Energy-Efficiency of Concast Communication in Wireless Sensor Networks

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Concast everywhere

Wireless Sensor Networks (WSN)

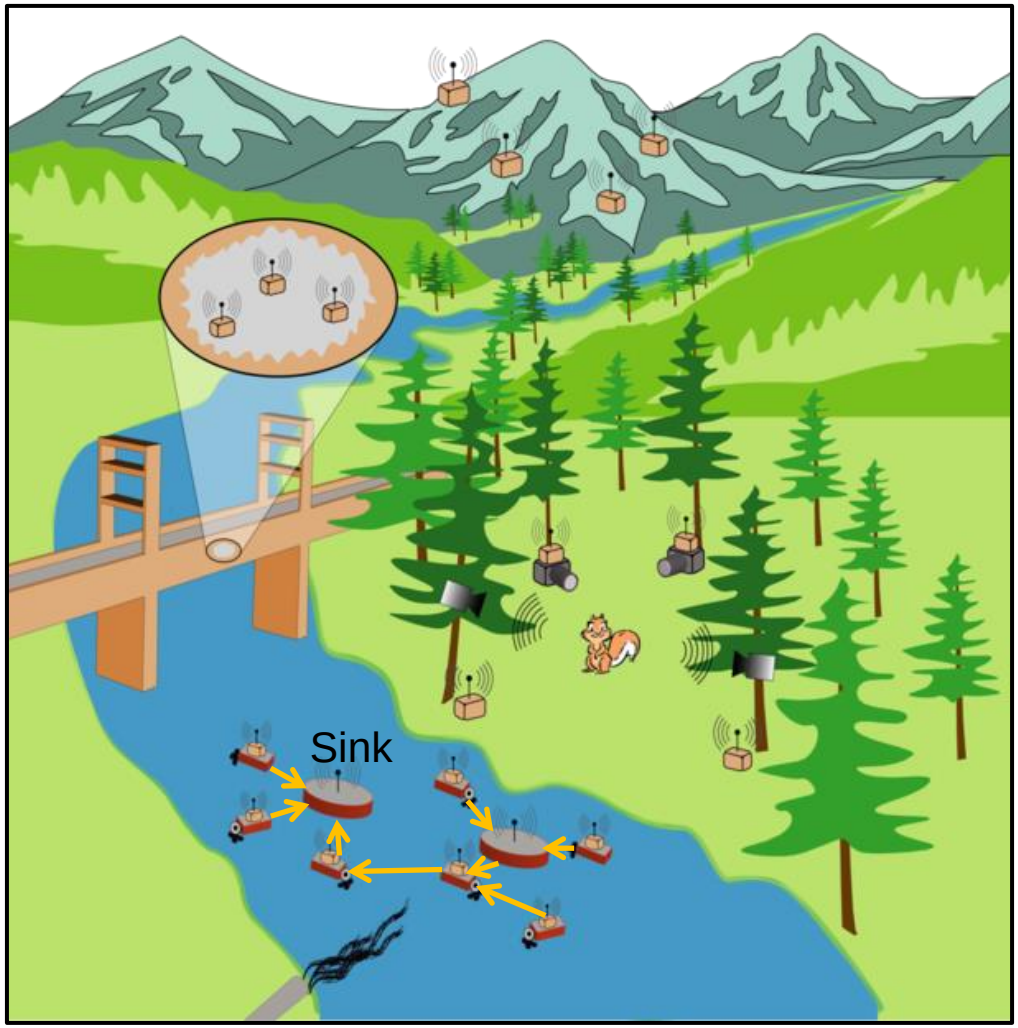
- Consist of many small and cheap sensor nodes
- Limited resources (processor, memory, radio, energy)

Monitoring Scenarios

- Concast Communication
- Multi-Hop topology
- Lifetime of months to years required

Most important development target: Energy-Efficiency (EE)

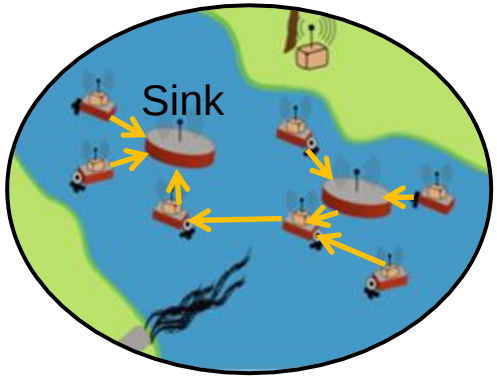
- How to implement an energy efficient Concast protocol?



State of the art

Many approaches to improve EE of concast communication

- … apply some kind of aggregation
  - Reduces number and/or volume of data packets
- … algorithms to set up routing tree
  - Reduces hop count to sink and/or affects impact of aggregation



Aggregation strategies fit into:

- No aggregation: Forward sensor readings immediately after reception towards sink
- Packet aggregation: Forward readings received together with own sensor reading in one data packet towards sink
- Data aggregation: Only send a single aggregated reading out of all received sensor readings towards sink

Common assumption: Reduced number and volume of data packets improves EE

- Many evaluations only count packets and data volume and argue from that on EE
- Evaluation is limited to transport network layer

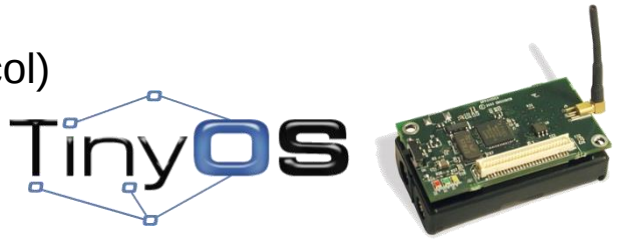
A more realistic approach

In [MSWIM'11], we showed that depending on MAC protocol and hardware

- … the amount of communication can be virtually of no relevance to EE
- … sending a large payload can even consume less energy than a small payload

Idea: Evaluate a complete application

- Concast protocol
- MAC protocol (should be a duty cycling MAC protocol)
- Operating System (TinyOS)
- Hardware platform (MICAz)



Using a suitable EE metric (can be application dependent)

- Possible metrics: Network operation duration, number of sensor readings received

Using Avrora simulator

- Runs unmodified sensor network application code by emulating nodes
- Provides realistic energy consumption data for specific hardware platforms
- Has been improved to Avrora+, which provides results close to reality [EWSN'12]
- Has been validated for concast communication using SANDbed testbed [Sensys'11]

Duty-Cycling MAC Protocols

Default MAC

- IEEE 802
- No Dut g

TinyOS LPL

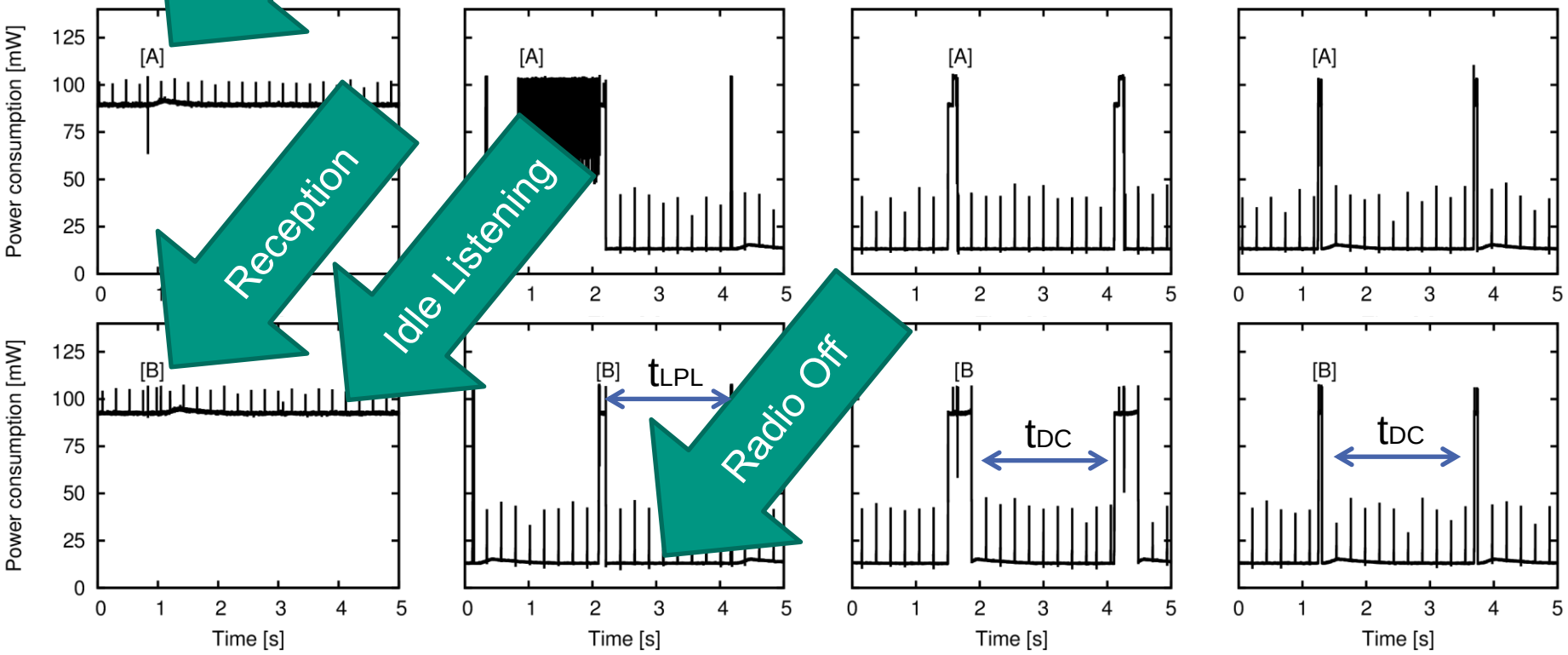
- Reactive approach
- Nodes “synchronize” on demand

Sensor-MAC

- Synchronizes proactively
- Neighbors keep same schedule

Simple TDMA

- Requires pre-synchronization
- All nodes keep same schedule



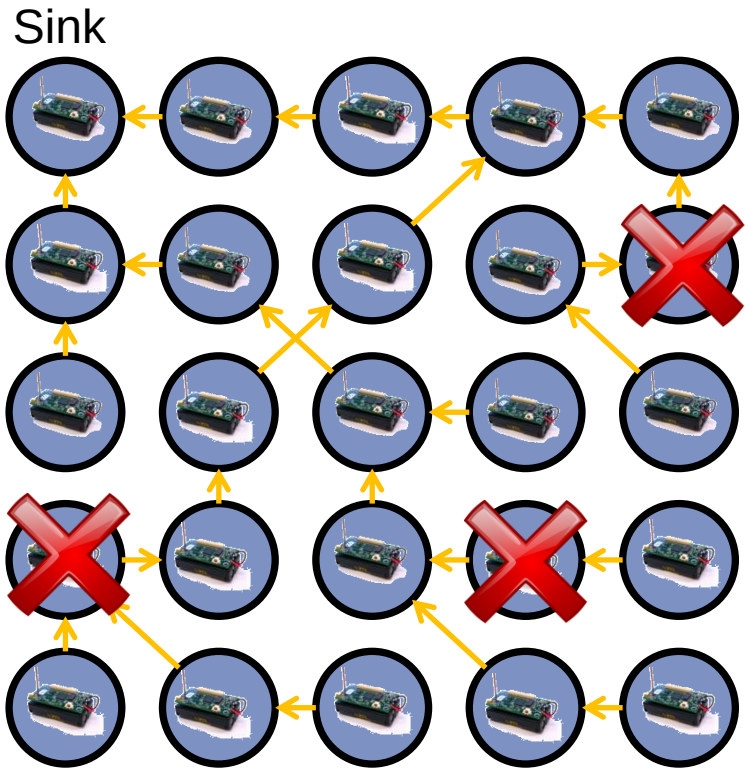
Experiment setup

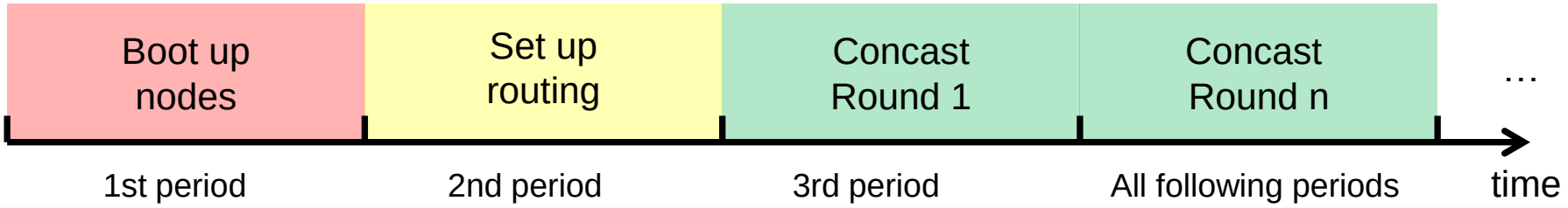
Concast scenario

- Concast period 60 seconds
- Each node has a limited energy budget of 100 Joule

Parameters

- MAC protocols
  TDMA, SMAC, LPL, 802.15.4
- Aggregation type
  NA, PA, DA
- Routing tree
  Flooding (other methods not shown here)





Metric and expectations

Observation

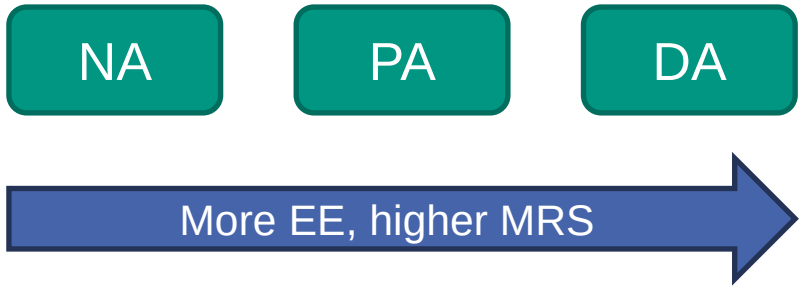
- Data aggregation (DA) reduces number of packets and data volume
- Packet aggregation (PA) only reduces number of packets
- No aggregation (NA) implies most overhead

Rating energy-efficiency

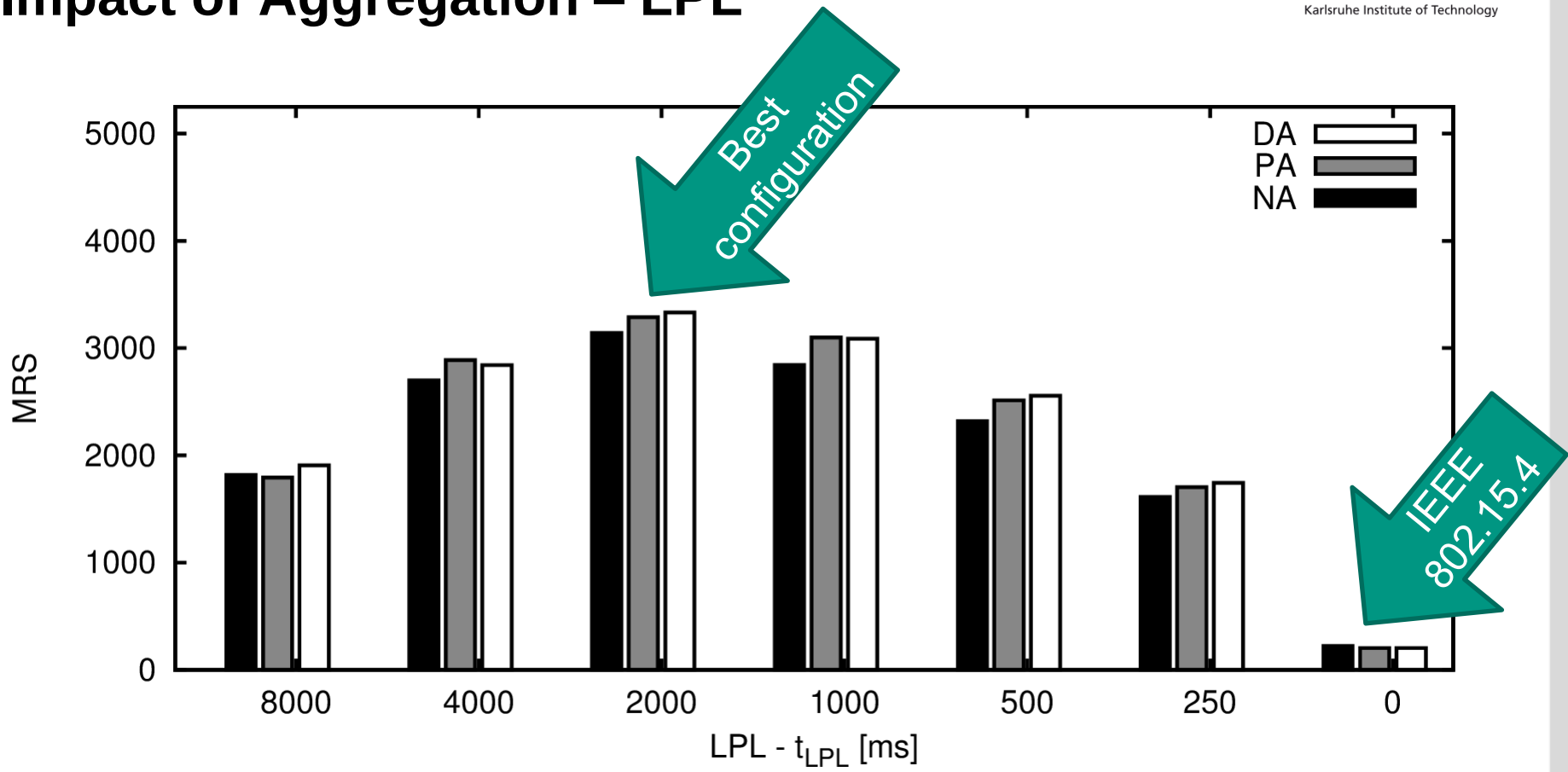
- Number of measurement readings received at sink (MRS)

Expectation with respect to state of the art

- DA provides best EE, NA provides worst EE

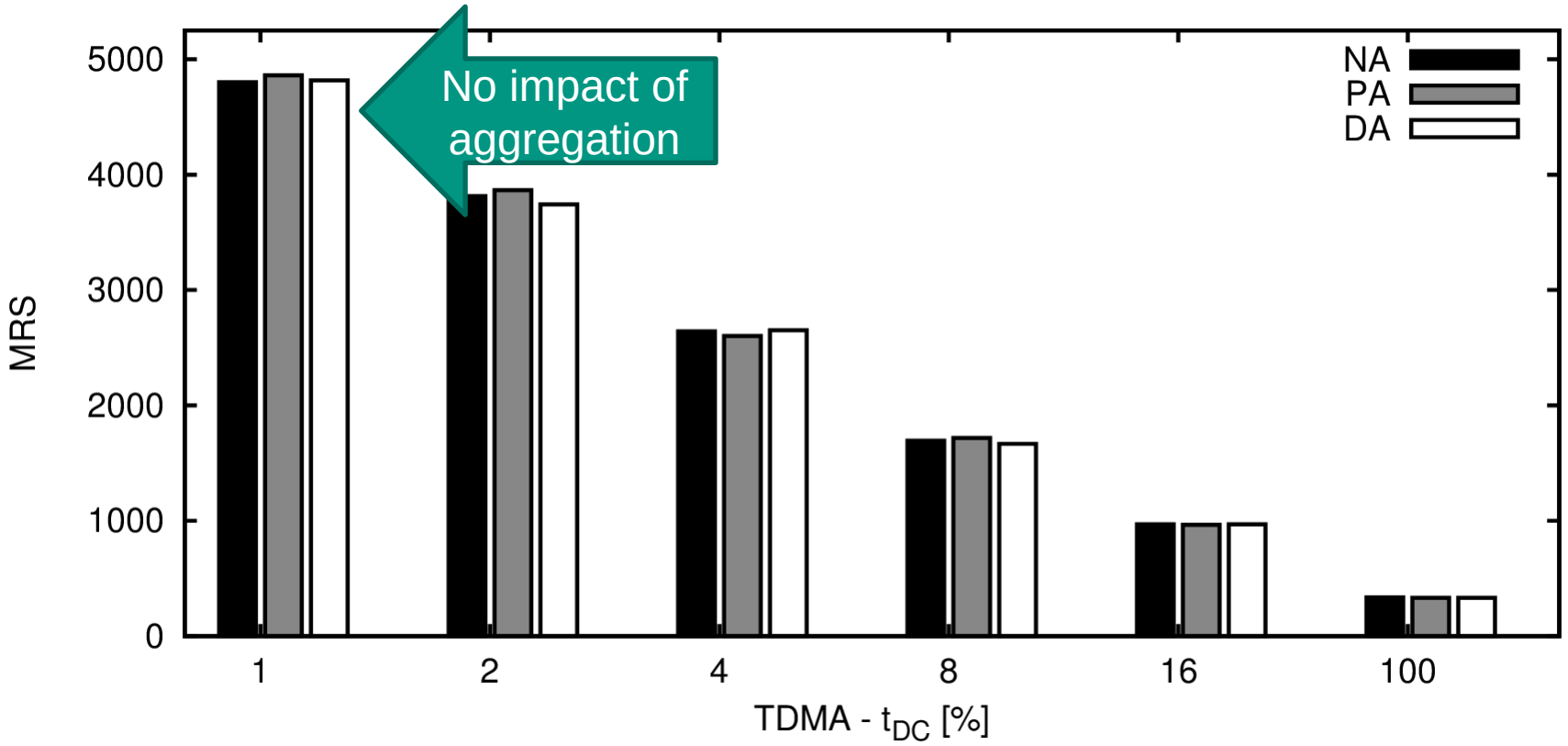


Impact of Aggregation – LPL



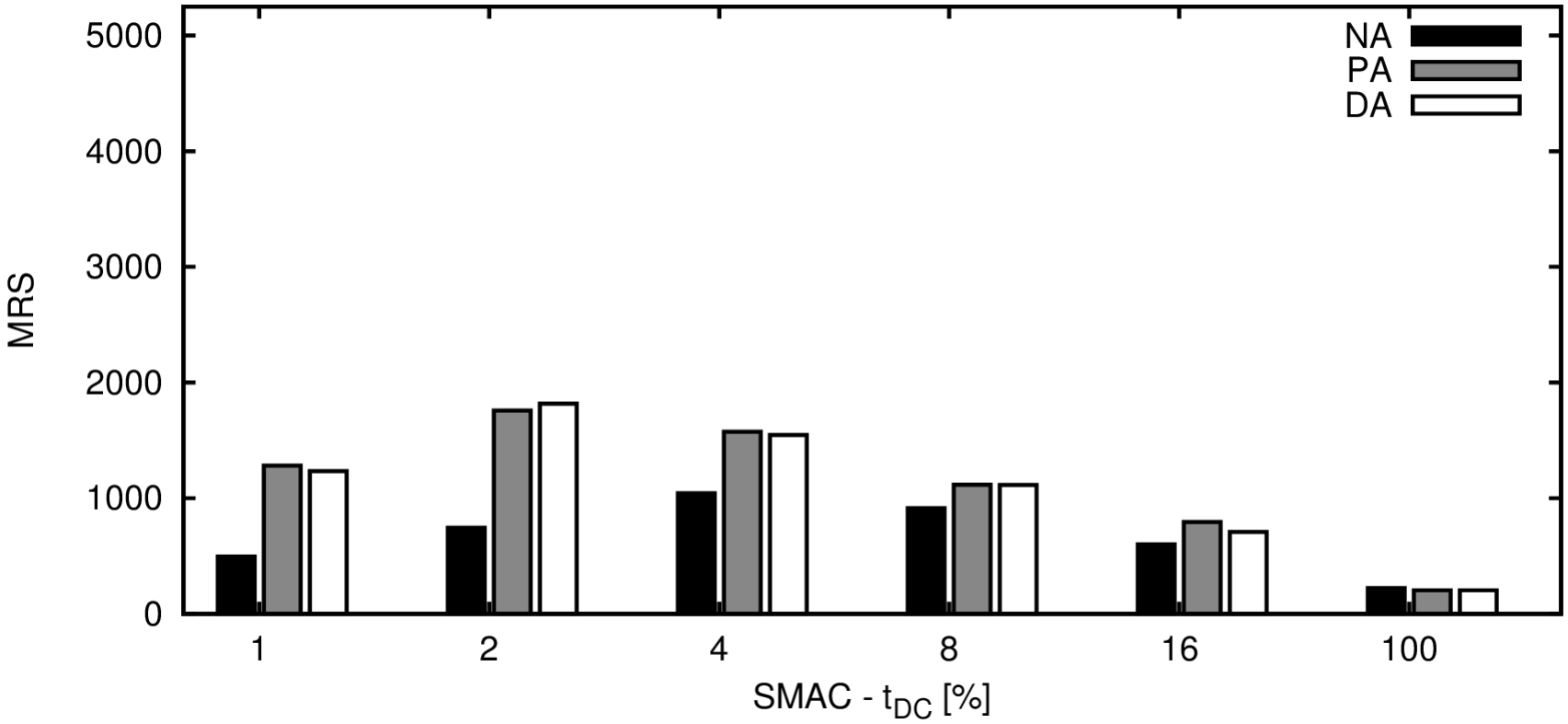
- Duty-Cycling greatly improves MRS
- Aggregation improves MRS by ~5%, regardless of being PA or DA
  - LPL implies large fixed overhead for transmission itself
  - Size of packet is rather unimportant for total energy consumption

Impact of Aggregation – TDMA



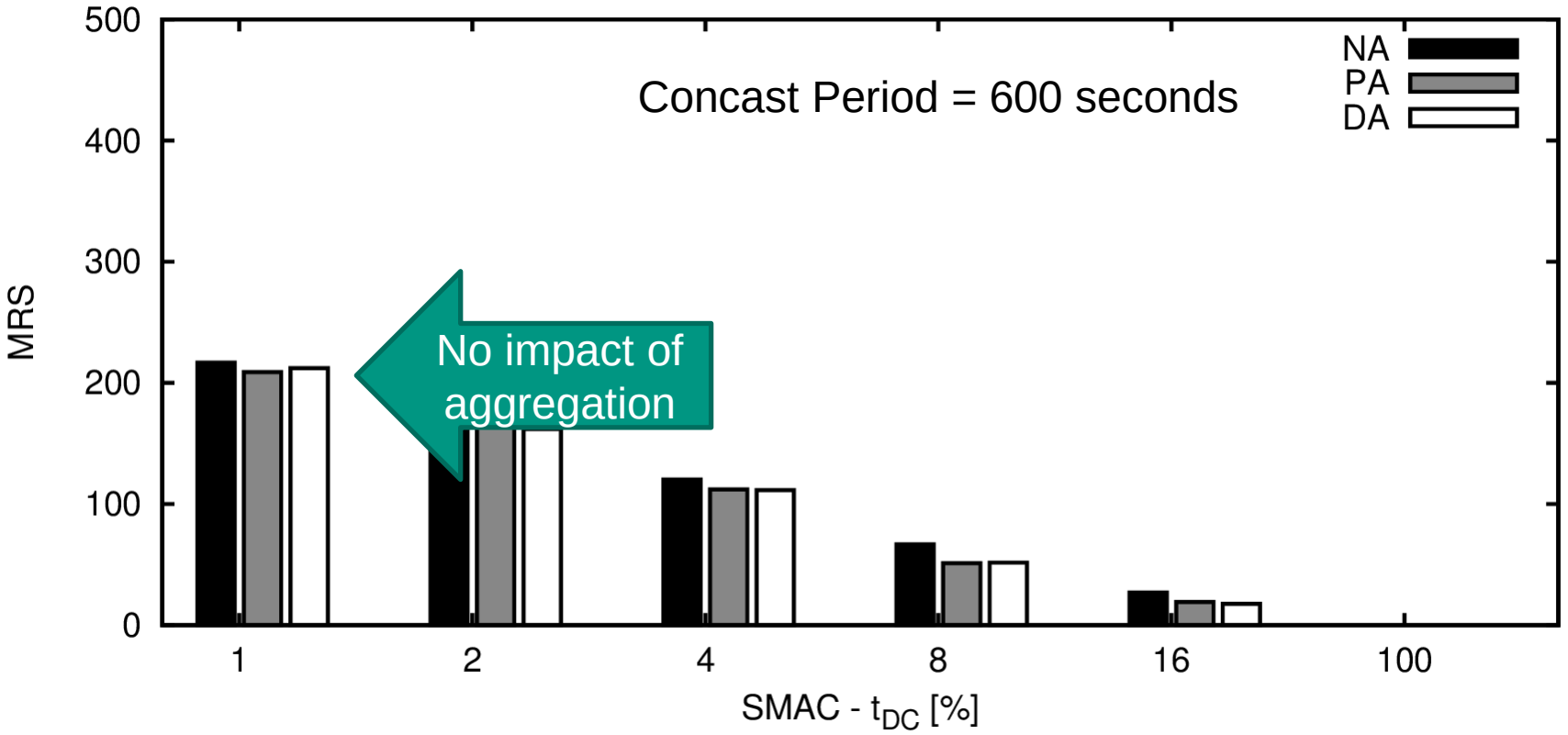
- TDMA results in higher MRS than with LPL
- Aggregation does not improve MRS
  - Duty-cycle is fixed and not influenced by the amount of communication

Impact of Aggregation – SMAC



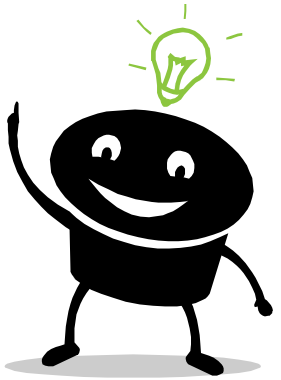
- SMAC results in lower MRS than TDMA (synchronization overhead)
- Aggregation greatly improves MRS!
  - SMAC implementation allows only one transmission per active slot → congestion
  - Differences should disappear with longer concast period

Impact of Aggregation – SMAC (II)



- Aggregation has no impact on MRS
  - Like TDMA, Duty-Cycle is fixed for SMAC
  - No congestion

Lessons learned



Rating energy-efficiency is more than just counting packets

- Energy consumption cannot be evaluated realistically by looking at a single protocols
- Impact of communication on energy-efficiency heavily depends on MAC protocol and WSN hardware

Regarding energy-efficiency of concast communication

- Impact of aggregation depends on MAC protocol
- DA could not outperform PA regarding energy-efficiency in any scenario
- Impact of MAC protocol and its parameterization is far more important than that of aggregation
- Also applies to other routing trees (not shown here)

Summary and Conclusion

Energy-efficiency is a cross-layer issue

- Always evaluate a complete application
- Different MAC protocols can turn energy-efficiency of aggregation upside down

No general best MAC protocol for concast communication

- Depends on concast period time, other network traffic, hardware, …

Future work

- Impact of mobility on energy-efficiency
- Multi-Path Concast
  - Multi-Path aggregation only possible with duplicate-insensitive data aggregation functions or with any packet aggregation
- Further metrics: latency

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Thank you for your attention!

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Further reading

[Sensys'11] C. Haas, J. Wilke. **Energy-Efficiency of WSN Concast Communication – A Reality-Check**. Proceedings of the 9th ACM Conference on Embedded Networked Sensor Systems, pp. 351-352, Seattle, Washington, USA

[MSWiM'11] C. Haas, J. Wilke. **Energy Evaluations in Wireless Sensor Networks - A Reality-Check**. Proceedings of the 14th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems, pp. 27-30, Miami Beach, Florida, USA

[EWSN'12] C. Haas, V. Stöhr, J. Wilke. **Realistic Simulation of Energy Consumption in Wireless Sensor Networks**. Proceedings of the 9th European Conference on Wireless Sensor Networks, pp. 82-97, Trento, Italy

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