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

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Wireless Sensor Networks

- Sensor nodes are deployed in the monitored region to detect an event
- 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

Scalability
Fault tolerance
Long lifetime

→

Network design

Self-organizing
Fully distributed
Low energy consumption

Sensor Network as a Social Infrastructure

- Provide a safe and secure living environment
  - Security (intrusion, fire, gas leakage)
  - Disaster (earthquake, flood, volcanic eruption)
  - Weather (temperature, humidity)
  - Health (blood pressure, body temperature)
- Based on unstable radio communications
- Need to transmit urgent information with higher reliability and lower latency

→ prioritized and differentiated services

QoS in Sensor Networks

coverage control, sleep scheduling, class-based

Our mechanism

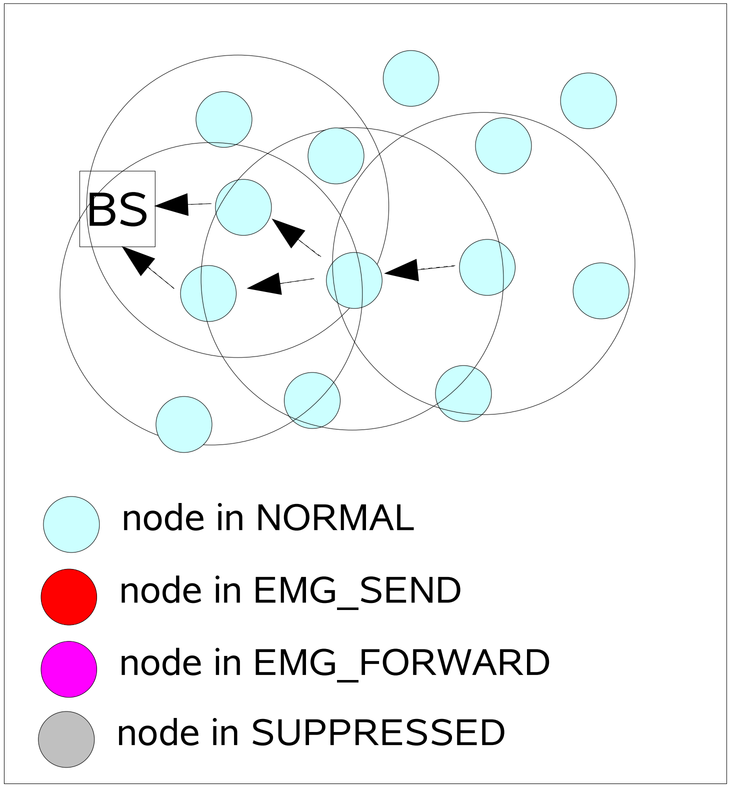
multipath [5], multipacket [5], congestion control [7]

RTS/CTS, EDF scheduling, wait time and backoff scheduling

[5] B. Deb, S. Bhatnagar, and B. Nath, “ReInForM: Reliable Information Forwarding using Multiple Paths in Sensor Networks”, in Proc. of LCN 2003, October 2003.
[7] Y. Sankarasubramaniam, B Akan and I. F. Akyildiz, “ESRT: Event-to-Sink Reliable Transport in Wireless Sensor Networks”, in Proc. of MobiHoc 2003, June 2003.

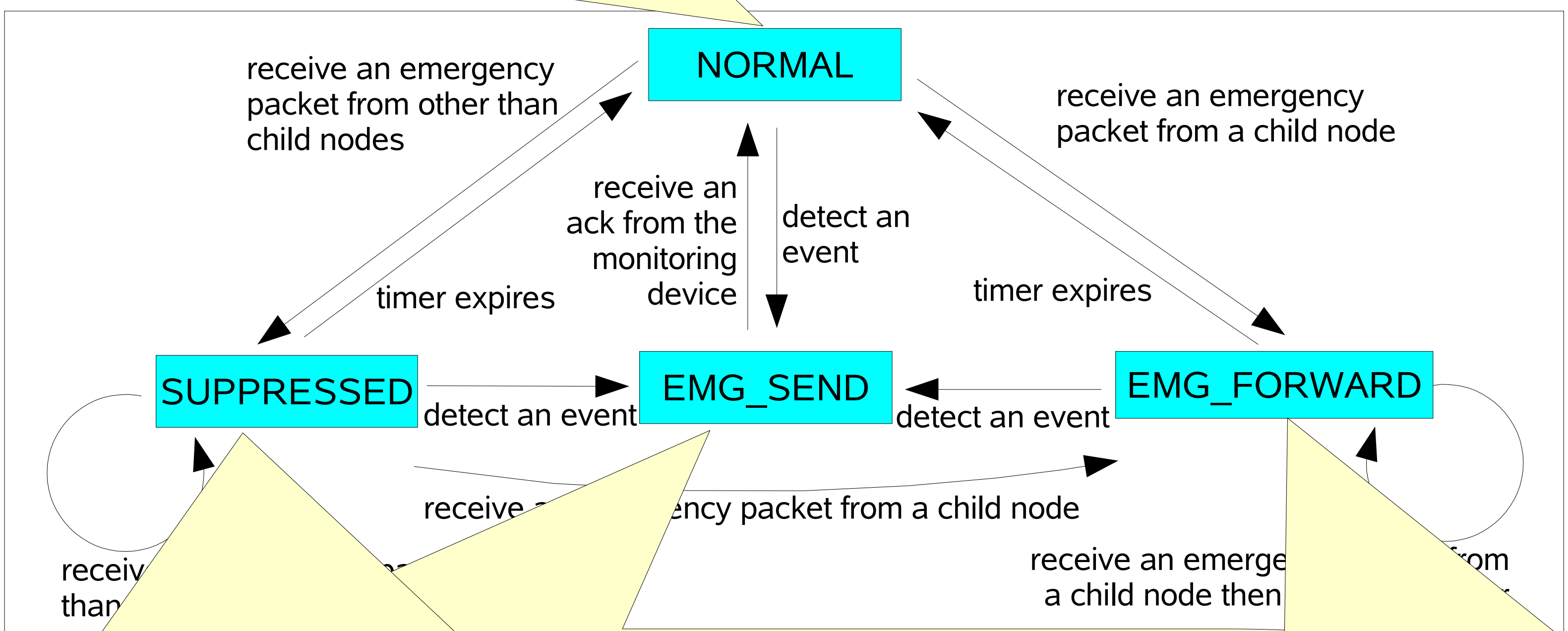
“Assured Corridor” Mechanism

- Avoid packet loss caused by collisions
  - keep the surrounding nodes quiet while emergency packets are being transmitted
- Avoid delay caused by sleep of forwarding nodes
  - keep the forwarding nodes awake while emergency packets are being transmitted



State Transitions of a Node

not involved in urgent information transmission under normal operation

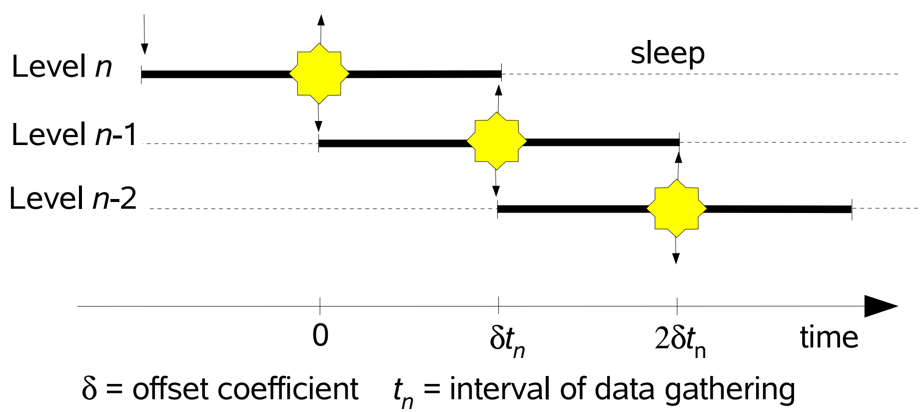


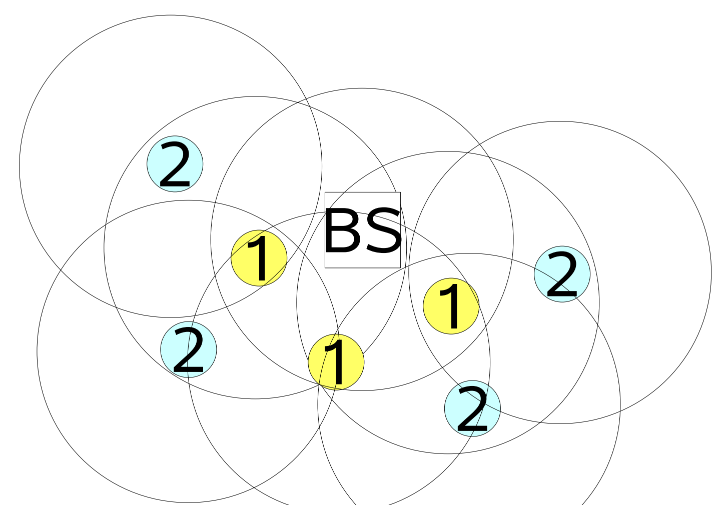
suppress the transmission of normal packets

chedule
emergency packets

Synchronization-based Data Gathering Scheme

- Synchronized transmission
  - biologically inspired pulse-coupled oscillator model
- Sensor data propagation as a circular wave from the edge to the BS



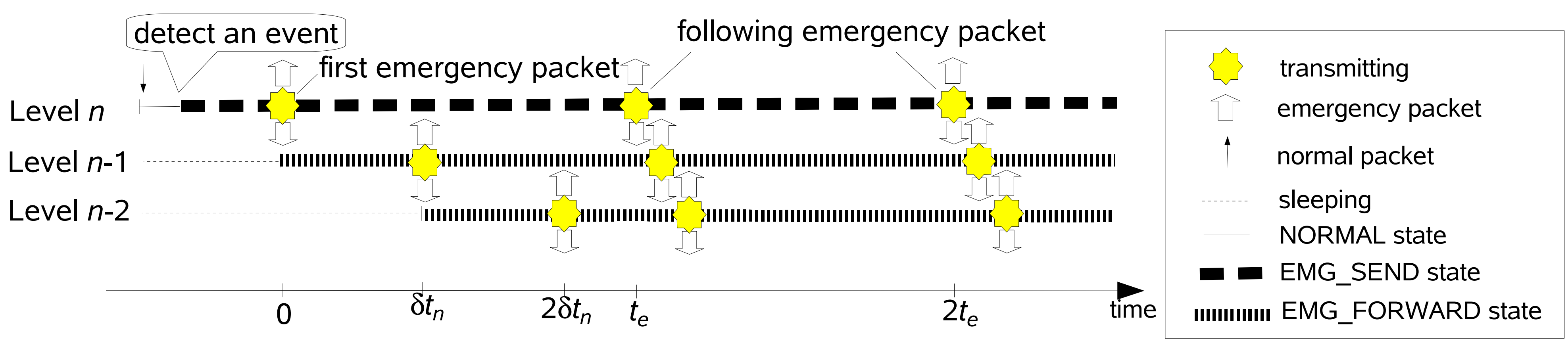


→ energy efficient, fully distributed, self-organizing, scalable, flexible, robust, but prone to collisions

[8] N. Wakamiya a… in Proc. of Bio-ADIT 2004, pp 412-427 (2004).

Emergency Packets

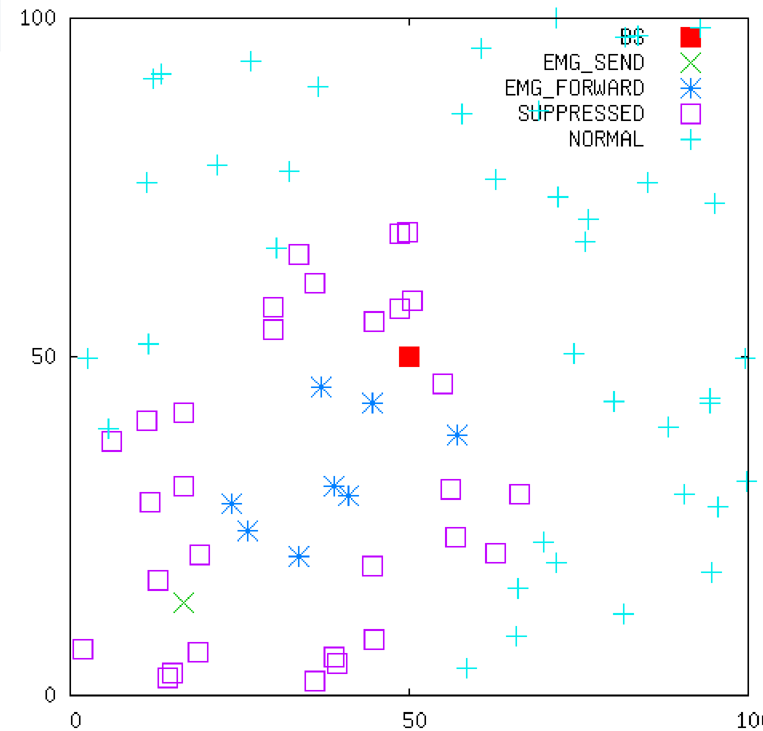
- First emergency packets
  - follow the ordinary data gathering cycle
  - as being transmitted to the BS, an “assured corridor” is built up
- Following emergency packets
  - forwarded immediately through the “assured corridor”



t_e = interval of emergency packet transmission

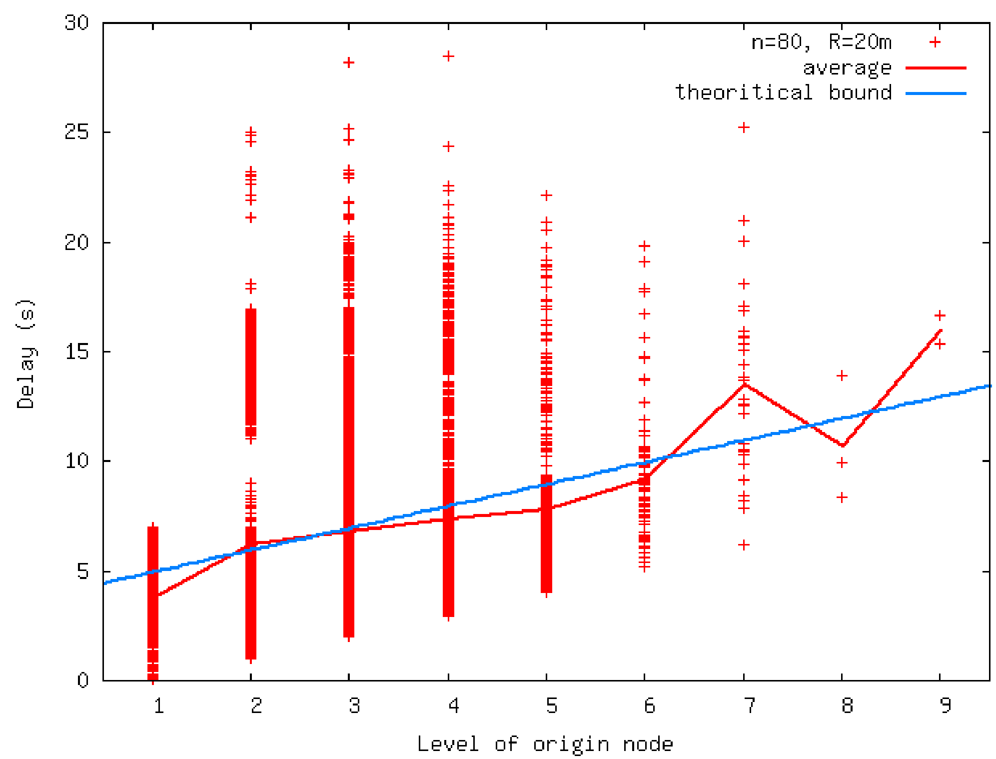
Simulation

- 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
- Simulation duration = 3000 s
- 100 simulations with the BS at center, another 100 with the BS at the corner



Delay of First Emergency Packets

- **Delay:** D_n
  Duration between when a node of level *n* detects an event and when BS receives an emergency packet
- Theoretically $D_n < (n+4)$ seconds but only 70% are within this bound

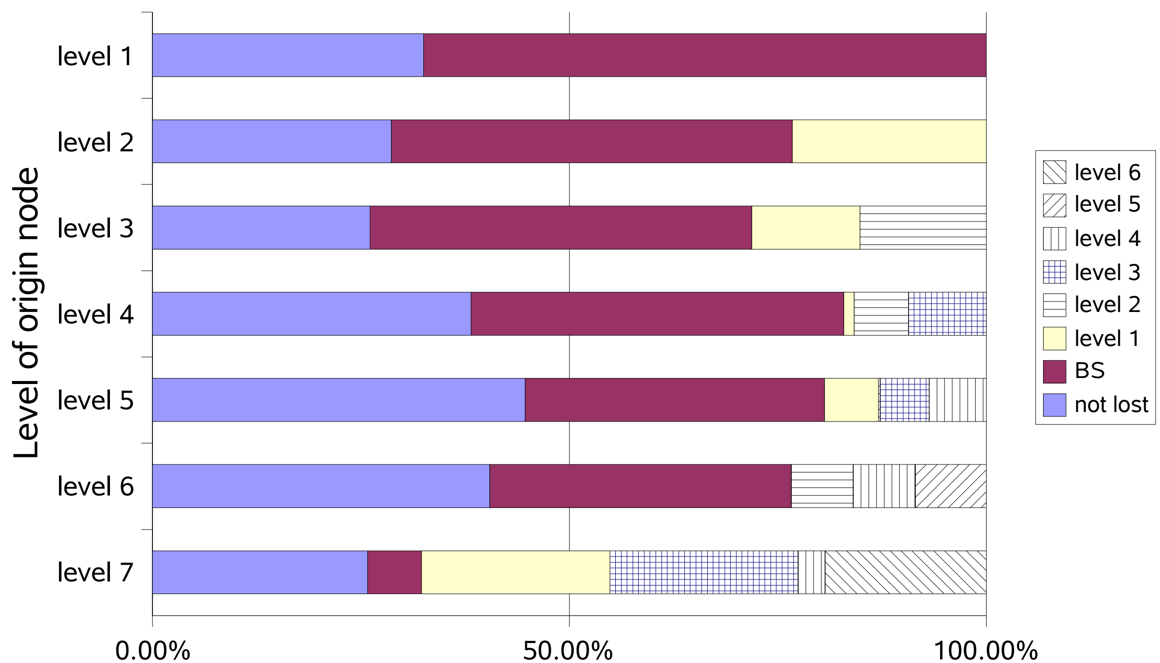


Delay of urgent information

- Many emergency packets are lost due to collisions without corridor

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
- P_2, P_3 ~ 30% while P_4, P_5 ~ 40% (multipath effetct)

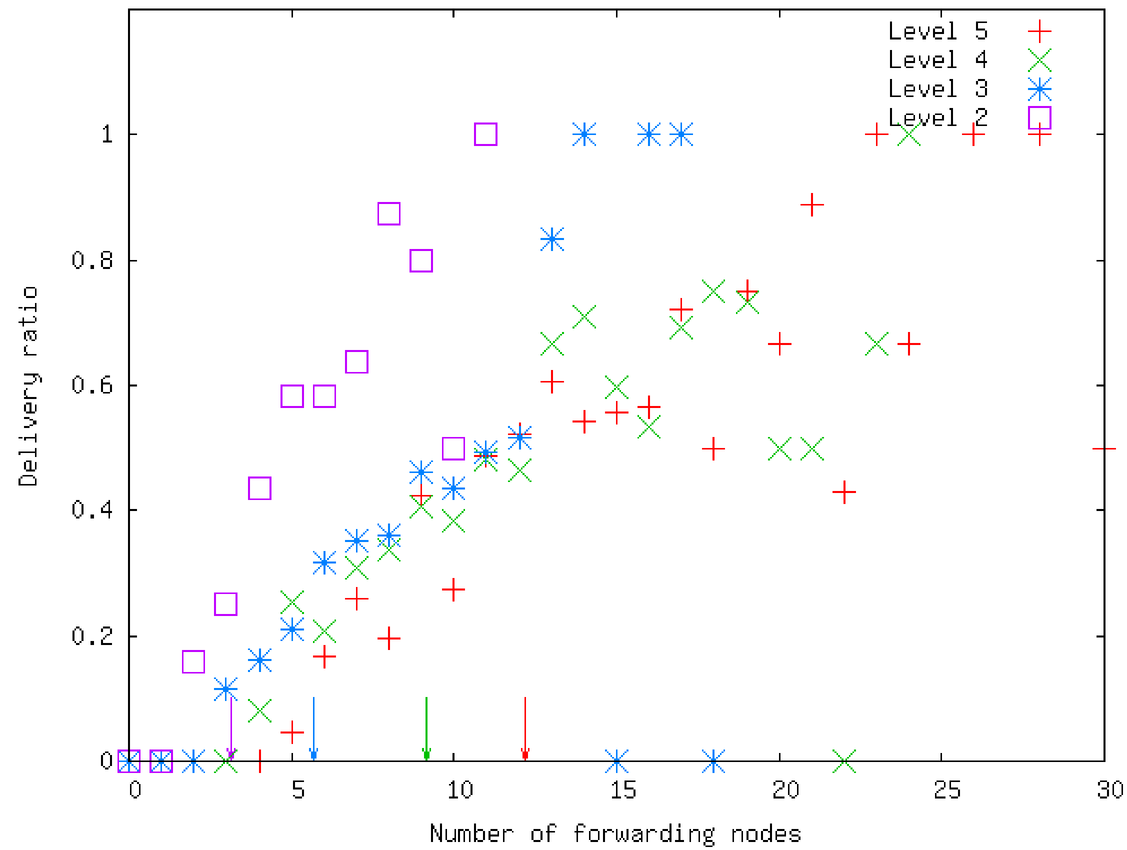


Levels where the first emergency packets are lost

- $P_6 > P_7$; Negative effect of too many hops is more influential than positive multipath effect
- Collisions are most likely to occur at the BS

Number of Forwarding Nodes and Delivery Ratio

- P_n increases proportionally to the number of forwarding nodes (multipath effect)



- Level 4 and 5 nodes have adequate forwarding nodes but level 2 and 3 nodes do not
- Finding more parents would improve the delivery ratio for level 2 and 3

Delivery Ratio and Delay of Following Emergency Packets

Origin level	1	2	3	4	5	6	7	ave.
Delivery ratio (%)	99.4	98.5	96.4	96.7	95.9	95.1	94.9	96.0
Ave. delay (ms)	4.3	12.3	23.3	33.7	42.6	55.6	60.6	46.6

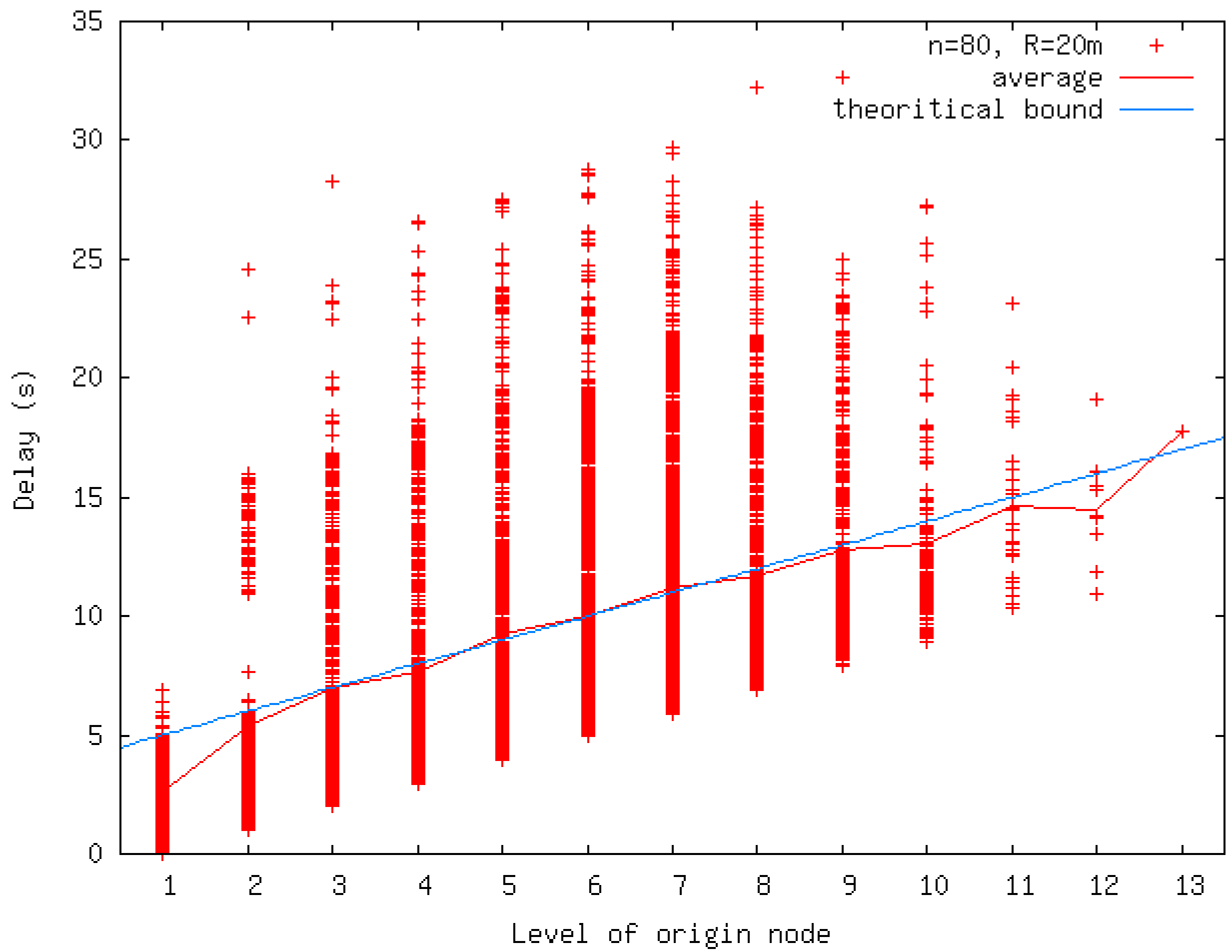
- Once the corridor is set up, following emergency packets are immediately forwarded to the BS by flooding
- P_n and D_n are improved by the “assured corridor” mechanism

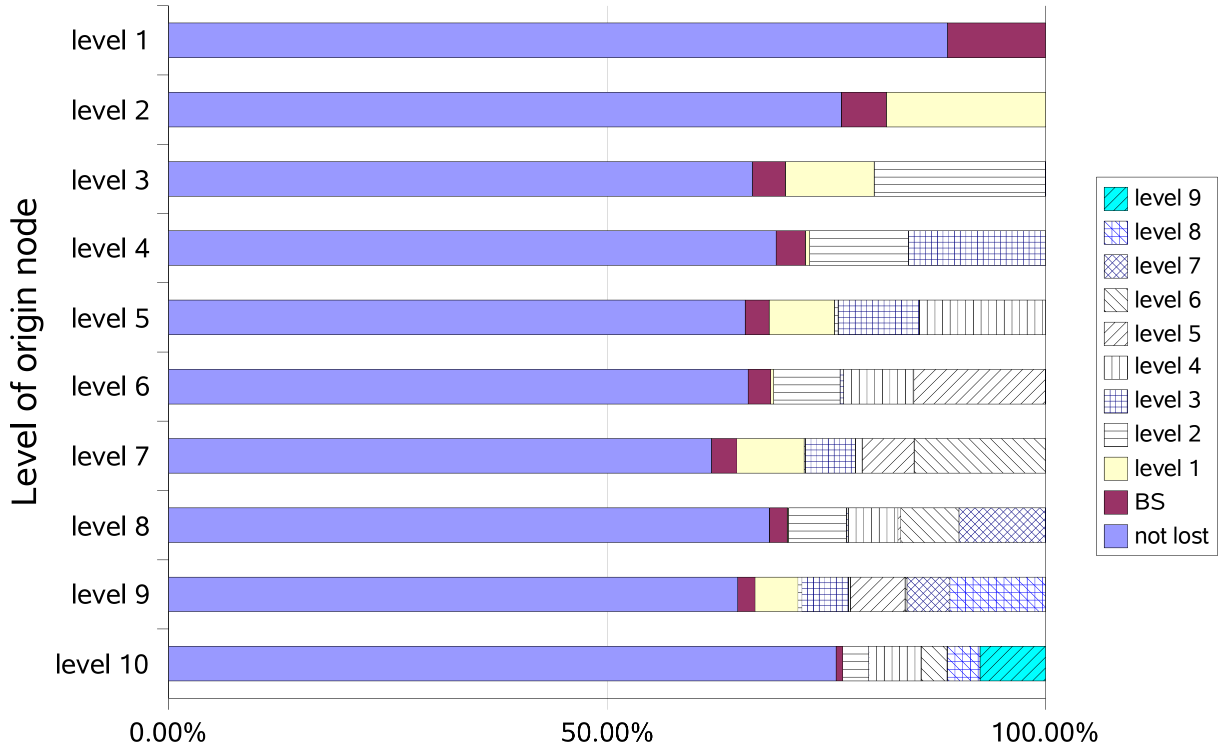
Conclusion

- We propose an “assured corridor” mechanism for urgent 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

- Improve the delivery ratio of first emergency packets by introducing retransmissions
- Clarify the relation between multipath and reliability and develop a mechanism to optimize multipath forwarding
- Develop more flexible prioritization and differentiation scheme


n=80, R=20m
average
theoritical bound
Delay (s)
Level of origin node
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10
11
12
13


Level of origin node
level 1
level 2
level 3
level 4
level 5
level 6
level 7
level 8
level 9
level 10
0.00%
50.00%
100.00%
level 9
level 8
level 7
level 6
level 5
level 4
level 3
level 2
level 1
BS
not lost