Quality of service in wireless sensor networks: mechanisms for a new concept?

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Overview

- Services and their quality in WSN?
- How to express?
- How to realize?

Why QoS in WSN?

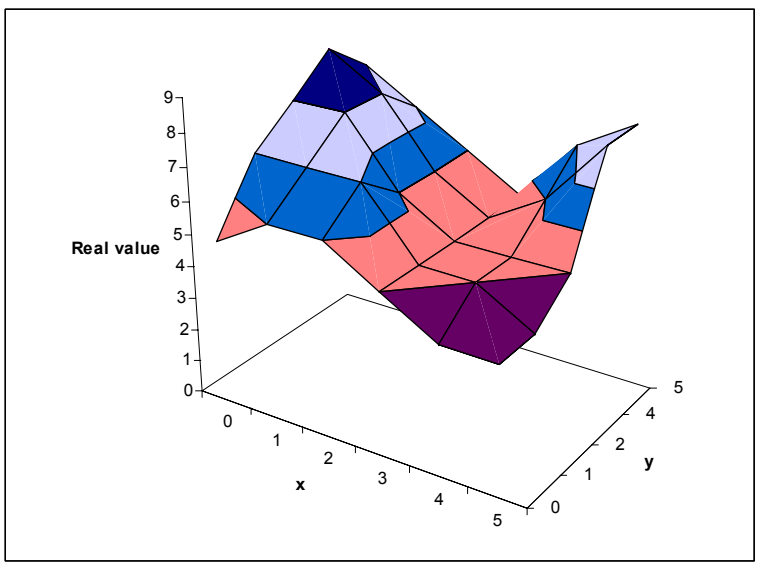
- Traditional QoS
  - Network level: Delay, throughput, jitter, etc.
    - Known to be largely irrelevant
  - Application level: Perceptual QoS metrics
    - Mean opinion score for voice, for example
    - Much more important and useful
  - Clearly, inadequate for WSN
- What are appropriate QoS metrics for WSN?
  - What is the *service* of a WSN?
  - What is its *quality*?

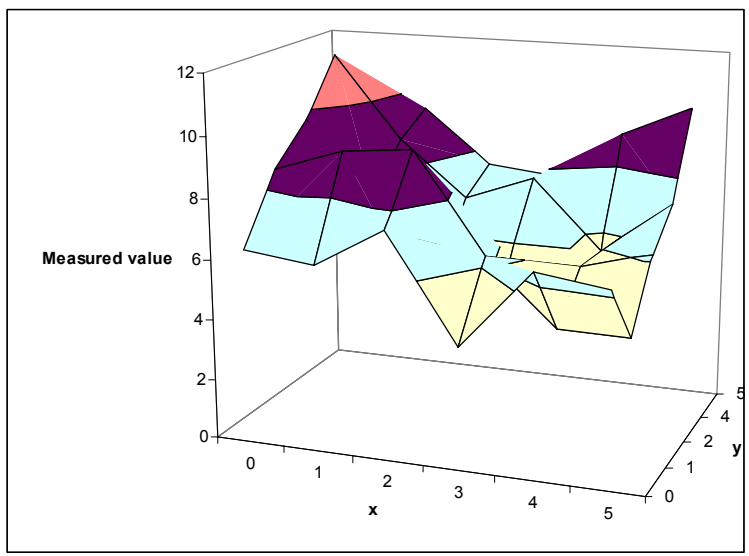
Service of a WSN

- Provide information
  - Measurements of some physical processes
  - Appropriately aggregated, condensed, put into perspective
  - "*People want answers, not numbers*" (S. Glaser)
- Make decisions
  - Decide how to control certain actuators
  - Actuators in networks will become increasingly important

Quality of information / decisions

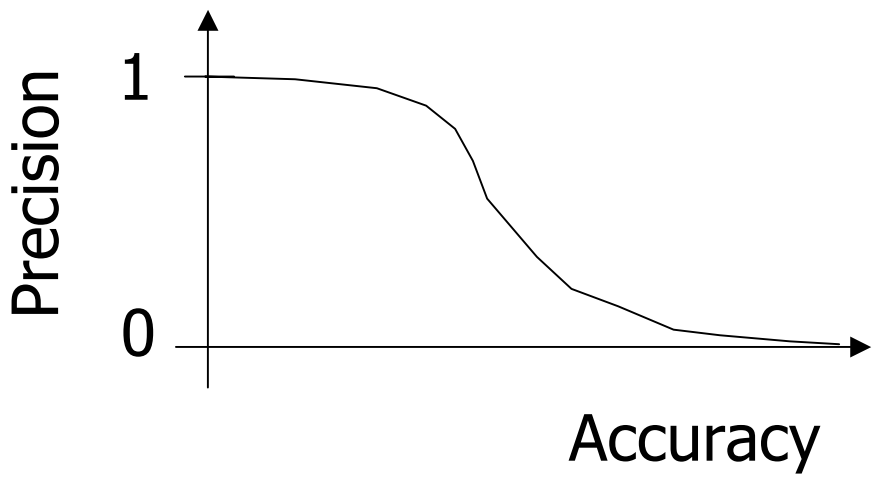
- Accuracy: Measure of the discrepancy between
  - The real-world values and the provided results
  - The correct/optimal decision and the taken one
  - Time is implicit part of accuracy
- Example: Use WSN to provide an approximate representation of a value field





Quality of information / decisions

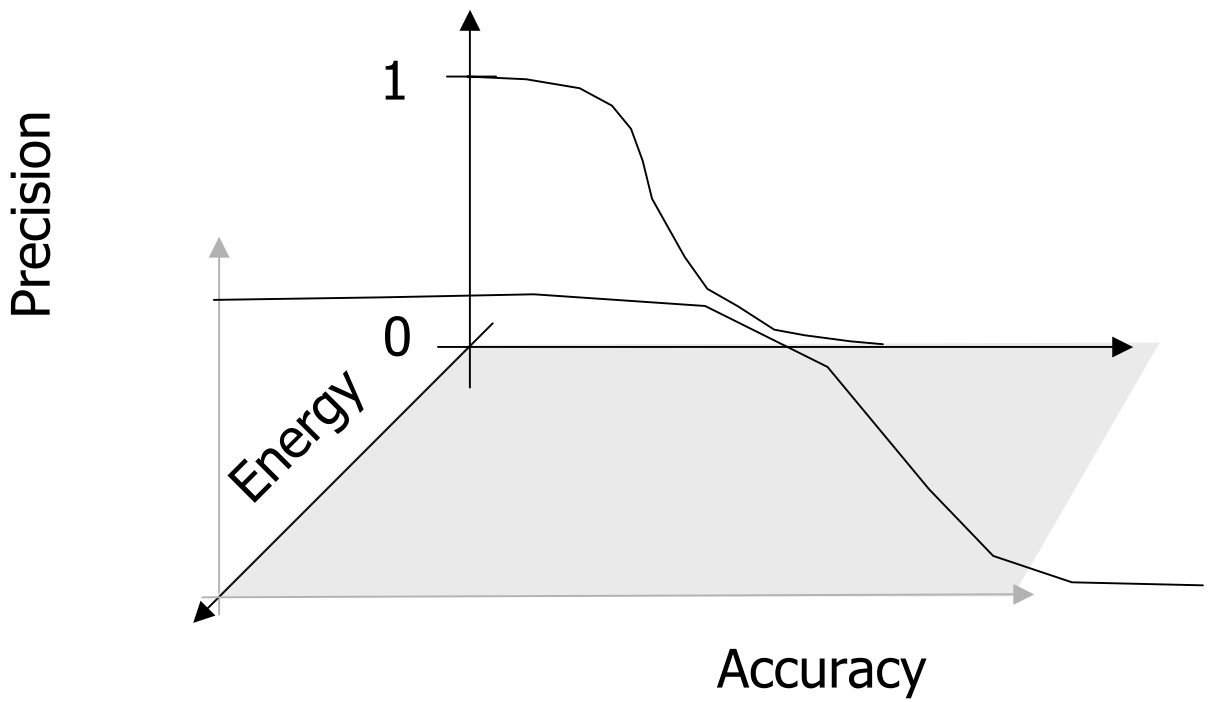
- Accuracy: Measure of the discrepancy between
  - The real-world values and the provided results
  - The correct/optimal decision and the taken one
  - Time is implicit part of accuracy
- Precision: Probability with which a given accuracy is achieved



- Better understanding of this curve is required!
  - Limited by: errors, time, …

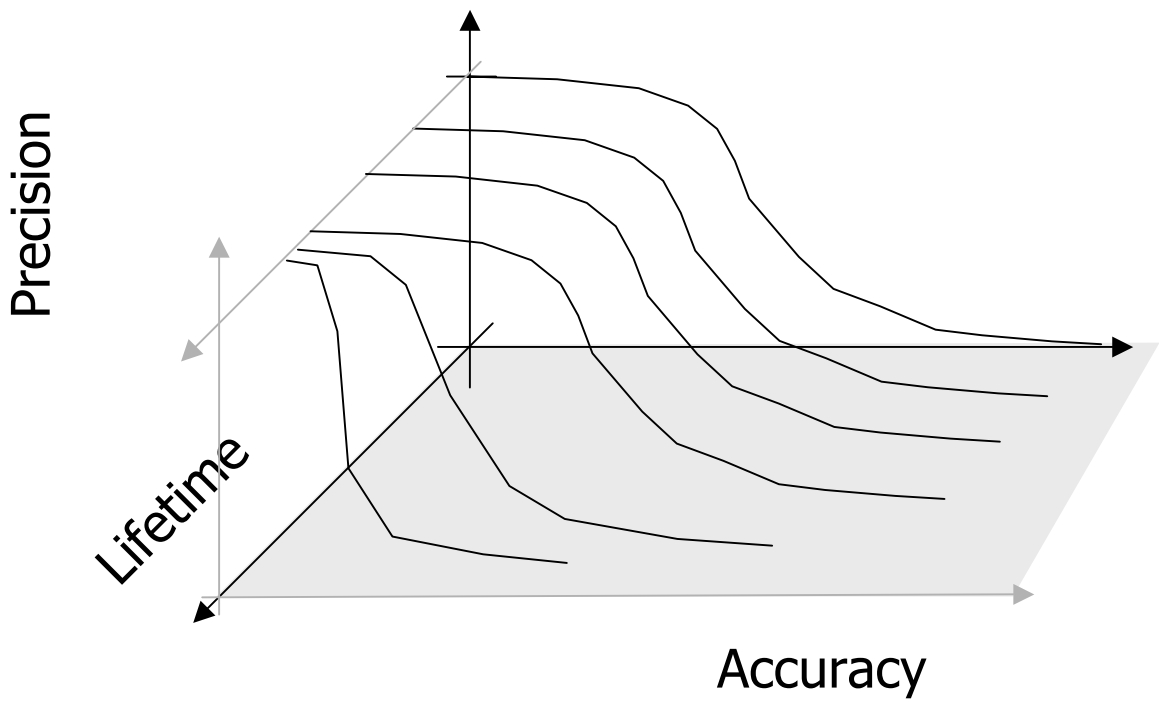
Quality of operation: energy per operation

- Energy can be the most limiting factor to accuracy/precision
  - With arbitrary energy, force through any amount of data



Quality of operation: lifetime

- Related to, but not equivalent with energy
  - Worry about the critical node, which energy does not
- As operational time of the network progresses, accuracy will suffer
  - Likely: phase transition characteristics – "bottom falls out suddenly"



Quality of deployment: Cost

- Deployment will influence overall quality
  - Typical example: almost a 0/1 behavior for connectivity/size of largest component as function of number of neighbors
- Assume a fixed budget available for a WSN solution, how to split it?
  - More nodes? Nodes with bigger batteries? Fewer, but more complex nodes?
  - Consider cost in design decisions – e.g., connectivity is not important, look at size of largest component in a graph
- What are cost-quality-density tradeoffs?

Quality relation

- In general: Set of feasible tuples

  (accuracy, precision, energy/power, lifetime, cost)

  has to be characterized

- Perhaps not in detail, but principal behavior characteristics need to be explored
  - E.g., are there phase transitions or smooth variations for some parameters?
- What are upper bounds?

How to express QoS requirements?

- Wide open field
- Application programmer needs "knobs" to express
  - How much energy should be spent for a given operation
    - Maximizing the operation's accuracy
  - What is the smallest required accuracy
    - Minimizing the energy requirements
  - Similarly for lifetime
  - Cost is less of a programming but a deployment/planning/management issue
- Currently: "do is somehow, optimize something"
  - Acceptable tradeoffs cannot be clearly expressed
- Even better: higher abstractions? Hiding details behind a middleware?

How to realize QoS requirements?

- Assuming basic tradeoffs can be characterized
- Assuming application programmer has expressed needs

- Open question:
  - How far can upper bounds on tradeoffs be reached?
  - How can protocols adapt to given restrictions?
    - Either minimize energy consumption or accuracy, …

Need for transport layer protocols in WSN

- In effect: transport layer protocols are needed!
  - Very little work so far, e.g., RMST or PSFQ
  - Also: congestion control will become important

- One possible idea for making accuracy explicit: k-out-of-m concast
  - Ask for convergecast from k nodes out of m nodes in a convergecast tree
  - Lowers load, can possibly maintain accuracy
  - On-going work

Conclusion

- A broader notion for QoS is required in WSN than in traditional networks
- Explicit tradeoffs are required
  - Have to be characterized and their limit behavior understood
  - Have to be expressed by programmer
  - Have to be embraced by adaptive protocol design
- Essentially, we need a system theory