Dynamic Voltage and Frequency Management Based on Variable Update Intervals for Frequency Setting

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Outline

- Prior Work
- Dynamic voltage and frequency management
- Adaptive frequency scheduling based on an effective deadline
  - Effective deadline prediction
  - Frequency scheduling
  - Underload and overload conditions
- Experimental results
Prior work

- Commercial processors with DVS capability
- Burd et al, 2000, Arm8 processor core
- Nowka et al, 2002, PowerPC processor
- Flautner and Flynn, 2002, arm9 processor core
- Kihwan et al, 2003-05, StrongArm and Xscale
- ...
- Nakai et al, embedded microprocessor
Dynamic Voltage and Frequency Management

DVFM architecture [Nakai et al, JSSC-05]
Dynamic Voltage Management

Diagram depicting the process of dynamic voltage management, including a pulse generator, delay synthesizer, and encoder. The diagram shows the interaction between reference clock, detect pulse, and detect clock, leading to an encoder and delay line element, converting the delay gap to target binary data.
Dynamic Frequency Management

- Frequency scheduling based on fixed interval
  [Nakai et al, JSSC-05]
Adaptive Frequency Scheduling Based on an Effective Deadline

- **Fixed Interval**

  Voltage (mV)

  1600
  1500
  1400

  Freq. (MHz)

  135
  120
  105

  Time (ms)

  0.00 0.50 1.00 1.50 2.00 2.50 3.00

- **Adaptive Interval**
  - Lower updates
  - Near optimal frequency & voltage

Power Network Fluctuations

Adaptive Interval

Near optimal frequency & voltage

Steady:

4 up-4 down → useless changes

4 up-1 down → avg. freq
Effective Deadline

- Soft Real Time Application
- Periodic Workloads
- Arrival of the next workload

\[
E_1 = 16E_2
\]

\[
f_{\text{peak}} = 4f_{\text{eff}}
\]
Prediction of the Effective Deadline

- Arrival time of the next workload
  - Reported in terms of system cycles

- Effective Deadline
  - Update the interval
  - Compute the frequency

- Adaptive Adjustment
  - 2 consecutive increases
    - Interval_step * 2
  - 2 consecutive decreases
    - Interval_step / 2
Frequency Adjustment

- Frequency Up

- Frequency Down

- Frequency Steady
Overload and Underload Conditions

**Interval without overload detection**

**Interval with overload detection**
Results (Periodic Workload)

**Fixed Interval**

- Voltage (mV) vs. Time (ms)
- Frequency (MHz) vs. Time (ms)

**Adaptive Interval**

- Voltage (mV) vs. Time (ms)
- Frequency (MHz) vs. Time (ms)
Results

<table>
<thead>
<tr>
<th>Workload %</th>
<th>Fixed Interval</th>
<th>Adaptive Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>123</td>
<td>1580</td>
</tr>
<tr>
<td>70%</td>
<td>123</td>
<td>1585</td>
</tr>
<tr>
<td>80%</td>
<td>123</td>
<td>1585</td>
</tr>
<tr>
<td>90%</td>
<td>123</td>
<td>1585</td>
</tr>
<tr>
<td>100%</td>
<td>123</td>
<td>1580</td>
</tr>
</tbody>
</table>

![Graph showing power consumption for different workloads and intervals]
Results (Correlated Workloads)
Summary

- Presented an efficient adaptive method to perform dynamic voltage and frequency management (DVFM) for minimizing the energy consumption of microprocessor chips
  - Uses adaptive update intervals for optimal frequency and voltage scheduling
  - Rapidly tracks the workload changes so as to meet soft real-time deadlines
  - Utilizes the correlation between consecutive values of the workload for future workload prediction
- Because the frequency and voltage update rates are dynamically set based on variable update interval lengths, voltage fluctuations on the power network are minimized
- The technique leads to power savings of up to 60% for highly correlated workloads compared to DVFM systems based on fixed update intervals.