

Understanding the impacts of Google's IO announcements



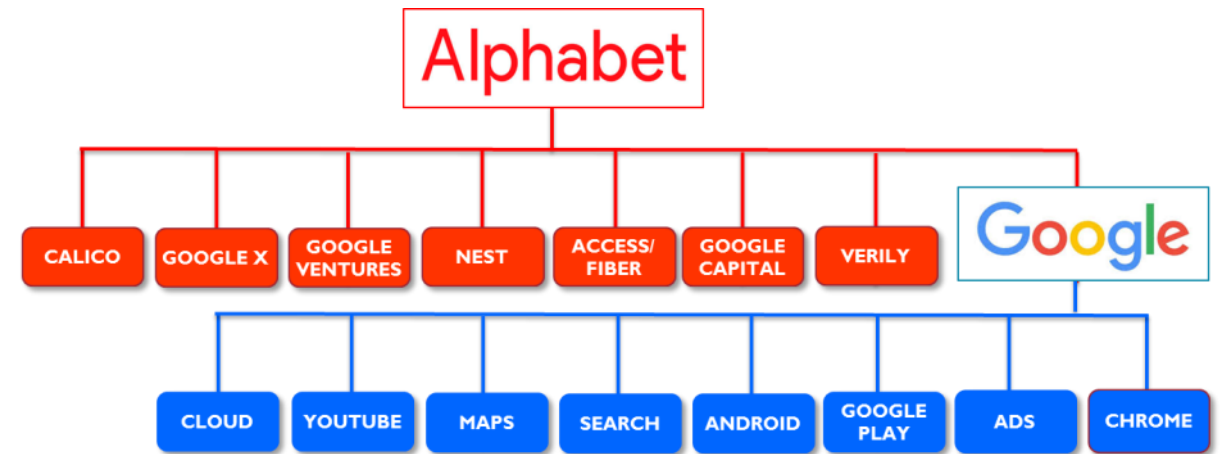
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ARM Tech Forum Taipei
July 1st, 2016

Alphabet – Google Redefined

Google Restructured in 2015 to Bring Transparency and Accountability

- Division of company to carve out the speculative new ventures of the business
- Multiple internal and external pressures prompted restructure
 - New CFO Ruth Porat from Morgan Stanley drove the restructuring to provide transparency and accountability for investors to value the businesses.
 - The need to attract top exec talent – “our model is to have a strong CEO run each business”.
 - Potential spin-offs provide retention incentives for key employees.

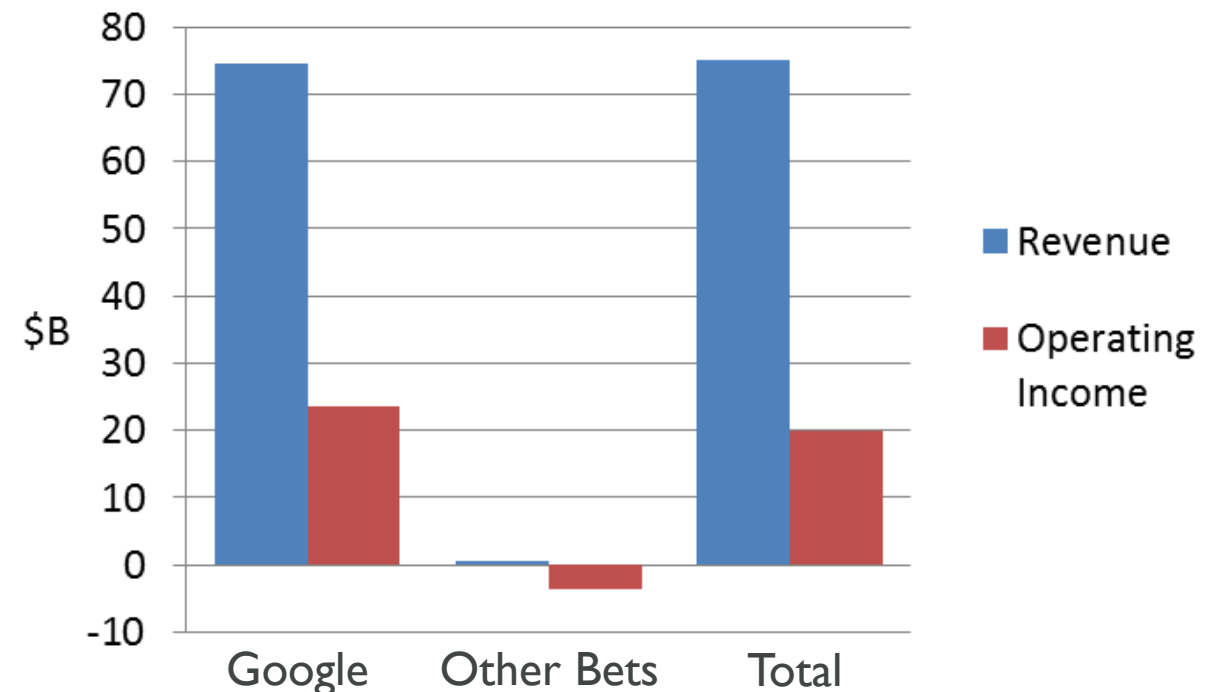


How Alphabet Makes Money

It's All About Search – Its Still the Traditional Google

- 90% of overall revenue comes from advertising on websites and mobile
 - Search, display ads, content.
- Google generates 117% of operating income
- Other Bets revenues primarily:
 - Sales of Nest branded hardware (\$340M in 2015).
 - Revenues from internet and TV services.
 - Revenues from licensing and R&D services.

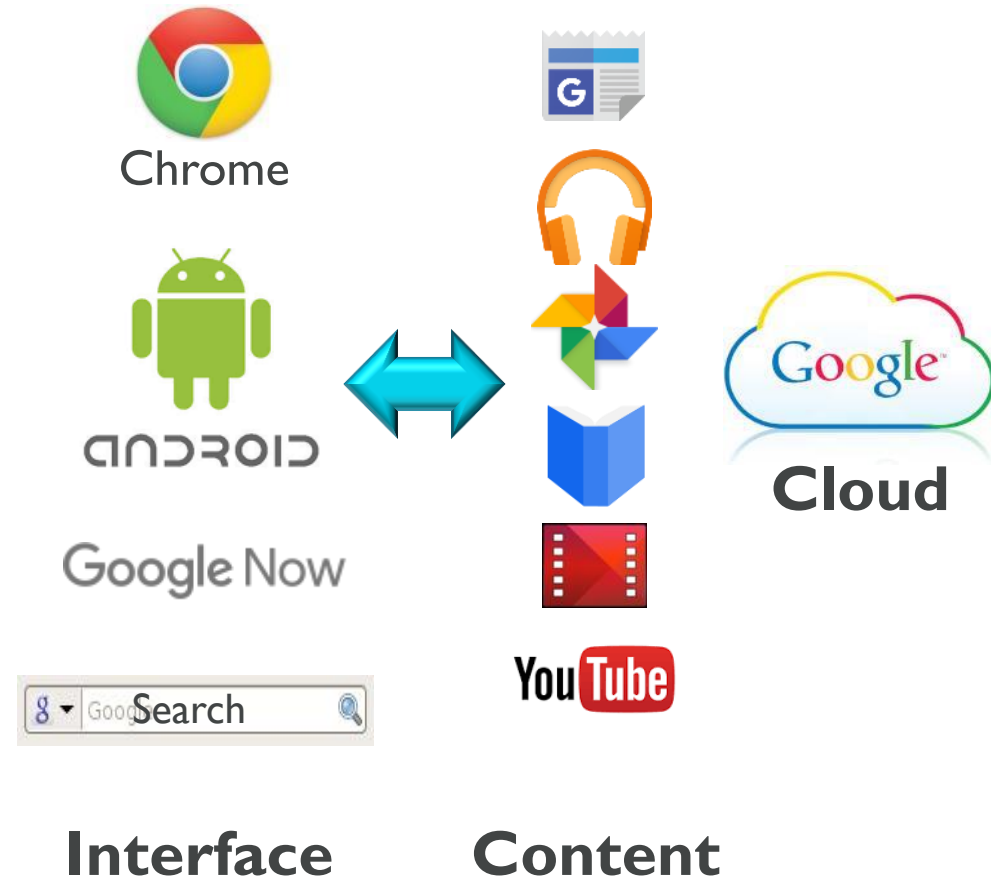
Alphabet 2015 Revenue and Operating Income



Alphabet Vision

Be the Interface to All Information and Content

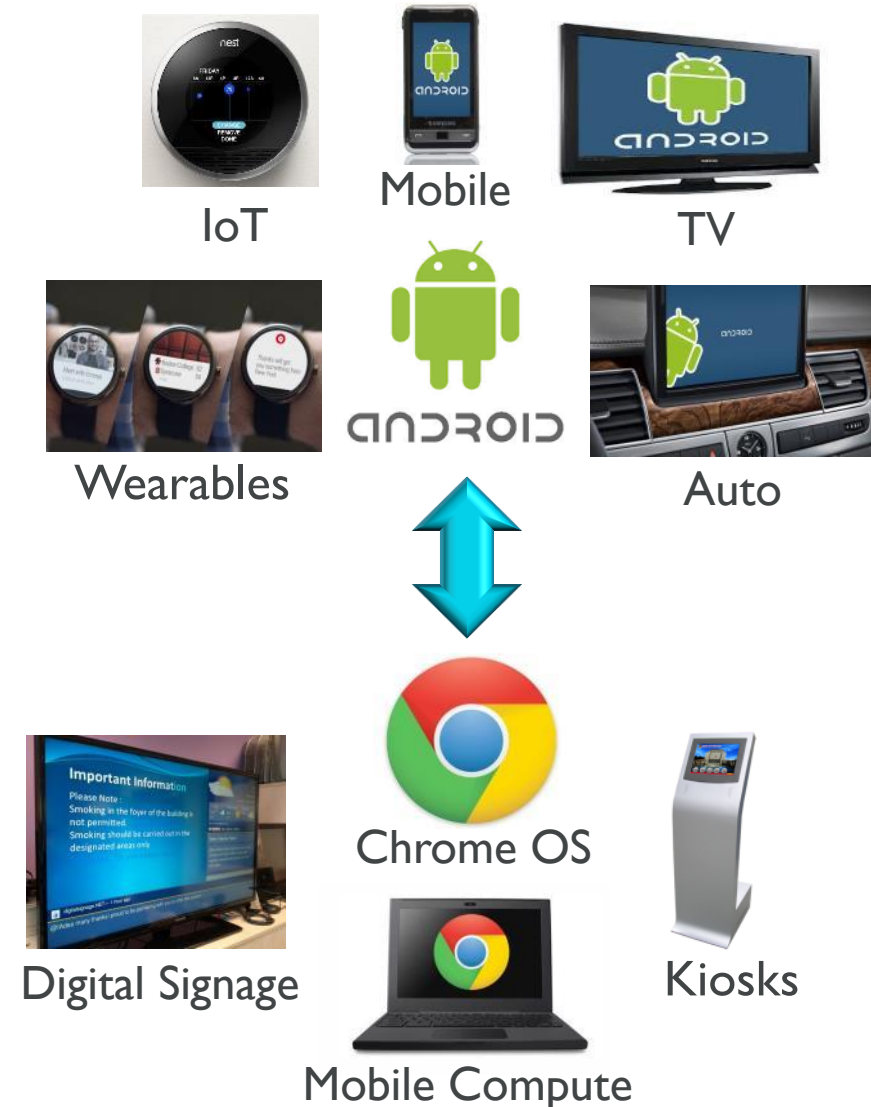
- Connect the 60% of the population that is offline
 - Project Loon and other initiatives.
- Improve internet quality and speed
 - Google Fiber.
- Be the user's interface to all information and digital content
 - Android, Chrome and Brillo.



Google's Software Platform Strategy

Leverage Android's Huge Success in Mobile to Other Devices

- Android and Chrome each bring important benefits
 - Android enabled an app ecosystem – hundreds of thousands of applications.
 - More Android devices drives more demand for Google Services.
 - Chrome offers manageability and security.
- Chrome and Android engineering teams are now merged
 - Allows ecosystems to merge.
 - Mobile and clamshell roadmaps will converge – at some point.
- Brillo/Weave, their IoT platform, will deliver the benefits of both



Google is Differentiating Its Cloud Services

Their Strategy Will Impact the Capabilities of Consumer Devices

- Google is currently a small player behind Amazon and Microsoft (approximately 5% market share for standard cloud services – delivering software as a service)
- To differentiate and gain share, Google is utilizing machine learning as platform to deliver unique capabilities and experience
 - Access to voice recognition, image/video analytics, real-time translation, and more to come.
 - Fully integrated with Google's Cloud Services (e.g. Big Data analytics).
- Local devices will need more performance as certain capabilities are pushed to the edge
 - For example - always on keyword recognition on Cortex-M on mobile device.
- Machine learning and computer vision will deliver autonomous vehicles
 - Early days, however significant investments and testing underway.

Alphabet / ARM relationship

- Google has increasingly focused on HW products, both devices and silicon which opens up an opportunity for ARM
 - Pixel, Nexus, Chromecast, Silicon teams, etc. all under new HW group
 - Google is increasingly becoming more vertical is for HW (devices and silicon)
- Android is the basis of their singular SW platform strategy for IoT, mobile, wearables to TVs and automotive
 - Explore the future direction of this SW platform strategy
- Key investments being made to ensure Android/ChromeOS on ARM if fully optimized

Google is transitioning from a device company to an AI company

- Machine Learning and Artificial Intelligence is driving new features/products for Google.
 - The massive amount of data that they have from years of search algorithms, Google photos, and YouTube is allowing them to create ML models for applications
- Google Assistant is a conversational assistant that combines natural language processing and is able to understand context and the ambient experience
 - Able to do natural language queries and utilizes the massive ML backend they have accumulated over the years from search, photos, YouTube, etc.
 - Fundamental technology that will be accessible from numerous devices/methods.
 - Search, Android, Google Home, Allo/Duo, etc.
 - Bringing ML/AI to the masses
- Cloud services with machine learning that will demand different capability on local devices.

Google IO

Android N (Nougat) Highlights

- Android Nougat will focus on platform security, efficiency, productivity, innovation
- Platform security
 - Cost of applying updates much lower. Auto-applied updates
 - Sandboxing and exploit mitigation
- Efficiency
 - Power: Extending Doze mode – extreme battery savings mode when idle (up to 100% better battery life) introduced in M
 - N - ability to doze when screen is off or in your pocket
 - Performance: New JIT compiler and hybrid JIT/AOT for better performance and memory utilization
- Productivity
 - Native multi-window support
 - Notification bundles and inline controls
- Innovation
 - Advanced touch and haptic HW support
 - Better support for Clamshells



ARM

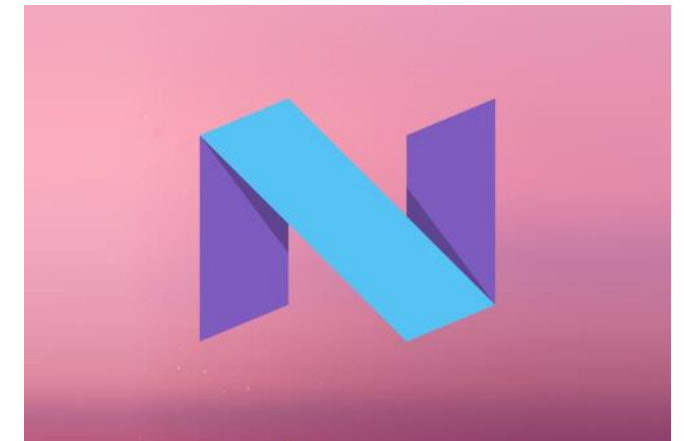
Android Nougat Runtime Features and Schedule

- CLang/LLVM
 - M Nexus devices are almost all Clang built from AOSP
 - Not preventing others from using GCC
 - Kernel and a few Google/3rd Party Packages left
 - NDK is now primarily CLang and same as ASOP
- More aggressive release schedule



Feb 2016

- Long access time for developers/OEM's
- AOSP available before device shipment
- More devices (not just Nexus) than before

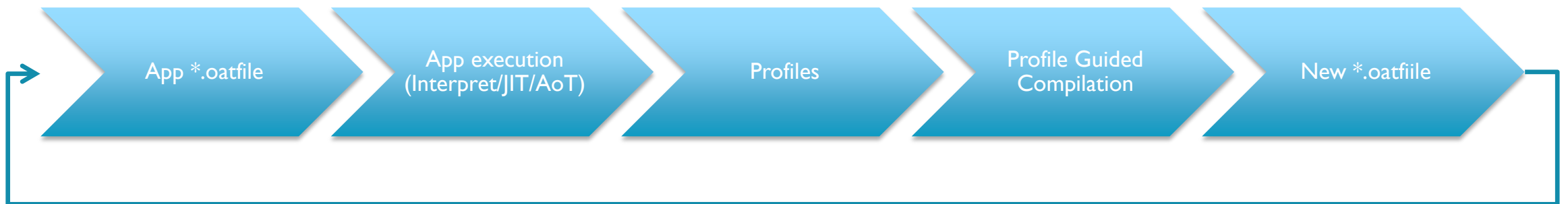


ARM

Android Run-Time (ART)

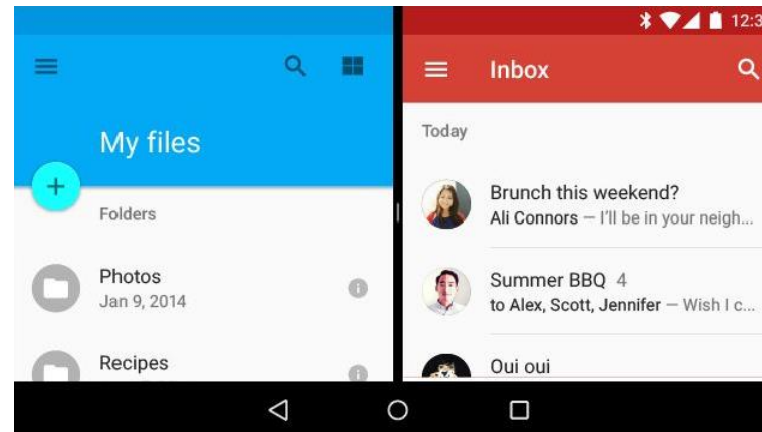
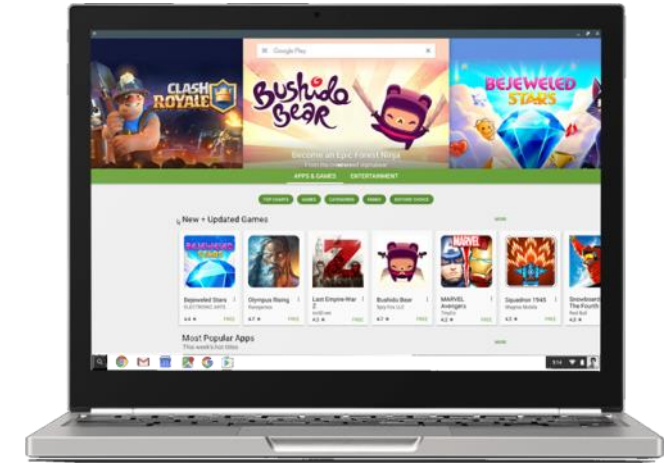


- Interpreter/JIT/ART Optimizing Compiler
 - Continuous profile of execution while interpreting and executing native code
 - When device idle and charging e.g. night time compile based on profile
 - New method based JIT- only JITs hot methods
 - Reduces install and update time (no heavy, visible compiles)
 - Reduce RAM footprint- only compile important code
 - 2X Faster and up to 50% memory footprint saving



Better support for large screen Mobile Compute

- Multi-window mode allows multiple activities to be visible on screen at the same time.
- The activities are resizable up to the full area of the screen and down to a smaller area of the screen as allowed by the app and system controls.
- Split-screen
- Freeform (large screen devices only)
- Picture-In-Picture (Android TV only)



Split Screen



Free-form

New Use Cases Driving Sustained System Performance



Google's platform for high quality mobile VR - Daydream

- High quality mobile VR comes to Android N
- This is a set of HW and SW specifications to ensure high quality VR experience
 - HQ sensors, sustained performance will determine whether mobile device is VR ready
- There are a number of performance enhancements designed for developers, including single buffer rendering and access to an exclusive CPU core for VR apps.
 - Within your apps, you can take advantage of smooth head-tracking and stereo notifications that work for VR.
 - Most importantly, Android N provides for very low latency graphics;
- Google will provide a reference HW design which includes headset (to hold phone) and controller which includes orientation sensors
- Daydream ready phones will be available this Fall
- Silicon providers included QCOM, IMG and ARM



Android Daydream

- ARM has been collaborating closely with Google in defining Daydream platform to enable VR on Android
 - Defining extensions and capabilities required to achieve Daydream ready
 - Ensuring Mali GPUs, Video and Display processors are well placed to deliver a good Daydream experience
- Working with leading silicon partners and OEMs, enabling them to ship their first wave of Daydream ready devices



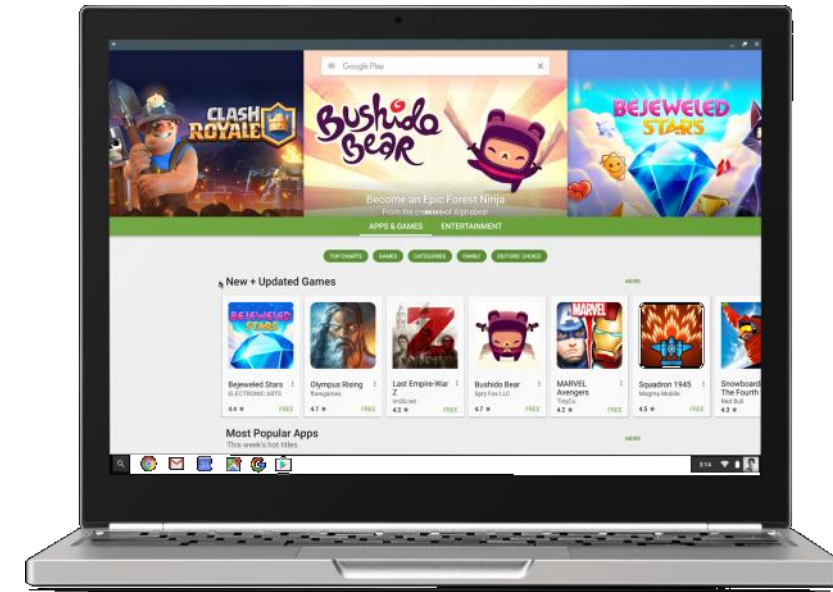
Mali Enabling the VR Experience

- Mali GPUs provide several technologies and benefits to deliver a smooth mobile VR experience
 - Scalable GPUs with multiple cores
 - OpenGL ES and EGL extensions to reduce latency and improve performance
 - 4x Anti-aliasing to reduce visual artifacts from pixel magnification
 - ARM Framebuffer Compression significantly reduces system bandwidth



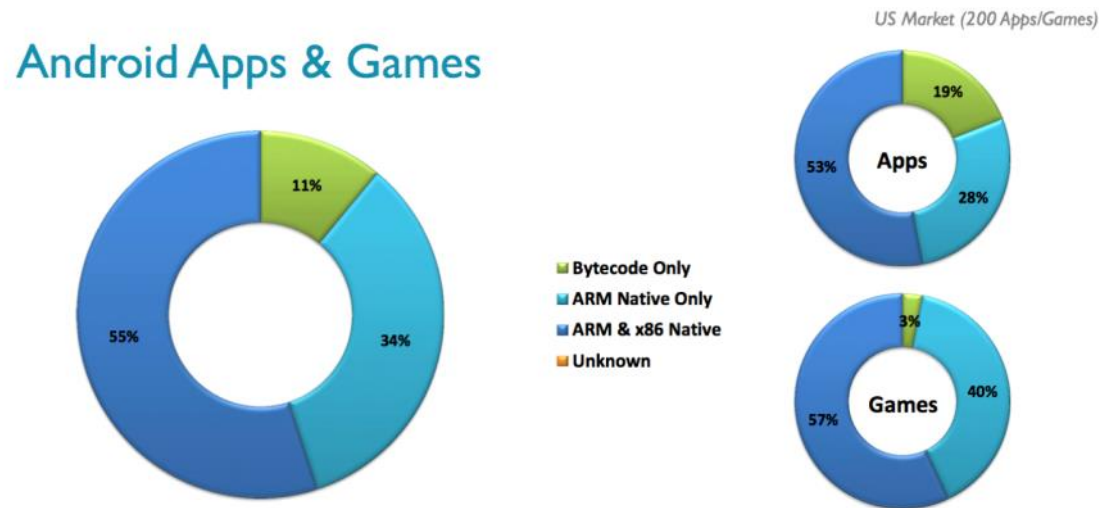
Android apps comes to Chromebooks

- Google is bringing Google Play (the most popular app store in the world) to Chromebooks.
- Over >1 million apps that run on phones and tablets can now run on Chromebooks without compromising their speed, simplicity or security.
- Combines the Android application ecosystem with the security and manageability of ChromeOS
- This means you'll be able to download and use Android apps, so you can make a Skype call, work with Office files and be productive offline or play high quality Android games.
- Consumers will soon begin to engage with big-screen devices in ways that echo the satisfying and productive experiences they have enjoyed on their smartphones



ARM-based Chromebooks offer no compromise performance

- Native Android performance for Android ARM
 - Binary translation of ARM code is required to run on X86 Chromebooks which hurts both performance of the system as well as battery life
- 97% of all games are ARM native.
- 40% of top 100 apps/games are ARM native only
- 89% apps & games target the ARM architecture.



- 89% Apps & Games Target **ARM** Architecture (~1.6x more than **x86**)
- ...97% for Games alone (~1.7x more than **x86**)

How Android apps run on ChromeOS

- Runs Android on top of Linux and uses Linux “namespaces” and alternate sys call tables to isolate Android from Chrome OS.
- Native ARM binaries in Android applications run natively on ARM-based Chromebooks
 - Binary translation of ARM code is required to run on X86 Chromebooks which hurts both performance of the system as well as battery life
 - For example, searching for a text string in a PDF document can take four times longer on a non-ARM-based device.
- *Schedule and availability*
 - Availability: Appears in Chrome build 53, available in Chrome Dev Channel NOW on Asus Flip (ARM-based), general availability Sept 2016

Bringing the mobile ecosystem to Chromebooks

- ARM has worked closely with its partners to deliver compelling designs on Android and Chromebook devices—thin, sleek devices that offer long battery life and compelling performance such as:
 - Goal to move mobile HW features into large screen devices
- Rich mobile applications are moving to large-screen devices
 - Tablets, laptops, convertibles, 2-in-1 devices
- ARM-based Chromebooks deliver native performance for Android apps!

Location and Context

- Goal is to understand the user's location & context to provide better user experience
 - Fitness & user activity, parking location, smart unlock, geo-fencing,
- Low power always-on sensor processing - Context Hub
- Reference context hub implementation open-source
 - android.googlesource.com/device/google/contexthub
- Implemented on ST Micro Cortex-M4 in Nexus Phones
- Reference code for sensors
 - Shipping in Android M today
- Huge opportunity for Silicon vendors/OEMs to leverage Google sensor/ML knowledge
- Cortex A - Cortex M SoC configuration highly recommended



Google making machine learning accessible

- Google making available vast neural network and machine learning capabilities and experience
- API access to machine learning capabilities for features such as Voice recognition, Image/video analytics, and real-time translation, and more to come.....
- Full integration with Google's Cloud Services (e.g. Big Data analytics)
- Machine learning will drive future mobile device capabilities as some processing best done locally/on-device
 - E.g. Always on keyword recognition on Cortex-M



Brillo



- Brillo makes it easy and cost-effective to build a secure connected device
- Free, maintained OS and integrated development toolkit for connected devices
- Devices will use- Cortex-A5/A7/A32 & above, not Cortex-M.
- Can run in devices with <32MB memory footprint, but with additional services this will likely be 64MB/128MB.
- Brillo Starter Kits Hardware
 - Across ARM, Intel x86, and MIPS-based hardware
 - Compatible boards conform to specific guidelines
- Software
 - An embedded OS based on Android, core services built-in
- Operate at scale
 - OTA updates, runtime metrics, and crash reporting
 - Secure services are available through a single developer console.
 - A solution for OEMs, App developers and Users



Weave

- Communications platform/Schema Language for IoT devices enabling
 - Easy Device provisioning
 - Phone-to-device-to-cloud communication
 - User interaction from mobile devices and the web
- Runs on Brillo- Headless Android+ Google Services and Analytics
- LibWeave on Linux to enable non Brillo Devices
- LibWeave on baremetal embedded MCU with BLE
- Certification tests (CTS-like) to deliver Weave compliant device
- “Works with Weave”
- Google wants to work with specific SiPs who play in specific device categories



ARM

Android Wear

- Android Wear is Google's platform for wearable computing devices
- Provides contextually aware, relevant information
- Allows for “micro-interactions” (<10 secs) between user and device
- Initial focus is wrist-based wearable's with color displays
- Plans to support more form-factors and displays over time
- Uses a modular form of Android
- Wear 2.0 (announced Google IO 2016) somewhat removes need to phone
 - Google Assistant integration along with additional “Smart Replies” and mini keyboard
 - Adds direct connectivity to Internet w/o need of phone via WiFi and/or cellular
 - Support for standalone Wear apps that run only on watch
 - Google Fit no longer needs a phone
 - Context Hub will appear in Wear 2.0 devices



Project Ara - modular Smartphone



- Project Ara is now an official product and division within Alphabet
- The Ara body contains a fixed CPU, GPU, antennas, sensors, battery, and display
 - These core components are no longer on a module.
 - Frames will have to be upgraded if you want to upgrade the processors/GPUs on the phone
- Developer module kit
- Future frames will have different form factors – embedded/consumer focused
- Modules Hot swap and "OK Google" voice control to eject module
- Module development- Screens, cameras, sensors, storage,
- Module Developer Edition Q4, 2016
- Consumer edition 2017

Key Takeaways

- Android Nougat releasing sooner gives OEMs time to ship phones in Q4, 2016
- Daydream VR sets HW and SW standards to ensure high quality mobile VR experience
- Android applications are coming to Chromebooks
 - Brings the mobile device experience to large form factor devices
- Artificial intelligence and machine learning will be pervasive in devices
- Huge opportunities beyond smartphones and tablets
 - New form factors and modular devices will help user experience



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