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Selection and Navigation of Mobile Sensor Nodes

Seminar: Ad Hoc Networks

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Overview

1. **Motivation**
2. **Introduction**
   - Hybrid Sensor Networks
   - Problem Formulation
3. **Selection**
   - Weight Request Packet
   - Weight Computation
4. **Navigation**
   - Credit Based Navigation Field
   - Navigating of MSN
5. **Review**
   - Simulation results
   - Application fields
   - Conclusion

1. Motivation

- **Ad-hoc networks**
  - Static and mobile sensor nodes ⇨ dynamic topology
  - Wireless
  - No base stations
- **Tasks:**
  - Environmental sensing,
  - Communication, computation, …
- **Conditions:**
  - Robustness, flexibility,
  - System costs, energy consumption, …
- **Problem:** Find approaches with suitable tradeoffs between such conditions

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2. Introduction: Hybrid Sensor Networks

- How does the network structure look like? What are the assumptions to it?

Hybrid Sensor Network

- **Static Sensor Nodes**
  - Static environmental sensing
  - Communication and navigation capabilities
  - Fewer resources
    (e.g. power, sensor, computation)
  - Cheap
    ⇨ good coverage
- **Mobile Sensor Nodes**

Hybrid Sensor Network

- **Static Sensor Nodes**
  - Static environmental sensing
  - Communication and navigation capabilities
  - Fewer resources
    (e.g. power, sensor, computation)
  - Cheap
    ⇨ good coverage
- **Mobile Sensor Nodes**
  - Reallocation of resources
    (e.g. sensing, networking, computing)
  - Collect data
  - More resources
    (e.g. power, sensors, computation)
  - Expensive

Hybrid Sensor Network (2)

- **Advantages of a mixture**
  - Reduces the costs
  - Preserves the flexibility
  - Remain powerful

- **Assumptions:**
  - No prior map of environment available
  - Location of Mobile Sensor Nodes (MSN) not known
  - Only sensors within transmission range can communicate

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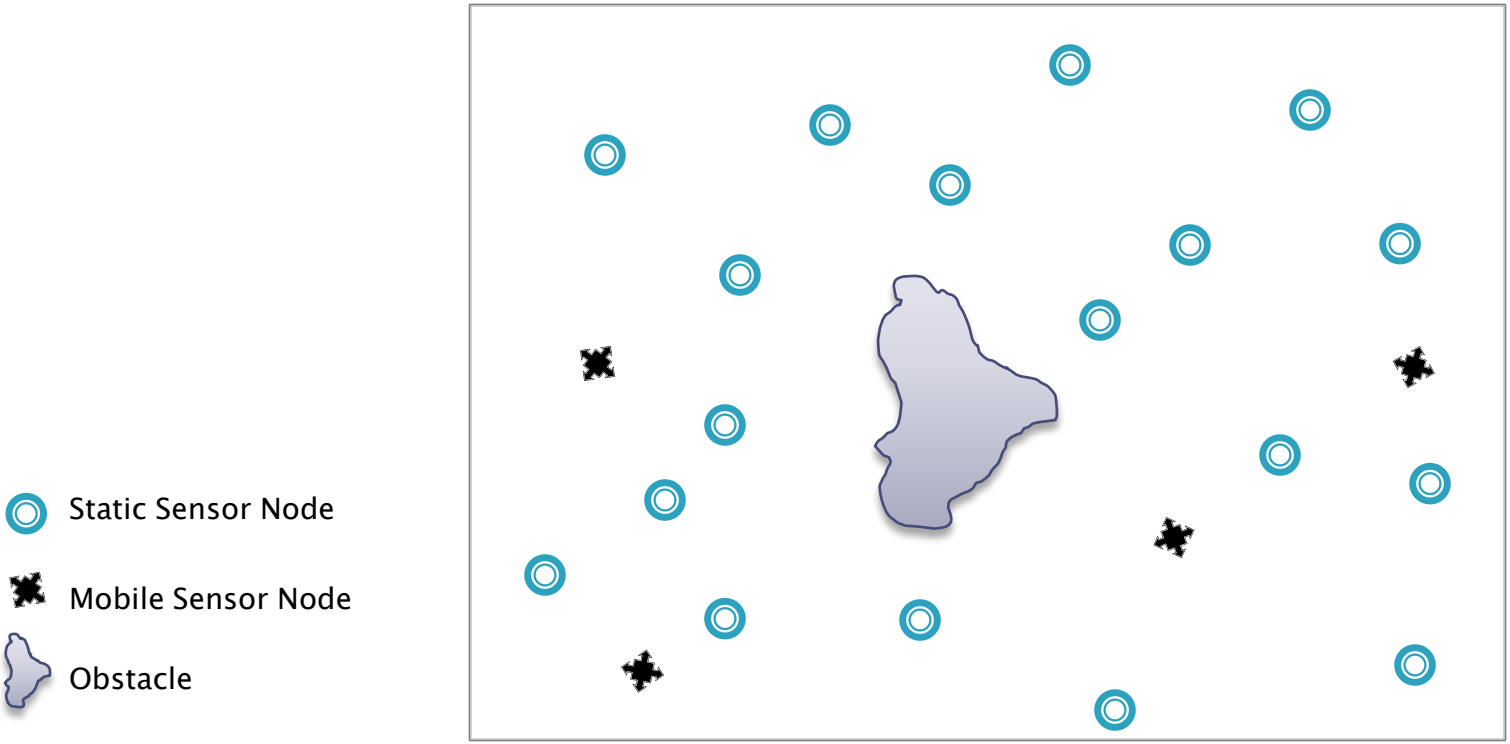
2. Introduction: Problem Formulation

- What are the objectives?

Co-operative Tasks

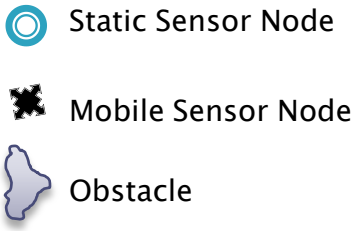
- **Main Task**
  - Environmental sensing
- **Problem**
  - Static Sensor Node detect an event (⇨ *phenomenon*)
  - Additional or more powerful capabilities are needed
- **Idea:** Mobile Sensor Nodes can be moved to provide assistance
- **Goals:**
  1. **Select** mobile node
  2. **Navigate** selected mobile node to point of event

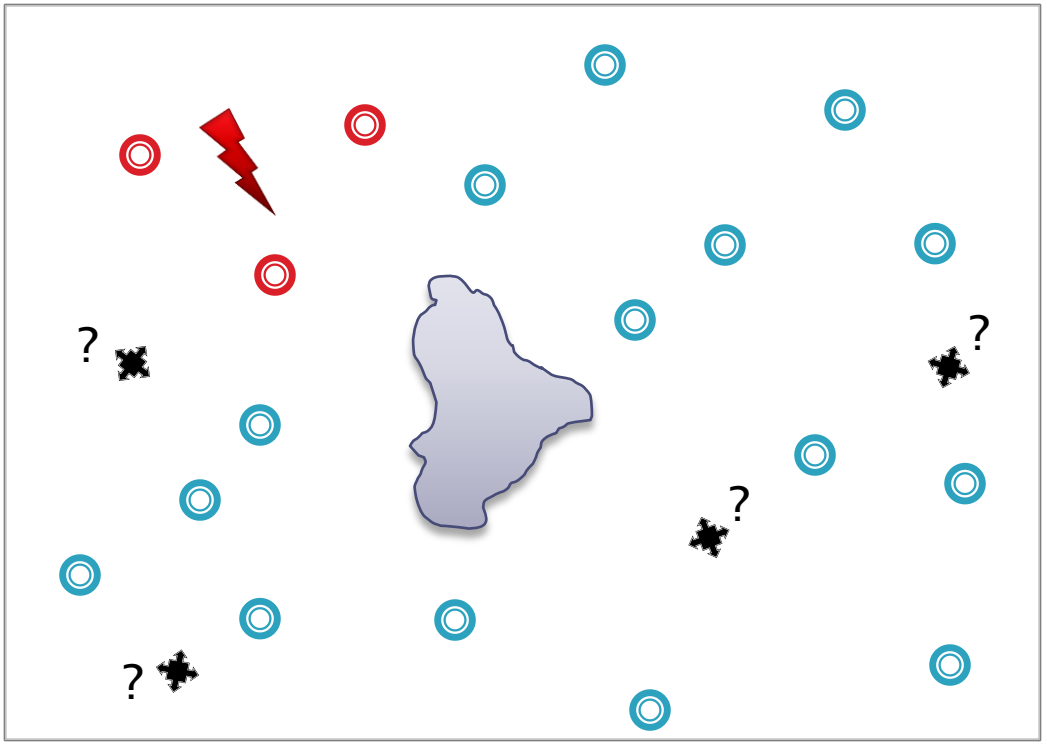
Example – Network



Hybrid Sensor Network [1]

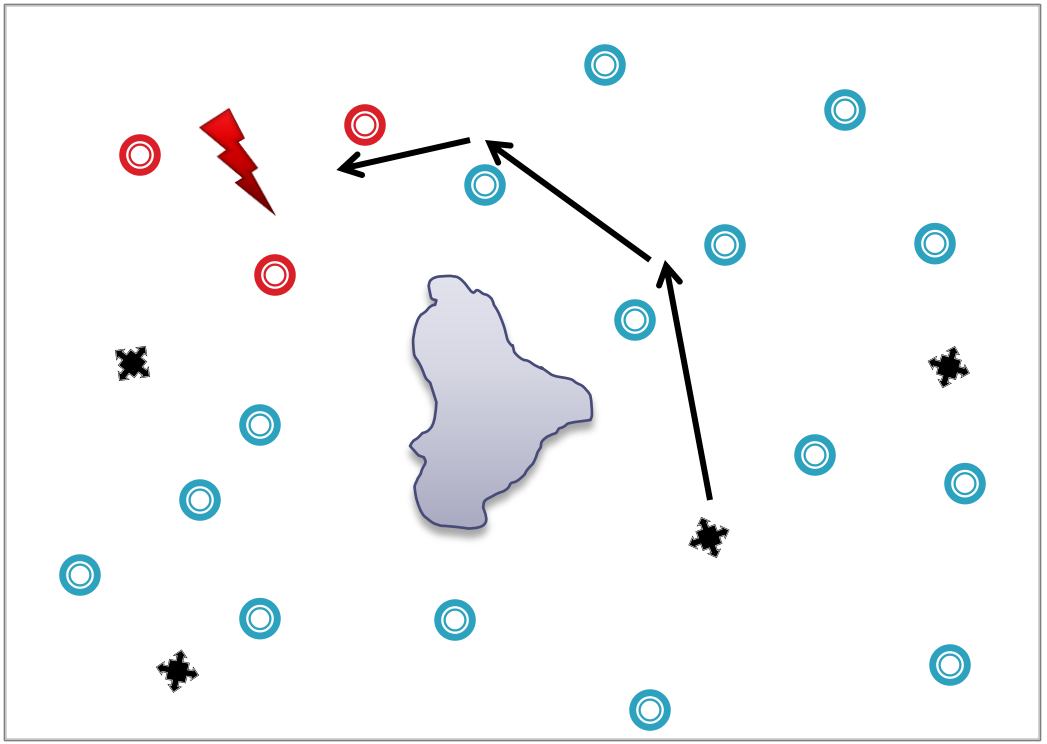
Example – Selection





Hybrid Sensor Network [1]

Example – Navigation



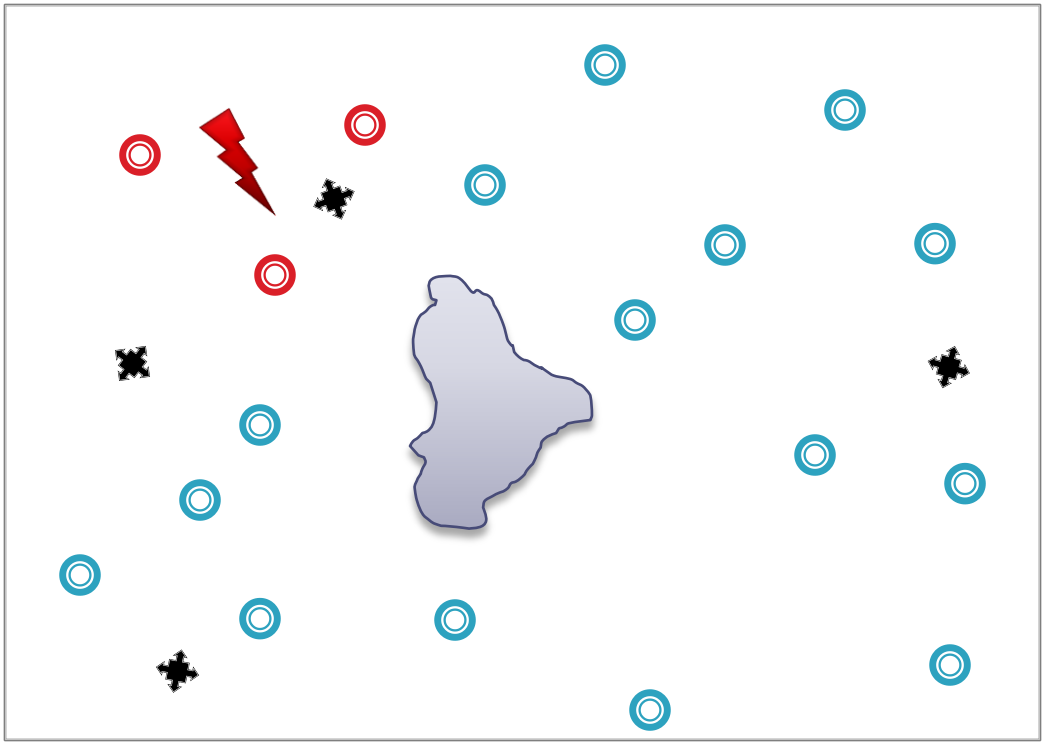
Hybrid Sensor Network [1]

Static Sensor Node

Mobile Sensor Node

Obstacle

Example – Navigation (2)



Static Sensor Node

Mobile Sensor Node

Obstacle

Hybrid Sensor Network [1]

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3. Selection

- Which mobile node should be selected?

How to involve every MSN?

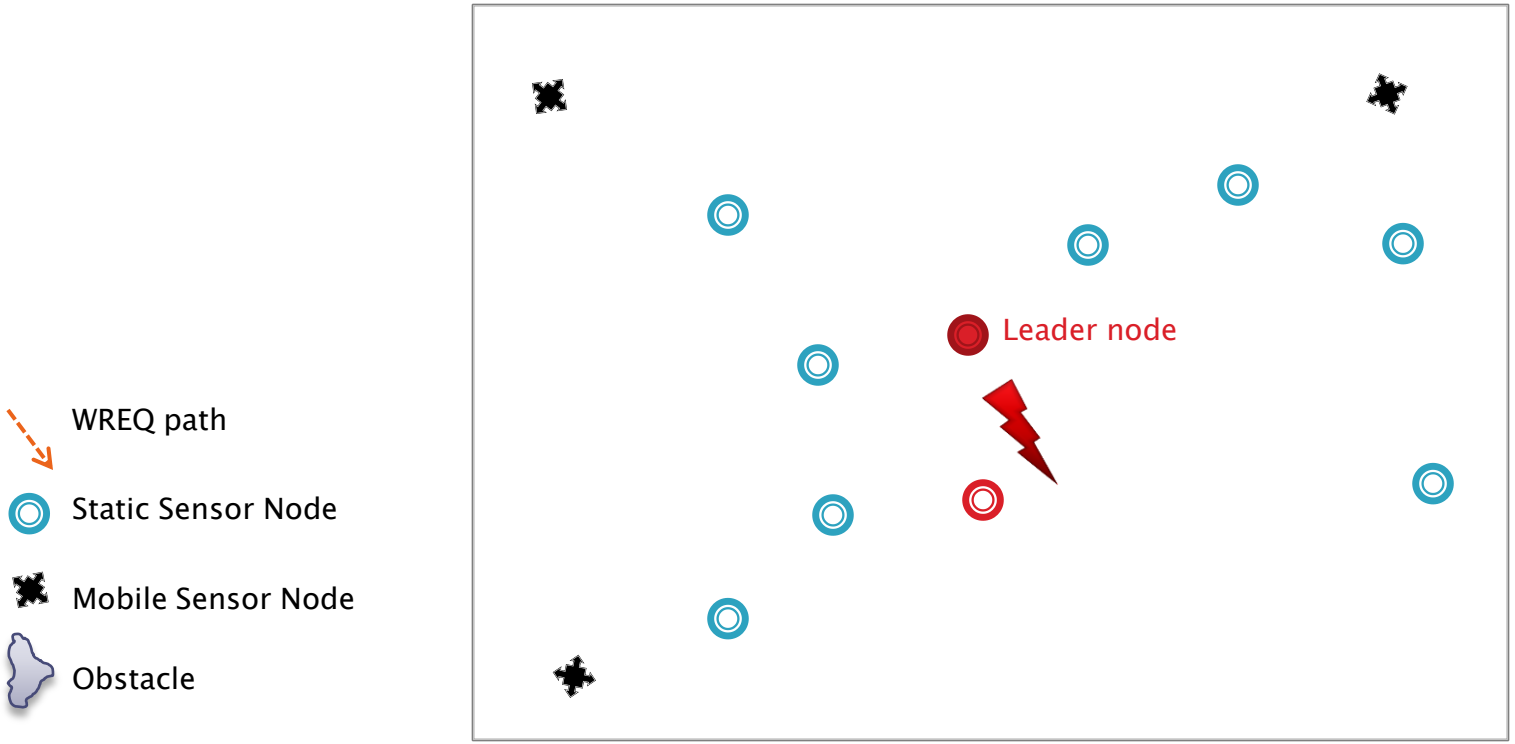
- Assumptions (*repetition*):
  - No prior map of environment available
  - Location of Mobile Sensor Nodes (MSN) not known
  - Sensors within transmission range can communicate

- **Idea:** Broadcast a request

The Selecting Procedure

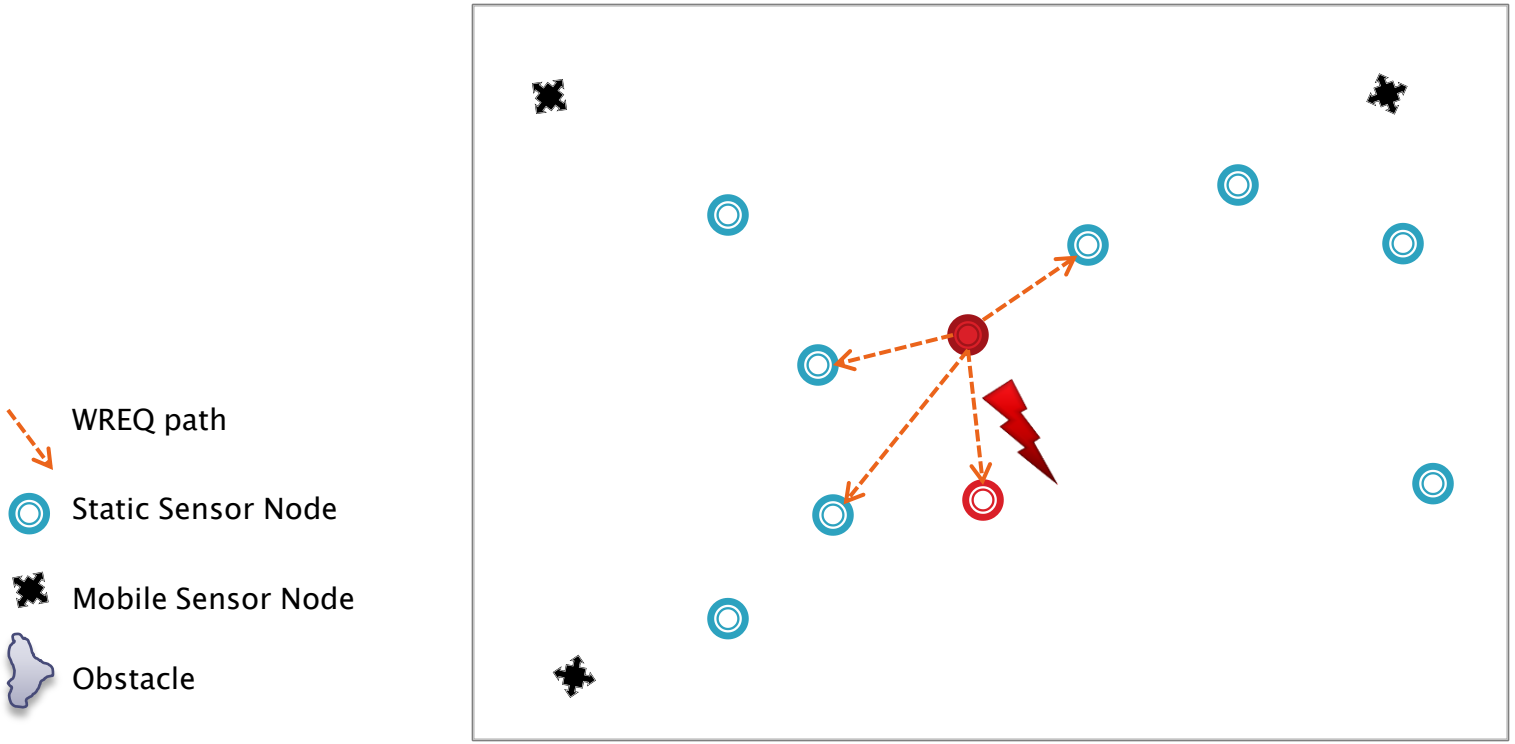
1. Sensors detect an event and elect a leader
2. Leader broadcasts a Weight Request Packet (WREQ) into network
3. Every reached available MSN computes his weight value (*later*)
4. MSNs reply the weight back by reversing the WREQ routes
5. Leader selects the MSN with the least weight

Example – WREQ



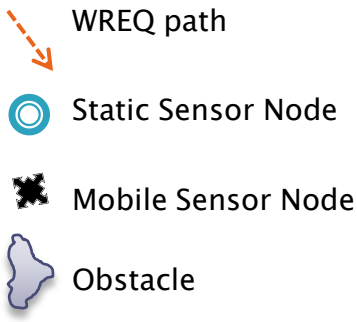
Hybrid Sensor Network [1]

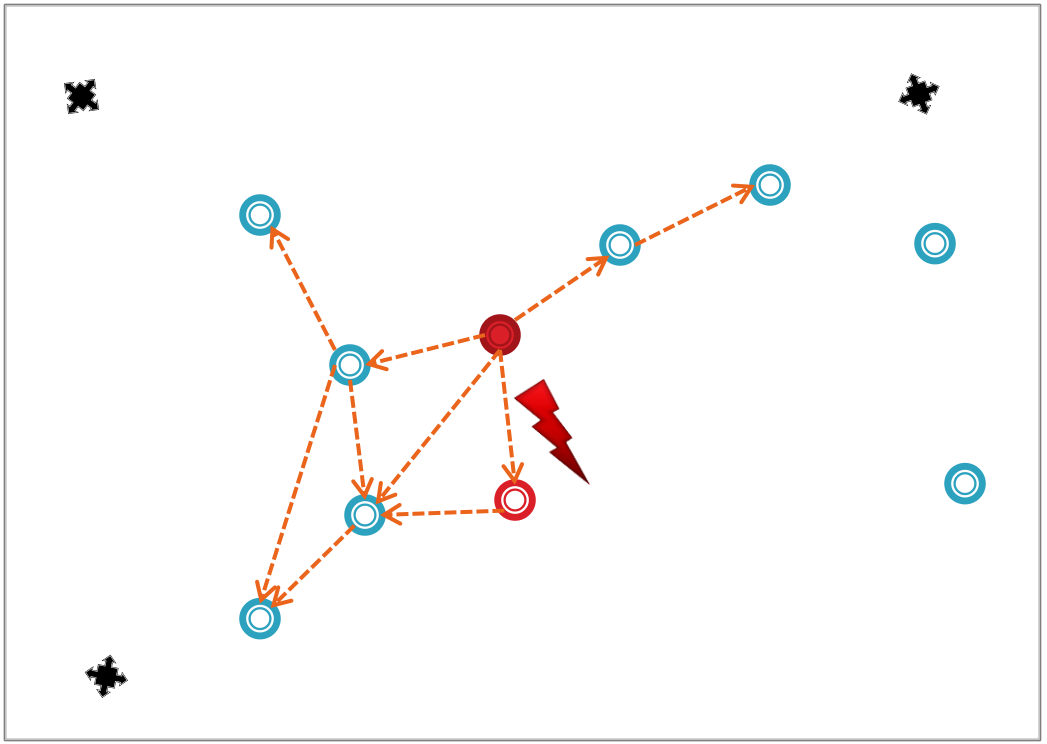
Example – WREQ (2)



Hybrid Sensor Network [1]

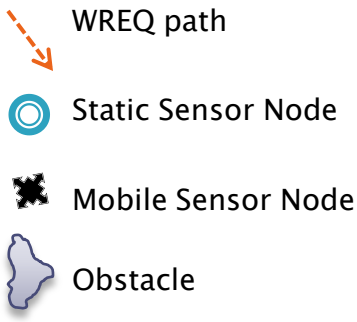
Example – WREQ (3)

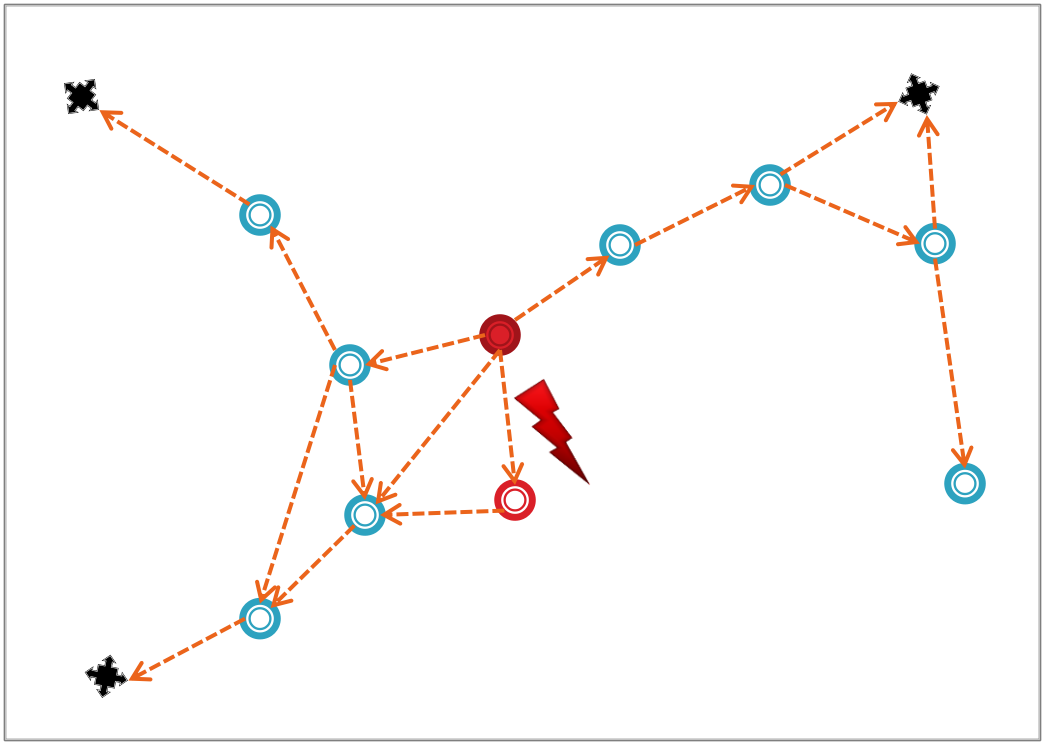




Hybrid Sensor Network [1]

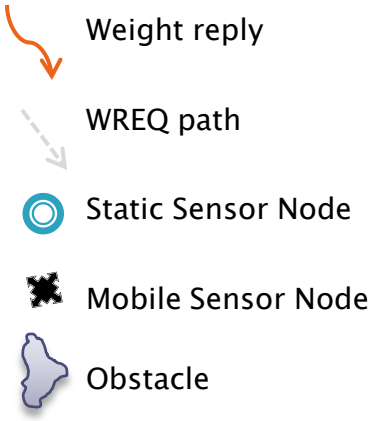
Example – WREQ (4)

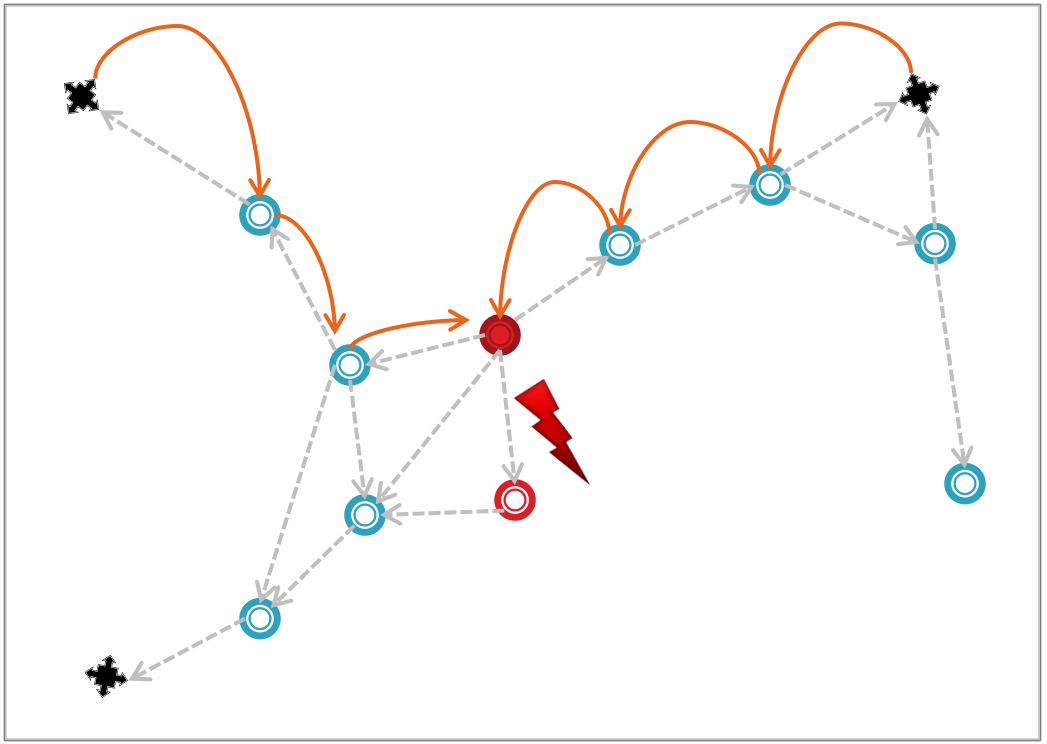




Hybrid Sensor Network [1]

Example – WREQ (5)





Hybrid Sensor Network [1]

How to compute the weight?

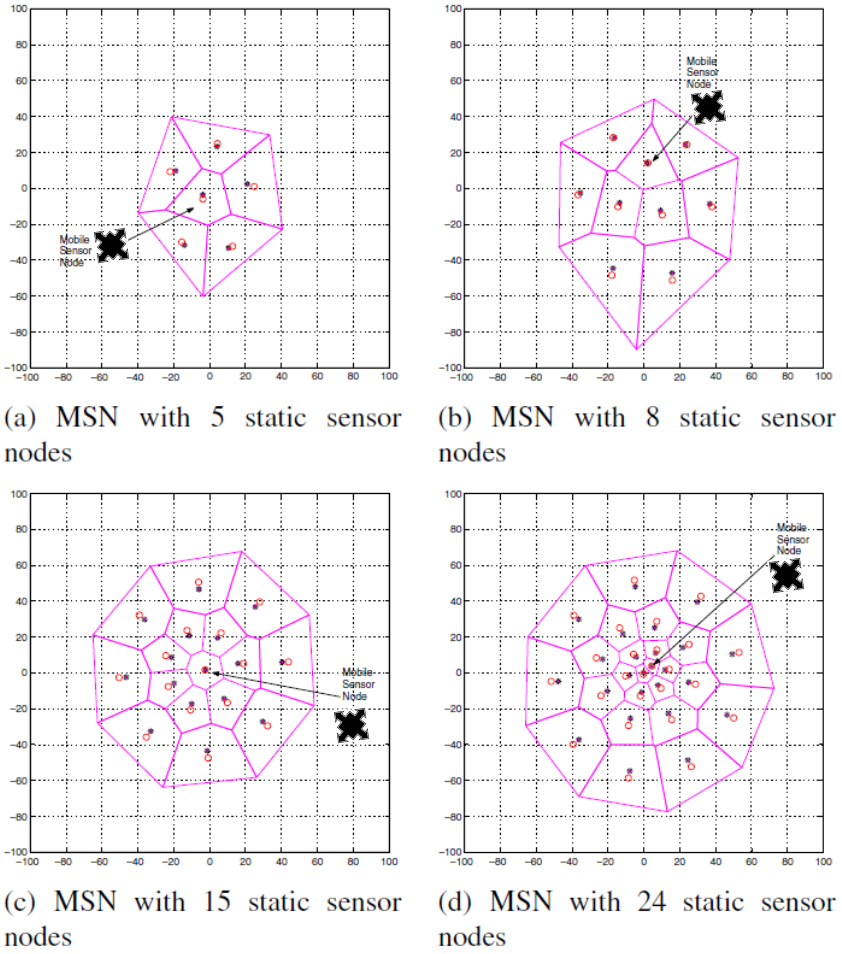
- **Three metrics are evaluated by MSNs:**
  - Power of the MSN ⇨ battery lifetime
  - Distance between MSN and event ⇨ # hops
  - Provided coverage area by MSN ⇨ Voronoi Area

$$\text{Weight} = \frac{\text{Voronoi\_Area} \times \text{Distance}}{\text{Power}}$$

How to compute the weight? (2)

- **Computing Voronoi Area**

1. MSN broadcasts “Hello” messages with hop length
2. Recipients reply with location information (x,y)
3. MSN calculates Voronoi Area



(a) MSN with 5 static sensor nodes

(b) MSN with 8 static sensor nodes

(c) MSN with 15 static sensor nodes

(d) MSN with 24 static sensor nodes

Voronoi Area for a MSN [1]

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4. Navigation

- How to guide a mobile node to an event?

How to navigate a mobile node?

- **Tasks:**
  - Selected mobile nodes should be guided to the point of event
  - Obstacles should be avoided
  - The moving distance should be as short as possible
- **Assumption:**
  - The request packets form WREQ followed the shortest path
- Idea: Build a path along the WREQ route

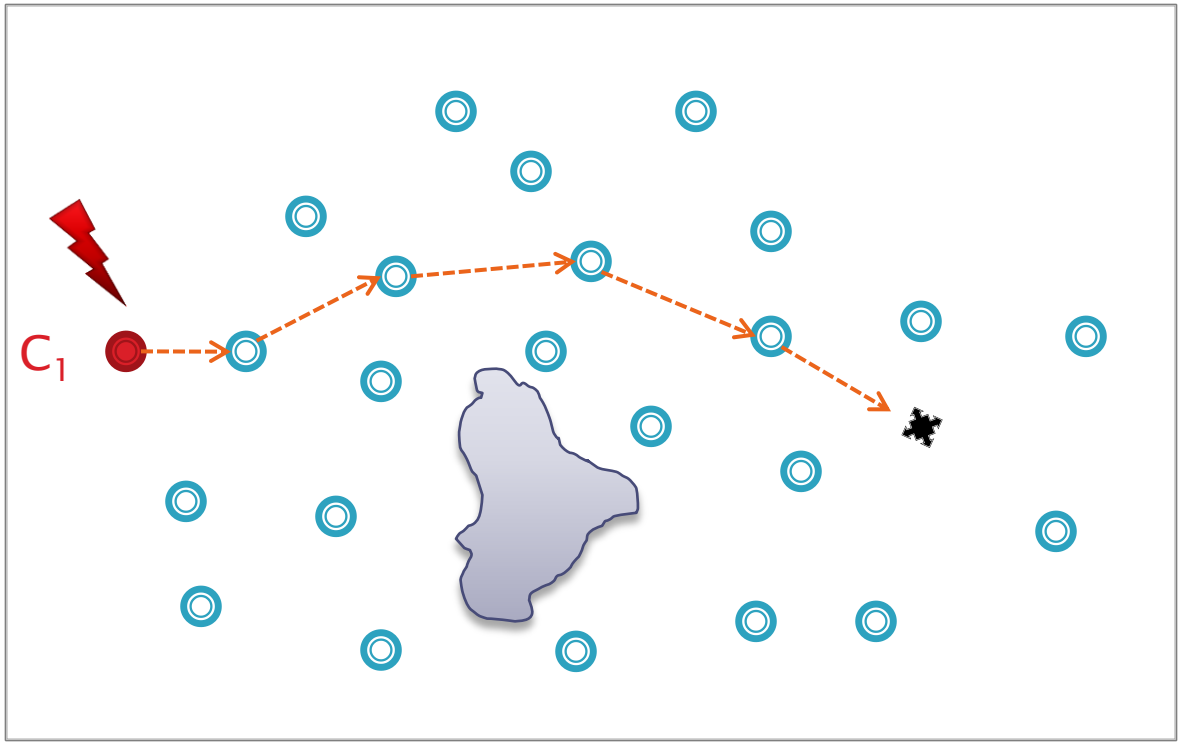
Building up a Navigation Field

- Build a credit based navigation field from leader to selected mobile node

1. Leader node's credit value C_1 is set as highest
2. This node broadcasts an advertisement packet (ADV) with C_1
3. Recipient nodes set their credit value C_2 such that $C_2 < C_1$
4. From all recipients only nodes from WREQ route proceed broadcasting according to the leader node
5. Process continues creating this credit hierarchy till ADV packet reaches the MSN

Example – Navigation Field

Leader node's credit value C_1 is set as highest



Credit Navigation Field [1]

Shortest WREQ path

Static Sensor Node

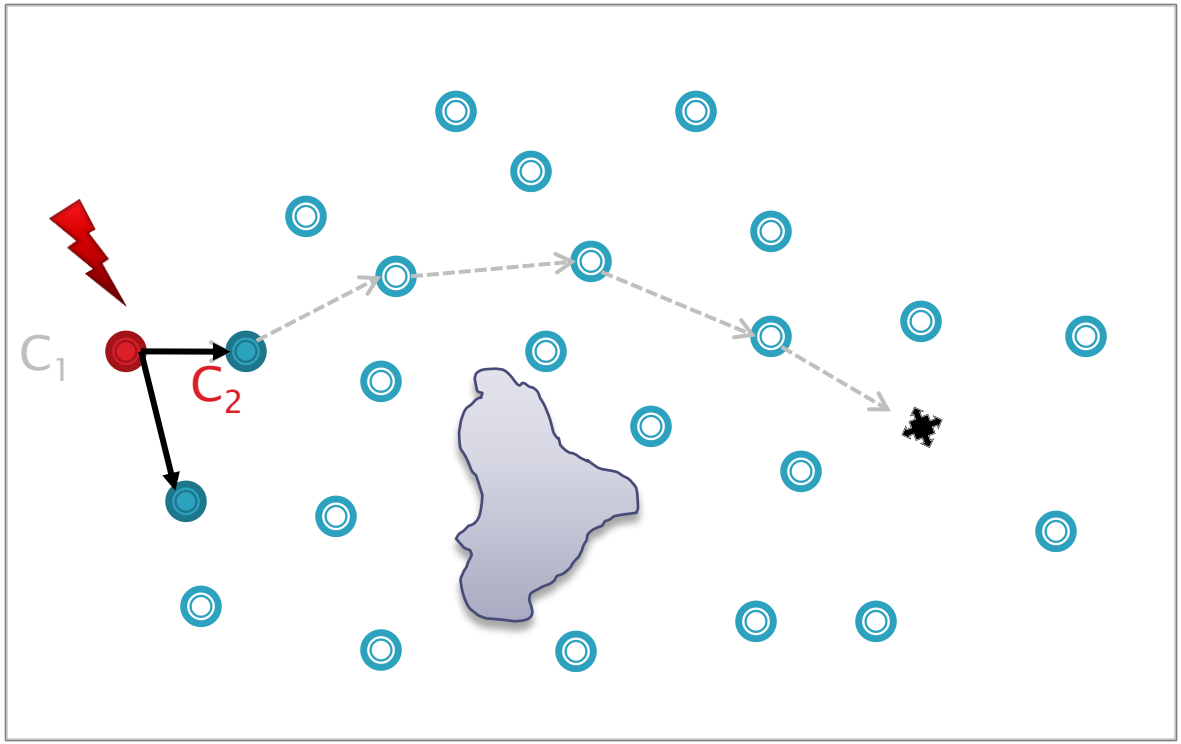
Mobile Sensor Node

Obstacle

Example – Navigation Field (2)

Node broadcasts ADV with C_1

Recipient nodes set their credit value C_2 such that $C_2 < C_1$



Credit Navigation Field [1]

Shortest WREQ path

Static Sensor Node

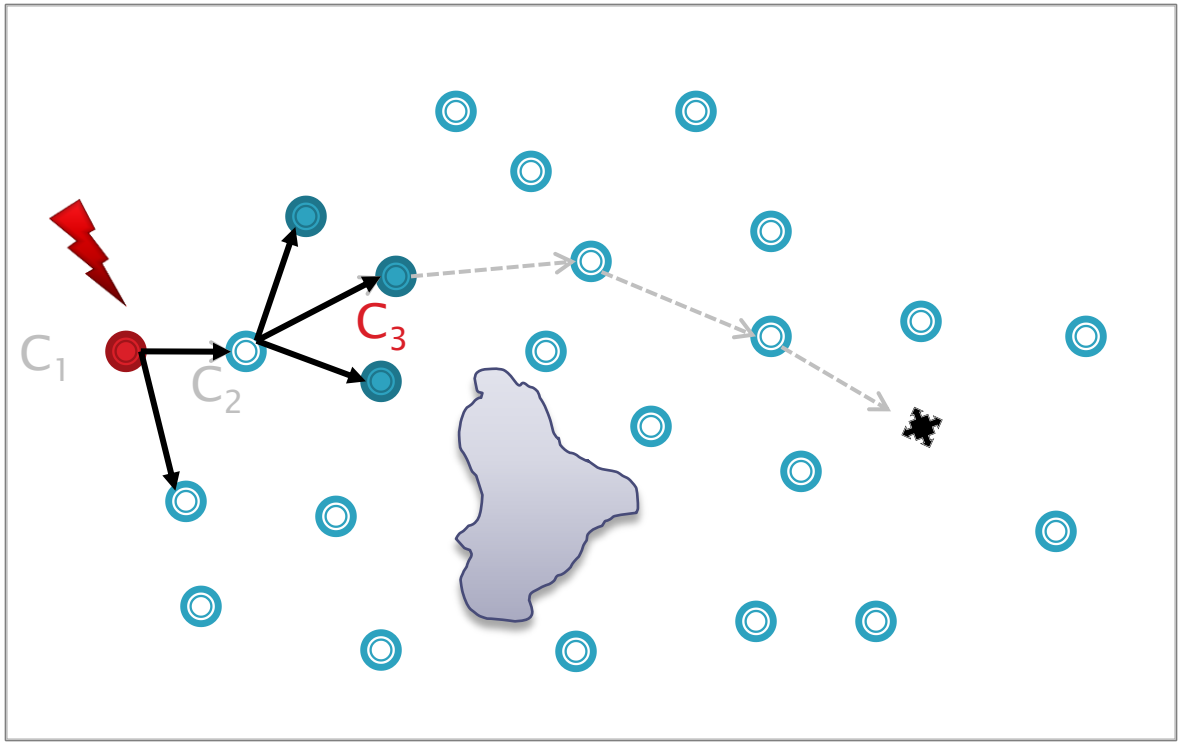
Mobile Sensor Node

Obstacle

Example – Navigation Field (3)

Node broadcasts ADV with C_2

Recipient nodes set their credit value C_3 such that $C_3 < C_2$



Credit Navigation Field [1]

Shortest WREQ path

Static Sensor Node

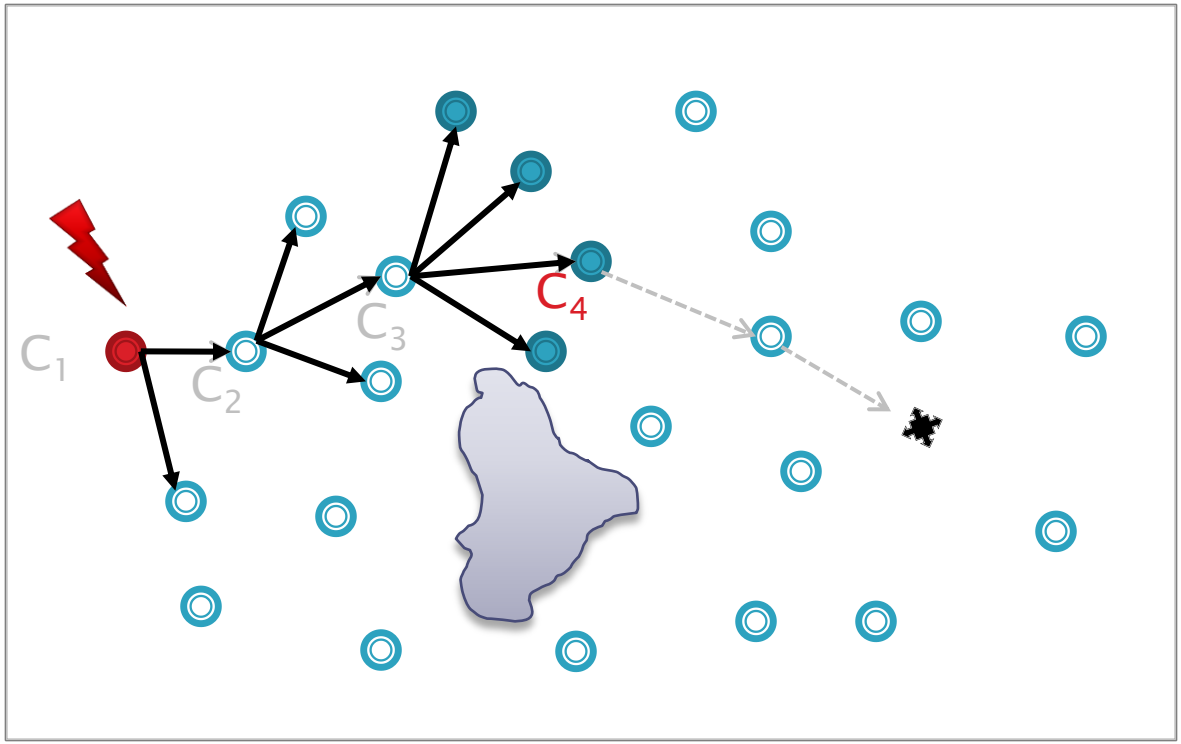
Mobile Sensor Node

Obstacle

Example – Navigation Field (4)

Node broadcasts ADV with C_3

Recipient nodes set their credit value C_4 such that $C_4 < C_3$



Credit Navigation Field [1]

Shortest WREQ path

Static Sensor Node

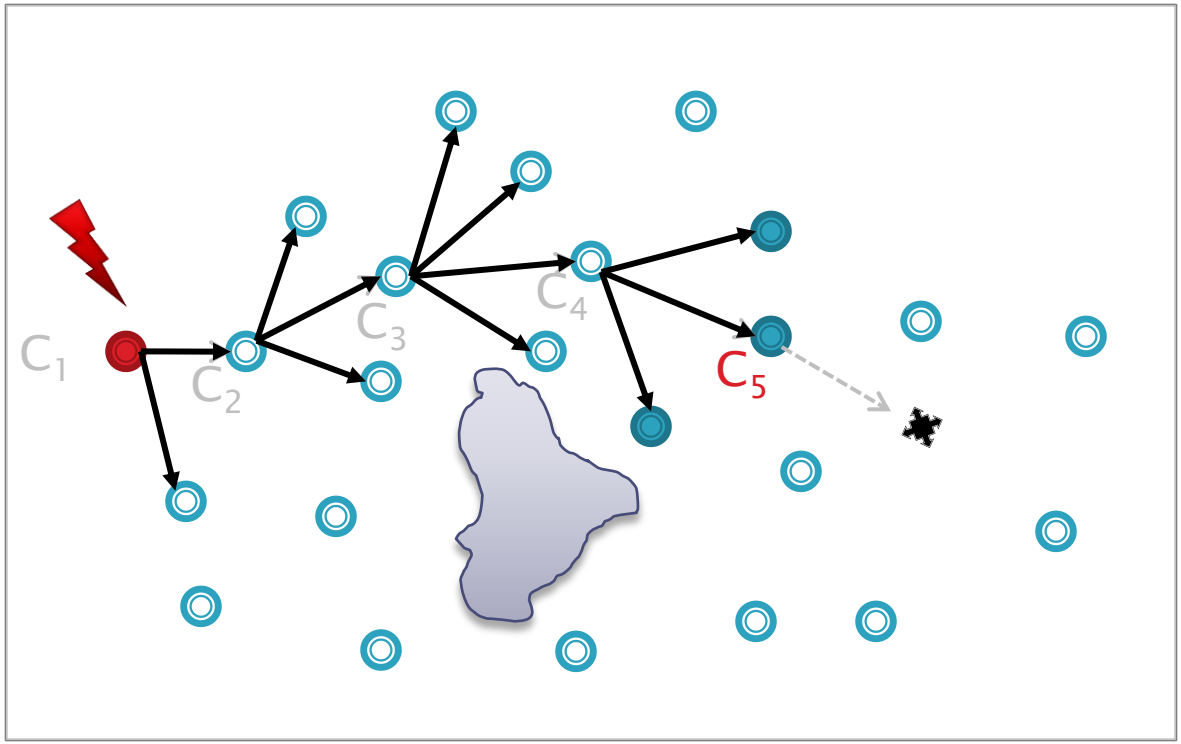
Mobile Sensor Node

Obstacle

Example – Navigation Field (5)

Node broadcasts ADV with C_4

Recipient nodes set their credit value C_5 such that $C_5 < C_4$



Credit Navigation Field [1]

Shortest WREQ path

Static Sensor Node

Mobile Sensor Node

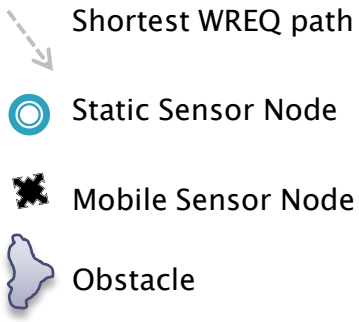
Obstacle

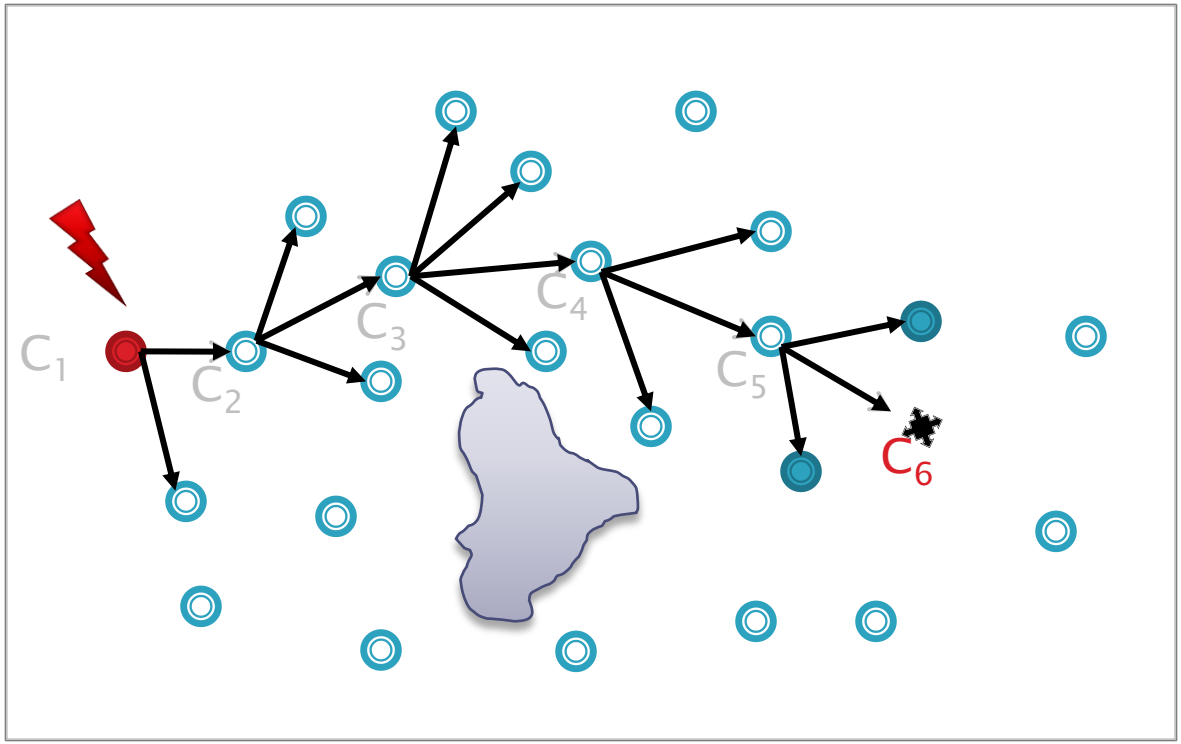
Example – Navigation Field (6)

Node broadcasts ADV with C_5

Recipient nodes set their credit value C_6 such that $C_6 < C_5$

MSN reached



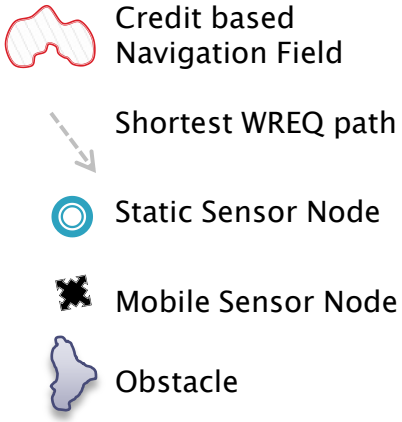


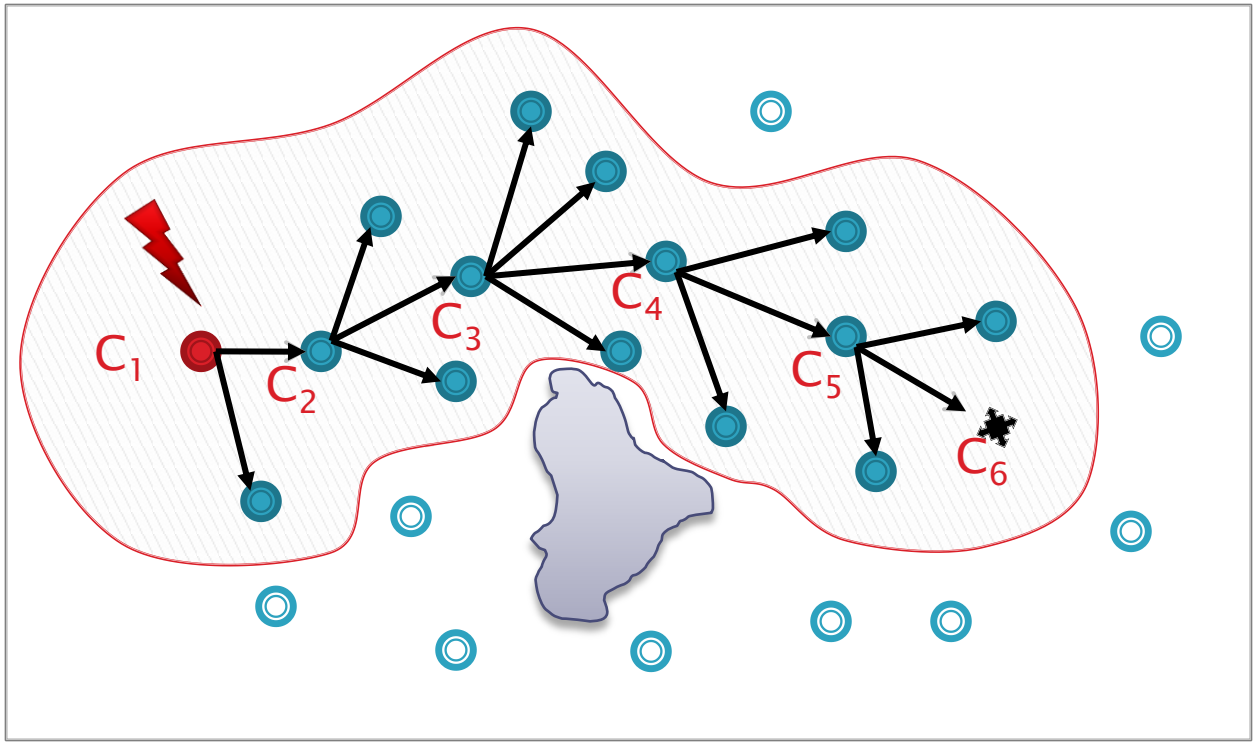
Credit Navigation Field [1]

Example – Navigation Field (7)

Credit based Navigation Field complete

$C_1 > C_2 > \ldots > C_6$





Credit Navigation Field [1]

How can a MSN use the field?

- Guiding the MSN to the event with the credit based navigation field

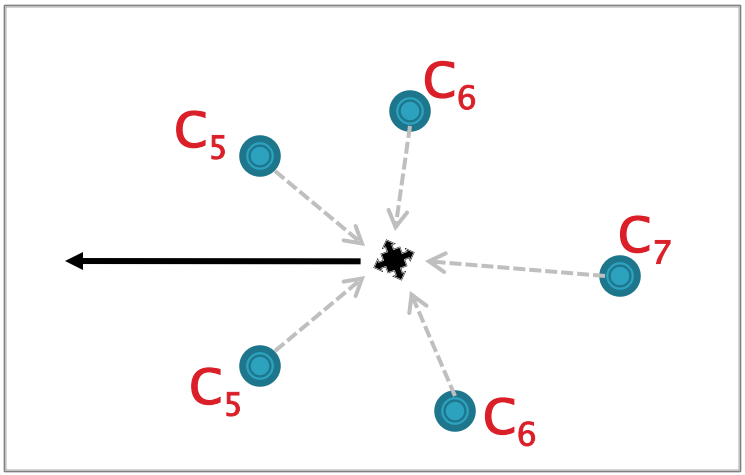
1. Broadcast a Navigation Request (NAV)
2. Collect all credit field values and location information from neighbors
3. Select node with max credit value and update value of MSN
4. Compute the direction with the collected information and move
5. If value of MSN ≠ value of leader sensor node:
   ⇨ Return to step 1

   Else:
   ⇨ Stop, point of event reached

Example – Navigating of MSN

Credit Field Values:

$C_1 > C_2 > \ldots > C_7$



Calculating MSN's direction [1]

Calculated moving direction

Information provided by the sensor nodes

Static Sensor Node with credit value

Mobile Sensor Node

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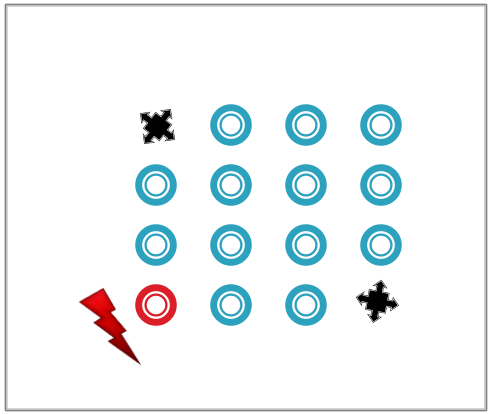
Review

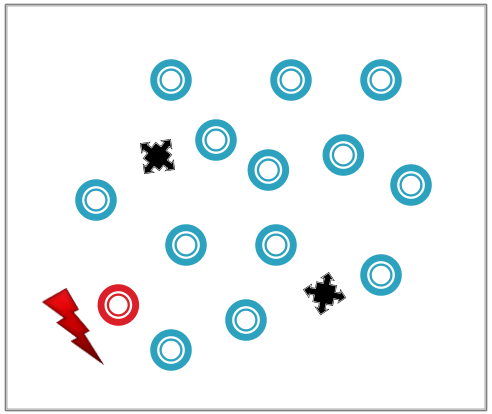
- What have been verified by the authors?

Results

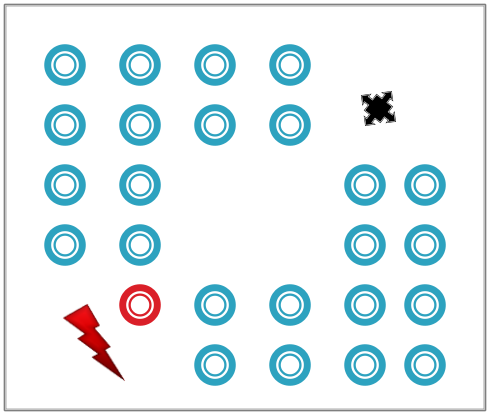
- Hybrid sensor network tested in a simulation environment (*Network Simulator ns-2* [2])
  a) Uniformly distributed sensor network ⇨ passed
  b) Randomly distributed sensor network ⇨ passed
  c) Sensor network with a coverage hole ⇨ passed



a)



b)



c)

Application Fields

- Environment observation
  - Weather, Water level, Movement
- Habitat monitoring
  - Fire, Temperature, Health
- Military applications
  - Battlefield surveillance, Reconnaissance, Enemy tracking

Conclusion

- Credit Field approach can be used for navigating mobile sensor nodes thru a hybrid network of mobile and static sensors with:
  - No prior information about location or quantity of MSNs
  - No prior map of environment
- Only Obstacles less than the transmission range of sensor nodes are avoided
- Introduced techniques seems to provide a suitable tradeoff between flexibility, overall system costs and energy consumption
- Only simulation tests performed

Thanks for your attention

» Any questions?

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Sources

- [1] Selection and Navigation of Mobile Sensor Nodes Using a Sensor Network,
  - Atul Verma, Hemjit Sawant and Jindong Tan,
  - in the proceeding of IEEE Percom 2005.
- [2] Network Simulator ns-2
  - 2009.02.09: http://nsnam.isi.edu/nsnam/index.php/User_Information