Energy Aware Scheduling on Android

Todd Kjos
Google

Robin Randhawa
ARM
Session Intro

● We’ve combined two sessions to allow for more discussion time on EAS/Android topics:
  ○ Energy Aware Scheduling (EAS) on Android
  ○ Better compute control for Android using SchedTune and SCHED_DEADLINE
● We’ll go through the entire presentation and then spend some time on questions and discussion during the 2nd slot
SoC Power/Performance Characteristics are Complex

Nexus 5X: 4 A53 x 2 A57

- A53 (little)
- A57 (big)

Performance (dhrystone normalized to max=1024) vs Power (mW)
Perf/Power Tuning Difficult Without Standard Interfaces

- Per-SoC Vendor solutions to optimize perf/power
- Loose integration between Android framework and scheduler (CPUSets, PowerHints)
- SoC vendor mods to the Android framework need re-work for every new Android release
- Difficult to tune power and performance for new devices
- Opportunities to use Android framework knowledge left on the table due to lack of standard tuning surface
What Does Android Framework Know?

- Importance of task to the user’s current experience
  - Top-App: User’s focus
  - Foreground: Part of user’s experience
  - Background: Not part of User’s current experience
- Interactions (touch, swipe)
- Some workload attributes (Video, Audio, Frame-rates, Render times)
Why EAS?

- Needed standard capacity- and energy-aware scheduler that allows Android framework to adjust scheduling policies
- Looking for solution that is closely aligned with mainline
- SoC designs have increasingly sophisticated topologies. EAS provides SoC vendors with a saner strategy for supporting these designs (saner - not perfect)
EAS Overview

- Energy model driven task placement by the scheduler
- Misc extensions to per-task load tracking, load balancer pathways

**EAS-Core**

- The scheduler estimates and controls the frequency and voltage
- New cpufreq <-> scheduler interop via sched-freq governor

**sched-freq**

- Localised tuning surface with an API for Framework coupling
- Permits per-task and system wide tuning
EAS on Pixel Phone

- Met EAS engineers at LPC last year
- After experimenting with EAS on a tablet device with promising results, proposed a collaboration with ARM team to develop EAS for Android with a goal to ship on 2016 Nexus devices
- EAS on Pixel was 3-way collaboration between ARM, Qualcomm and Google
Pixel Energy Model

Pixel: 2 Kryo Silver x 2 Kryo Gold

Power (mW)

Perf (dhrystone normalized to max=1024)
The Challenge

- Qualcomm has done significant engineering on their custom scheduler/governor for Snapdragon 821
  - Could not compromise important power or performance metrics when swapping EAS for Qualcomm’s QHMP scheduler
- Goal was performance/power parity vs Qualcomm’s technology
Some modifications to EAS

- EAS Scheduler wake path modified to avoid big.LITTLE assumptions (e.g. lowest cluster is most power efficient)
- SchedTune cgroups added an attribute to express placement policy (Spread vs Pack)
- Used Window Assisted Load Tracking (WALT) instead of Per-Entity Load Tracking (PELT)
- Modified sched-freq governor to use different throttle thresholds for raising (500us) and lowering OPP (50ms)
Scheduling Policies for Pixel

- Top-app: spread policy + SchedTune boost of 10%
- Foreground: spread policy, no boost
- Background: pack policy, no boost
- Everything else (kthreads / system-threads): pack policy, no boost
Pixel Cpusets

- Top-App
- Foreground
- System-Background
- Background
- Gold Core
- Silver Core
- Gold Core
- Silver Core
## EAS vs HMP: Power

<table>
<thead>
<tr>
<th>Activity</th>
<th>EASBetter by &gt;= 10%</th>
<th>EASBetter by &gt;= 3%</th>
<th>Results differ by &lt; 3%</th>
<th>HMPBetter by &gt;= 3%</th>
<th>HMPBetter by &gt;= 10%</th>
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<tbody>
<tr>
<td>Airplane + Wifi</td>
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<td>Radio+Wifi+BT+Location</td>
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<td>Phone Call</td>
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<td>Phone Call (VoLTE Off)</td>
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<td>All Apps Screen</td>
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<td>Home Screen (airplane)</td>
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<td>Flight simulator</td>
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<td>Compose Gmail</td>
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<td>Video Playback</td>
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<td>Chrome browsing</td>
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### Activities

- **Camera Preview**
- **Camera Image Capture**
- **Camera Image Capture (HDR)**
- **Location: GPS 1 min**
- **CPU Idle**
- **Radio+Wifi+BT on Suspend Doze**
- **Battery Save Mode - Video Playback**
- **Battery Save Mode - Flight Simulator**
- **mp3 Playback**
- **Home Screen**

### Apps

- **Video Playback**
- **Map Navigation**
- **Music Streaming**
- **Facebook**
- **SMS messaging**
- **MMS messaging**
- **Twitter, scrolling 2s**
- **YouTube, 360p**
- **YouTube, 1080p**
- **YouTube, 1440p**
- **Email**
- **Browser**
- **Gmail Sync**
- **Google Now Doze**

### Additional Features

- **Rear Video, 1080p, 30fps**
- **Rear Video, 1080p, 120fps**
- **Rear Video, 4K, 30fps**
- **Rear Video, 1080p, preview**
- **Facebook, scrolling 2s**
- **YouTube, 360p**
- **YouTube, 1080p**
- **Twitter, scrolling 2s**
- **YouTube, 1440p**
- **Flipboard, scrolling 2s**
- **Gmail Sync**
- **Google Now Doze**

### Battery Modes

- **Battery Save Mode - Video Playback**
- **Battery Save Mode - Flight Simulator**
- **Beach buggy racing**
## EAS vs HMP: Performance

<table>
<thead>
<tr>
<th>Calendar Items Fling</th>
<th>Framework - ListView fling</th>
<th>System UI - Settings Fling</th>
<th>UI Benchmark - Layout Cache Low Hitrate</th>
<th>Antutu</th>
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</thead>
<tbody>
<tr>
<td>Chrome - OverflowMenu Render</td>
<td>Framework - Loading animation</td>
<td>System UI - Widgets fling</td>
<td>UI Benchmark - Trivial Animation</td>
<td>Geekbench (MT)</td>
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<td>Contacts - All contacts fling</td>
<td>Framework - Simple Transition animation</td>
<td>UI Benchmark - Bitmap Upload</td>
<td>UI Benchmark - Trivial List View Fling</td>
<td>Geekbench (ST)</td>
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<td>Dialer - Call init screen popup</td>
<td>Framework - View Flip animation</td>
<td>UI Benchmark - Dialog List fling</td>
<td>UI Benchmark - Trivial RecyclerView Fling</td>
<td>AndroBench Seq Rd</td>
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<td>Dialer - Call log fling</td>
<td>System UI - All Apps Container swipe</td>
<td>UI Benchmark - Full Screen Overdraw</td>
<td>YouTube - Simple Fling</td>
<td>AndroBench Seq Wr</td>
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<td>Framework - Activity Transition Animation</td>
<td>System UI - Home Screen swipe</td>
<td>UI Benchmark - GL Texture View</td>
<td>testShadowGridListFling</td>
<td>AndroBench Rand Rd</td>
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<td>Framework - Cloning Animation</td>
<td>System UI - Notification List pull</td>
<td>UI Benchmark - Inflating List View</td>
<td>testActivityTransitionsAnimation</td>
<td>AndroBench Rand Wr</td>
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<tr>
<td>Framework - Expandable list expansion</td>
<td>System UI - Open and Close All Apps</td>
<td>UI Benchmark - Invalidate GL</td>
<td>testWebViewFling</td>
<td>PC Mark Overall</td>
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<tr>
<td>Framework - Hide/Show Animation</td>
<td>System UI - Recent Apps fling</td>
<td>UI Benchmark - Layout Cache High Hitrate</td>
<td>CoreMark</td>
<td>Vellamo Browser</td>
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<td>Vellamo Multicore</td>
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<td>Vellamo Metal</td>
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Current Status

- EAS is merged into Android 3.18 and 4.4 common kernels and will be in future common kernels
- EAS enabled in Pixel phone and Acer R13 Chromebook
  - Also on dev boards eg. 96Boards HiKey
- Uses Sched-freq ("sched") governor
  - Will be moving to newer "schedutil" governor