Self Optimization in Wireless Sensor Networks

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Sensor networks represent a fundamental paradigm shift from Interpersonal Communication to Communication with the Environment.

This must change the way we analyze and design these systems.
Analysis and Design of Wireless Sensor Networks

- Mathematical Models and Performance Analysis
- Self-optimization

**Protocol**
- algorithm choice
- parameters

**Environment**
- channel condition
- spatial correlation
- data dynamics

**Application**
- traffic
- placement
- topology
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Analysis of Directed Diffusion

- Expressions for overhead of push versus pull diffusion to determine application conditions where each is suitable

Analysis of ACQUIRE

- Analysis of an active query forwarding mechanism providing a lookahead parameter to tune between flood-based and trajectory-based querying

Analysis of Routing with Compression

- There exists a static clustering technique that provides near optimal routing with compression across a wide range of spatial correlation levels

\[ E_s(c) = nH_1[1 + \frac{(s-1)}{2(1+c)}] + \frac{D}{s} + \frac{(s-1)D}{(s)(1+c)} \]

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Self-Optimization*

- The traditional approach is to take into account application requirements prior to operation and pre-configure/pre-optimize the protocol parameters.

- This is simply insufficient in sensor networks, where the characteristics of the environment, which can be inherently unpredictable, play a key role.

- A powerful design principle we must embrace is the use of autonomous learning through sensor observations during operation, so that network protocols can optimize their own performance over time.

- These protocols must be distributed and localized for scalability and efficiency.

* Ongoing collaboration with Marc Pearlman, Kraken Inc.
Simultaneous Localization and Tracking

- Current techniques attempt to localize nodes prior to operation based on communication constraints or ranging estimates.

- In a target tracking application, sensor observations of the moving target introduce additional constraints that can be used to further reduce the localization error over time.

Model-based Compression

- In some cases, the underlying physics of the phenomena can provide a spatio-temporal model (e.g. PDE models for heat or chemical diffusion).

- Then instead of sending raw data, it suffices to send the model parameters, which can be learned through observations over time.

\[ x_t(t, \xi) = \theta_1 x_{\xi\xi}(t, \xi) + \theta_2 x_{\xi}(t, \xi) + \theta_3 x(t, \xi) \]

Reinforced Querying and Routing

- Technique suitable for querying about targets or pushing data to sinks that have a underlying (unknown) probabilistic location pattern

- The basic idea is to start with a random walk, and change forwarding weights based on reinforcements

Reinforced Querying and Routing

- Converges over a period of time to an efficient trajectory

Summary and Conclusions

- Sensor Networks represent a fundamental paradigm shift from interpersonal communication to communication with the environment. This has significant implications for both analysis and design:

  - **Analysis**: Protocol performance must be analyzed with respect to a combination of environmental effects, application specifications and protocol parameters.

  - **Design**: Protocols must be designed to be self-optimizing, improving autonomously over time by incorporating sensor observations.