Adaptive Battery Charge Scheduling with Bursty Workloads

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Motivation

Sensor devices need to be charged after deployment for sustainable performance

Existing Solutions use fixed voltage thresholds for charging, which causes task failures with bursty workloads.
Problem

What is a good voltage threshold to trigger battery charge?
- challenge: bursty workloads
- goal: maintain high utilization of energy

How to adjust battery charge schedule?
- challenge: adapt to workload changes
- goal: maximize a node’s lifetime with a fixed number of charges, while minimizing the task failure ratio
Approach

Bursty workloads
- triggered by physical phenomenon
- spatiotemporal properties
- can be learned over time

Adaptive battery charge schedule
- task failure ratio vs. lifetime
- based on predicted workload patterns
- use feedback control to adapt
Contributions

1. Bursty workloads of sensor nodes are caused by the spatiotemporal nature of physical phenomenon. We design a learning model to capture and predict such workload patterns.

2. By monitoring the workload and the voltage levels, a feedback control solution is applied to adjust the charging schedules. Evaluation shows that we achieve a 68.26% lower task failure ratio compared to existing schemes, with a 3.45% decrease in system lifetime.
Empirical Studies

![Graph showing voltage over time for different currents](image-url)
Empirical Discharging Model

\[ r_{\text{discharge}} = a \times w + b \]

where \( r_{\text{discharge}} \) represents the battery discharging rate, \( w \) represents system workload, and \( a \) and \( b \) are model parameters obtained from experiments. Different batteries have different values of \( a \) and \( b \).
Markov Bursty Workload Model

$S_i$: a task $i$ runs for a certain period of time $T_i$

$idle_i$: idle state $i$ runs for a time duration of $I_i$

$S_i$: a subset of tasks run together, a task in this group is $s_i$

$p(S_i | s_i)$: transition probability from task $s_i$ to a burst of tasks $S_i$
Feedback Control based
Adaptive Schedule
Evaluation Setup

Trace-driven analysis: we use real battery charge/discharge data from empirical studies

Four types of schedules
- periodic
- on-demand
- adaptive
- robust

We test three types of workloads
- random
- bursty
- hybrid

The number of charging cycles is set as 10,000. The simulation is run 40 times for statistical results.
Evaluation Results
Evaluation Results
Conclusions

We design a feedback control based charge scheduling algorithm to adapt to bursty workloads.

Our algorithm is based on an empirical battery model obtained from experiments.

Our solution

- achieves a 68.26% lower task failure ratio with a decrease of 3.45% in the system lifetime under bursty workloads

- adapts to workload and battery characteristics