Dependable k-coverage algorithms for sensor networks

Gyula SIMON
Miklós MOLNAR
Laszló GÖNCZY
Bernard COUSIN

TEU of Budapest
IRISA/ France

Outline

- Cooperation project BALATON
- Project goals: dependable web services based on dependable networking
- Dependable measurement: k-coverage
- Problem of sensor powers
- Related works
- Scheduling proposition based on a drowsiness factor
  - Centralized and distributed versions
- Perspectives
**Cooperation project BALATON**

- Intergovernmental cooperation
- Limited budget
  - Two short missions per year in each country
- Partners: Department of Measurement and Information Theory
  - Measurement, Web services, formal methods
  - Dependable systems, computing
  - MITMOT plate-form

---

**Dependable k-coverage algorithms for sensor networks**

**Project goals: dependable web services based on dependable networking**

“Dependable web service architectures for real time applications in intelligent networks”

- Dependable Web service architectures based on SN
- UML models (design patterns)
- Dependable communication, routing
- Pilot application
Dependable k-coverage algorithms for sensor networks

Sensor networks
- Ad hoc networks without infrastructure
- Sensors and actors
- Mobiles or not
- Collect of data
- Services
- Control

Dependable measurement: k-coverage
- some technologies and the dependable aspect need multiple observations / measurement of a same value.
Dependable k-coverage algorithms for sensor networks

- Dependable measurement: k-coverage
- Problem of sensor powers
  - Sensors are dotted with autonomous batteries
    - Lifetime ~ 48 h
  - Measurement and communication consume power
- Idea
  - Put a lot of sensors in the area (over-dimensioning)
  - Alternate awake and doze states (turn off certain sensors)
- Constraints:
  - k-coverage
  - Power

Related works

- Ronny Krashinsky and Hari Balakrishnan. Minimizing energy for wireless web access with bounded slowdown, MobiCom '02
- Lawrence S. Brakmo, Deborah A. Wallach and Marc A. Viredaz. Sleep: a technique for reducing energy consumption in handheld devices, MobiSys '04
- Chih-fan Hsin and Mingyan Liu. Network coverage using low duty-cycled sensors: random & coordinated sleep algorithms, IPSN'04
- Santosh Kumar, Ten H. Lai and Jozsef Balogh, On k-coverage in a mostly sleeping sensor network, MobiCom '04
**Dependable k-coverage algorithms for sensor networks**

### Related works

**Random scheduling**
- Each sensor decides to go to sleep with probability $p = \frac{k}{m}$
- Lifetime is prolonged with $\frac{m}{k}$
- Without communication cost
- Does not guarantee the k-coverage

**Coordinated sleeping**
- k-coverage is assumed
- Important communication between nodes and election of sleeping sensors

---

**Dependable k-coverage algorithms for sensor networks**

### Scheduling proposition based on a drowsiness factor

- Graph of dependences: bipartite graph

- **Coverage ration of a region:**
  $$\Phi_r = \begin{cases} 
  \frac{1}{c_r - K} & \text{if } c_r > K \\
  -1 & \text{otherwise}
  \end{cases}$$

- **Drowsiness factor of a sensor:**
  $$D_s = \frac{1}{E_s} \sum_{r \in R} \Phi_r \delta(r, s)$$

---
Dependable k-coverage algorithms for sensor networks

- Scheduling proposition based on a drowsiness factor
  - Centralized version
    1. Run the network for a period of T
    2. Wake up all sensors which should send state information
    3. Calculate drowsiness factor for each node.
    4. Select the node with the largest positive drowsiness factor. Send this node to sleep if it is possible (k-coverage).
    5. Repeat Steps 3-4 while possible (i.e. there is at least one node with positive drowsiness factor).
  - Note: if a sensor does not receive a go to sleep message, it remains the active state

Dependable k-coverage algorithms for sensor networks

- Scheduling proposition based on a drowsiness factor
  - Distributed versions
    1. Run the network for a period of T
    2. Wake up all sensors and broadcast its state locally
    3. If the time out Td1 arrives, calculate drowsiness factor and broadcast it in the neighborhood (the same if there is changes)
    4. If a message is received, store the received drowsiness f.
    5. If the time out Td2 arrives go to 6, else go to 4
    6. If the node is the node with the largest positive drowsiness factor, make the decision and broadcast the local decision (eventually, go to sleep).
    7. If a message is received recompute the factor and broadcast it if necessary and go to 6.
    8. If the time out Td3 arrives, make the final decision
Some results

The performance of the random (a) and the proposed centralized (b) algorithms for a randomly distributed sensor network containing 100 nodes.

Perspectives

- Improvement and performance analysis
  - Region tail
  - Robustness and security
- Routing solution
  - In-cast tree
  - Direct diffusion
  - Clustering
  - Fault tolerance, protection
- Web services
  - Heterogeneous network
  - Reactive or proactive measurement
  - QoS parameters
- Implementation MITMOT