Design Methodology of a Wireless Sensor Network Architecture for Urgent Information Transmission

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Outline
1. Introduction
2. Design Methodology
3. UMIUSI Architecture
4. Practical Experiments
5. Conclusion

Design Methodology
Combining simple mechanisms working in different spatial and temporal levels
Mechanisms are... to the surrounding situation
No additional mechanisms to identify the scale or situation of the event

Overview of the Architecture

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Normal situation</th>
<th>Emergency situation</th>
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</thead>
<tbody>
<tr>
<td>-scalability</td>
<td>-scalability</td>
<td></td>
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<tr>
<td>-fault tolerance</td>
<td>-fault tolerance</td>
<td></td>
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<tr>
<td>-long lifetime</td>
<td>-reliability and latency</td>
<td>-adaptability to situation</td>
</tr>
</tbody>
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Application layer
Building automation, public surveillance, ...
QoS control mechanisms

Network and MAC layers
existing algorithm / data gathering scheme e.g. directed diffusion, S-MAC ...

Design Objectives
- High reliability and low latency
- Urgent information should be preferred according to their importance
- Self-organizing and distributed behavior
  - A WSN should be adaptive to the scale of an emergency and dynamically changing conditions
  - A globally-organized behavior emerges as results of reactions to the surroundings of each node and local interaction among nodes
- Simplicity
  - A sensor node has limited resources

Design Methodology
Combining simple mechanisms working in different spatial and temporal levels
Mechanisms are implemented on each node
Mechanisms work independently with each other
Mechanisms of appropriate levels come into effect responding to the surrounding situation
No additional mechanisms to identify the scale or situation of the event

Wireless Sensor Networks as a Social Infrastructure
- Sensor nodes are deployed in a region to monitor and collect environmental information
- Sensor nodes have limited computational capabilities and power resources
- Based on unstable radio communications
- Carry various types of information
  - Security, disaster, weather, health, ...
- Need to transmit urgent information with higher reliability and lower latency

differentiated and prioritized services
Overview of UMIUSI

**Application Layer**
- Building automation, public surveillance...

**Our architecture**
- UMIUSI Architecture
- Autonomous Mechanisms Integrated for Urgent Sensor Information

**Network Layer**
- Data gathering scheme
- Multihop routing + Sleep scheduling

**MAC Layer**
- Contention based MAC

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UMIUSI Architecture

- Sensor information is categorized into three traffic classes
  - Normal
  - Non-urgent
  - Transient loss and delay in emergency
  - Gathered at an interval of \( t_{trans} \) in normal situation

- Important
  - Urgent but tolerate loss and delay to some extent when the network is overloaded
  - Transmitted at an interval of \( t_{trans} \) (< \( t_{trans} \)) but the sending rate is regulated in case of congestion

- Critical
  - Most urgent and important
  - Transmitted at an interval of \( t_{trans} \) (< \( t_{trans} \)) and the sending rate is not regulated by the rate control mechanisms to retain the reporting rate

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UMIUSI Architecture (contd.)

- Five mechanisms are incorporated
  - Priority queuing
  - Rate control by local congestion detection
  - Assured Corridor Mechanism (ACM)

- Rate control by backpressure

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“Assured Corridor” Mechanism

- Keep surrounding nodes quiet
- Avoid packet loss caused by collisions
- Keep forwarding nodes awake
- Avoid delay caused by sleeping of forwarding nodes

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Contribution of Mechanisms

- In a small-scale event
  - It takes a while for ACM to take effect
  - Priority queuing and rate control do not help much

- In a large-scale event
  - ACM does not work since collisions occur among emergency packets
  - Rate control is effective to mitigate congestion

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Experiments (Testbed A)

- 25 nodes in a 10m x 6m room
- Lower layer protocols
  - 802.15.4 non-beacon mode MAC
  - Synchronization-based data gathering scheme [10]
  - \( t_{trans} = t_{trans} = 0.5 s \) (rate = 2 packets/s)

- Scenarios
  - Small-scale event with one EMG_SEND node
    - Repeat twice for each of randomly chosen 8 EMG_SEND nodes
  - Large-scale event with 8 EMG_SEND nodes
    - one critical and seven important class nodes
    - Repeat twice for 8 sets of randomly chosen 8 EMG_SEND nodes

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**Node layouts in Testbed A**

- 4 hops to the BS at maximum
- In normal operation, delivery ratio: between 65-80% without any retransmission

**Large Scale Event**

- In FULL, the total throughput of important class decreases in 30 seconds as the important traffic is regulated by the rate control mechanisms

**Experiments (Testbed B)**

- 4 hops at maximum
- In normal operation, delivery ratio is between 65-75%

**Small Scale Event**

- ACM improves reliability of transmission
- Retransmission further lowers the loss rate
- But introducing retransmission incurs increase of delay

**Large Scale Event**

- Suppression of normal packets has little contribution
- Retransmission and rate control are effective to improve reliability
- In FULL, loss rate and delay decreases in 30 seconds as the important traffic is regulated by the rate control mechanisms
Conclusion

- We propose a design methodology of a sensor network architecture supporting differentiated and prioritized services for urgent information.
- Several simple mechanisms working in different time and topological ranges are integrated to adapt to the scale of emergency.
- We propose UMIUSI architecture.
- Sensor information is classified into three classes and five mechanisms collaborate to prioritize urgent information.
- Results of practical experiments show that UMIUSI successfully improved the delivery ratio and the delay of emergency packets.

Thank you