Adaptive Battery Charge Scheduling with Bursty Workloads

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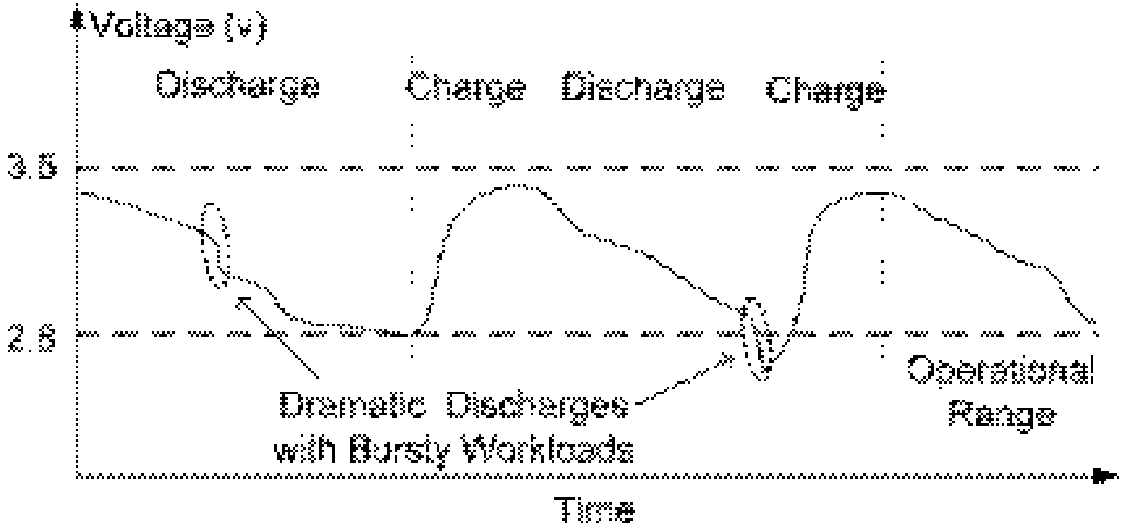
Motivation

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

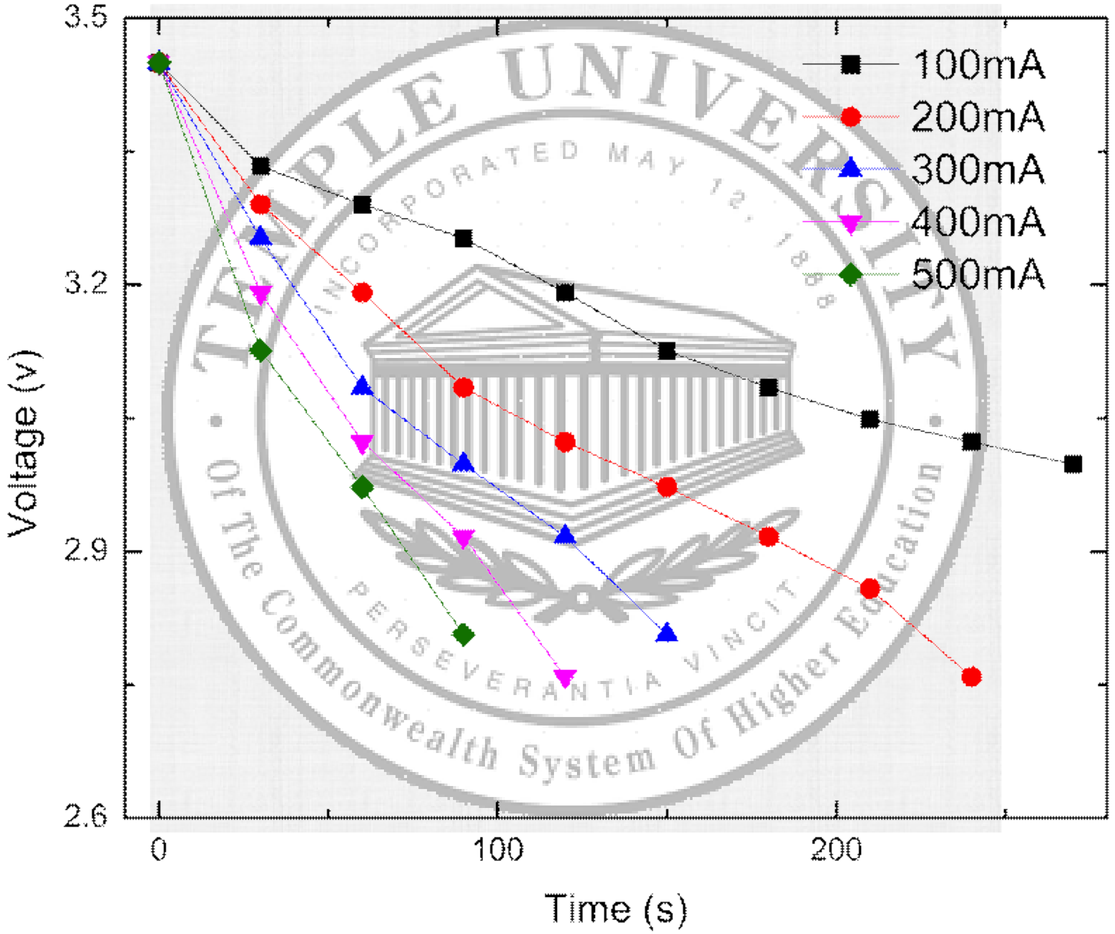
- task failure ratio vs. lifetime
- based on predicted workload patterns
- use feedback control to adapt

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



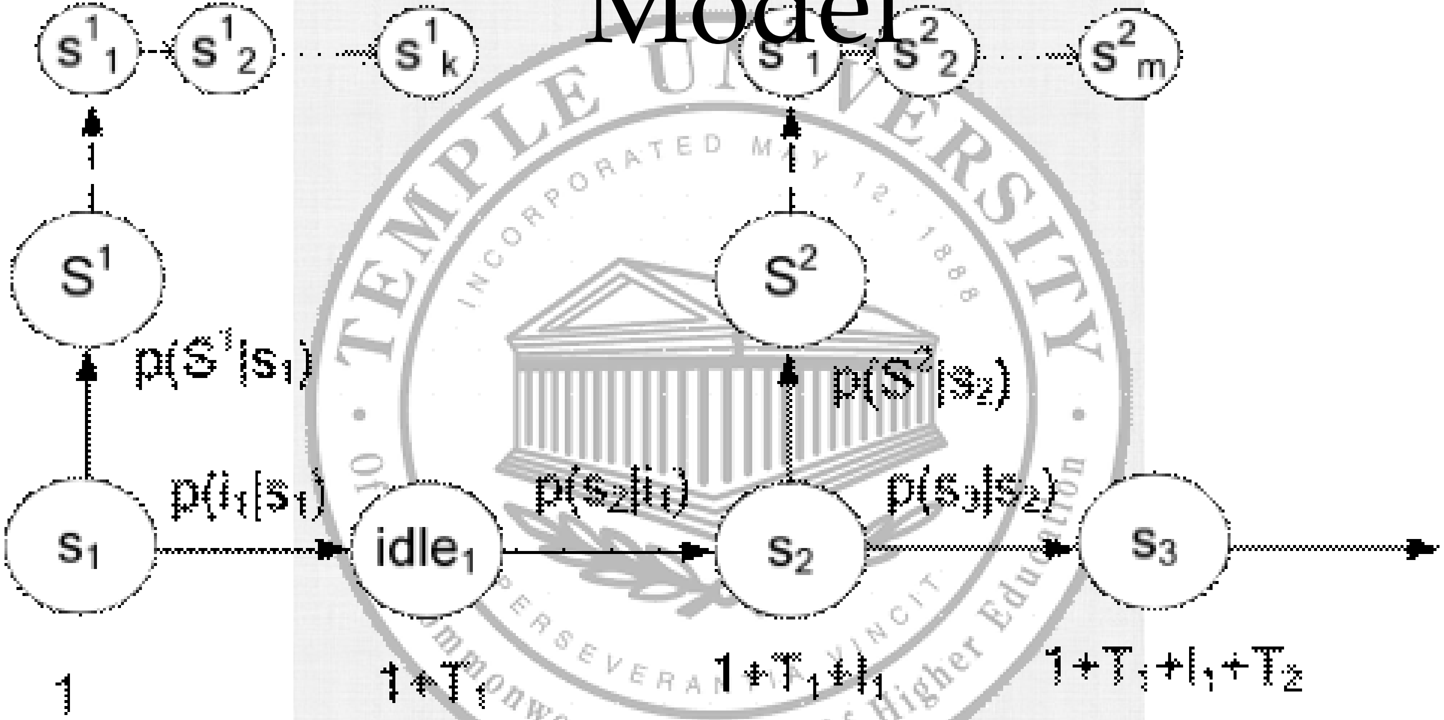
Empirical Discharging Model

$$r_{discharge} = a \times w + b$$

where $r_{discharge}$ 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



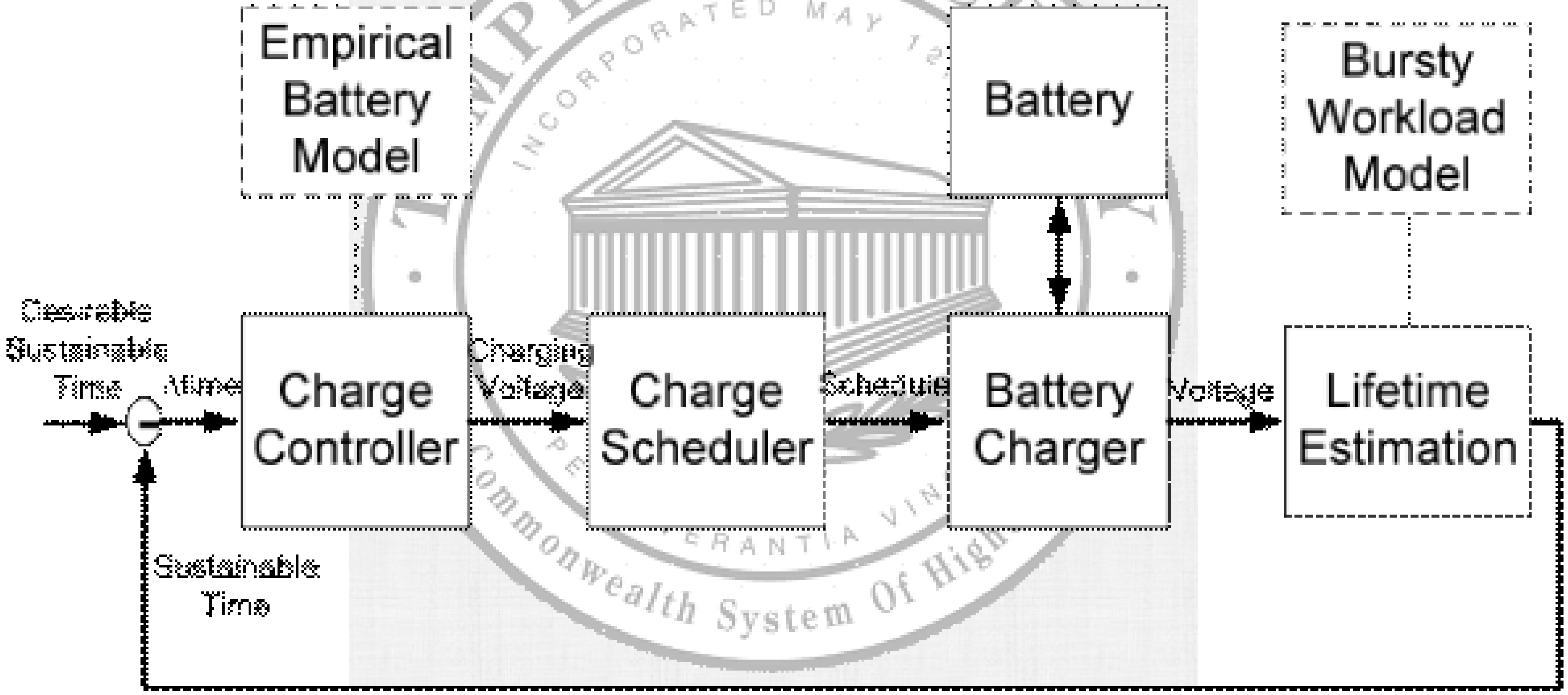
S_i: a task i runs for a certain period of time T_i

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

S^j: a subset of tasks run together, a task in this group is s^j_i

$p(S^j | s_i)$: transition probability from task s_i to a burst of tasks S^j

Feedback Control based Adaptive Schedule



Evaluation Setup

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

Four types of schedules

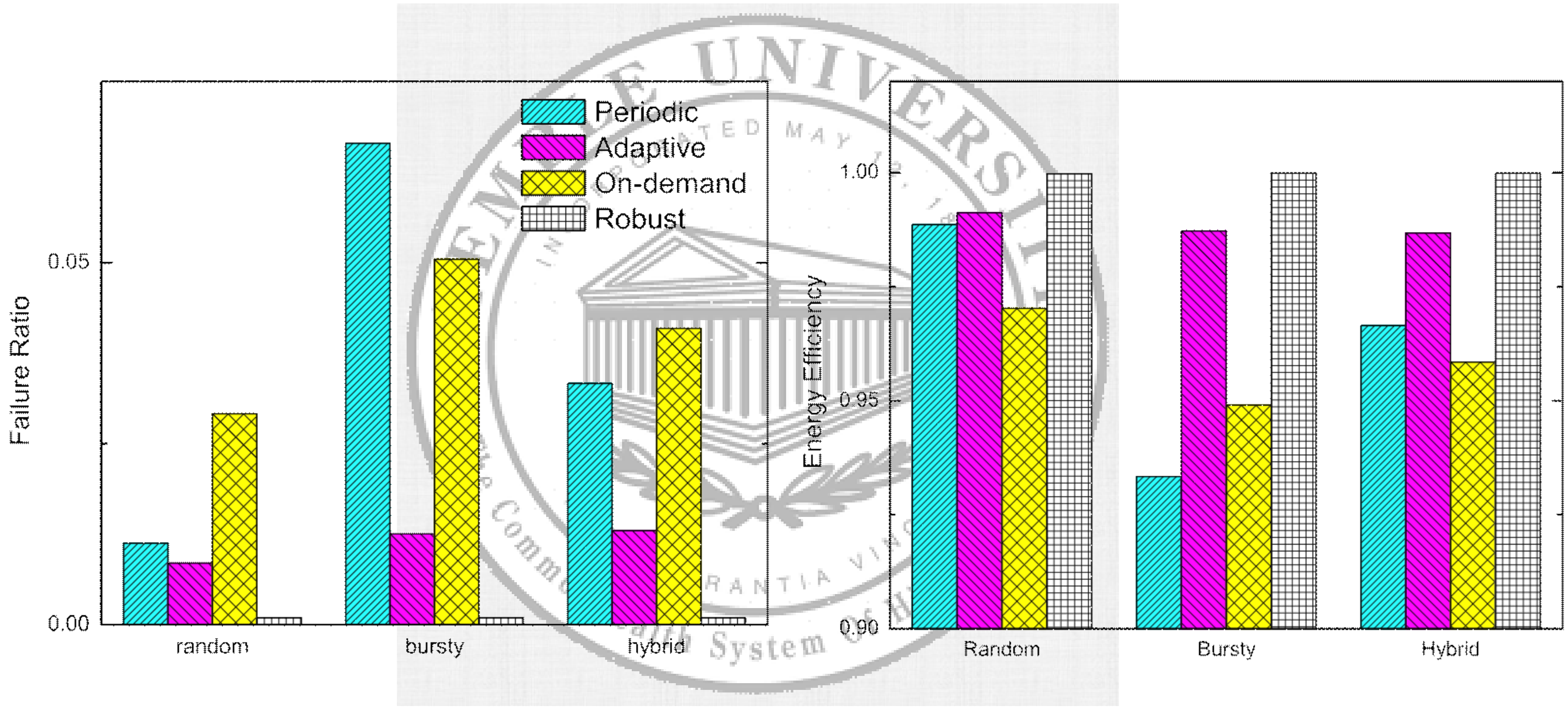
- periodic
- on-demand
- adaptive
- robust

We test three types of workloads

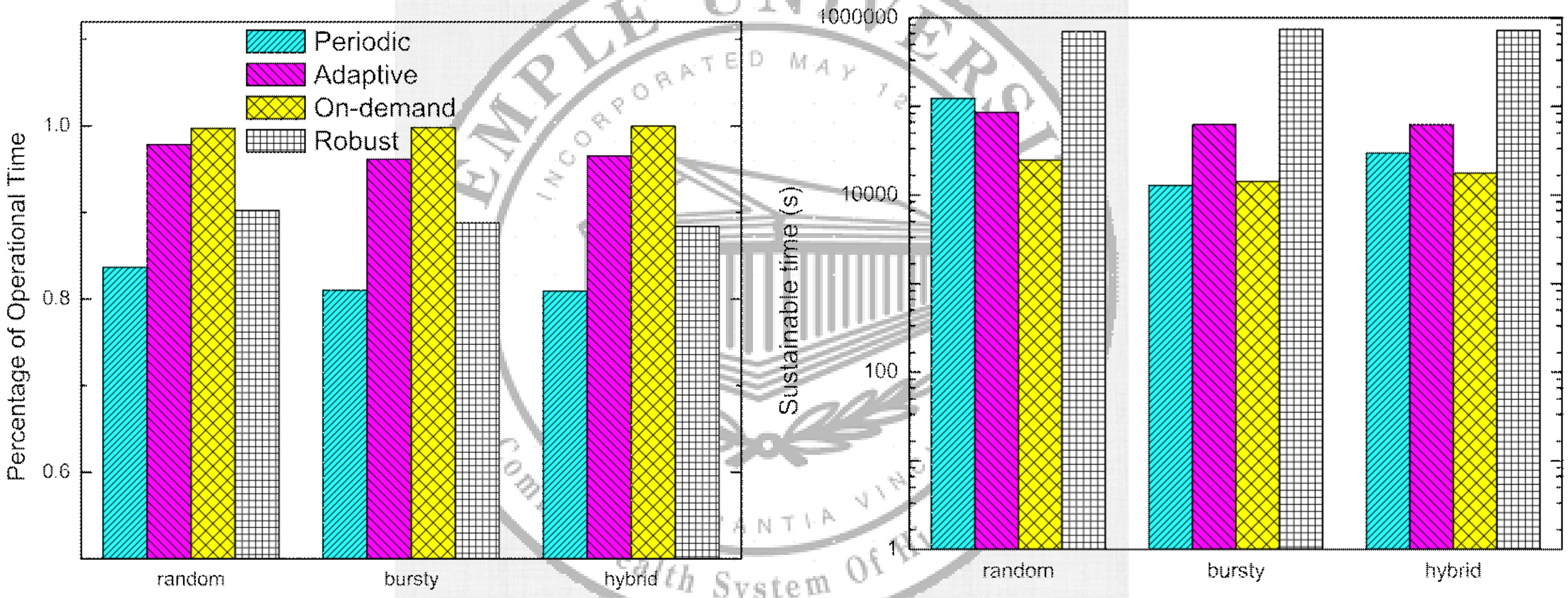
- random
- bursty
- hybrid

The number of charging cycles is set as10,000. 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