Arc++ Graphics

Rendering, Compositing and Window Management

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Arc++

Arc++ is Android running alongside ChromeOS and providing ChromeOS users with Play Store Android apps without developer action.

Background

App Runtime for Chrome (ARC), was launched September 2014 with a few curated applications. Due to the heavy involvement of Google Engineering team on curating those apps, in April 2015, we decided to open the program for anyone to submit an app. Despite doing so, there has not been a lot of developers submitting applications.

Arc++ Goals

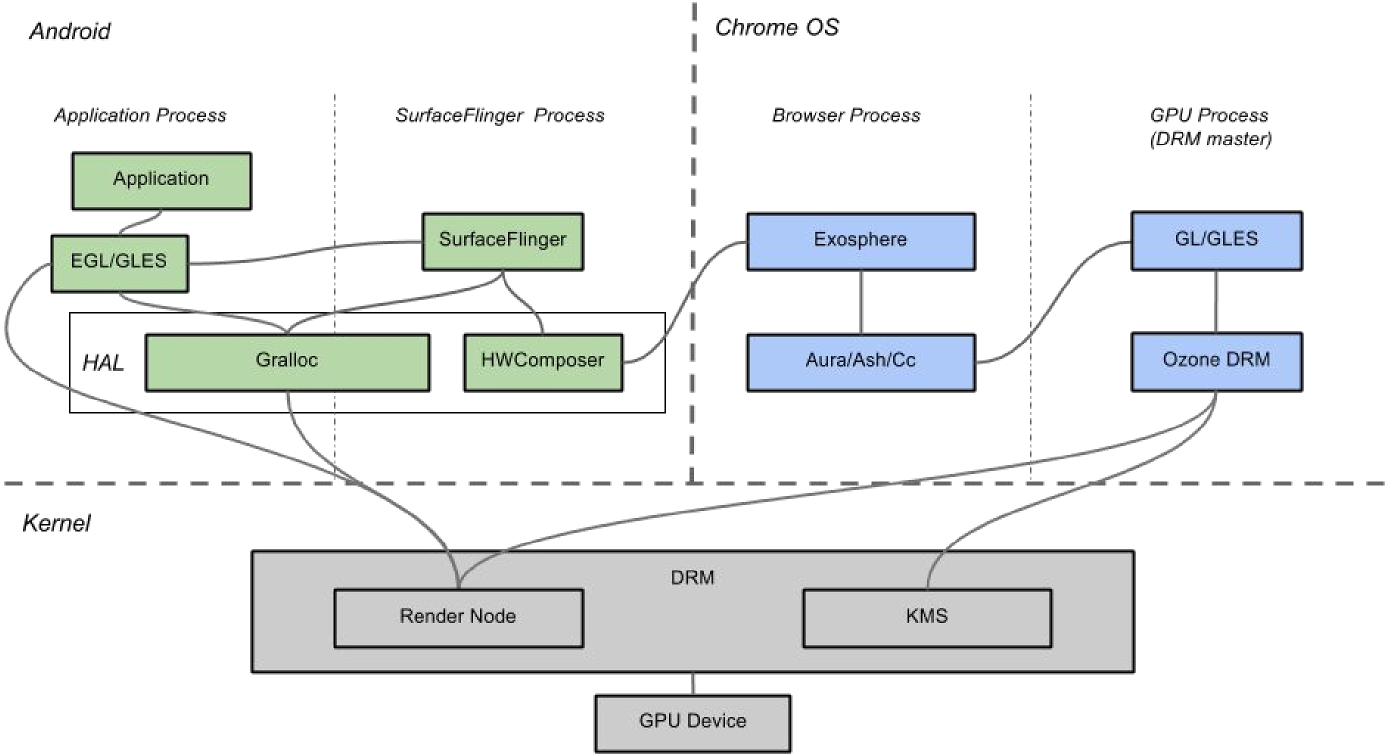
Full Play Store access

Minimize Android Framework changes

Keep Chrome OS secure

Maintain Chrome’s update model

Graphics Overview



Rendering

- Hardware-accelerated Canvas API
  - OpenGL ES 2.0 since Android 4.0
- OpenGL ES (GLES) directly
- Everything is rendered onto a "surface."
  - Producer side of a buffer queue that is consumed by SurfaceFlinger
  - The Gralloc HAL is used to allocate buffers for each buffer queue
- ARC++
  - Gralloc and the GLES driver are using the Direct Rendering Manager (DRM)
  - Apps still have access to a fully accelerated GLES implementation
  - Apps using a different rendering API works too

Compositing

- Android windows are backed by surfaces
  - Surfaces are sent to SurfaceFlinger for compositing onto the display
  - SurfaceFlinger uses GLES for compositing
- HWComposer HAL
  - Allows the OEM to handle some surfaces using overlay hardware
- ARC++
  - All surfaces are handled by HWComposer
  - Forwarded to Chrome for compositing together with the rest of the ChromeOS UI
  - Chrome compositor uses overlay hardware when available

Window Management

Shared between Android and Chrome

Chrome

- Maximize, minimize and full-screen
- Application switching, multiple profiles, screen magnifiers, etc.

Android

- Absolute positioning
- Resizing

DRM/KMS

Direct Rendering Manager “DRM”

- Used for rendering and buffer allocation on both Android and ChromeOS
- Allows for efficient sharing of graphics resources (DMA Buffers) between the two platforms
- Chrome is DRM-Master and can program a display-controller
- Android doesn’t need mode-setting capabilities in ARC++
  - Render-node access to the GPU is sufficient

DMA Buffer Sharing and PRIME

- Linux kernel internal API designed to provide a generic mechanism to share DMA buffers
- PRIME file descriptors are used for buffer sharing
- Unix operating systems provide a safe way to pass them through an Unix domain socket using the SCM_RIGHTS semantics

Gralloc

Provides a type of shared memory on Android that is also shared with the GPU

- Written to directly by regular CPU code
- Used as a OpenGL texture

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- Gralloc implementation that allocates buffers through the DRM API
- Android “surfaces” are backed by DRM buffers and can be shared with Chrome using PRIME file descriptors

Ozone/Freon

Chrome platform abstraction layer beneath the Aura window system that is used for low level input and graphics

- Supports underlying systems ranging from embedded SoC targets to new X11-alternatives on Linux such as Wayland

ChromeOS devices that run ARC++ uses the Freon graphics stack

- Under the Freon driver model, the Chrome browser talks directly to the kernel's DRM/KMS APIs

GpuMemoryBuffer

- Allows platform independent code in Chrome such as the compositor take advantage of low-level graphics buffers
- Designed to support Chrome's multi-process architecture and security model
- Implementation backed by DRM buffers and PRIME file descriptors
- Extended for ARC++ with support for importing of foreign graphics buffers
  - Used by ARC++ to have Gralloc allocated DRM buffers imported into Chrome as GMBs

Pixel Formats

For a DRM buffer to be imported into Chrome the pixel format needs to be supported by Chrome

Chrome's support for pixel formats has been extended for ARC++

Format	**FourCC**	**Compositing**	**HW Overlay**
HAL_PIXEL_FORMAT_RGBA_8888	DRM_FORMAT_ABGR8888	Enabled	Enabled (Minnie)
HAL_PIXEL_FORMAT_RGBX_8888	DRM_FORMAT_XBGR8888	Enabled	Disabled
HAL_PIXEL_FORMAT_BGRA_8888	DRM_FORMAT_ARGB8888	Enabled	Disabled
HAL_PIXEL_FORMAT_RGB_565	DRM_FORMAT_RGB565	Enabled	Disabled
HAL_PIXEL_FORMAT_YV12	DRM_FORMAT_YVU420	Enabled	Disabled

Exosphere

Chrome component that provides the functionality needed for an external client to connect to Chrome

- Protects Chrome from malicious clients
- Efficient delivery and integration of graphics frames

Built on top of the GpuMemoryBuffer framework

- Takes advantage of Chrome's ability to import graphics buffers

Shared Window Mangement

- Some WM operations handled by Chrome (Ash) some by Android WM

WM Operation	Controller
Minimize	Ash
Maximize	Ash
Fullscreen	Ash
Close	Both
Activation	Both
Position	Android WM
Size	Android WM

Google

Chrome Compositor

Responsible for compositing contents from web pages and ChromeOS UI

- Clients produce frames in the form of a set of quads
- Each quad is typically backed by a GLES texture
- GpuMemoryBuffer framework allows these textures to ultimately be backed by GMBs
- Quads are rendered or scheduled as overlays by the compositor instance in the browser process

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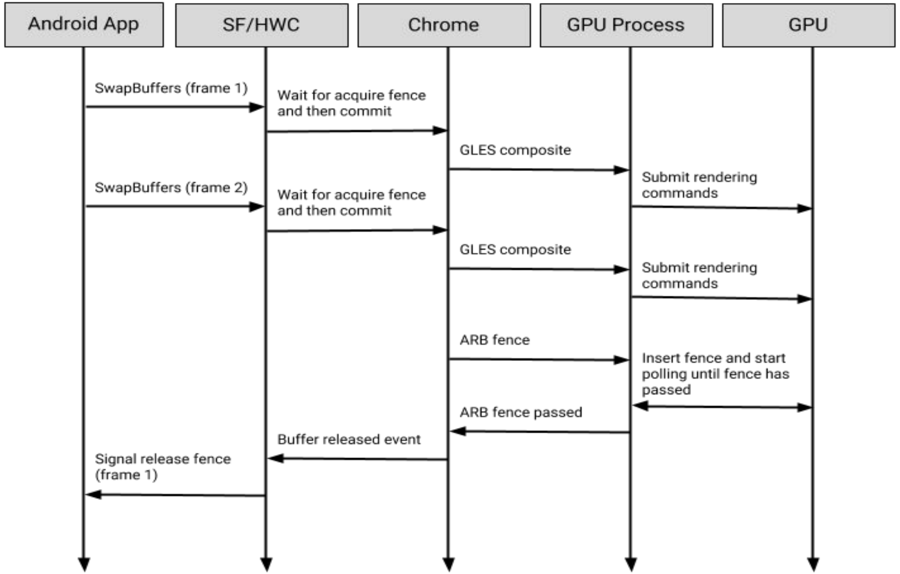
- Exosphere produces frames in the form of a number of quads
- Quads are backed by GMBs that have been created by importing the graphics buffers allocated by Android

Synchronization

Preventing Android from reusing a buffer before GPU has finished reading from it



Wayland

Protocol for a compositor to talk to its clients as well as a C library implementation of that protocol

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- Graphics, window management and input related communication between Android and Chrome

Benefits

- De facto protocol for secure compositor communication by Linux apps
- Provides well established interfaces for most of the communication needed between Android and Chrome
- New interfaces are easily added as needed for ARC++
- Existing world of Wayland clients provides an excellent set of examples and integration tests
- Offers maximum code reuse and minimizes the attack surface if we were to enable more generic container support

Wayland Interfaces

In addition to the core wayland protocol, Chromium implements the following interfaces

- wp_viewporter
- xdg_shell_v5 (zxdg_shell_v6 experimental)
- wl_drm
- zwp_linux_dmabuf_v1

Chromium Wayland Interfaces

cr_alpha_compositing

Allows the client to specify the blending equation and alpha value used for compositing

cr_gaming_input

Provide secure access to gaming input devices for a given seat (limited to gamepads today)

cr_aura_shell (aka remote_shell)

Extension to xdg_shell that provides additional shell functionality needed for ARC++

cr_secure_output

Allow surfaces to be marked as only visible on secure outputs

cr_stylus

Allows a wl_pointer to represent an on-screen stylus

cr_vsync_feedback

Informs the client about vertical synchronization timing in a precise way and without unnecessary overhead

Future Wayland Interfaces

- Explicit synchronization
    - Releasing buffers
    - Presentation timing
- Protected buffers
    - Digital rights management

Building and Testing

Exosphere code:
`src/components/exo/`

Wayland bindings code:
`src/components/exo/wayland/`

Wayland extensions:
`src/third_party/wayland-protocols/`

```
$ gn args out/exosphere
Contents of args:
target_os = "chromeos"
use_xkbcommon = true
```

$ ninja -C out/exosphere exo_unittests chrome

$ ./out/exosphere/chrome --enable-wayland-server

Questions?

THANK YOU