Agenda

Delivering great battery life
Delivering great performance and experiences
Battery Life
Battery life design considerations

Who is your target audience?

What device and price point are you targeting?

Starts with hardware choices followed by firmware, operating system, drivers then apps

Same design practice and process applicable to any battery powered device
Power Modeling

Build your power budget prior to locking down the BOM

Leverage the energy consumption data on component datasheets to estimate total power needs

<table>
<thead>
<tr>
<th>Component</th>
<th>Component Selection</th>
<th>Screen On Idle</th>
<th>Standby</th>
<th>Video Playback</th>
<th>Web browsing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform chipset</td>
<td>IHV Part #A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Display size and resolution</td>
<td>IHV Part #B</td>
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<tr>
<td>Touch controller</td>
<td>IHV Part #C</td>
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<tr>
<td>Memory type and Size</td>
<td>IHV Part #D</td>
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<tr>
<td>Storage</td>
<td>IHV Part #E</td>
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<tr>
<td>Wi-Fi</td>
<td>IHV Part #F</td>
<td></td>
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<tr>
<td>Mobile broadband</td>
<td>IHV Part #G</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensors</td>
<td>IHV Part #H</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMIC, battery controller</td>
<td>IHV Part #I</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Other parts</td>
<td>IHV Part #J,K</td>
<td></td>
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<tr>
<td>Total Avg Power (mW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Battery Capacity (Whr)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Est. Runtime with battery (hr)</td>
<td></td>
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</tr>
</tbody>
</table>
Energy efficient coding guidance

Processor/SoC
Do not change the System Timer Resolution (leave @ 15.6ms)
Use event-driven designs instead of periodic designs like polling, spinning, and endless loops
Use coalescable timers with periodicities that are multiples of 1s
Remove printf debug statements from retail binaries
Schedule maintenance tasks using Automatic Maintenance

Disk
Avoid periodic disk activity like logging

Apps
Stop rendering UI updates when the display is off
Stop animations when the user is not interacting with the device

Network Updates
Apps should leverage Windows Notification Service (Push)
Delivering great battery life agenda

Modern Standby

Energy Estimation Engine (E3)

Other power optimization features

Scenarios (browsing, full screen video playback, productivity, casual gaming)

Tools
Modern Standby (MS) Overview
The first iteration of Modern Standby was called Connected Standby and first shipped in Windows 8. Modern Standby expands the Windows 8 Connected Standby concept, allowing more flexibility in component selection.

* S4 is only supported on X86/X64

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Supported Sleep States</th>
<th>Devices</th>
<th>Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 7</td>
<td>S3 + S4</td>
<td>![Device Images]</td>
<td>X86/X64</td>
</tr>
<tr>
<td>Windows 8</td>
<td>S3 + S4</td>
<td>![Device Images]</td>
<td>X86/X64/ARM</td>
</tr>
<tr>
<td>Windows 10</td>
<td>S3 + S4</td>
<td>![Device Images]</td>
<td>X86/X64</td>
</tr>
</tbody>
</table>

Connected Standby + S4*
Modern Standby is a Windows feature that is automatically enabled if the device meets all the hardware (new low power state) and firmware requirements.

What is new about this **low power state** is unlike S3 where the device is not active, a modern standby device remains active when the screen is off but in a much lower power state than S3 to accept phone calls, receive messages and alert you.

Like Windows 8, Windows 10 continues to support two power models (S3 & Modern Standby).
Connected vs. Disconnected Standby

**Connected Standby**
- System is connected to network and network triggers device to wake
- Enables end users to stay connected to email, social networks, VOIP, and receive push notifications in standby
- Recommended design for premium devices

**Disconnected Standby**
- Limited network connectivity
- Enables fast wake sources that are not available on S3 devices
- Continue listening to music and casting after entering standby
- Recommended for mainstream devices
The Desktop Activity Moderator (DAM) is a run-time Windows component only active on Modern Standby devices. DAM pauses all desktop applications and throttles runtime of third-party system services when the device is in standby. Whenever the screen turns off, the device is in Modern Standby state which activates DAM.
Modern Standby devices

- Qualcomm SoC
- Intel Bay Trail and Cherry Trail
- Intel Haswell and Skylake

More silicon to come that support Modern Standby. Contact your Silicon provider for information.
Additional Modern Standby Benefits
# Modern Standby benefits

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>S3</th>
<th>DS</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wake Sources</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wake on user presence with proximity sensor</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Performance &amp; Security</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast Resume (Instant On)</td>
<td></td>
<td>☒️</td>
<td>✔️</td>
</tr>
<tr>
<td>Device Encryption</td>
<td></td>
<td>☒️</td>
<td>✔️</td>
</tr>
<tr>
<td>Windows is up-to-date</td>
<td></td>
<td>☒️</td>
<td>☒️</td>
</tr>
<tr>
<td><strong>Entertainment &amp; Staying Connected</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninterrupted low power Audio Playback</td>
<td></td>
<td>☒️</td>
<td>✔️</td>
</tr>
<tr>
<td>Receive Skype Calls &amp; IM’s</td>
<td></td>
<td>☒️</td>
<td>☒️</td>
</tr>
<tr>
<td>Email &amp; Calendar are up-to-date</td>
<td></td>
<td>☒️</td>
<td>☒️</td>
</tr>
<tr>
<td>Social media and other push notifications</td>
<td></td>
<td>☒️</td>
<td>☒️</td>
</tr>
<tr>
<td>Sync with Bluetooth Devices (E.g., Fitness watch)</td>
<td></td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>
Faster resume

Resuming from Modern Standby is 3 times faster than from S3

Based on telemetry data collected between 3/20/2016 - 3/26/2016

Includes 15k resume from standby sessions on laptops & tablets running Windows 10 build 10586
Wake on user presence

Windows supports short & long range proximity sensors for waking a device from standby on motion detection

Modern Standby devices provide a faster resume experience than S3 devices

Surface Hub demo video shows device waking up from standby

Device encryption

Modern Standby & TPM 2.0 are required in order to enable Device Encryption on Windows Home SKU

Windows Update

Windows stays up-to-date when in connected standby

Improved user experience – reduce chances of resuming from standby and waiting for updates to finish installing
Uninterrupted audio playback

Enjoy local and streaming low power audio playback in UWP apps after entering standby

Does audio continue to play after entering standby?

<table>
<thead>
<tr>
<th>Device Power State</th>
<th>S3</th>
<th>DS</th>
<th>CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device on &amp; screen on</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Device on &amp; screen off</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Device in standby</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>

Uninterrupted audio playback

Enjoy local and streaming low power audio playback in UWP apps after entering standby

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<tr>
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<td>YES</td>
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<td>YES</td>
</tr>
<tr>
<td>Device on &amp; screen off</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Device in standby</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
Skype Calls & IM’s

Receive Calls and Instant Messages from the UWP Messaging & Skype app when a device is in connected standby
Email & Calendar

UWP based Email & Calendar apps are up-to-date on connected standby devices
Push notifications

Social media, security, doorbell, and many other UWP apps can wake a device from a connected standby state.
Sync with Bluetooth devices

Disconnected and Connected standby devices running UWP apps can sync with Bluetooth devices such as fitness watches while remaining in standby.
Modern Standby
Windows
Improvements
Modern Standby improvements

New policies to limit Windows activity while in standby
Windows Update, Push Notifications and Background Tasks are better monitored and limited

Faster resume has HW/FW dependency
Auto transition from S4 to S0 prior to user interaction
Requires firmware support for Time & Alarm Device in ACPI

Learn more about HW/FW dependency
9.18 Time and Alarm Device” in the ACPI spec
Energy Estimation Engine (E3)
E3 overview

E3 is a service running on all battery powered Windows 10 devices
Provides energy usage data by hardware, apps, and services
Runs and generates energy data with or without a hardware monitoring solution on the device
E3 benefits

Low cost instrumented device
Enable more engineers to measure, analyze, and optimize DV & PV devices for power Include hardware based power monitoring chip to improve accuracy of energy data

Provides end-users with more control of their battery life
Built-in battery saver app in Windows desktop and mobile

Mine internal self-host data
Collect & mine E3 data from internal self-host devices within your company
E3 Software Estimation vs. Hardware Measurement

<table>
<thead>
<tr>
<th>E3 Configuration</th>
<th>Approximate accuracy per power model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPU</td>
</tr>
<tr>
<td>Software Estimation *</td>
<td>87%</td>
</tr>
<tr>
<td>Hardware Measurement **</td>
<td>98%</td>
</tr>
</tbody>
</table>

* Actual accuracy varies depending on how different the hardware power characteristics are from the device Microsoft used to generate the default power profiles.

** Hardware based power monitoring chips can be included in pre-production & retail devices.

Note: The accuracy data above is specific to screen on scenarios.
E3 software estimation vs. hardware measurement

Accurate energy estimation (target is +/-2% error) & no software power model code executed

Example of a power monitoring solution
Maxim Energy-Accumulation part # MAX34407EWE+T (2mm x 2mm package)
Accumulates energy for four power rails and connects to a processor using an I2C bus
1024 Hz sample rate during active use, 8 Hz sample rate in Modern Standby
Power footprint: ~3mW per chip @ 1024 Hz, ~0.3mW @ 8 Hz
Contact sales@maximintegrated.com for specs, cost, sales info and free evaluation kit
Battery Saver provides end users more control of battery life
Extends battery life by limiting background activity and providing user with data about which apps, services, and hardware components are consuming the most energy
Viewing E3 data: 200 Level

“PowerCfg /SRUMUTIL” generates a CSV dump of E3 data

Target Audience: Power optimization engineers, tech enthusiasts

Documentation & training on how to convert the raw data into actionable information


Energy data (millijoules) attributed to apps and hardware components
Viewing E3 data: 300 level

Windows Performance Analyzer (WPA) E3 plugin enables power engineers to visualize E3 data in graphs.
Screen on Battery Life (hours)
Distribution for 1 retail Win10 device model

- 3.9 hrs (10%)
- 4.5 hrs
- 50% of devices last 5.9 hrs
- 7.1 hrs
- 9.8 hrs (90%)
E3 Call to Action

Leverage hardware power monitoring solutions to provide higher accurate power draw readings

Ask your engineering teams to view the battery life optimization training videos available on Channel 9 MSDN (http://channel9.msdn.com)

Defrag Tools #150 - Media eXperience Analyzer part 2: Video Playback Power Saving
Defrag Tools #157 – Energy Estimation Engine (E3)
Additional Power Optimizations
Audio offload for APOs overview

Windows supports offloading APOs to hardware
APO = Audio Processing Object (E.g., Dolby, Waves, DTS, SRS, Maxx)
Supported on all chipsets that support offloading audio

Extends battery life during media playback scenarios
Up to 40% improvement during Low Power Audio (LPA) and 5% during Full Screen Video Playback

Requires an updated audio driver INF file
https://msdn.microsoft.com/library/windows/hardware/mt604857(v=vs.85).aspx

Additional Audio Offload Resources
Defrag Tools # 158– Media eXperience Analyzer (Audio Offload)
Video power saving features

Multi-plane overlays (MPO) and independent flip
Multi-plane overlays offload video processing to hardware, reduces memory copies & power

Low refresh rate
Power savings up to 7%
Automatically enabled when using UWP playback apps (E.g., Netflix, Movies & TV apps)
Requires a display panel that supports low refresh rate

Video batching
Increases the amount of CPU, Disk and GPU idleness by decoding and processing video samples in batches
Store app background execution policy

Users have higher confidence that Store apps will not significantly drain battery

Background activity is limited on apps based on functionality and/or usage

Power budget allocated for background app activity

User is always in control and can change the policy
Power optimizations Call to Action

Refresh software images that ship with APOs to offload audio to hardware

Verify video power saving features are enabled during full screen video playback

Develop and preinstall power efficient Windows Store apps
Battery Life
Assessments and Tools
Energy efficiency workload: full screen video

Plays back 720p, 1080p or UHD content in Movies & TV app

Streams protected 1080p content in the Movies & TV app
Energy efficiency workload: Edge browsing

Browses several websites
Tools

Windows Performance Analyzer

Media eXperience Analyzer
Battery life Call to Action

Start by defining your battery life and/or power targets

Check the power spec and validate the power consumption of your HW choices

Validate the total device power consumption with tuned firmware, drivers and apps running on the latest version of Windows

Validate battery life under different scenarios based on the target segment/audience

Do not trade-off battery life with responsiveness and vice versa
Performance
Responsiveness

Responsiveness is the ability of a device to respond quickly (user perception) to a user’s action
Transitioning from off to on (boot, resume)
Going through the first boot experience (OOBE)
Launching apps
Browsing the web
Glitch free media experience
File transfers
Gaming

Responsiveness must not compromise security
On/Off transition improvements

App registration time improvement improves OOBE time
Target OOBE time of <2 minutes

First logon time reduced

Boot prefcher
Prefetching mechanism used to mitigate the impact of disk IO during trained full boots
Improvements of 15% to 60% expected (dependent on disk speed and software preload)

Shutdown
OneDrive deadlock during process termination phase (up to 6s delay fixed)
Long Hiberfile Write duration due to CPU throttling (>10s delay fixed)

Resume from S3/S4 diagnostics
Easier to collect and share actionable traces
Define hardware configurations that deliver great performance and user experiences

**RAM size recommendations**

- >=4 GB RAM on 64-bit Windows Desktop (avoid 2 GB RAM with HDD)
- 2 GB RAM on 32-bit Windows Desktop (min requirement)

Based on 64-bit Windows
Microsoft Edge improvements

- Scrolling performance improvements
- Improved performance of top JavaScript APIs
- Intelligent auto-pause and user control of Flash content
- Quieter background tabs
- Battery life benefits from all these performance improvements
Performance Call to Action

Carefully consider your hardware choices based on your target scenarios and customer expectations

If using 64-bit Windows desktop, we strongly recommend a minimum of 4 GB of RAM

Carefully consider your preinstalled app choices and analyze their impact on the overall user experience (performance, battery life, reliability)
Performance Assessments
Performance assessments

**Windows Store App**
The updated metric ends when the UI becomes responsive to user input
Leverages a new internal ETW event
Only applicable to Microsoft apps today

**Out of Box Experience (OOBE)**
Provides a light weight tracing profile to gather OOBE measurements without impacting OOBE performance

**File Handling**
Reboot capability between iterations was added to clear antimalware temporary memory caches
Media quality assessment

Workloads
Netflix streaming quality
Groove Music quality
Movies & TV quality (local & streaming)

Quality Metrics
Audio, video & DWM glitches
Dropped video frames
Startup latency
Assessments Call to Action

Looking at test results alone is not adequate, your engineers have to dig deeper (analyze) to root cause the issue.

Assess device (hardware and software image) quality through the entire development process.
Training Reference
## Additional References

<table>
<thead>
<tr>
<th>Reference</th>
<th>Training videos on channel 9 MSDN</th>
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<tbody>
<tr>
<td>Assessment and Deployment Kit</td>
<td>Media eXperience Analyzer part 1</td>
</tr>
<tr>
<td><em>Introducing Modern Standby</em></td>
<td>Media eXperience Analyzer part 2: Video Playback Power Saving</td>
</tr>
<tr>
<td></td>
<td>Media eXperience Analyzer part 3: Audio Glitch Analysis 1</td>
</tr>
<tr>
<td></td>
<td>Media eXperience Analyzer part 4: Video Glitch Analysis</td>
</tr>
<tr>
<td></td>
<td>Media eXperience Analyzer part 5: Audio Glitch Analysis 2</td>
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<tr>
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<td>Memory Footprint and Leaks</td>
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<td>Boot Performance</td>
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<td>Critical Path Analysis with Windows Performance Analyzer</td>
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<td>Energy Estimation Engine (E3)</td>
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<td></td>
<td>Media eXperience Analyzer (Audio Offload)</td>
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<tr>
<td></td>
<td>Powercfg</td>
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<tr>
<td></td>
<td>and many more to come ...</td>
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</table>
Thank You
Appendix
Battery Life
## Energy Efficiency Workload Test Environment

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Brightness</td>
<td>150 nits</td>
<td>LS-100 Konica Minolta Light Meter Measure brightness while on battery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use notepad for an all white background</td>
</tr>
<tr>
<td>System Audio Volume Level</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Movies &amp; TV app volume level</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Windows Updates</td>
<td>Installed</td>
<td></td>
</tr>
<tr>
<td>Adaptive Brightness</td>
<td>Disabled</td>
<td></td>
</tr>
<tr>
<td>Display dimming</td>
<td>Disabled</td>
<td></td>
</tr>
<tr>
<td>Turn off display</td>
<td>Never</td>
<td></td>
</tr>
<tr>
<td>Keyboard backlight</td>
<td>Disabled</td>
<td></td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>Enabled</td>
<td>Direct connection to the internet (not proxy)</td>
</tr>
<tr>
<td>Attached USB devices</td>
<td>Unplugged</td>
<td>Unplug all external USB devices</td>
</tr>
</tbody>
</table>
How to verify Audio Offload

Channel 9 Defrag Tools Video
Modern Standby
Modern Standby wake sources

Real-time clock (RTC) or always-on timer

Buttons
Power button, lid switch

Communications devices
Wi-Fi, MBB, BT, LAN

Input devices
Keyboard, Touchpad, Mouse

Insertion or removal of a connector or device
USB device, SD card, Dock, Headphone/MIC

Environmental context changes
Power source change(DC/AC), Thermal event
Modern Standby - DRIPS

Deepest Runtime Idle Platform State (DRIPS) is the lowest power consumption state for the SoC in which memory is preserved in a self-refresh mode.

DRIPS allows the SoC to wake on events from networking, radio, and input devices.

No CPU code is allowed to run during the DRIPS state.

When the SoC is in the DRIPS state, the platform is consuming the least amount of power possible during standby (with the exception of variances in power consumption caused by networking and radio devices).
Modern Standby integrating apps

Windows Store Apps
Windows Store apps can create background tasks by using a specific set of WinRT APIs that allow the task to execute on a regular schedule or in response to an incoming network event.

Desktop Applications and Services
Desktop applications typically require no extra work to integrate with modern standby. The Desktop Activity Moderator (DAM) is the Windows component that pauses all desktop applications and throttles the runtime of third-party system services during modern standby.
Modern Standby Wi-Fi bring up

**ACPI configure**
_S4W and _S0W object.
GPIO resource for WoW (SDIO interface needed)
Reset interface for PLDR (optional)

**Driver preparation**
Protocol offload
WoW support

**Hardware connection**
GPIO and reset pin
The process for preparing the hardware for low-power during connected standby can be visualized as an upside-down pyramid, as shown below. The lowest power is achieved when the whole SoC chip is powered down, but this can occur only after each set of devices above it in the pyramid has been powered down.
Wake on user presence

Example of a sensor that has detection range of 0.2 to 1.5 m
Sharp GP2Y0A02YK0F: http://www.sharpsma.com/webfm_send/1487

API Reference

SDK Samples
https://github.com/Microsoft/Windows-universal-samples/tree/master/Samples/ProximitySensor
Modern Standby design decisions

Platform designs that support Windows 8 Connected Standby can also support Modern Standby
ACPI_S0_LOW_POWER_IDLE FADT flag
Platform Extension Plug-in (PEP)
x86/x64-based Connected Standby or Modern Standby PCs must also support Hibernate.

Network component selection
A Connected Standby design requires at least 1 network component to be NDIS 6.3 compliant, for wake-on-LAN (WoL) patterns, protocol offloads and D0 packet coalescing
If there is no NDIS 6.3 compliant network, Windows defaults to Disconnected Standby

Storage selection
If the boot storage component reports a seek penalty/rotational delay (indicates traditional rotational drive) then Windows defaults to Disconnected Standby
If the boot storage component does not have rotational delay or seek penalty (e.g., SSD, eMMC), then Windows defaults to Connected Standby
Generally, components outside the SoC must be capable of entering a low-power mode that consumes <1 mW of power. Components that cannot achieve <1 mW with an internal clock-gated state should implement power-gating through D3 Cold. Network and radio devices are the notable exception to the <1 mW guidance since these components may require more power to maintain a network connection or listen to wireless devices.
Prepare software for Modern Standby

On entry to modern standby, apps and system software must be made ready for the transition to low-power operation.

Powering down the display is the first activity when entering standby.

Software preparation phases

After the display is powered off, Windows transitions through a set of phases to prepare apps and services in achieving low power.
Powercfg
Run `powercfg /sleepstudy`

ADK
Modern Standby assessments
Windows Performance Analyzer to analyze performance and DRIPS residency issues

HLK
Connected Standby tests

PowerShell
Can be used to query for storage reliability counters to inspect Load/Unload cycles
Performance
When analyzing CPU and disk usage, there’s marginally higher amount of activity from inbox processes and some transient spikes, but the metric in TH2 is 3-4x larger than in 8.1. The regression level arises from the way the heuristic computes the metric. We’ll look into revisiting the heuristic (or the way we consider post on/off in programs like WER) to determine if there’s a more accurate way of representing the user experience. Telemetry data shows that post-boot activity isn’t as slowed down as this metric in the assessment toolkit may indicate.
Entry level system example

Configuration: 2GB+64bits OS, dual core N3050 @ 1.6GHz + rotational drive capable of 0.36MB/s random I/Os

ADK Assessment reports 1 min for boot time
Boot to desktop in 25 seconds. Decent experience for the price and configuration
Post on/off is 34 seconds and appears to be 100% non-stop CPU usage when glanced over

With proper analysis filters, the impactful CPU usage (>50% per core) only lasts for 15 seconds then goes to 7% average per core
Low priority CPU activity removed, test binaries, sppsVC.exe, OEM preinstalled apps and SkypeHost.exe
OOBE Assessment Update

Provides a light weight tracing profile to gather OOBE measurements without impacting OOBE performance.