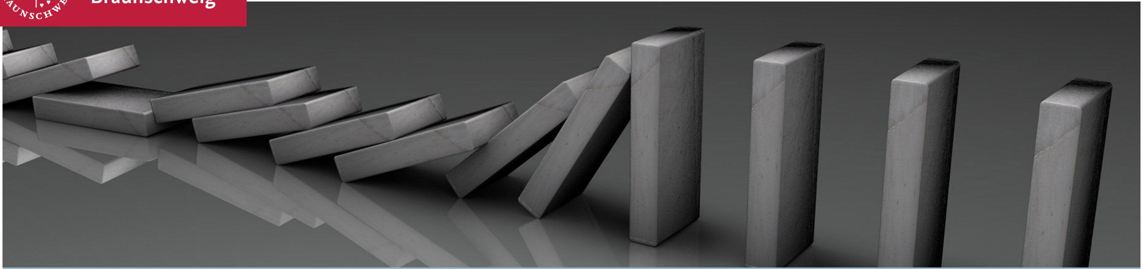


Energy Efficiency Impact of Transient Node Failures when using RPL

WoWMoM 2017

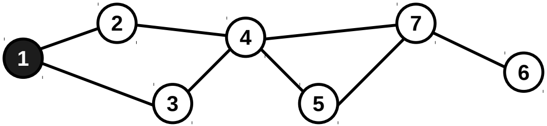
Ulf Kulau, Silas Müller, Sebastian Schildt, Arthur Martens, Felix Büsching and Lars Wolf, 13.06.2017

Technische Universität Braunschweig, IBR

Classical WSN Applications

Distributed Sensing Application

- Several wireless sensor nodes collect data in the field and *forward them to a sink node*



- Routing challenges:
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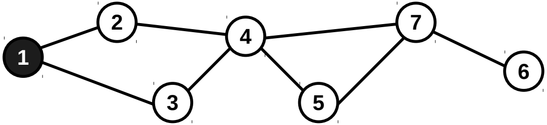

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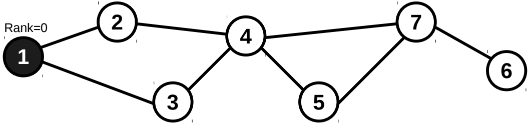
RPL – **R**outing **P**rotocol for Low Power and **L**ossy Networks

(De-facto standard for routing in 6LoWPAN WSNs)

Brief introduction: RPL

Construction of a **D**estination **O**riented **D**irected **A**cyclic **G**raph (DODAG)



- Control messages:

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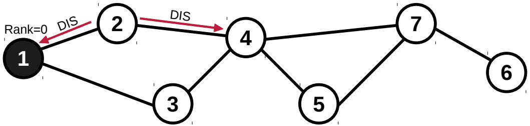

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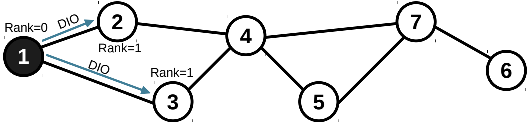

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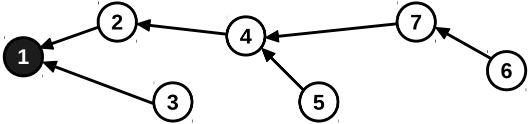

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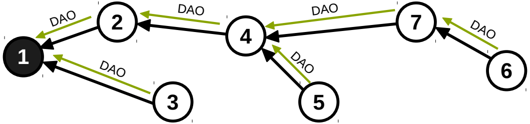

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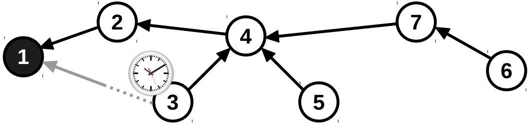

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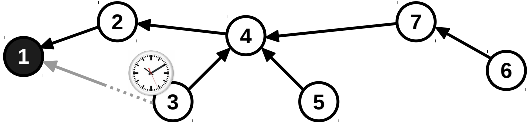

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In general: **RPL** well suited for WSN requirements

Real world WSN deployments

Transient node failures in WSNs

Energy constraints

SW bugs

Harsh environmental conditions

Intended attacks

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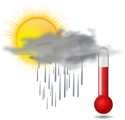

Harsh environmental conditions

Intended attacks

- Node failures often trigger a reset (watchdog)
- Low-power nodes and cheap hardware → RPL state is kept in RAM
- RPL state is lost and RPL reacts...
  1. when losing the node
  2. when reintegrating the node

Performance analysis of RPL

A plethora of existing studies

- Comprehensive evaluations but mainly focused on routing performance metrics [1, 2, 3]

J. Ko et al., *Evaluating the Performance of RPL and 6LoWPAN in TinyOS*,IP+SN, 2011

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Impact of transient node failures (lost routing state)

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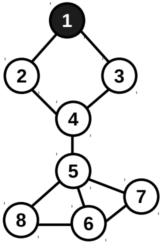
Disregarded issue: Impact of node failures on the **energy efficiency** of the WSN

Test setup for the investigation

First exemplary WSN topology with 8 nodes

→ What is the impact on the energy efficiency of a **single node reset** within t_{run}



Test setup for the investigation

Framework: Cooja (WSN Simulator) + CoojaTrace plugin (energy metering)

- Settings for each experiment

Parameter	Value
Implementation	Contiki RPL standard
Simulation runs	1000
Simulation time	$t_{run} = 10\,\text{min}$
Reset	random $2\,\text{min} \leq t_{rst} \leq 9.5\,\text{min}$
Link quality	$100\,\%$

Node type: TmoteSky

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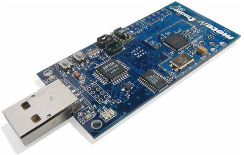


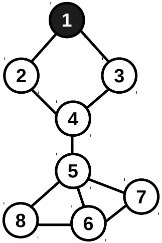
Node type: TmoteSky

- Each experiment was compared against a reference simulation (2000 runs)

Basic Scenario – Experimental results

Exemplary WSN topology with 8 nodes

→ Results: Impact of a **single node reset** within t_{run}



DODAG for the majority of sim runs

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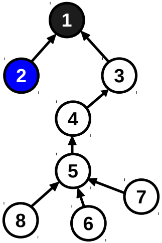

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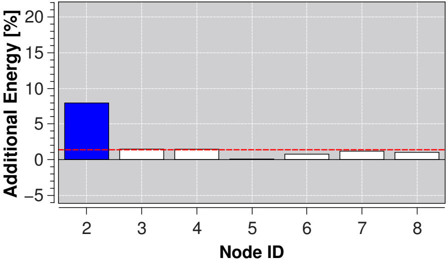

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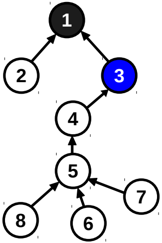

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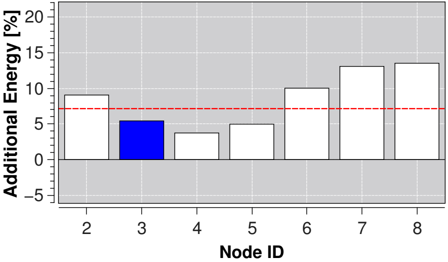

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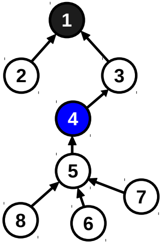

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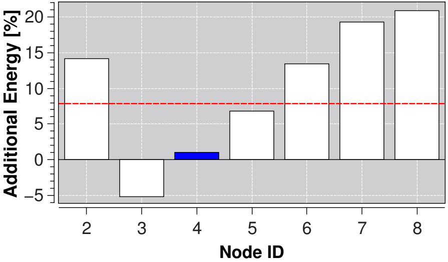

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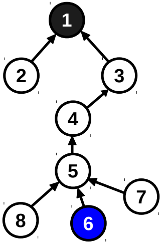

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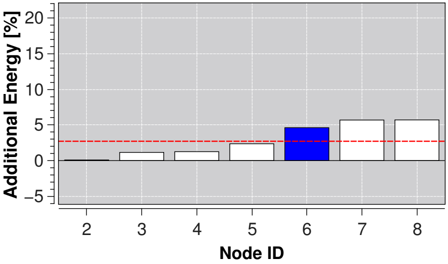
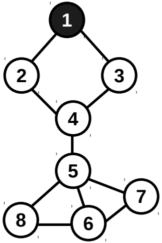


Basic Scenario – Review

Results

→ Significant energy overhead due to a single (!) node reset (1.3 % to 8 %)



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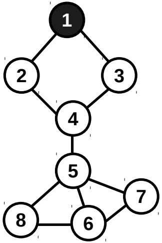

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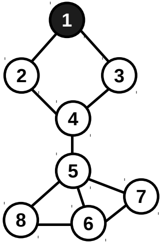

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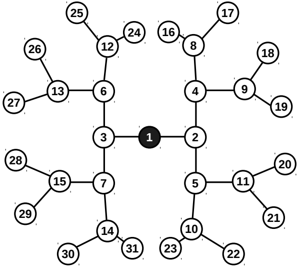
Beside the regular failures in WSNs...

→ Resetting nodes is actually a suitable attack vector for WSNs (DoE)

Mesh and Binary-tree Scenario

Further investigation with two common WSN topologies

1. Binary-tree: (1-connected graph)



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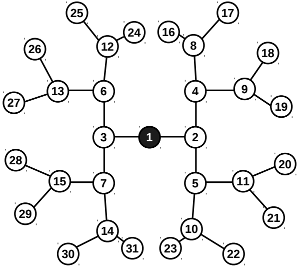
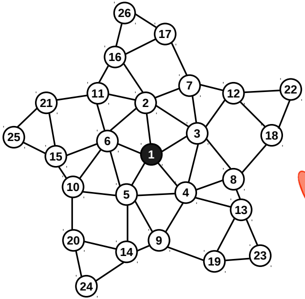
Further investigation with two common WSN topologies

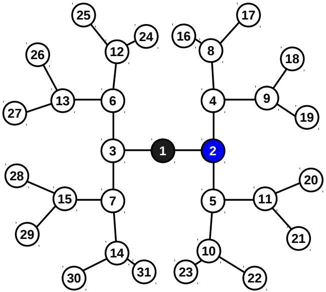
1. Binary-tree: (1-connected graph)
2. Mesh: (2-connected graph)

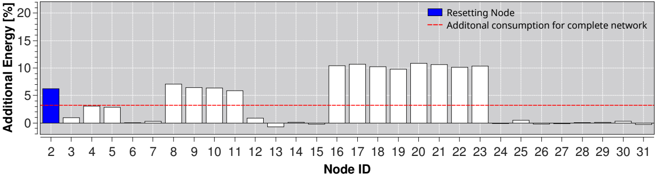




Binary-tree Scenario

Results: Single node reset (1 hop and 2 hop distance to sink)





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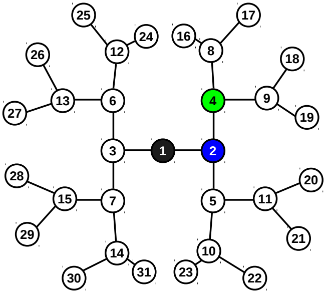

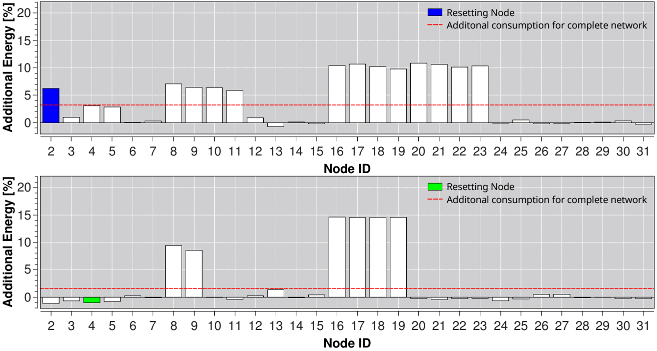

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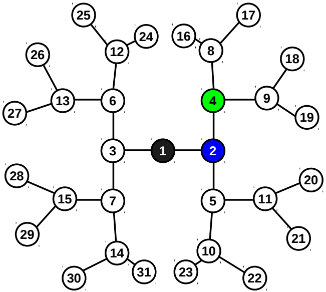

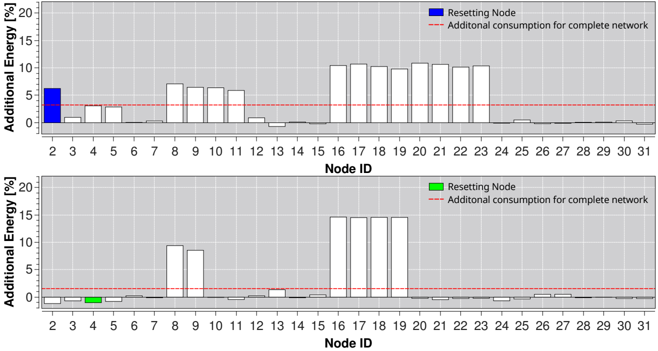

→ Subtree of bottleneck nodes is highly affected

→ Overhead decreases with distance to sink

Mesh Scenario

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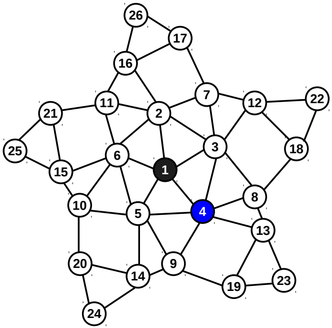

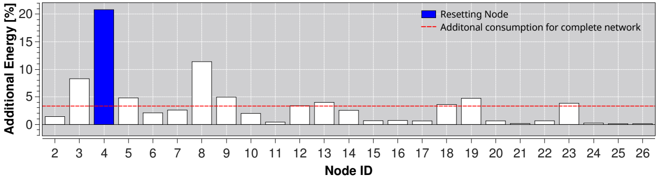

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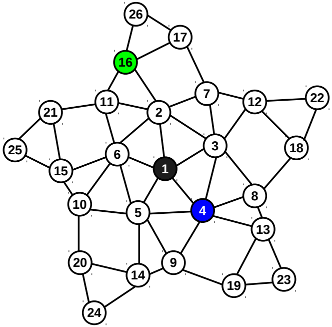

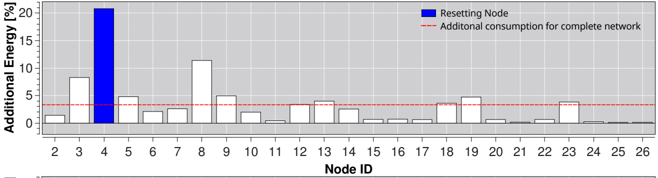

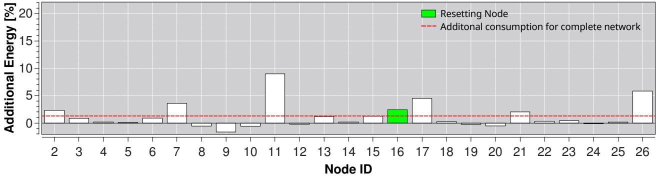

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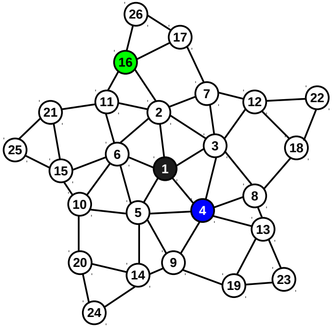

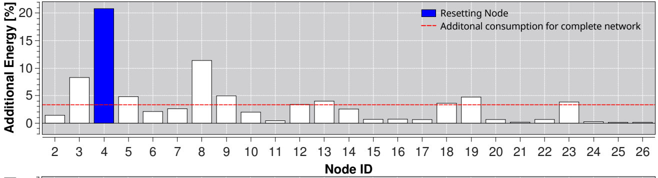

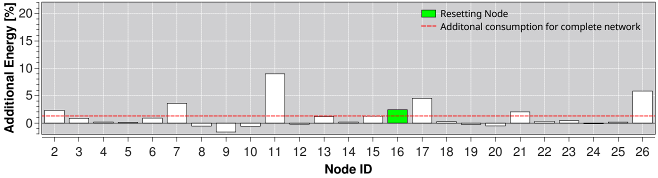

→ Neighboring nodes are affected above-average

→ Overhead decreases with distance to sink

Impact of multiple node resets

In real WSNs nodes might reset several times (Also: possible attack vector for DoE)

Results: Multiple node resets within t_{run}

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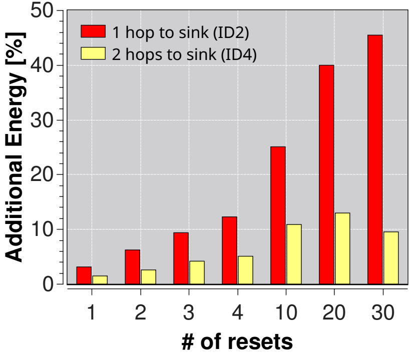

Binary tree scenario

- Additional resets increase overall energy consumption significantly
- Effect declines with high reset frequencies (down-time of nodes)

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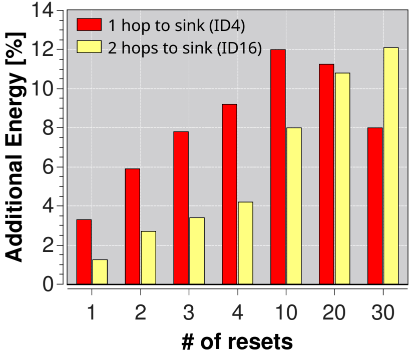

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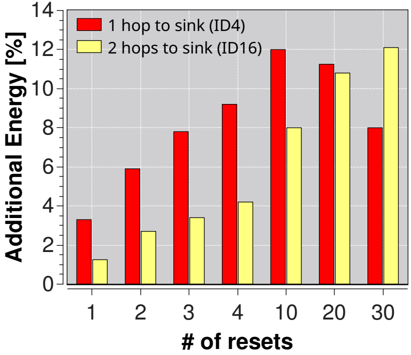

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Attacker’s advice:
→ reset different nodes

Summary

Disregarded issue of resetting nodes on RPL

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Thank you for your attention! Questions?

Ulf Kulau

`kulau@ibr.cs.tu-bs.de`