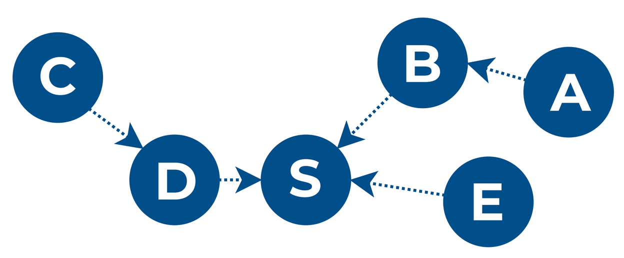
KOM3: Could a Wireless Stack Based on Synchronous Transmissions Challenge 6TiSCH?

Michał Rzepka, Carsten Herrmann, Marco Zimmerling

Motivation

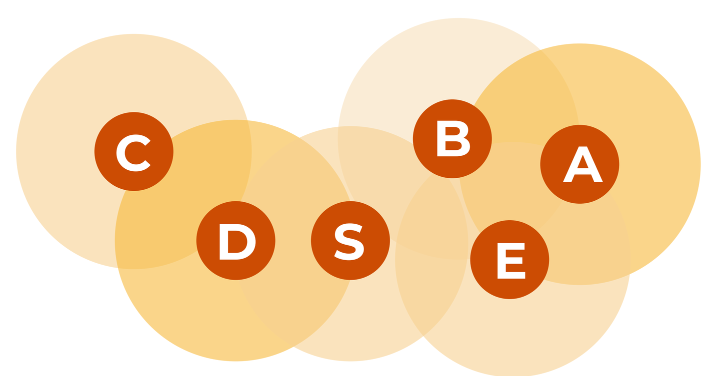
Approaches to **Low-Power Mesh-Communication**

Routing



based on the abstraction of links, coordinated unicasts over an established topology, sensitive to traffic patterns

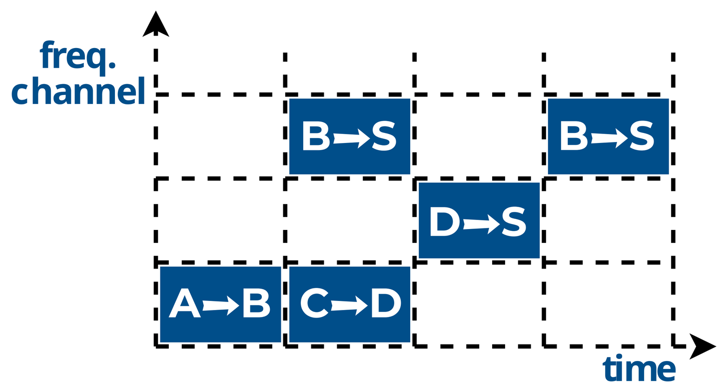
Flooding



broadcast-based, minimal topology awareness, traffic-pattern agnostic, **synchronous transmissions** (STX) → multiple simultaneous senders

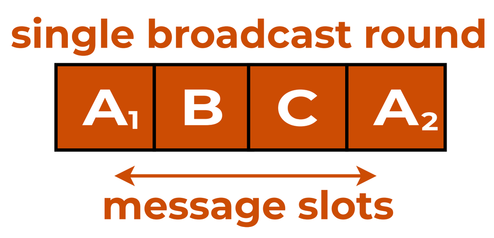
6TiSCH[1]

established IPv6 **architecture** based on routing (RPL)



Mixer[2]

mesh broadcast **primitive** based on STX-flooding



What is missing?

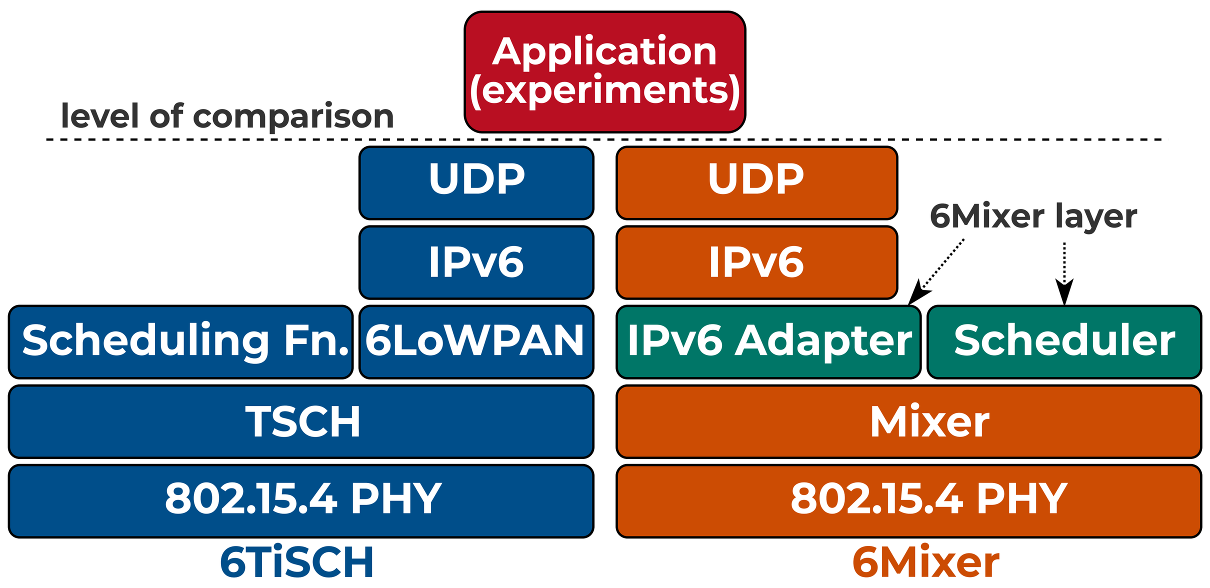
Comprehensive **performance comparison** of modern, **IPv6-enabled**, general-purpose network stacks, based on the above paradigms, in a **fair**, **real-world setup**.

Towards a Fair Comparison

Methodology: Run identical experiments on the **D-Cube**[3] testbed.

Stacks: 6TiSCH – Contiki-NG,[4] Mixer – fork of original code.[2]

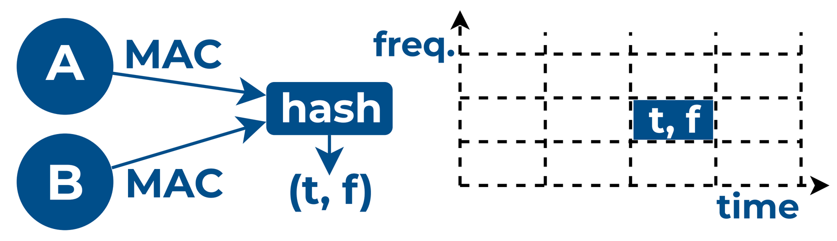
Problem: Comparing apples to oranges?



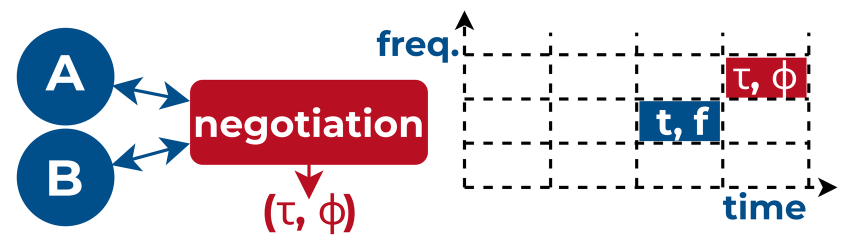
Approach: Extend Mixer into a **6Mixer** stack to compare both paradigms at the **same level**, i.e. UDP/IPv6 application.

Scheduling: Adaptive policies in both stacks.

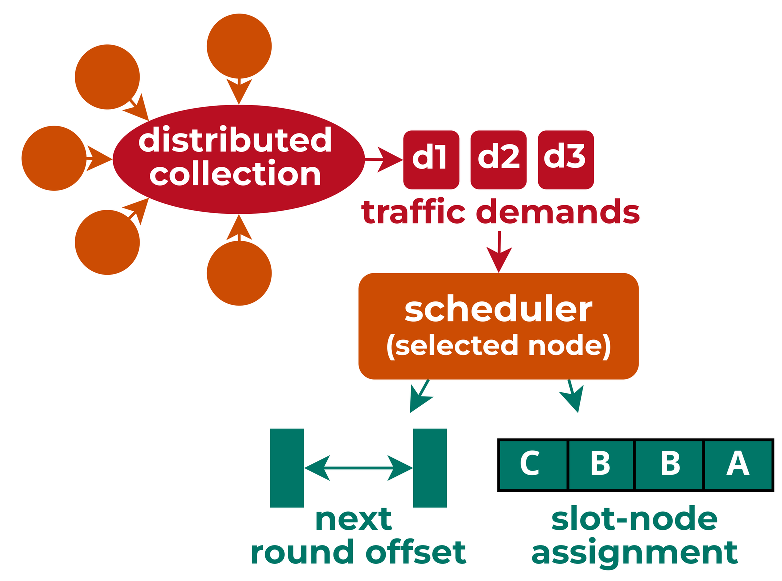
6TiSCH: minimal bandwidth between neighbors



6TiSCH: increased traffic demand



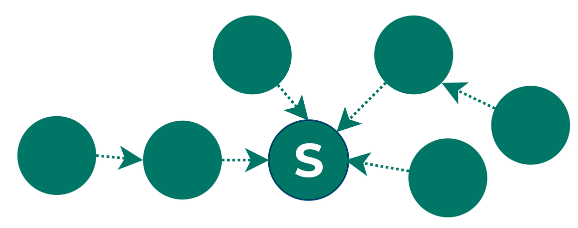
6Mixer: distributed collection of traffic demands



Experiment Scenarios Reflecting Different Classes of Applications

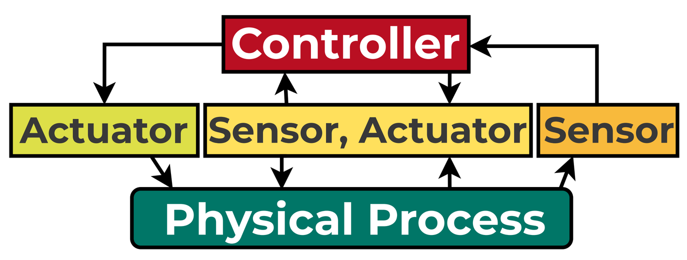
Wireless Sensor Networks (WSN)

"Traditional" application of mesh networks.
Traffic: Towards a common sink, periodic at second- to hour-intervals.
Payload: Few to tens of bytes.



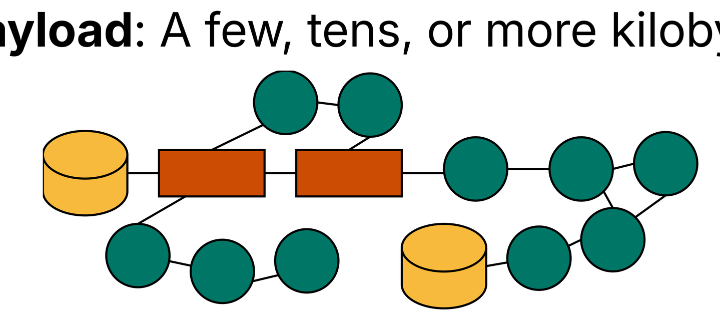
Cyber-Physical Systems (CPS)

Industrial feedback control systems.
Traffic: One-to-many or many-to-many, periodic, at milli- to second-intervals, strict **timeliness** requirements.
Payload: A few to tens of bytes.

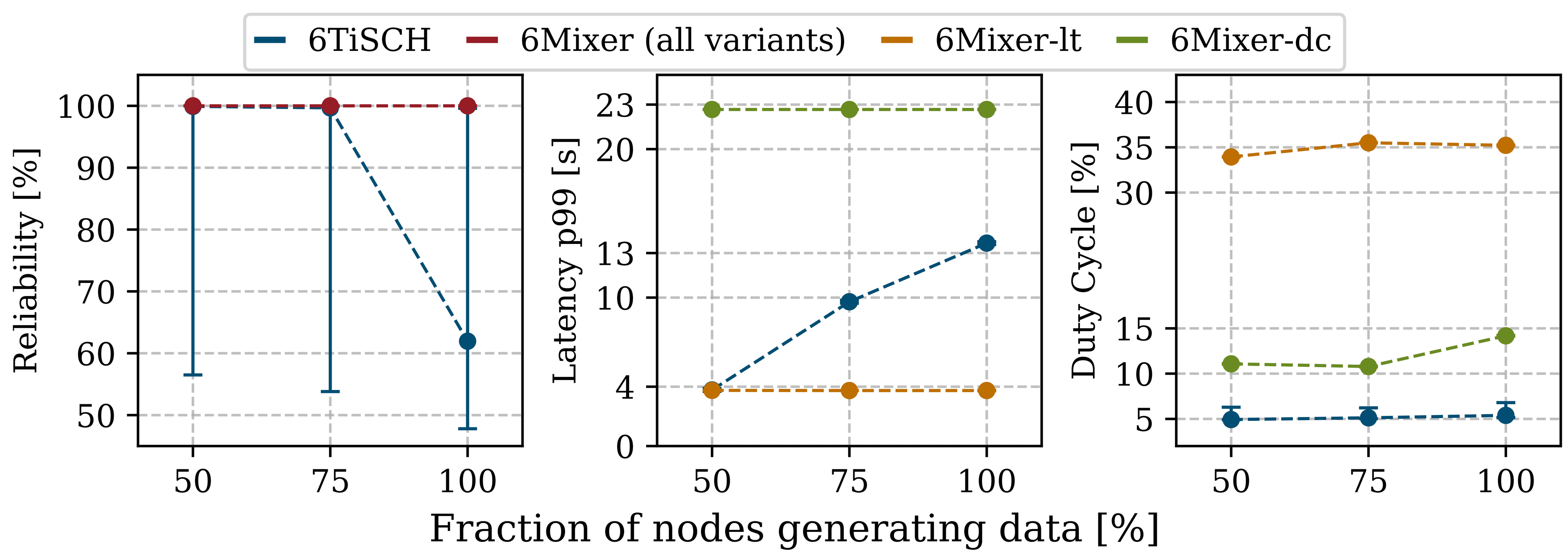


Internet of Things (IoT)

Vision of a heterogeneous landscape with thousands of interconnected devices.
Traffic: Aperiodic, peer-to-peer.
Payload: A few, tens, or more kilobytes.



Preliminary Experimental Results: WSN Scenario on D-Cube



Setup Description: Nodes generate 16-byte UDP payloads towards a common sink at 15s intervals, at three different loads. Two 6Mixer variants: optimized for latency (6Mixer-lt) and optimized for duty cycle (6Mixer-dc).

Results Discussion

6TiSCH: Better latency-energy trade-off.
Duty cycle 2-7x smaller, with equal or smaller latency values.
However: higher variance and **reliability drops** to **48-62%** at higher loads.

6Mixer: 100% reliability and almost no variance, **regardless of the traffic load**. Comparable latency achievable but at 7x higher energy expense.

Qualitative Summary (to be further evaluated):

6TiSCH: more energy-efficient in sparse traffic towards sink.
6Mixer: more predictable, sustains higher loads, and "bulky", many-to-many traffic.

References

[1] X. Vilajosana, T. Watteyne, M. Vučinić, T. Chang, and K. S. Pister, "6TiSCH: Industrial performance for IPv6 Internet-of-Things Networks," Proceedings of the IEEE, vol. 107, no. 6, pp. 1153–1165, 2019.
[2] C. Herrmann, F. Mager, and M. Zimmerling, "Mixer: Efficient Many-to-All Broadcast in Dynamic Wireless Mesh Networks," in Proceedings of ACM SenSys, 2018.
[3] M. Schuß, C. A. Boano, M. Weber, and K. Römer, "A competition to push the dependability of low-power wireless protocols to the edge," in Proceedings of the EWSN, Feb. 2017.
[4] G. Oikonomou, S. Duquennoy, A. Elsts, J. Eriksson, Y. Tanaka, and N. Tsiftes, "The Contiki-Ng Open Source Operating System for Next Generation IoT Devices," SoftwareX, vol. 18, p. 101089, 2022.

Acknowledgments

We thank Adrian Kaßmann for the initial work on 6Mixer.
Our research has been funded by the LOEWE initiative (Hesse, Germany) within the emergenCITY center [LOEWE/1/12/519/03/05.001(0016)/72].

emergenCITY
NES Networked Embedded Systems Lab
Technische Universität Darmstadt
Universität Kassel
Philipps Universität Marburg
Bundesamt für Bevölkerungsschutz und Katastrophenhilfe
Wissenschaftsstadt Darmstadt
DLR
LOEWE Exzellente Forschung für Hessens Zukunft