TU Clausthal

CLAP: Cooperative Locality-Aware Data Processing in Heterogeneous Fog Environments

Aditya Raj, Andreas Reinhardt

GI/ITG KuVS Fachgespräch “Fog Computing”

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Overview

- Introduction and problem statement
- CLAP: Collaborative Locality-Aware Data Processing
  - Design overview
  - Implementation
  - Evaluation
- Conclusions and outlook

INTRODUCTION

AND PROBLEM STATEMENT

Wireless sensors

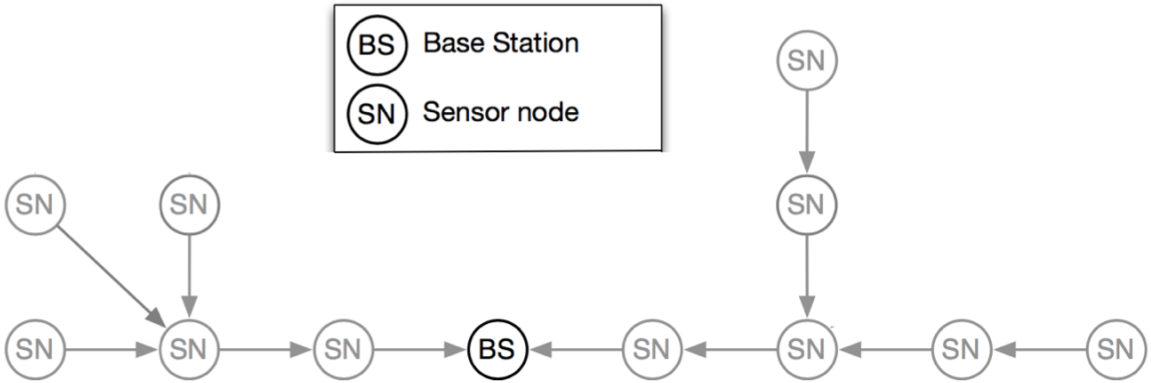
- Diverse sensing modalities
  - Temperature
  - Humidity
  - Brightness
  - ...

Image source: https://www.thermofisher.com.au

- Advantages
  - Battery-driven operation – less restrictions for device placement
  - No central entity required for coordination purposes
    - No single point of failure
  - Can be deployed in remote areas
    - Disaster relief, military scenarios

Data forwarding in wireless sensor networks

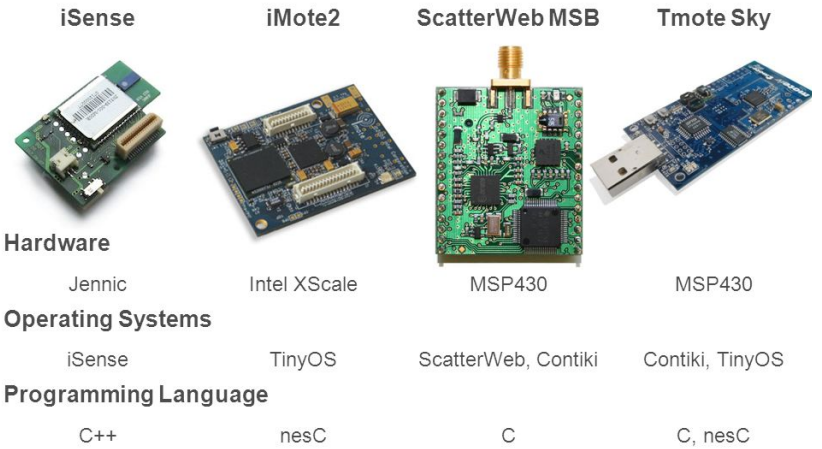
- Multi-hop relaying along a ‘collection tree’
  - Each node learns the address of the next hop (its ‘parent’ node)
  - Packets are iteratively forwarded to nodes’ parents until they reach the network edge (a.k.a. the ‘base station’)
  - Data processing is prevalently run on the base station



Device heterogeneity in the Internet of Things

- Nodes by different manufacturers may use the same communication standard (e.g., IEEE 802.11 or IEEE 802.15.4)

- But they often differ in terms of:
  - Processing power
  - Available memory
  - Residual energy
  - Available sensors/actuators
  - Operating system support



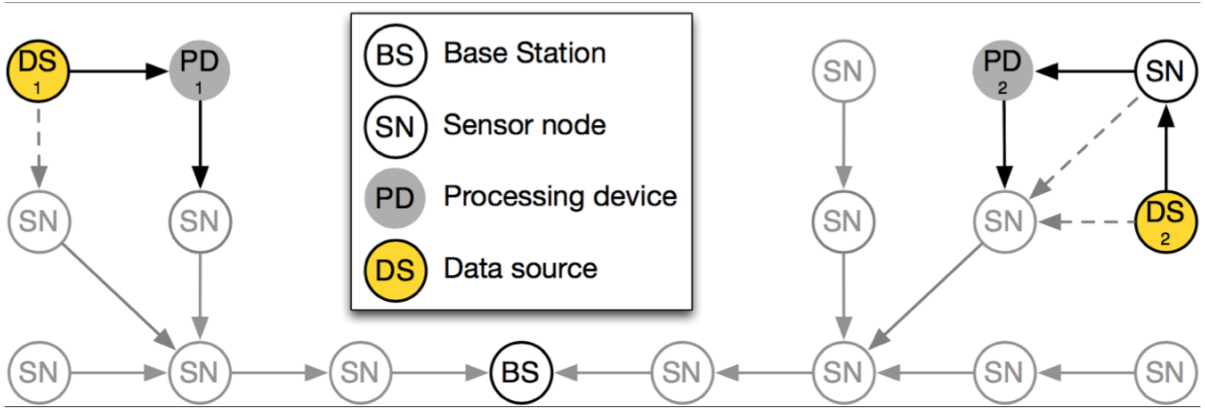
So why not use them for processing the sensor data collected distributedly within the wireless sensor network?

Dr.-Ing. Andreas Reinhardt
Dept. of Informatics, TU Clausthal

Image source: T. Baumgartner et al., “Wiselib: A Generic Algorithm Library for Heterogeneous Sensor Networks”, EWSN 2010

Scenario for collaborative data processing

- Introduce heterogeneous processing devices (PDs) into the network
  - Initial consideration: Deployment at arbitrary locations
- Achieve locality-aware (i.e., in the immediate neighborhood) data processing
  - Less traffic to the base station → energy savings
  - Shorter distances to the processing device → lower latency



Requirements to collaborative data processing

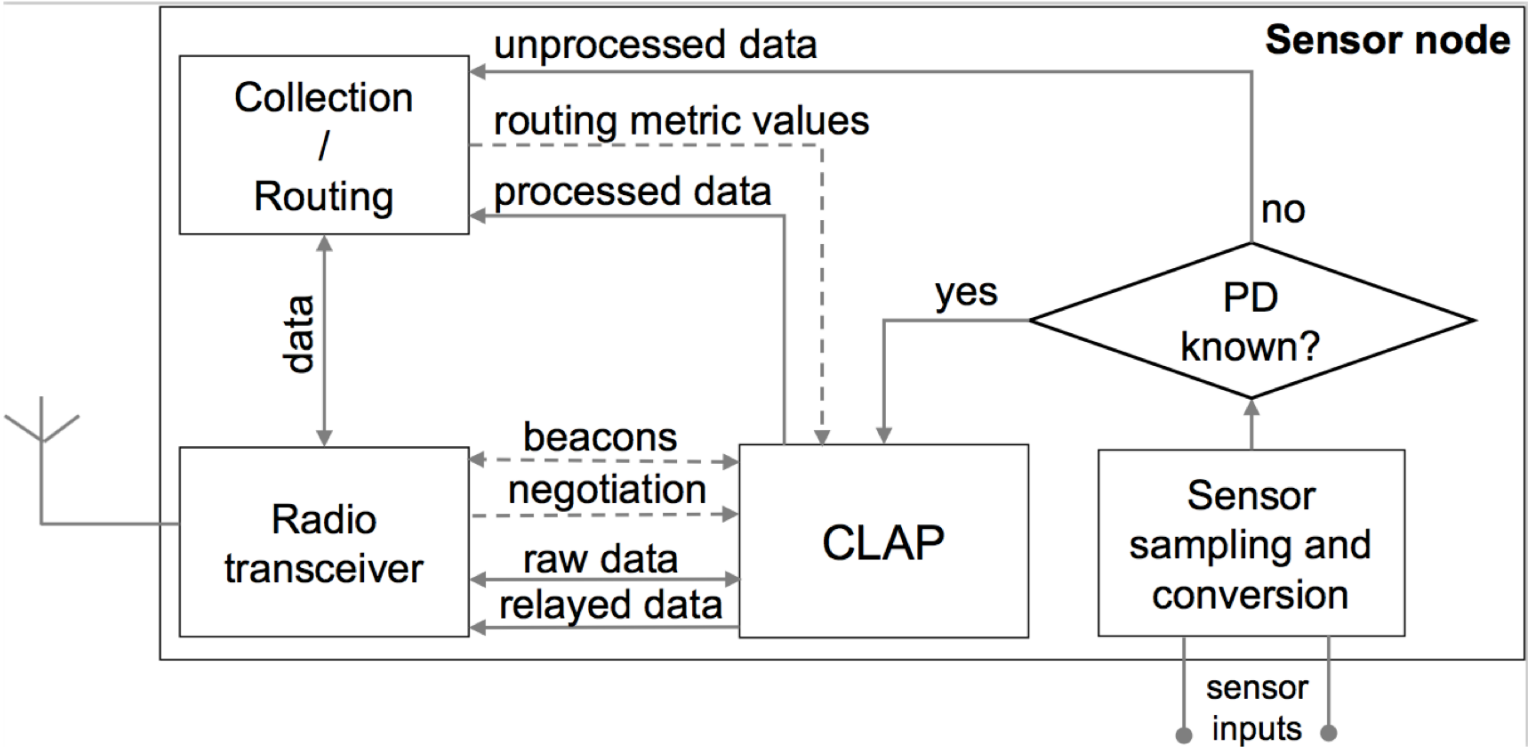
- Interoperability with existing collection protocols (e.g., CTP)
  - Fundamental protocol family for data collection networks
- Locality-aware node discovery
  - To avoid long routes to processing devices, only direct and two-hop neighbors shall be considered
- Negotiation of processing requirements (e.g., which function to execute) and temporal duration of the agreement
- Feasibility must be ensured, i.e., actual savings in terms of energy, bandwidth requirements, or latency be proven

CLAP: DESIGN OVERVIEW

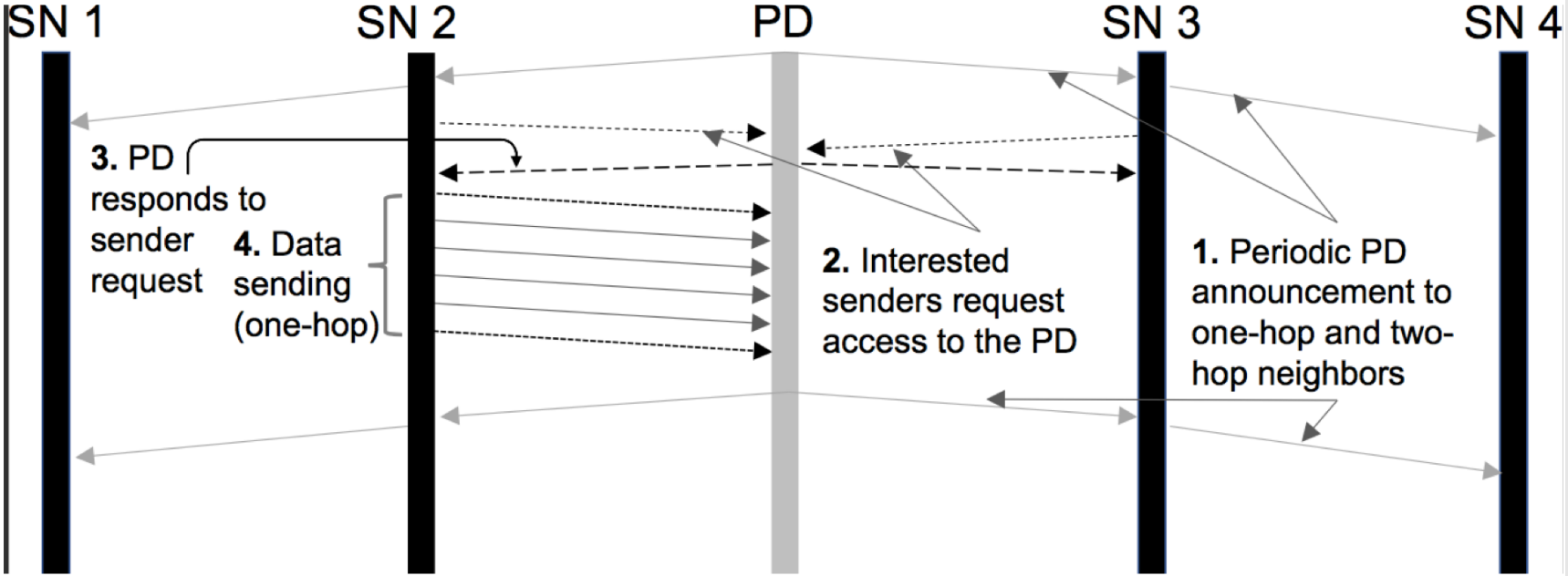
CLAP: Design decisions

- Data collection handled by the (existing) collection tree protocol CTP
- PDs send advertisement beacons periodically
  - Indicators of their availability to process data
  - Relayed once by each neighbor of the PD to reach the two-hop neighborhood
  - Selection of PD (and possibly relay node) based on the ETX metric, i.e., closeness to the base station (value provided by CTP)
- Once a SN wants to make use of a PD's processing services
  - Handshake protocol to indicate start and end of the data transmission phase
  - Data sources (SNs) are served in a first-come-first-serve manner
  - Requests from devices further than two hops away are discarded

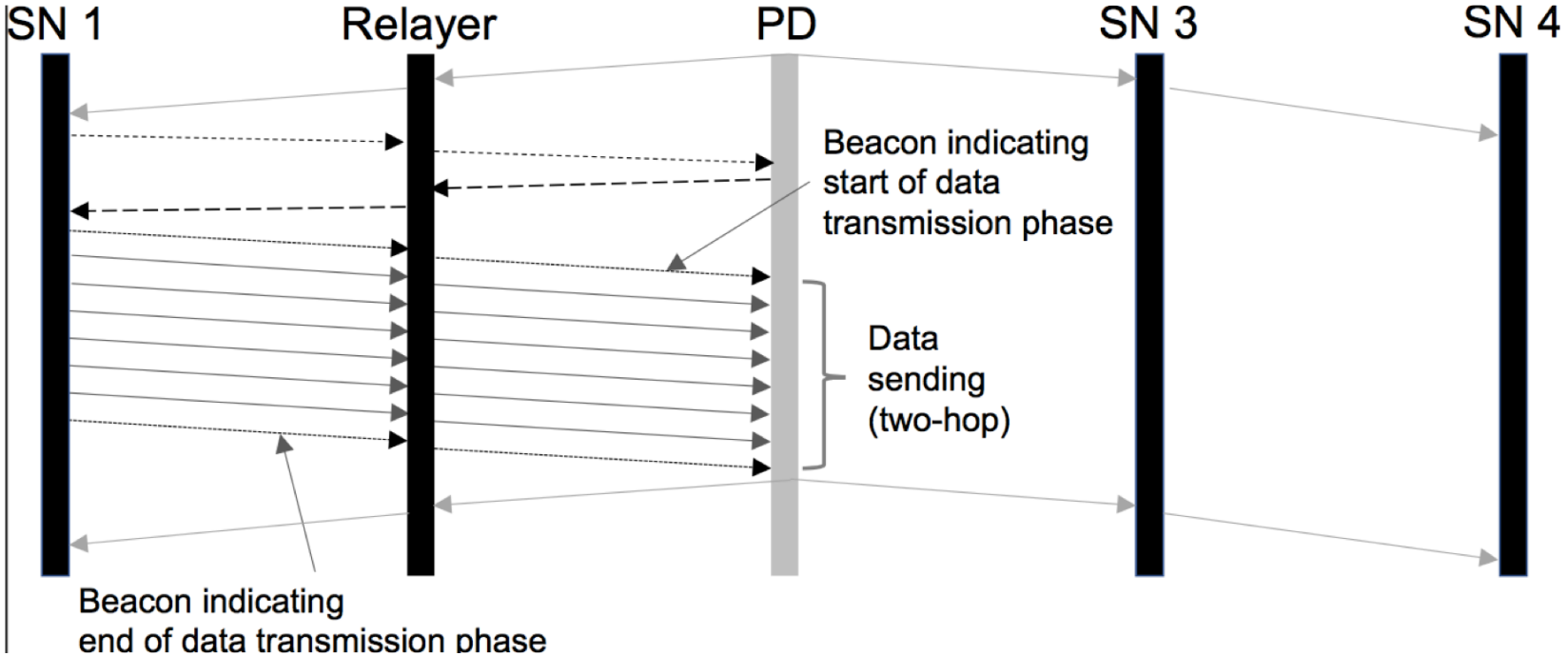
CLAP: Components w.r.t. node architecture



CLAP: One hop transmission



CLAP: Two-hop transmission



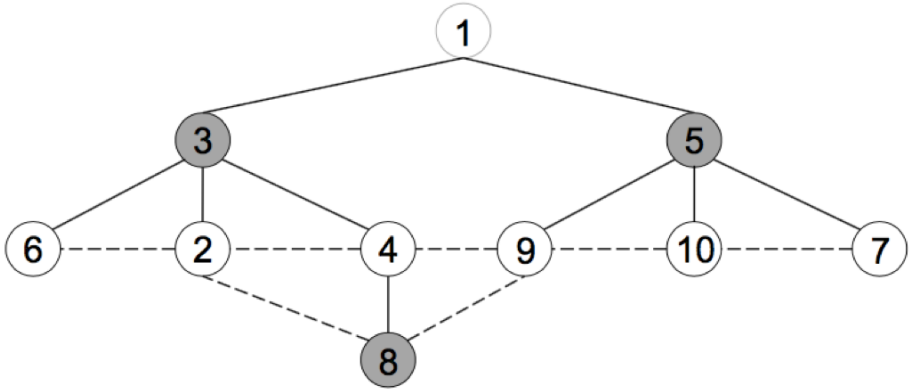
EVALUATION

Evaluation setup

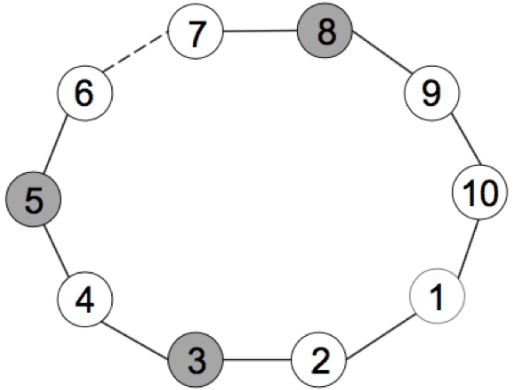
- COOJA simulator for wireless sensor networks
  - With hardware emulation for accurate modeling of timing/energy
- Implementation of CLAP in TinyOS (WSN operating system with CTP support)
  - Tmote sky (TelosB) as the sensor node
- Data generation and processing
  - 16-bit random payload every 100 ms
  - Processing function: Summation of all received values

Topologies considered

PD
SN
BS



(a) Tree topology.



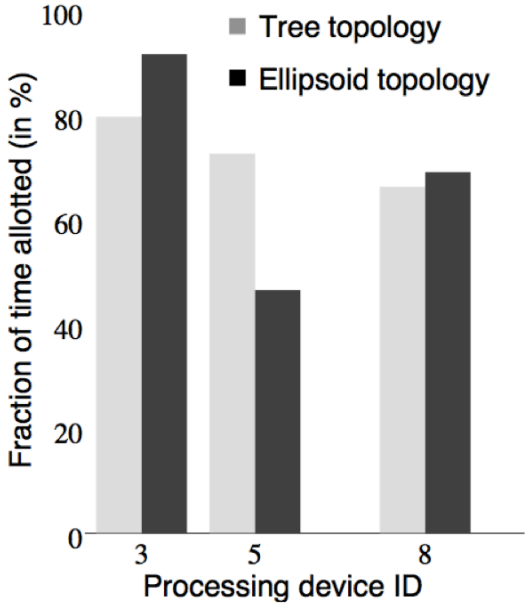
(b) Ellipsoid topology.

Direct Connectivity

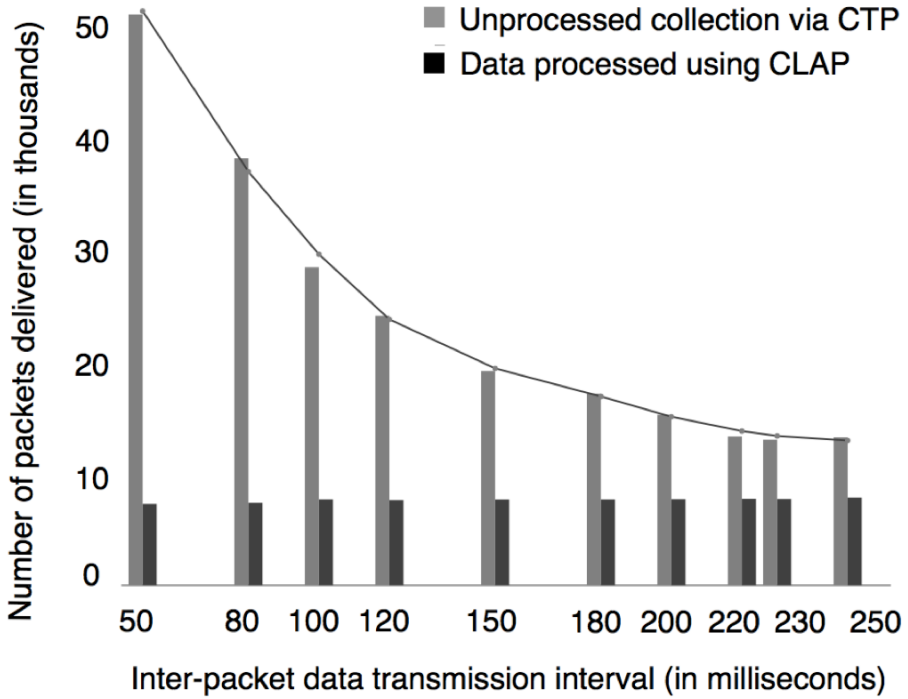
Additional Connectivity

Computational allocation to PDs

- Finding
  - Each of the PDs is busy during more than 60% of simulation run time
- Reason
  - The PDs announce themselves to neighbors as soon as it becomes available again



CTP vs CLAP


Unprocessed collection via CTP
Data processed using CLAP
Number of packets delivered (in thousands)
0
10
20
30
40
50
50
80
100
120
150
180
200
220
230
250
Inter-packet data transmission interval (in milliseconds)

CONCLUSIONS

AND OUTLOOK

Conclusions and further research

- CLAP is a protocol to exploit heterogeneity for in-network data processing
  - Applicability specifically in resource-constrained scenarios
    - Wireless sensor networks, fog computing, Internet of Things
  - Practical demonstration of its efficacy in two simulation settings
- Future work
  - Practical Testbed evaluation of simulation
  - Using USB interface to add external ‘co-processors’ to emulate a heterogeneous processing capability
  - Deploying high processing requirements algorithms like Fourier transform, compressions, etc.

Thank you for your attention!

Andreas Reinhardt
reinhardt@ieee.org

Image source: djd / Tourismusbetrieb der Stadt Oberharz am Brocken