Power Management for Mobile CPU
DVFS for Embedded Linux

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What is Power?

• General Terms
  • Ability to do something
    - Collins Cobuild
  • In physics, power is the rate at which work is performed or energy is converted.
    - wikipedia.org
What is Power?

• The energy consumed by electric components
Why is Power Important?

- More need for power
  - More components into a mobile equipment
  - More powerful functions need more power

- The longer, the better
CPU Power Consumption

- Why CPU?
  - It's the most important for computer systems
CPU Power Consumption

- Why CPU?
  - It's known as one of the most power-consuming devices in computers

<table>
<thead>
<tr>
<th></th>
<th>Full</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>224W</td>
<td>143W</td>
</tr>
<tr>
<td>Server</td>
<td>133W</td>
<td>107W</td>
</tr>
</tbody>
</table>
Processors are Evolving

We need something COOL

Unit: W

wikipedia.org
• Dynamic Voltage & Frequency Scaling
  • Allowing devices to dynamically change their voltage and frequency level
  • To utilize varying performance needs

\[ P = C \cdot V^2 \cdot f \]

\[ f \propto V \]
Examples of DVFS

- Enhanced Intel Speedstep Technology
  - Intel
- Cool'n'Quiet
  - AMD desktop, server chips
- PowerNow!
  - AMD mobile chips
Is It Important?

**Lower Power Capabilities**

- **Enhanced Intel® SpeedStep® Technology**
  Allows for better match of performance to application demand.

- **Low Thermal Design Power**
  Lower thermal design power enables thinner, lighter MID devices as it reduces the cooling requirements. This enables MID devices to be pocketable.

- **Enhanced Deeper Sleep (C4)**
  Saves power by flushing cache data to system
Is It Important?

Samsung S3C6410 Key Features

- ARM1176ZJF 533/667MHz VFP/SIMD
- 65nm low-power process
- **DVFS power management**
- Dedicated x32 mDDR/DDR, x32 mSDR/SDR
- WVGA or higher display resolution
- Hard-wired 3D GFX accelerator
Deep into the Mobile CPU
CPU Power Consumption

• CPU is one of ...
  • The most power-consuming devices in the desktop computers
  • The least power-consuming devices in the mobile devices
Anorexia of Mobile CPU

How about Server?

- Xeon Server
  - Intel Xeon E5520 Quadcore 2.26GHz x 2
  - Total 8 cores with SMT
  - Can save 59W of total 225W

![CPU Usage Diagrams]

ETRI  Embedded Software Research Department
How about Laptop?

- **Lenovo X60**
  - Intel Core Duo T2400 1.83 GHz
  - 2 cores
  - Can save 16W of total 56W
How about Mobile?

- Kontron nanoETXexpress-SP
  - Intel Atom Z530 1.6GHz
  - Unicore with 2 SMT
  - Can save 0.3W of total 12W
How about Mobile?

- Meritech SMDK6410
- Samsung S3C6410 532MHz
- ARM 11-based

Unit: W

- Higher Frequency Mode (532MHz)
- Lower Frequency Mode (133MHz)

- S3C6410
- 4.8" LCD
- Others
Power Characteristics

- Xeon
- Opteron
- Atom

Normalized idle power consumption

Performance Step

Normalized power
Power Characteristics

![Graph showing power characteristics of different processors over performance steps.](image-url)
Other Devices

• Network interface card control
  • 1 Gbps NIC is commonly found
  • Modern NIC looks like a small computer
• nanoETXexpress-SP
  • Broadcom BCM 5787
  • 10/100/1000 Mbps
  • High-speed RISC with 32KB cache
Broadcom BCM 5787
NIC Control

- Network Bandwidth Scaling
  - Power increases with higher bandwidth transmissions
  - Not all moments actually need gigabit speeds

![Graph showing network power consumption vs. bandwidth](graph.png)

**System Power Consumption**

- Unit: W
- 10 Mbps
- 100 Mbps
- 1 Gbps
NIC Control

- Speed recognition
  
  ethtool eth0

- Adjustment
  
  ethtool -s eth0 autoneg off speed 10
Implications

• DVFS is designed to reduce CPU power consumption
• Mobile CPU requires very little power
  • With powerful capability

• Mobile DVFS could be ineffective or even harmful for energy efficiency
Implications

• Different CPU has different power characteristics
• Peripherals are really important

• Need for different strategies specialized for each mobile device
Thank You
Extra Slides
What can I do?

• What?
  • Battery Consumers
    • Display
    • CPU
    • Board
    • Peripheral Devices, etc.
What can I do?

• Who?
  • Hardware
    • Low-powered hardware
    • Thermal design
  • Software
    • OS
    • Middleware
    • Application
  • User
What can I do?

• When?
What can I do?

• How?
  • Hardware takes orders from software
    • Turning off
    • Slowing down
DVFS Algorithms

- Interval-based Algorithm
- Task-based Algorithm
Power Characteristics

![Graph showing power characteristics for different processors. The graph includes three lines representing Xeon, Opteron, and Atom, with performance steps on the x-axis and frequency (GHz) on the y-axis.](graph.png)
Environment

- Xeon Dual-Processor Server
  - Intel Xeon E5520 QuadCore 2.26GHz
- Lenovo X60
  - Intel Core Duo T2400 1.83 GHz
- Kontron nanoETXexpress-SP
  - Intel Atom Z530 1.6GHz
- Samsung SMDK6410
  - S3C6410 532MHz
How to Measure

- National Instrument DMM

<table>
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<tr>
<th>Equipment</th>
<th>Power Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xeon Server</td>
<td>AC Power 220V</td>
</tr>
<tr>
<td>Lenovo Laptop</td>
<td>AC Power 220V</td>
</tr>
<tr>
<td>Atom Board</td>
<td>DC Power 12V</td>
</tr>
<tr>
<td>6410 Board</td>
<td>DC Power 5V</td>
</tr>
</tbody>
</table>
References

• LessWatts
  • http://www.lesswatts.org/
• Wikipedia
  • http://www.wikipedia.org/