Power Management for Solar-Driven Sensor Nodes

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Outline

- System Model
- Problem Statement
- Lazy Scheduling
- Admittance Test
- Simulation
- Conclusion

System Model

energy source

energy storage

computing device

tasks

Task $J_i$

- can be preempted
- arrives at time $a_i$
- has deadline $d_i$
- needs total energy $e_i$ to complete
- can consume power $0 \leq P_D(t) \leq P_{max}$
- therefore, needs time

$$w_i \geq \frac{e_i}{P_{max}}$$
Problem Statement

- Determine an **optimal on-line scheduling** algorithm:
  
  If the task set is schedulable, it determines a feasible schedule.

- Construct an **admittance test**:
  Determine, whether a set of event streams with a given characteristic is schedulable.

Nothing known so far …

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Problem Statement - EDF

Greedy scheduling is not suited.
Problem Statement - ALAP

ALAP does not work either.
And what happens if the energy storage is full?

Lazy Scheduling Algorithm

optimal starting time $s_i$

$$s_i = d_i - \frac{\min (E_C(a_i) + E_S(a_i, d_i), C + E_S(s_i, d_i))}{P_{max}}$$

**Rule 1:** All tasks with $s_i \leq t$ are processed with EDF scheduling using $P_{max}$.

**Rule 2:** If there is no task with $s_i < t$ and the energy storage is full, all incoming power $P_S(t)$ is assigned to the task with the currently earliest deadline.
Optimality of Lazy Scheduling Algorithm

**Theorem:**
If the Lazy Scheduling Algorithm LSA cannot schedule a given set of tasks, then no other scheduling algorithm can schedule it.

**Sketch of Proof**

Energy-Constrained

\[ \Delta : \text{with } C + E_S < \sum_{i} e_i \]

Time-Constrained

\[ \Delta : \text{with } \Delta < \frac{\sum_{i} e_i}{P_{\text{max}}} \]
Admittance Test

Is the scheduling of the event streams feasible with LSA?

Event stream: delay requirement $d$
energy request per event $c$
arrival curve $\alpha(\Delta)$

Energy source: energy variability $[c^l(\Delta), c^u(\Delta)]$

Admittance Test

A given set of event streams $J_i$, $i \in I$ is schedulable with initially stored energy $C$, iff

$$\forall \Delta : \sum_{i \in I} e_i \alpha_i(\Delta - d_i) \leq \min \{c^l(\Delta) + C, P_{max} \Delta\}$$
Simulation Results

Capacity savings of ~40% measured for random task sets for LSA with \( \varepsilon'(\Delta) \) compared to EDF

Conclusions

Scheduling Scenario | Optimal Lazy Scheduling | Admittance Test | Simulation Results
---|---|---|---
EDF | LSA with \( \varepsilon' \) | \( C_{\text{min}} \) |
Future Work

- Modular Real-Time Analysis

\[ e^1(\Delta) \]

- \( d_1, e_1 \)
- \( d_2, e_2 \)
- \( d_3, e_3 \)