A Reliability-Aware Medium Access Control for Unidirectional Time-Constrained WSNs

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6th Nov 2015, RTNS

Introduction

Wireless Sensor Networks:

- Networks of spatially distributed independent sensors to monitor physical or environmental conditions, e.g. temperature, moisture, sound, etc.
- Pass their information to a central location, e.g. a monitor that displays temperature, server, etc.
- Uses all kind of wireless communication technologies, e.g. RFID, WIFI, ZigBee, etc.

Uni- vs Bidirectional

- All Systems use either uni- or bidirectional transmission

Unidirectional	Bidirectional
sender *or* receiver	transceiver
no acknowledgement	acknowledgement
no synchronization	synchronization
cheap & energy efficient	expensive
-	routing
-	retransmission

→ Unidirectional communication is error-prone

→ Hence most systems are bidirectional

Our Goal

- **Our Goal:** Develop a Medium Access Control to guarantee specified reliability requirements in unidirectional WSNs

- **Motivation:** Substantial cost saving, in particular, for networks with a large number of nodes

Intertechno Set ~12€

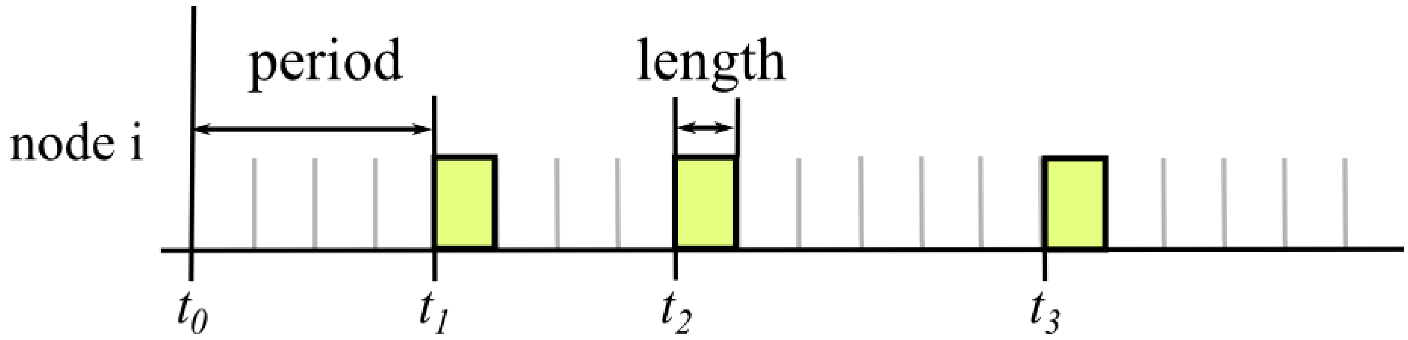
KNX RF Switch ~100€

Comparison with similar approaches

- Most existing approaches have major disadvantages:
  - Use hybrid systems, i.e. only partly unidirectional [1]
  - Increase reliability, but do not allow quantifying it [1]
  - Allow reliable communication, but are very pessimistic, i.e. sending more data than necessary → low energy-efficiency, high maximum delay [2][3]
- Our approach specifies:
  - Bounded delay, i.e. time from activation to reception
  - Reduced energy consumption
  - Modeling worst-case probability of packet loss

Design considerations

- Nodes send packets multiple times (sequence) with random inter-packet times (periods)
- Each sequence starts with a random transmission break (pause)
- Data length of a packet is minimal (6 byte packet size) to reduce transmission duration

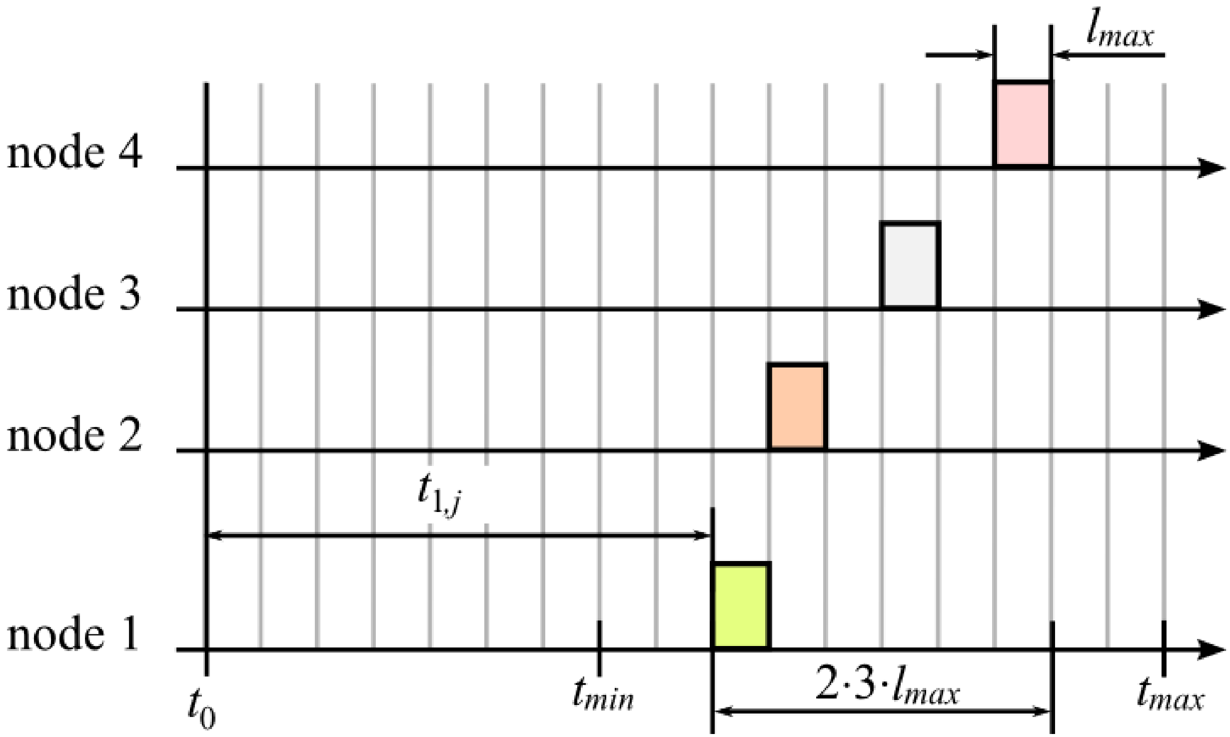


Design considerations

- Given parameters:
  - Reliability ρ
  - Deadline d_{max}
  - Packet length l_{max}
  - Number of nodes n
- Missing parameters:
  - Inter-packet-times $[t_{min}, t_{max}]$
  - Number of packets per node κ

Probability of loosing single packets

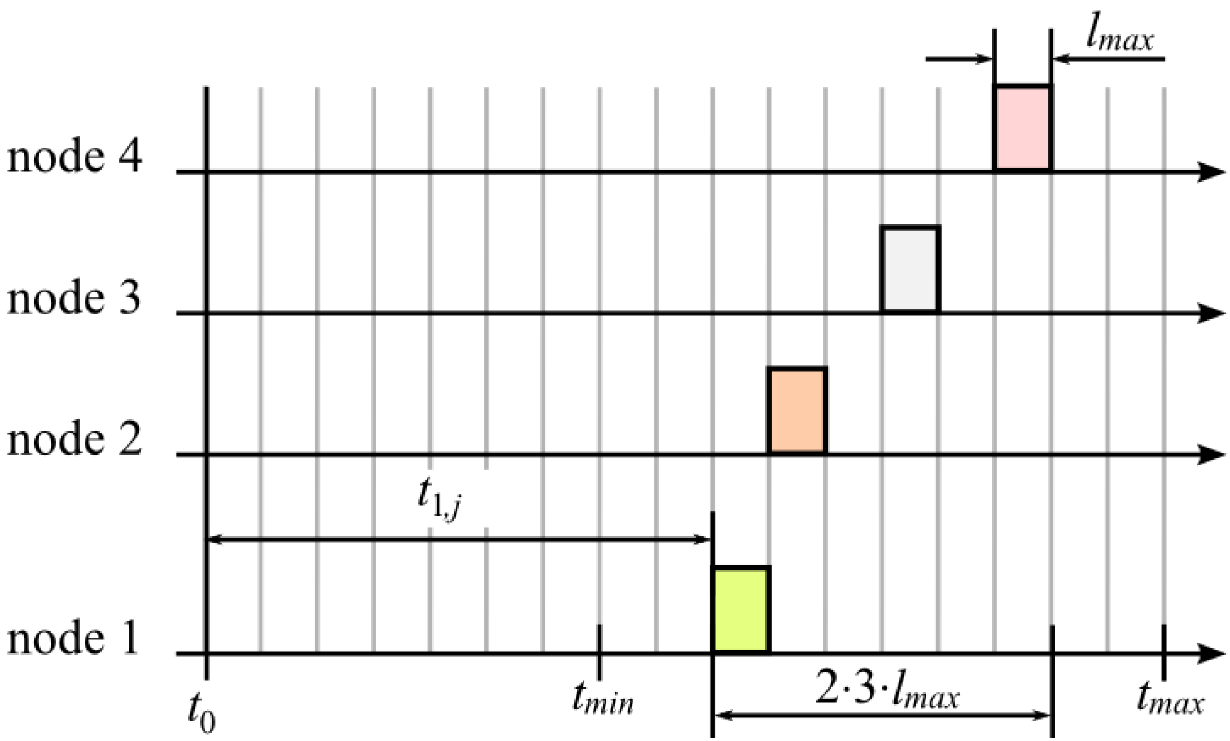
- Packets can be lost due to interference from other nodes or external sources
- WC scenario: periods [t_{min}, t_{max}] overlap completely



Probability of loosing single packets

- Collision interval

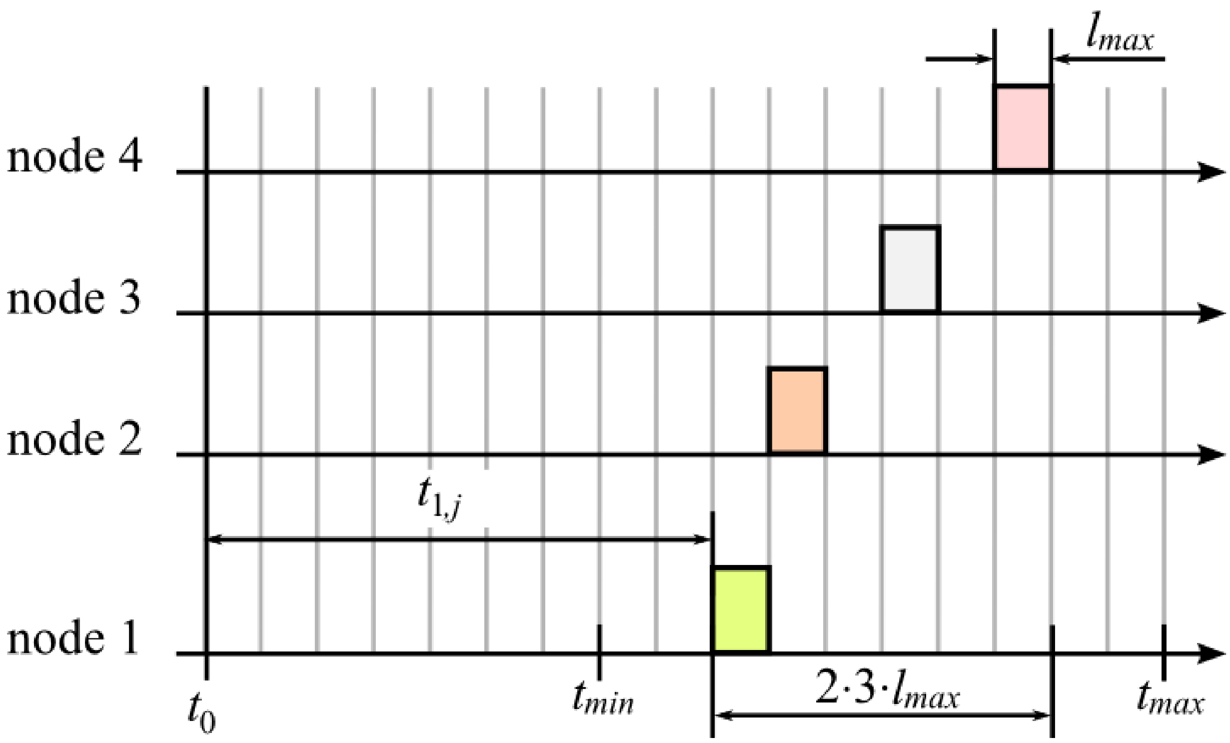
$$\Delta_{coll} = 2(n-1)l_{max}$$



Probability of loosing single packets

- Probability of loosing a single packet

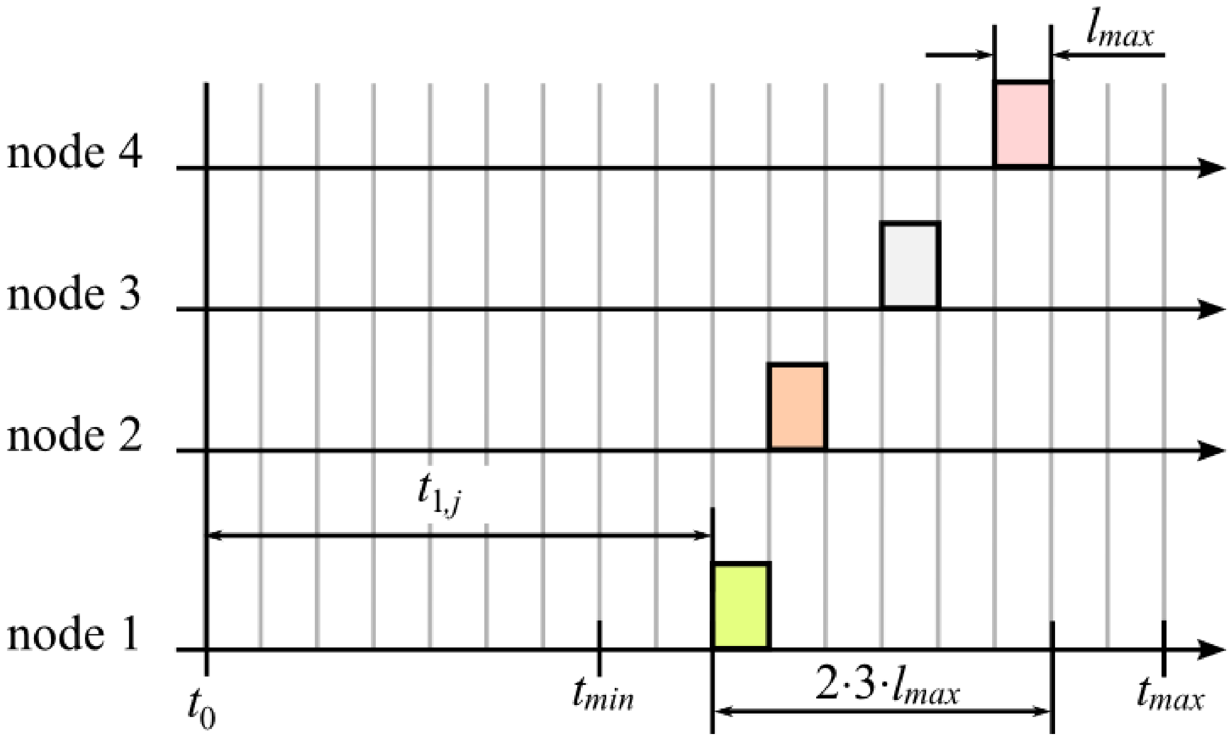
$$q = \frac{2\,(n-1)l_{max}}{t_{max} - t_{min}}$$



Probability of loosing single packets

- Generalization: *m*

$$\Delta_{coll} = 2m(n-1)l_{max} \qquad q = \frac{2m(n-1)l_{max}}{t_{max} - t_{min}}$$



Reliability

- Since n, l_{max}, t_{min}, t_{max} *and* m are system parameters, they are independent of nodes and packets

  → we can model packet transmission as binomial distribution

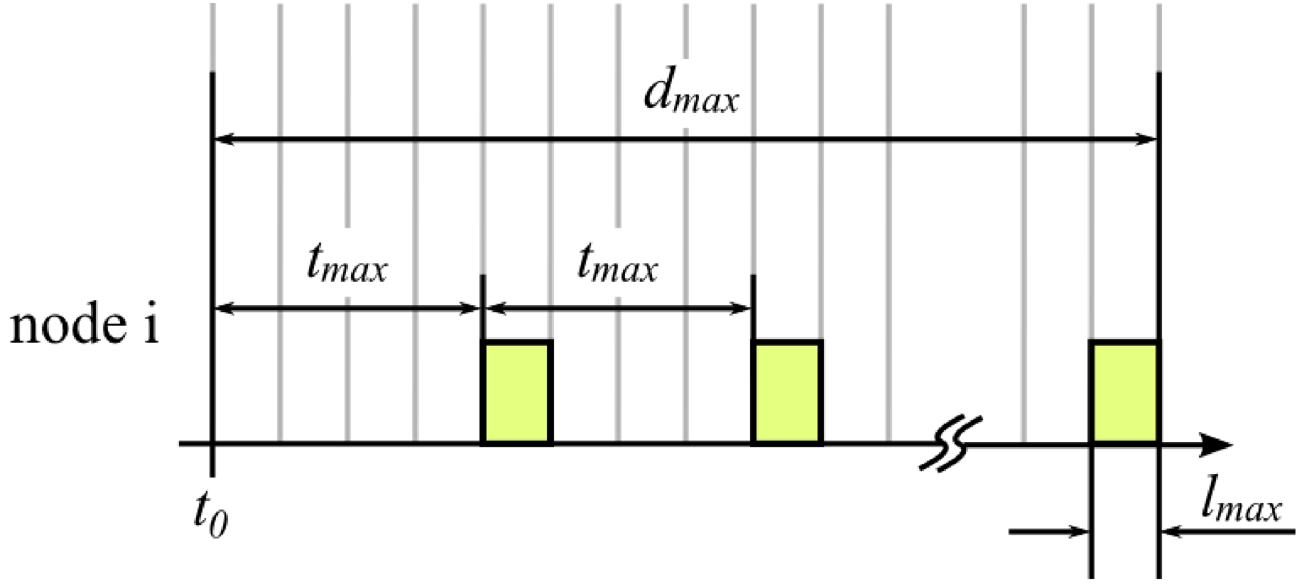
- Probability of receiving at least one out of κ consecutive packets (reliability)

$$p = 1 - \left(\frac{2m(n-1)l_{max}}{t_{max} - t_{min}} \right)^k$$

Inter-packet-times: t_{max}

- We have to send κ_i packets before d_{max}

$$t_{max} \leq \frac{d_{max} - l_{max}}{\kappa}$$



Inter-packet-times: t_{min}

- Rearranging the reliability formula:

$$t_{min} \leq t_{max} - \frac{2m(n-1)l_{max}}{\sqrt[k]{1-p}}$$

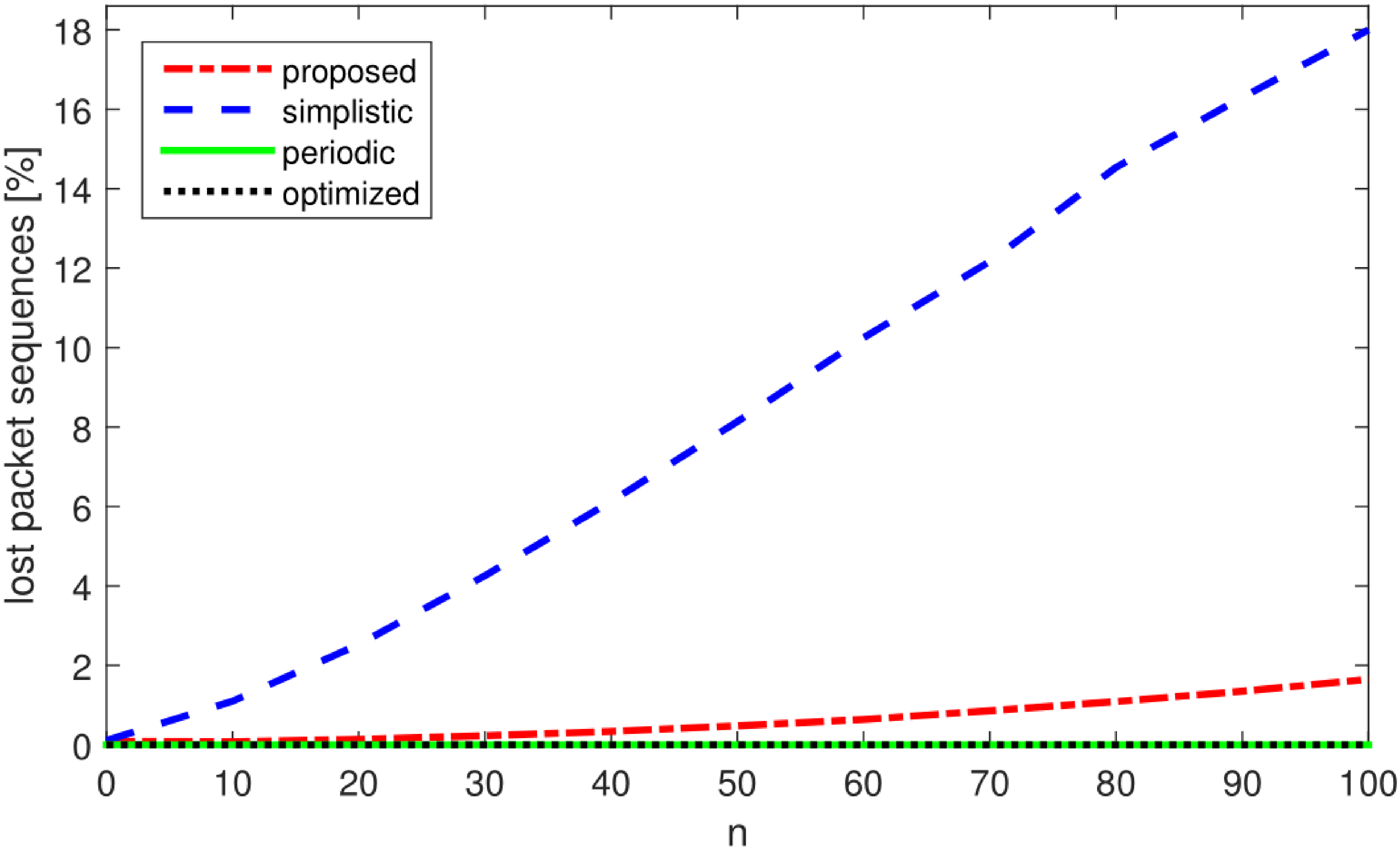
- The higher the reliability, the larger the difference between $t_{max} - t_{min}$
- The more packets we send, the smaller the difference between $t_{max} - t_{min}$

→ A reliability of 100% is not possible with this method

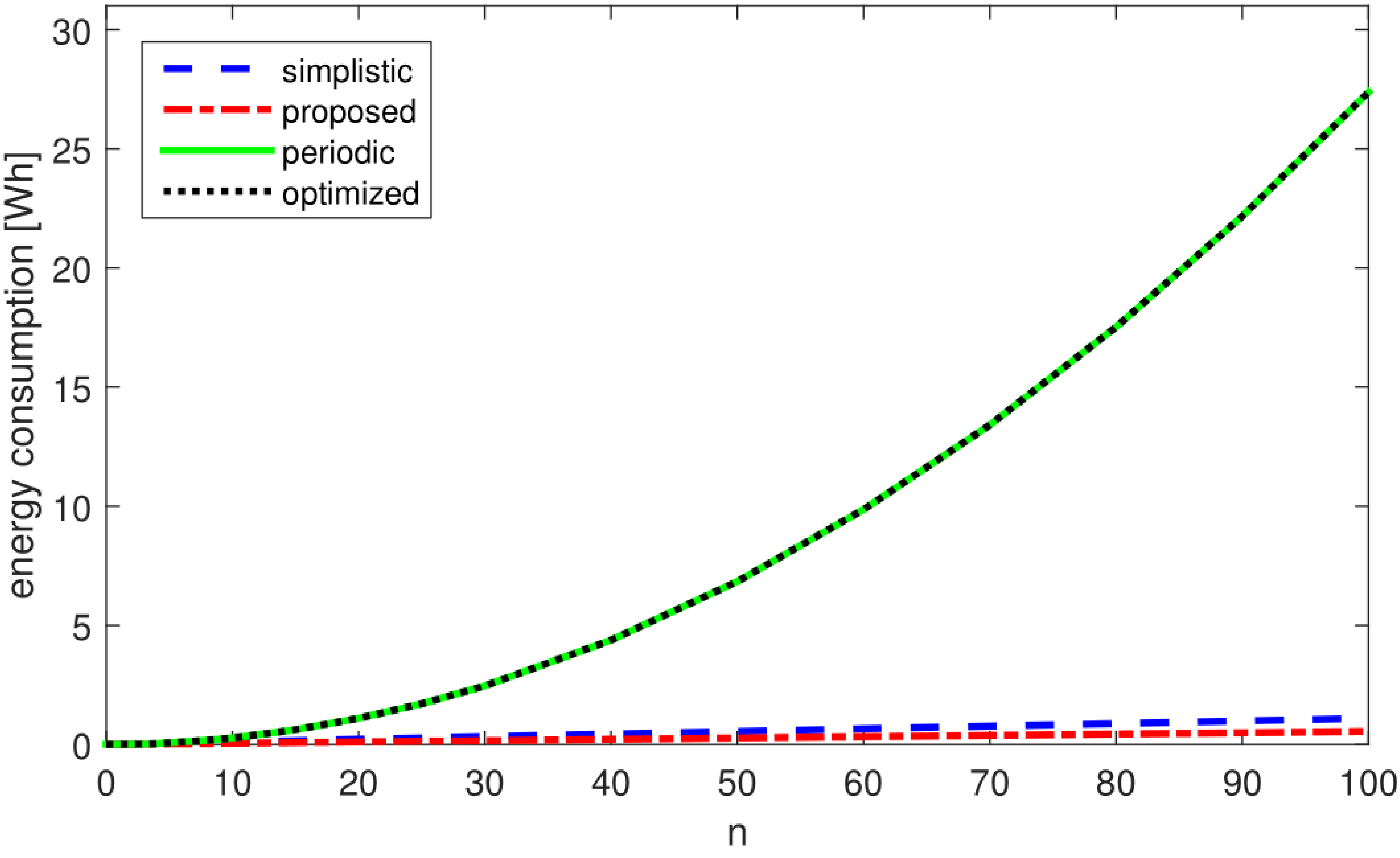
Results and simulations

- Theory has been validated by simulation using the framework OMNet++ and its extension MiXim.
  - **Proposed**: The presented Algorithm (d_{max} =0.5s, κ =2, ρ =0.95)
  - **Simplistic**: *4* consecutive packets are transmitted followed by a pause of 500ms
  - **Periodic**: sends n packets with constant inter-packet-times followed by a transmission pause. [3]
  - **Optimized**: Same as periodic, except inter-packet-times are shorter (ILP optimization). [2]

Results and simulations



Results and simulations



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Summary

- We presented a transmission scheme in which each node sends a sequence of κ packets in randomly chosen time intervals $[t_{min,}\ t_{max}]$ within a deadline d_{max}
- This allows us to:
  - Design unidirectional WSNs with a specified reliability ρ and deadline d_{max}
  - Find lowest packet number κ that has to be sent
  - High energy efficiency
- Paper covers external interferences and clock drift

Thank you for your attention

Thank you. Questions?

References

[1] B. Radunovic, H. L. Truong, and M. Weisenhorn, “Receiver Architectures for UWB-Based Transmit-Only Sensor Networks,” in Proceedings of the IEEE International Conference on Ultra-Wideband (ICU). IEEE,2005, pp. 379–384.

[2] B. Andersson, N. Pereira, and E. Tovar, “Delay-Bounded Medium Access for Unidirectional Wireless Links,” in Proceedings of International Conference on Real-Time Networks and Systems (RTNS), 2007.

[3] P. Parsch, A. Masrur, and W. Hardt, “Designing Reliable Home-Automation Networks based on Unidirectional Nodes,” in Proceedings of the IEEE International Symposium on Industrial Embedded Systems(SIES), 2014.