Implementation of Controlled Sink Mobility Strategies with a Gradient Field in Wireless Sensor Networks

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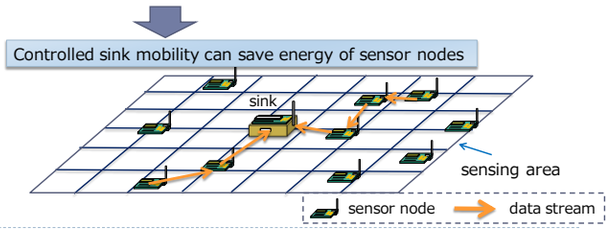
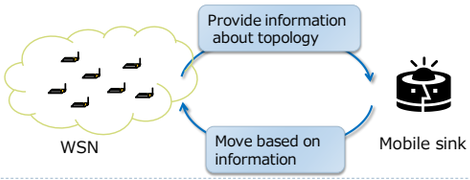
Research background

- Wireless sensor networks (WSN)
  - Consist of radio devices with sensors (sensor nodes)
    - Sensor nodes deliver data to one of sinks in a multi-hop manner
  - Require prolonging network lifetime
    - Sensor nodes are desired to save energy



Controlled mobility

- Mobile node's mobility is dynamically controlled by received information from inside or outside of networks
  - Prolonging network lifetime
    - A mobile sink takes over energy consumption of sensor nodes
  - Improving network coverage
    - A mobile sink relay packets from one network to another



Motivation of our research

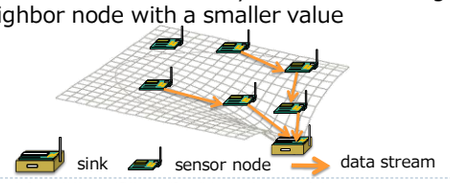
- Realizing GPS-free control for indoor environment
  - Existing controlled mobility strategy is based on GPS
  - GPS-based localization solutions cannot provide reliable location estimate in indoor environments

Motivation: Realizing controlling the mobility of a mobile sink so that it approaches an arbitrary sensor node as a elemental technology of controlled mobility

- Instead of GPS, we use a gradient field which is originally constructed for routing
  - Flexible for a network change

Gradient-based routing

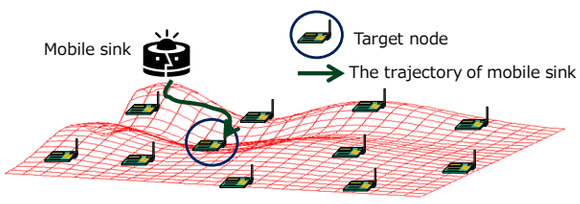
- A highly scalable, robust, and load balancing routing protocol based on gradient field in WSN[1]
- To construct a gradient field
  - Sinks have the minimum value
  - Sensor nodes with smaller hop-count to a sink have a smaller value obtained by local message exchange
- Data can reach one of sinks by node's forwarding it to a neighbor node with a smaller value



[1] D. Kominami, M. Sugano, M. Murata and T. Hatauchi, "Controlled potential-based routing for large-scale wireless sensor networks," in Proc. of ACM MSWiM, pp. 187-196, June. 2011.

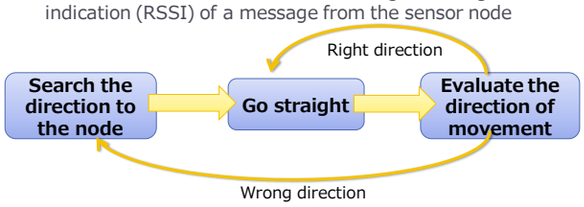
Key idea

1. Target node sets up a gradient field
   - Target node floods a control message, and each node records a hop count from the target node
2. A mobile sink moves toward the node with smaller gradient like a data flow in gradient-based routing



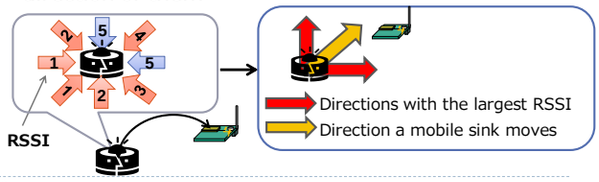
Overview of mobility control

1. A mobile sink intercepts gradient exchanged in a network
   - A mobile sink records the smallest gradient to approach a sensor node with smaller gradient
2. A mobile sink moves to approach the sender node
   - A mobile sink measures the received signal strength indication (RSSI) of a message from the sensor node



Search the direction to the node

1. A mobile sink rotates and measures RSSIs of N directions
2. A mobile sink records the direction with the largest RSSI and the smallest gradient
3. When multiple directions with the largest RSSI exist, a mobile sink records the composite direction of them

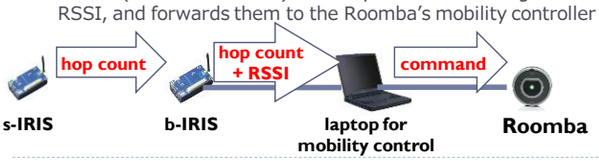


Evaluate the direction of movement

- A mobile sink may happen to go to the wrong direction
  - noise, radio interference
- Using the exponential moving average (EMA) of RSSI to revise the direction of movement of a mobile sink
  - If EMA of RSSI increases, a mobile sink goes straight
  - Otherwise, a mobile sink searches the direction to the node

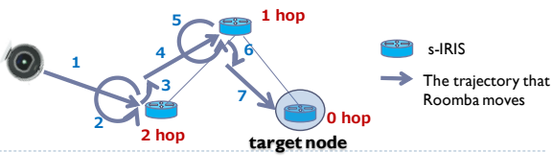
Implementation of controlled mobility

- Used devices
  - Mobile entity: Roomba 790 (iRobot Corp.)
  - Sensor nodes: IRIS Mote XM2100 (Crossbow Technology)
  - Mobility controller: laptop computer (Let's Note CF-S9)
- Two types of IRIS with different function
  - s-IRIS (sensing IRIS): generates sensing data and constructs the gradient field
  - b-IRIS (base station IRIS): intercepts control messages and RSSI, and forwards them to the Roomba's mobility controller



Overview of controlled mobility

1. Roomba moves based on its original mobility algorithm
2. When b-IRIS receives a control message, Roomba starts to approach the sender node
   1. When b-IRIS receives control message contained smaller gradient, Roomba approaches the sender node
   2. Roomba turns 360 degrees to search the direction with the largest RSSIs
   3. Roomba turns to the recorded direction and goes straight



Experiment settings

- Node deployment
  - 12m × 8m square domain (indoor room)
  - 6 sensor nodes are deployed
    - 1 node of them is a target node
- Evaluation metric
  - The time required for the mobile sink to approach and to receive a control message from the target node

Radio frequency	2.4 GHz
Control message rate	1 packet/s
Mobile sink velocity	1 m/s
Mobile sink angular velocity	$\frac{\pi}{7}$ rad/s

Experiment image

Experimental evaluation

- The Roomba reaches and communicates with the target nodes in about 6 minutes

	Time for appraoch and communication
With controlled mobility	371.12 ± 93.3 s

Conclusion and future work

- We propose a method of controlled mobility using a gradient field
  - the proposed method saves the time required for a mobile sink to approach a target node
- The case multiple networks or multiple mobile sinks exist is not taken into consideration
  - evaluate whether a mobile sink can approach all the target nodes by rotation when multiple target nodes exist