Sensor Networks for (Building)Automation

Energy Efficiency

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Überblick

- Introduction of Chair for Technical Information Systems

- Application Scenario
  - General requirements
  - Sensor data
  - Deployment difficulties
- Approach description
  - General approach
  - Two-step controller
- Evaluation
  - Beacon order over time
  - Energy over time
  - Relative delay over parameterization

TECHNISCHE UNIVERSITÄT DRESDEN

Introduction

SAP

Chair for Technical Information Systems
Prof. Kabitzsch

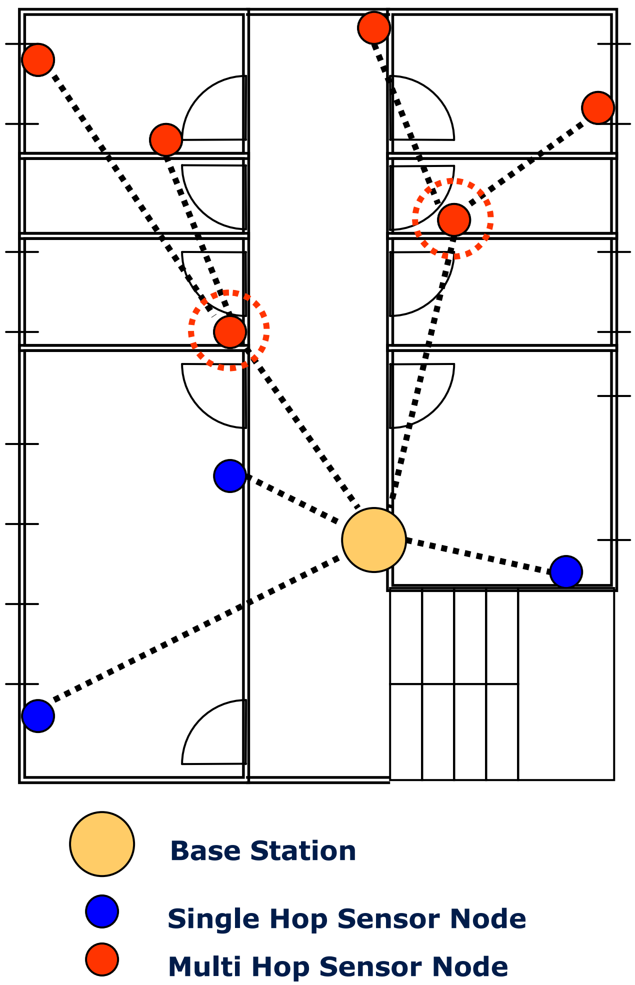
- Fieldbus Networks
  - Building Automation
  - Performance Analysis
  - Network Design Principles
- Wireless Sensor Networks
  - Energy Efficiency
  - Applications for Building Automation
- Test and Diagnosis
  - AutoSPy (Diagnosis for SPS)
  - EXTRAKT (Event Based Diagnosis)

- Cooperation with SAP Research Lab Dresden
  - Smart Items Research Program

Application Scenario (1)

Building Automation

- Monitoring
  - Temperature
  - Humidity
  - Outside Wind
  - Air Pressure
  - Precipitation
  - Sky covering
- Multiple Hops possible
  - Lower transmission range
  - Save additional base station
- Non-Realtime and Soft-Realtime
- Market Maturity of IEEE 802.15.4



Application Scenario (2)

Analysis of some typical weather data:

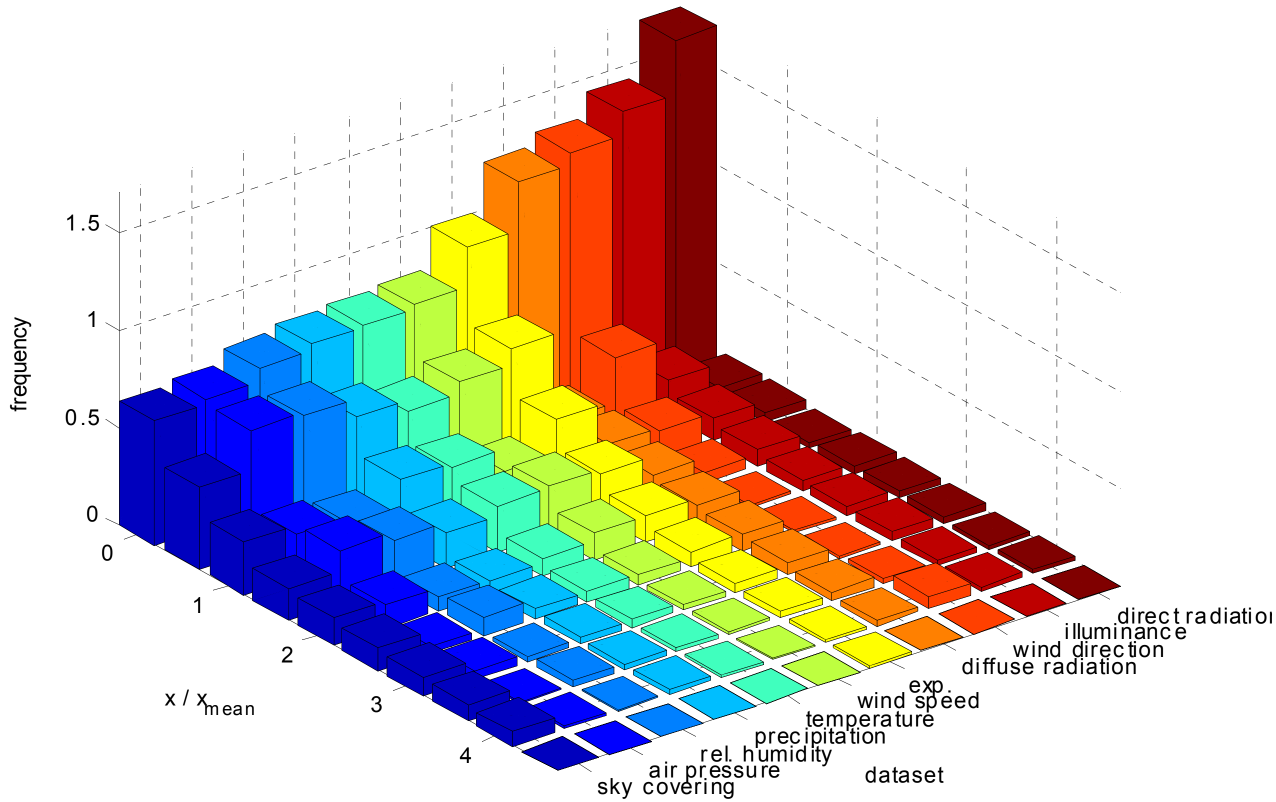
- Several slow changing processes

	E[f]	Unit
Temperature	$1.85 \cdot 10^{-4}$	°C
Rel. Humidity	$8.45 \cdot 10^{-6}$	
Wind Speed	$2.9 \cdot 10^{-4}$	m/s
Air Pressure	$9.0 \cdot 10^{-5}$	hpa
Precipitation	$1.36 \cdot 10^{-5}$	mm/h
Sky Covering	$1.67 \cdot 10^{-5}$	

Application Scenario (3)

Analysis of some typical weather data:

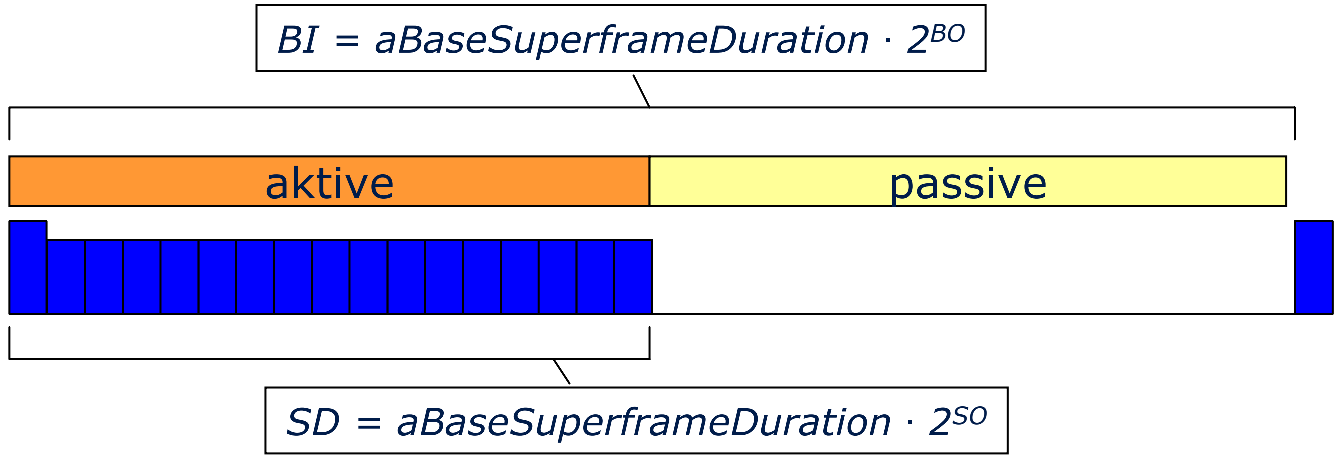
- Exponentially distributed gradient
- Exponentially distributed inter-arrival time (sendOnDelta)



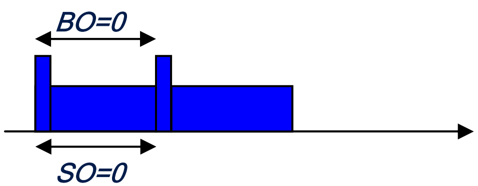
Deployment Difficulties

Questions for deployment of sensors:

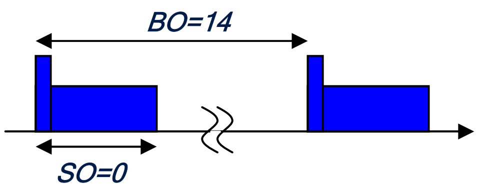
- How to adjust the duty cycle?
  - IEEE adjustment of beacon order for unknown process



$$\frac{active}{passive} = \frac{1}{0}$$



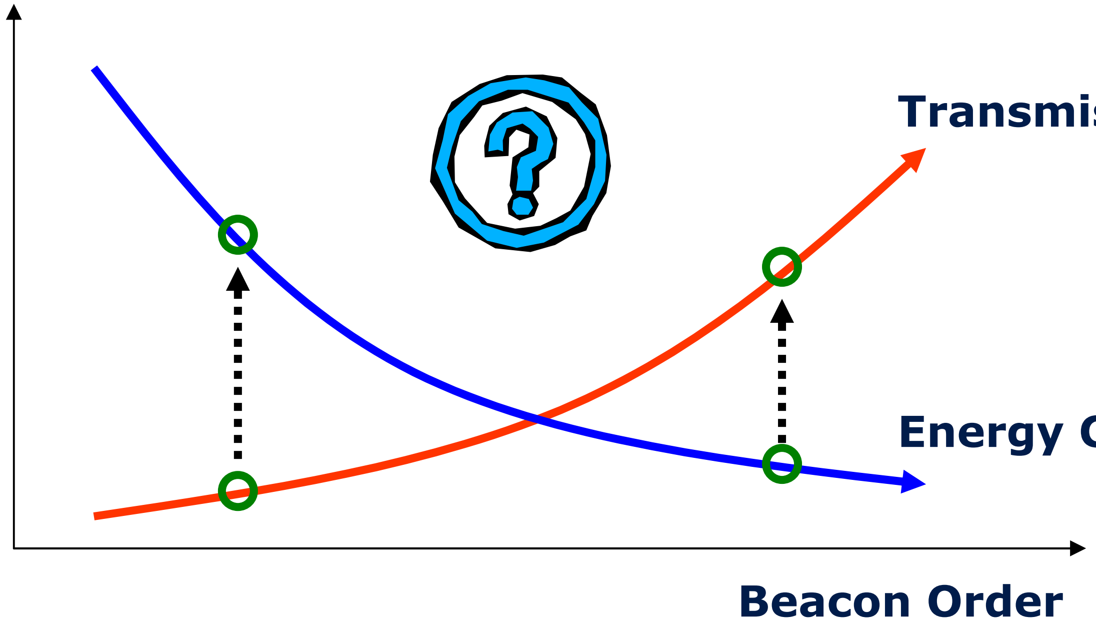
$$\frac{active}{passive} = \frac{1}{16384}$$



Deployment Difficulties

Questions for deployment of sensors:

- How to adjust the duty cycle?
  - IEEE adjustment of beacon order for unknown process
- Trade off between energy consumption and transmission delay?



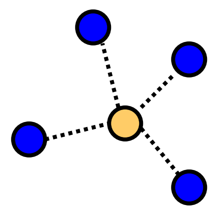
Deployment Difficulties

Questions for deployment of sensors:

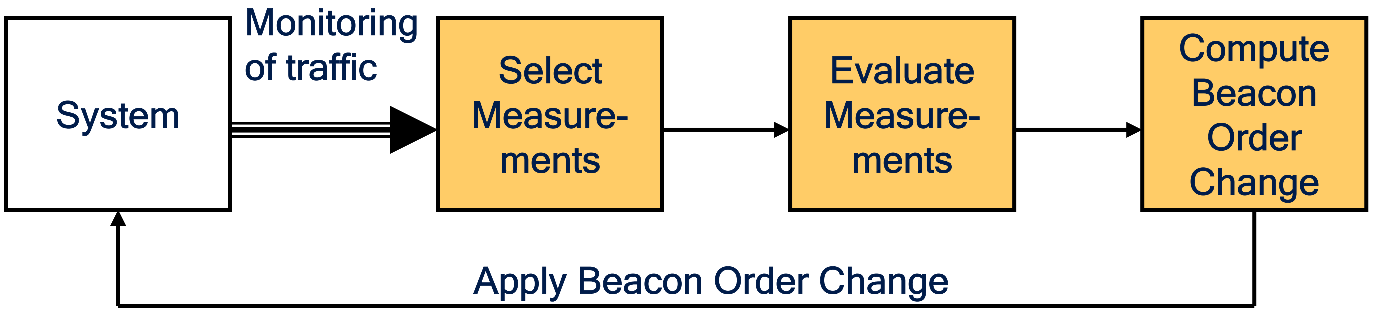
- How to adjust the duty cycle?
  - IEEE adjustment of beacon order for unknown process
- Trade off between energy consumption and transmission delay?
- How to make algorithm lightweight?
  - Limited computation power, memory and energy in sensor node

Approach Description

- Adaptation of beacon order according to traffic
- Coordinator:
  - Monitoring of traffic
  - Select measurements
  - Evaluate measurements
  - Compute beacon order change
  - Apply beacon order change



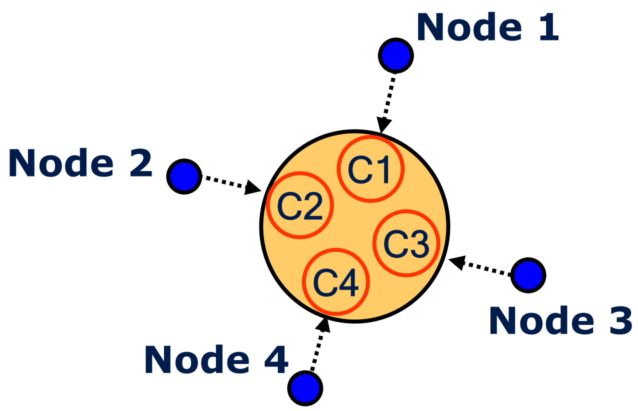
Examinations here restricted to one star



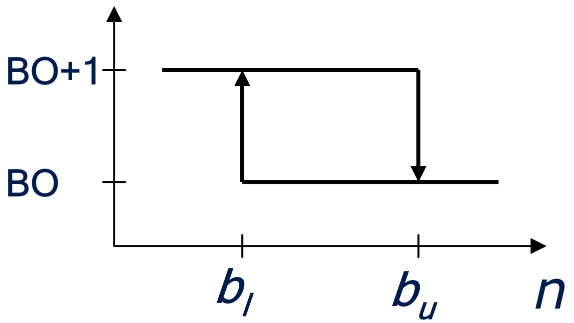
Approach Description

In detail:

- Monitoring
  - Count packtes arriving from subordinated nodes
  - Record counted packets over period (n beacon intervals)



- Computation of beacon order change
  - Determine number of messages *n* from most active node
  - Apply two-step controller

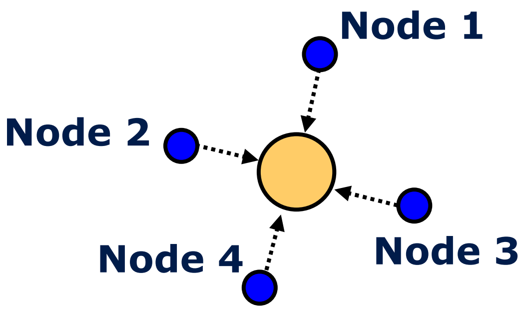


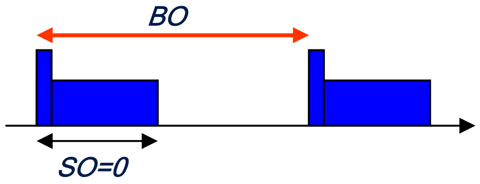
- Apply new beacon order with broadcast of next beacon packet

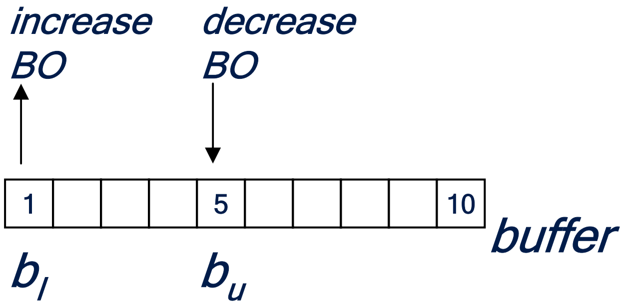
Evaluation

Simulation Scenario

- One coordinator, four sensor nodes around
- $\lambda_1 = 0.01$ messages/s
- $\lambda_2 = 0.1$ messages/s
- $\lambda_3 = 1$ message/s
- Only adaptation of beacon order (no superframe order change)
- Two-step controller:
  - Evaluation of last 10 beacon intervals
  - $b_l = 1$; $b_u = 5$



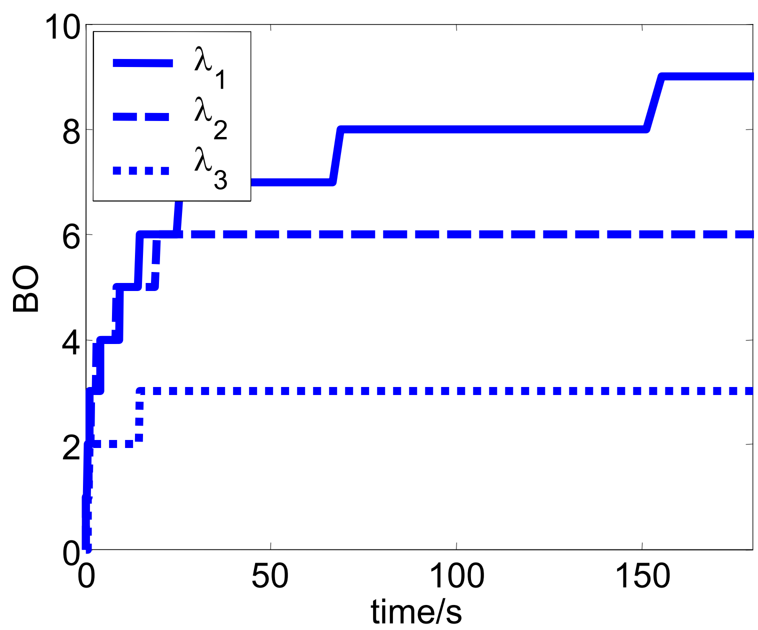




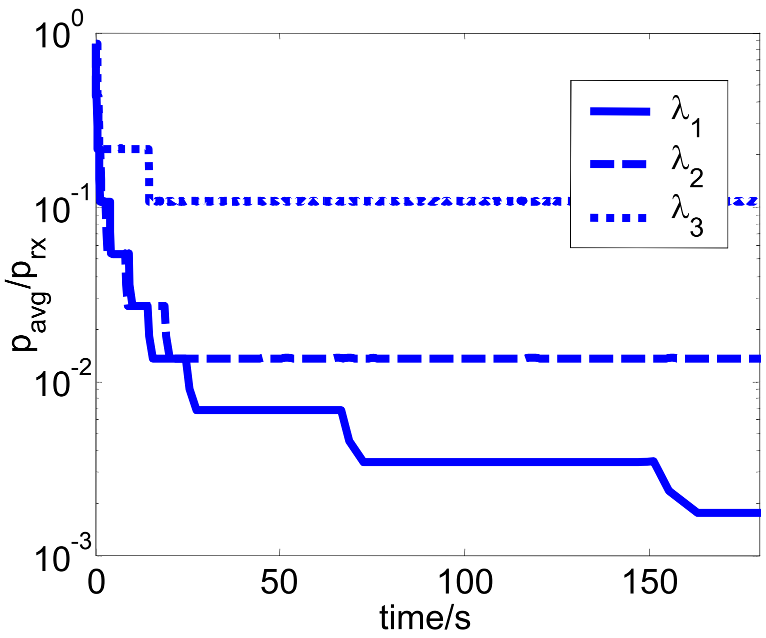
Evaluation

- Adaptation behaviour over time

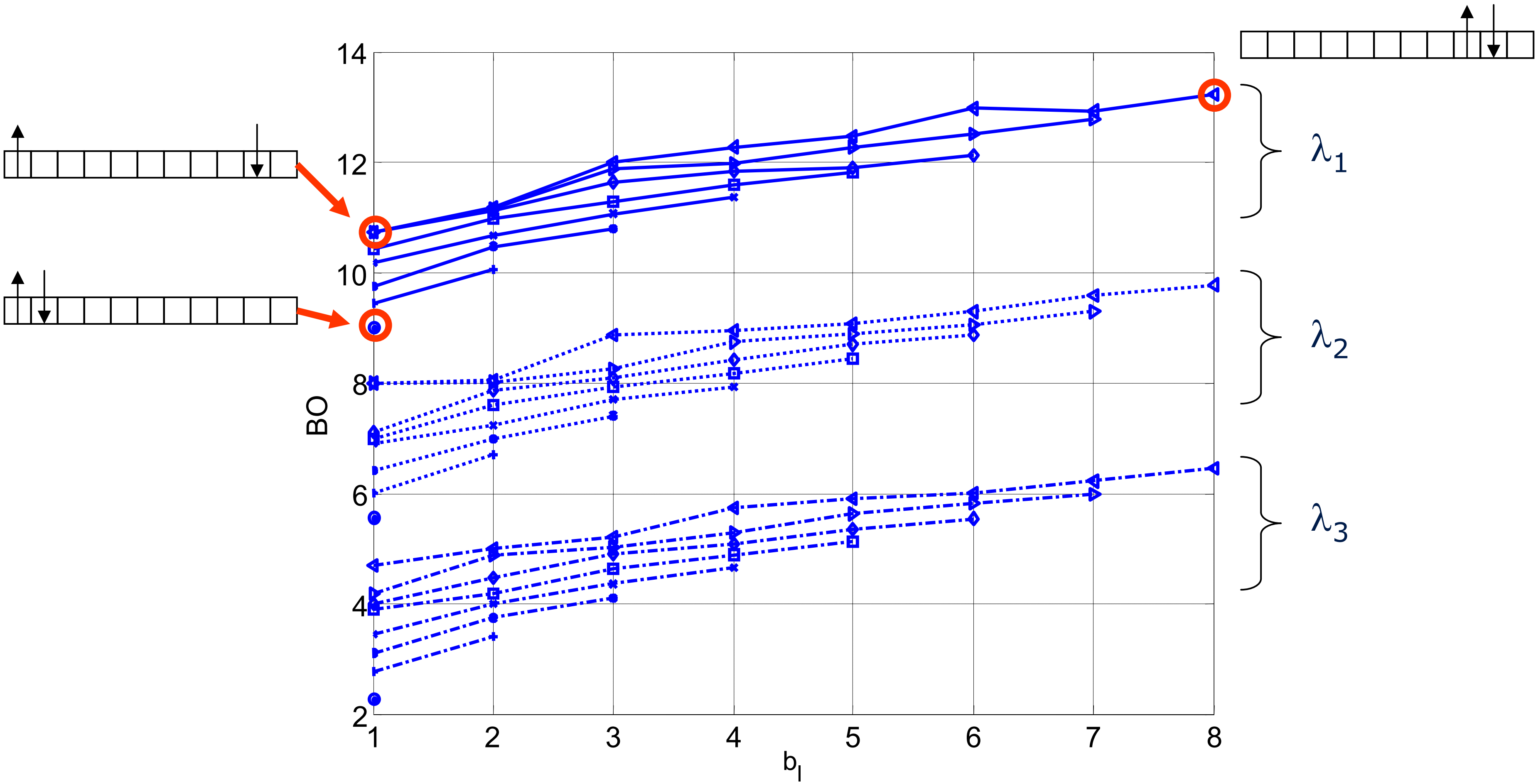
Beacon Order



p_{avg}/p_{rx} in coordinator



Average beacon order with different two-step settings



Evaluation

- Average beacon order impacts in packet delay
- but different impact according to arrival rate
  - i. e. 1s delay compared to
    - λ_1= 0.01 messages/s
    - λ_2= 0.1 messages/s
    - λ_3= 1 message/s

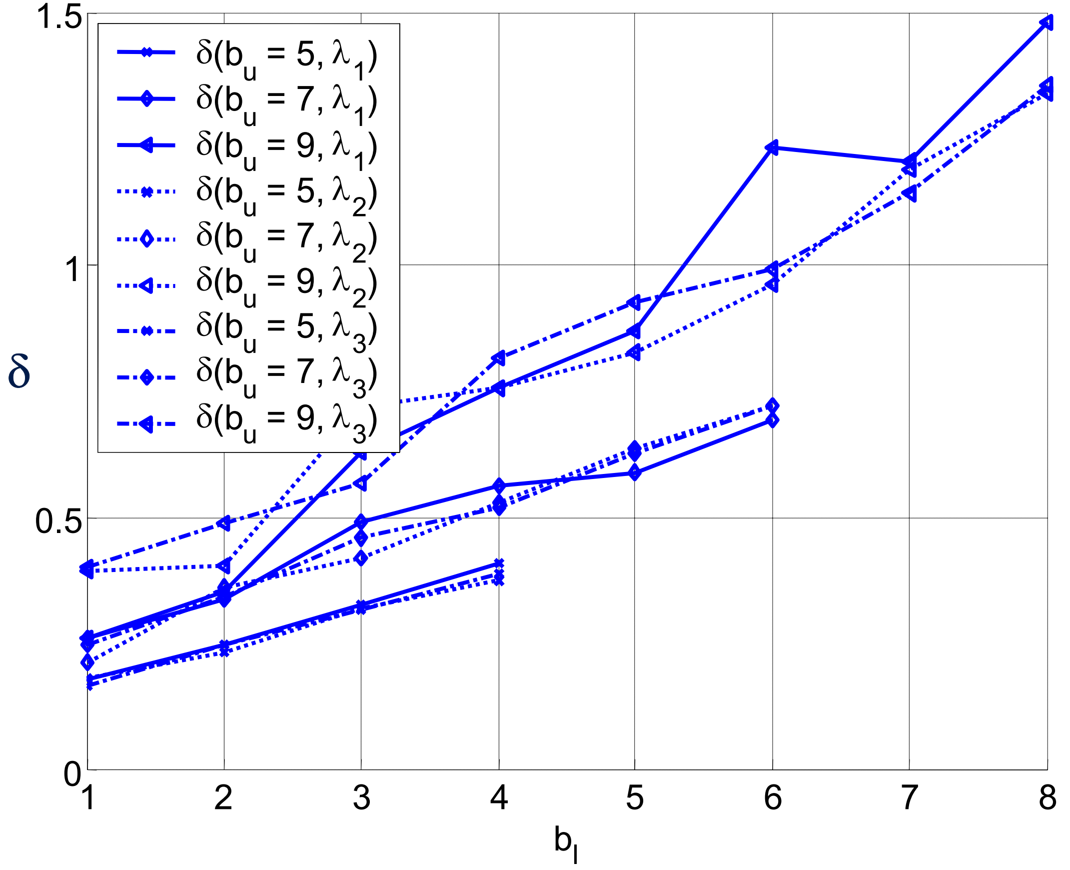
➢ Measure the maximal delay related to arrival rate: $\boldsymbol{\delta = BI/\lambda^{-1}}$

Evaluation

$\delta = \mathbf{BI}/\lambda^{-1}$ vs. b_l

Same parameterization, different arrival rate

- Similar delays with regard to arrival rate



Summary

- Introduced beacon order adaptation algorithm
- Based on IEEE 802.15.4
- Change of beacon order depending on traffic observed
- **No traffic knowledge required**
- Beacon order depends on parameterization
  - Impacts energy consumption
  - Impacts absolute delay
  - Leads to similar delay related to arrival rate

- Applicable for a variety of monitoring tasks
- Not suited for certain applications (i. e. light switch) with real-time requirements

- Further examinations (i. e. changing arrival rate)