Extending Network Lifetime for Precision-Constrained Data Aggregation in Wireless Sensor Networks
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Introduction

- Wireless Sensor Network
- Base Station
- Application
- ... energy consumption!
Problem Statement

- Network lifetime is important.
- How to optimize network lifetime?

- Lifetime of sensor nodes depends on:
  - the changing pattern of sensor readings
  - the residual energy of sensor nodes
  - the communication cost between sensor and base
Related Work

- Routing and media access is researched a lot
- Exact query processing over sensed data too (but with little attention to energy efficiency!)
- The trade-off between energy and precision has been researched (but only on individual sensor nodes)
- Algorithmic design is often not general enough
The model

• Three commonly used types of aggregations:
  • SUM
  • COUNT
  • AVERAGE
• Error bound (EB) per node is the preciseness
• The total error bound $E$ is the sum of the error bounds
• Nodes only send updates if the value changed enough
Precision Allocation in Single-Hop Networks

- Precision Allocation is the allocation of EB per node
- Sensors communicate with the base station directly
- The chain is as strong as the weakest link
- An $EB$ of 0 for sensors is possible
  - (high energy nodes, slow change)
- Sensors with faster changing data, have an $EB > 0$
Precision Allocation in Single-Hop Networks - Adaptive Approach

• Sensor nodes report to the base station
  • sample error bounds
  • with associated normalized energy consumption
• Base station optimizes the precision allocation
  • only using the sample error bounds!
• Sample precision allocations
  • optimal: optimal sample precision allocation
Precision Allocation in Multi-Hop Networks

- Base station out of range? → Multi-hop network!
- Sensor nodes in tree formation, root at base station
- *local* and *gross* EB
  - *local*: local readings per sensor node
  - *gross*: total error bound of the sub-tree at node
- Still only send data at updates!
Precision Allocation in Multi-Hop Networks - Adaptive Approach

- Same as Single-Hop networks, but then layered
- Leaf nodes act exactly the same, \( local \ EB = gross \ EB \)
- Intermediate sensor nodes act like the base station
  - Gain \( sample \ precision \ allocations \) from the leaves
  - Calculate \( optimal \ sample \ allocation \) for the \( gross \ EB \)

- Continue this method till the base station is reached!
Performance Evaluation - Setup

• Small amount of nodes (10 and 20)

• A new simulator based on:
  • ns-2 (version 2.26)
  • NRL’s sensor network extension

• Used real data (Air Temperature and Wind speed)
• Base station computes AVERAGE
Performance Evaluation - Results

Adaptive PA, the proposed algorithm

Network Lifetime (Time Units)

Number of Sample Error Bounds (m)

AT Trace
WIND Trace
Adaptive-PA needs some adjustment time, but then it has the best projected network lifetime.
Performance Evaluation - Results

If the designated error bound is increased, the difference in performance is even greater.
Conclusion

Exploiting the tradeoff between data quality and energy consumption pays off!

- Uniform precision allocation does not perform well
- Extending network lifetime needs balancing of energy
- The adaptive precision scheme outperforms the rest!
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Questions?
Critical notes

- Implementing other aggregations (such as MIN and MAX) are noted as “future work”
  - MIN and MAX might be doable, but what about median?
- How does this algorithm scale?
  - Only tested for low number of nodes
- In a tree, the topmost nodes will be using more energy… no notion of this or if the effect is noticeable.
Performance Evaluation - Results

Fig. 8. Energy Consumed at Different Sensor Nodes (Single-Hop Network, $E = 0.4$)
Performance Evaluation - Results

Fig. 7. Network Lifetime vs. Designated Error Bound (Single-Hop Network)