Approximation Algorithm for Maximum Lifetime in Wireless Sensor Networks with Data Aggregation

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Presented by
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Outline

- Network Model
- Contribution and related work
- Centralized algorithm
- Conclusions and future work
Network Model

- Sensor is on all the times
- Sensor’s location is known
- Adjustable communication range
- Stationary
- Report to Base station directly or via other sensors as relays
- Data aggregation capability
Contribution and related work

- **Contribution**
  - Centralized algorithm with approximation ratio

- **Related work**

<table>
<thead>
<tr>
<th>Protocols/algorithms</th>
<th>By</th>
<th>Centralized/Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. MLDA</td>
<td>K. Kalpakis, K. Dasgupta, and P. Namjoshi</td>
<td>Centralized</td>
</tr>
<tr>
<td>2. LEACH</td>
<td>W. Heinzelman, A. Chandrakasan, and H. Balakrishnan</td>
<td>Distributed</td>
</tr>
<tr>
<td>3. PEGASIS</td>
<td>S. Lindsey and C. C. Raghavendra</td>
<td>Distributed</td>
</tr>
</tbody>
</table>
Centralized algorithm

- Maximize Total time until the first sensor runs out of energy
Problem formulation

- Lifetime Maximization problem – To find a monitoring schedule \{ (A_{r_1}, t_1), \ldots, (A_{r_k}, t_k) \}
  - \[ \text{Max } \sum t_{A_r} \]
  - s.t. \[ \sum P_{A_r} (v_i) t_{A_r} \leq E(v_i) \]
  - \[ P_{A_r} (v_i) = TX(v_i, v_j = \text{parent of } v_i \text{ in } A_r) + (\# \text{children of } v_i \text{ in } A_r)RX \]

- Exact algorithm called MLDA (K. Kalpakis, K. Dasgupta, and P. Namjoshi)
  - \[ O(n^{15}\log n) \]
Example schedule

Ar1t1

Ar2t2

Ar3t3
Approximation algorithms

- Heuristics (K. Kalpakis, K. Dasgupta, and P. Namjoshi)
  - G-CMLDA
  - I-CMLDA
- Garg-Könemann approx. alg. with minimum length columns
  - Find $A_r$ that Minimizes $\sum P_{A_r}(v_i) y_i$
  - Minimum cost spanning arborescence problem
Problem reduction

Base Station $r$

\[ P_{Ar}(s_1) = y_1 TX_{1,2} \]

\[ P_{Ar}(s_2) = y_2 (2RX + TX_{2,r}) \]

\[ P_{Ar}(s_3) = y_3 TX_{3,2} \]
Approximation ratio

- (1-ε) Garg-Könemann approx. alg.
  - Exact algorithm of finding minimum cost spanning arborescence
  - (1-ε) approximation ratio
  - $O(n^3 \frac{1}{\varepsilon} \log n)$ complexity
Experimental information

- 40, 50, and 60 nodes in 50x50m²
- Base station is at (25,150)
- Initial energy is 1 J.
- Receiving power consumption
  - 50 nJ/bit
- Transmitting power consumption
  - 50 nJ/bit + 100*d² pJ/bit
- Package size 1000 bits
### Experimental result

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Quality</th>
<th>Running time</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPT (MLDA)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>G-CMLDA</td>
<td>0.91</td>
<td>0.1</td>
</tr>
<tr>
<td>I-CMLDA</td>
<td>0.97</td>
<td>0.33</td>
</tr>
<tr>
<td>GK</td>
<td>0.975</td>
<td>0.07</td>
</tr>
</tbody>
</table>

$\varepsilon = 0.1$
Conclusions and Future work

■ Conclusion
  ■ Centralized algorithm with (1-ε) approximation ratio
  ■ Actual results on average within 2.5% of optimum
  ■ Running time on average within 7% of one for finding optimum

■ Future work
  ■ Implement faster minimum cost arborescence algorithm
  ■ Methods, tools for finding optimum of large sensor networks
    ■ CPLEX on 80 nodes takes 28.5 hours
Questions?

Thank You