A Fast and Reliable Transmission Mechanism of Urgent Information in Sensor Networks

T. Kawai, N. Wakamiya, and M. Murata
Graduate School of Information Science and Technology, Osaka University

Sensor Network as a Social Infrastructure
- Carry various types of information
  - Security
  - Disaster
  - Weather
  - Health
- Based on unstable radio communications
- Need to transmit urgent information with higher reliability and lower latency
- **differentiated and prioritized services**

Wireless Sensor Networks
- Sensor nodes are deployed in a region to monitor to collect environment information
- Sensor nodes have limited computation capabilities and power resources
- A sensor network consists of 100s or 1000s sensor nodes and is highly dynamic

QoS in Sensor Networks
- **Application Layer**
  - coverage control, sleep scheduling, class-based access control
  - Our mechanism
- **Network Layer**
  - Admission control and proportional rate allocation
- **MAC Layer**
  - RTS/CTS, EDF scheduling, wait time and backoff scheduling
- **Physical Layer**
  - We focus on
    - Packet loss by collisions in radio communication
    - Delay by sleeping nodes

"Assured Corridor" Mechanism
- Keep the surrounding nodes quiet
  - Avoid packet loss caused by collisions
- Keep the forwarding nodes awake
  - Avoid delay caused by sleeping of forwarding nodes

Synchronization-based Data Gathering Scheme
- Synchronized transmission
  - pulse-coupled oscillator model
  - wait for parents to wake up and send
- Sensor data propagation as a circular wave from the edge to the BS
  - Energy efficient, fully distributed, self-organizing, scalable, flexible, robust, but prone to collisions
**Emergency Packets**

- First emergency packets transmitted according to the ordinary data gathering scheme as being transmitted to the BS, an "assured corridor" is built up.
- Following emergency packets forwarded immediately through the "assured corridor".

**Retransmission of First Emergency Packets**

- Acknowledge by overhearing a parent forwarding the emergency packet to a grandparent.
- Forward an emergency packet immediately when receiving a retransmitted packet.

**Simulation**

- ns-2 package with IEEE 802.15.4 MAC
- 80 nodes in 100 m x 100 m region
- Transmission range $R = 20$ m
- Interval of data gathering $t_n = 5$ s
- Offset coefficient $\delta = 0.2$, $\delta t_n = 1$ s
- Interval of emergency packet transmission $t_e = 2$ s
- Make a randomly chosen node enter EMG_SEND state at random time. Go back to NORMAL state after 20 s
- Simulation duration = 3000 s
- 100 simulations with the BS at center

**Delay of Urgent Information**

- Duration between when a node of level $n$ detects an event and when BS receives an emergency packet.
- $\max(D_e) = t_e + (n-1)\delta t_e$ without retransmission
- $\max(D_e) = t_e + (n-1)\delta t_e$ with retransmission

**Delivery Ratio of First Emergency Packets**

- Delivery ratio $P_n$:
  - the ratio of number of first emergency packets received by BS to the number of those transmitted from a level $n$ node.

<table>
<thead>
<tr>
<th>Origin level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>without retransmission (%)</td>
<td>32.5</td>
<td>28.7</td>
<td>26.1</td>
<td>28.2</td>
<td>44.7</td>
<td>40.4</td>
<td>25.8</td>
<td>31.8</td>
</tr>
<tr>
<td>with retransmission (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Delivery Ratio and Delay of Following Emergency Packets**

- Delivery ratio $P_n$:
  - without retransmission
  - $P_2 < P_3 < P_4$: multipath effect
  - $P_2 > P_3$: too many hops
  - with retransmission
  - first emergency packets are delivered reliably

- $P_n$ and $D_e$ are improved by the "assured corridor" mechanism.
**Conclusion**

- We propose the “assured corridor” mechanism for urgent sensor information transmission
- Forwarding nodes suspend sleeping
- Surrounding nodes refrain from transmitting normal packets
- Emergency packets are forwarded preferentially in the corridor
- Simulations show that emergency packets are transmitted with high reliability and low latency once the corridor is established

**Future Work**

- Introduce some techniques to control collisions among emergency packets and mitigate congestion in case that two or more nodes transmit emergency packets
- Clarify the relation between multipath and reliability and develop a mechanism to optimize multipath forwarding
- Develop more flexible prioritization and differentiation scheme