DSME-LoRa

Seamless Long Range Communication Between Arbitrary Nodes in the Constrained IoT

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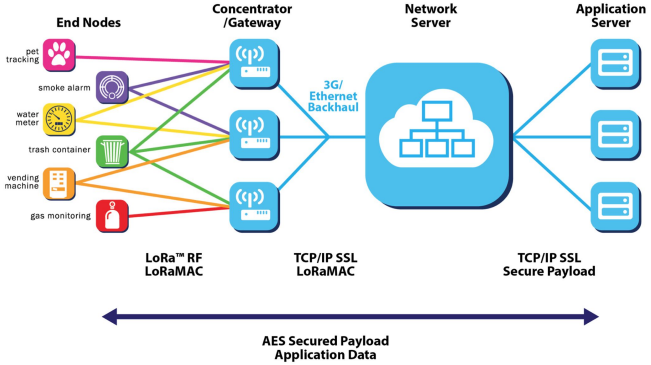
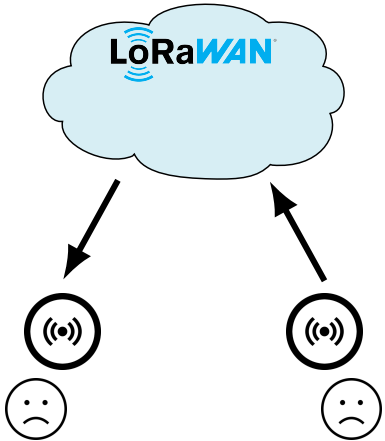
LoRaWAN

LPWAN specification over the proprietary LoRa modulation.

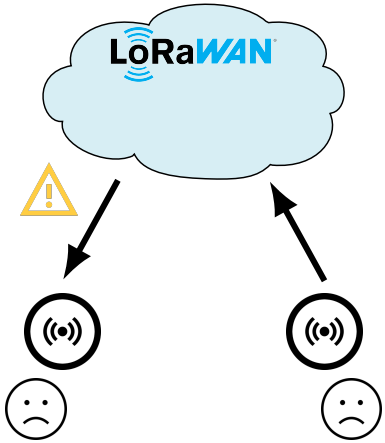


LoRaWAN limitations



- Restricted downlink communication
- No peer to peer communication
- Requires permanent infrastructure backhaul

LoRaWAN limitations



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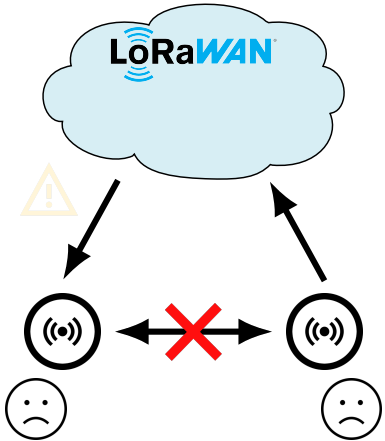

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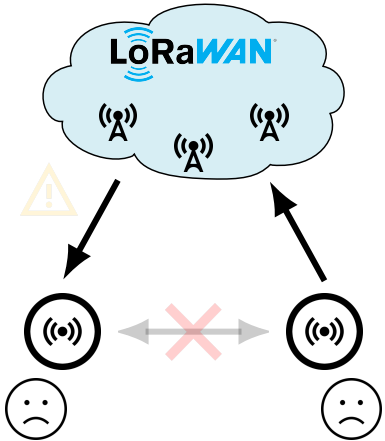

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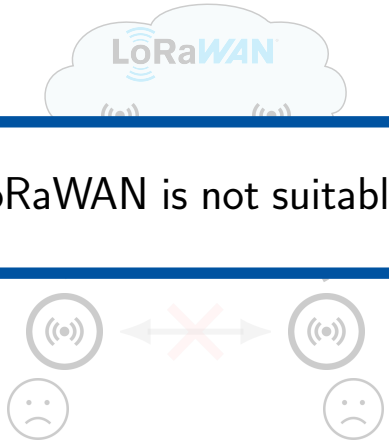

- Restricted downlink

LoRaWAN is not suitable for many IoT control scenarios

- Requires permanent infrastructure backhaul

Proposal: IEEE 802.15.4 DSME MAC

- Supports contention-based and contention-free transmissions.
- Out of the box peer to peer or cluster tree topologies.
- Low power operation.

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Can DSME over LoRa overcome LoRaWAN limitations and enable direct and reliable peer to peer communication?

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DSME-LoRa PHY mappings

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Large Scale DSME-LoRa

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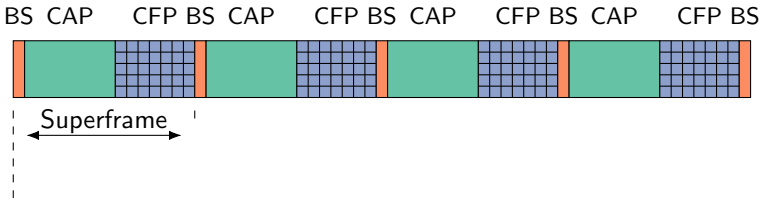
DSME Superframe structure



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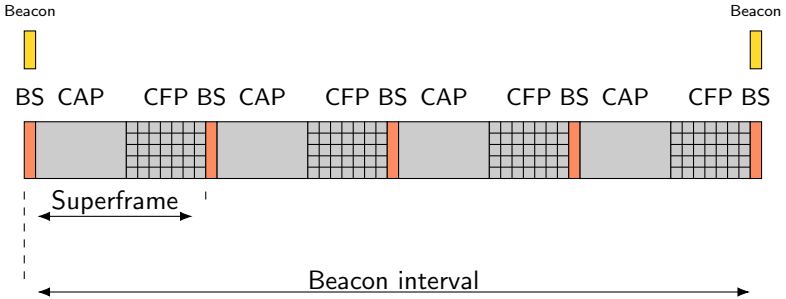
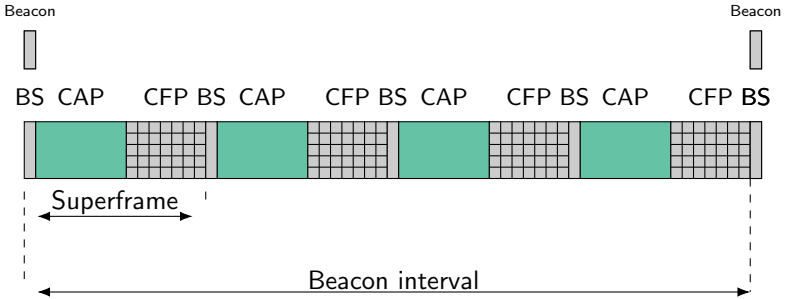


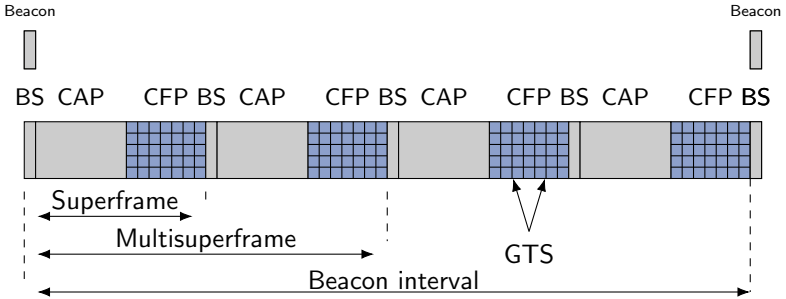
Beacon Slot: Synchronization

DSME Superframe structure



Contention Access Period: **CSMA/CA** transmission

DSME Superframe structure



Contention Free Period: **Guaranteed Time Slot** transmission

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PHY Mappings

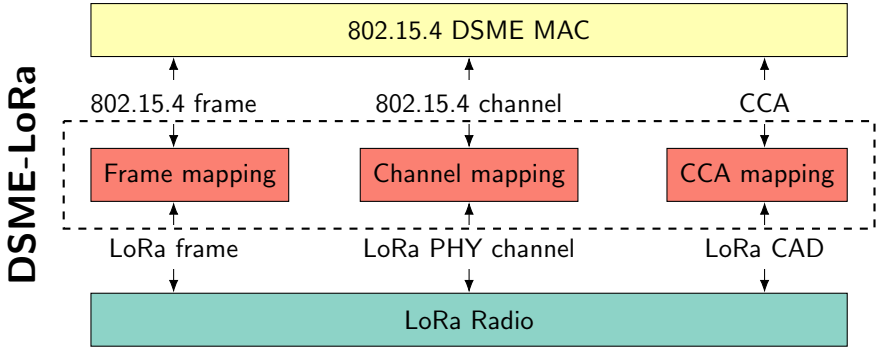

Figure: Overview of DSME-LoRa PHY mappings.

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Simulation environment

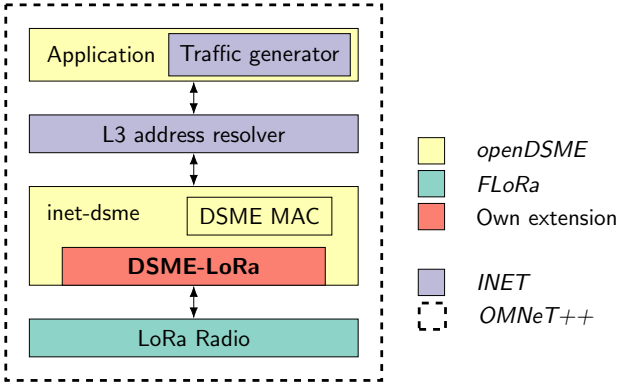

Figure: DSME-LoRa simulation environment and our contribution.

Implementation in RIOT OS

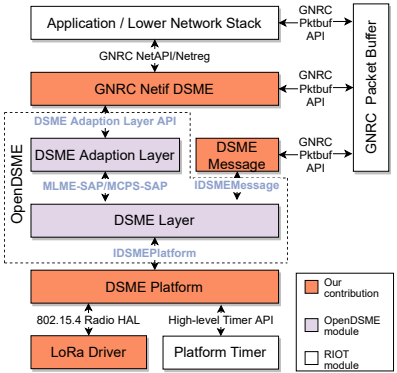

Figure: DSME-LoRa integration into the networking subsystem of RIOT.

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Evaluation scenario

- B-L072z-LRWAN1 (STM32L0) on IoT-LAB testbed.
  - ARM Cortex-M0+ @ 32 MHz
  - 256 kB ROM, 20 kB RAM
  - SX1276 LoRa transceiver.
- 7.68 s superframe duration
  - Minimal duration for TX of 127 bytes IEEE 802.15.4 frames over LoRa
- One superframe per multisuperframe
  - Renders only 7 slots.
  - A slot repeats every 7.68 s

Data transmission: CSMA/CA

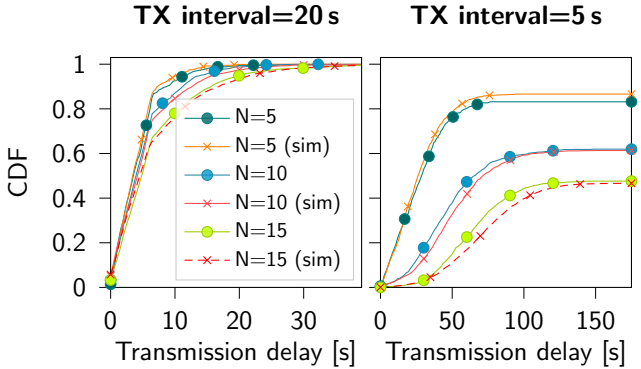
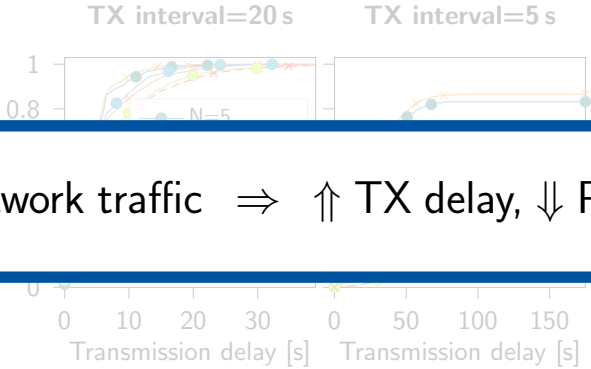


Figure: Transmission delays and PRR for confirmed transmissions in simulation environment and testbed. We vary the number (N) of source devices and the TX interval

Data transmission: CSMA/CA



$\Uparrow$ Network traffic $\Rightarrow$ $\Uparrow$ TX delay, $\Downarrow$ PRR

Figure: Transmission delays and PRR for confirmed transmissions in simulation environment and testbed. We vary the number (N) of source devices and the TX interval

Data transmission: GTS (slotted)

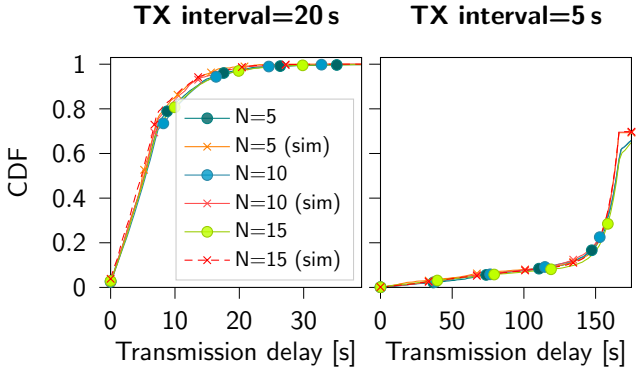


Figure: Comparison of transmission delays and PRR for confirmed transmissions (single GTS) in simulation environment and testbed. We vary the number (N) of source devices and the transmission interval

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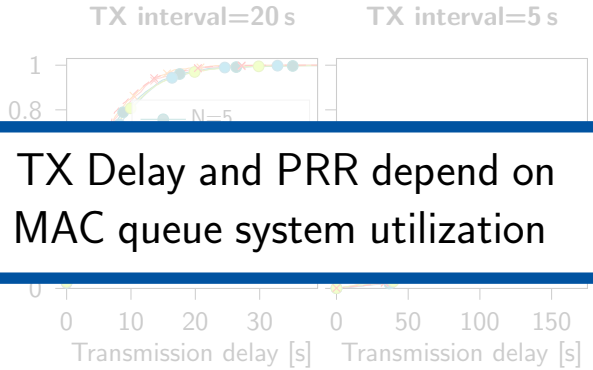

TX Delay and PRR depend on
MAC queue system utilization

Figure: Comparison of transmission delays and PRR for confirmed transmissions (single GTS) in simulation environment and testbed. We vary the number (N) of source devices and the transmission interval

Energy consumption

MO	Delay [s]	Power [mW]	Lifetime [y]
3	3.87	0.58	1.82
4	7.81	0.47	2.24
5	15.9	0.42	2.53
6	32.97	0.39	2.71
7	71.16	0.38	2.81

Table: Comparison of average transmission delay [s], power [mW] and lifetime [y] for a DSME-LoRa sender device with GTS transmissions, TX interval=15 m, Beacon Interval=123 s and transceiver off during CAP, for varying multisuperframe order. We assume 2800 mAh batteries for the lifetime estimation

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Suitable for battery-powered devices

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Other insights

- LoRa CAD effective as CCA mechanism.
  - Increases PRR by up to 17 %
  - Decreases frame retransmissions by up to 95 %
- DSME-LoRa can operate under LoRaWAN cross-traffic.
- Heavy interference on common channel may lead to device desynchronization.

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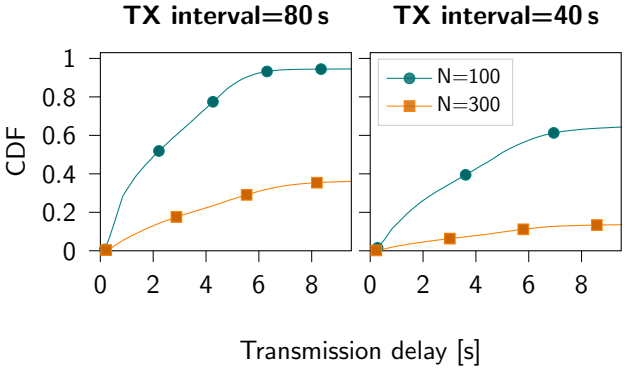
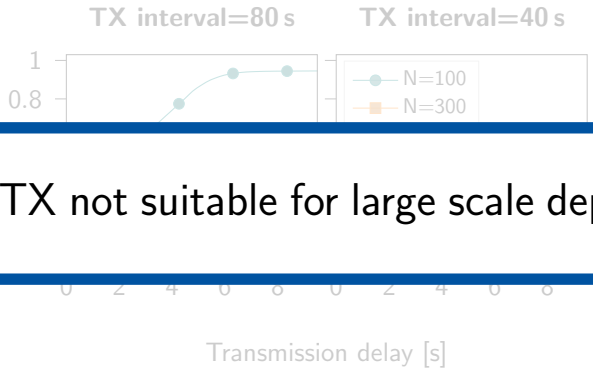


Figure: Comparison of transmission delays for relaxed and stressed scenarios, during CAP (CSMA/CA), for confirmed transmissions and a varying number (N) of nodes.

Large scale DSME-LoRa: CSMA/CA



CSMA/CA TX not suitable for large scale deployments

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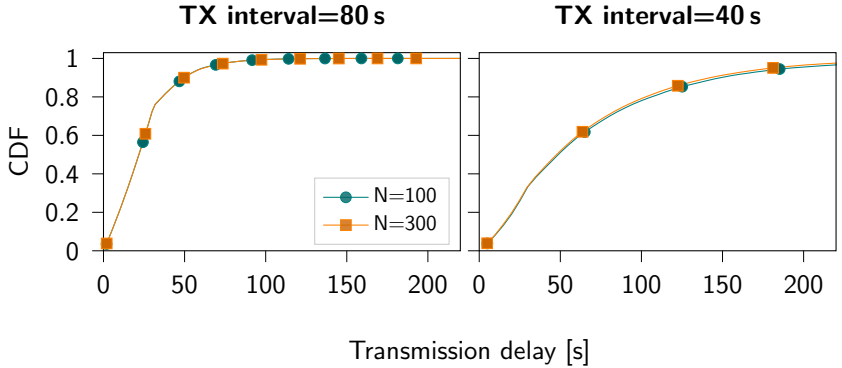
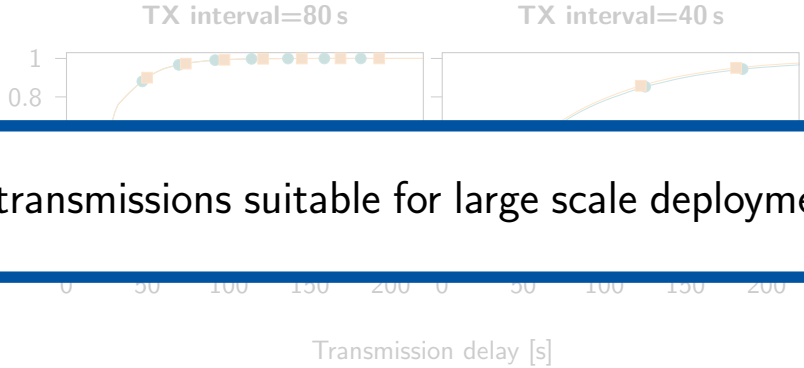


Figure: Comparison of transmission delays for relaxed and stressed scenarios, during CFP (GTS), for confirmed transmissions and a varying number (N) of nodes. We set 4 superframes per multisuperframe.

Large scale DSME-LoRa: GTS



GTS transmissions suitable for large scale deployments

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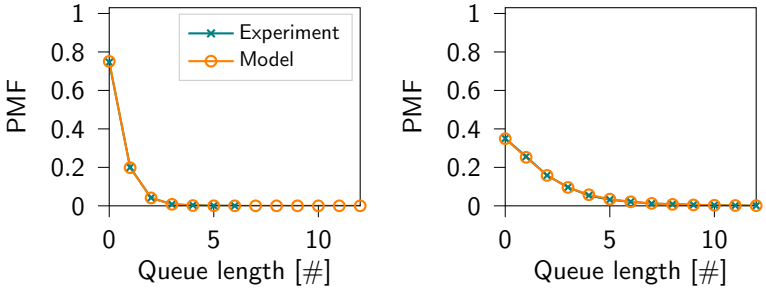
Markov model for queue length distribution on slotted transmissions



(a) TX interval=20 s (b) TX interval=10 s

Figure: Validation of the analytical stochastic model with experimental results. Comparison of transmission delay distributions for varying transmission intervals.

Queue length and system utilization

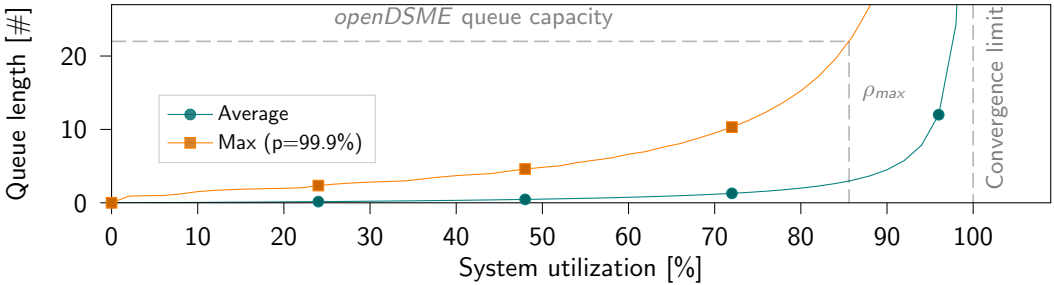


Figure: Estimation of avg. and max. queue length varying system utilization (single GTS case).

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DSME-LoRa enables reliable long range P2P communication

- Suitable for large networks and battery-powered applications

Future work

- IPv6 over DSME-LoRa
- Dynamic slot allocation
- Suitable network layers and performance under massive industrial deployments.

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Thanks!

We fully support reproducible research and open source software

`https://github.com/inetrg/tosn-dsmelora22`