Fine-Grained Application Analysis for Energy-Aware Computing

This white paper describes how software “idle” behavior can have a negative impact on battery life. It also explains how to find the root cause of an application behavior that impacts battery life and the steps necessary to mitigate it. This document has been written for ISVs, OEMs, ODMs, the technical press, and technical enthusiasts.

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The Importance of Battery Life
Software plays an important role in battery life. The OS, firmware, drivers, and all small components are typically optimized to give better performance and energy efficiency. As the notebook PC (and smaller form factor devices, including tablets and smart phones) become pervasive compute platforms, battery life is becoming increasingly important, particularly with regard to standby or idle time.

In addition, as hardware power states become more sensitive, software must be well behaved at idle so it doesn’t needlessly wake components, which would limit battery life. Several case studies presented here show how software “idle” behavior can have a negative impact in this area on Windows®-based systems.

Tools Introduction
We used four easily available developer tools to mitigate the behavior of the application, as described in this section.

Intel® Power Checker
Intel® Power Checker can quickly assess idle power efficiency, platform timer tick, and power-aware behavior for applications that run on mobile platforms using the Intel® Core™ processor family or Intel® Atom™ processor. It is typically used as the first step of power analysis. It can also be used as cloud tool for developers to track power efficiency during the development cycle. Intel Power Checker also helps ISVs and OEMs create customized software assessment reports on power efficiency.

Powercfg to view and modify power plans and settings such as standby time, wake timer, and power schemes.

Powercfg-energy (with energy option) analyzes common energy-efficiency and battery life problems, such as platform timer-tick setting changes, changes to timers by application processes or DLLs, processor utilization per process, and power-management settings in hardware and OSs. Administrator permission is required to run Windows Powercfg.


Battery Life Analyzer (BLA)
This simple tool written by Intel monitors various software and hardware activities that affect battery life on Windows-based systems. BLA supports Intel® 5 Series Mobile Chipset, the Intel® Core™ i7, Core™ i5, and Core™ i3 processors, and 2nd generation Intel® Core™ i7, Core™ i5, and Core™ i3 processors. BLA can identify misbehaving drivers, processes, and...
The main focus of this paper is to accurately characterize the battery life impact of applications during their “idle” state. In this paper, application “idle” state is defined as a state where the application is launched (login is done if needed for connected applications). For applications that require network connectivity, power measurement is done while connected to the Internet. For the experiment, we randomly selected applications in daily use by typical industry users from the following categories:

- Media playback applications
- Messenger/chat applications
- Browser applications
- Anti-virus applications

During the first phase of our analysis, we selected top applications in the current consumer market from different categories and measured total power above baseline using the Fluke NetDAQ instrument. Figure 1 shows baseline “system idle” total platform power with a fresh Windows install (including drivers).

Comparing Figure 2, which was taken from a presentation given at the Intel Developer Forum 2010, San Francisco, we can interpret that the media application decreases system battery life at “idle” by approximately 75 minutes while not “active,” a clearly significant impact.

This paper studies why “idle” software impacts battery life and how small changes by developers can extend the battery life of target systems. From Figure 1 we selected for deeper analysis the worst performing application in terms of power usage at “idle.”

To perform the analysis, we downloaded a full version of the media application onto a system with a clean Windows 7 Ultimate install (including drivers).
install. We simulated a real-world scenario by opening the application in default windowed mode and let it run for 10 to 15 minutes. We collected total platform power utilization using the Fluke NetDAQ system for 10 minutes. Figure 3 shows the total platform power consumption over time between “clean system idle” and “media application idle.”

An application at “idle” must not act as an “active” workload; it must increase power usage only minimally, relative to system idle. To identify the reason for the increase in power usage, we used tools for root-cause analysis, as described below.

Deep Analysis with Intel Power Checker

This simple application measures high level power usage by idle and active applications. The following steps provide high-level information from Intel Power Checker, as illustrated in Figure 4:

1. Enter name of application (e.g., Media Playback)
2. Select “Measure Power Awareness”
3. Select “Generate Report File”
4. Select “Launch Application”

Once the process is completed, Intel Power Checker generates a report showing the change in C-state, timer tick, and other measurements between baseline and application workload. The results in Figure 5 show that this media application set timer tick to 1.25msec from 15.6 msec.

Figure 2. Intel Developer Forum reference battery life.

Figure 3. System "idle" platform power versus media application "idle" power.

Figure 4. Intel® Power Checker initiation screen.
Deep Analysis with Battery Life Analyzer (BLA)
BLA is a very simple, lightweight tool written by Intel to find high-level issues related to hardware and software. BLA indicates misbehaving drivers, processes, and hardware that prevent the platform from entering low-power states.

We collected C-state data with BLA in “system idle” and “application idle” periods. Figure 6 shows the impact of the “idle” application on C-state. When more time is spent in deeper C-states, more power is saved, but more time is required for the processor to return to its full-power operating state. For more information on C-state, see http://origin-software.intel.com/en-us/blogs/2008/03/27/update-c-states-c-states-and-even-more-c-states/.

Deep Analysis with Windows Powercfg
C-state data from BLA indicated that processor wakeup frequently causes more C-state transitions. To analyze the cause of C-state package residency, we used the Windows Powercfg command-line utility to collect a 60-second trace. Figure 7 shows the output of the Powercfg tool.

In Figure 7, the Powercfg utility shows that the media application is changing timer tick resolution to 1.25 msec from the system default of 15.6 msec, even at “idle” when there is no activity. Changing the timer tick to high granularity causes more frequent wake-ups; a timer tick setting of 15.6 msec creates 64 periodic wake-ups per second, and a 1.25 msec setting generates 800 periodic calls per second. That figure represents 10 times more calls per second than at “idle.”

To check the significance of timer tick settings on actual power usage, we changed the timer tick setting to 15.6 msec at “idle.” Figure 9 shows the change in power numbers. Setting the timer tick back to the system default creates significant gains in power savings. Average power increases for “application” idle decreases from 44 percent (default timer tick) to 16 percent (timer tick setting of 15.6).

Next we drilled down to perform more detailed analysis and to look at other issues that cause power consumption, using BLA and Windows Performance Analyzer to find the root causes. BLA gives details of periodic activity including timer tick when the application is running idle, as shown in Table 1.
change in timer tick from Windows default settings, and analysis of C-state package residency and various driver interrupts. For the next level of analysis, we use Windows Performance Analyzer (xperf) to determine whether synchronization API usage causes interrupts.

Deep Analysis with Windows Performance Analyzer
We downloaded Windows Performance Analyzer and collected a CSwitches trace for 180 seconds on a media "idle" application using the following command line script:

```
run_xperf.cmd:
  xperf –on diageasy
  call wait 120
  xperf –d NewTrace.etl
  wait.cmd
@choice /D y /T %1% >NUL
```

**Platform Timer Resolution: Platform Timer Resolution**
The default platform timer resolution is 15.6ms (15625000ns) and should be used whenever the system is idle. If the timer resolution is increased, processor power management technologies may not be effective. The timer resolution may be increased due to multimedia playback or graphical animations.

- Current Timer Resolution (100ns units) **12500**
- Maximum Timer Period (100ns) **156001**

**Platform Timer Resolution: Outstanding Timer Request**
A program or service has requested a time resolution smaller than the platform maximum timer resolution.

- Requested Period **20000**
- Requesting Process ID **2792**
- Requesting Process Path `\Device\HarddiskVolume2\Program Files (x86)\MediaPlayer\Player.exe`

**Platform Timer Resolution: Timer Request Stack**
The stack of modules responsible for the lowest platform time setting in this process.

- Requested Period **20000**
- Requesting Process ID **2792**
- Requesting Process Path `\Device\HarddiskVolume2\Program Files (x86)\MediaPlayer\Player.exe`
- Calling Module Stack `\Device\HarddiskVolume2\Windows\SysWOW64\ntdll.dll`
  `\Device\HarddiskVolume2\Windows\SysWOW64\winmm.dll`
  `\Device\HarddiskVolume2\Windows\Program Files (x86)\MediaPlayer\Media.dll`

**Figure 7.** Windows® Powercfg output.

**Figure 8.** System “Idle” versus media idle after overriding timer tick.
This script collects the stack walk Windows trace for 180 seconds and outputs the file newtttrace.etl. We opened that file in xperf and resolved the symbols by adding symbol path. Note that it is important to set the symbol paths before enabling “Load Symbols” and before opening a summary view. You can also modify the _NT_SYMBOL_PATH and _NT_SYMCACHE_PATH environment variables to make these changes permanent. The standard symbol path that includes Microsoft’s symbol server configuration is as follows:

```plaintext
_NT_SYMCACHE_PATH:C:\symbols
_NT_SYMBOL_PATH:

srv*c:\symbols*http://msdl.microsoft.com/download/symbols;
```

To add symbols from your own builds, add C:\apps\directory\bin to _NT_SYMBOL_PATH. As with all Windows paths, the symbol path uses semicolons (;) as separators. Figure 10 shows the high level view using xperf for the media playback application.

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**Table 1. Periodic activity during idle application running time.**

<table>
<thead>
<tr>
<th>IMAGE NAME</th>
<th>SYSTEM IDLE CALLS/SEC</th>
<th>PLAYBACK IDLE CALLS/SEC</th>
<th>REASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>hal.dll</td>
<td>64.1</td>
<td>800</td>
<td>Due to timer tick setting change</td>
</tr>
<tr>
<td>dxgkrnl.sys</td>
<td>1</td>
<td>290</td>
<td>Due to graphics activity at “idle”</td>
</tr>
<tr>
<td>USBPORT.SYS</td>
<td>10</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>ataPort.SYS</td>
<td>3.0</td>
<td>4.2</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Application threshold at idle impact on power due to interrupts.**

<table>
<thead>
<tr>
<th>DRIVER</th>
<th>INTERRUPT SOURCE</th>
<th>TYPICAL INTERRUPTS/SEC @ IDLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACPI.sys</td>
<td>Motherboard</td>
<td>&lt;1</td>
</tr>
<tr>
<td>dxgkrnl.sys</td>
<td>Graphics</td>
<td>&lt;10 (depends on activity)</td>
</tr>
<tr>
<td>hal.dll</td>
<td>Timer tick</td>
<td>64</td>
</tr>
<tr>
<td>i8042prt.sys</td>
<td>PS/2 KB/Mouse</td>
<td>0</td>
</tr>
<tr>
<td>msahci.sys</td>
<td>SATA (HDD/DVD)</td>
<td>&lt;10 (depends on activity)</td>
</tr>
<tr>
<td>ndis.sys</td>
<td>Network (GbE/Wi-Fi)</td>
<td>&lt;40 (Wi-Fi, associated, no traffic)</td>
</tr>
<tr>
<td>USBPORT.SYS</td>
<td>USB (UHCI/ehci)</td>
<td>0</td>
</tr>
</tbody>
</table>

---

Figure 9. Application idle (1msec TT) versus application idle (15.6 TT).

Figure 10. High-level view for Windows xperf.
The next step is to drill down to the issues that are causing frequent processor wake-ups. To do so, right-click CPU Scheduling and click Select View. Right-click again and click to view the summary table. Remember to have Load Symbols selected from the menu.

Figure 11 shows context switches occurring at “idle” when no audio or video is playing. One of the main causes of these context switches is timer tick activity. Another reason was the media application calling a sleep function every 10 msec, as shown in Figure 12.

Visualizing the code, we see that this media application had several sleep functions in a loop:

```c
for(;;){
  if(, check some condition) {
    do something...
    SetEvent()
  }
  Sleep(10); //wait for next tick
}
```

A better implementation would be the following:

```c
for(;;) { WaitForSingleObject();
  .... Do something #1 ...
}
for(;;) { WaitForSingleObject();
  .... Do something #2 ...
}
```

Figure 11. Context Switches view from xperf.

Figure 12. Sleep function calls from a media application.
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Summary
Software has a huge impact on "idle" and "active" battery life of mobile systems. Small changes in code can help bring the power level of "application idle" closer to that of "platform idle." Setting timer tick to a finer granularity, even at "idle," where performance and quality is not a concern, is not a good programming practice. Use of Windows Coalescing APIs, event polling, and keeping default timer tick settings can help extend the battery life of mobile systems.

References
Intel® Power Checker: http://www.intel.com/partner/satppe
Microsoft Timer Coalescing: http://download.microsoft.com/download/9/C/5/9C5B2167-8017-4B8E-9FDE-DS99BAC8184A/TimerCoal.docx

About the Author
Manuj Sabharwal is a software engineer in the Software Solutions Group at Intel. Manuj has been involved in exploring power enhancement opportunities for idle and active software workloads. He has significant research experience in power efficiency and has delivered tutorials and technical sessions in the industry. He also works on enabling client platforms through software optimization techniques.

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References