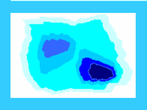
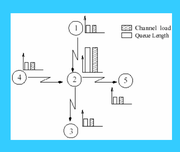
Dealing with Faults in Wireless Sensor Networks: The State of the Art

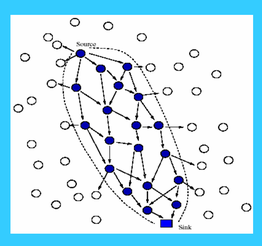
Fault Prevention Techniques
-prevent faults from happening through network monitoring and data delivery redundancy



• Monitor node energy levels to predict battery depletion

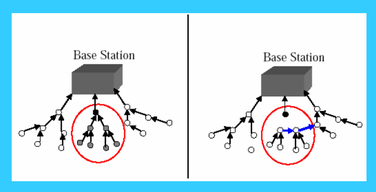
• Monitor channel load and queue length to control congestion





• Multipath routing is used for load balancing and reliable data delivery

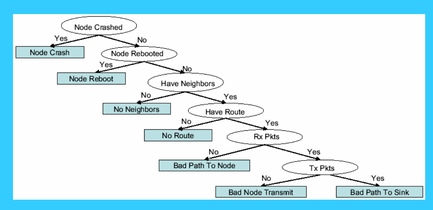
Fault Detection Techniques
-if fault prevention is insufficient and failures happen, detecting the root of fault will speed up recovery



• Differentiate between failure of a single node or a whole region using fault tracing

• Node, link or sink may be the cause for failure

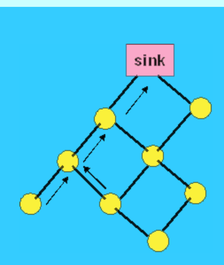
• Network traffic, connectivity, and flow metrics are used to root cause faults

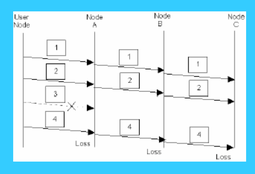


Fault Recovery Techniques
-fault recovery techniques may vary for data collection and dissemination protocols

• Upstream data delivery does not require 100% reliability, as long as event is detected

• Changing reporting or retransmission rate to achieve desired reliability





• Delivery of code and new tasks downstream requires 100% reliability

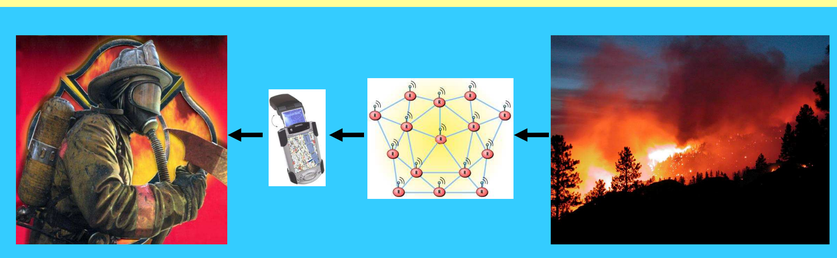
• Caching and hop-by-hop recovery are necessary

ESCORT: Energy Efficient Support for Sensor Applications with COmposite Needs of Reliability and Timeliness

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 Concept
minimize energy consumption
s.t. $t \leq T$ and $r \geq R$

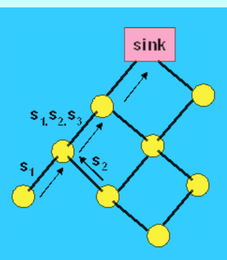


Example Application: Natural Disaster Response
- Monitor forest temperature for timely determination of forest fire and reliably communicating it to firefighters to save lives
- First responders need to receive information about event within a given time, and they have to receive certain number of data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

ESCORT: Protocol Design Details

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

• At each hop nodes combine reports with reports of their children to reduce number of packets to send and save energy

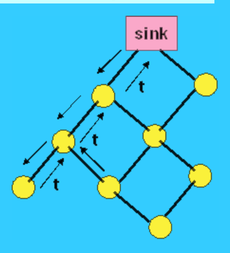


• Node broadcasts packets to multiple parents and multiple parents may forward it to the sink:

•Increased reliability and enhanced tolerance to node/link failures

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.

- Event detection deadline T
- Local report deadline T_l
- b - % of late packets with $t > T$
- β – maximum % of late packets
- If $b > \beta$ => reduce T_l
- If b=0 => increase T_l



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

•Use snooping
•No need for ACK packets
•Node listens for its parent after period t
•Node will retransmit the packet up to f times

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

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

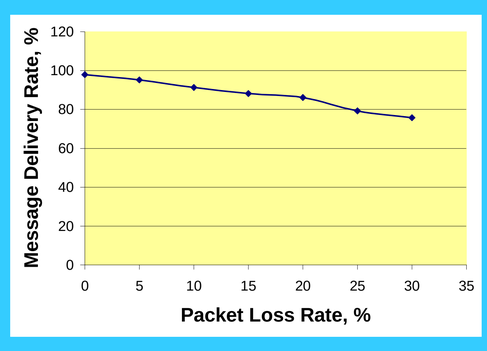
Congestion Control
- If not handled, congestion can exacerbate with increased retransmission rate f

•Nodes monitor rate of increase of their queues
•If congestion is detected
•Locally reduce f and set congestion bit to 1

•In case of persistent congestion sink may decide that T_l or f need to changed for the whole network

ESCORT: Preliminary Results and Future Work

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



•Preliminary results: message delivery success rate as function of packet loss rate

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

Project Team: Lilia Paradis, Qi Han, Department of Mathematical and Computer Sciences, Colorado School of Mines, June 2006