Interval-based Clock Synchronization for Ad-Hoc Sensor Networks

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Motivation

- clock drift
- message-delay uncertainty
- specific communication pattern for synchronization
- dynamic structures

- sensor nodes
- sensing areas
Related Work

• Clustering

• Tree construction
Overview

• Goal: Synchronization in ad-hoc sensor networks with *arbitrary* communication patterns.
• Claim: *Interval-based* synchronization is particularly suited.
• Recent results on interval-based synchronization.
Interval-Based Synchronization of Drift-Constraint Clocks

\[ \rho_j(t) = \frac{dh_j(t)}{dt} - 1 \]

\[ -\hat{\rho}_j \leq \rho_j(t) \leq +\hat{\rho}_j \]

Advantages of Interval-Based Synchronization

• Optimal combination of time information.
• No particular communication pattern.
• Guaranteed bounds on fused sensor data.
• Concerted actions guaranteed to succeed.
Internal Synchronization

Given the local time $h_j(t_s)$ of node $N_j$ at real time $t_s$, find tight bounds on the local time $h_i(t_s)$ of another node $N_i$ at time $t_s$.

$$H^l_i(t_s) = \frac{h_j(t_s) - h_j(t_0)}{1 + \rho_j} (1 - \rho_i)$$

$$H^u_i(t_s) = \frac{\text{Instantaneous message exchange.}}{\text{No delay uncertainty.}}$$

K. Römer, *Time Synchronization in Ad Hoc*
Recent Results: Improved Synchronization

- Simply intersecting current bounds is worst-case-optimal.
- In the average case, previous bounds (the “back path”) enhance synchronization.

P. Blum, L. Meier, and L. Thiele: Improved Interval-Based Clock Synchronization in Sensor Networks, IPSN’04.
Recent Results: Improved Synchronization

P. Blum, L. Meier, and L. Thiele: *Improved Interval-Based Clock Synchronization in Sensor Networks*, IPSN'04.
Recent Results: Optimal Synchronization

- Arbitrary scenarios: traverse all paths and choose best bounds.
- No algorithm can do better.
- Need to store and exchange complete histories of all nodes.
Is it practical?

- The optimal algorithm is too expensive.
- Trade off history size vs. synchronization quality.
- Store only recent events.
Conclusion

Interval-based synchronization
- needs no particular communication pattern
- provides guaranteed bounds on fused data
- guarantees success of concerted actions

- and hence is particularly suited for ad-hoc sensor networks.
Open Questions

- Ideal history size.
- Mobile nodes.
- Node density and connectivity.
- Faulty or misbehaving nodes.
Thank you.

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