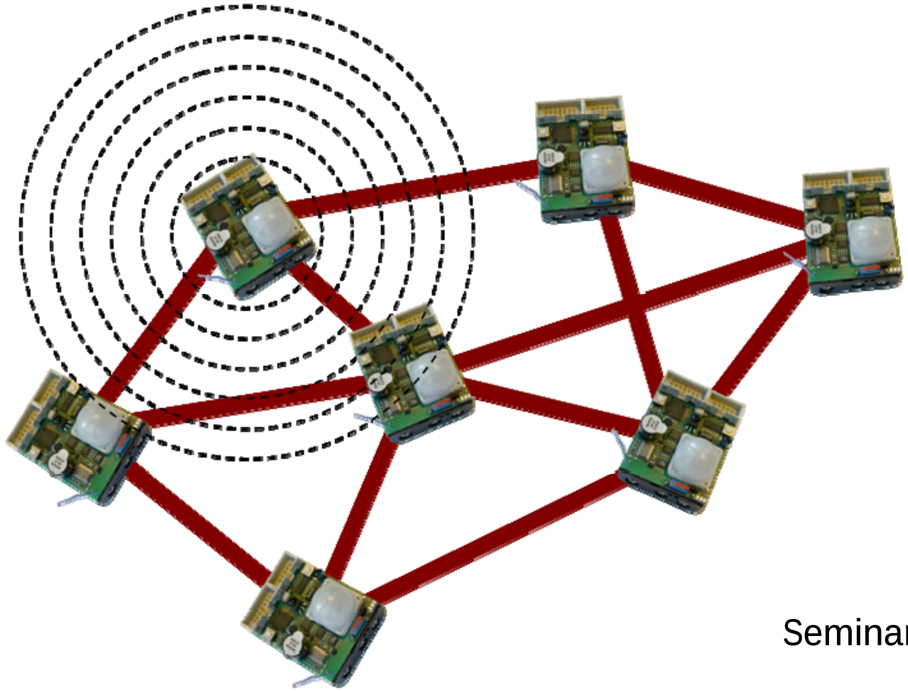
Extending Network Lifetime for Precision-Constrained Data Aggregation in Wireless Sensor Networks

Xueyan Tang, Jianliang Xu



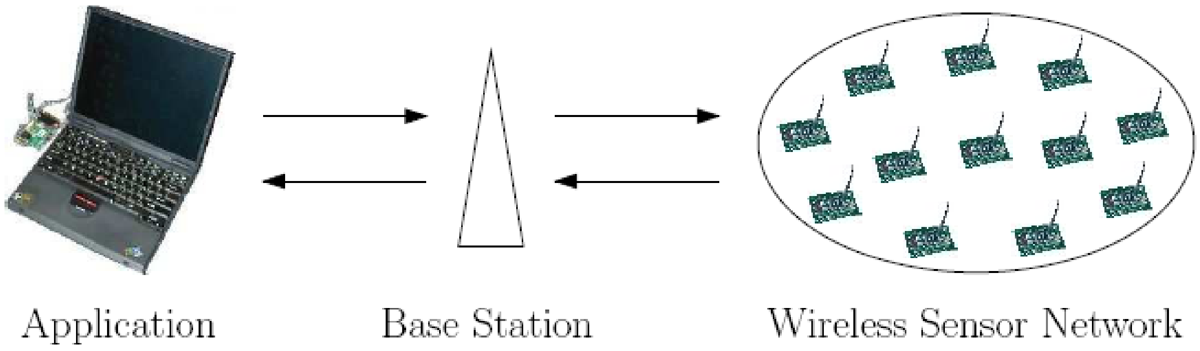
Seminar Wireless Sensor Networks
Johannes Bertens

18-3-2009

Delft University of Technology

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

TU Delft

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

TU Delft

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

TU Delft

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*

TU Delft

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!

TU Delft

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 leafs
  - Calculate *optimal sample allocation* for the *gross EB*

- Continue this method till the base station is reached!

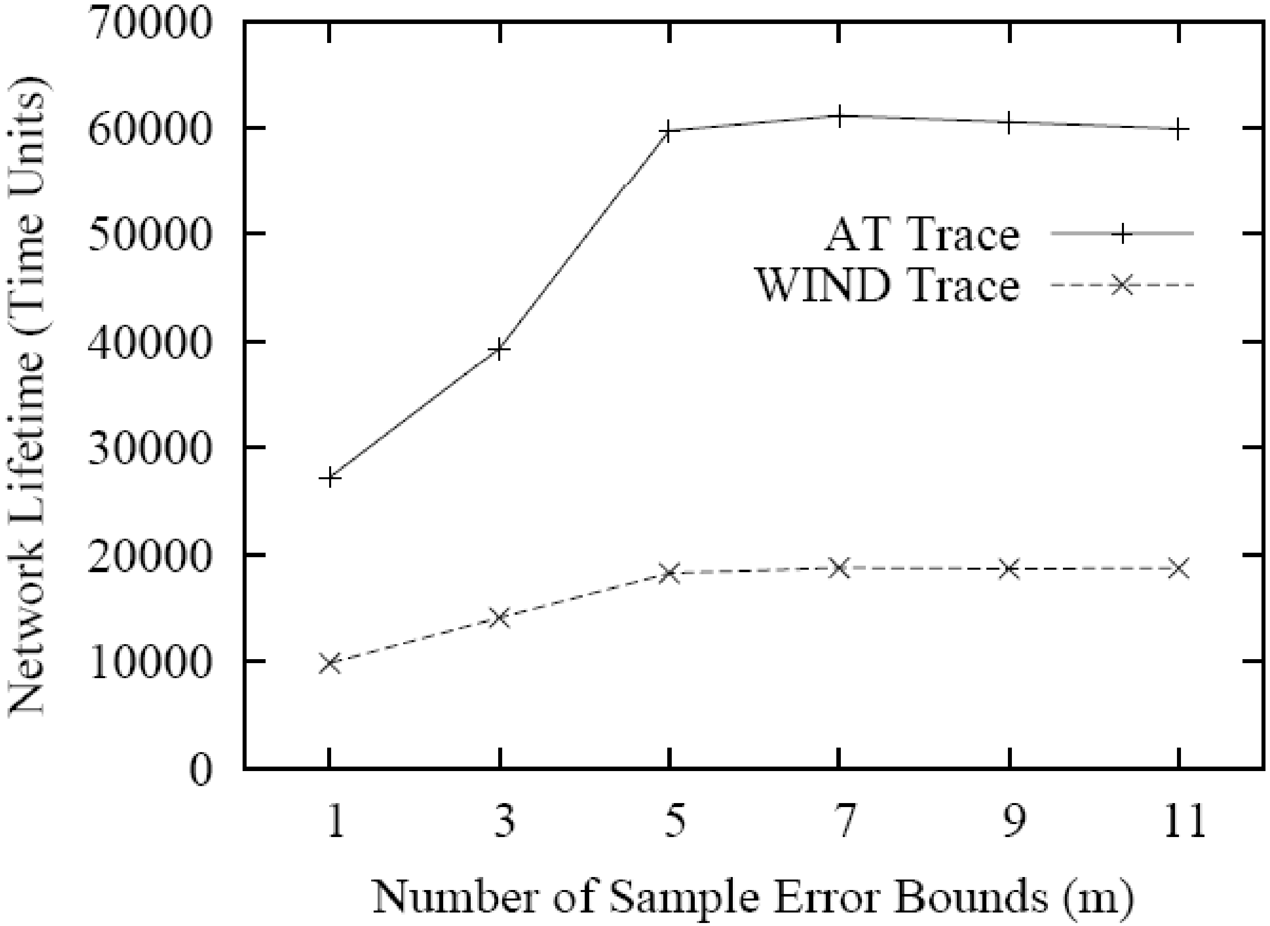
Performance Evaluation – Setup

- 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

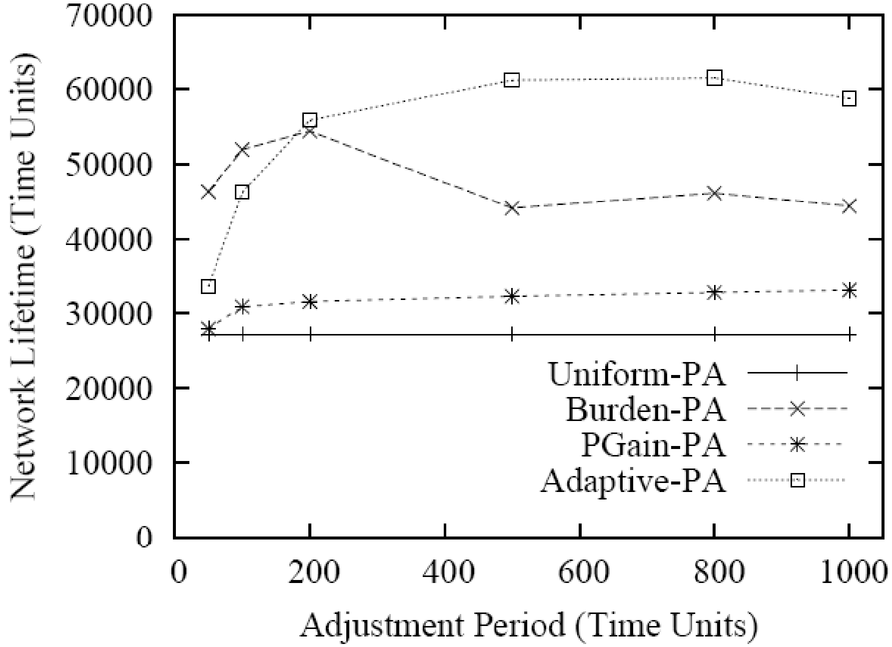
Performance Evaluation – Results



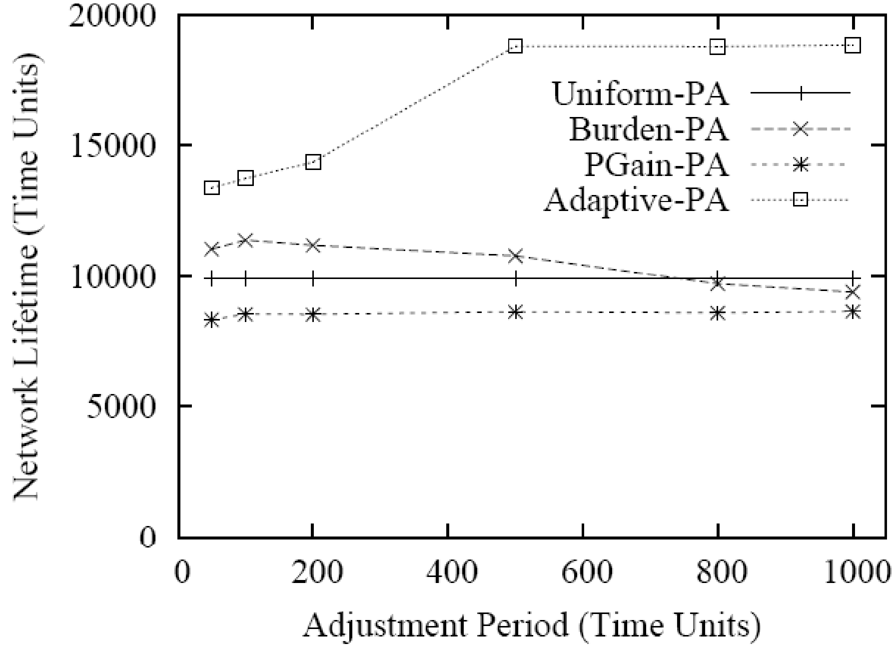
Adaptive PA, the proposed algorithm

TU Delft

Performance Evaluation – Results



(a) AT Trace



(b) WIND Trace

Fig. 6. Network Lifetime vs. Adjustment Period (Single-Hop Network, $E = 0.4$)

Adaptive-PA needs some adjustment time,
but then it has the best projected network lifetime

Performance Evaluation – Results

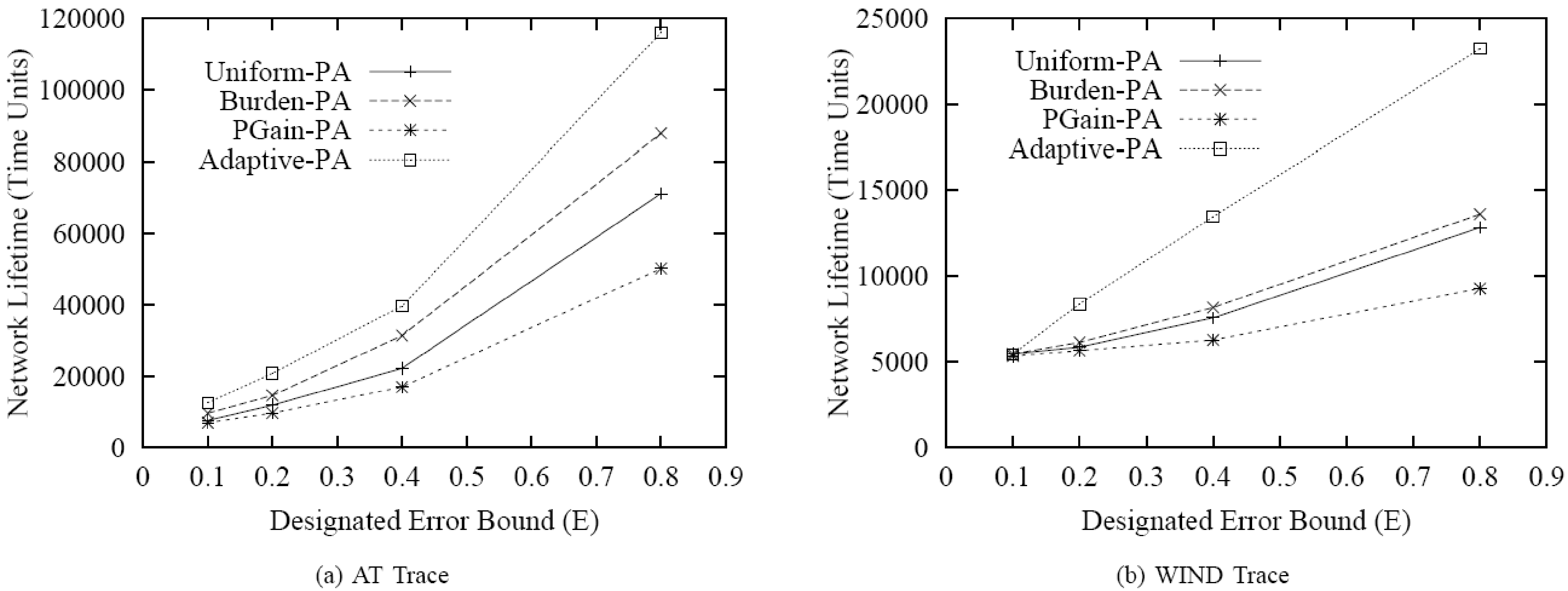


Fig. 9. Network Lifetime vs. Designated Error Bound (Multi-Hop Network)

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

TU Delft

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!

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

Xueyan Tang, Jianliang Xu

Questions?

18-3-2009

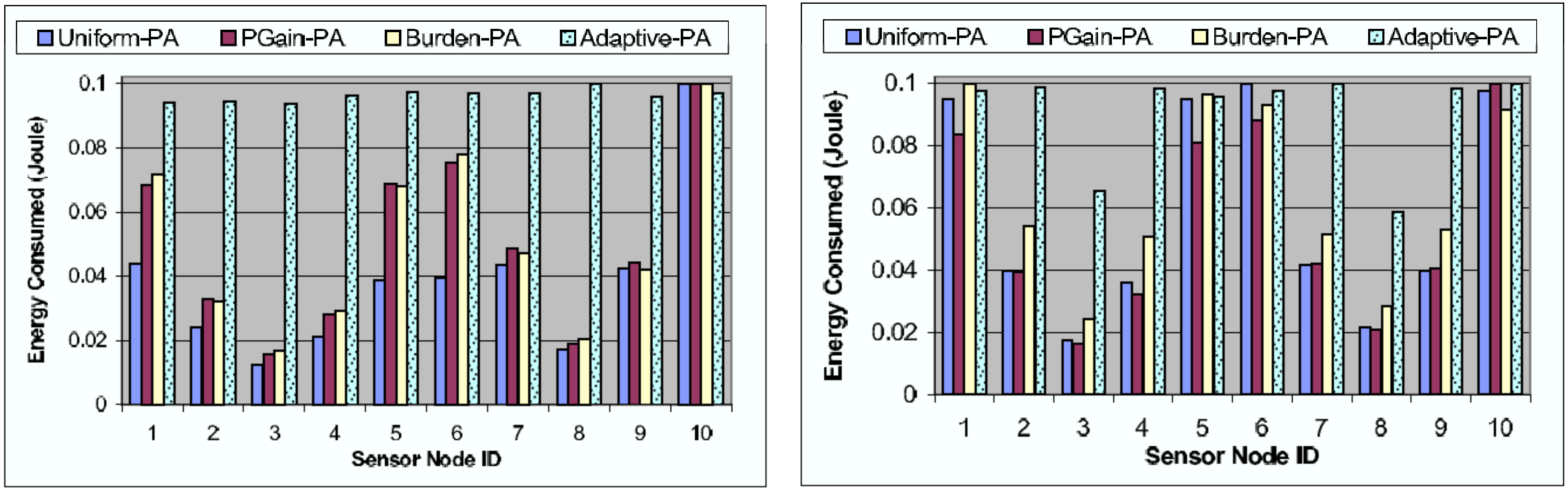
Seminar Wireless Sensor Networks
Johannes Bertens

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 noticable

TU Delft

Performance Evaluation – Results



(a) AT Trace

(b) WIND Trace

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

TU Delft

Performance Evaluation – Results

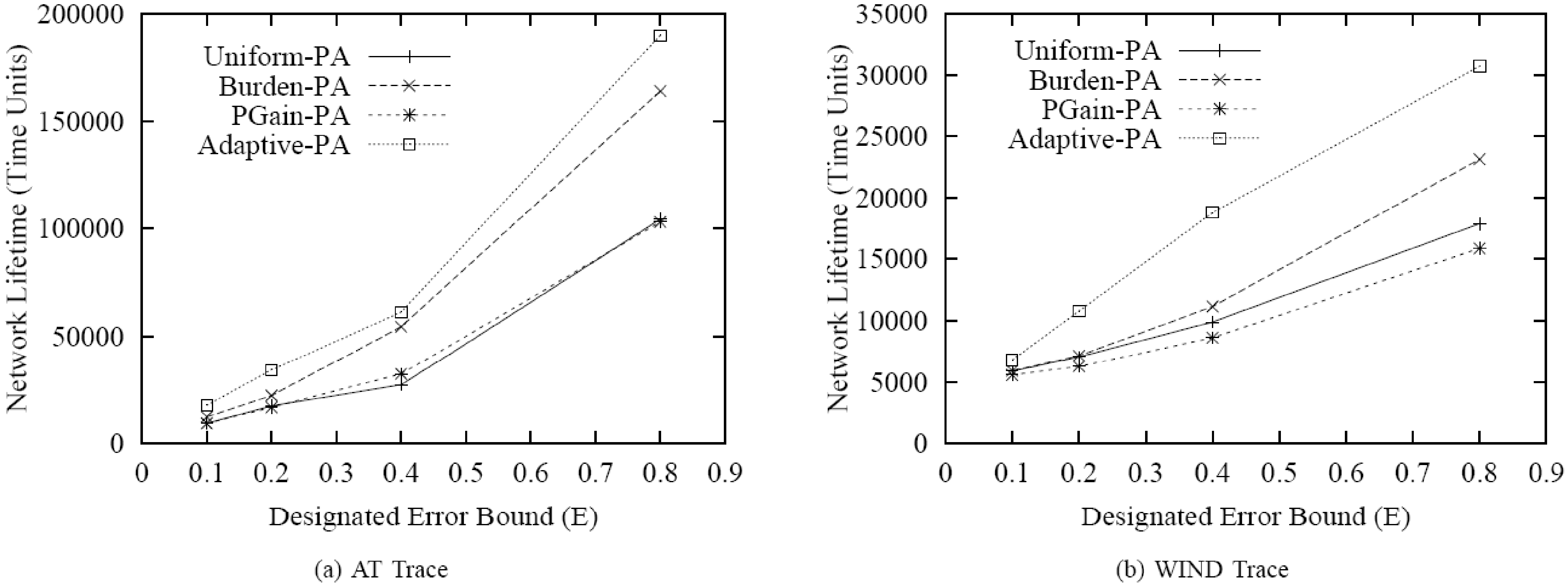


Fig. 7. Network Lifetime vs. Designated Error Bound (Single-Hop Network)