Dynamic Energy Model to handle leakage power

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Agenda

- What is the Energy Model (EM) in Linux kernel
- Relation between Energy Aware Scheduler (EAS) and EM
- Power and temperature relation in recent SoCs
- Runtime adjustable EM
- Other use cases
What is the Energy Model (EM) in Linux kernel

- A constant array of frequency, power and cost tuples (setup during boot)
- Contains 'cost' (based on power) for EAS to speed up calculation
- Decision/information source for EAS to make task placement decisions
- There is one EM for each Performance Domain

<table>
<thead>
<tr>
<th>Frequency [kHz]</th>
<th>Power [uW]</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>500000</td>
<td>79613</td>
<td>446151</td>
</tr>
<tr>
<td>851000</td>
<td>148208</td>
<td>487989</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2704000</td>
<td>1801528</td>
<td>1866820</td>
</tr>
<tr>
<td>2802000</td>
<td>2158976</td>
<td>2158976</td>
</tr>
</tbody>
</table>
Relation between Energy Aware Scheduler (EAS) and EM

- EAS tries to minimize energy by looking at all possible Performance Domains (Big CPUs, Medium (Mid) CPUs, Little CPUs) when selecting the CPU for a woken-up task.
- EAS uses EM information for comparisons.
Power and temperature relation in recent SoCs

- Total power: dynamic + static power
- The static power (leakage) increases with temperature
- SoC has different types of CPUs, which are built with different goals: performance or power efficiency
- Performance cores (Big CPU) leak more
- Performance cores are more affected by the temperature increase than efficient cores (Mid CPU)
Power and temperature relation in recent SoCs

- Temperature of the SoC can be increased by adjacent devices (e.g. GPU)
  - e.g. increases the CPUs temperature by +20..30degC more than their normal temperature at the same frequency

- Power vs. Performance curve of a CPU can "go up"
  - Big CPU's curve would go up a bit more
Power and temperature relation in recent SoCs

- Big CPU and Mid CPU curves position is different, therefore EAS decision should also be different.
Power and temperature relation in recent SoCs

- Example power plots from a real phone (2021)
- CPU's temperature +20degC vs. normal due to GPU heat
- Big CPU Power increase
  - +15 ... 18.5%
- Mid CPU Power increase
  - +5 ... 8%

![Diagram showing total power and extra static power due to higher temperature](image)
Runtime adjustable EM

- Runtime EM change requested by a kernel module
  - No sysfs interface for a user-space
  - No thermal framework changes

- EM main data structure is allocated by the EM framework
  - EM is the memory owner (task scheduler requirement)

- New 'power' values are populated by the caller (kernel module)

- New EM data is used by the EAS during task placement (after RCU re-assignment for the pointer)
Other use cases

- allow to provide (after boot) the total power values for each frequency not limited to any formula or DT data
- allow to provide power values proper for a given SoC manufactured with different binning and read from FW or kernel module
- change EM at runtime for a specific workload on screen, which is utilizing HW resources differently (Gaming, video recording, web browsing)
Thank You
Danke
Gracias
Grazie
谢谢
ありがとう
ありがとう
Asante
Merci
감사합니다
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Kiitos
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