



DiMo: Distributed Node Monitoring in Wireless Sensor Networks

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joint work with

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1. Status monitoring¹:

- Node failure report: ≤ 5 minutes (at the sink)



2. Event reporting¹:

- Alarm delay: ≤ 10 seconds (node to sink)
- Robust and reliable

3. Energy efficiency:

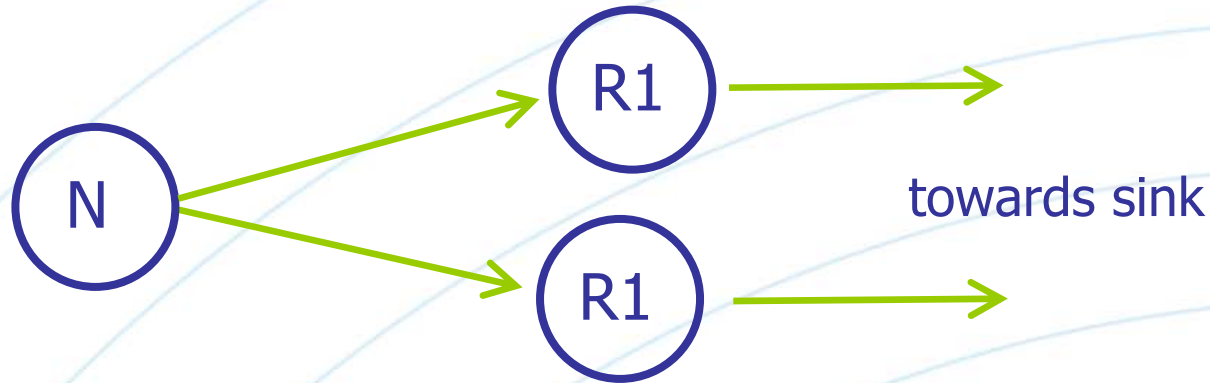
- Lifetime greater than 3 years (on 2xAA): $< 1\%$ duty cycle

→ Large deployments require multi-hop solution

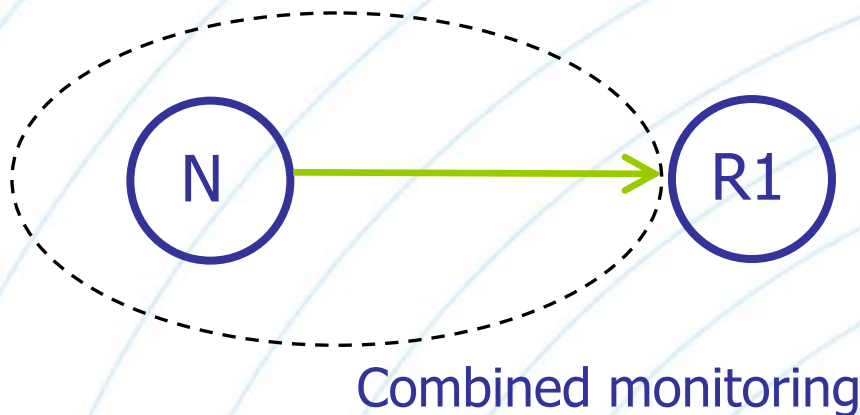
¹ European Norm (EN) 54-25:2008-06, June 2008

- Detect failed nodes within a given time bound: e.g., 5min
- Monitor nodes AND links: Network ready to send alarm
- Energy efficiency: minimal (message) overhead
- Minimize false positives: costly on-site inspection
- Scalability: no increased load towards sink, no bitmask

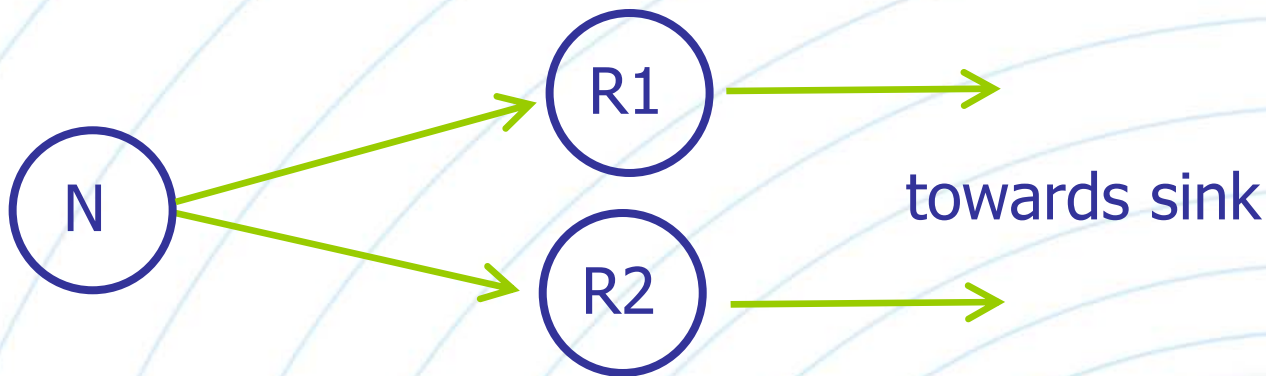
1. Redundant topology



2. Monitoring of node and link

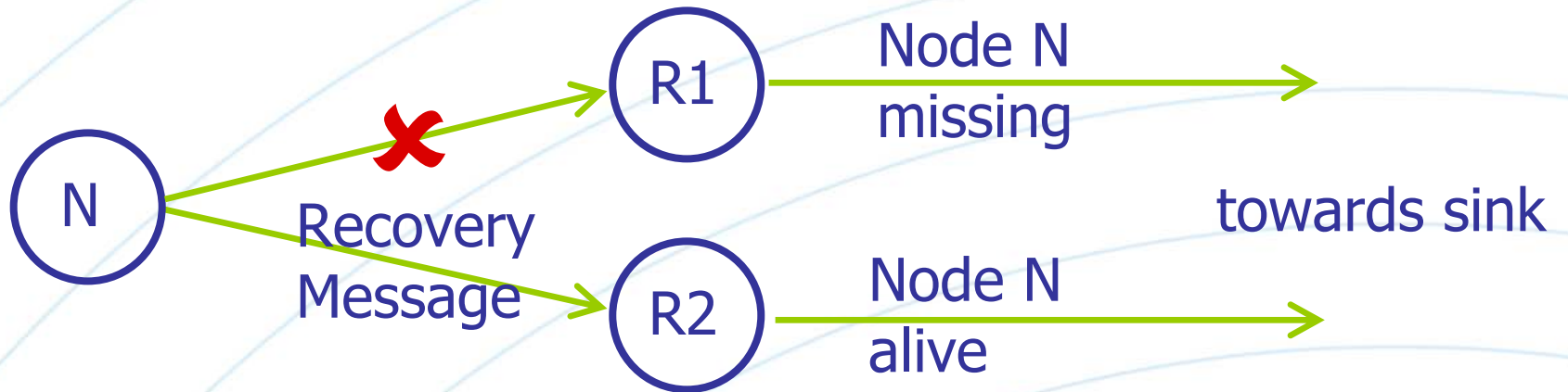


- All nodes are connected to at least two relay nodes
 - Whenever possible given the (physical) network topology
- Relay node provides route to the sink with smaller cost
- For a single tree:
 - All nodes have only one relay/parent
 - Cost metric is hop count.



- Every node is monitored by its relay nodes
 - Reports to one relay every monitoring interval (e.g., 4 min)
 - Observe the node and the link (topology)
- Dynamic observation schedule
 - The node alternates between its relays
- If the link to the relay fails (no ACK)
 - The relay reports the node missing to the sink
 - Report to alternate relay that sends recovery message

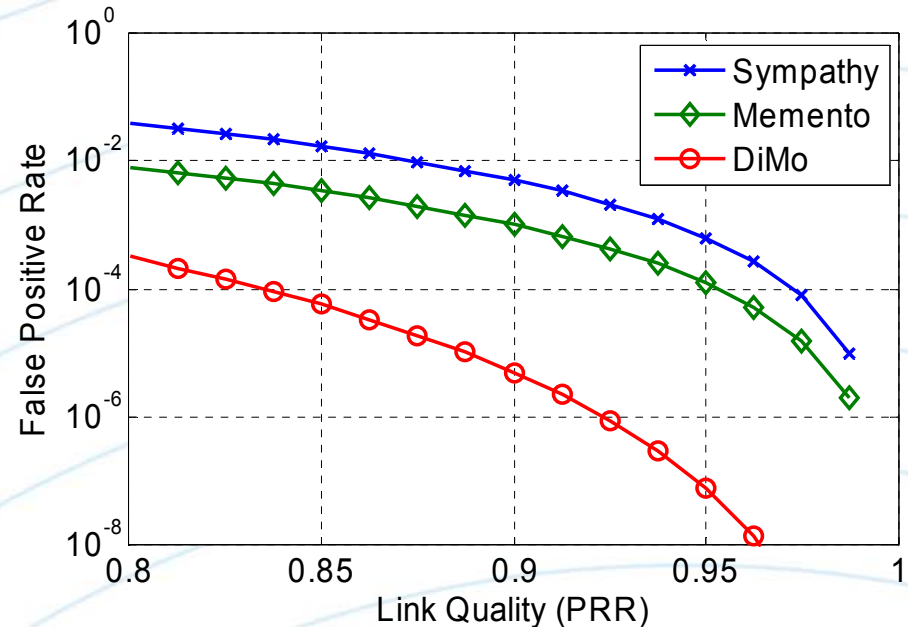
DiMo: Example with 2 relay nodes



- Memento [SECON'06]
 - Periodic heartbeat – aggregated in a bitmask
 - Aggregation delays failure detection and does not scale
- Sympathy [SenSys'05] & NUCLEUS [EWSN'05]
 - Periodic heartbeats from all nodes
 - Combined with regular traffic if possible
 - Great overhead for nodes close to the sink
- Dwarf [DCOSS'07]
 - Ring based gossiping scheme with latency bounds
 - Bitmask and ring scheme do not scale, contention likely

False Positives: Analytical Comparison (Formulas in Paper)

- False positives depend on link quality
 - Sympathy sends retries
 - Memento sends r messages every interval
 - DiMo sends recovery message to alternate relay
- DiMo reduces false positives by two orders of magnitude



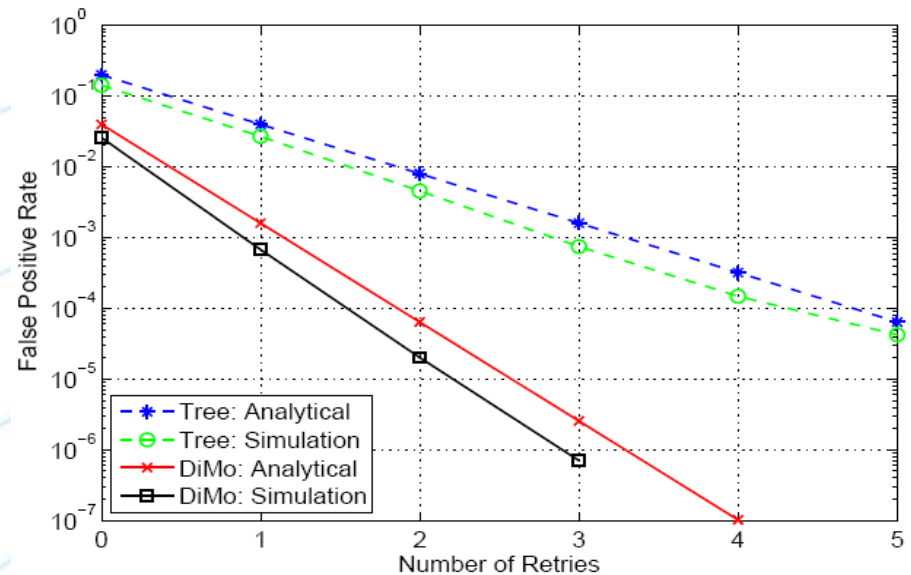
MAC: 2 retries ($r = 3$)

Low false positive rate also implies a reliable transport of events

- **Castalia: State of the art WSN simulator**
 - Based on Omnet++
 - Provides a realistic channel model [Zuniga2004]
- **Simulation in an 80-node network**
 - Grid topology plus displacement
 - Signal strength according to [Zuniga2004]
 - Up to 6 hops to the sink
- **Media Access Control (MAC)**
 - SpeckMAC (packet based B-MAC)
 - With acknowledgements
- **Initialization and link estimation with NoSE [SenSys'08]**

Simulation vs. Analytical Analysis

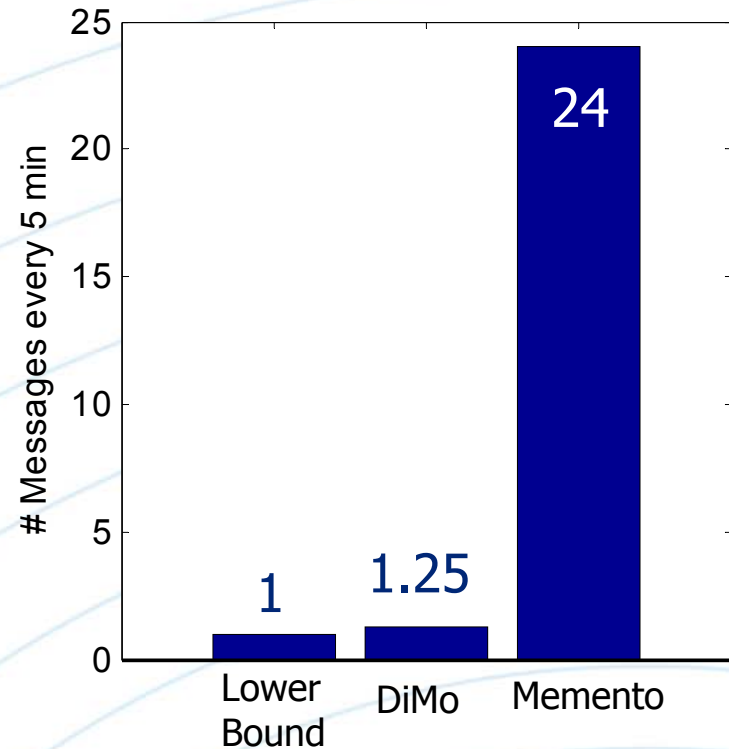
- Simulation confirms analytical results
- Tree topology does not provide redundancy
 - DiMo's redundancy greatly increases robustness
- DiMo achieves a false positive rate of 10^{-7}
 - One false positive in a 80-node network per year



Find PRR = 0.8

Energy Efficiency: Message Overhead

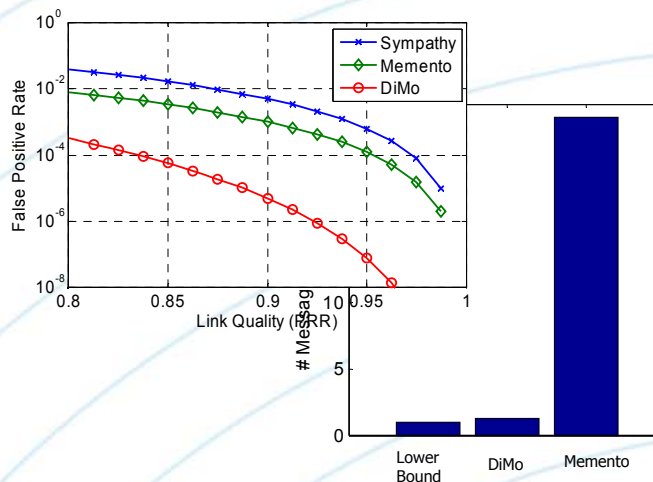
- Detect missing node after maximally 5 min
 - Lower bound for message frequency: 5 min
- DiMo: 1 msg every 4 min
 - Almost meeting lower bound
- Memento: High message frequency due to delay introduced by aggregation



Parameterized for a false positive rate of 10^{-4}

Conclusion

- Safety critical WSNs require to
 - Detect missing nodes in 5 min
 - Have the network ready for timely send events
- DiMo simultaneously monitors node and topology
- DiMo greatly reduces
 - False positives
 - Energy consumption



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