A Quick and Reliable Routing for Infrastructure Surveillance with Wireless Sensor Networks

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Outline

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- Target Problem
- Our Approach
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Introduction

- Mission-critical application of infrastructure surveillance
  - Detect and respond in an extremely short time frame

- Wireless sensor networks and multi-hop relay
  - From any sensor detecting the event
  - To any available sink
• Link Burstiness
  ◦ Each link’s transmission has its uncertainty
  ◦ CPDF measurement
    • A link with a string of consecutive successes or failures has a relatively stable quality for the successor selection in the upcoming relay.
Challenges

- SIMO model is adopted in surveillance reporting: information oscillation to guide the best destination candidate.
- Duty cycle system: shortest hop-distance path is not the best.
- Link burstiness
How to determine the mutual impact of link burstiness on other factors of end-to-end delay?
  - How does one failure of transmission delay the whole reporting process?
  - Weight?

Whether is a failed transmission worthy to retry?
  - Upon dynamic configuration changes
  - In the global view, we may need to consider (in other candidates of possible paths):

How many retransmission are allowed along a path?
  - For other path decision to refer
The problem is not trivial!

- How many (re-)transmissions are needed to move the message at least 1-hop advance (i.e., greedy forwarding) along the shortest path?
- How to find the path with the minimum number of retransmissions in the dynamic networks?
- How to find the quickest path with the consideration of:
  - Hop distance
  - Schedule delay (cycle waiting time, when to initiate the transmission)
  - Transmission delay (how long to successfully receive the signal from rely neighbor)
Our approach

- Estimate (or predict) delay at each hop (via CPDF).
- Estimate delay cost of a reference path.
- Selection of a forwarding successor with a relatively better performance (less delay) in our metric, in the same direction of the reference path.
- Approach to the destination gradually in a greedy manner (in terms of end-to-end delay).
- The closer the routing approach the destination, the more accurate the successor selection will be.
• Each node has four regions

• For each region, a node has a normalized metric value $M$ (where $1/M$ indicates delay to reach the edge of network in this region): $1/M(u) = R_{(u,v)} \times C_{(u,v)} + 1/M(v)$
Routing \( (u, v, d) \)

- If \( d \in n(u) \), \( v = d \).
- Determine all four request zones \( Z_k(u) \) (1 \( \leq k \leq 4 \)).

Transmission phase
- Select \( v \in N(u) \) where \( v \) has the highest \( M \) value (minimum \( 1/M \)).
- Wait \( R_{(u,v)} \times C_{(u,v)} \) until message is delivered.

Otherwise, backup phase
- If \( v \) miss the contact at the expected time, \( u \) switches to anycasting mode.
Performance Analysis

- No detour when $M(s) > 0$.
- Information converged quickly.
- Keep effectiveness in SIMO model.
- The probability of a change of $M$: $P(M) \sim k$
  - when $k$ is the number of links that have a burstiness out of the expectation in the CPDF and there is no cycle schedule change.
- $P(M) \sim \sqrt{k}$
  - when $k$ is the number of nodes with new cycle schedules and there is no link change its quality described in the CPDF.
Experimental Results

- Cost of information update (both cycle schedule change and link quality change)
• Cost of information update (only link quality change)
• Cost of information update (only cycle schedule change)
- Duty cycle system (10%)
  - Non-reservation, anycasting (NR)
  - Fixed-reservation, 30% additional time, not for individual case (FR)
  - Dynamic-reservation, with CPDF (DR)
Conclusion

- Some fresh insights of link burstiness vs.
  - Channel reservation
  - End-to-end delay performance

- A practical estimation solution with the consideration of the computational complexity and cost
Future Work

- Other constraints such as energy cost
- Cycle schedule to mitigate the impact of link burstiness
- Extension in MIMO model (e.g., from greedy procedure to parallel processes with Nash equilibrium based fairness)
Thank you!

- Questions and Comments