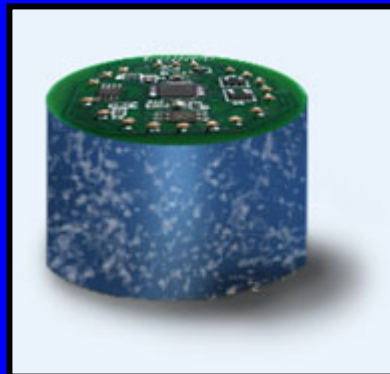


Serving Dynamic Queries in Large-scale Wireless Sensor Networks

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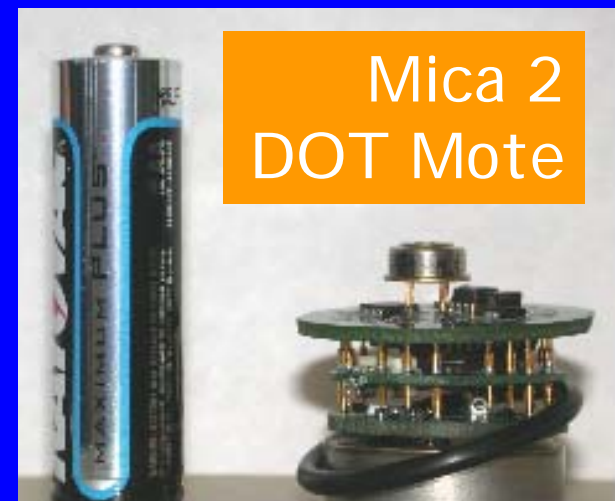
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A Sensor Node

Individual sensor chip consists of:

- Embedded Processor
- Memory
- Transceiver (typically wireless)
- Battery
- Sensing Hardware



Types of Sensors

- Sensors attach via daughtercard

- Weather

- Temperature
- Light
- Air Pressure
- Humidity

- Vibration

- Tracking

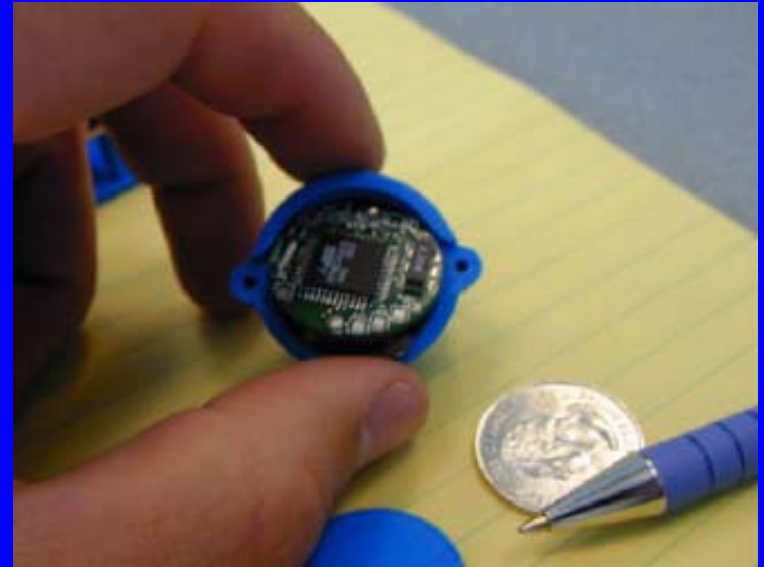
- Microphone
- Magnetometer

- GPS



Why Now?

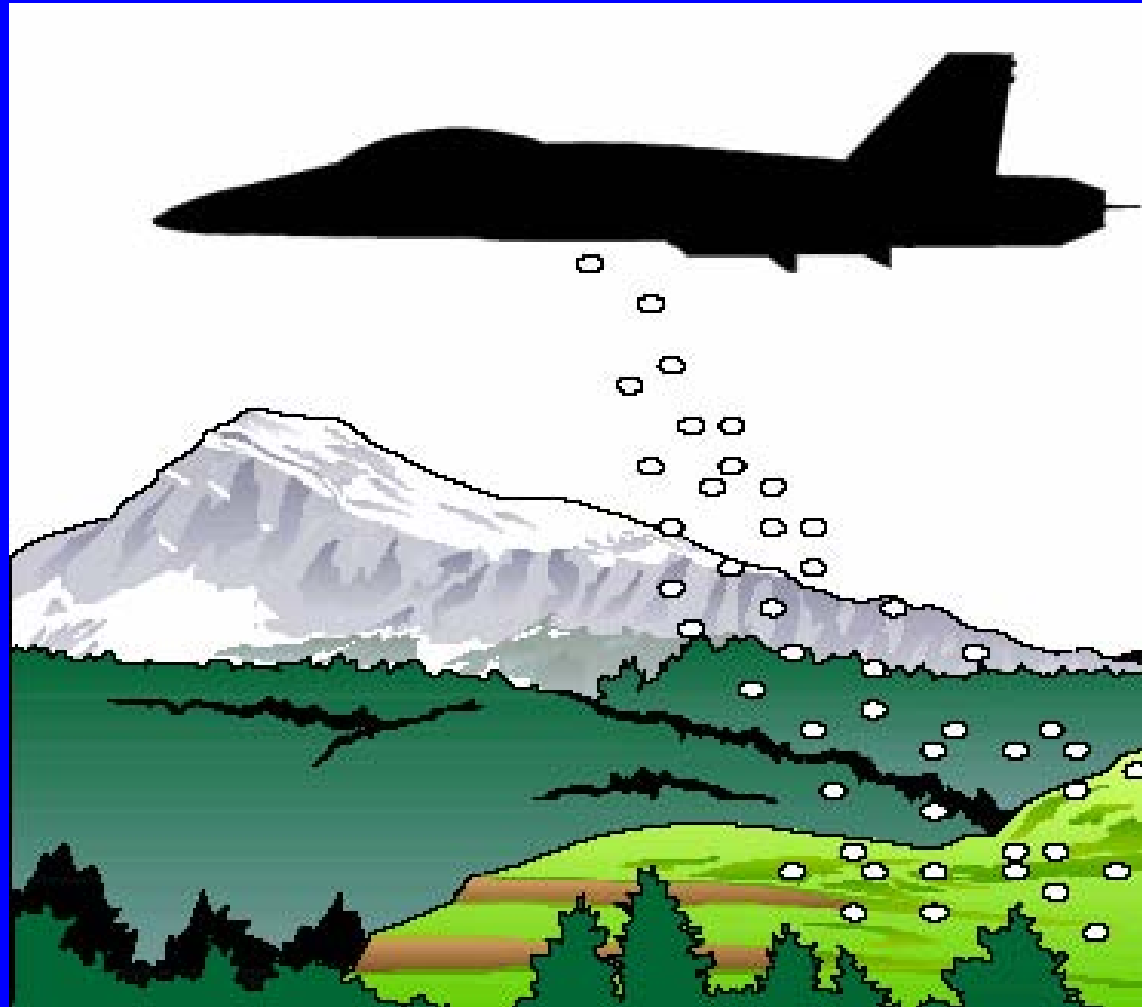
- Commoditization of radio hardware
- Low cost -> many/tiny
- Real application for ad-hoc networks



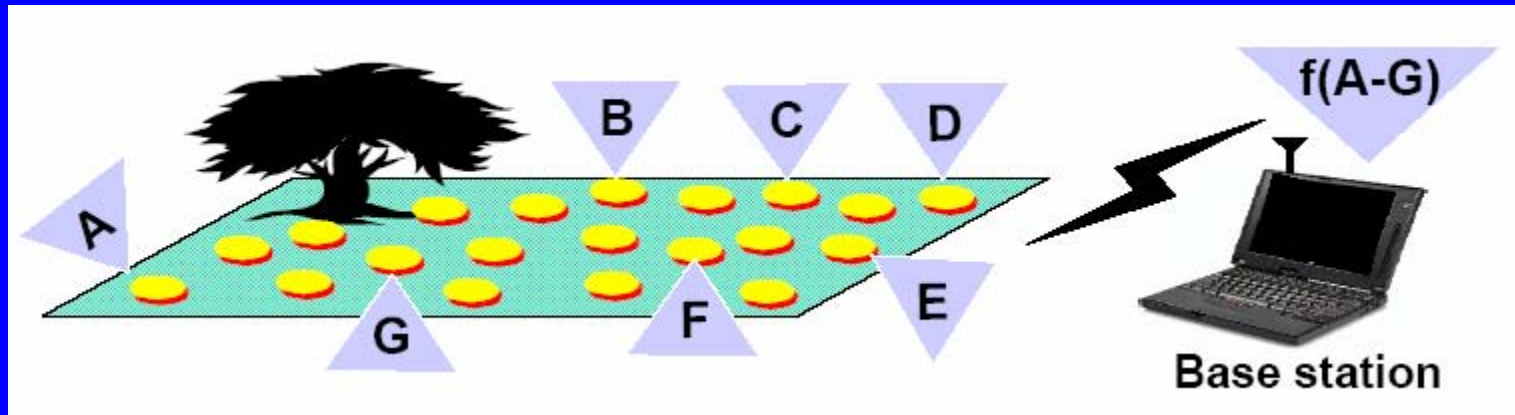
- Variety of novel applications: scientific, industrial, commercial
- Great platform for mobile and ubiquitous computing experimentation

Deployment

Micro-sensor nodes could be dropped from planes to enable monitoring of remote or dangerous areas



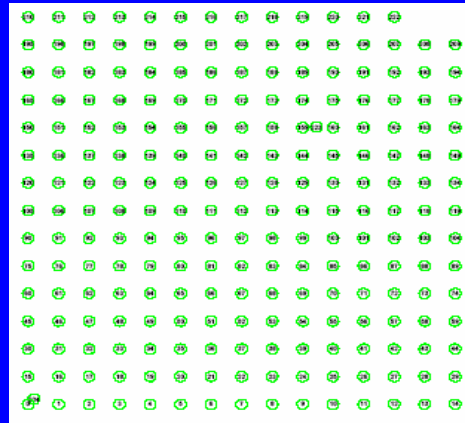
A Wireless Sensor Network



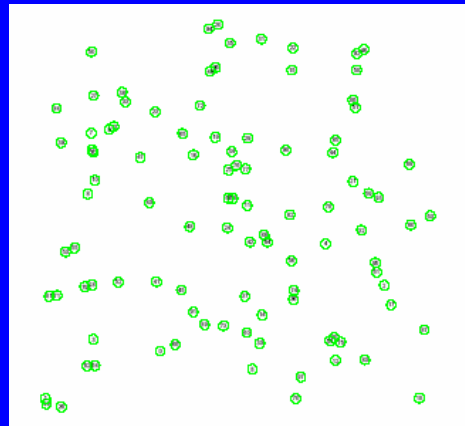
Each node obtains a certain view of the environment. By intelligently combining the view of the nodes, the end-user can remotely monitor events in the environment.

Challenges in Sensor Networks

- Ad-hoc deployment
- Little remote assistance
- Energy constraints
- Limited bandwidth
- Failure recovery



Grid
Deployment



Random
Deployment

Research Overview

The technology is still in its early stage and sensor network environments, inherently different from the internet, pose unique challenges to systems researchers.

We focus on

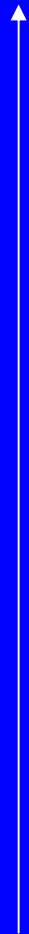


Business Models


Application Layer

Network Layer

Physical Layer

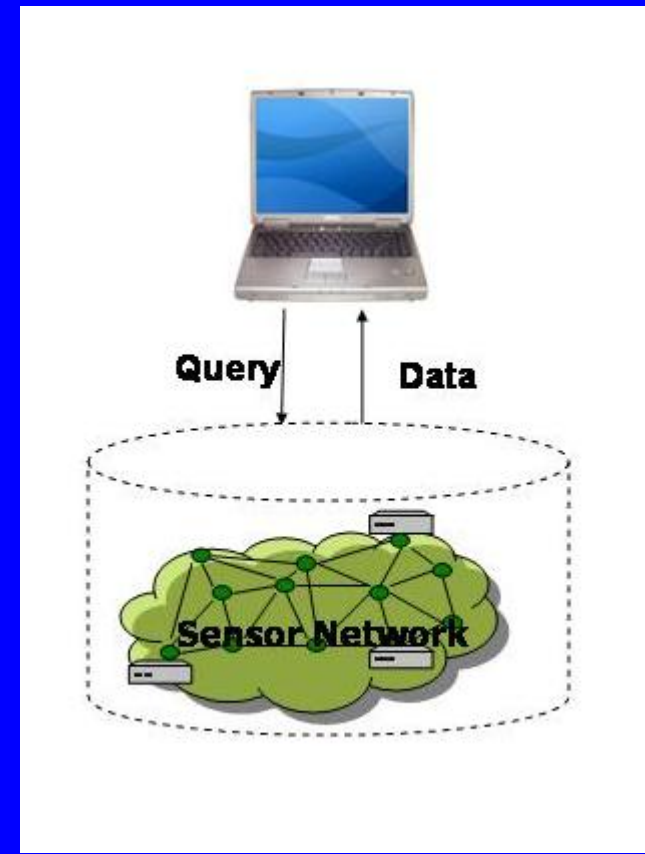


Problem Motivation

- Sensors generally do not store data and are preprogrammed to send their data to the base-station after every 's' seconds.
- Accessing the data collected by sensor networks would be like drinking from a fire hose, only worse! 
- A query based approach is desirable where users are provided with only as much information as they asked for.

Query based network protocol

- How to efficiently locate the sensor node that stores a particular data item?

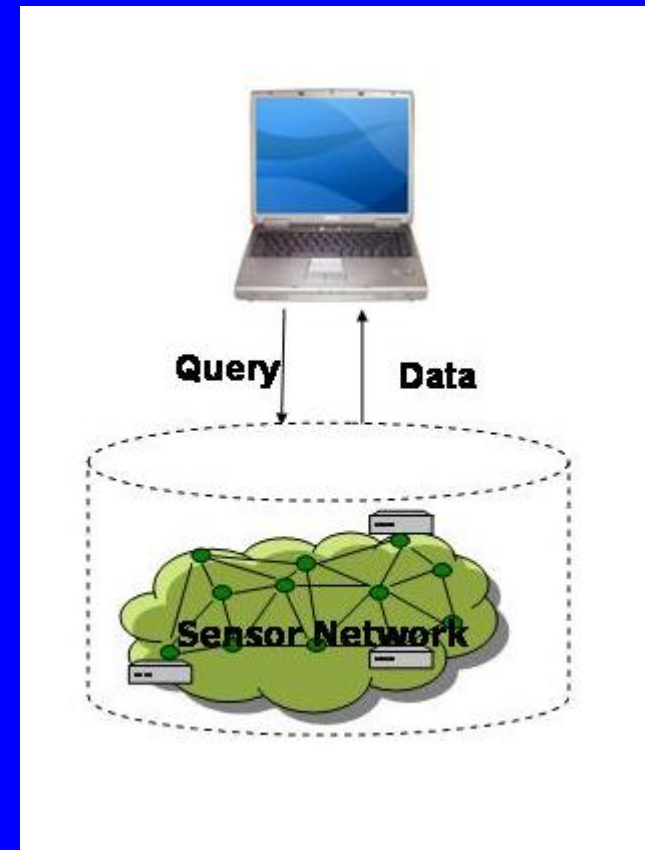


Query based network protocol

- How to efficiently locate the sensor node that stores a particular data item?

Distributed hash table (DHT) based Internet peer-to-peer (P2P) protocols provide near-optimum data lookup times for queries

However, DHT based protocols are widely considered not suitable for sensor networks.



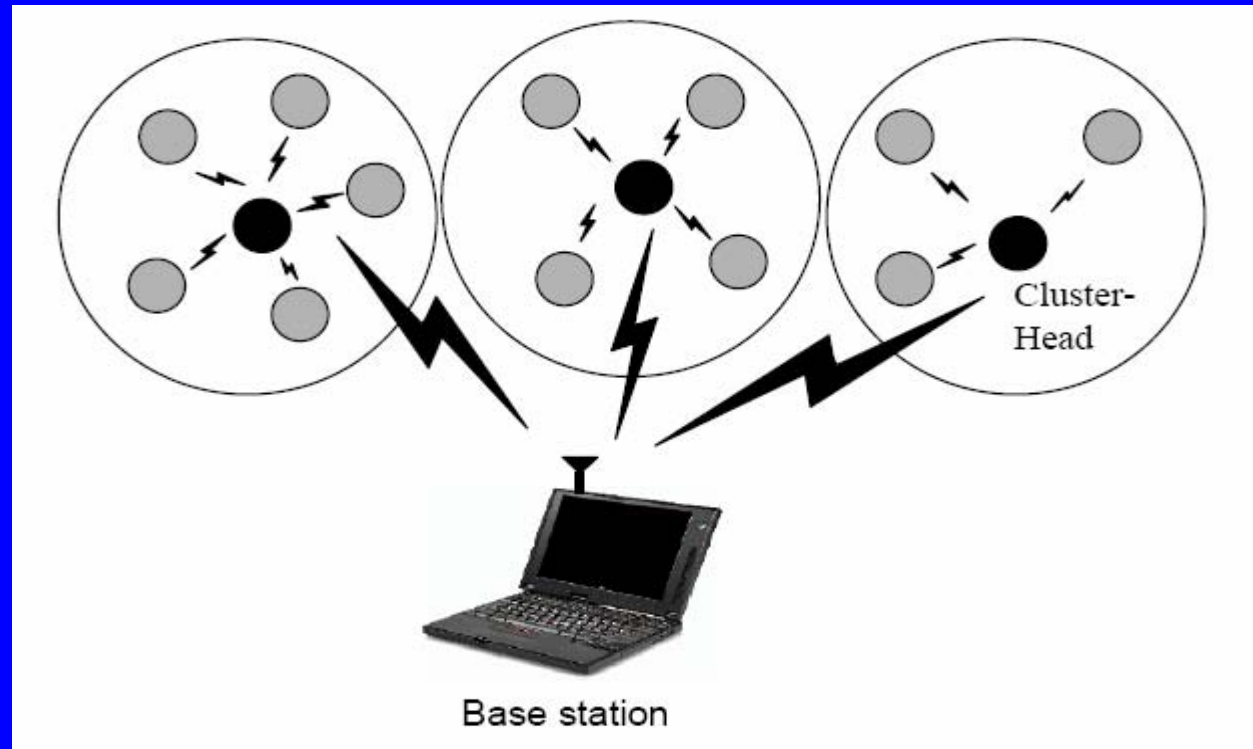
DHT not suitable for Sensor Networks?

- (1) Node interconnections, in DHT approaches, are independent of their proximity in the physical network topology
- (2) Maintaining routing information for all pairs of nodes becomes expensive in energy-constrained sensor network environments
- (3) The unique IP address of each node in the Internet is used for obtaining unique node identifiers, whereas sensor nodes are generally not named

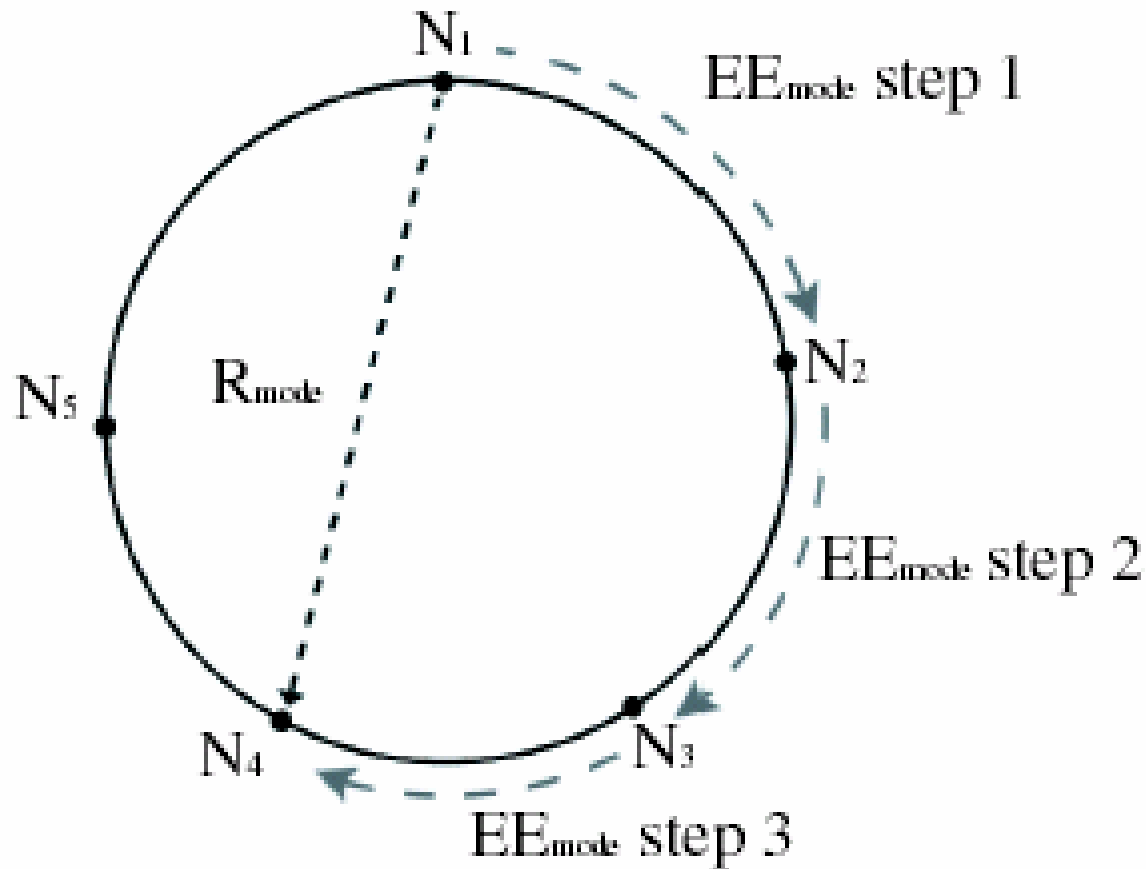
Clustering

In clustering, data are passed from the nodes to the cluster heads who forward the data to the base station

CSN is a clustering-based network protocol.



CSN modes of operation



Simulation & Experiment Results

- Test bed developed in C/C++
- Simulator uses First Order Radio Model:

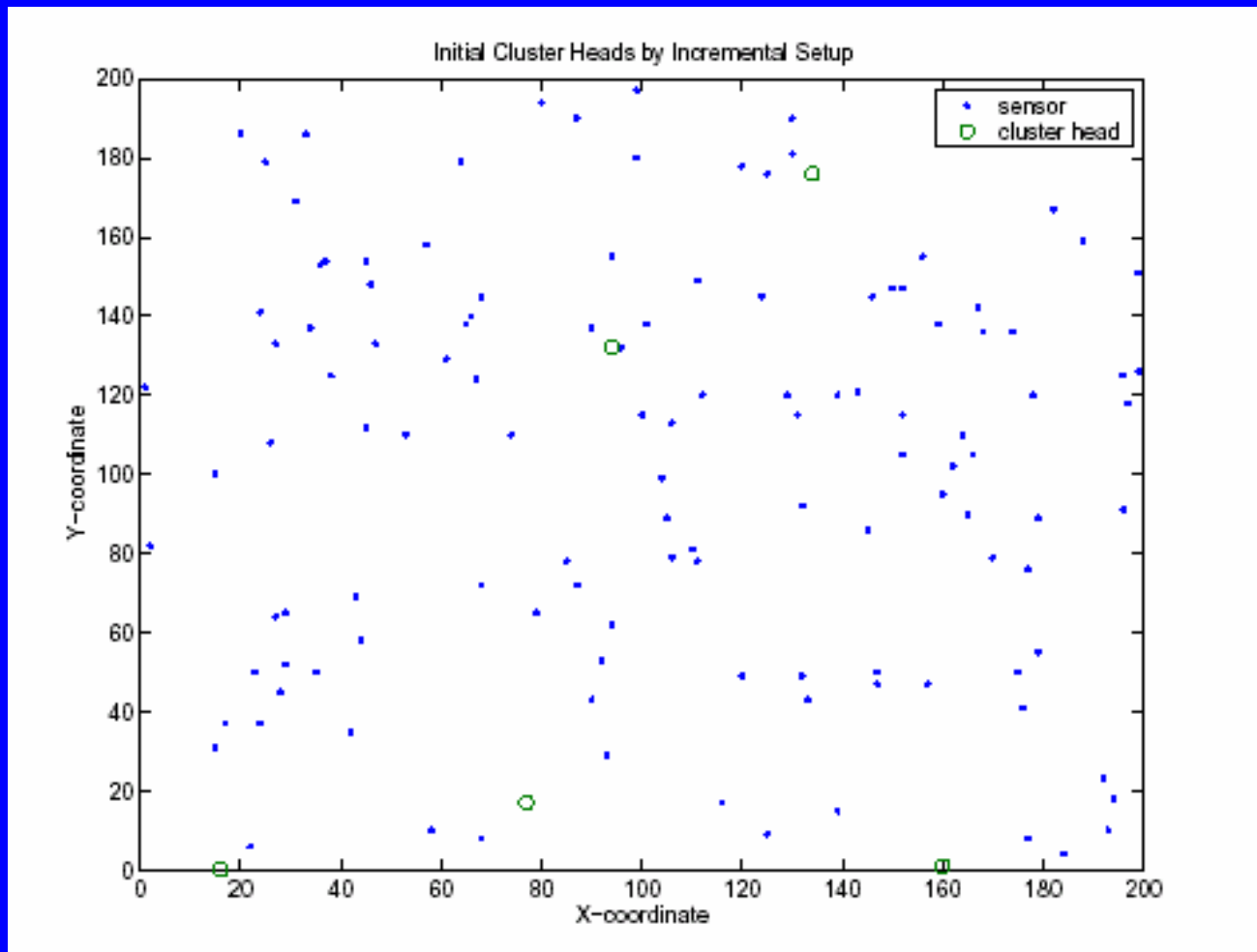
$$E_{\text{transmit}}(k,d) = E_{\text{electric}} * k + E_{\text{amplifier}} * k * d^2$$

$$E_{\text{receive}}(k) = E_{\text{electric}} * k$$

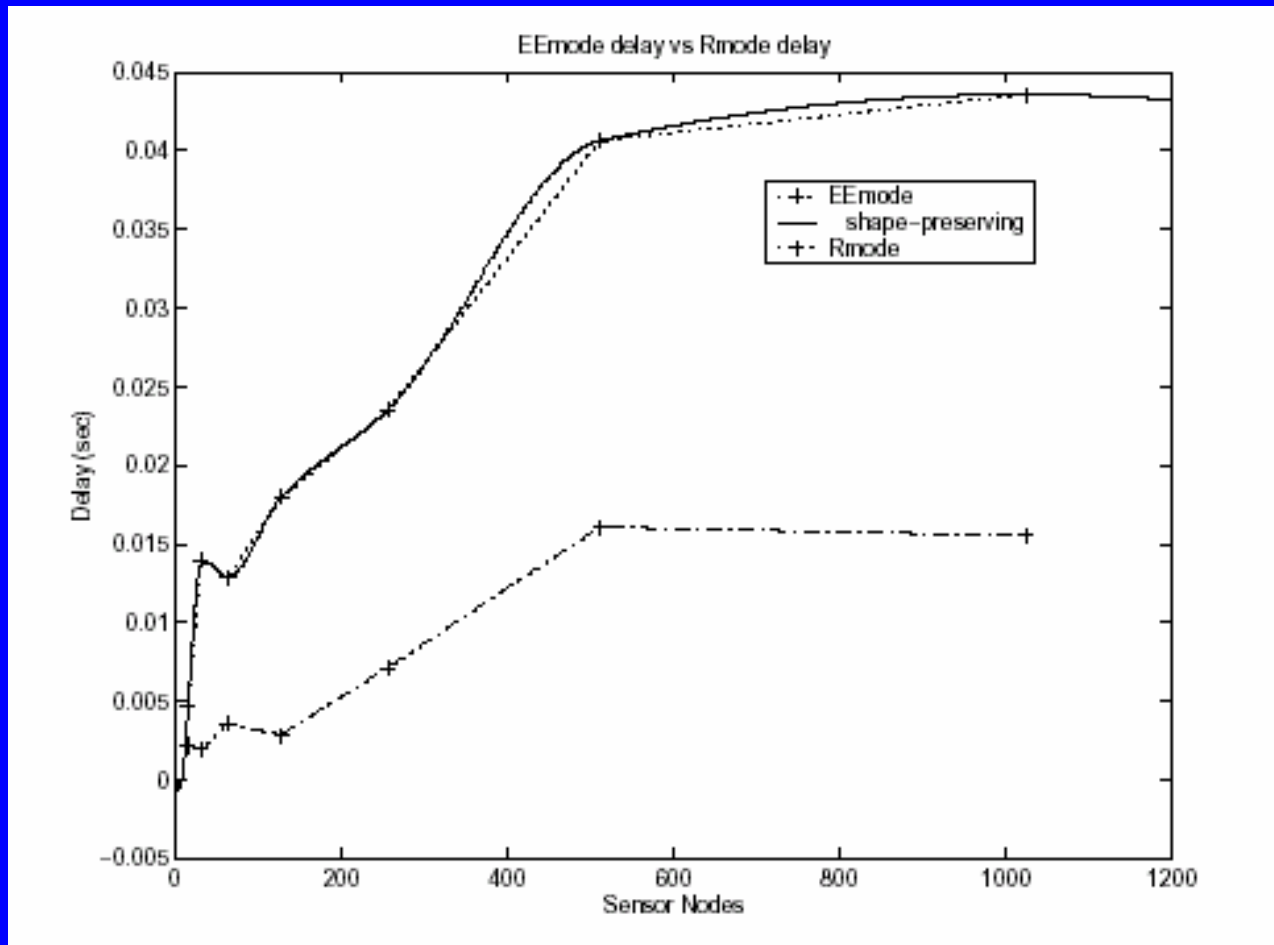
K implies k-bits per packet

d = distance

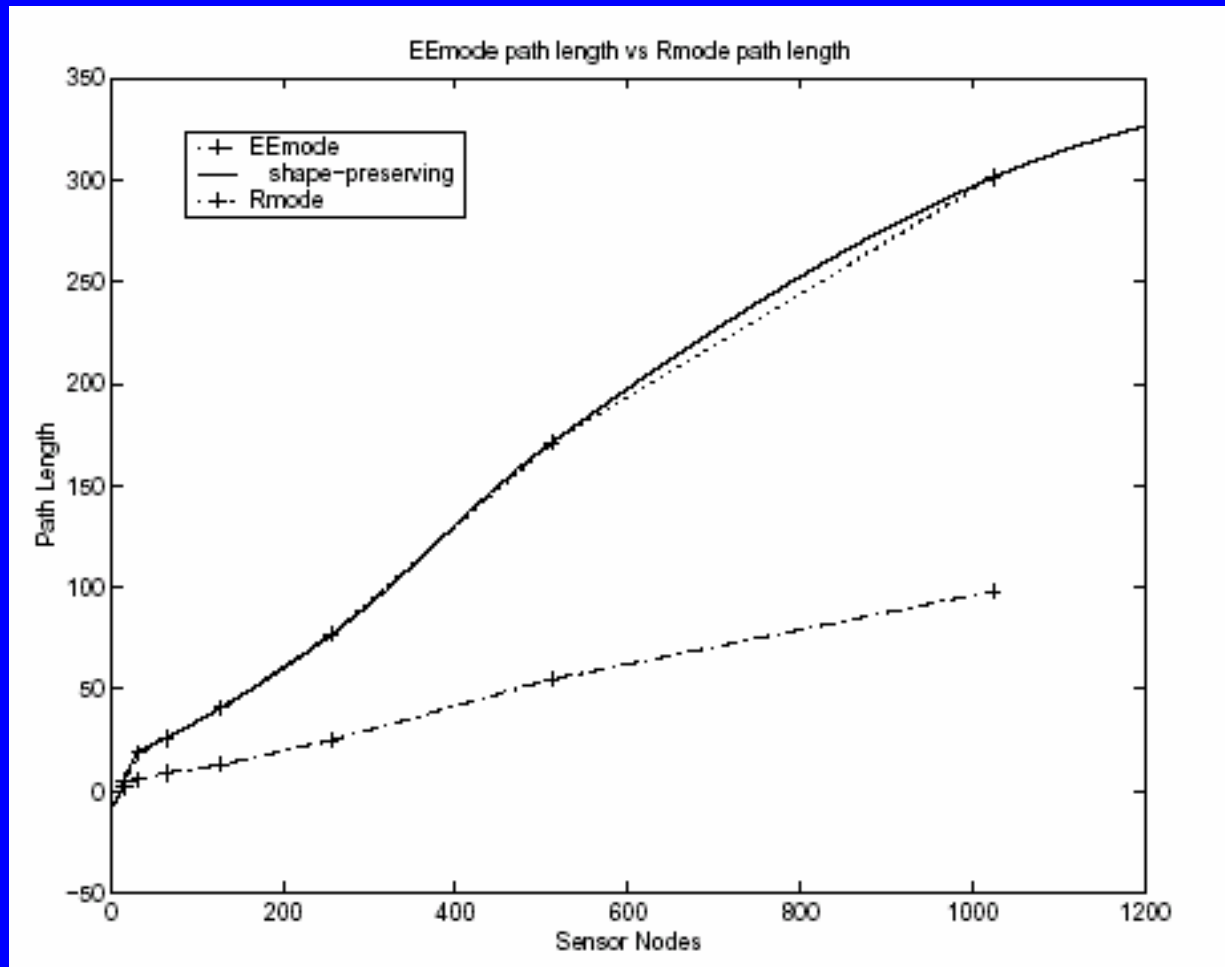
Random Deployment of Nodes



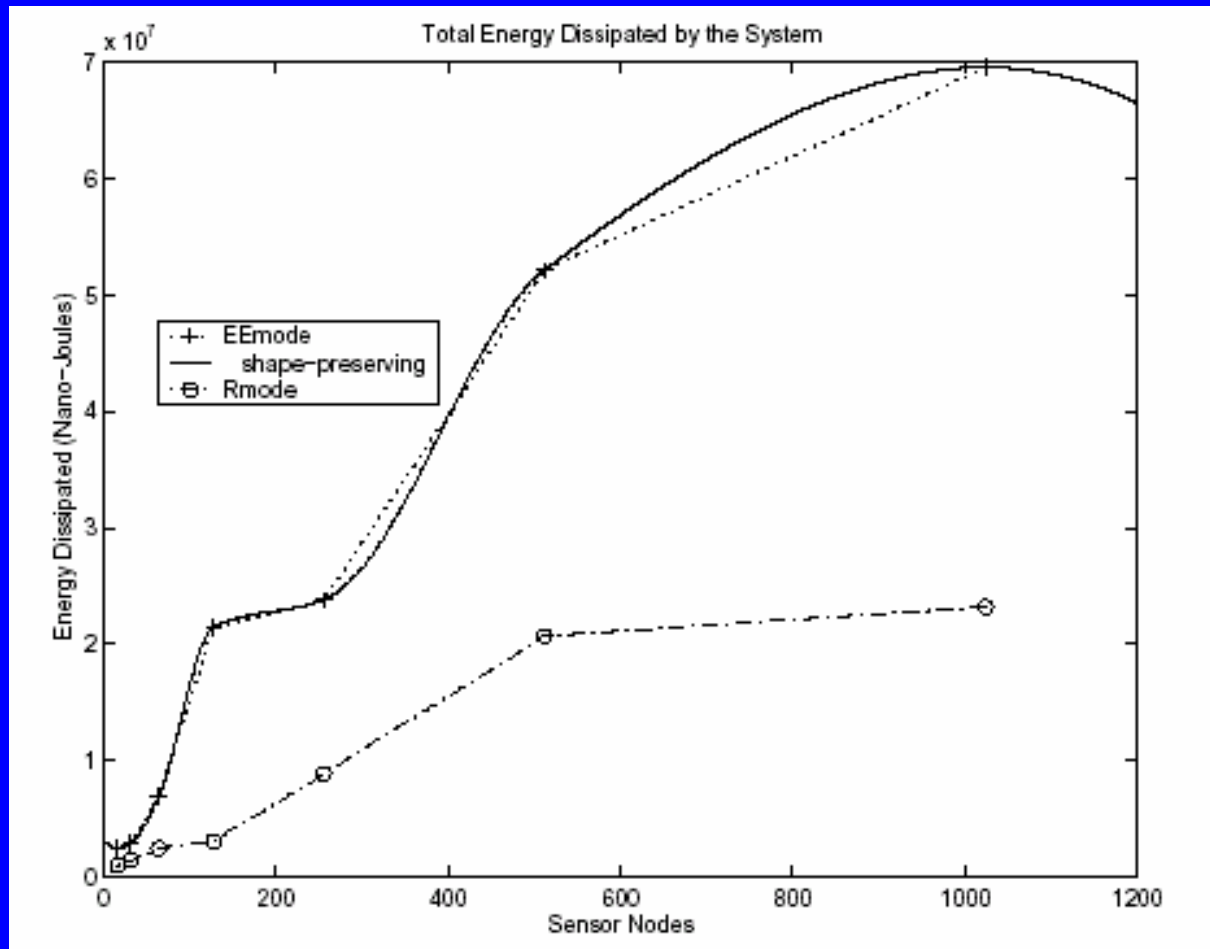
Delay



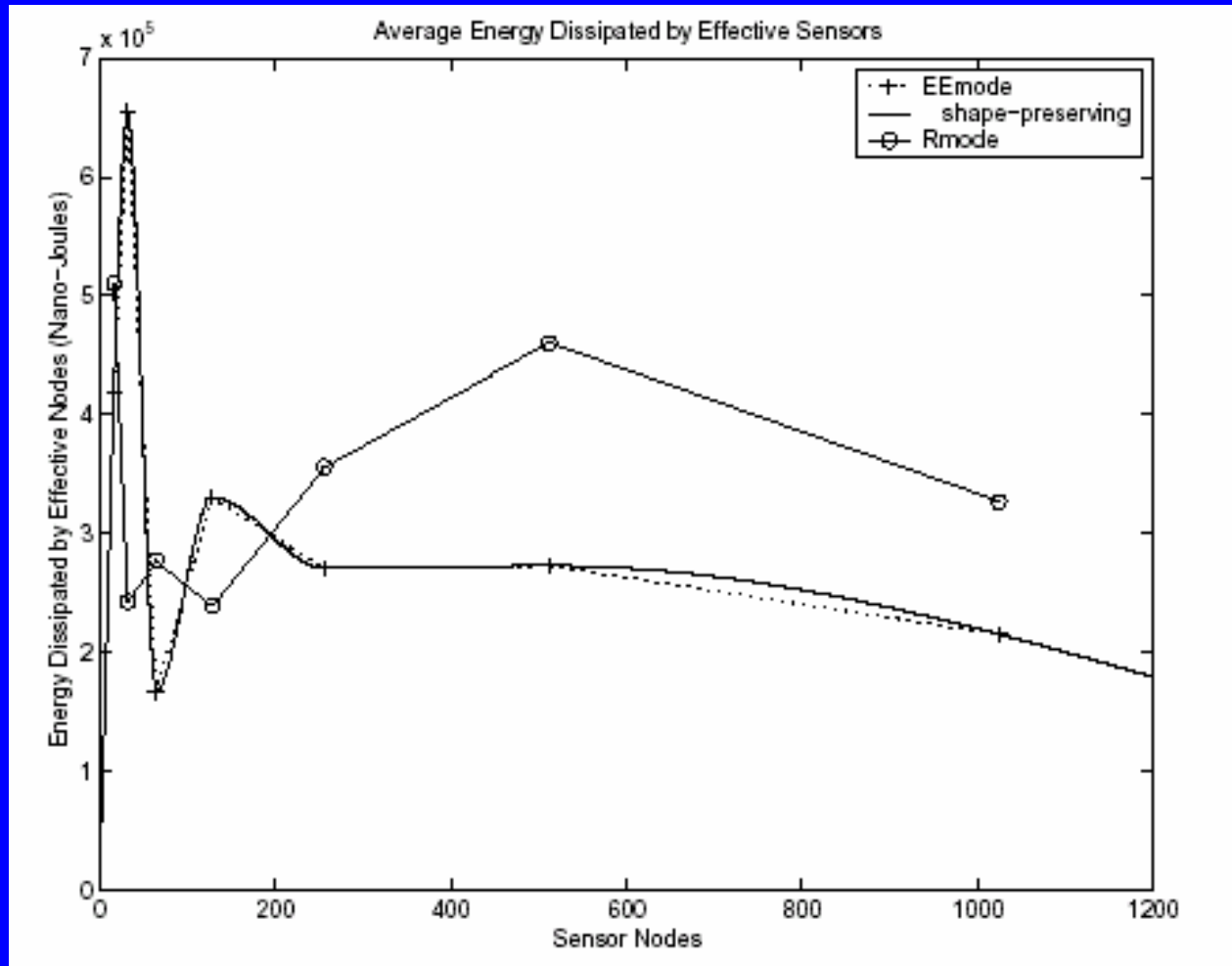
Path Length



Total Energy Dissipated (By System)



Average Energy Dissipated (Each Node)



Conclusion & Future Work

- DHT based approaches, e.g CSN, could be used in sensor networks to efficiently serve dynamic queries of data
 - CSN *Robust mode* performs data lookup with a bound of $O(\log N)$
 - CSN *energy-efficient mode* performs data lookup with the least amount of energy dissipated by each node
 - CSN scales well to large scale networks
-
- Currently, incorporating mobility into CSN
 - Carrying out experimentations on real test beds (using Berkeley MOTES)
 - Exploring means to increase storage capacity of individual sensors

Further Information

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Thank You!