Software Strategies for Portable Computer Energy Management

• Paper by Jacob R. Lorch and Alan J. Smith at the University of California
• In mobile computing, power consumption is an obvious concern
  – Battery life is not improving at the same rate as computational power.
• Computer hardware often has built in power saving features.
  – Must have software that takes advantage of the power saving modes available in hardware, and minimizes power use while making the experience as pleasant as possible for the user.
  – Three main strategy types for energy conservation:
    • Transition strategy
    • Load Change strategy
    • Adaptation strategy
Transition

• Transition strategy: The strategy used for when you switch to a low power mode.
• Need to balance performance and the needs of the rest of the system
  – Other components still use power when waiting for component to return to an “on” state
  – Don’t want to harm the users perception of the performance.
Inactivity Threshold

• Assumes the longer the period on inactivity has been, the more likely that there will be a long period of inactivity following it.
• Uses this assumption to put the device in a low power mode.
  – Example: Screen savers
Load Balancing

- Load Balancing Strategy: Changing how a device operates so that it uses less power
  - Examples: Caching data from a hard drive so that the hard drive motor can be shut down more often
  - Another Example: Storing data locally so that wireless networking card can be used less often, broadcasting common data so that the portable device does not have to broadcast a request.
Adaptation Strategy

• Adaptation Strategy: Using software to allow novel, power saving use of components
  – Example: Using a broadcast disc so that a mobile device does not need to have its own permanent storage.
Energy Considerations

- Need to balance the energy concerns of the entire system.
  - If other components must stay on longer to allow one component to be put in a low power state, it could cost more power.
  - Different components take different amounts of power.
    - Can only save as much power as a component uses.
    - Saving power with some components gives a greater gain than others.
<table>
<thead>
<tr>
<th>Component</th>
<th>Hyp. 386</th>
<th>Duo 230</th>
<th>Duo 270c</th>
<th>Duo 280c</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>4%</td>
<td>17%</td>
<td>9%</td>
<td>25%</td>
<td>14%</td>
</tr>
<tr>
<td>Hard disk</td>
<td>12%</td>
<td>9%</td>
<td>4%</td>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>Backlight</td>
<td>17%</td>
<td>25%</td>
<td>26%</td>
<td>25%</td>
<td>23%</td>
</tr>
<tr>
<td>Display</td>
<td>4%</td>
<td>4%</td>
<td>17%</td>
<td>10%</td>
<td>9%</td>
</tr>
<tr>
<td>Modem</td>
<td>n/a</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>FPU</td>
<td>1%</td>
<td>n/a</td>
<td>3%</td>
<td>n/a</td>
<td>2%</td>
</tr>
<tr>
<td>Video</td>
<td>26%</td>
<td>8%</td>
<td>10%</td>
<td>6%</td>
<td>13%</td>
</tr>
<tr>
<td>Memory</td>
<td>3%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Other</td>
<td>33%</td>
<td>35%</td>
<td>28%</td>
<td>22%</td>
<td>30%</td>
</tr>
<tr>
<td>Total</td>
<td>6 W</td>
<td>5 W</td>
<td>4 W</td>
<td>8 W</td>
<td>6 W</td>
</tr>
</tbody>
</table>

*Table 2. For various portable computers, percentage of total power used by each component when power-saving techniques are used [4, 5].*
Hard Drives

• Primary power saving mode is to stop the rotation of the hard disk platter
  – Best power saving with frequent stops
  – Problems:
    • Restarting the hard drive causes an annoying wait as the hard drive begins spinning again
    • Frequently stopping a hard drive increases the wear on the hard drive, causing the hard drive to last a much shorter time.
# Hard Drive Power Consumption

<table>
<thead>
<tr>
<th>Hard disk</th>
<th>Maxtor Mobile Max 251350</th>
<th>Road Warrior 815 Mbyte Slimline</th>
<th>Toshiba MK2720</th>
<th>WD Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>1.35 Gbyte</td>
<td>815 Mbyte</td>
<td>1.35 Gbyte</td>
<td>1.0 Gbyte</td>
</tr>
<tr>
<td>Idle power</td>
<td>0.9 W</td>
<td>0.9 W</td>
<td>1.4 W</td>
<td>0.95 W</td>
</tr>
<tr>
<td>Standby power</td>
<td>0.23 W</td>
<td>0.5 W</td>
<td>0.35 W</td>
<td>0.20 W</td>
</tr>
<tr>
<td>Sleep power</td>
<td>0.025 W</td>
<td>0.15 W</td>
<td>0.15 W</td>
<td>0.095 W</td>
</tr>
<tr>
<td>Spin-up time</td>
<td>1 s</td>
<td>5 s</td>
<td>5 s</td>
<td>6 s</td>
</tr>
<tr>
<td>Spin-up energy</td>
<td>4.4 J</td>
<td>17.5 J</td>
<td>19.5 J</td>
<td>30 J</td>
</tr>
</tbody>
</table>

*Table 3. Characteristics of various hard disks [12–15].*
Hard Drive Power Saving Strategies

• Most common approach: Hard drive spins down after fixed inactivity period
  – Simple to implement
• Another strategy is to keep track of how effective various intervals have been.
  – Attempt to use intervals that have been successful before
• Strategy 3: Weight strategy to strategies that would be effective for recent data
  – Assumes data use changes over time
More Hard Drive Strategies

- Another strategy: Use a random interval
  - Good worse case performance
  - Other algorithms can defeat it in the average case.
- Some attempts have been made to predict when hard drive accesses will be made.
  - In theory could result in performance improvement over using an inactivity interval.
  - None have been made to work well in a real life application as of this paper.
Alternatives to Hard Drives

• Flash memory can be used instead of a hard drive.
  – Positives:
    • Fast in retrieving data
    • Lower power usage
  – Downside:
    • More expensive than a hard drive
    • Writes take a longer amount of time.
    • Can only make a limited number of writes.
Wireless Networking as Hard Drive Alternative

- Can use Network as a Disk, broadcasting necessary data
  - Positives:
    - Low power usage
    - Requires less hardware for the mobile device
  - Negatives:
    - Much slower than a hard drive
    - Susceptible to network failures
    - Need to be in range of a central server.
Processor Power Savings

• Processor uses much less power if it gets turned off.
  – Modern operating systems have the ability to turn off the processor when all the processes are blocked.
  – Operating System can be tuned to prevent processes from busy waiting.
Regulate Processor Speed

• If it corresponds to being able to reduce core voltage, reducing processor clock speed can lead to power savings
  – Frequent changes in speed can cost more power than a higher overall clock rate.
  – Need to change gradually change speed.
    • React too slowly and the device can have trouble dealing with peak workloads
    • React too quickly and power savings are lost.
Networking Devices

• Can save power using Network devices in several ways.
  – Can enter sleep mode to save power
  • Can enable device to enter sleep mode more often by reducing network usage, such as compressing TCP packets
  • Devices can be put into listen mode more often by having a central server broadcast frequently used data such as in broadcast discs.
More Networking Information

- Can reduce power by reducing broadcast power
  - Advantages
    - Uses less power
    - Improves the ability of other devices to broadcast
  - Disadvantages
    - Increases bit error rate
      - May require more error bits
      - May require it to transmit more often
Strategies to Lower Broadcast Power

• Can communicate with other devices about the observed quality of service and level of interference
  – Use information to adjust broadcast power

• Device can also make adjustments based on its observed interference and adjust power accordingly
  – Can provide reasonable efficiency while simpler to implement.
Display Power Savings

- Display devices are among the most expensive devices power wise.
- Most common power saving strategy is to turn off the monitor.
  - Can not turn it off too quickly or it can be annoying to the user
- Other strategies include lowering the refresh rate, dimming the display, or switching to black and white
Overall Strategies

• Can also implement power savings system wide.
  – Advantages:
    • Simple to implement
    • More tolerable to the user
  – Disadvantages:
    • Save power less efficiently than component by component strategies.