Density, accuracy, delay and lifetime tradeoffs in wireless sensor networks – A multidimensional design perspective

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Introduction: How is designing sensor networks different?

- **Network centric v/s device centric**
  Collaborative behavior is more important than individual node.
- **Multiple parameters of interest**
  Number of nodes, Lifetime of the network, Accuracy of obtained results, Delay in obtaining the results, Monitored area by the network etc.
- **Traditional design paradigm does not works!**
  Focus is on run time protocol optimization and individual device improvement.
- **Novel design paradigm**
  Should take into account the global picture and optimizations should be performed on the network scale.

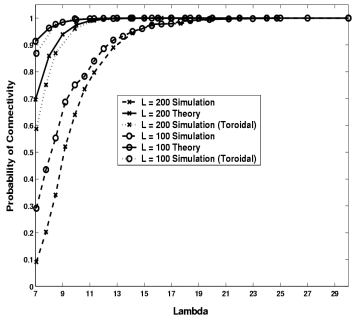
Problem Description: Develop a design time methodology for sensor networks

- **Identify four QoS parameters from users perspective**
  Density, Accuracy, Delay and Lifetime.
- **Analyze the QoS parameters individually**
  Develop mathematical models and verify them via simulations.
- **Analyze the interaction between these QoS parameters**
  Study tradeoffs between them to make judicious design time choices.
- **Develop a design time recipe**

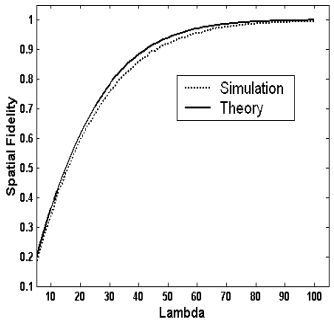
Proposed Solution: Design time recipe for sensor networks

QoS parameters

- **Density**
  - Average number of neighbors per node.
  - Network topology is more important than the total number of nodes.
  - *Network connectivity* imposes a lower bound.
  - *Budget* imposes an upper bound



- **Accuracy**
  - *Temporal* – how often data is generated.
  - *Spatial* – how well an area is covered
  - Define *spatial fidelity* as weighted average of nodes covering an area
  - *Shaping function* associates the confidence which a user places in an observation.

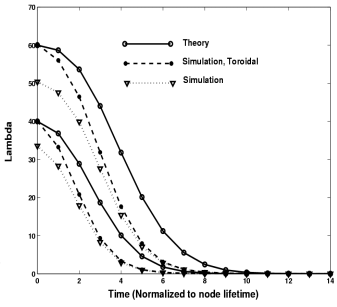


- **Delay**
  - Depends on number of hops the data takes and the latency per hop.
  - Number of hops depend on the diameter of underlying graph
  - Latency per hop depends on transmission delay and MAC overhead delay
  - Several topology management schemes like STEM have been proposed which tradeoff the latency or delay to improve the lifetime.
  - At design time we need to take into account any gains in lifetime that can be achieved if no latency constrained are imposed

- **Lifetime**
  - A network is rendered useless if either the accuracy falls or connectivity is lost.
  - Define utility of a to represents overall useful information derived from the network

$$U(t) = S(\lambda(t)) * P_{connectedness}(\lambda(t))$$

$$\lambda(mT) = \lambda((m-1)T) - \lambda(0).\frac{M^{m-1}e^{-M}}{(m-1)!}$$



Design time recipe

- User has fixed budget of 480 nodes.
- At least one node should report the intrusion to the end user.
- Objective is to maximize network lifetime.

Case I – Stringent latency bound

- Average end to end delay bound is 75ms.
- Because of strict latency bound only schemes like GAF can be used to improve the lifetime.

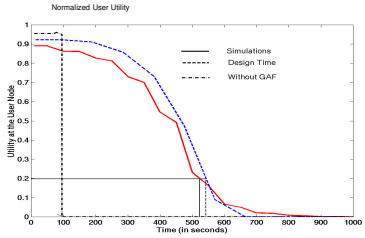


Figure 1: Stringent Delay Requirement

Case II – Loose latency bound

- Average end to end delay bound is 400ms.
- Designer can use schemes like STEM to improve network lifetime.

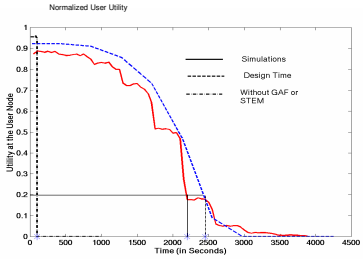


Figure 2: No Delay Requirement