# 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).

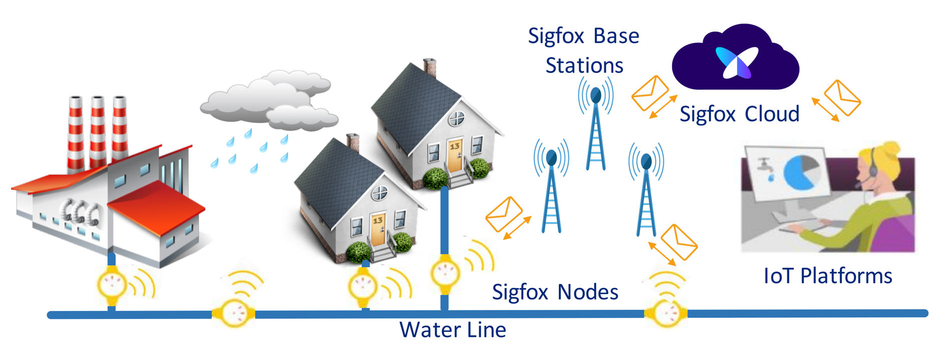


**Fig. 1:** Urban water monitoring systems

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 model-checking 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].

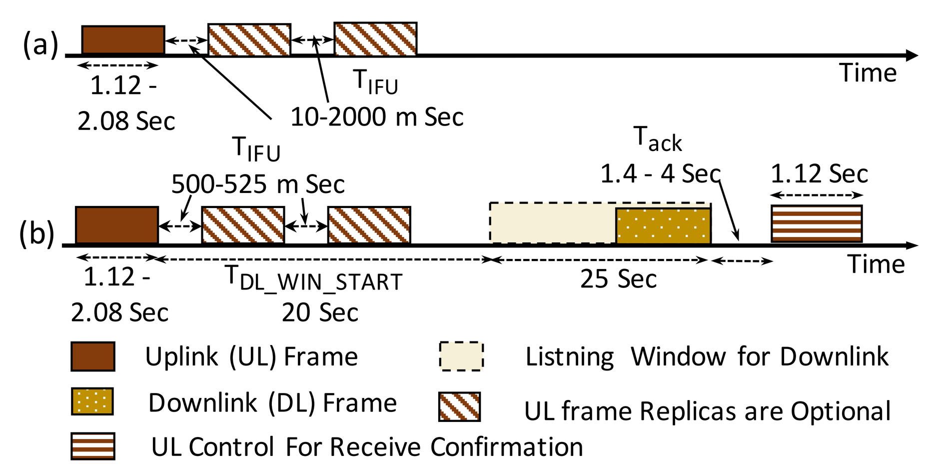


**Fig. 2:** Sigfox communication procedures (a) Uni-directional (b) Bi-directional

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

**Table 1:** Frame transmission time for different payload sizes

## UPPAAL Model

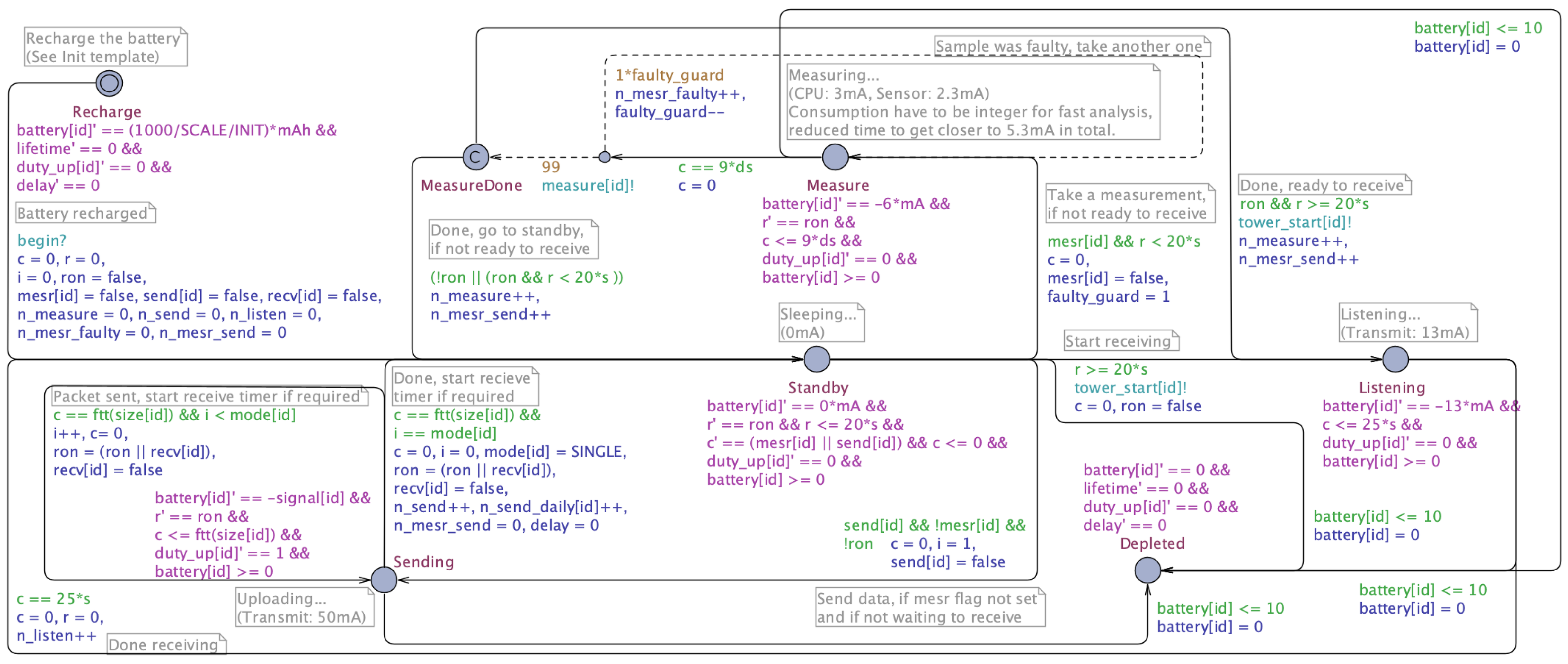

**Fig. 3:** UPPAAL model for sensor

## Results

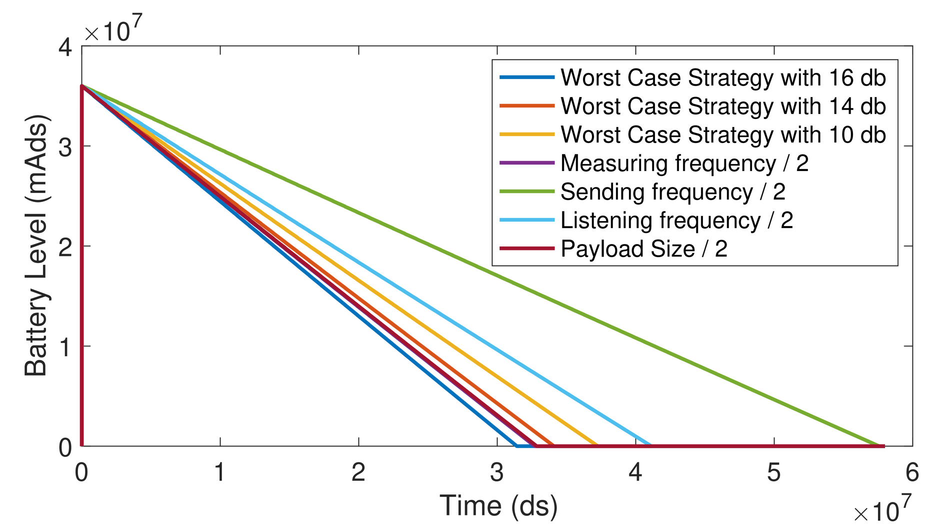


**Fig. 4:** Battery Lifetime by Reducing p Parameters

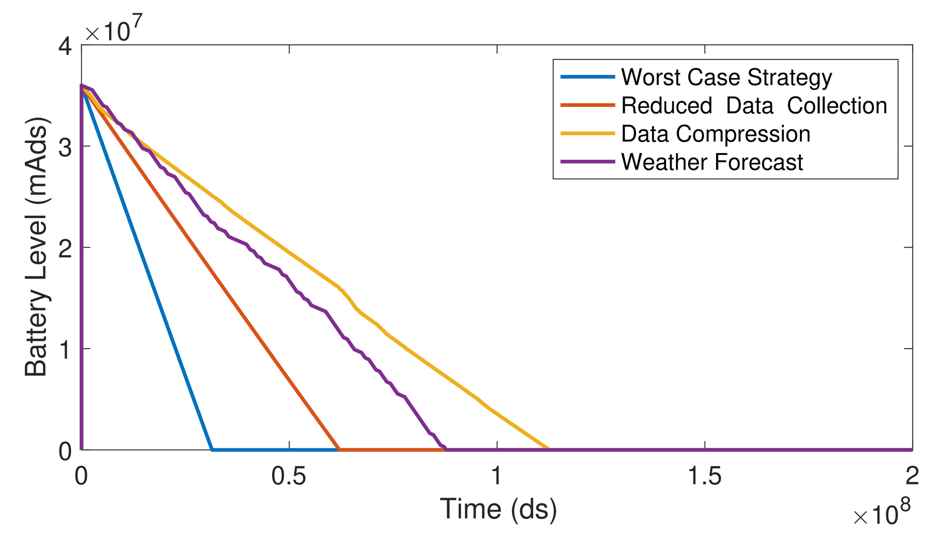


**Fig. 5:** Battery Lifetime for Proposed strategies

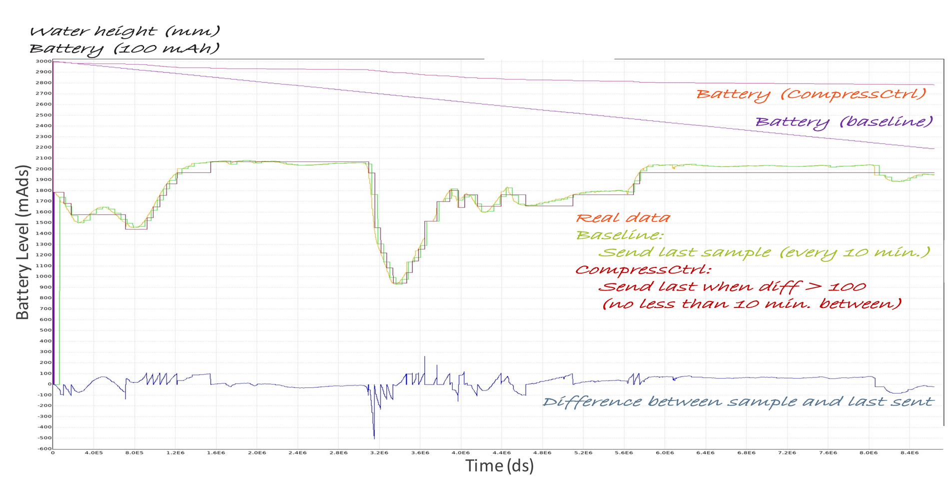

**Fig. 6:** Data Compression Strategy Behaviour

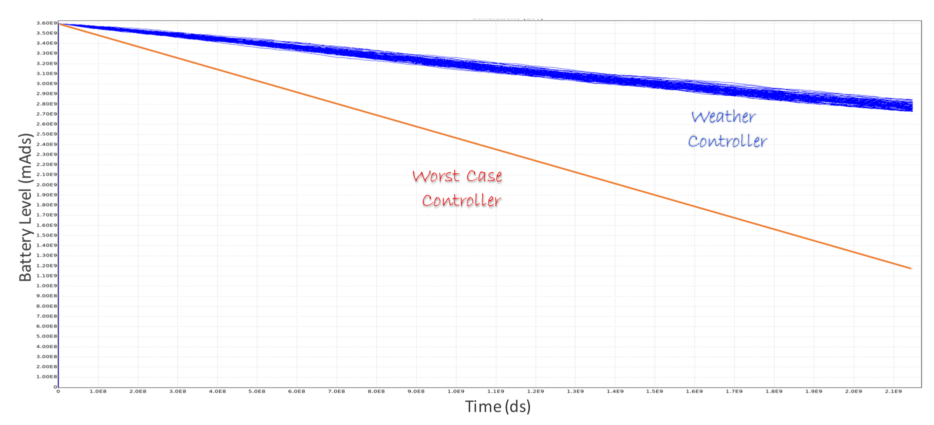


**Fig. 7:** Effect of rain controller simulation with 100 runs

| Description | Query | Results |
|---|---|---|
| Maximum lifetime | 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 listened | E[<=MAX](max:Sensor(0).n_listen*SCALE) | 53060 s |
| Total times received | E[<=MAX](max:Tower(0).n_send*SCALE) | 1,480 s |

**Table 2:** Estimating Lifetime

## 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 indicator 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.

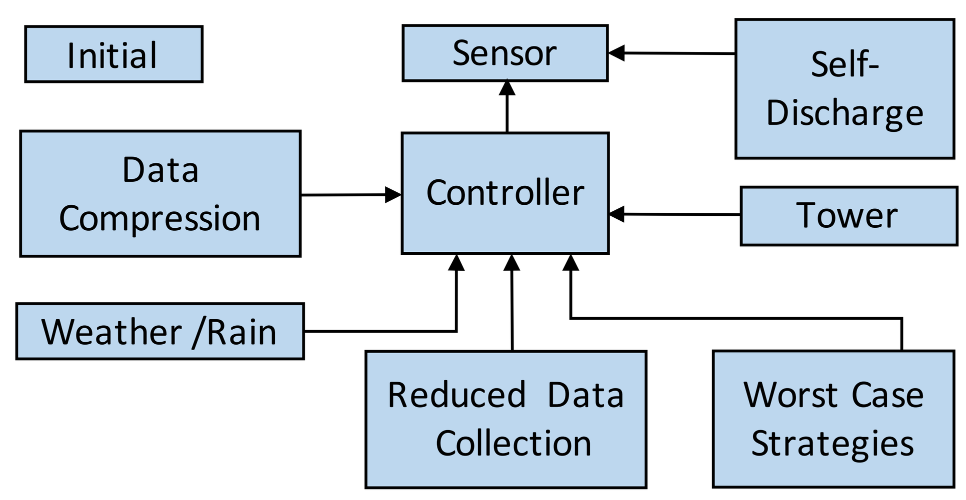


**Fig. 8:** Model Architecture with transmission strategies

## 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

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[2] David, A., Larsen, K.G., Legay, A., Mikučionis, M., Poulsen, D.B. 2015 Uppaal SMC tutorial, International 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.