Optimizing Tree Reconfiguration for Mobile Target Tracking in Sensor Networks

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Outline

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- Optimizing Tree Reconfiguration schemes
  - Optimized Complete Reconf. (OCR)
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Introduction

- Advances in micro-electro-mechanics and wireless communication, we can distribute a huge number of sensor nodes over a vast field to obtain sensing data.
- Use redundant nodes to deal with failures and obtain high-precision sensing data.

Introduction

- Mobile Target Tracking
  - The sensor nodes surrounding the moving target should promptly detect the target
  - Aggregate their sensing data to generate robust and reliable sensing reports in an energy-efficient way.
  - Node involved in the collaboration may change over time.

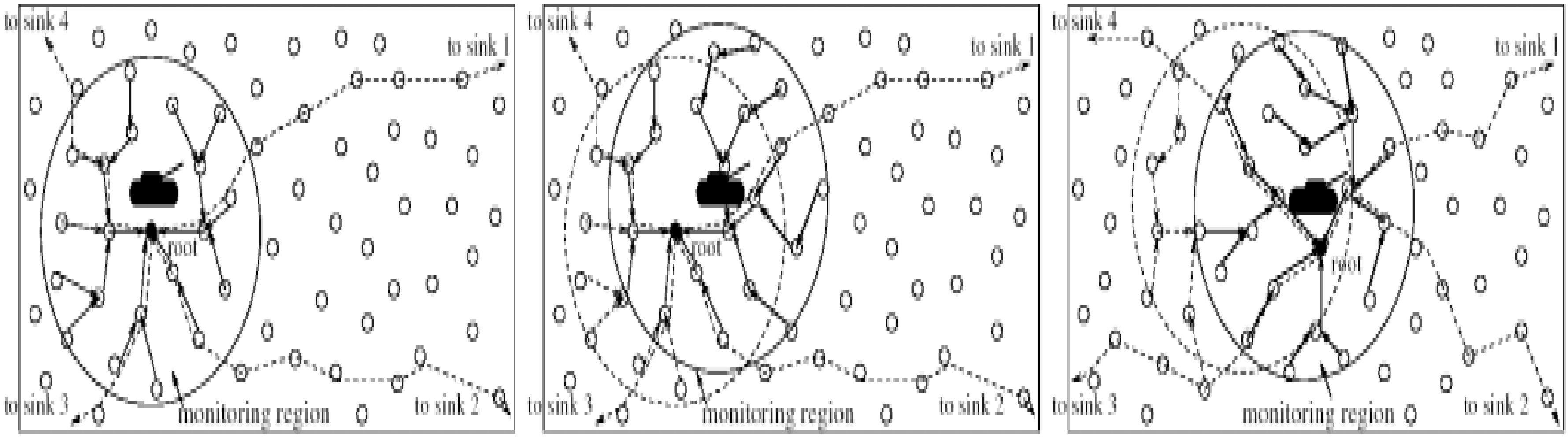
Introduction

- Dynamic Convoy Tree-based Collaboration (DCTC) [1]
  - A framework for mobile target tracking
  - Relies on a tree structure called *convoy tree*, which includes sensor nodes around the moving target
  - The tree dynamically evolves by adding some nodes and pruning some nodes as the target moves.

Introduction

- Dynamic Convoy Tree-based Collaboration (DCTC) [1]
  - Constructing the convoy tree
  - Collecting sensing data via the tree
  - Tree expansion and pruning
  - Tree reconfiguration

Introduction



(a) (b) (c)

Preliminaries

- Assumptions
  - Sensor nodes are stationary and have a fix communication range (d_c).
  - Each nodes is aware of its own location.
  - Use GAF protocol to save energy.
    - Sensor network is divided into grids
    - When there is no target close to a grid, only the *grid head* is awake, and other nodes only need to wake up periodically.

Preliminaries

- Assumptions of the network model
  - Nodes are densely and uniformly deployed with density ρ.
  - The number of hops between two nodes is proportional to the geographic distance between them.($hop(A, B)=d_{A,B}/d_c$)
  - The target keeps its velocity for a relatively long time before any change.

Preliminaries

- The target (locate at L_t) with a certain *monitoring radius* d_s form a *monitoring region*.
- All nodes involve in the monitoring region (S_t) are required to participate in detecting the target.

Optimizing Tree Reconfiguration schemes

- Root replacement rules
  - The current root (*R*) predicts the location of the target at the next data collection time(L_{t+1}), by using certain movement prediction techniques.
  - When the distance between *R* and L_{t+1} is larger than a threshold d_r ($d_r > d_c$), *R* is replaced by a node closest to L_{t+1}.

Optimizing Tree Reconfiguration schemes

- It is important to select an appropriate value for d_r.
- According to the root replacement rule, root replacement is performed every $k(v) = d_r/v$ time units.

Optimizing Tree Reconfiguration schemes

- We can compute the average energy consumption per time unit by

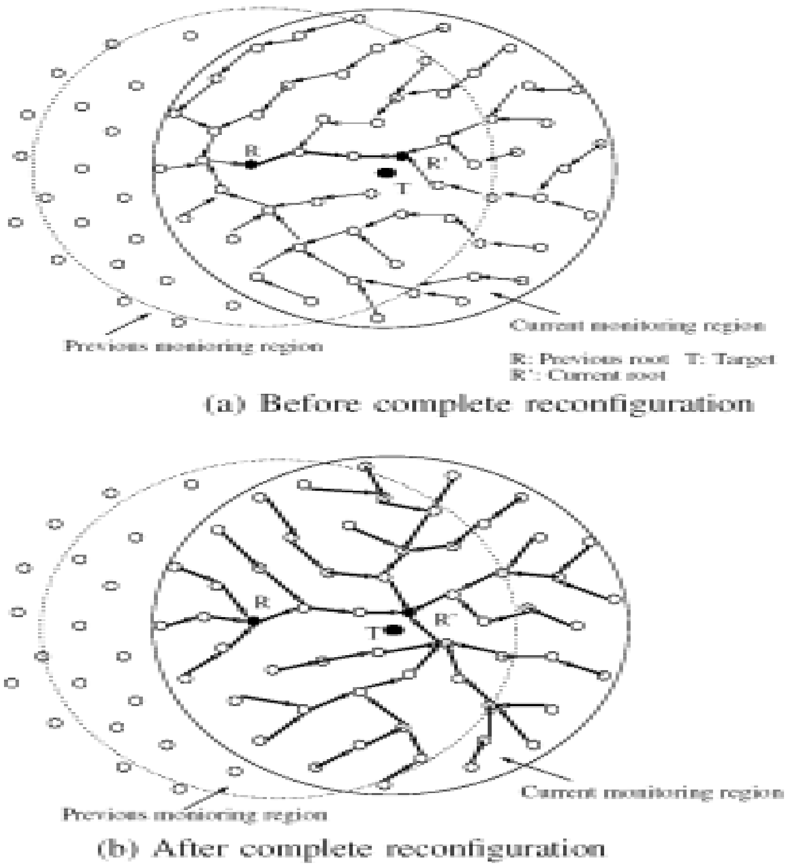
$$\overline{E}(k(v), v) = \frac{\sum_{i=0}^{\lceil k(v) \rceil - 1} \overline{E^d}(i * v) + \overline{E^t}(k(v) * v)}{k(v)} \qquad (1)$$

- Therefore, to minimize *E*(*k*(*v*), *v*) , we can compute k(v)

$$k(v) = arg_{i \in (0, \frac{d_s}{v})} min\{\overline{E}(i, v)\} \qquad (2)$$

Optimized Complete Reconfiguration (OCR)

- Use root replacement rule to replace the root.
- New root (R`) broadcast a message *reconf*(*R*,*R*`)
- Grid head need to re-broadcast the message.
- Other nodes use attach/detach operations to add/leave a tree.
- Continues until all nodes <u>within the monitoring region</u> have received the message.



Optimized Complete Reconfiguration (OCR)

- data collection overhead

$$\overline{E^d}(u) = \frac{2 * \rho * e * s_d}{d_c} * \int_{-d_s}^{d_s} \int_0^{\sqrt{d_s^2 - x^2}} \sqrt{(x+u)^2 + y^2}\, dy\, dx$$

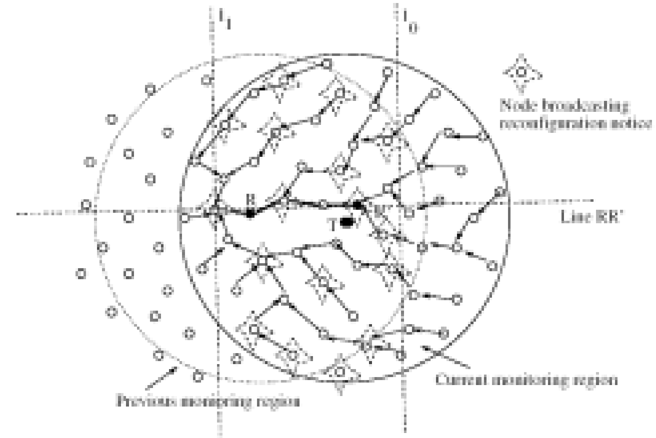
- Tree reconfiguration overhead:

$$\overline{E^t}(k(v)) = 2 * \rho * s_c * \pi d_s^2$$

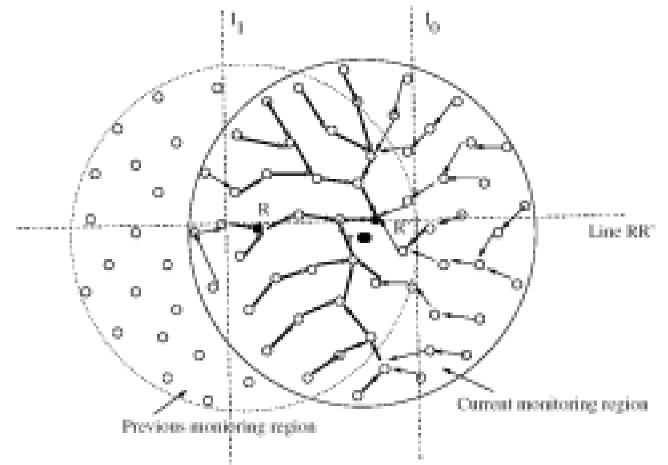
Optimized Interception-Base Reconfiguration (OIR)

- OIR only reconfigures a small part of the tree.
- Let the coordinate of R and R` be $(x_0, 0)$ $(x_1, 0)$
- A node P(x, y) is involved in the reconfiguration if and only if it satisfies

$$\begin{cases} d_{P,L_t} \le d_s, \\ x_0 - d_c \le x \le x_1 + d_c \end{cases}$$



(a) The process of interception-based reconfiguration



(b) After interception-based reconfiguration

Optimized Interception-Base Reconfiguration (OIR)

- Estimate data collection overhead by three part.
  - Nodes between line l_0 and l_1
  - Nodes on the left side of line l_1
  - Nodes on the right side of line l_0

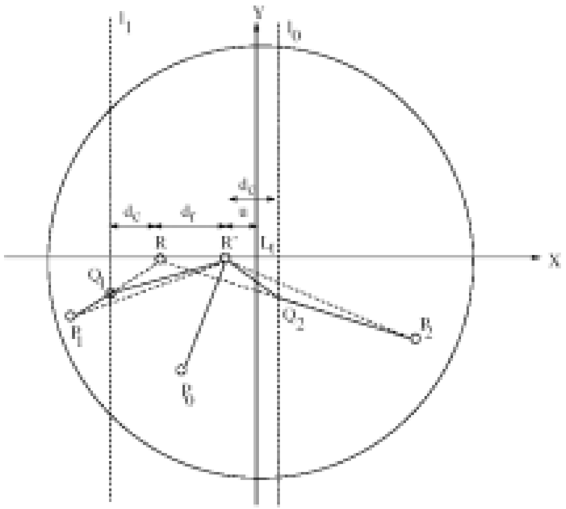


Fig. 8. Analyzing $\overline{E^d}(u)$ of the interception-based reconfiguration scheme

Optimized Interception-Base Reconfiguration (OIR)

- Nodes on the left side of line l_1
  - Data collection overhead is ($\rho * e * s_d * A_1$) where

$$A_1 = \int_{-d_s}^{-u-d_r-d_c} \int_{-\sqrt{d_s^2-x^2}}^{\sqrt{d_s^2-x^2}} c_1 * \frac{d_{P_1,R}}{d_c} \, dy \, dx$$

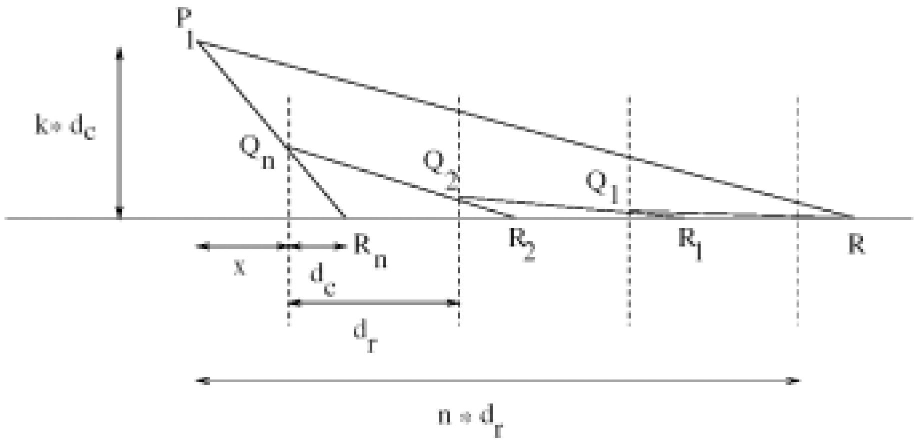


Fig. 9. The principle of estimating parameter c_1

  - C_1 can be compute by

$$c_1 = \frac{hop(P_1, R)}{d_{P_1,R}/d_c}$$

where

$$hop(P_1, R) = \frac{d_{P_1,Q_n} + \sum_{i=2}^{i=n} d_{Q_i,Q_{i-1}} + d_{Q_1,R}}{d_c}$$

Optimized Interception-Base Reconfiguration (OIR)

- Data collection overhead

$$\overline{E^d}(u) = \rho * e * s_d * (A_0 + A_1 + A_2)$$

- Tree reconfiguration overhead

$$\overline{E^t}(d_r) = 2 * \rho * s_c \int_{-u-d_r-d_c}^{d_c} \sqrt{d_s^2 - x^2}\, dx$$

Performance Evaluations

TABLE I

NON-OPTIMIZED RECONFIGURATION SCHEMES

Name	Characteristics
Aggressive Complete Reconfiguration (ACR)	A complete reconfiguration is initiated when $d_{R,L_{t+1}} \geq d_c$
Conservative Complete Reconfiguration (CCR)	A complete reconfiguration is initiated when $d_{R,L_{t+1}} \geq d_s$
Aggressive Interception-based Reconfiguration (AIR)	An interception-based reconfiguration is initiated when $d_{R,L_{t+1}} \geq d_c$
Conservative Interception-based Reconfiguration (CIR)	An interception-based reconfiguration is initiated when $d_{R,L_{t+1}} \geq d_s$

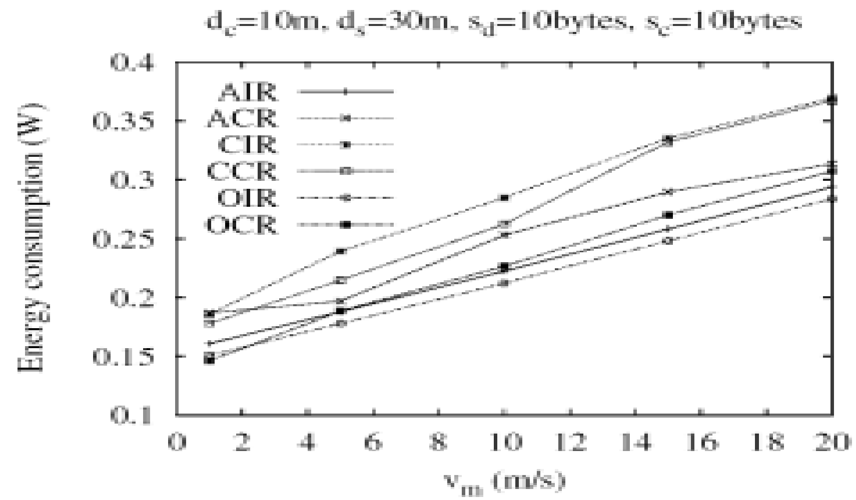
TABLE II

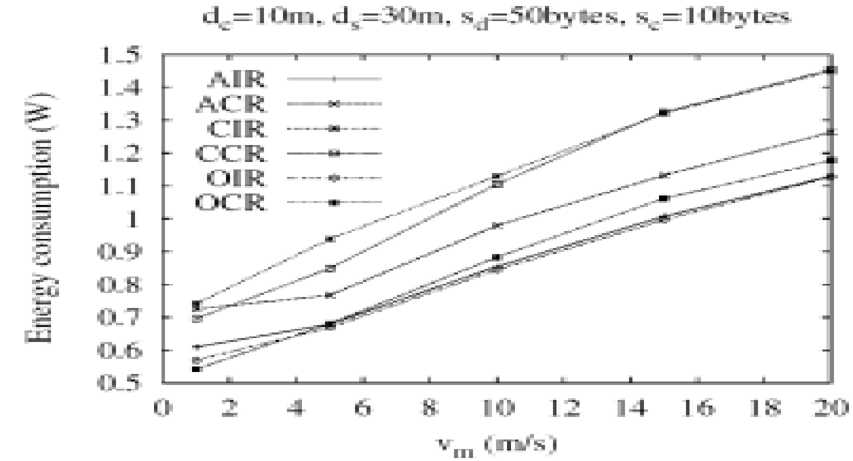
SIMULATION PARAMETERS

Parameter	Values
field size (m^2)	$400.0 * 400.0$
number of nodes	6000
communication range (m): d_c	20.0
monitoring radius (m): d_s	30.0, 60.0
size of data report ($byte$): s_d	10,50
size of control message ($byte$): d_c	10
maximum velocity of a mobile target (m/s): v_m	$[1.0, 20.0]$
probability that the mobile target keeps the same velocity: p_k	$[0.6, 0.9]$
data collection interval (s)	1.0

Performance Evaluations

- Energy consumption
  - OIR outperforms OCR when s_d/s_c and d_s/d_c are small , velocity is high.





Conclusion

- This paper proposed two optimizing tree reconfiguration methods.
  - OCR
  - OIR
- Not so practical?
- Can look for more detail method
  - Tree construction
  - Support higher speed system
  - Etc..