Topology Control in Mobile Sensor Networks using Information Space Feedback

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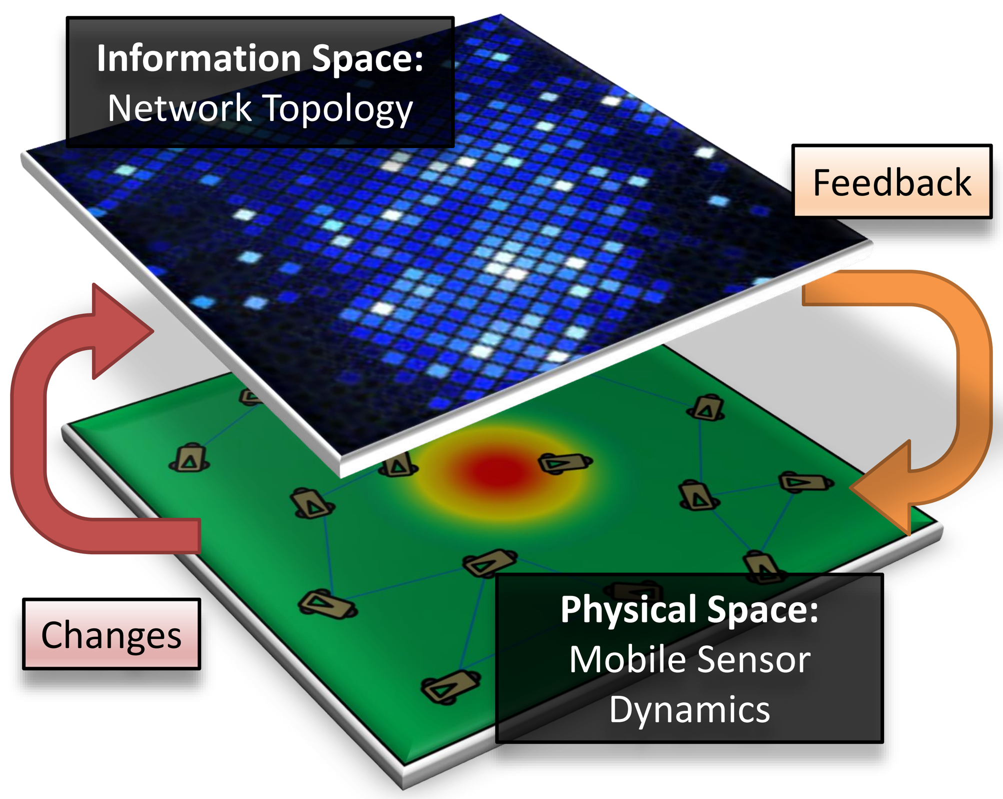
Abstract

- Time-varying network topology plays a key role in mobile sensor networks for detection of an event of interest and subsequent awareness propagation within a surveillance framework.
- **Feedback** control scheme **tunes key network topology parameters** (e.g., average degree and degree distribution) resulting in a desired network topology.
- The idea is to **modify the timelines of the asynchronous belief update protocol** depending on the **node-level belief/awareness**.

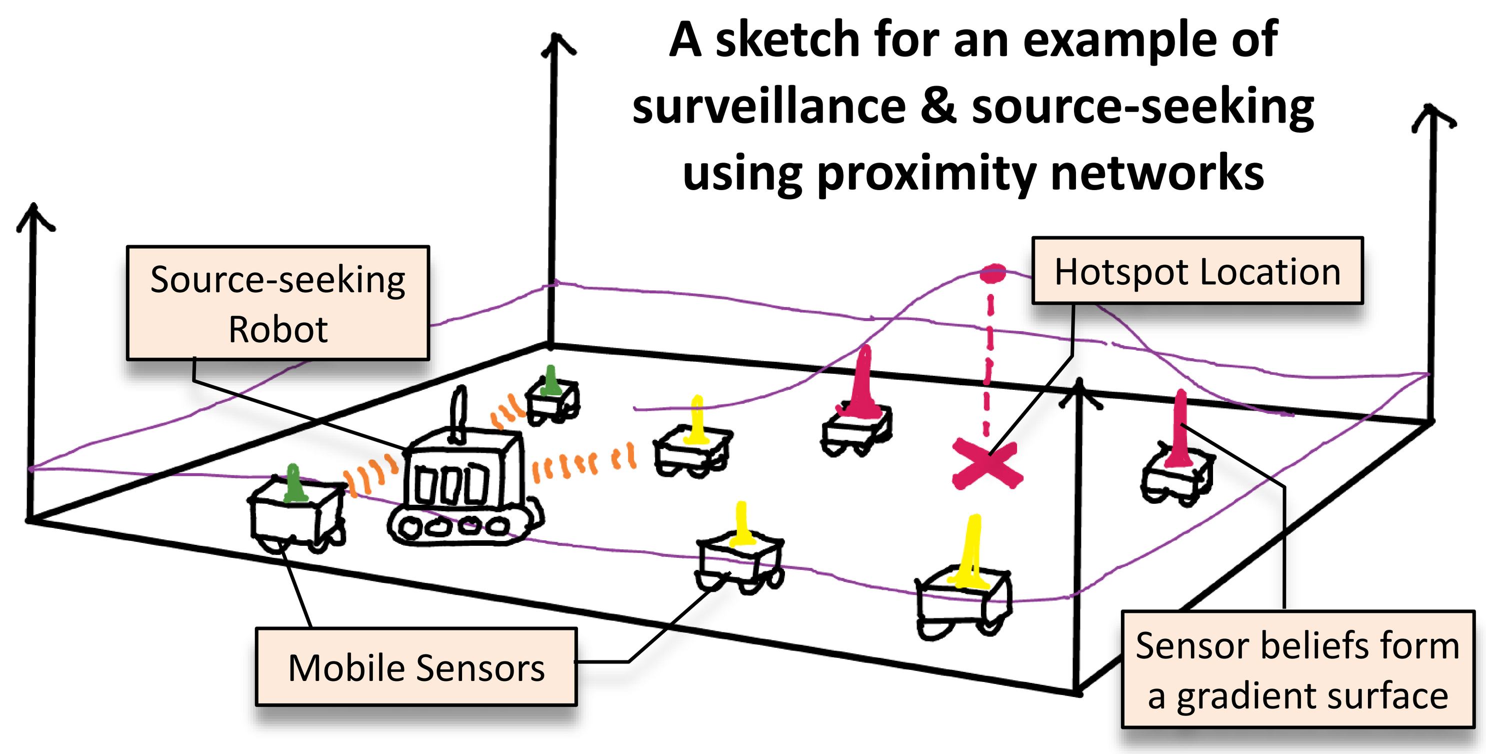


Introduction & Motivation

- Wireless sensor networks (WSN) is gaining prominence in the following areas:

Process Monitoring	Military Reconnaissance
Safety Control	Resource Operations

- In undersea surveillance, **GPS capabilities are limited** and long range communications are subject to **transmission loss** due to the dense fluid medium.
- **Optimizing** network topology is important in such a situation where proximity networks are implemented.



Better topology results in a better gradient surface that allows the source-seeking robot to determine its waypoint more effectively.

Topology Control with Message Lifetime Actuation

- The Generalized Gossip Algorithm for Proximity Networks:

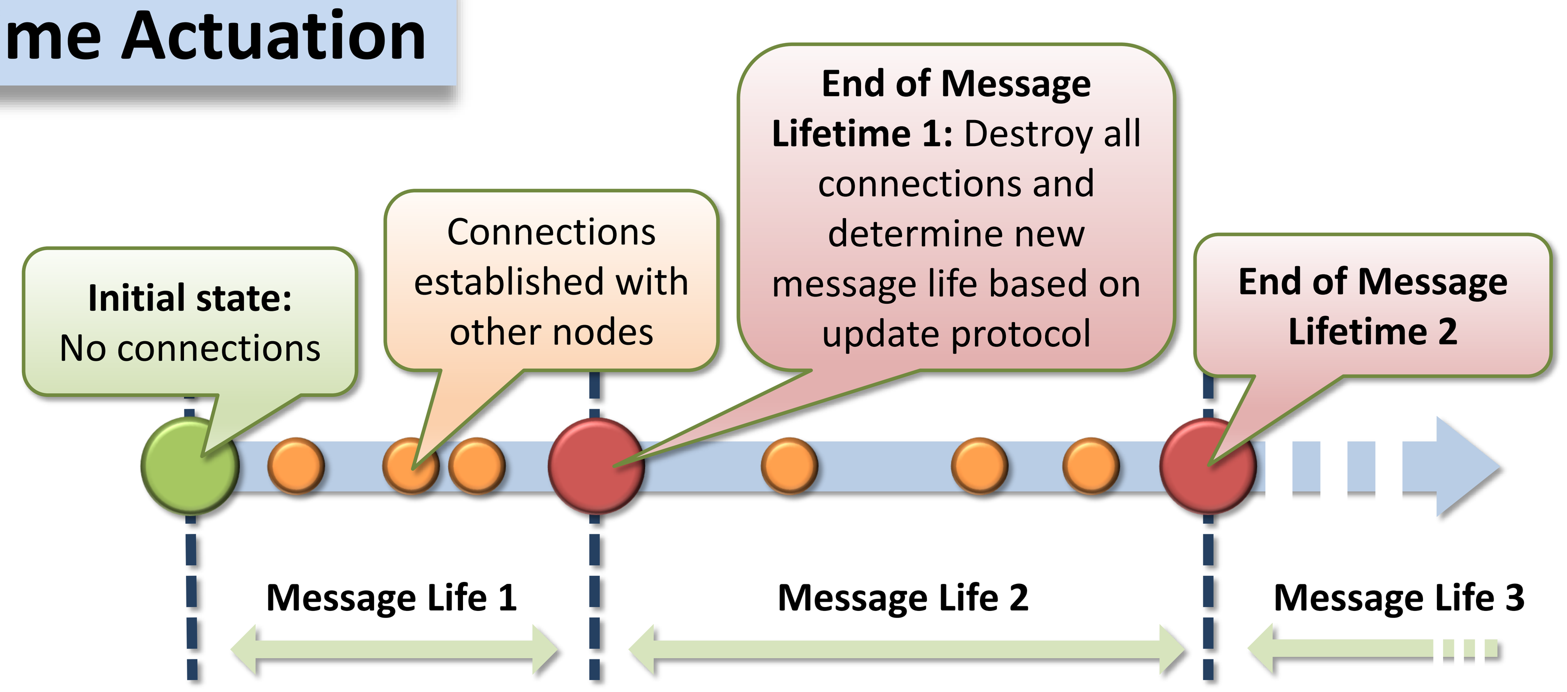
$$v_\theta\big|_{\tau+1} = (1-\theta)\,\Pi\big|_\tau\, v_\theta\big|_\tau + \theta\,\chi\big|_\tau$$

Belief of Next Time Instant = Current Neighborhood Belief + Current Observation

- Introducing a proportional constant P results in an additional degree of freedom and increase flexibility of information network topology:

$$L_m^i = L_{mb} + P(L_{mb} v^i)$$

Updated Message Life = Base Message Life + Tuning Constant × Altered Base Message Life



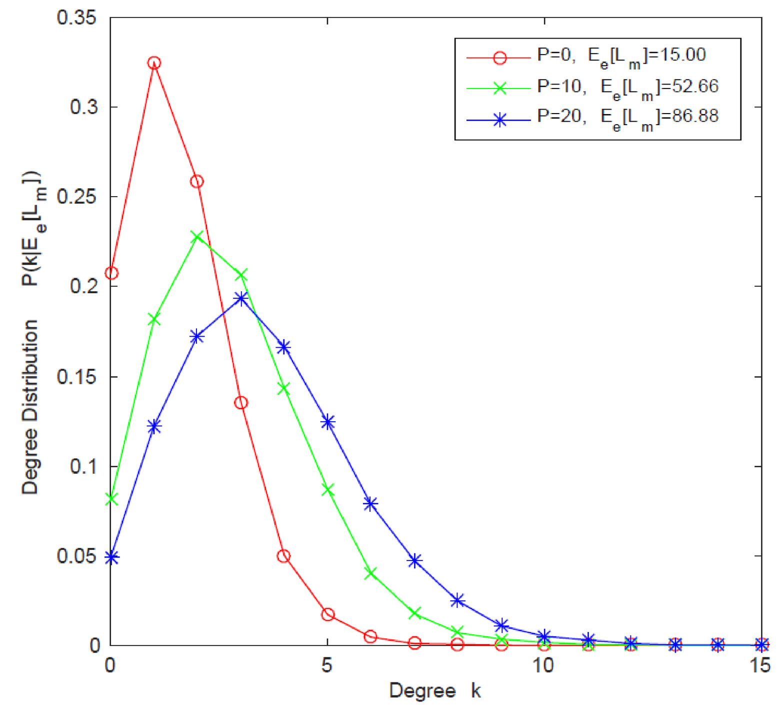
▲ Altering message lifetime based on sensor beliefs from the information space can directly affect network topology.

- Message lifetimes among nodes are now heterogeneous due to the asynchronous belief update scheme.
- **Expected degree (connected nodes) increases linearly with increasing message life.**
- Proportional constant P affects how much the expected degree of the network varies with belief.

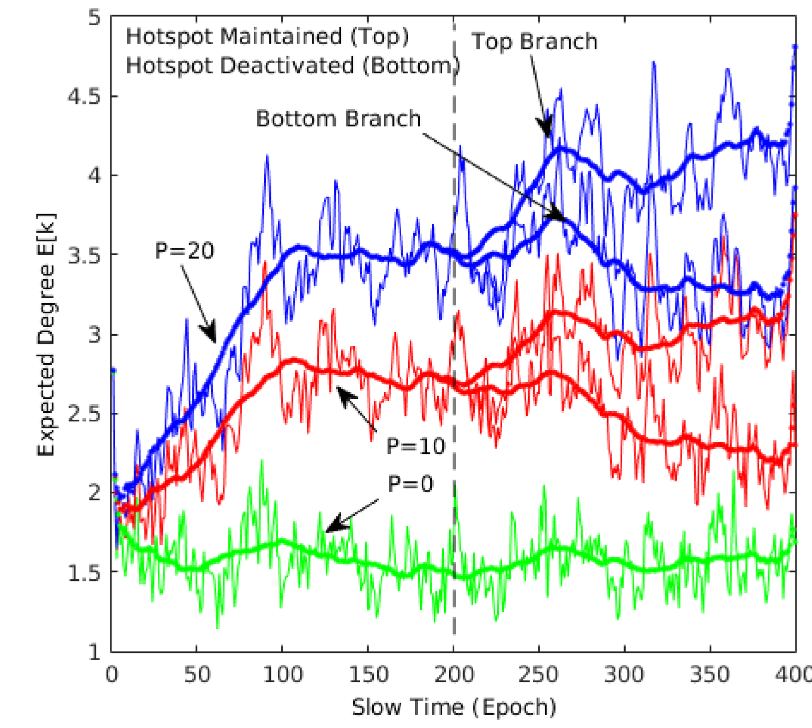
Results

Expected degree demonstrates a linear relationship with ensemble expectation of message lifetime controlled via belief feedback:

$$E_e[k]_i \approx E[L_m]\left(\alpha g_i \sum_j g_j\right) \quad \text{for} \quad \alpha E_e[L_m] \ll 1$$

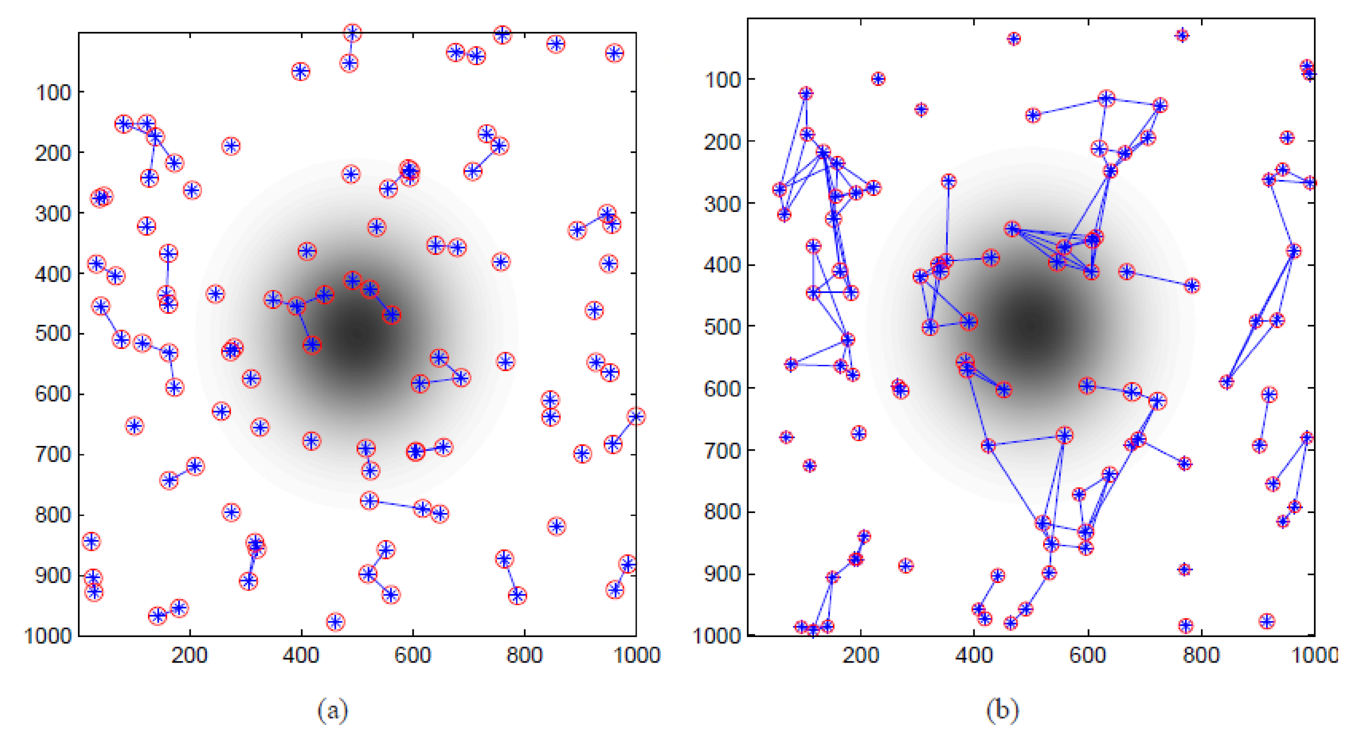


▲ Degree distribution exhibits a Poisson distribution according to the following equation:



▲ Variation of expected degree with P and its behavior in response to the presence or removal of the hotspot.

$$P(k|E_e[L_m]) = \binom{N}{k} p^k (1-p)^{N-k} \approx \frac{(E_e[k])^k}{k!} e^{E_e[k]}\,;\, N \gg 1$$



◄ Network degree is directly influenced by tuning the proportional constant $P = 0$, $P = 20$ for figures (a) and (b) respectively.

Future Work

- Analyze relationship between proportional constant P and the rate degree/belief convergence under current framework;
- Analyze evaluation of expected characteristic of interaction matrix Π;
- Determine the impact of proportional feedback control policy on the centrality measure of the network.

References

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