Dealing with Faults in Wireless Sensor Networks: The State of the Art

ESCORT: Energy Efficient Support for Sensor Applications with COnsideration of Node/link Failures

Problem Statement
Design a fault-tolerant protocol for Wireless Sensor Networks that maximizes performance along the following three dimensions:
- Meet application timeliness requirements
- Meet expected data reliability regardless of faults
- Require minimum energy consumption

Design Challenges
- How to measure reliability of data?
- How to achieve time synchronization?
- Is location information necessary?
- How to deal with congestion?
- How to minimize processing on the node side to extend network lifetime?

Key Design Elements
- Use the tradeoff between timeliness and energy efficiency
- Use the tradeoff between reliability and energy efficiency
- Packet recovery on a hop-by-hop basis
- Local and network-wide congestion control
- Tolerance to node failures and topology changes by using multipath packet routing

Timeliness
- The longer each node waits for its children the more chances it has to combine a few readings together and save energy, and the longer the end-to-end delay is.

Reliability
- The longer each node waits for its children the more chances it has to combine a few readings together and save energy, and the longer the end-to-end delay is.

Packet Recovery
- Packets are recovered on a hop-by-hop basis, no need for retransmission all the way from the source

Packet Loss Rate, %

Congestion Control
- If congestion is detected
- Locally reduce \( f \) and set congestion bit to \( I \)
- In case of persistent congestion sink may decide that \( T_i \) or \( \beta \) need to be changed for the whole network

Simulation Setup
- ESCORT prototype is simulated in NS2
- Initial testing is held on a small network of 25 nodes
- Currently implemented features:
  - Batch data transmission
  - Snooping
  - Packet retransmission if node doesn’t hear transmission by at least one of the parent

Future Work
- Fully implement ESCORT features in NS2 simulation
- Finding optimal \( f \) and \( T_i \)
- Congestion detection and control
- Add energy model and track energy expenditures
- In case both reliability \( R \) and late packet tolerance \( \beta \) cannot be satisfied at the same time, user should choose what is more important
- Testbed implementation on TinyOS

Example Application: Natural Disaster Response
- Monitor forest temperature for timely determination of forest fire and reliably communicating it to firefighters to save lives
- First responders need to receive information about event within a given time, and they have to receive certain number of data reports to consider event detection reliable
- Network has to last as long as possible

ESCORT: Protocol Design Details

Reliability
- Fraction of distinct items sent that reach the sink
- The more retransmissions for each packet – the higher it is, and more energy is used

Reliability
- Desired reliability \( R \)
- Observed reliability \( r \)
- Retransmission rate \( f \)
- If \( f < R \) => increase \( f \) to get higher \( r \)
- If \( f > R \) => energy is wasted, decrease \( f \)

ESCORT: Preliminary Results and Future Work