Towards Application Driven Sensor Network Control

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Scenario

 Observer wants to observe something about the phenomenon
  - Track all the lions in this area to within 10 meter accuracy

 Observer is not aware of the sensor network infrastructure – Network is self configuring

 How is this intent conveyed to the network and realized effectively by it?
Sensor Network Organization

Infrastructure
- Number of sensors
- Deployment strategy (e.g. grid, random, etc.)

Network Protocol
- Creating paths for communication
- Optimizing Medium Access
- Aggregating/Fusing data?

Observer/Application
- “Interested” in phenomenon
Types of Interests

Continuous Monitoring
- In space? In time?
- E.g., temperature sensing

Phenomenon-driven
- Report based on state of phenomenon

Observer-driven
- Observer generates a query

Hybrid
Observer Interest to Reporting Discipline

Much work on networking sensors but…

Who decides what sensors report and when?
- Observer? Sensor? “Network”?
- Ideally, observer is unaware of the infrastructure

What criteria to select reporting discipline?
- Meet observer’s interests (coverage, accuracy, other?)
- Do it efficiently

Function of what the application wants + what infrastructure looks like
Infrastructure Characteristics

- Sensor capabilities
- Number of sensors
- Deployment strategies
- Reporting Model
Deployment Strategies

Grid-like  Random uniform  Biased
Evaluation Environment

- Framework extends ns-2
- Flexible, realistic model
- Separation of
  - Phenomenon
  - Sensors
  - Observer
Motivating Study

Continuous and phenomenon driven model
- Report if in range with phenomenon

Performance Metrics
- Goodput
- Delay
- Energy expenditure

New metric
- Accuracy as an application-specific performance metric (RMS of samples received at each time)
Accuracy

Relative distance determines accuracy

I enjoy my sleep

Sensing range

Location (4,4)

Lion(5,5)

Lion(10,15)

Someone(25,30)
Goodput Study (Grid)

effect of reporting period on goodput

percentage goodput %

reporting period in seconds

5x5 grid
10x10 grid
12x12 grid
15x15 grid
Delay Study (Grid)

effect of reporting period on delay

average per packet delay in seconds vs. reporting period in seconds

- 5x5 grid
- 10x10 grid
- 12x12 grid
- 15x15 grid
Accuracy Study (Grid)

Effect of reporting period on accuracy

![Graph showing the effect of reporting period on accuracy for different grid sizes.](image-url)
Energy Expenditure (Grid)

energy expenditure study

Total energy spent by the n/w

reporting period in seconds

5x5 grid
10x10 grid
12x12 grid
15x15 grid
Biased Versus Uniform

Accuracy comparison for random versus planned network

- 100 uniform density
- 144 uniform density
- 100 non-uniform density
- 144 non-uniform density

average error vs. reporting period in seconds
Conclusions

Lesson: Efficient Reporting Discipline function of application requirement + infrastructure

Semantic gap: How to allow application to configure infrastructure to produce an efficient reporting discipline?

What is the equivalent of TCP’s maximize throughput?
Co-operative + Redundancy

Get information that satisfies application requirements, and can be efficiently networked.
Research Plan – Short Term

- Optimizations that do not require application-level information
  - Congestion avoidance
  - “zero suppression”
  - Sensor controlled reporting rate

- Study applications: what makes a good reporting discipline?
Application-Driven Control

Feedback Control Framework to converge on reporting Discipline

- Diffuse Interest through region
- Sensors respond with “coverage”
- In-network control of redundancy
- Many open problems/challenges
Thank You!

Any questions?
Conclusions

- Intuition may not provide correct solutions
  - Need formal study to determine optimal solutions

- Deployment strategy
  - No appreciable difference between grid and uniform random
  - Biased network deployment can be a better alternative
Conclusions (cont.)

- Congestion may degrade sensor networks
  - Channel capacity and application requirements provide bounds on data requirements
  - Network protocol should operate sensor network to provide optimal application-specific benefit

- Future work: developing congestion management for sensor networks
Outline

- Sensor Network Organization
- Implications of Infrastructure Decisions
- Application-Driven Distributed Control
- Proposed Framework
- Conclusions
  - Gather more information about phenomenon
  - High accuracy, longer lifetime
- Intuitive Solution
  - More sensors
  - Aggressive reporting

Is this solution right???
Simple Analysis

Channel capacity upper bound

\[ Data = \sum_{i=1}^{M} b(S_i) \]

\[ \sum_{i=1}^{M} b(S_i) \leq \alpha C_{total} \]

Application-specific lower bound

\[ C_{application} \leq \sum_{i=1}^{M} b(S_i) \leq \alpha C_{total} \]
Congestion Management

Internet Goal: maximize aggregate throughput with fairness

Elton John Music
www.mp3.com

Knuth’s book
www.cs.stanford.edu

Can either one be cut off?