Minimum Latency Scheduling for Multi-Regional Query in Wireless Sensor Networks

Introduction

Periodical query processing
- Dynamic
- Dynamic query processing target at the entire network
  - Broadcast consume extra energy
- Scheduling techniques with a single global scheduling tree
  - more latency in order to avoid collision

Introduction

Problem Definition

Network Model
- n sensor nodes
- One sink
- Transmission/Interference range: unit disk with radius 1
- Topology graph: unit disk graph $G=(V, E)$
Problem Definition

Multi-Regional Query

A query targeting at user interested data from multiple regions in a WSN

```
SELECT S_x, S_y, S_z, ..., S_n
FROM S_1, S_2, ..., S_n
WHERE condition
```

Minimum Latency Multi-Regional Query Scheduling (ML-MRQS)

Given a MRQ targeting at regions R_1, R_2, ..., R_n, the QFT constructed in R_i is represented by \(T_i = (E, F, \pi, \rightarrow)\) in the MRQFT. Let \(\delta_i\) be the set of all child祖先→parent transmissions on \(T_i\). \(\delta_i = \{\delta_{i1}, \delta_{i2}, \delta_{i3}, ..., \delta_{in}\}\), and \(\delta_{ij}\) represents the set of transmissions on \(T_i\) that are scheduled at time \(t_j\). An ML-MRQS is a sequence of transmission sets denoted by \(\delta = (\delta_{11}, \delta_{12}, \delta_{13}, ..., \delta_{1m}), (\delta_{21}, \delta_{22}, \delta_{23}, ..., \delta_{2m}), ..., (\delta_{nm}, \delta_{nm}, \delta_{nm}, ..., \delta_{nm})\) satisfying the following conditions:

1. \(\delta_{ij} \cap \delta_{kj} = \emptyset\) if \(i \neq k\), \(1 \leq i, j \leq m\).
2. \(V \in \delta_{ih} \rightleftharpoons V \in \delta_{jk} \) \(\forall V \in \delta_{ih} \rightleftharpoons V \in \delta_{jk} \) if \(i \neq k\), \(1 \leq i, j \leq m\).

3. \(\delta_{ij} \cap \delta_{ik} = \emptyset\) \(\forall i \neq k\), \(1 \leq i, j \leq m\).

4. \(\sum_{j=1}^{m} \delta_{ij} = \delta_{ii}\)

5. Data are aggregated from \(\bigcup_{j=1}^{m} \delta_{ij}\) to \(\delta_{ij} \cup \bigcup_{j=1}^{m} \delta_{ij}\) at time-slot \(t_i\), for all \(1 \leq i \leq m\). Data are aggregated to \(\delta_{ij} \cup \delta_{ij}\) at time-slot \(t_i\), for all \(1 \leq i \leq m\).

6. \(L\) is minimized.

Multi-Regional Query Scheduling

Construction of Multi-Regional Query Forest (MRQF)

- Construct a CDS-based Regional Query tree (RQT) within each region
  - Dominator: white. Dominator and connector: black or gray

```
SELECT R_x, R_y, R_z, ..., R_n
FROM R_1, R_2, ..., R_n
WHERE condition
```
Performance Analysis

Latency
- A MRQ with m query regions $R_1, R_2, \ldots, R_m$ is upper bounded by $23A + B + C$
  \[ A = \max_i D^\prime_i, \quad B = \max_i (23D_i + 5A + 21)(k_i), \quad C = \sum_{i=1}^{m} H_i + 5A + m + 17 \]
- $m$ is the number of regions
- $\Delta$ is the maximum node degree in the WSN
- $D_i$ is the diameter of $R_i$
- $k_i$ is the maximum overlapped degree of sensor nodes in $R_i$
- $H_i$ represents the distance of $R_i$ with respect to the sink, and
- $D_{left} i$ is the diameter of the non-overlapped part of $R_i$

Performance evaluation

- Simulation result
  - Monitoring area: $1000m \times 1000m$
  - Interference/transmission range: $50m$
  - Sink: upper left corner
  - Data for the same query is aggregated during transmission
  - Latency: time interval between the first transmit and the last transmit
  - Comparison algorithm: C-DCQS

Conclusion

- We investigate the ML-MRQS problem for WSNs
- The ML-MRQS problem is NP-Hard. Hence, a heuristic collision free scheduling algorithm is proposed to solve the ML-MRQS problem.
- Theoretically prove that the latency of MRQSA is upper bounded