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

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1

Wireless Sensor Networks

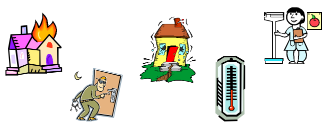
- Sensor nodes are deployed in a region to monitor to collect environment information
- Sensor nodes have limited computation capabilities and power resources
- A sensor network consists of 100s or 1000s sensor nodes and is highly dynamic

Network requirements		Network design
Scalability Fault tolerance Long lifetime	→	Self-organizing Fully distributed Low energy consumption

2

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

3

QoS in Sensor Networks

Application Layer	coverage control, sleep scheduling, class-based …
Network Layer	multi… control, admission control and proportional rate allocation
MAC Layer	RTS/CTS, EDF scheduling, wait time and backoff scheduling
Physical Layer	

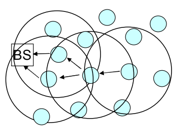
Our mechanism

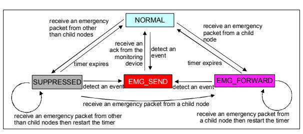
We focus on
- Packet loss by collisions in radio communication
- Delay by sleeping nodes

4

"Assured Corridor" Mechanism

- Keep the surrounding nodes <u>quiet</u>
  - Avoid packet loss caused by collisions
- Keep the forwarding nodes <u>awake</u>
  - Avoid delay caused by sleeping of forwarding nodes



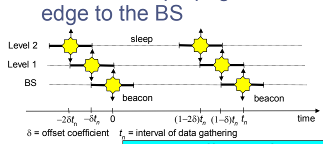


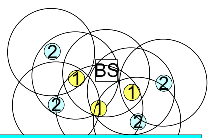
State transitions

5

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





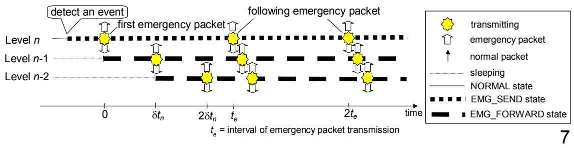
→ energy efficient, fully distributed, self-organizing, scalable, flexible, robust, but prone to collisions

[1] N. Wakamiya and M. Murata: "Scalable and robust scheme for data gathering in sensor networks", in Proc. of Bio-ADIT 2004, pp 412-427 (2004).

6

Emergency Packets

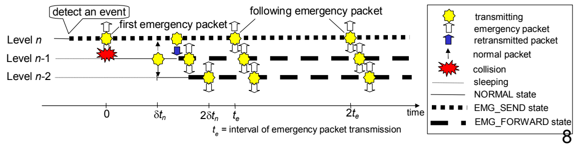
- First emergency packets
  - transmitted according to the ordinary data gathering scheme
  - as being transmitted to the BS, an "assured corridor" is built up
- Following emergency packets
  - forwarded immediately through the "assured corridor"



7

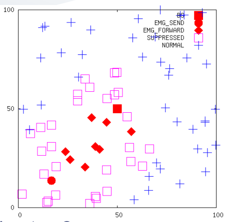
Retransmission of First Emergency Packets

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



8

Simulation

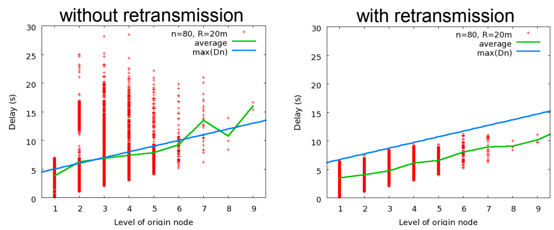


- ns-2 package with IEEE 802.15.4 MAC
- 80 nodes in 100 m x 100 m region
- Transmission range R = 20 m
- Interval of data gathering t_n = 5 s
- Offset coefficient δ = 0.2. δt_n = 1 s
- Interval of emergency packet transmission t_e = 2 s
- Make a randomly chosen node enter EMG_SEND state at random time.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

9

Delay of Urgent Information

- **Delay:** D_n
  - Duration between when a node of level n detects an event and when BS receives an emergency packet
  - $\max(D_n) = t_n + (n-1)\delta t_n$



10

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

Origin level	1	2	3	4	5	6	7	Total
without retransmission (%)	32.5	28.7	26.1	38.2	44.7	40.4	25.8	31.8
with retransmission (%)	100	100	100	100	100	100	100	100

- without retransmission
  - P_2, P_3 < P_4, P_5; multipath effect
  - P_6 > P_7; too many hops
- with retransmission
  - first emergency packets are delivered reliably

11

Delivery Ratio and Delay of Following Emergency Packets

Origin level	1	2	3	4	5	6	7	Total
Delivery ratio P_n (%)								
without corridor	89.8	92.2	91.2	96.1	90.7	95.4	86.3	93.2
with corridor	99.5	94.9	96.9	96.9	97.3	97.3	99.0	96.8
Avg. delay D_n (ms)								
without corridor	4.6	14.7	34.7	37.8	46.2	29.8	60.1	27.4
with corridor	4.3	14.1	22.7	31.4	39.4	49.1	56.3	21.4

- P_n and D_n are improved by the "assured corridor" mechanism

12

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

13

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

14