Application-Oriented Networking

- **Sensor networks**
  - Collection of data samples

- **Operating mode**
  - Application specific

- **Design decisions**
  - Unlike human networks
Notion of Reliability

Regular notion of reliability
- Important at the scale of data packets
  - Email, voice, ...

Sensor networks driven by application
- Reliability definition application-specific
  - Reliability possible at different scales
  - Examples?

TCP does not know how to offer R=75% reliability
- Does UDP know?
Reliability per Event

- One possible reliability scale → EVENTS
  - Only care about event notification
    - Not individual data packets
  
  - Example:
    - Temp > 100, Earthquake tremor > 4.5

- Reliability
  - No. of data packets per event per time interval
  - Its enough if 75 out of 100 people send earthquake alert
ESRT: Basic Idea

- **If receiving more packets than needed**
  - Have sensors reduce frequency
    - Reduces congestion
    - Saves transmission energy

- **If receiving too few packets**
  - Have sensors increase sending frequency
    - No need for e2e retransmission (!= TCP)

- Flow control prescribed only at sink
Is that a great idea?
Is it overlooking something?

Event

Sensor sources

Link fails

Sensor sink
No consideration for in-network optimization

What if few Disjoint routes leading to sink

What if losses due to wireless channel variation

Any ideas on improving?

How about: Try harder to forward packets if it has travelled longer
ESRT: Assumptions

- **Complexity not allowed at Network/MAC**
  - Trivial lower layer logic

- **Sinks can be within network**
  - Not at periphery

- **Reliability**
  - Losses dominated by congestion, not wireless
  - You cannot have hi-resolution control (58% of pkts)
    - **WHY?**
Problem Definition

- **Observed event reliability** $r_i$:
  - # of packets received in decision interval $I$

- **Desired event reliability** $R$:
  - # of packets required for reliable event detection
  - Application-specific

- **Goal**: configure the reporting rate of nodes
  - To make $r_i \rightarrow R$
  - Minimize energy consumption
Reliability vs. Reporting Frequency

- Reliability increases linearly with frequency, until $f_{\text{max}}$
- $F_{\text{max}}$ decreases when the # of nodes increases

Medium density
For Higher Density

- Reliability increases linearly with frequency, until \( f_{\text{max}} \).
- \( F_{\text{max}} \) decreases when the \# of nodes increases.
Characteristic Regions

- NC, HR
- HC, HR
- NC, LR
- HC, LR
ESRT Protocol Operation

<table>
<thead>
<tr>
<th>Network State ($S_i$)</th>
<th>Description</th>
<th>ESRT Action</th>
</tr>
</thead>
</table>
| (NC, LR)               | No Congestion, Low Reliability | Multiplicatively increase $f$  
Achieve required reliability as soon as possible |
| (NC, HR)               | No Congestion, High Reliability | Decrease $f$ conservatively  
Cautiously reduce energy consumption so as not compromise on reliability |
| (C, HR)                | Congestion, High Reliability | Decrease $f$ aggressively to state (NC,HR) to relieve congestion  
Then follow action in (NC,HR) |
| (C, LR)                | Congestion, Low/equal Reliability | Decrease $f$ exponentially  
Relieve congestion as soon as possible |
| OOR                    | Optimal Operating Region | $f$ remains unchanged |

- **(NC, LR):**
  \[
  f_{i+1} = \frac{f_i}{\eta_i}
  \]

- **(NC, HR):**
  \[
  f_{i+1} = \frac{f_i}{2} \left( 1 + \frac{1}{\eta_i} \right)
  \]

- **(C, HR):**
  \[
  f_{i+1} = \frac{f_i}{\eta_i}
  \]

- **(C, LR):**
  \[
  f_{i+1} = f_i^{(\eta_i/k)}
  \]

Will this converge?
How to Distinguish (LC, HR) (HC, HR)
Both done at the sink

Congestion:
- Nodes monitor their buffer queues
- Inform the sink (flag bit = 1) if overflow occurs

Reliability Level
- Calculated by the sink at the end of each interval
- If flag == 1, then its (HC, HR)
  - Reduce rate
Setting the Congestion Flag

- Each sensor monitors its own buffer

- Assumption
  - Incoming traffic does not change per interval

- If:
  
  \[ \text{current buffer + last buffer change} > \text{maximum buffer} \]

  \[ \Rightarrow \text{set congestion notification bit} \]

Any Issues?

No idea where the bit is set -- close to sink or source?
Simulation on ns2

- Parameters to note:
  - 100 X 100 sqm
  - Number of nodes: 200
  - Tx range: 40m
  - Event range: 30 to 40m
  - Event Occurrence: Not in remote corners (39, 58)

Is this a fine system to evaluate?
Performance (convergence time)
Performance (convergence time)

- C, LR
- NC, LR
- OOR

Time

Normalized Reliability

$\tau = 10 \text{ min}$
$t_1 = 400.000$
$n_1 = 0.5425$
$t_2 = 0.0038$
$n_2 = 0.0203$
$t_3 = 1.058$
$n_3 = 0.3848$
$t_4 = 4.058$
$n_4 = 0.9822$
Energy Consumption

NC, HR

OOR

Time
ESRT: Conclusion

- Reliability notion is application-based
  - No delivery guarantees for individual packets

- Reliability and congestion control
  - By changing the reporting rate of nodes

- Pushes all complexity to the sink

- Single-hop operation only
Discussion

- Identified an important issue
  - That reliability notion is unlike regular networks

- First attempt toward event-reliability

- However, some implicit assumptions
  - May not be all realistic

- Much room for improvement ...
  - Energy consumption not considered
  - Will sleeping automatically solve problem
  - Is Gossip an easier solution? Offers high resolution?
Questions ?