Energy Aware Scheduling on Android

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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
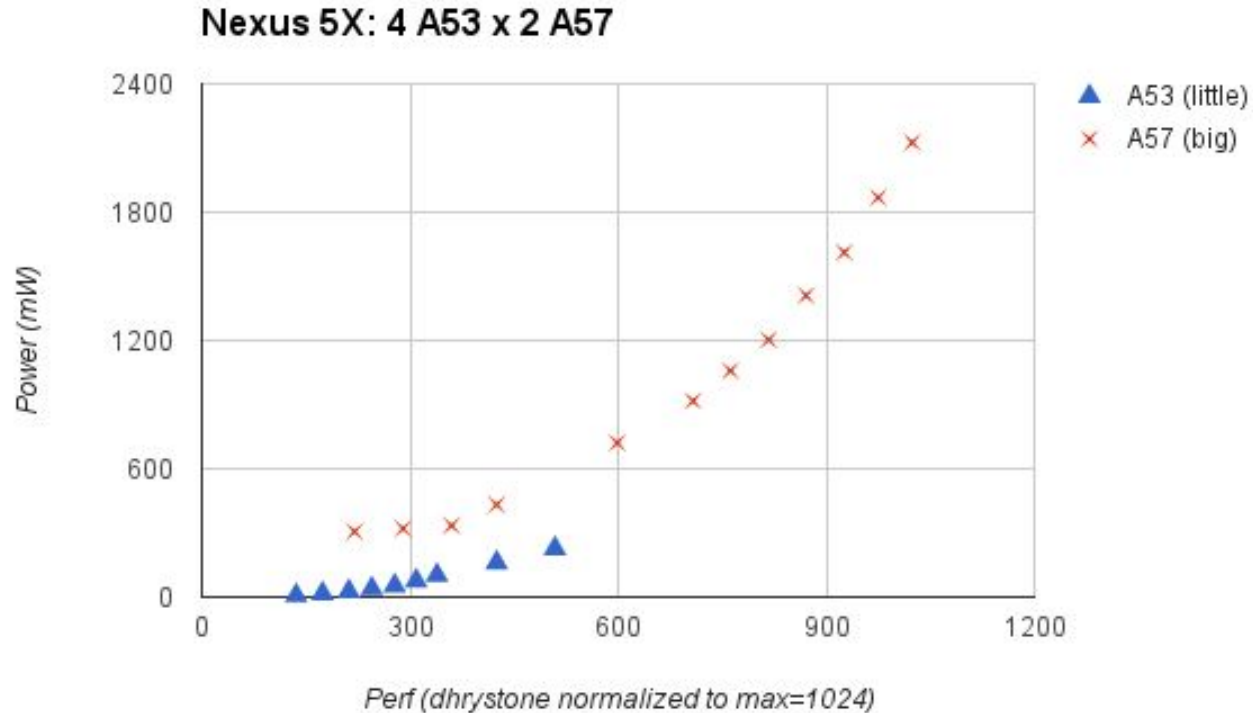
Perf/Power Tuning Difficult Without Standard Interfaces

- 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

EAS-Core

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

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sched-freq

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

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SchedTune

- 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
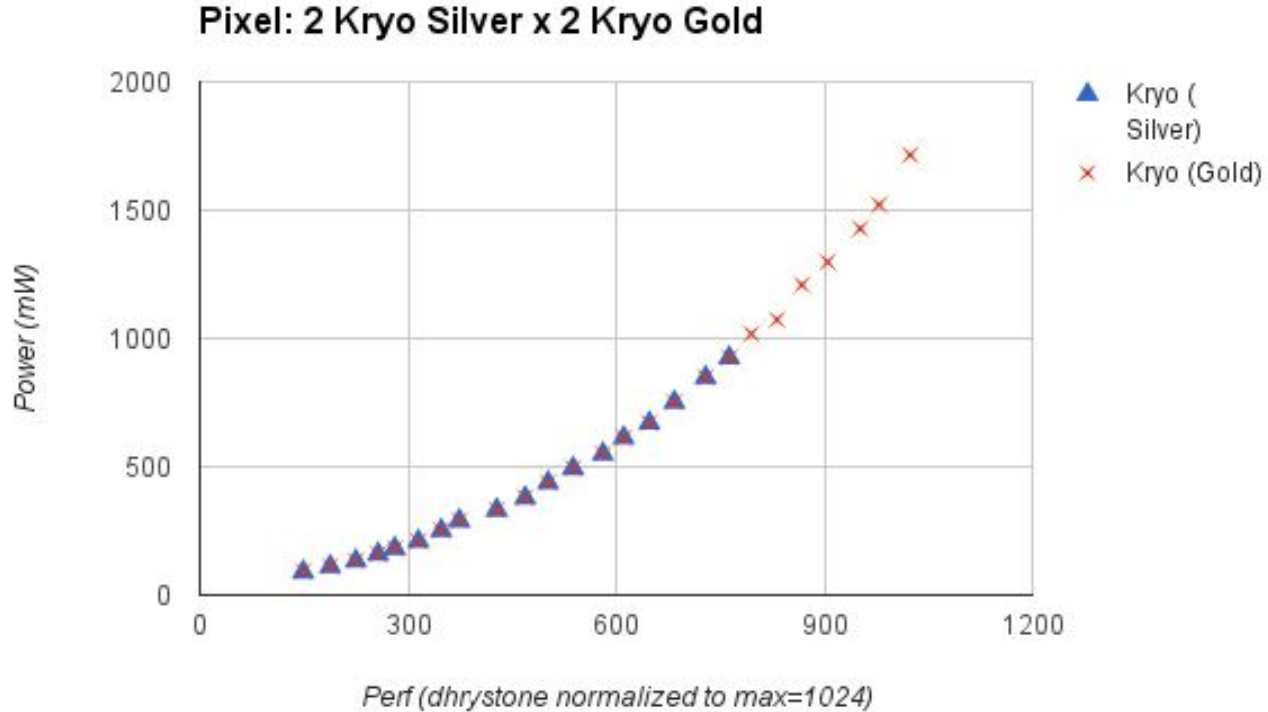
The Challenge

- 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
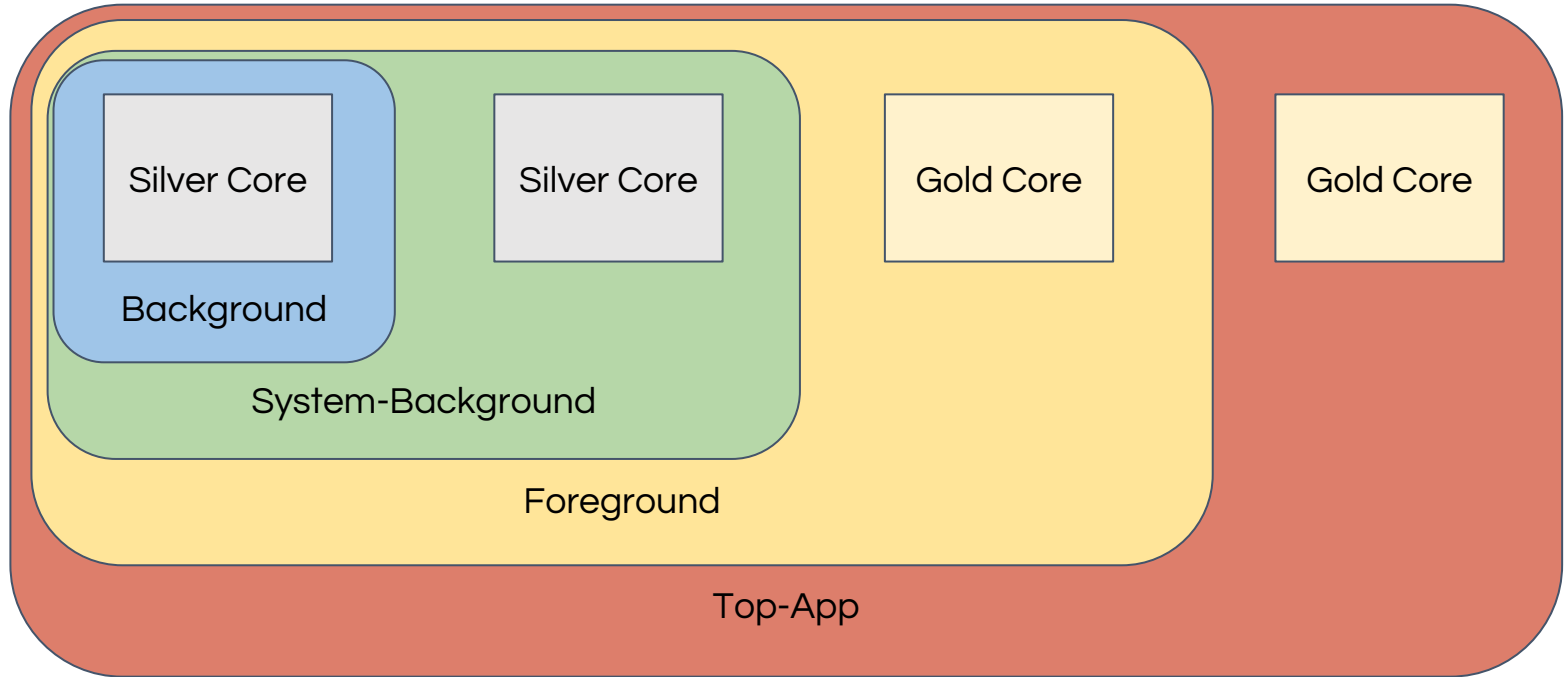
EAS vs HMP: Power

▮	EAS better by >= 10%
▮	EAS better by >= 3%
▮	Results differ by < 3%
▮	HMP better by >= 3%
▮	HMP better by >= 10%

Airplane + Wifi	Camera Preview	Rear Video, 1080p, 30fps	Video Playback	Map Navigation
Radio+Wifi+BT+Location	Camera Image Capture	Rear Video, 1080p, 120fps	Video Record (1080p, 30fps)	Music Streaming
Phone Call	Camera Image Capture (HDR)	Rear Video, 4K, 30fps	Video Preview	Facebook
Phone Call (VoLTE Off)	Location: GPS 1 min	Rear Video, 1080p, preview	Camera Preview	SMS messaging
All Apps Screen	CPU Idle	Facebook, scrolling 2s	YouTube, 360p	MMS messaging
Home screen (airplane)	Radio+Wifi+BT on Suspend Doze	Twitter, scrolling 2s	YouTube, 1080p	Video Playing
Flight simulator	Battery Save Mode - Video Playback	Flipboard, scrolling 2s	Email	Picture Browsing
Compose Gmail	Battery Save Mode - Flight Simulator	Youtube, 1440p	Browser	
Video Playback	mp3 Playback	Beach buggy racing	Gmail Sync	
Chrome browsing	Home Screen	All Apps Screen	Google Now Doze	

EAS vs HMP: Performance

![legend green dark]	EAS better by >= 10%
![legend green light]	EAS better by >= 3%
![legend white]	Results differ by < 3%
![legend red light]	HMP better by >= 3%
![legend red dark]	HMP better by >= 10%

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

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