Exercise Sheet 6
Battery-Awareness

C2 – Battery-Aware Scheduling

Exercise E6.1 *(Multiple Choice)*
Check the correct answer. There is only one correct answer per question.

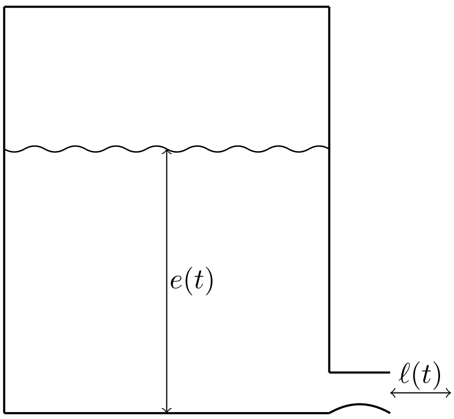
(a) What time point in a simulation on the KiBaM can only be approximated?

☐ When the available charge reaches its capacity. ☐ When the battery depletes.
☐ When the bound charge reaches its capacity.

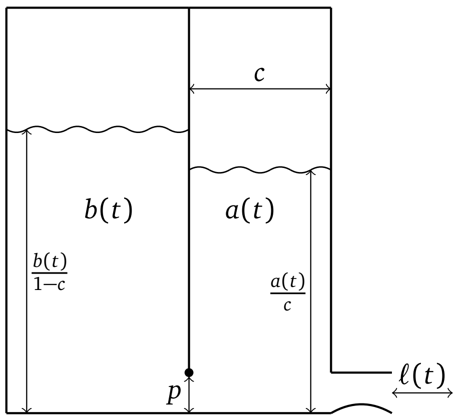
(b) Where is the cost in a priced timed automaton accumulated?

☐ Only in locations ☐ Only on edges ☐ On both locations and edges

Exercise E6.2 *(Relating the Linear and Kinetic Battery Model)*
Remember that the linear battery model (LiBaM) and the kinetic battery model (KiBaM) can be thought of as wells holding liquid that can be drained or replenished.



(a) The linear battery model.



(b) The kinetic battery model.

Figure 1: Schematic sketches of the linear and kinetic battery models.

The kinetic battery model improves on the linear battery model by simply splitting the well of liquid of the linear model into two interconnected wells of liquid.

(a) Given a KiBaM with fixed width-parameter $c \in]0, 1[$ (the width of the bound-charge well being $1 - c$) and an initial state of charge $[a(0); b(0)]$, how to choose the diffusion-rate parameter p such that the KiBaM simulates a linear battery model with initial state of charge (i) $e(0) = a(0)$, or (ii) $e(0) = a(0) + b(0)$?

(b) Given a KiBaM with fixed diffusion-rate parameter $p > 0$ and a respective initial charge level (the height of the fluid) of $a(0)/c$ and $b(0)/(1 - c)$, how to choose the width-parameter c such that the KiBaM simulates an ideal battery model with initial state of charge $e(0) = a(0) + b(0)$?

(c) Let $\ell(t) = \ell > 0$ be a constant discharge rate and K be a KiBaM with fixed $c \in]0, 1[$, $p > 0$ and initial state of charge $[a(0); b(0)]$. Furthermore, let L be a linear battery model with initial state of charge $e(0) = a(0)$. Under which condition (in terms of the parameters and initial state of charge of K) does L provide a safe under approximation of the lifetime of K (time until depletion) if subjected to the same discharge rate ℓ?

C3 – Battery-Aware Contact Plan Design

Exercise E6.3 *(Multiple Choice)*
Check the correct answer. There is only one correct answer per question.

(a) What is the main advantage of using a Store-Carry-and-Forward (SCaF) strategy in nanosatellite-based LEO constellations like Ulloriaq?

☐ It allows continuous communication with ground stations.
☐ It reduces on-board memory utilization.
☐ It offers flexibility in managing power constraints.
☐ It simplifies the satellite design.

(b) How can the Ulloriaq constellation efficiently use Inter-Satellite Links (ISLs) to meet power constraints?

☐ By enabling ISLs continuously to maximize data flow.
☐ By disabling ISLs completely to save power.
☐ By enabling ISLs sporadically to manage power consumption.
☐ By increasing the data rate of ISLs to 100 Mbit/s continuously.

(c) What is the primary reason for fractionating states longer than a given value in the Battery-Aware Contact Plan Design?

☐ To reduce the number of satellites in the constellation.
☐ To allow different Contact Plan Decisions (CPD) along the time.
☐ To increase the data rate of the satellite links.
☐ To simplify the satellite network topology.

Exercise E6.4
Explain why transmitting data only when an end-to-end (E2E) path exists would be problematic for a nanosatellite constellation (e.g. Ulloriaq)?

Exercise E6.5 *(Optimistic Power Budget)*
Assume you have a satellite using the new *NanoPower BPX* battery pack that has a total capacity of 86 Wh. You computed the following simple and overly optimistic power budget:

	Solar Panels	Background Load	Heater System	ISL Transponder
Sunlight	30 W	−6 W	0 W	−10 W
Eclipse	0 W	−6 W	−6 W	0 W

(a) Starting with a fully charged battery, compute how long your satellite can stay in the eclipse until the battery is fully discharged.

(b) Assume that each orbit has exactly the same duration of sunlight and eclipse phases. Would this power budget in theory work to power the satellite for its 5-year lifespan?

(c) Unfortunately, the previous assumption does not always hold. Assume now that each orbit takes 90 min and that during each orbit, the satellite is 46 % in sunlight and 54 % in eclipse. Compute how long your satellite can operate until the battery is fully discharged.

Exercise E6.6 *(Duty Cycling)*
Given the following power consumption details for a satellite with an ISL transponder:

	Solar Panels	Background Load	ISL Transponder
Sunlight	15 W	−5 W	−10 W (if enabled)
Eclipse	0 W	−5 W	−10 W (if enabled)

Assume the battery capacity is 77 Wh and the satellite experiences 40 minutes of eclipse and 50 minutes of sunlight. Compute the duty cycle (i.e. the percentage of time in which the ISL is active) which is required for the ISL transponder to ensure that the battery is never depleted.

C4 – Routing in LEO

Exercise E6.7
Name three advantages of LEO over GEO.

Exercise E6.8
Why are routes with fewer hops usually better than routes with (slightly) shorter distance?

Exercise E6.9
Describe in your own words why changing from a 'fast' (i.e. low delay) route to a 'slow' (i.e. high delay) one can be bad for your TCP performance. Do the same for changing from a 'slow' route to a 'fast' one can be bad for your TCP performance.

Which change is more critical and why?

Exercise E6.10
In the context of route stability, why does SetCover have a worse TCP (Tahoe / Reno) performance (in terms of average data rate) than Tenacious despite having longer route validity times and less bad route changes?