Minimum Latency Broadcasting with Conflict Awareness in Wireless Sensor Networks

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Outline

- Introduction
- Target Problem
- Our Approach
- Experimental Results
- Conclusion & Future Work
Introduction

- Apply pipeline to optimize the broadcasting performance in wireless sensor networks
  - Broadcasting is not a new problem
  - Existing methods adopt hop distance based flooding
- Broadcasting in wireless sensor networks
  - Conflict (by interference)
  - Color scheme
  - Color selection
  - Back-off delay
Sample of back-off delay and its impact
The problem is not trivial!

- Cannot be solved by using
  - Neighbor node degree
  - Pre-determined pair of sender and receiver
  - Network diameter or hop distance
Target Problem

- Can we pipeline the relays so that the back-off delay along the critical path can be reduced?
Goals

• The optimal solution for minimum latency broadcasting, by given the network deployment?
  ◦ Greedy color scheme?
  ◦ \((1 + \varepsilon)\)–estimation?
  ◦ Hop distance?

• A more effective solution in the localized & distributed manner
Our approach

- Heuristic method is needed to find an optimal solution.
- To find a propagation in a color so that no other color selection can achieve better (faster) solution

\[ P(S) = \min\{t\} \]

subject to:
\[ t = M(\{s\}, ts) \]
\[ M(N, t) = t - 1, \text{ activity ends} \]
\[ M(W, t) = M(W + A(W, t), t + 1) \] where A is the receivers of selected color relays
\[ A(W, t) = \{N(u) \mid \forall u \in C_s(w) \land 1 \leq j \leq \lambda(W) \} \]
\[ M(W + C_s(W), t+1) \leq M(W + C_j(W), t+1) \]
• Color scheme: (e.g., Cs, Cj)
  ◦ A valid progress in information propagation
  ◦ Interference-freedom among all nodes in the same color
  ◦ Conflict with a node in other colors (necessity of being labeled).
(a) data sending/receiving  (b) color node  (c) interference block/wait

<table>
<thead>
<tr>
<th>Task $B(W, t)$, # of rounds</th>
<th>$\bigcup C_i$</th>
<th>$\bigcup B$ in consideration</th>
<th>$C_S$</th>
<th>$S(W, t)$</th>
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</thead>
<tbody>
<tr>
<td>$B({1}, 1)$</td>
<td>$C_1 : {1}$</td>
<td>$B({1, 2, 3}, 2)$</td>
<td>$C_1$</td>
<td>${2, 3}$</td>
</tr>
<tr>
<td>$B({1, 2, 3}, 2)$</td>
<td>$C_1 : {2}$</td>
<td>$B(N, 3)$</td>
<td>$C_1$</td>
<td>${4, 5}$</td>
</tr>
<tr>
<td>$B(N, 3) = 2$</td>
<td>$C_2 : {3}$</td>
<td>$B({1, 2, 3, 4}, 3)$</td>
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<tr>
<td>$B({1, 2, 3, 4}, 3)$</td>
<td>$C_1 : {2}$</td>
<td>$B(N, 4)$</td>
<td></td>
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<tr>
<td>$B(N, 4) = 3$</td>
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</tbody>
</table>
Properties

- Optimal performance
- \(2 + \text{(hop distance)}\)
Extension under the greedy coloring scheme:

- A new constraint:
  - The more receivers it connected, the earlier this sender will be labeled in the color scheme.
Duty cycle system

- Round -> slot
<table>
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<tr>
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<th>$\bigcup C_i$</th>
<th>$\bigcup \mathbb{B}$ in consideration</th>
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<th>$S(W, t)$</th>
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<td>$\mathbb{B}({1}, 2)$</td>
<td>$C_1 : {1}$</td>
<td>$\mathbb{B}({1, 2, 3}, 3)$</td>
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<td>N/A</td>
<td>$\mathbb{B}({1, 2, 3}, 4)$</td>
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<td>$\phi$</td>
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<td>$\mathbb{B}({1, 2, 3}, 4)$</td>
<td>$C_1 : {2}$</td>
<td>$\mathbb{B}(N, 5) = 4,$</td>
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<td>${4, 5}$</td>
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<td>$C_2 : {3}$</td>
<td>$\mathbb{B}({1, 2, 3, 4}, 5)$</td>
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<tr>
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<td>N/A</td>
<td>$\mathbb{B}({1, 2, 3, 4}, 6)$</td>
<td>N/A</td>
<td>$\phi$</td>
</tr>
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<td>...</td>
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</tr>
<tr>
<td>$\mathbb{B}({1, 2, 3, 4}, \xi + 3)$</td>
<td>$C_1 : {2}$</td>
<td>$\mathbb{B}(N, \xi + 4) &gt;&gt; 4$</td>
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</tbody>
</table>
• Costly?
• A cost-effective method is needed (in both round-based and duty cycle systems).
Each node has four regions

For each region, a node has a metric value $H$ (i.e., distance to the edge of network in this region): $H(u) = 1 + \min \{ H(v) \}$
To find $C_s$

$$B(W + C_s(W), t + 1) \leq B(W + C_j(W), t + 1)$$

$C_s = C_j$ where $u \in C_j$ has the largest $H$ in neighborhood
Experimental Results

- Round based system

![Experimental Results Graph](chart.png)
Experimental Results

- Duty cycle system (10%)
Conclusion

- Some new insights brought by pipeline
  - Effectiveness of greedy coloring scheme
  - Consideration of hop distance
  - Problem in pre-determined end set in process
- Optimal solution
- A better estimation solution with the consideration of the computational complexity and cost
Future Work

- Localized color scheme
- A more effective localized & distributed solution
- The broadcasting optimization with other constraints such as energy and traffic throughput
- Extension in other cyclic network deployments (e.g., vehicle networks)
Thank you!

- Questions and Comments