TREMA: A traffic-aware energy efficient MAC protocol to adapt the LoRaWAN capacity

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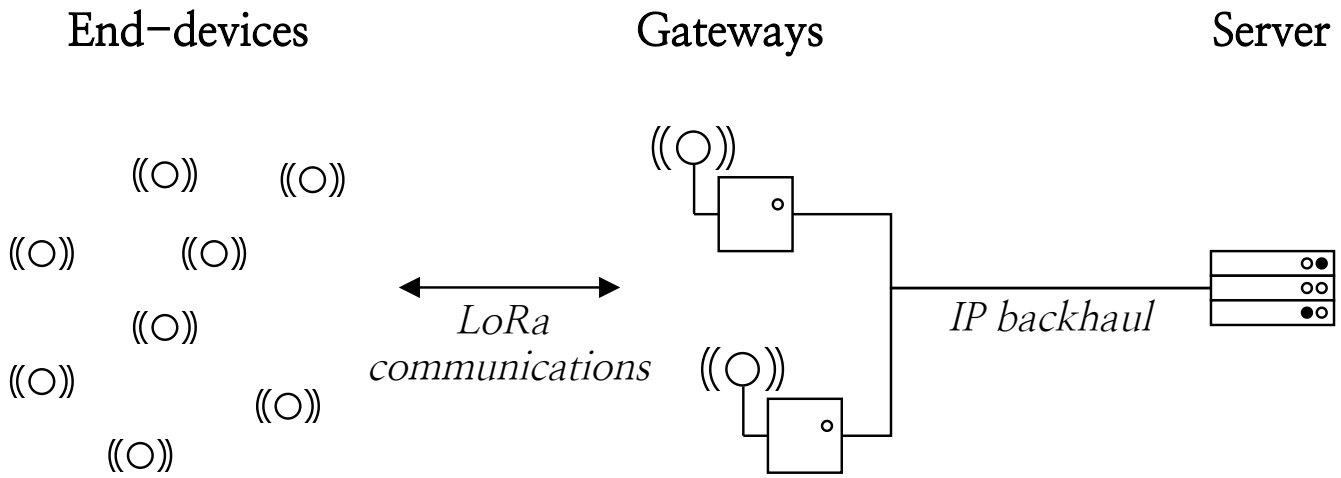
Introduction

Background on LoRa

- LoRa is an **LPWAN** technology (Low Power + Wide Area)
- **Low Power** : High energy constraints on nodes
  → Pure ALOHA access [1]
- **Wide Area** : Many nodes in the network
  → High collision rate
  → Scalability issues
  → Need for a synchronized approach



Motivation for TREMA

In a previous contribution [2] we introduced Class S, a framework relying on the Class B synchronization beacons to enable a time-synchronized slotted access over LoRaWAN. We showed that:

- For **low traffic loads** $\rightarrow$ **Pure ALOHA** is more energy-efficient.
- For **high traffic loads** $\rightarrow$ A **slotted access** is more energy-efficient.

Objective of this contribution

We present the TRaffic-aware Energy effcient MAC (TREMA) protocol to adapt the access scheme to the traffic conditions.

Design of TREMA

Overview

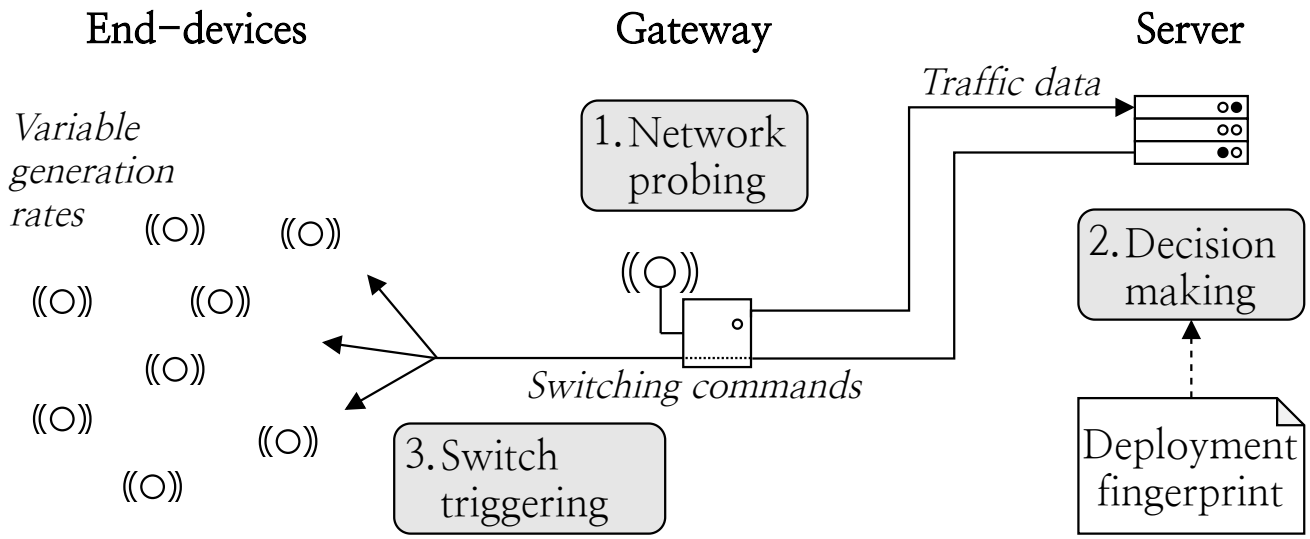


Figure: Overview of TREMA

TREMA defines:

- A **time-synchronized scheduled access** built over Class S, to be used when the traffic load is high.
- The definition of the **deployment fingerprint**, needed to wisely select the most efficient access scheme and estimate the traffic load.
- The **network probing** and **access scheme selection** mechanisms.
- A **signaling protocol** to control the MAC access scheme.

What is the deployment fingerprint and why is it needed?

Fingerprint definition

The **fingerprint** of a deployment is the characterization of the Throughput, Energy efficiency and Gateway Idle Listening Time (GILT) as a function of the traffic generation rate in the given deployment, for the considered synchronous and asynchronous access schemes.

- The **Throughput** fingerprint is needed to determine the deployment's capabilities under the considered access schemes and to compute the energy efficiency.
- The **energy efficiency** is used to determine which access scheme should be chosen for any traffic load.
- The **Gateway Idle Listening Time (GILT)** is probed by the gateway periodically. Its fingerprint is leveraged by the server to provide an estimation of the generated traffic. This is possible because the GILT is a strictly decreasing function of the network traffic load.

Throughput fingerprint[1]

- The synchronized access allows to double the achievable throughput.
- A significant increase is noticed when a significant portion of the devices in the network are synchronized.

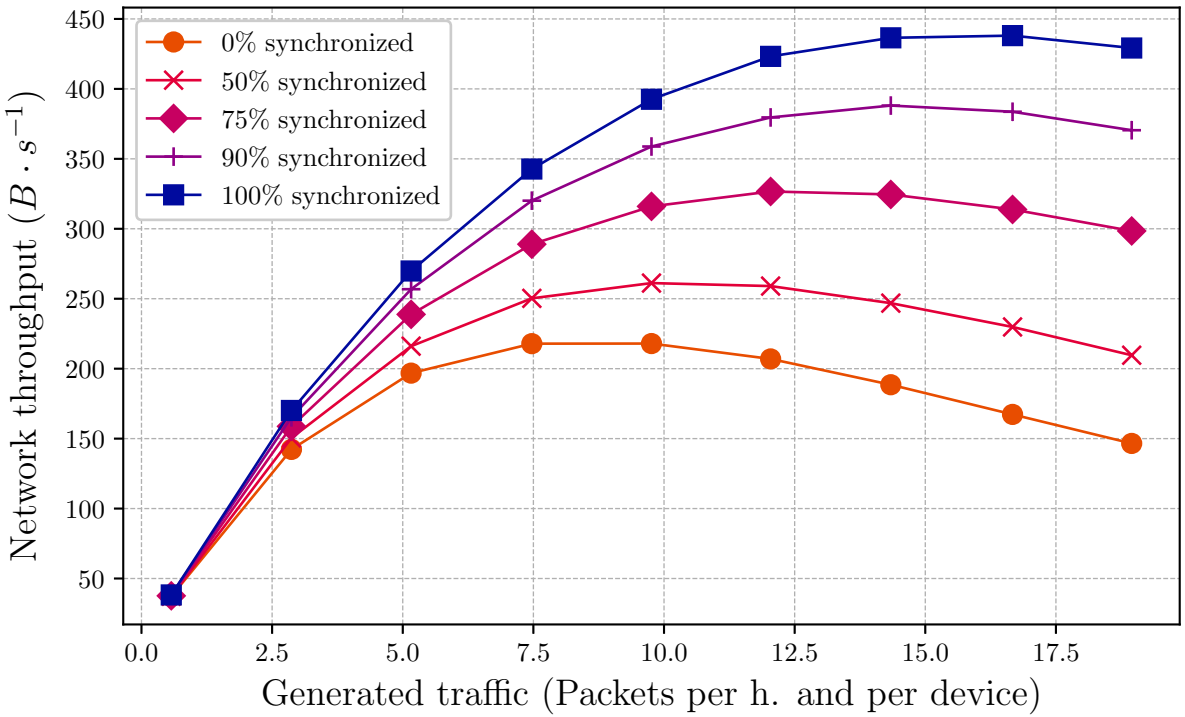


Figure: Throughput

[1] Exact deployment parameters used to obtain this fingerprint are listed on slide 21

Energy efficiency fingerprint[2]

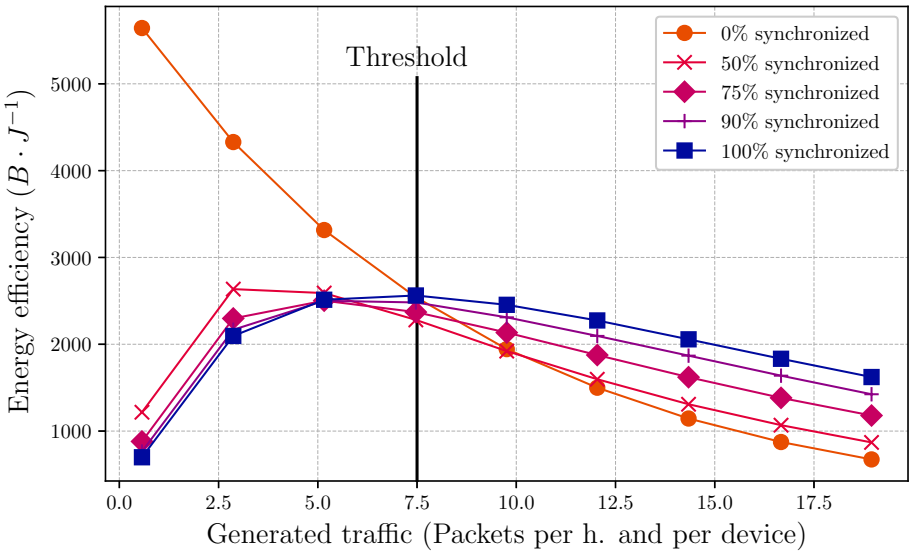


Figure: Energy efficiency ($n_{skip} = 0$)

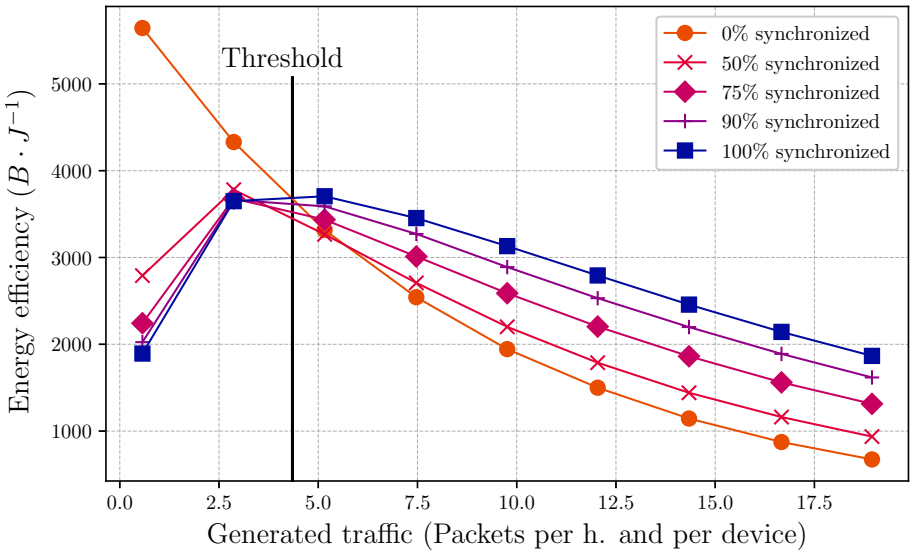


Figure: Energy efficiency ($n_{skip} = 3$)

[2] Exact deployment parameters used to obtain these fingerprints are listed on slide 21

Gateway Idle Listening Time (GILT) fingerprint[3]

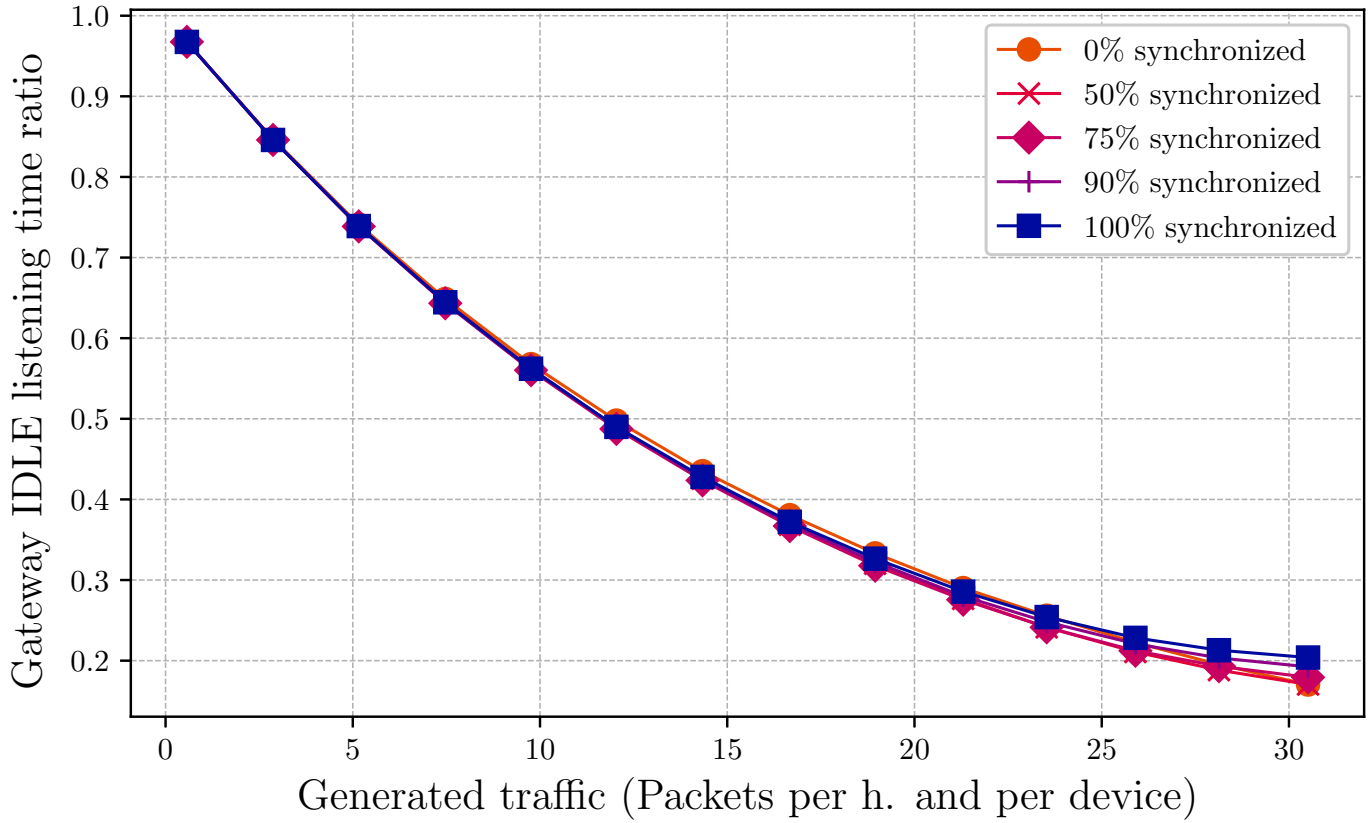


Figure: GILT fingerprint

[3] Exact deployment parameters used to obtain this fingerprint are listed on slide 21

Execution flowchart

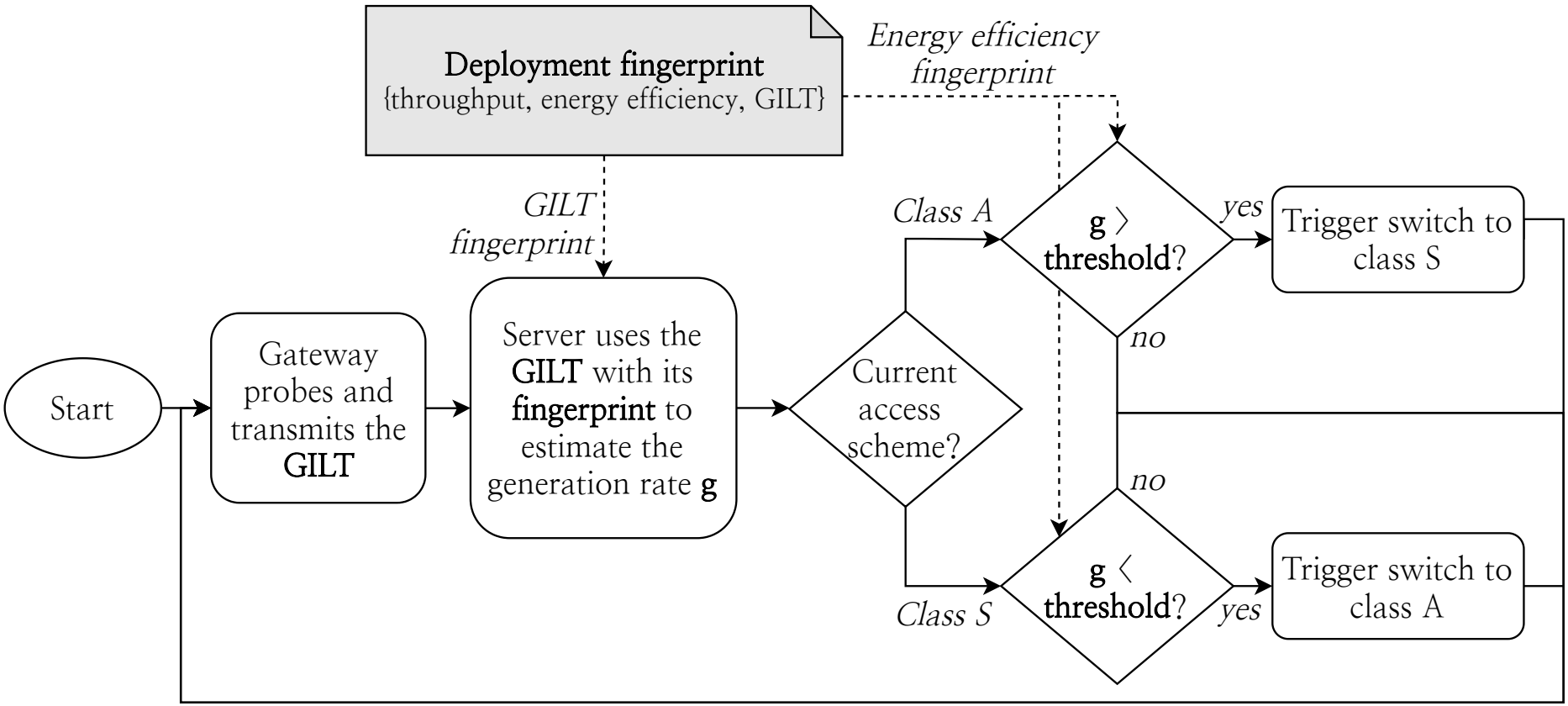


Figure: TREMA's execution flowchart

Testing of TREMA

Example scenario

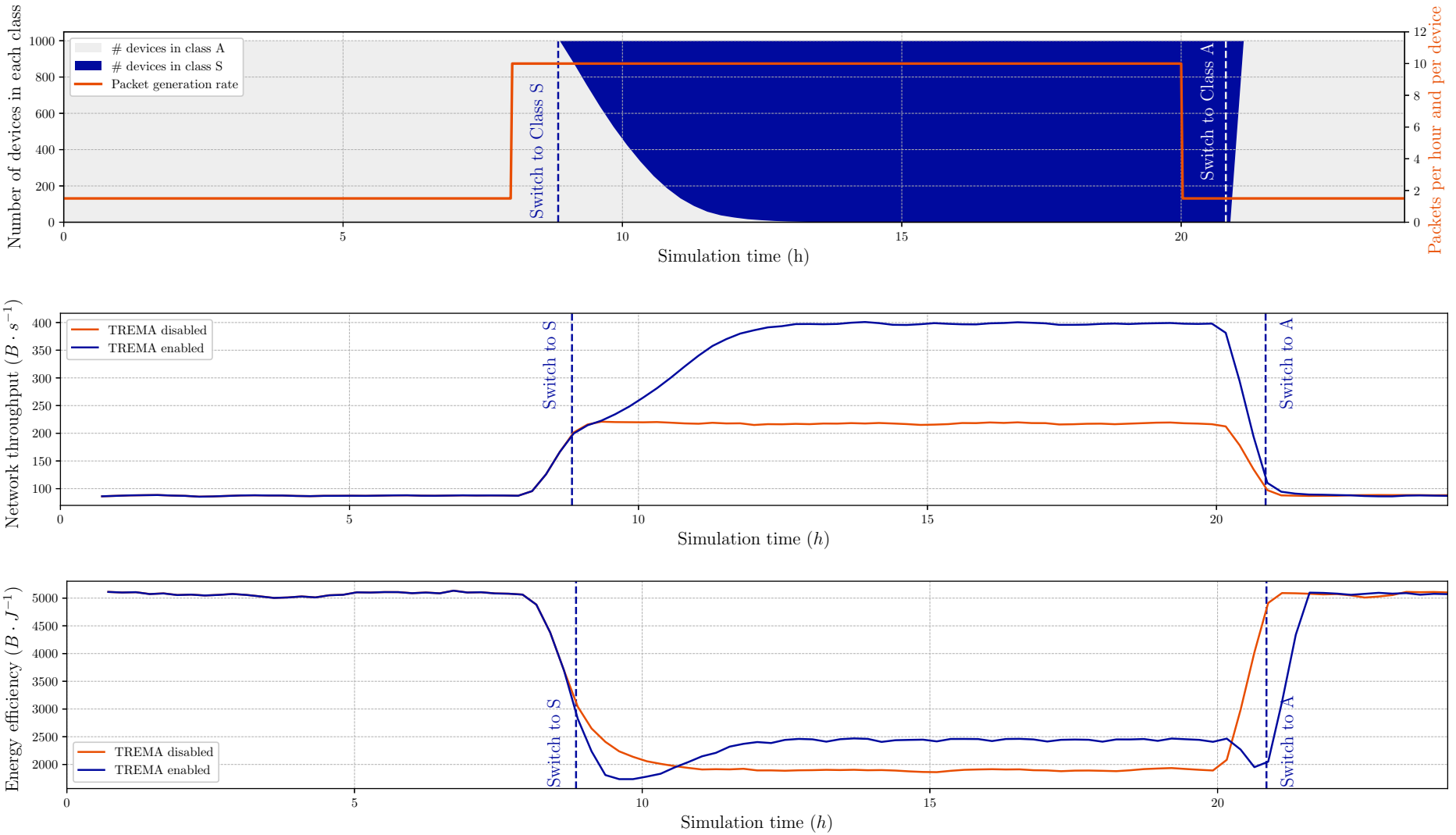
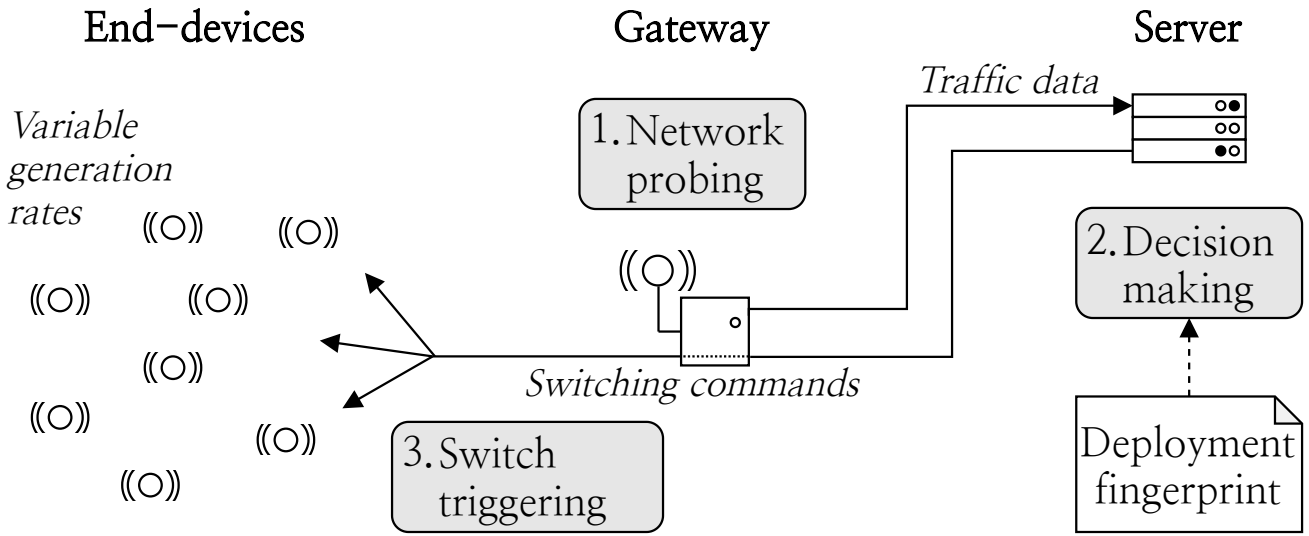


Figure: TREMA's switching mechanism example ($n_{skip} = 0$)

Conclusion

Conclusion


End−devices
Gateway
Server
Traffic data
Variable generation rates
1. Network probing
2. Decision making
Switching commands
3. Switch triggering
Deployment fingerprint

References

References I

[1] N. Abramson, "THE ALOHA SYSTEM: another alternative for computer communications," in *Proc. of AFIPS '70 (Fall)*, ser. AFIPS '70 (Fall). Houston, Texas: ACM, Nov. 1970, pp. 281–285.

[2] L. Chasserat, N. Accettura, and P. Berthou, "Short: Achieving energy efficiency in dense LoRaWANs through TDMA," in *IEEE International Symposium On a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, Cork, Ireland, Aug. 2020. [Online]. Available: https://hal.laas.fr/hal-02551973

[3] Semtech Corporation, "SX1276/77/78/79 datasheet," Jan. 2019.

Thank you very much!

Bonus: A time-synchronized scheduled access over Class S

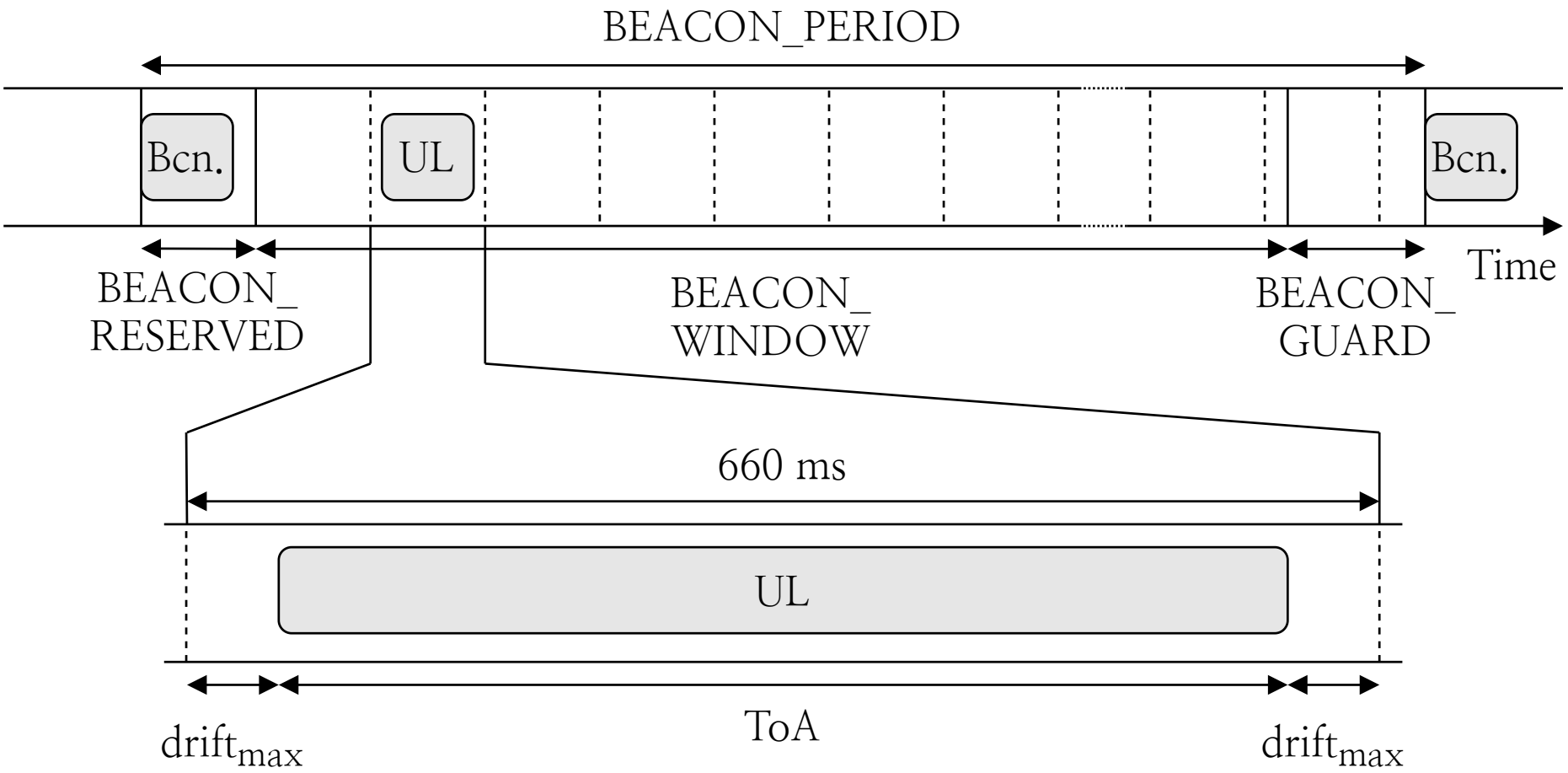


Figure: Scheduled access over Class S

Bonus: Simulated deployment parameters

Parameter	Value
Number of devices	1000
Simulation duration	24 hours
Spreading Factor	7
Frame time-on-air	626.94 ms
Beacon time-on-air	173.06 ms
Timeslot size	660 ms
Data rate	DR5 (SF7 with bandwidth 125 kHz)
Frame generation rate	Varies from ~ 0.5 to ~ 19 pkts. / h.
Channels	868.1, 868.3 and 868.5 MHz
Uplink Duty Cycle	1%
Device buffer size	1
Downlink data messages	Disabled
Acks and retransmissions	Disabled
Sensor voltage	3.3 V
Sensor current intensity	20 mA TX, 10.8 mA RX [3]

Bonus: Signaling protocol

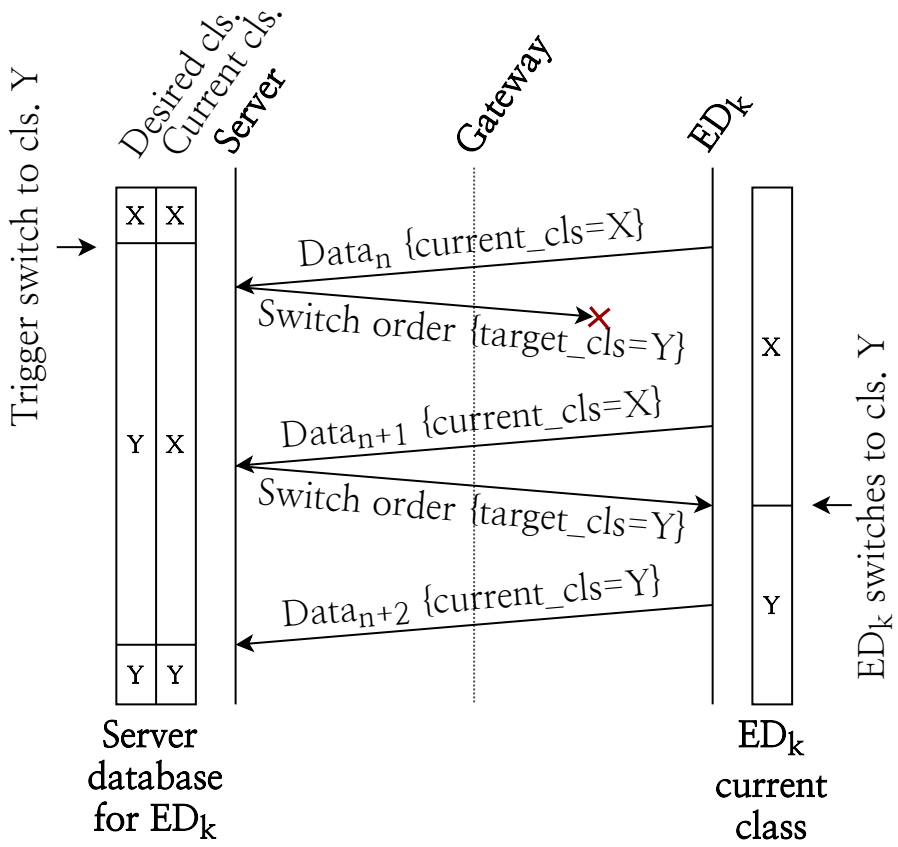


Figure: General-case signaling (used here to switch from Class A to Class S)

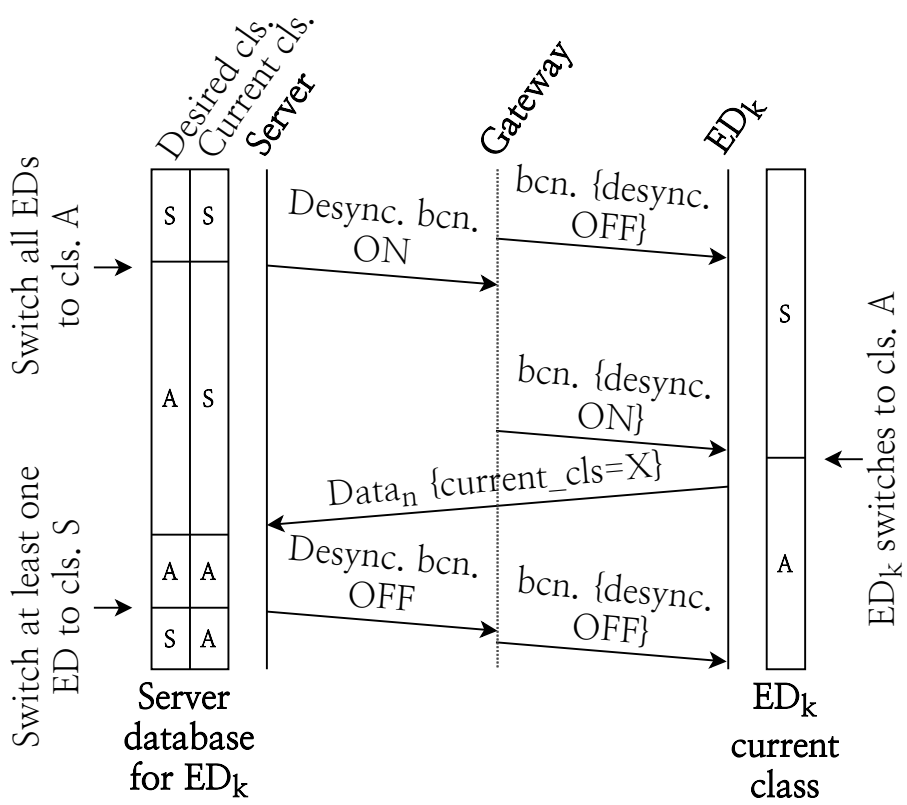


Figure: Signaling to switch from Class S to Class A

Bonus: Performance gain

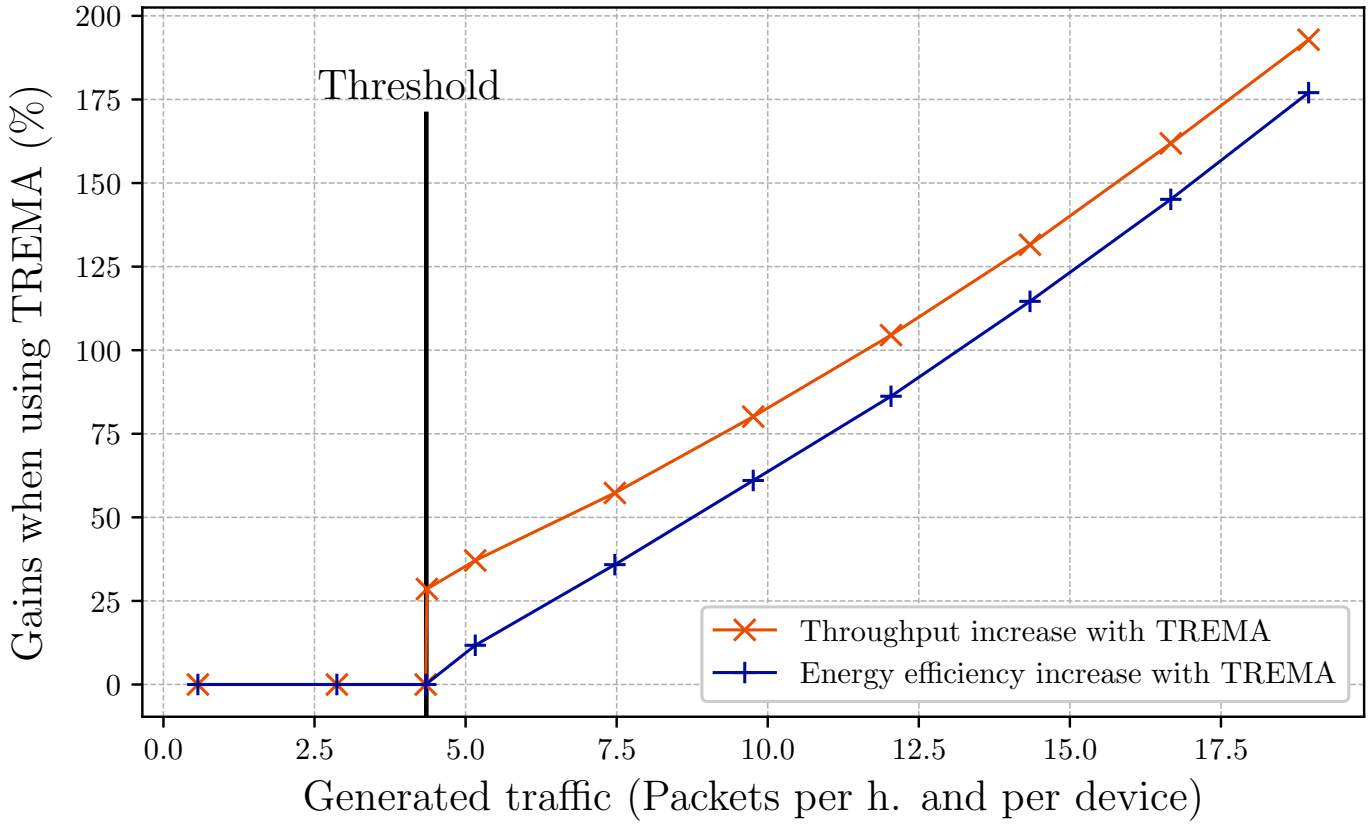


Figure: Performance gain when using TREMA ($n_{skip} = 3$)