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Battery Lifetime Estimation and Optimization for a WSN

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Introduction

Our work is done in the context of the Donut project, described further in [1], whose overall goal is to develop a unified cost-effective solution for distributed monitoring of the urban water system (See Figure 1).



Results

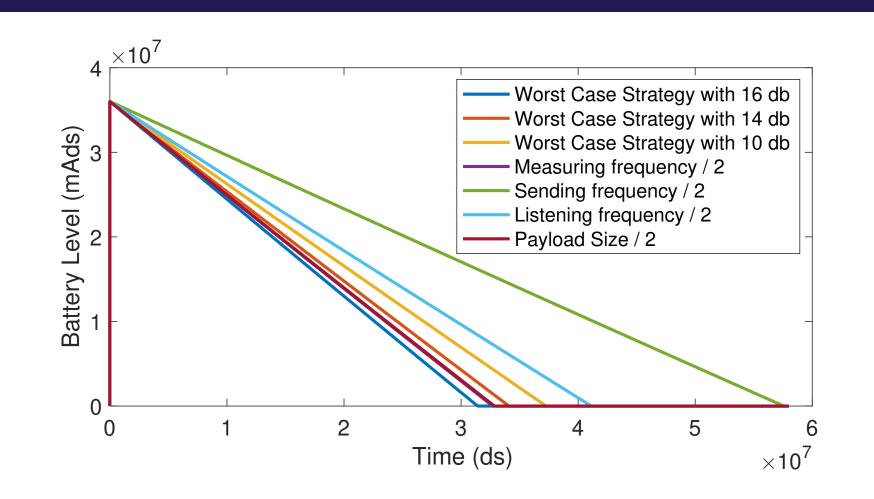


Fig. 4: Battery Lifetime by Reducing p Parameters

Transmission Strategies

- A "worst-case" strategy that transmits the maximum allowed number of Sigfox messages and performs the maximum number of raw samples that fit into a message.
- A "reduced data collection" controller that applies a fixed sampling rate and a fixed Sigfox message transmission rate. We analysed a number of different combinations to inspect the asymptotic limits.
- A "weather-based" strategy that is suitable for applications where rain is the main indi-

Water Line

Fig. 1: Urban water monitoring systems

A project partner (the Montem company) has developed a prototype of a wireless sensor node. The embedded based hardware is equipped with an ultra-sonic sensor, a Sigfox transceiver, and a battery.

We applied the Uppaal statistical modelchecking tool [2] to compute different quality metrics of the model, including the expected battery lifetime. The model includes the most energy consuming activities.

Sigfox

A Sigfox node has very particular duty cycle requirements that a node must respect: it may send at most 144 messages per day containing up to 12 bytes of payload, and receive at most 4 8-byte messages per day [3].

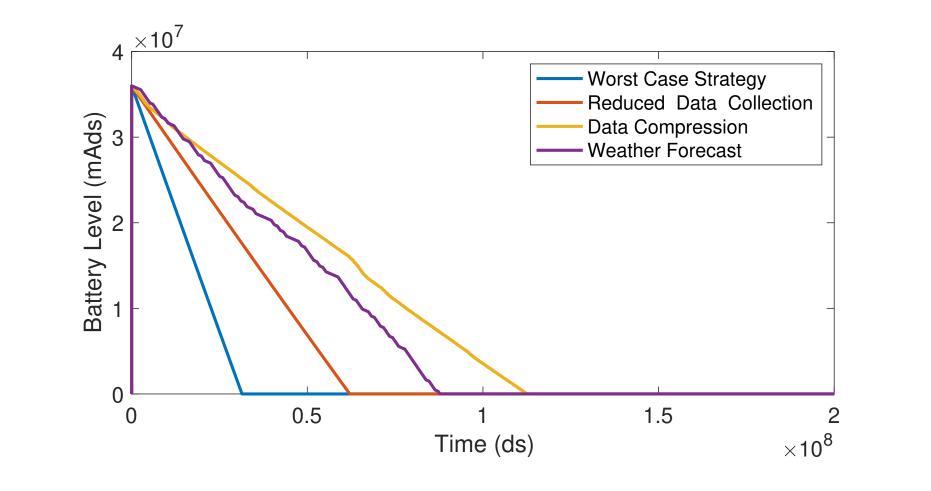


Fig. 5: Battery Lifetime for Proposed strategies

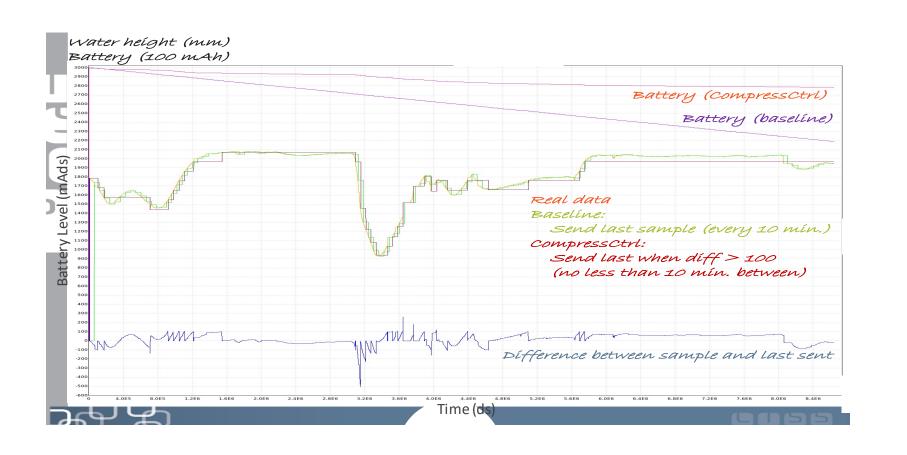
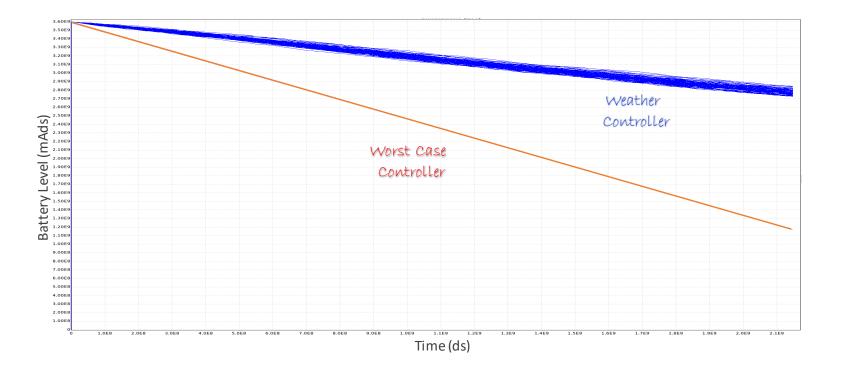


Fig. 6: Data Compression Strategy Behaviour



cator of the water condition. The nodes are configured with a downlink message at the beginning of the day such that it provides more frequent data on "rainy" days than "dry" days., since rain provides more interesting characterisation of the behaviour of the water level. We also considered the case that the configuration is wrong.

A simple "data-compression" controller that only transmits data when the difference between a collected sample and the last transmitted sample exceeds a certain threshold.

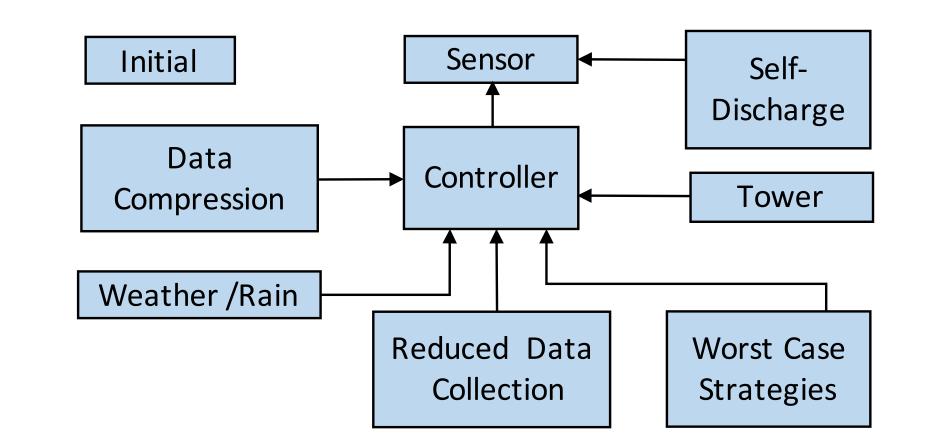


Fig. 8: Model Architecture with transmission strate-

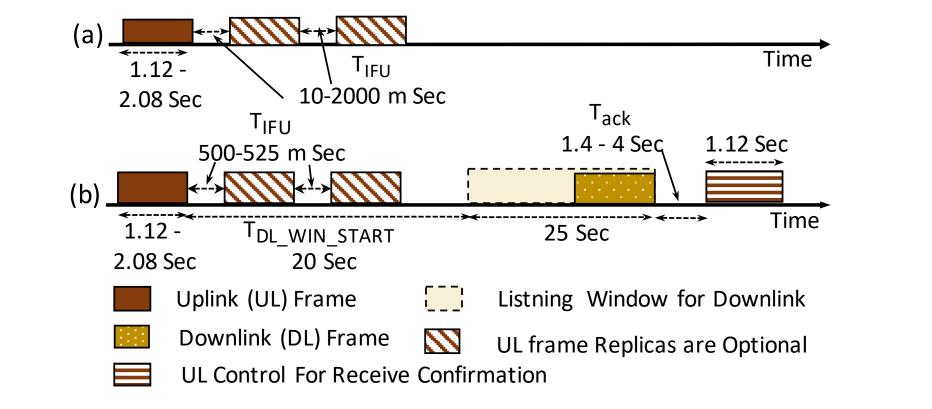


Fig. 2: Sigfox communication procedures (a) Unidirectional (b) Bi-directional

Payload	Frame Transmission	n Time
length	RC1/RC2/RC5	RC3/RC4
 <1 bit 2 bits-1 byte 2-4 byte 5-8 byte 9-12 byte 	 1.1 seconds 1.2 seconds 1.45 seconds 1.75 seconds 2 seconds 	190 ms 200 ms 250 ms 300 ms 350 ms

Table 1: Frame transmission time for different pay-load sizes

Fig. 7: Effect of rain controller simulation with 100 runs

Description	Query	Results
Maximum life- time	E[<=MAX](max:Sensor(0). lifetime/day*SCALE)	131 Days
Total number of measurements	E[<=MAX](max:Sensor(0). n_measure*SCALE)	187,725
Total times sent	E[<=MAX](max:Sensor(0) .n_send*SCALE)	53070 s
Total times lis- tened	E[<=MAX](max:Sensor(0) .n_listen*SCALE)	53060 s
Total times re- ceived	E[<=MAX](max:Tower(0) .n_send*SCALE)	1,480 s

 Table 2: Estimating Lifetime

gies

Conclusion

Our results from applying our general analysis method to Sigfox-based wireless sensor nodes for urban water drainage systems show a significant difference in expected battery lifetime dependent on data collection and communication strategies. The results suggest a huge improvement potential. As future work, we will measure power consumption on real sensors to confirm or refine the parameters of the model, and to include battery self-discharge. We envision an improved strategy where a prediction module is used to send data when the difference between actual and predicted water level exceeds a given threshold.

References

[1] Ahm, M.S., Duus, L.B., Rasch, P., Laursen, P.Ø., Høedholt, A., Larsen, K.L., Sørensen, L., Nielsen, J.E., Rasmussen, M.R. Distributed ONline monitoring of the Urban wa-Ter cycle (DONUT): vision and initial results. In 10th IWA Symposium on Modelling and Integrated Assessment, 1–4 September 2019, Copenhagen, Denmark A., [2] David, Larsen, K.G., Legay, A., D.B. 2015 M., Poulsen, Mikučionis, SMC International tutorial, Uppaal Journal on Software Tools for Technology Transfer 17(4), pp .397-415, 2015, https://doi.org/10.1007/s10009-014-0361-y [3] Zuniga, J. C., Ponsard, B. (2016). Sigfox system description. LPWAN@ IETF97, Nov. 14th, 25.

UPPAAL Model

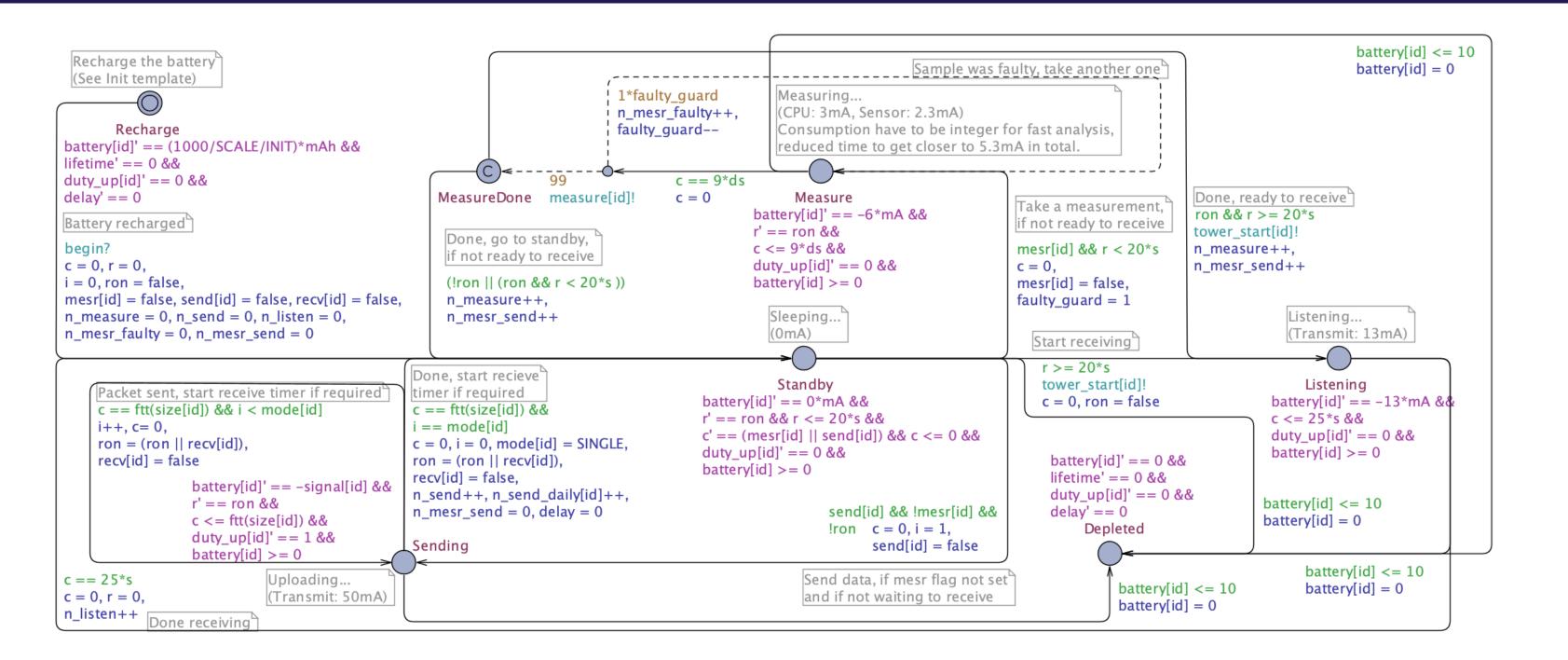


Fig. 3: UPPAAL model for sensor