

Energy efficient scheduling for cluster-tree WSNs with time-bounded data flows

application to IEEE 802.15.4/ZigBee

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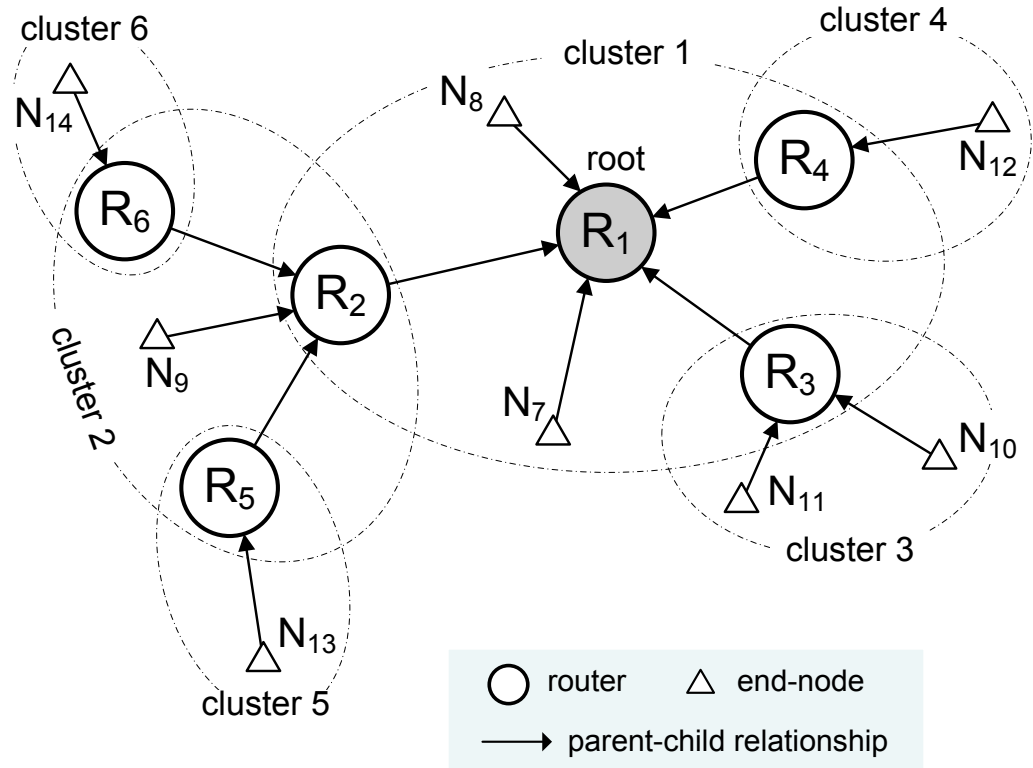
CAK Embedded Systems Colloquium, Prague
4th February 2010

Cluster-tree Topology Model

System Model

static wireless sensor networks (WSNs)

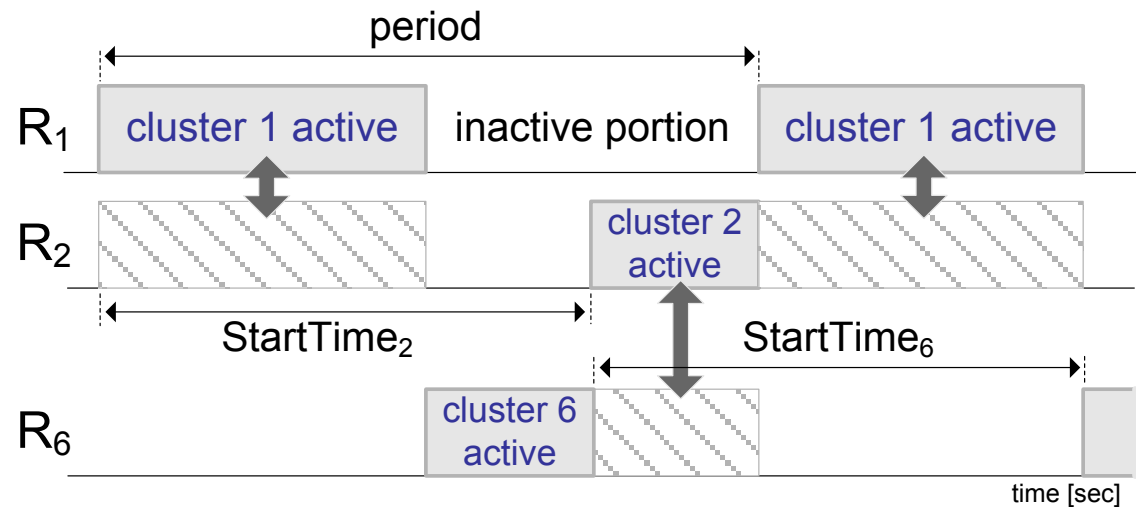
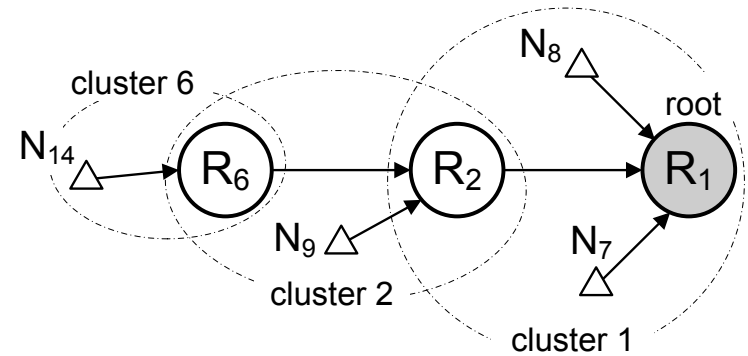
- cluster-tree topology
 - ▶ router R_i
 - ▶ end-node N_i
 - ▶ in-tree
- deterministic routing
 - ▶ single routing path
- cluster (star subnetwork)
 - ▶ cluster-head



Cluster-tree Topology Model

System Model

- cluster
 - active portion
 - inactive portion (low power mode)
- StartTime parameter
- collision domains



A. Koubaa, A. Cunha, M. Alves, and E. Tovar, *TDBS: a time division beacon scheduling mechanism for ZigBee cluster-tree wireless sensor networks*, Real-Time Systems Journal, vol. 40, no. 3, pp. 321-354, Oct.2008.

Data Flow Model

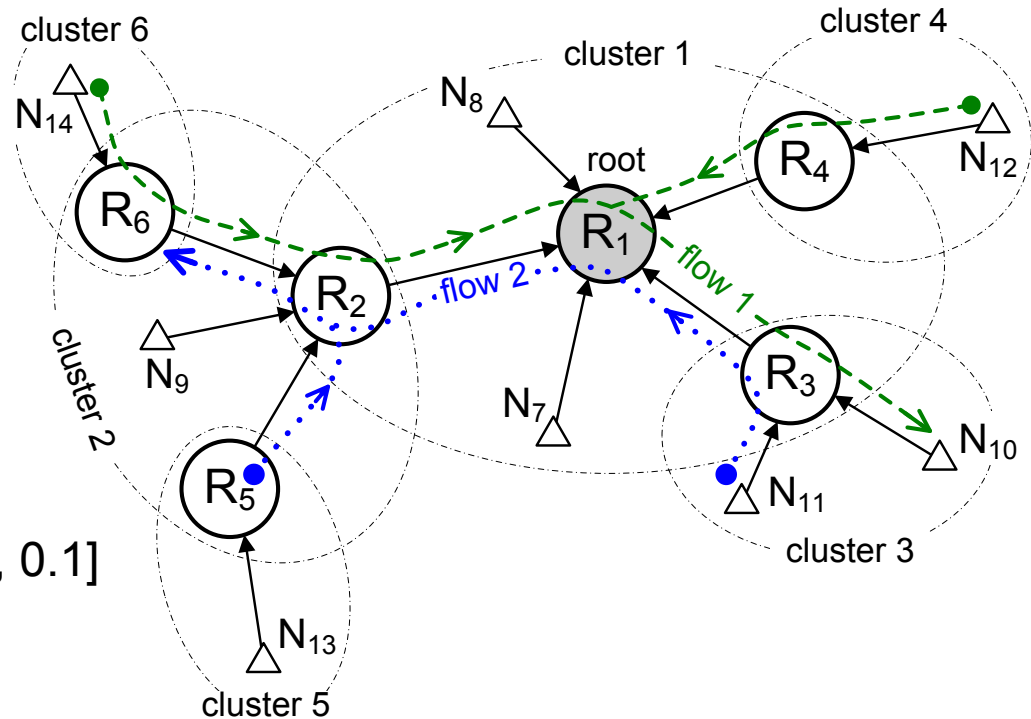
System Model

■ data flows

- predefined
- time-bounded
- multi-source mono-sink
- periodic
- parameters: [flow 1]
 - ▶ sources [N14, N12]
 - ▶ sink [N10]
 - ▶ end-to-end deadline [0.2, 0.1]
 - ▶ required period [0.4]
 - ▶ sample size [64]
 - ▶ acknowledgment [no]

■ communication errors

- bounded number of retransmissions

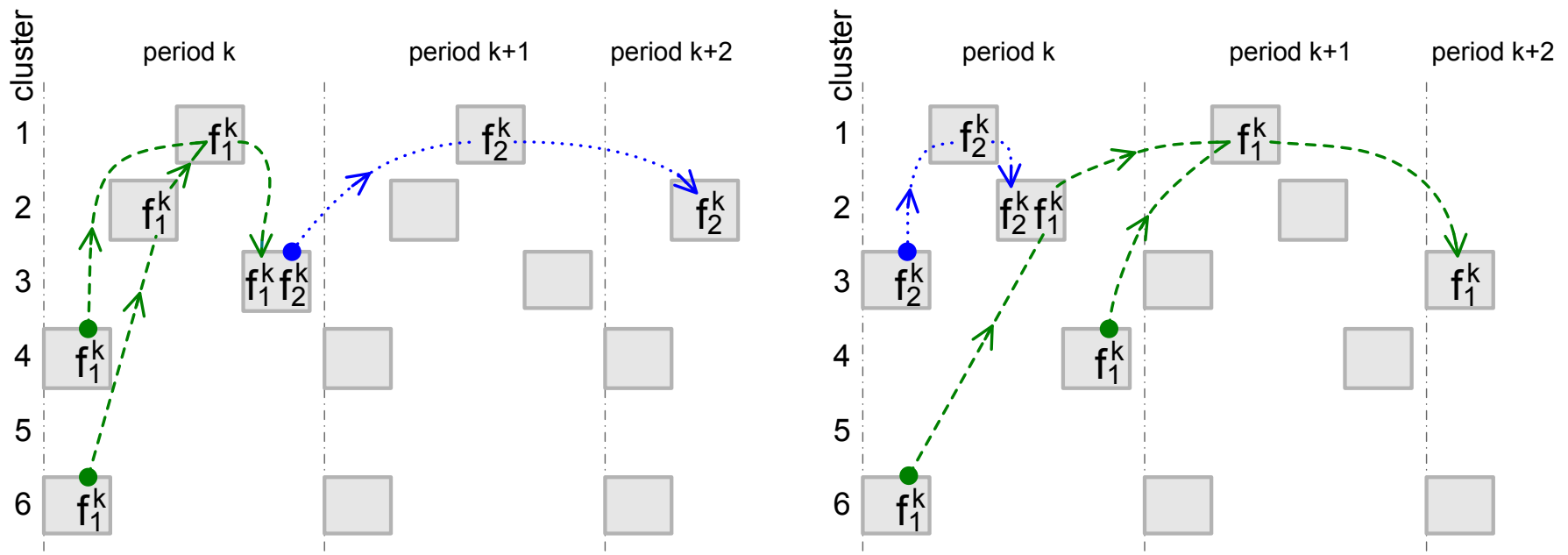


Problem Statement

problem statement:

■ cyclic clusters' schedule

- collision free
- energy efficient – minimize the energy consumption of the nodes
- meeting flows' parameters

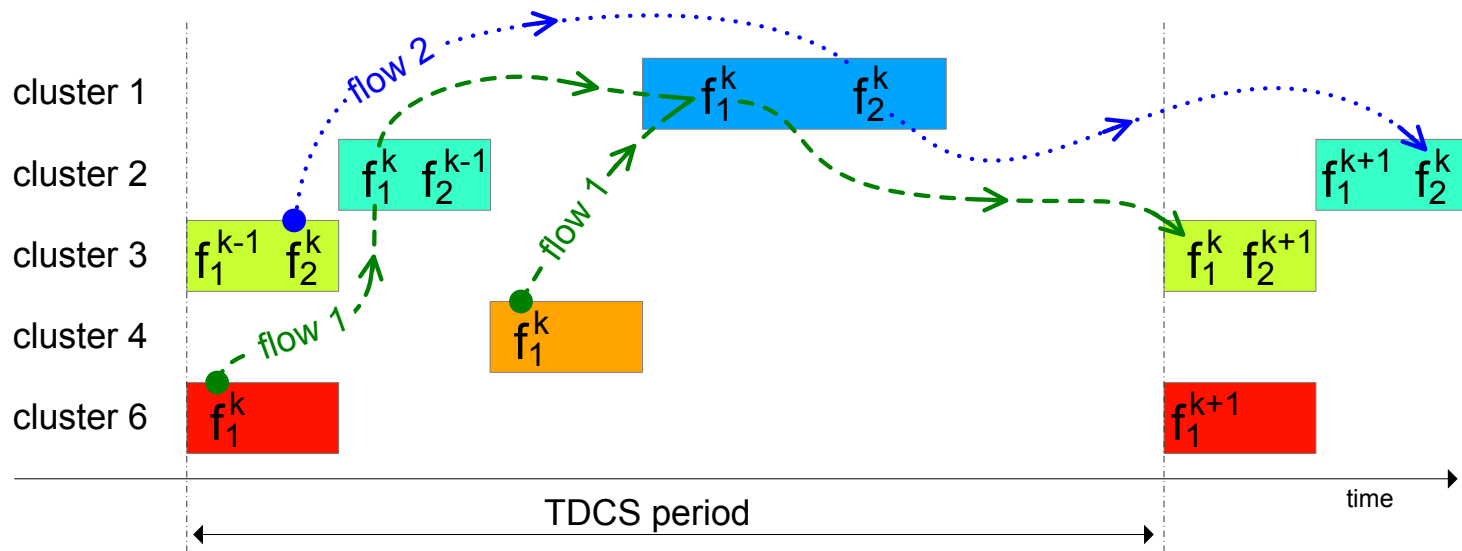


Time Division Cluster Scheduling

■ Time Division Cluster Scheduling (TDCS)

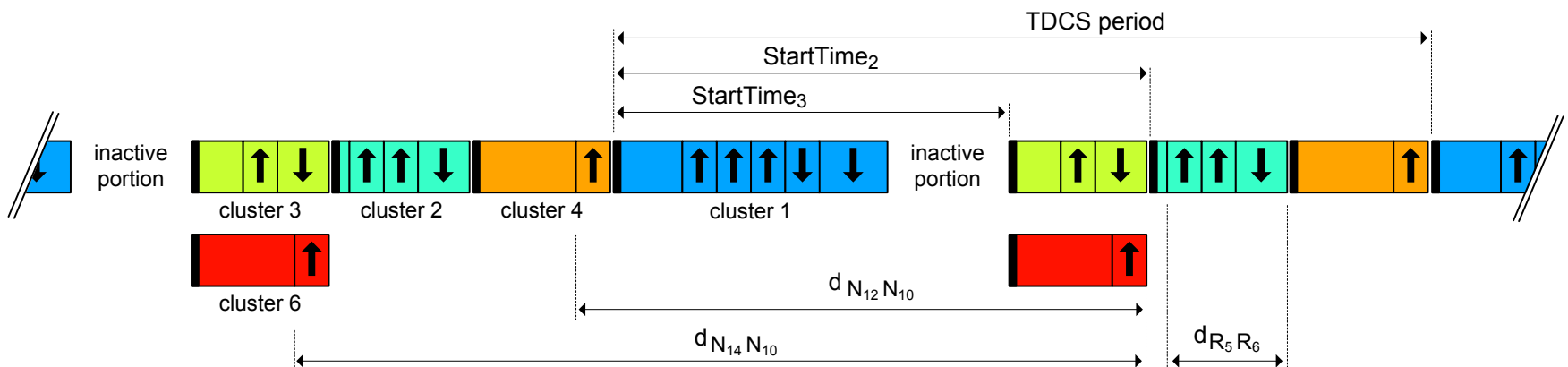
● TDCS period

- ▶ same for all clusters
- ▶ minimum = sum of clusters' active portions
- ▶ maximum = the shortest required period
- ▶ as long as possible → energy efficiency X end-to-end delay



Time Division Cluster Scheduling

- based on the cyclic extension of RCPS/TC (Resource Constrained Project Scheduling with Temporal Constraints)
- Integer Linear Programming (ILP)
- application to IEEE 802.15.4/ZigBee WSNs
- time complexity
 - Matlab tool based on GLPK solver
 - middle-sized WSN (hundreds of nodes)
- easy to use scheduling tool for network designers



Simulation Study

- communication errors
 - acknowledgment and retransmission mechanism
 - bounded the maximum number of retransmissions (*macMaxFrameRetries*)

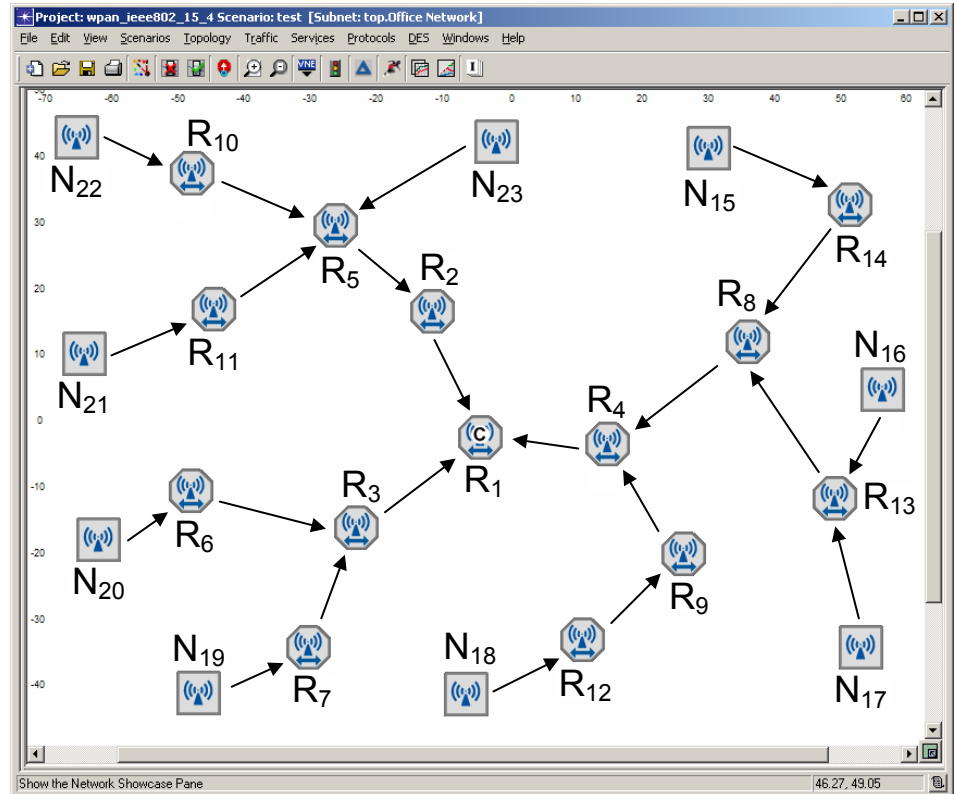
- How the maximum number of retransmissions impacts:
 - reliability of data transmission
 - energy consumption of the nodes
 - end-to-end communication delayin IEEE 802.15.5 cluster-tree WSN?

- IEEE 802.15.4/ZigBee Opnet simulation model
- configuration parameters – TDCS tool
- non-overlapping TDCS (single collision domain)

Simulation Scenario

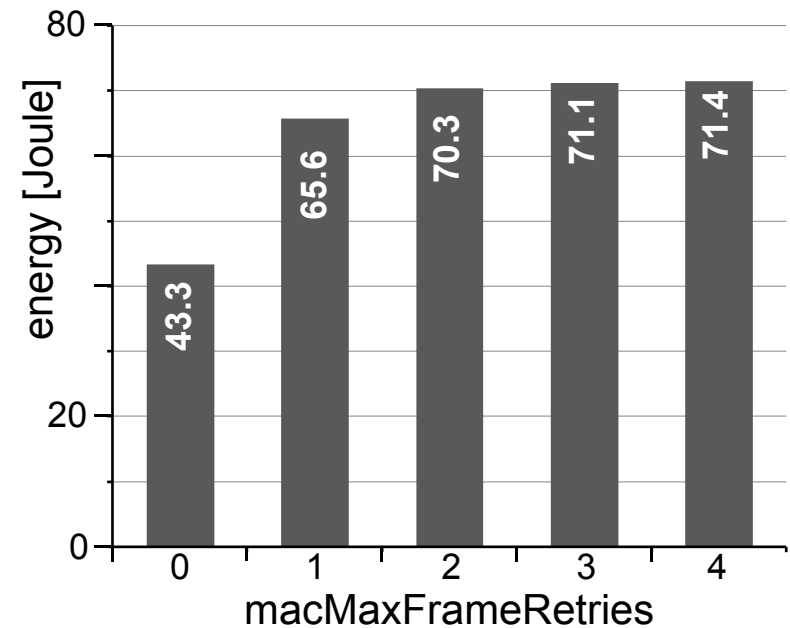
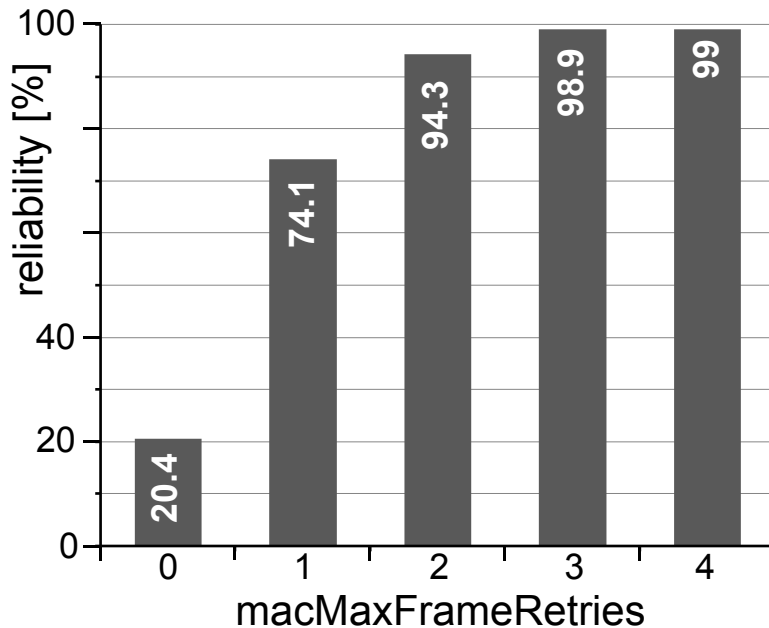
- 14 clusters
- 23 TelosB motes
- 3 flows

- homogenous channel error rate = 20%
- one run = 20 minutes



Reliability and Energy

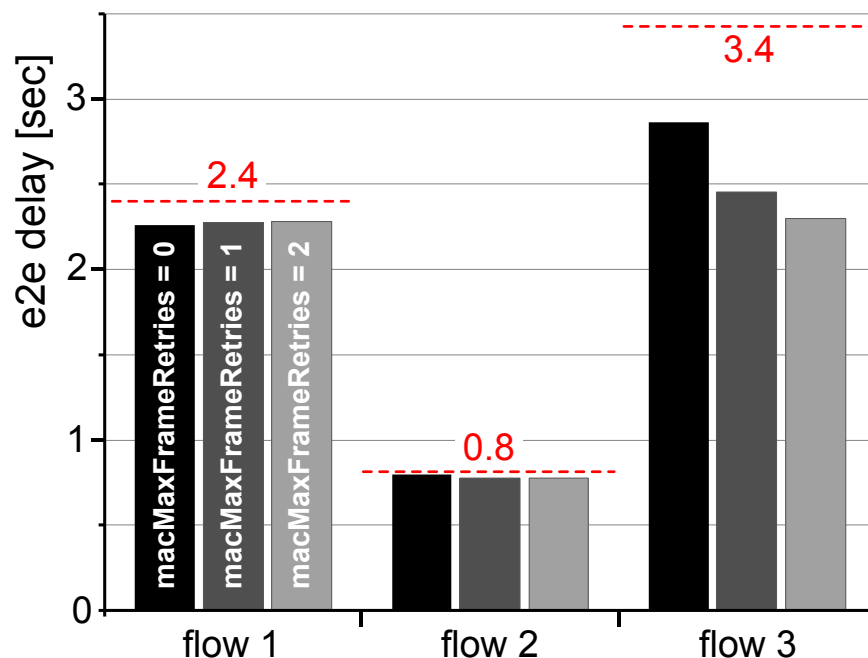
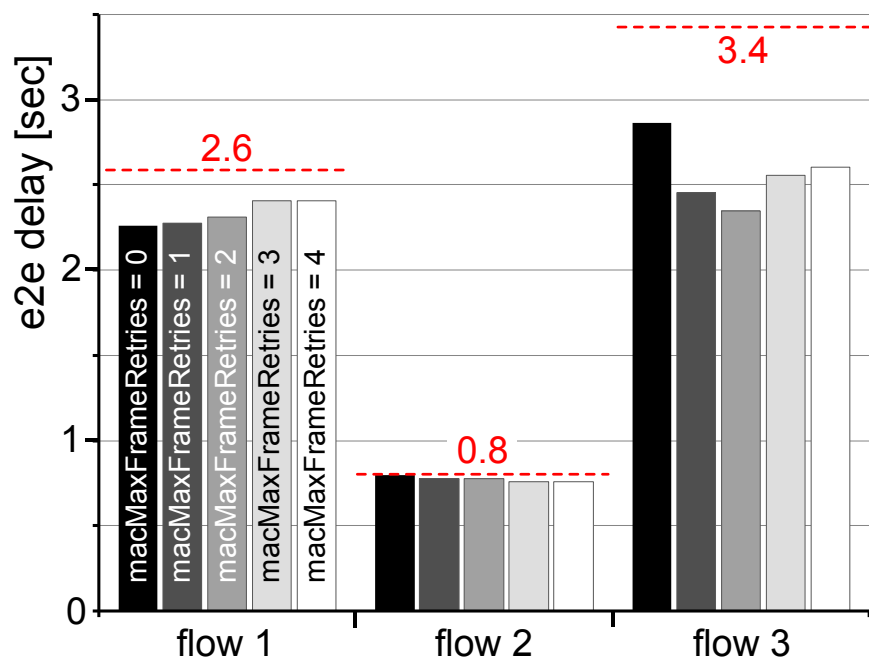
- reliability = dispatched frames / received frames
- sum of energy consumption of all nodes



End-to-end Delay

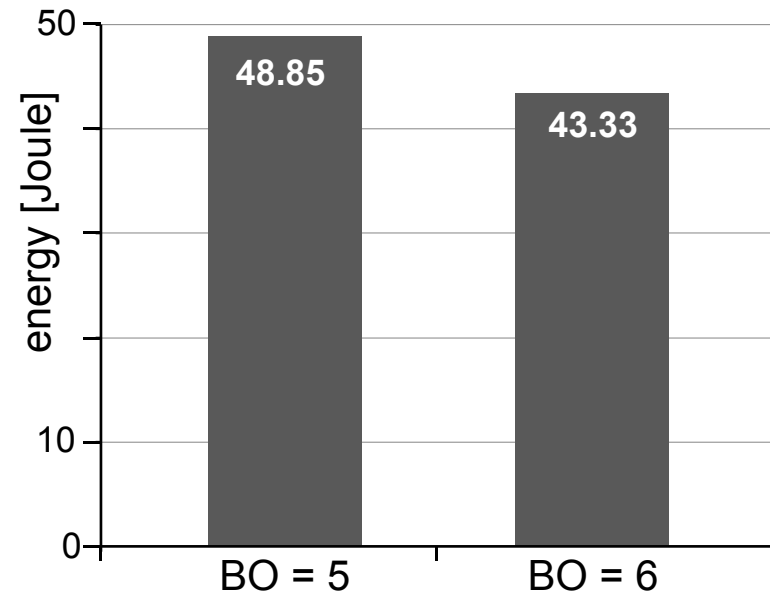
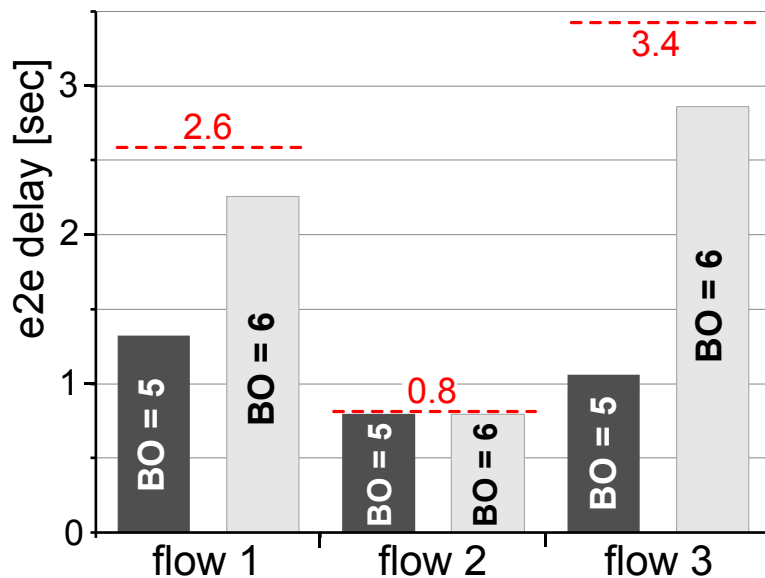
■ flow 1

- e2e deadline = 2.6 sec (*macMaxFrameRetries* = 4)
- e2e deadline = 2.4 sec (*macMaxFrameRetries* = 2)



Validation of TDCS tool

- unacknowledged transmission ($macMaxFrameRetries = 0$)
- shorter TDCS (BO=5) vs. longer TDCS (BO=6)



výsledky zaslány:

- IEEE Transactions on Industrial Informatics
- 8th IEEE International Workshop on Factory Communication Systems (WFCS)

IEEE 802.15.4/ZigBee Opnet Simulation Model

- <http://www.open-zb.net>
 - from 2007: 5000 downloads, 77800 visitors