Design and Evaluation of a Wireless Sensor Network Architecture for Fast and Reliable Transmission of Urgent Information

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Wireless Sensor Networks as a Social Infrastructure

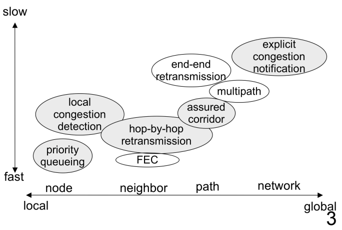
- Sensor nodes are deployed in a region to monitor to collect environmental information
- Sensor nodes have limited computational capabilities and power resources
- Carry various types of information
  - Security, disaster, weather, health, ...


- Based on unstable radio communications
- Need to transmit urgent information with higher reliability and lower latency

→ differentiated and prioritized services

Design Methodology

- Objectives
  - Reliability and latency
  - Self-organizing and localized behavior
  - Simplicity
- Integration of simple mechanisms working in different topological and time levels

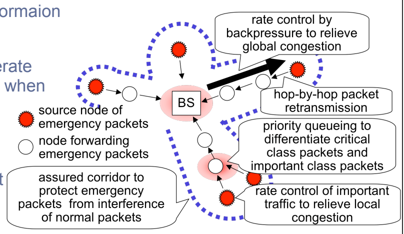


UMIUSI Architecture

Application Layer	Disaster detection system etc.
UMIUSI	aUtonomous Mechanisms Integrated for Urgent Sensor Information
Network Layer	Data gathering scheme • Multihop routing + Sleep scheduling
MAC Layer	Contention based MAC

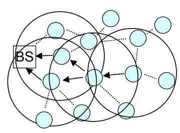
UMIUSI Architecture (contd.)

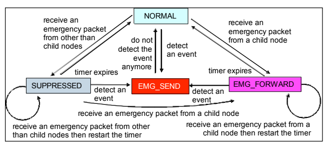
- Three classes of sensor information
  - Normal
    - Non-urgent informaion
  - Important
    - Urgent but tolerate loss and delay when the network is congested
  - Critical
    - most important information



"Assured Corridor" Mechanism (ACM)

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



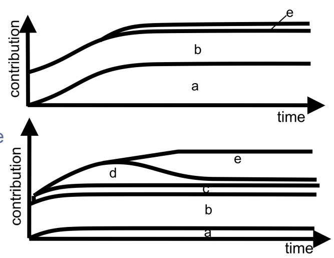


State transitions

Contribution of Mechanisms

- Small scale emergency
  - It takes a while for ACM to take effect
  - Priority queueing and rate control do not help much
- Large scale emergency
  - ACM does not work since collisions occur among emergency packets
  - Rate control is effective to mitigate congestion

a. assured corridor
b. scheduled retransmission
c. priority queueing
d. rate control by local congestion detection
e. rate control by backpressure



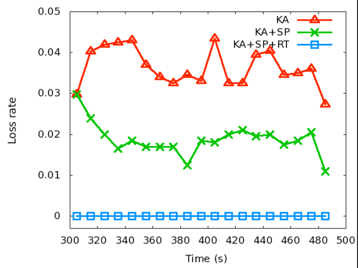
Simulation

- ns-2 with synchronization-based data gathering scheme [6] and IEEE 802.15.4 MAC
- Parameter Settings
  - 200 nodes in 20 m x 20 m region
  - Transmission range R = 2.5 m
  - After 300 sec. for initialization, make randomly chosen nodes move to *EMG_SEND* and get back to *NORMAL* state 180 sec. later. Terminated at 500 sec.
  - Interval of emergency packet transmission t_{emg} = 0.5 sec.
  - Maximum number of retransmission: 2
  - 100 simulations

[6] N. Wakamiya and M.Murata: IEICE Transactions on Communications, E88-B, 3, pp.873–881 (2005).

Loss Rate in a Small Scale Emergency

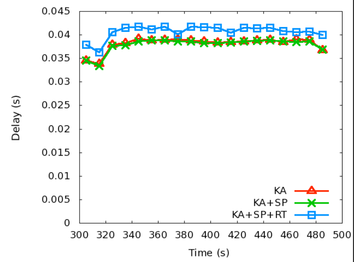
- One critical class *EMG_SEND* node sends emergency packets
- Ratio of emergency packets which are not received by the BS
- Decreases by half in 30 seconds with suppression (KA+SP)
- 15% more packet transmisson with RT but no loss



KA keep awake
SP suppression of normal packets
RT retransmission

Delay in a Small Scale Emergency

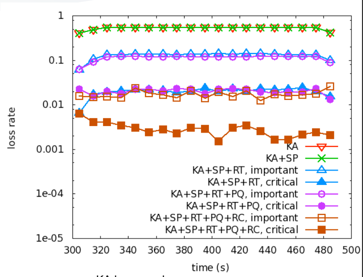
- End-to-end delay from an *EMG_SEND* node to the BS
- Much smaller than in normal state by KA
- Slightly smaller with SP
  - due to less intense contention in MAC layer
- Larger with RT



KA keep awake
SP suppression of normal packets
RT retransmission

Loss Rate in a Large Scale Emergency

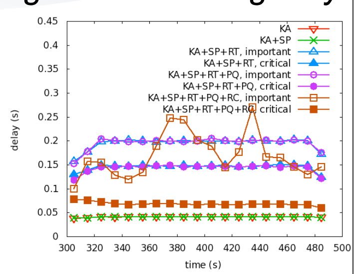
- Four critical class and 28 important class *EMG_SEND* nodes send emergency packets simultaneously
- SP does not help
- RT takes immediate effect
- RC comes into effect in 50 seconds



KA keep awake
SP suppression of normal packets
RT retransmission
PQ priority queueing
RC rate control of important class

Delay in a Large Scale Emergency

- Delay is smallest in KA and KA+SP
  - no retransmission involved
- Delay rises in 30 seconds with RT
  - due to collisions
  - smaller for critical class thanks to scheduled retransmission
- RC decreases the delay
  - fewer retransmission and backoff in MAC



KA keep awake
SP suppression of normal packets
RT retransmission
PQ priority queueing
RC rate control of important class

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
- Simulation results show that UMIUSI successfully improved the delivery ratio and the delay of emergency packets independently of the scale of emergency

Thank you