Aalto University
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Dynamic Power Management Based on Continuous-Time Markov Decision Processes

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Content

1. **Background**
2. **Discrete-time Dynamic Power Management model**
3. **Continuous-time Dynamic Power Management model**
4. **Results**

Background

Motivation

- **Battery-operated devices are expected to have ever better performance and more features while also improving battery life**
- **These results have been achieved with a mix of technological innovation, architechtural design and optimimization**
- **One of the most successful techniques is Dynamic Power Management**

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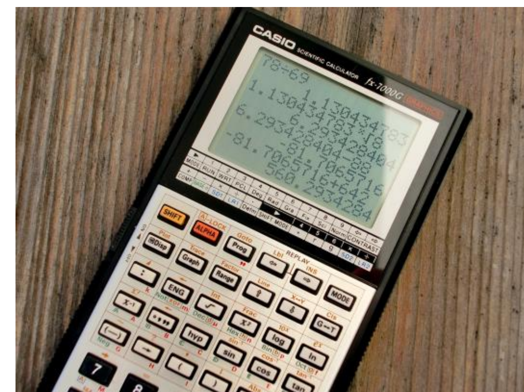
Dynamic Power Management 1/2

- **Component usage in a device is usually event driven**
  - Adjusting volume on your phone or pressing a number on a calculator
- **Components use electricity always when they are active whether there is usage or not**
- **This leads to power dissipation**
  - Increased cooling costs
  - Reliability issues
  - Less battery life



Dynamic Power Management 2/2

- **Reducing power dissipation**
  - Turn off components not in use
  - Decrease component performance when not fully used

- **System-level Power Management policy to dictate how and when a component should be shut down**
  - Minimize power dissipation under performance constraints

Heuristic Power Management policies

- **Time-out policy: Shut a component on and off after a given time *t***
  - *t* can be zero (greedy) or *t* can be calculated with predictive methods (e.g. regression)
  - Not efficient as transition from inactive to active requires time and power
  - Only applicable when events are highly correlated
- **N-policy: Component is turned on when N events are in queue and shut down when queue is empty**
  - Simple but efficient only if controlled componen has only two states (ON/OFF)

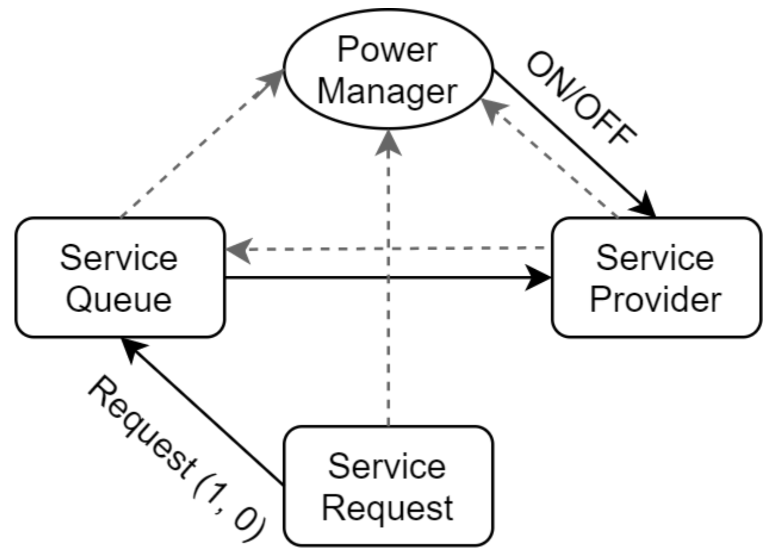
Discrete-time Dynamic Power Management model

Discrete-time Dynamic Power Management model 1/4

- **Recall Markov Decision Processes (MDP) and Policy Iteration from previous lectures**
  - Discounted rewards
  - Optimal stationary policy
- **This study builds on a Dynamic Power Management model based on Discrete-Time Markov Decision Process proposed by Paleologo et al. (1998)**
  - Significant improvements in performance and robustness compared to previous heuristic models
  - Has some shortcomings

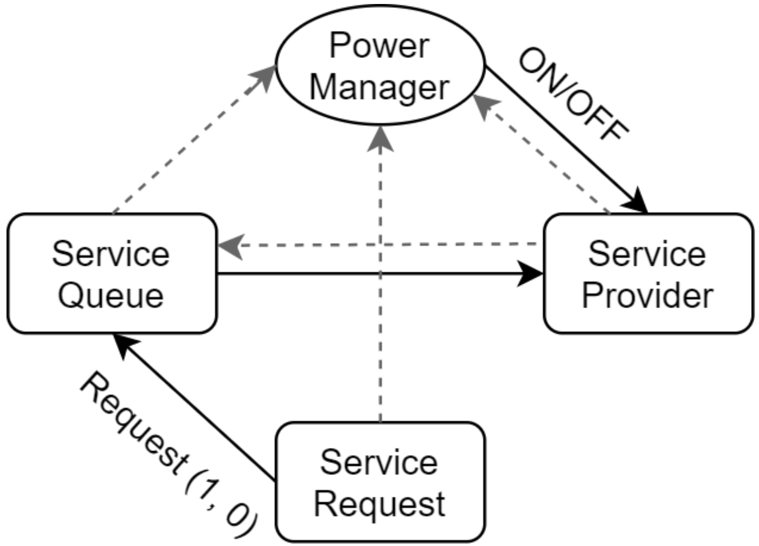
Discrete-time Dynamic Power Management model 2/4

- **Abstract visualization of the model presented by Paleologo et al. (1998)**
- **Considers only a single source of requests and max. 1 request per time period**
- **Service queue uses FIFO order**
- **If queue is full, request is lost**



Discrete-time Dynamic Power Management model 3/4

- **SR -> SQ: Fixed probability matrix**
- **SQ -> SP: Fixed probability matrix that depends on state of SP**
- **PM -> SP: Probabilities assigned depending on states of SR, SQ and SP**



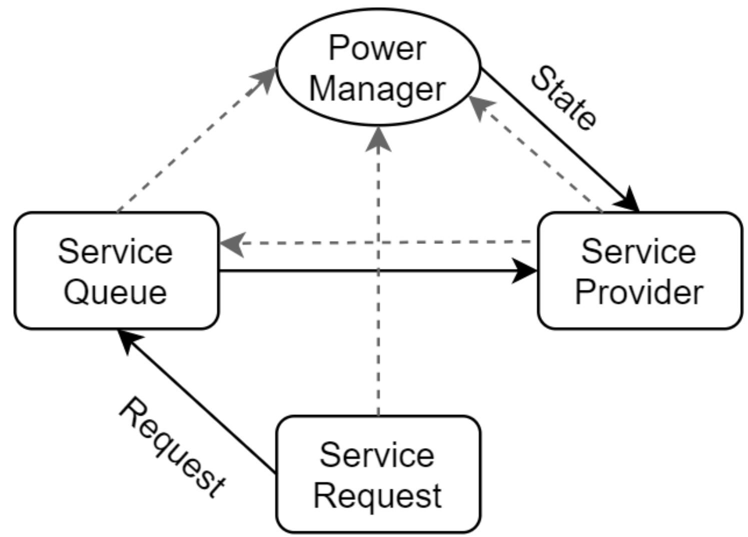
Discrete-time Dynamic Power Management model 4/4

- **Shortcomings of the model presented by Paleologo et al. (1998)**
  - Discrete-time domain limits real applications
  - Service provider only has two states (ON/OFF)
  - Transitions between the Service Queue and the Service Provider are independent which is inaccurate
  - Power Management send control signals in each time slice which leads to high signal traffic and unnecessary load on system resources
- **The Continuous-Time model helps overcome these shortcomings**

Continuous-time Dynamic Power Management model

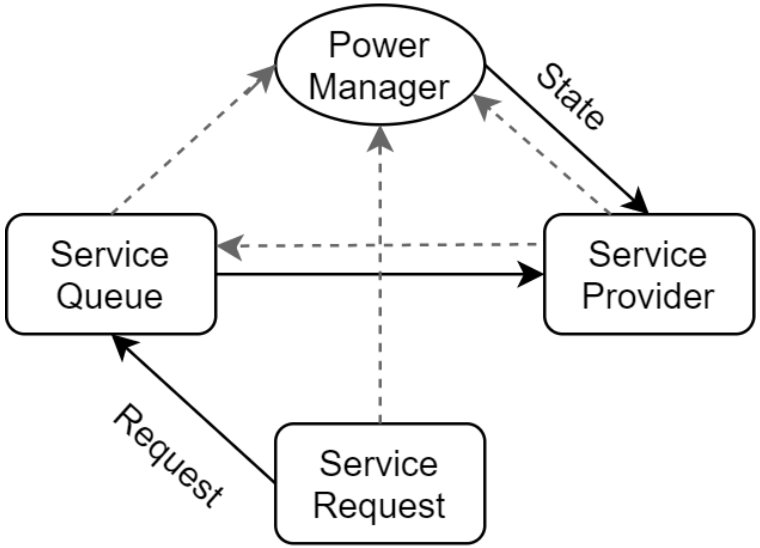
Continuous-time Dynamic Power Management model 1/2

- **Service provider can have many different states e.g. {active, waiting, sleeping}**
- **Service queue has states**
- **Service provider has state switching speeds**
- **Service provider has service rate depending on state**



Continuous-time Dynamic Power Management model 2/2

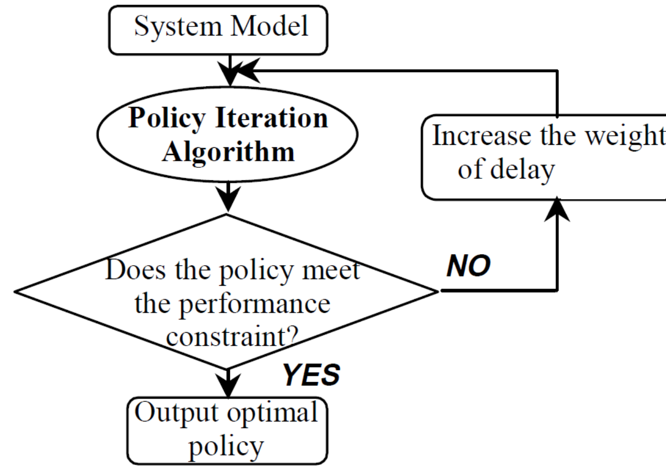
- **SR -> SQ:** ~~Fixed probability matrix~~ **Poisson distribution**
- **SQ -> SP:** ~~Fixed probability matrix~~ **Probability depends on state and service rate of SP as well as state of SQ**
- **PM -> SP:** ~~Probabilities assigned~~ **Mode switching commands depending on states of SR, SQ and SP**



Policy Iteration

- **Policy iteration is used find optimal stationary policy**

- **More efficient than the linear programming used to solve for optimal policy in study by Paleologo et al. (1998)**

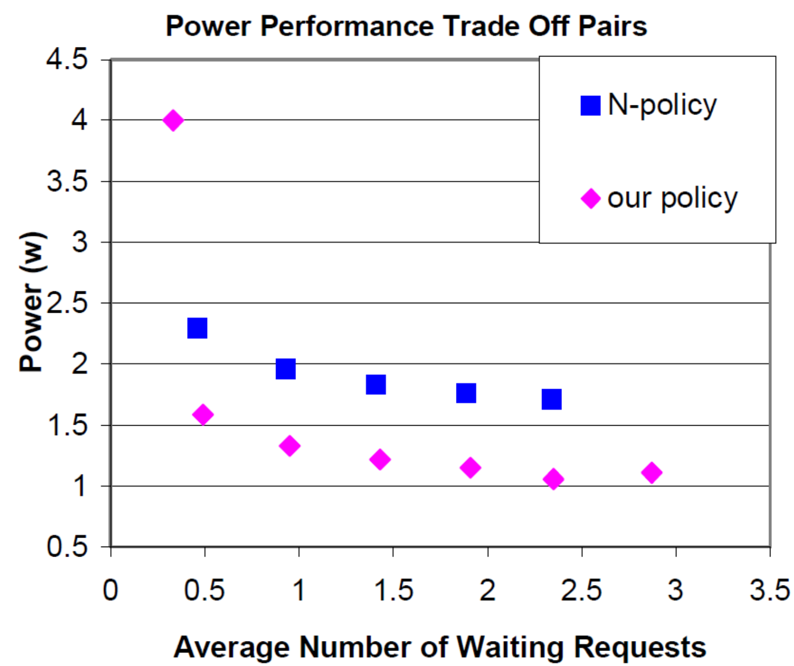


Results

Simulation results 1/3

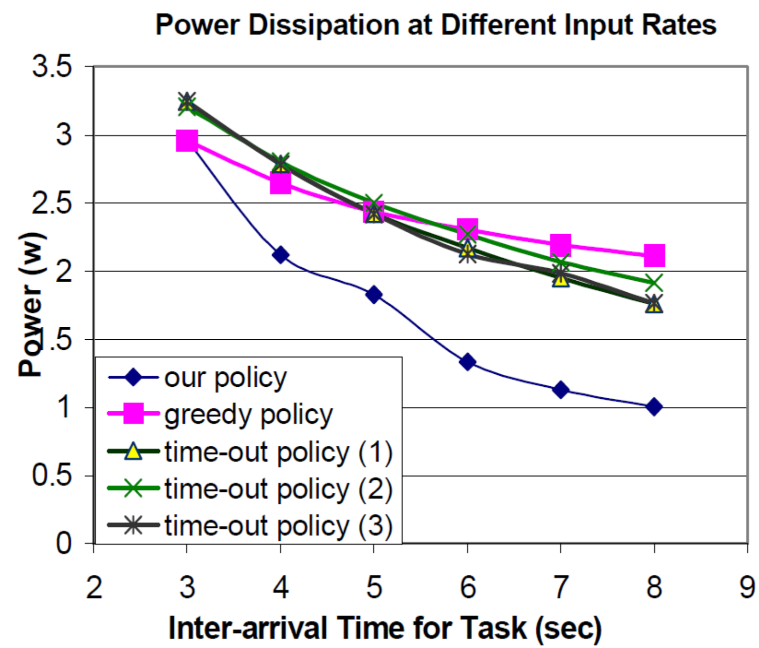
- **Results achieved by simulating real-time operation of a portable system with the implemented optimal power management policy**

- **First experiment: Presented policy vs. N-policy**
  - Shows lower power consumption in general



Simulation results 2/3

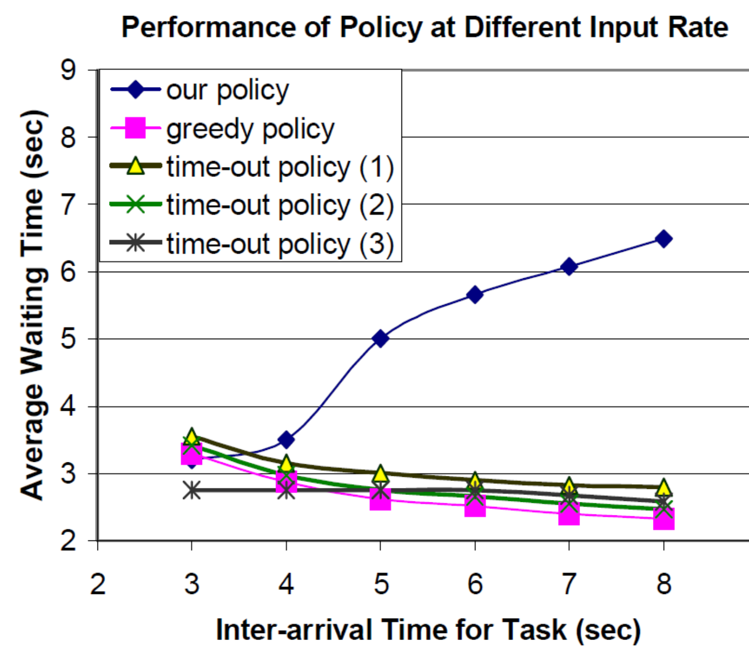
- Second experiment: Presented policy vs. various time-out policies
- Performance constraint: Average output must be less or equal to average input
- Presented model uses less power the more infrequent the task arrivals are



Simulation results 3/3

- **Performance constraint: Average output must be less or equal to average input**

- **Average waiting time increases a lot compared to time-out policies but is within performance constraint**



Summary

- **Components use energy when they are active but not in use**
- **Dynamic Power Management system needed to decrese energy dissipation**
- **A Continuous-time Dynamic Power Management model was presented based on Discrete-time model presented by Paleologo et al. (1998)**

Thank you!

References

Qiu, Qinru, and Massoud Pedram. "Dynamic power management based on continuous-time Markov decision processes." *Proceedings of the 36th annual ACM/IEEE Design Automation Conference*. 1999.

Paleologo, Giuseppe A., et al. "Policy optimization for dynamic power management." Proceedings 1998 Design and Automation Conference. 35th DAC.(Cat. No. 98CH36175). IEEE, 1998.

Homework

1. **Come up with an example that is not mentioned in this presentation or references where Dynamic Power Management is/would be useful**
2. **Briefly explain the system dynamics of your example i.e. what/how/why is it controlled**

DL 04.12.2020 at 09:00

Send your answer to: emil.nyman@aalto.fi