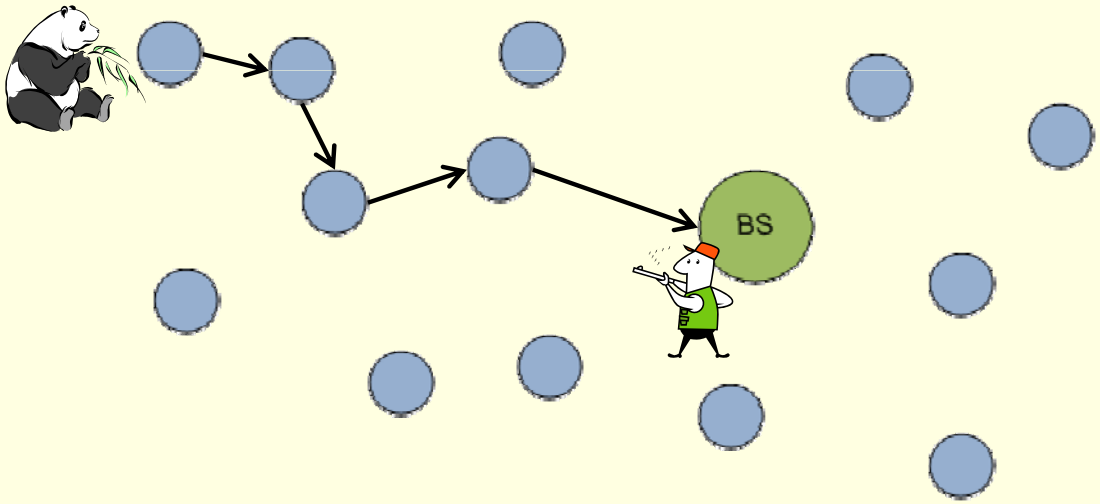
Traffic Pattern Protection

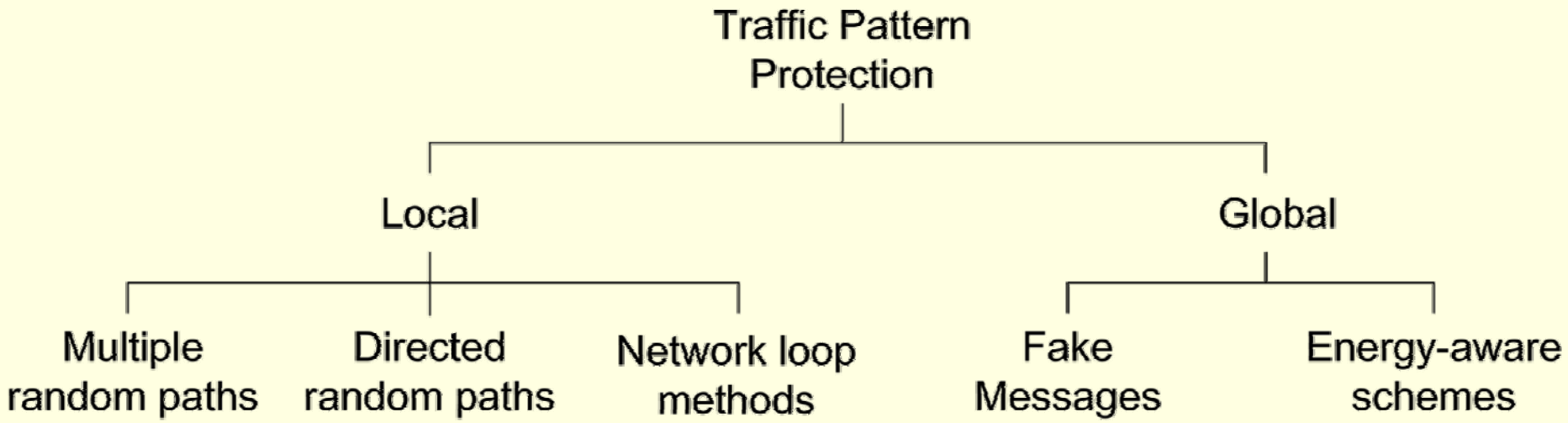
- A more skilled attacker can perform traffic analysis attacks to determine the location of source nodes
- Problem motivated by the ***Panda Hunter Game***:
  - Local adversary
  - Starting by the base station
  - Moves towards received packets



- The hunter finds the source because packets follow fixed paths

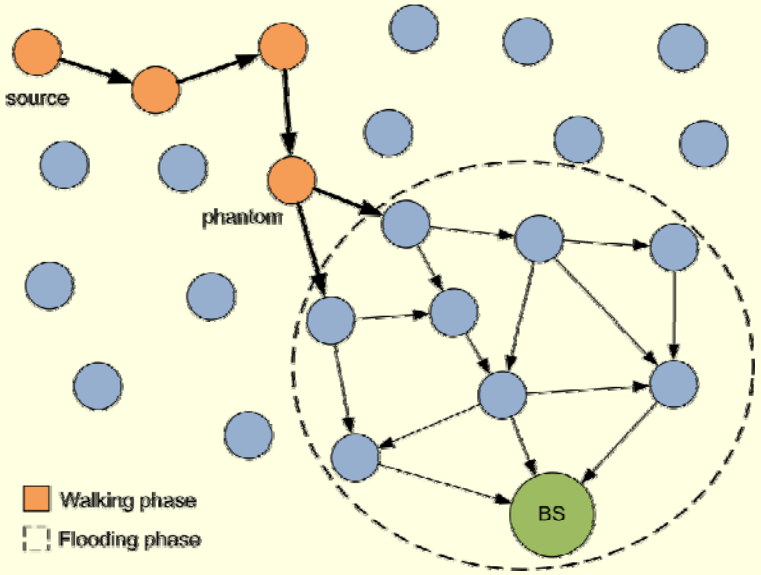
Traffic Analysis Countermeasures

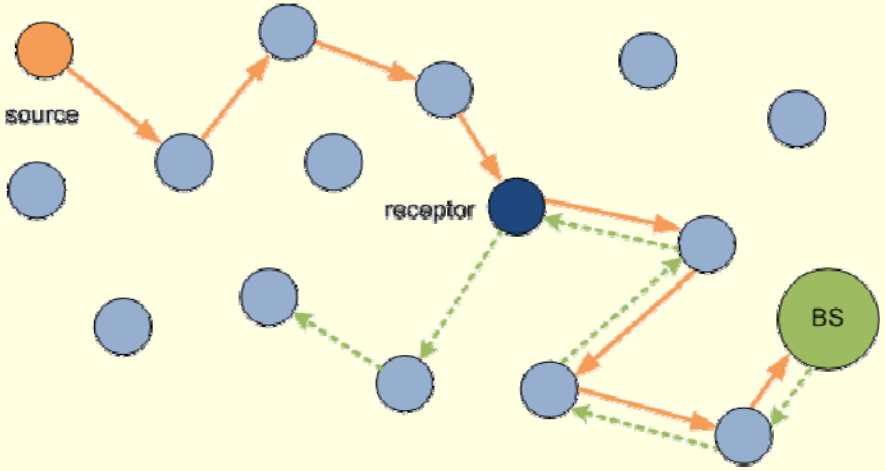
- We present and analyse a taxonomy of solutions based on the power of the adversary



Multiple Random Paths

- Mislead the adversary by using different routes for every message
  - Phantom Routing
  - Greedy Random Walk

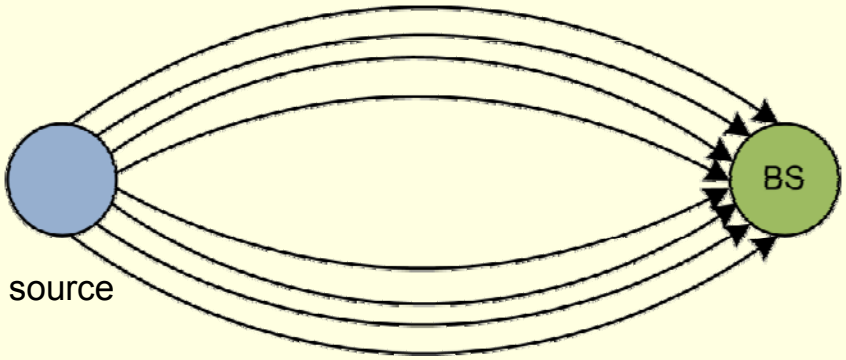




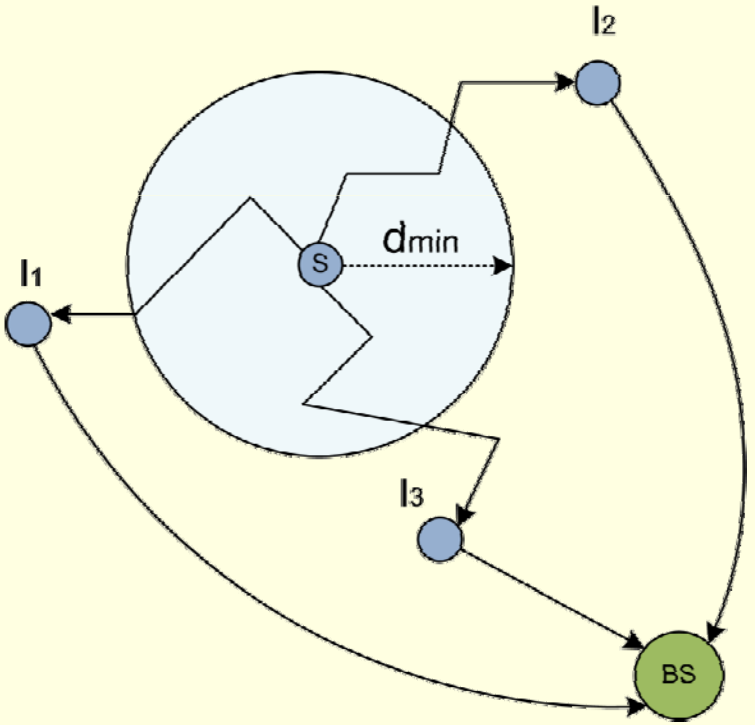
- Every packet follows a different path
- Receptors are away from source because it's greedy

Multiple Random Paths

- Random Parallel Routing



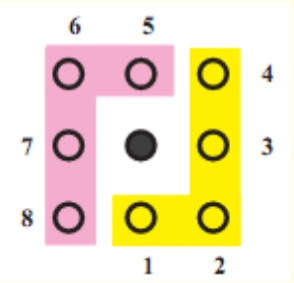
- Random Intermediate Node



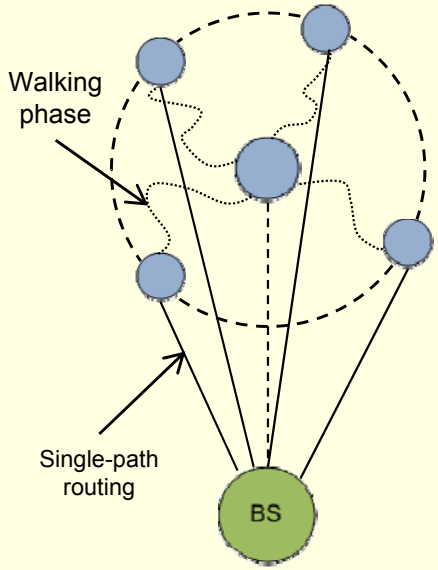
- Data packets are evenly distributed on each well-separated path
- Intermediate nodes are far away from the source

Directed Random Paths

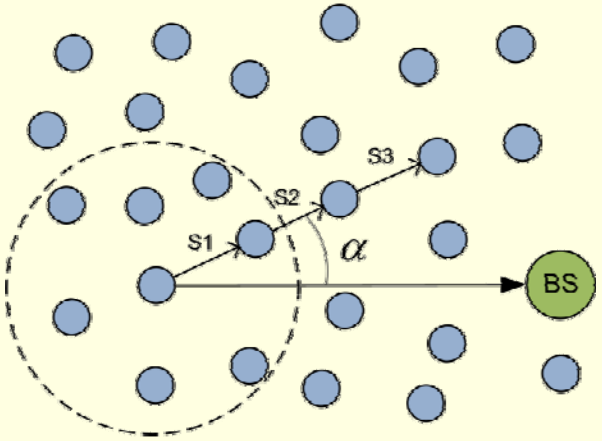
- Phantom Routing included directed random walks by separating neighbors in two groups



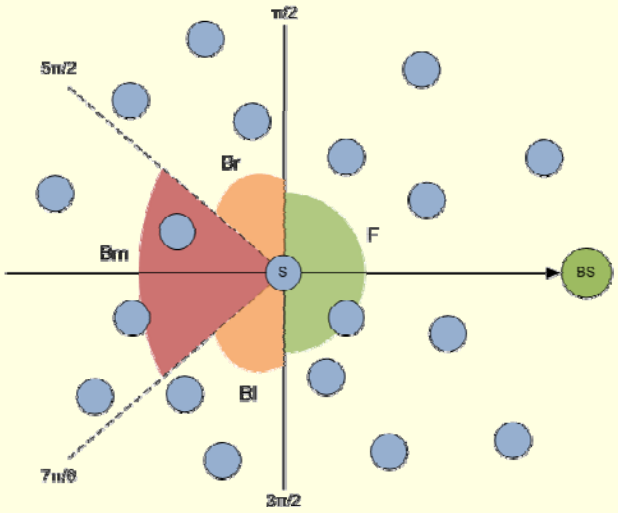
- The angle of arrival and the forwarding angle are typically used to direct random walks



PR with Location Angle



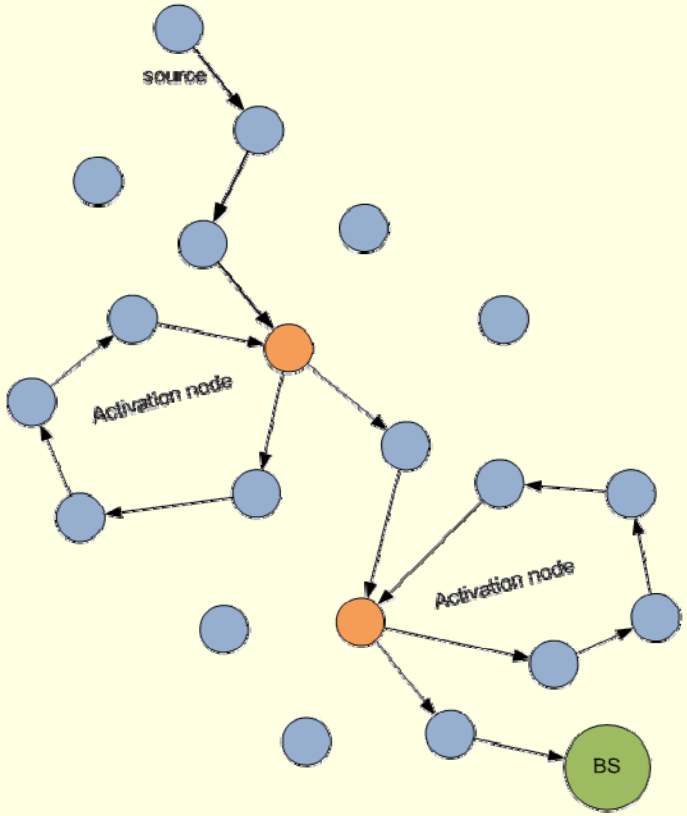
Weighted Random Stride



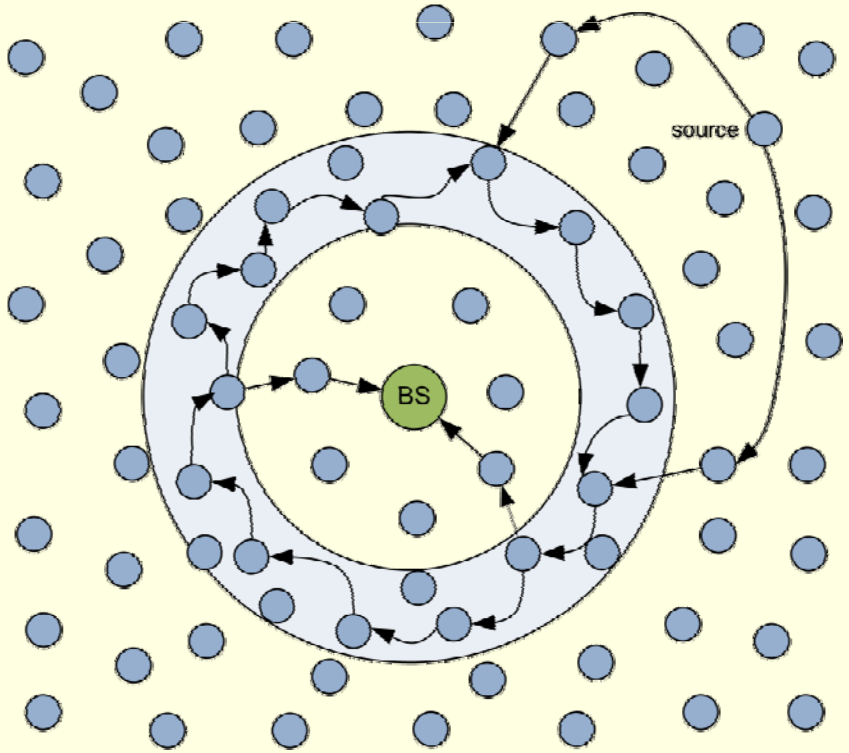
IRL (trustworthy routing)

Network Loop Methods

- The aim is either to trap the adversary into the loop or to mix packets making them indistinguishable



Cyclic Entrapment Method



Network Mixing Ring

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- Source Location Privacy
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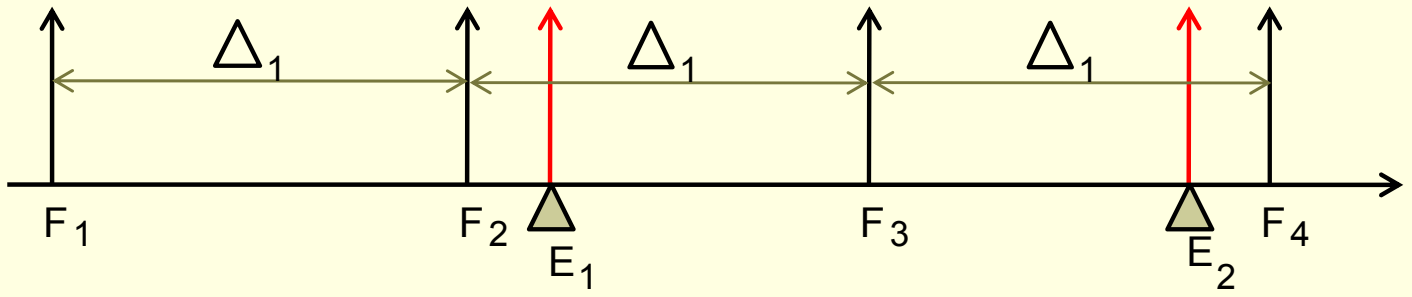
  - *Traffic Pattern Protection*
    - Local adversary
    - Global Adversary
- Conclusions

Fake Message Transmission

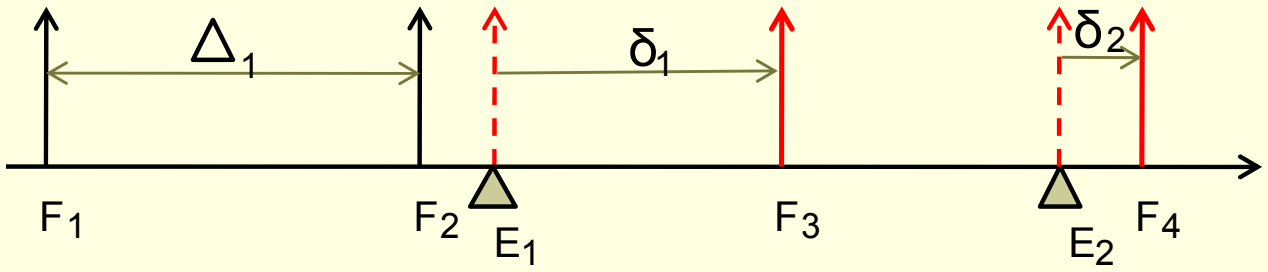
- Previous approaches are ineffective against global eavesdroppers since sensor nodes only transmit in the presence of real events
- Every node transmit fake messages (Fy) to hide the presence of real events (Ex)



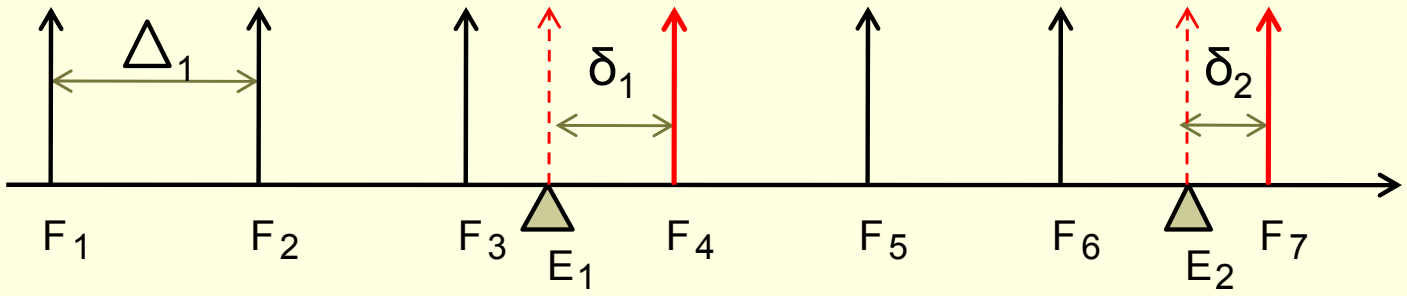
- However, this changes the message distribution!

Fake Message Transmission

- Periodic Collection delays (δ) real messages in order to follow the same distribution as fake messages
  - Incurs an excessive delay



- The delay can be reduced but this increments energy consumption



Energy-Aware Approaches

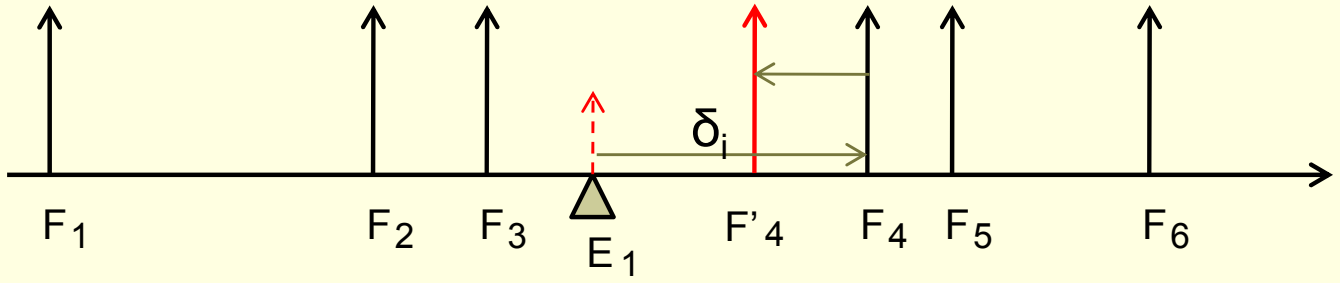
- The goal is to provide an adequate privacy level while saving energy and not introducing an excessive delay

- Different solutions
  - *Source simulation*: nodes simulate the behaviour of moving objects in the field
  - *Traffic filtering*: in PFS and TFS proxy nodes strategically placed filter out fake traffic
  - Using already *existing traffic*: messages are hidden within beacons
  - *Statistical approaches*: move forward real messages without modifying the message distribution

Statistical Approaches

- Fake messages are transmitted according to a probability distribution (F_X) within a sliding window

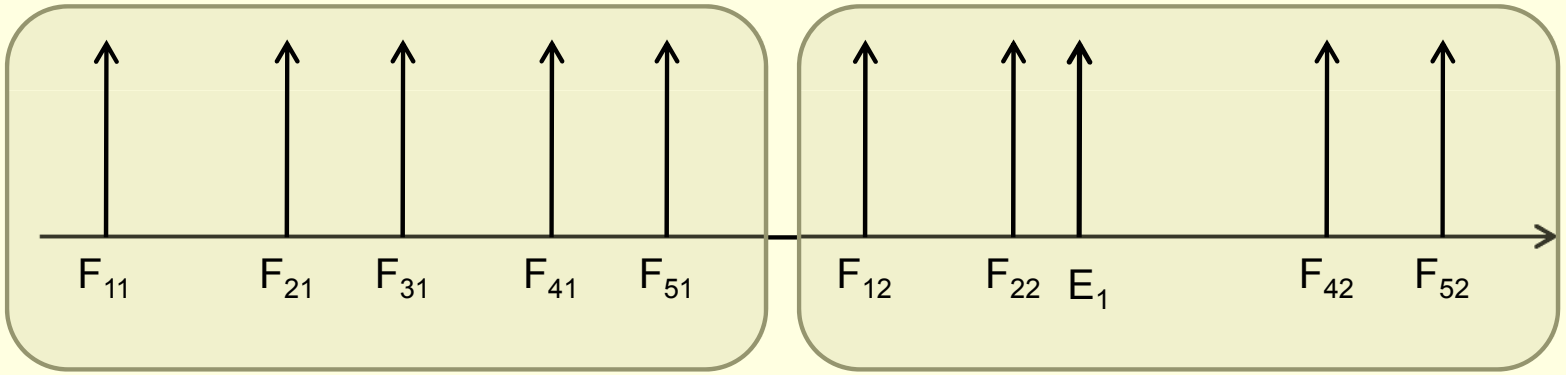
- Real events are transmitted a.s.a.p (F'_4) so that the probability distribution is unaltered



- The attacker gains no information by performing a statistical test

Statistical Approaches

- However, a more skilled attacker could spot differences between two sliding windows



- In the presence of real events, next transmissions are delayed
  - By counting the number of short-long inter-delays an attacker can distinguish intervals containing real events

- Solution is to design fake intervals to resemble real intervals as much as possible

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Conclusions

- We have proposed and discussed a taxonomy of solutions to a *single* privacy problem
  - Local Adversaries → Routing-based approaches
  - Global adversaries → Fake message transmissions

- Privacy preservation is challenging in WSNs because of the extreme limitation of nodes. Solutions must trade-off between the protection level and the cost associated

- New scenarios, adversarial models and solutions are expected to appear with the full integration of WSNs and the Internet

Thanks for your attention!

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