The Linux graphics stack, Optimus and the Nouveau driver

Cooperative rendering across GPUs on Linux

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Summary

General overview of the Linux Graphics stack

The graphics stack before 2005

- The X-Server provided everything:
  - Modesetting (CRTC & plane management);
  - 2D/3D acceleration;
  - Video rendering acceleration;
  - Input management.
- The X-Server talked to the GPU directly, as root.

The current graphics stack

- The X-Server got split into more than 200 components:
  - Privileged operations moved to the kernel;
  - 2D drivers got put into different shared objects;
  - 3D acceleration got put in mesa;
  - The list is too long (and boring) ;)

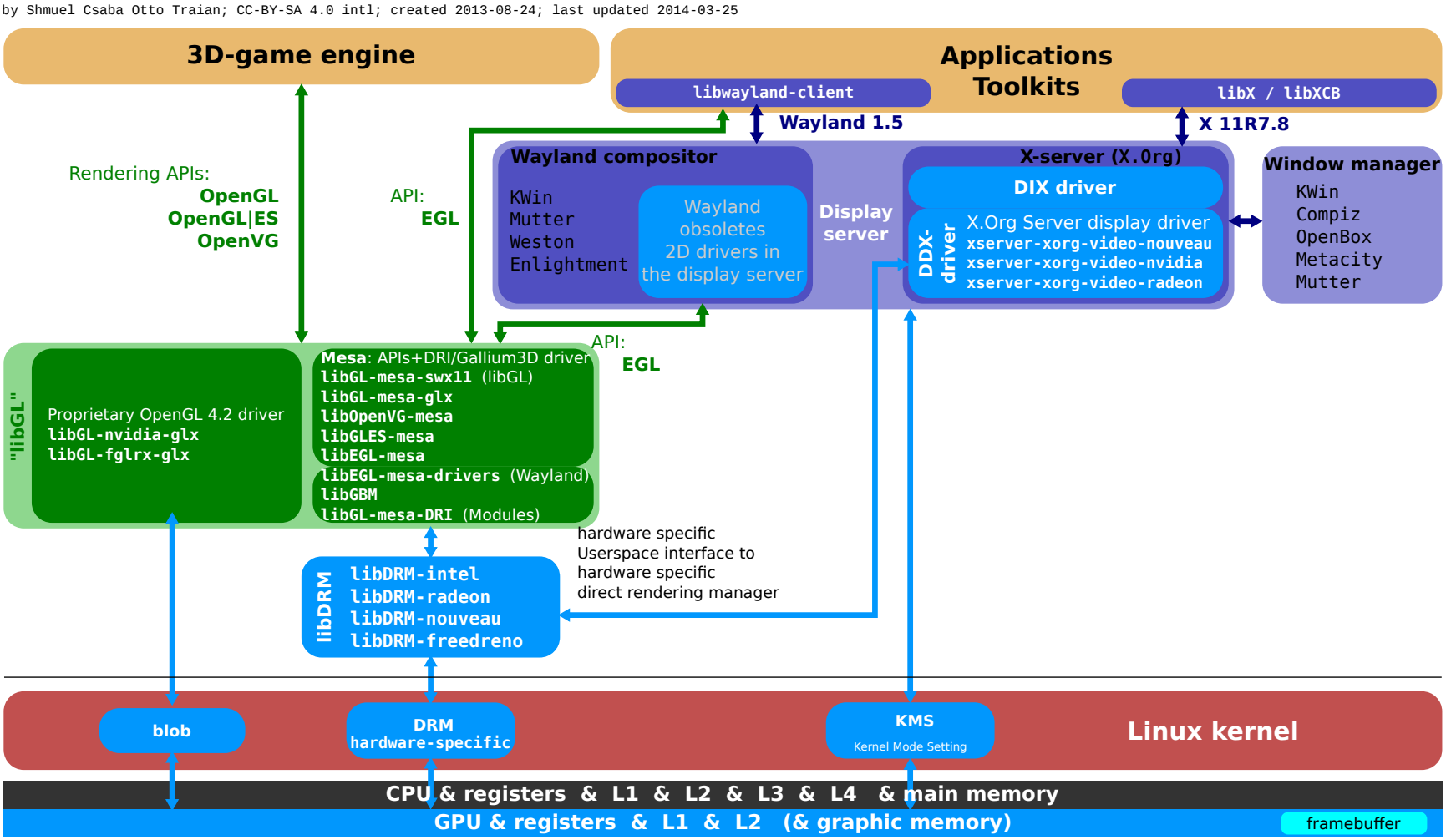


Figure: General overview of the Linux graphics stack

The kernel space

Direct Rendering Manager (DRM) : The common code

- This common code provides:
  - Kernel ModeSetting (KMS): CRTC & plane management;
  - Video memory management via GEM (with a TTM backend?);
  - Nodes with different capabilities (master or render nodes).

DRM open source drivers

- i810/i915: Intel;
- nouveau: NVIDIA;
- radeon: AMD/ATI;
- vmwgfx: VMware;
- many SoC GPUs (armada, exynos, msm, omap, tegra, ...).

Architecture of the X-Server

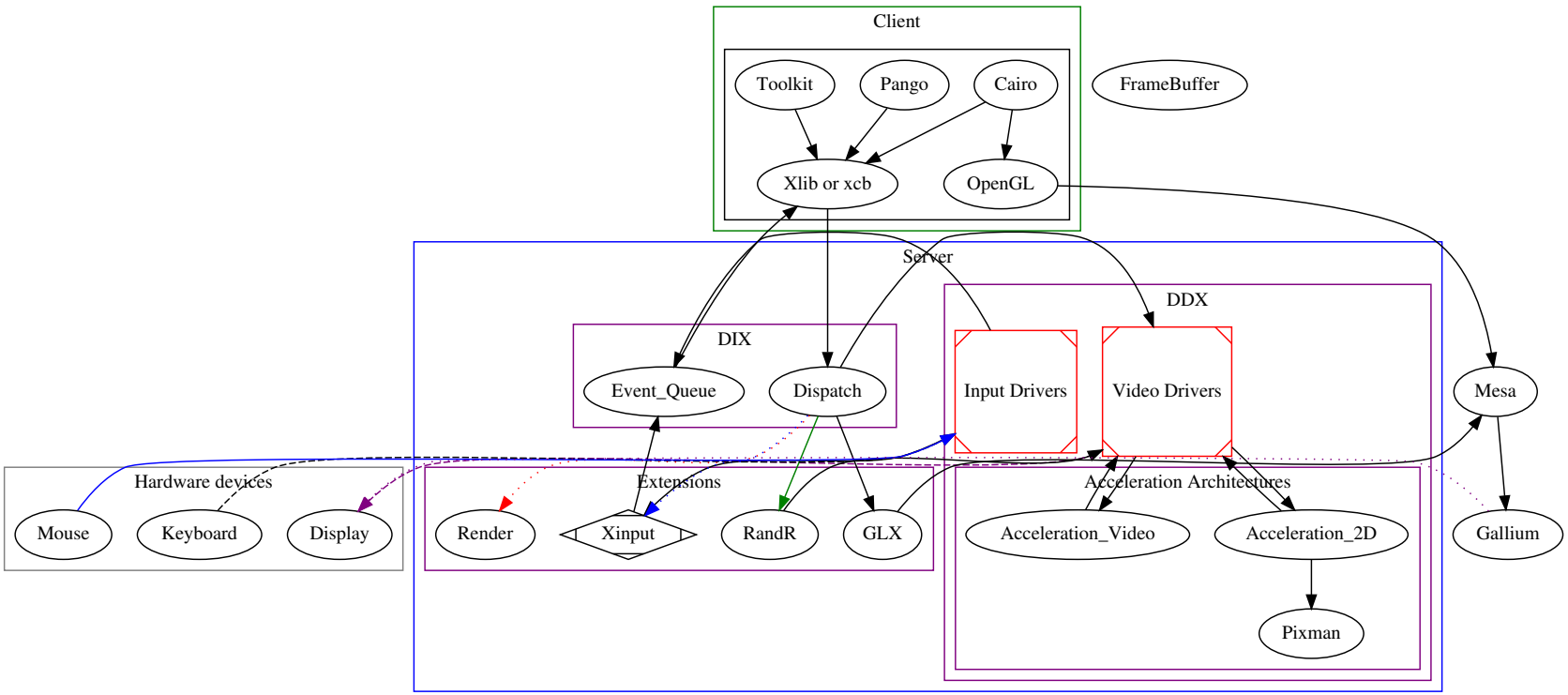


Figure: General overview of the X-Server's internal architecture

Architecture of Mesa

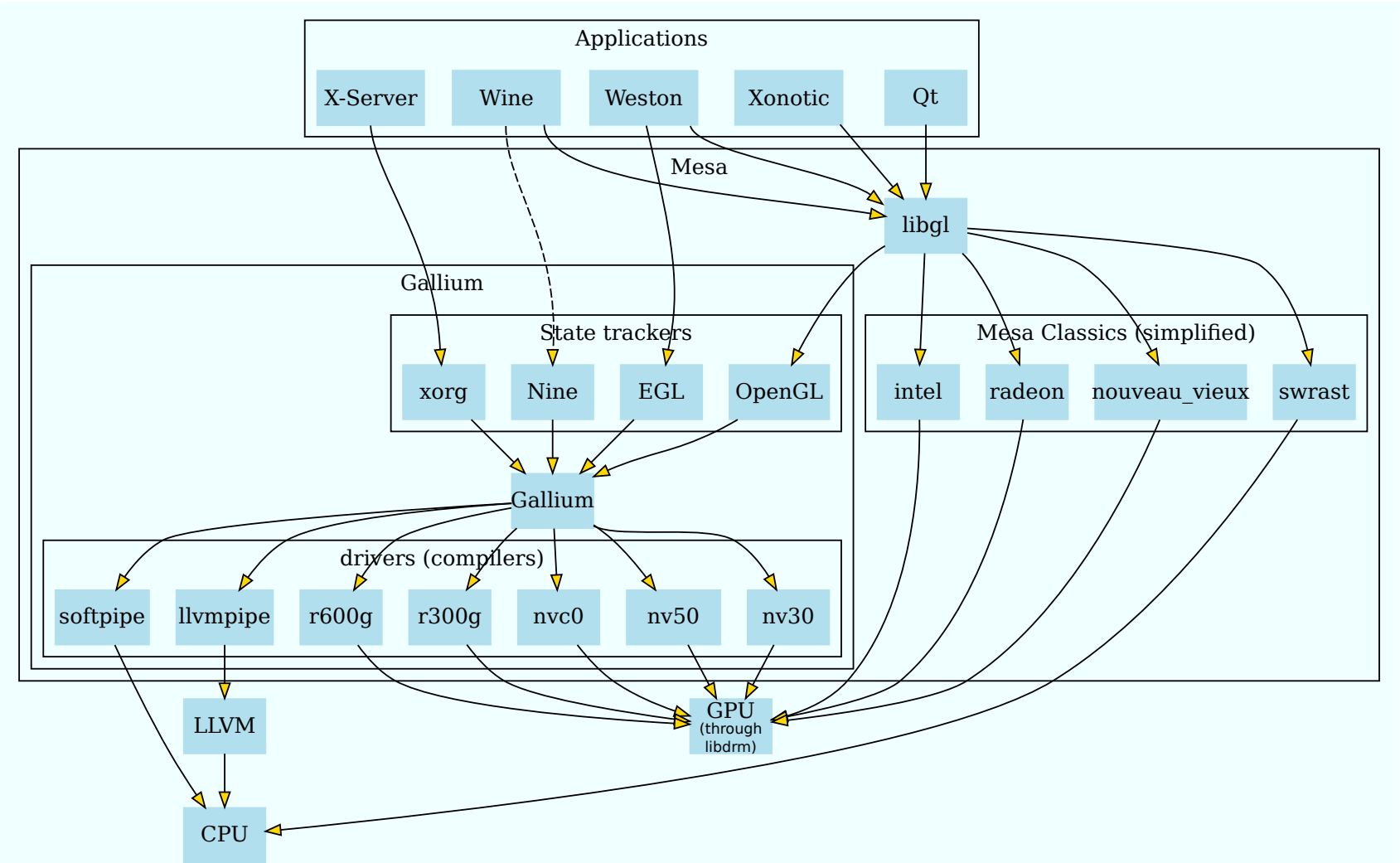


Figure: General overview of Mesa's internal architecture

Summary

Great performance, great battery-life

Optimus

- Laptops can be equipped with two GPUs;
- The Intel IGP is great for battery-life;
- NVIDIA's discrete GPU (dGPU) is great for performance;
- Dynamic switch between the 2: get the best of both worlds!

Challenges

- When/How the dGPU should be turned on/off?
- Who drives the outputs?
- How to copy buffers from one driver to another?
- How should we do application migration?
- How should we handle the HDMI "sound card"?

Turning the dGPU on/off

How

- Optimus laptops have ACPI functions to do that;
- Two ways of calling them:
  - bbswitch: Old kernel module for manual management;
  - vgaswitcheroo: Manual or automatic power management.

When: The case of vgaswitcheroo

- Turn off the dGPU when it has been idle for 5 seconds;
- Idle?:
  - no graphics context allocated;
  - no output is being used;
  - no sound interface used (not done);
  - no call to the drm driver has been made;

Handling the outputs : Hardware multiplexer

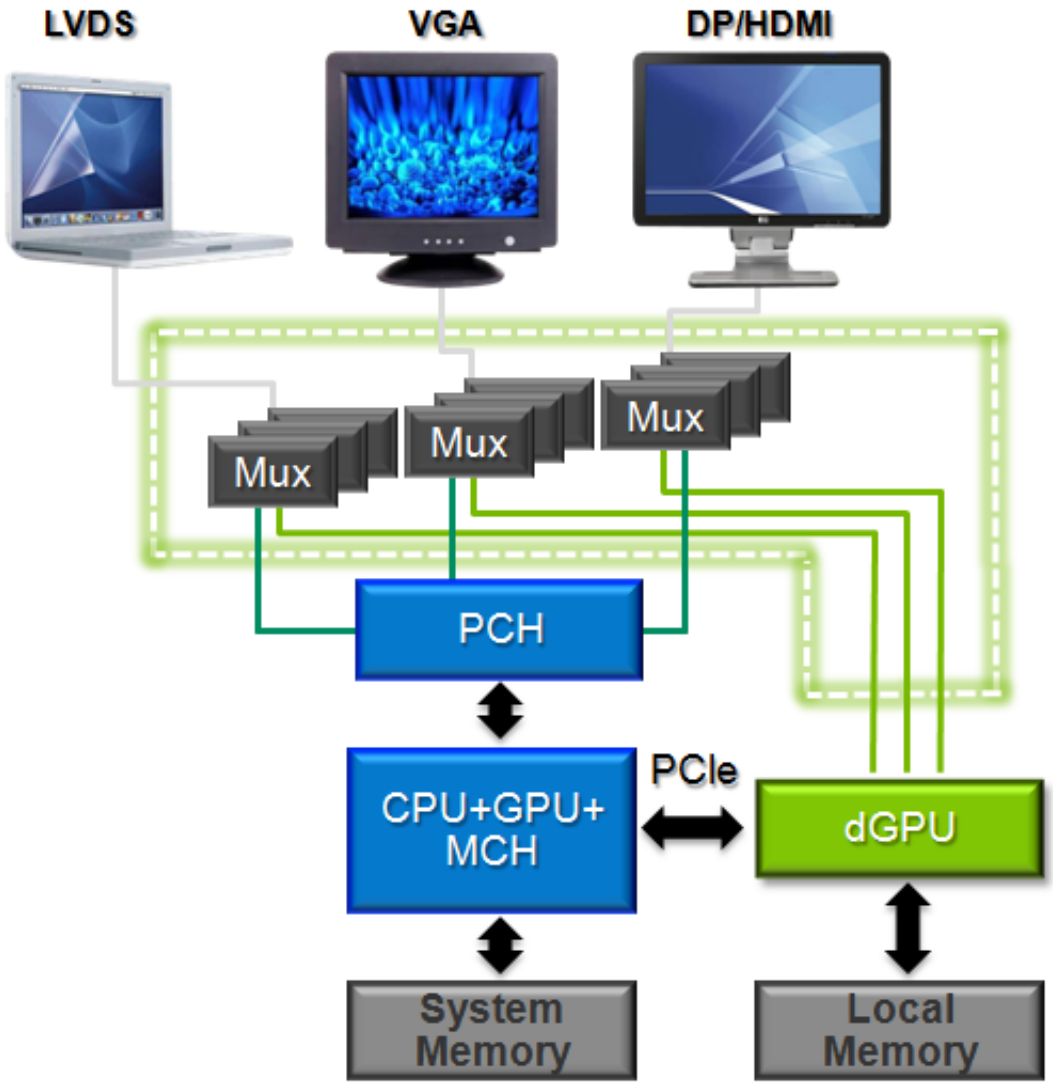


Figure: Switchable graphics

Handling the outputs : Software multiplexer

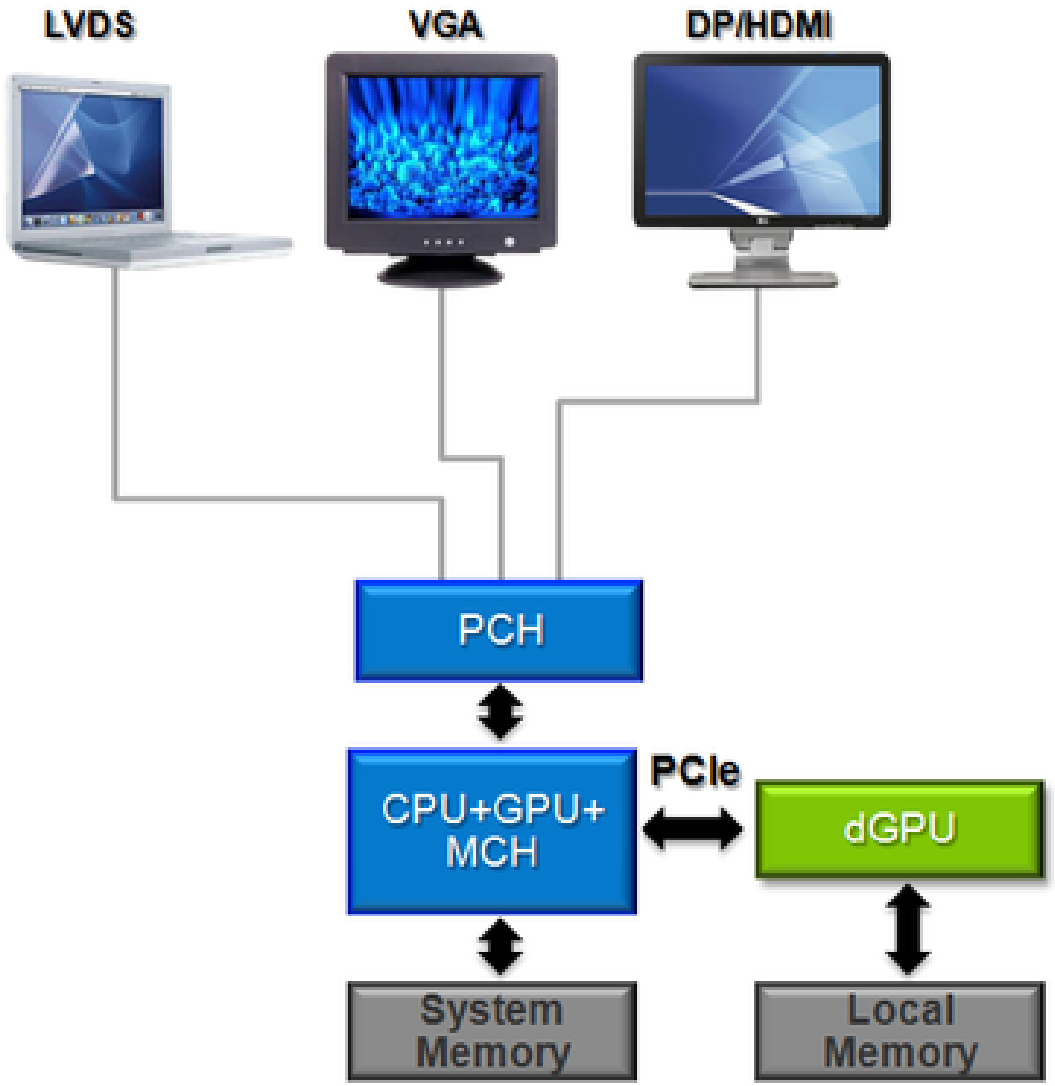


Figure: The “real” Optimus architecture

Sharing buffers across drivers

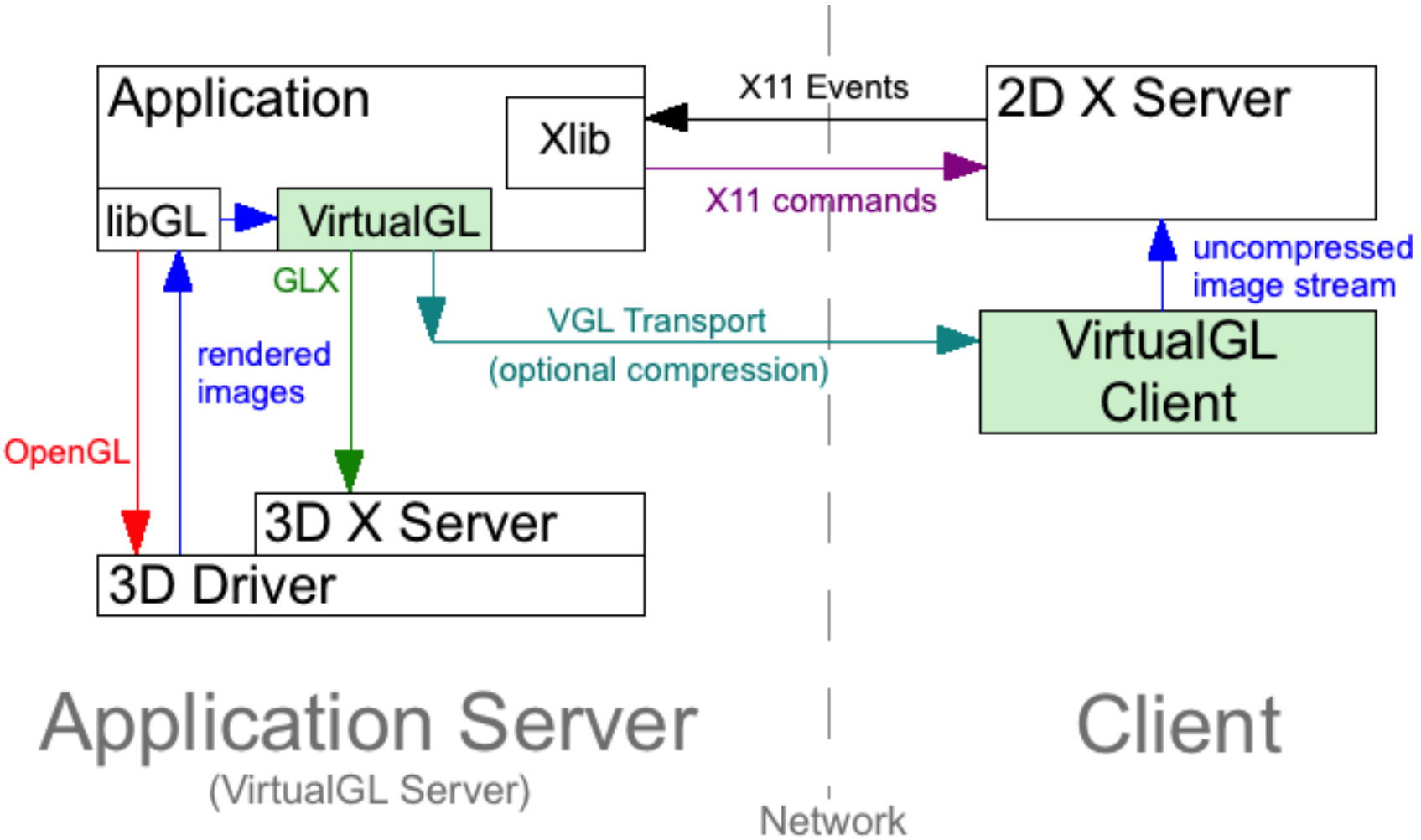
Cross-driver BO sharing : Challenges

- The memory representation for buffers is different from hardware to hardware:
  - pitch: number of pixels per row;
  - tiling: technique that increases the spatial locality.
- Synchronising rendering across drivers.

Solutions

- VirtualGL: Remote rendering solution that redirects rendering commands to a distant GPU and read back to rendered frame;
- Primus: Same solution as VirtualGL except in a more lightweight fashion!
- DMA-Buf: A Linux-only solution that allows sharing buffers between different GPUs without copies.

Sharing buffers across drivers : VirtualGL



Sharing buffers across drivers : DMA-Buf

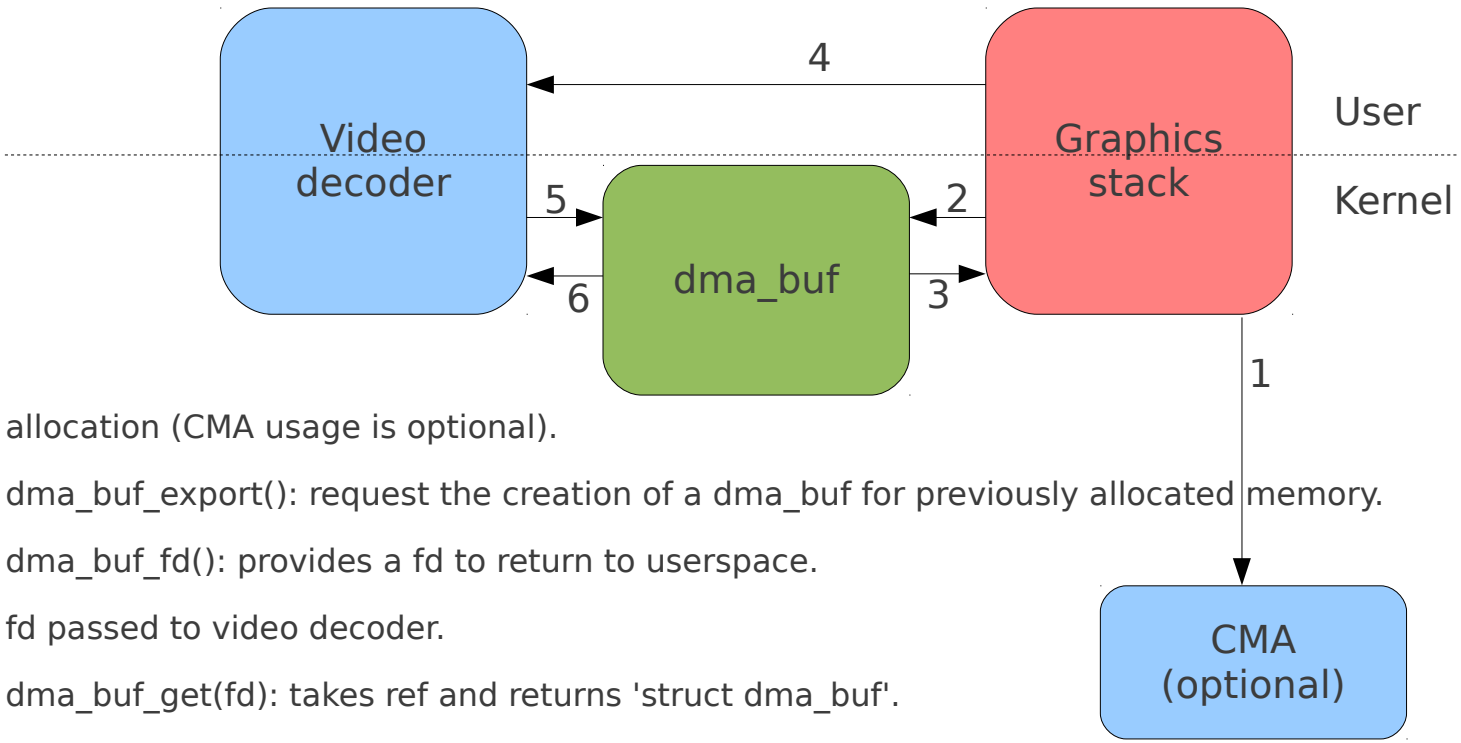
Driver roles

- Exporter: Being able to export a buffer;
- User: Being able to import a buffer.

General overview

- No standardised memory allocation: It's up to the exporter;
- An arbitrary buffer can be wrapped into a DMA buffer;
- An fd can be returned to the userspace to reference this buffer;
- The fd can be passed to another process;
- The fd can be mmapped and accessed by the CPU;
- The fd can be imported by any driver supporting the user role.

dma_buf usage flow



1) allocation (CMA usage is optional).

2) dma_buf_export(): request the creation of a dma_buf for previously allocated memory.

3) dma_buf_fd(): provides a fd to return to userspace.

4) fd passed to video decoder.

5) dma_buf_get(fd): takes ref and returns 'struct dma_buf'.

6) dma_buf_attach() + dma_buf_map_attachment(): to get info for dma

   a) dev->dma_parms should be expanded to tell if receiving device needs contiguous memory or any other special requirements

   b) allocation of backing pages could be deferred by exporting driver until it is known if importing driver requires contiguous memory.. to make things a bit easier on systems without IOMMU

How should we do application migration?

Short answer

We don't!

Why?

- The context is hardware-dependent;
- The context can be HUGE (hundreds of MB);
- The best way is to ask the application to re-upload its context: GL_ARB_robustness.

Optimus : How windows does it

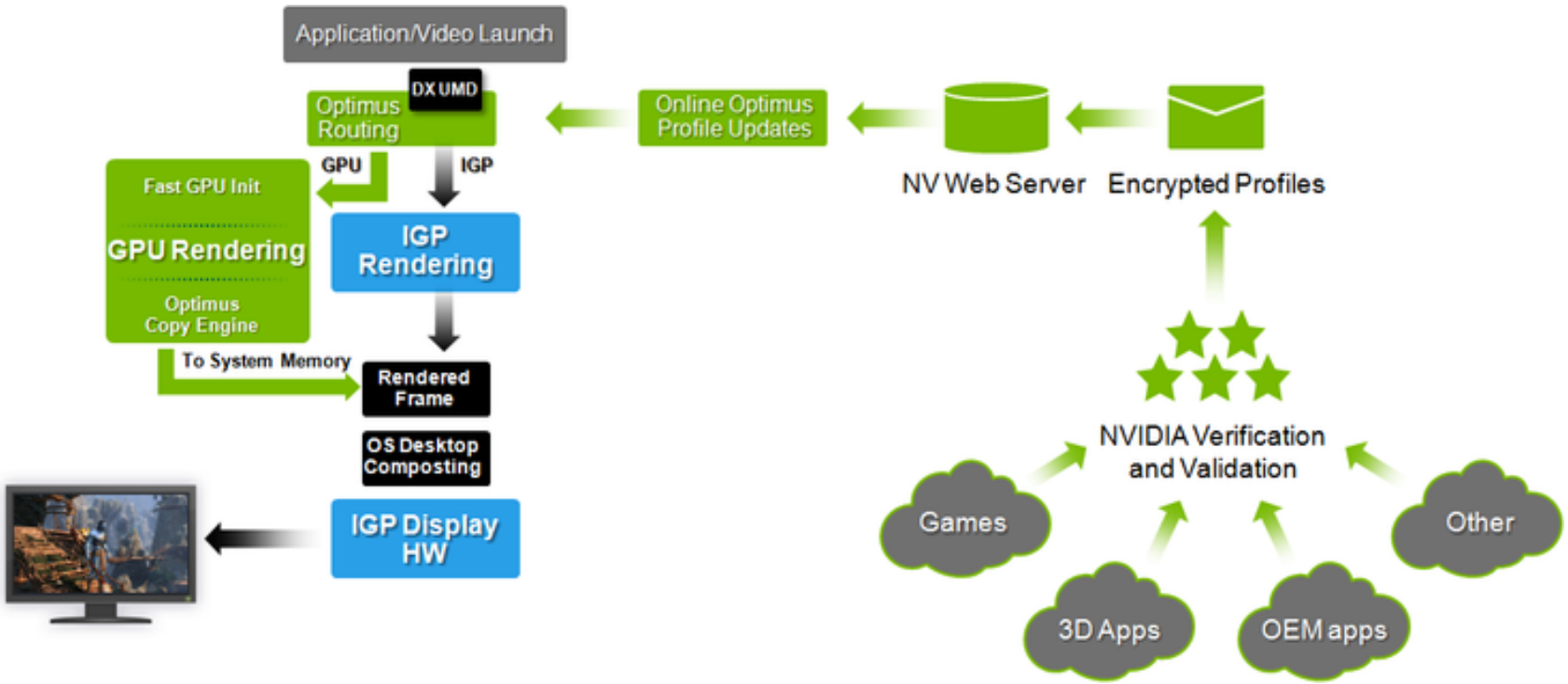


Figure: The global hardware/software infrastructure

Summary

Prime

Prime

Prime is the name for all the ustream open source technologies that make hybrid graphics possible:

- DMA-Buf: sharing buffers across drivers (Linux 3.3);
- vgaswitcheroo: switching graphics (Linux 3.12);
- Cross-device fence mechanism: make a driver wait on another driver to complete a task (Linux 3.17);
- DMA-Buf synchronisation: Wait for rendering completion of a DMA-Buf before compositing to avoid tearing (Linux 3.19?).

List of requirements

- running nouveau/radeon drm;
- running the nouveau/radeon ddx;

Prime: Simplified how-to for Nouveau

vgaswitcheroo

- # cd /sys/kernel/debug/vgaswitcheroo/
- # cat switch
- # echo (DIGD|DDIS) > switch
- (Re)start your desktop environment.

XRandr

- $ xrandr −−listproviders
- $ xrandr −−setprovideroffloadsink nouveau Intel
- This sets the order: Nouveau == offload, Intel == default

Prime: Simplified how-to for Nouveau

Usage

- DRI_PRIME=1 glxgears # Use the NVIDIA GPU
- DRI_PRIME=0 glxgears # Use the Intel GPU
- glxgears # Use the Intel GPU

Longer How-to for Nouveau

`http://nouveau.freedesktop.org/wiki/Optimus`

Prime: Demos

Current setup

- This is an Optimus laptop (Sandy Bridge + NVIDIA NVD9);
- All the outputs are connected to the Intel IGP.

List of demos

- Selecting the GPU and checking with glxinfo;
- Performance difference in glxgears;
- Video decoding with VDPAU on the NVIDIA GPU.

Summary

Nouveau: Introduction

Nouveau: An Open Source Linux driver for NVIDIA GPUs

- Merged in Linux 2.6.33 & left staging on Linux 3.4;
- Mostly developed by Red Hat and students.

Current features

- Modesetting support for almost all NVIDIA GPUs;
- 2D, 3D and video-rendering accel on NV04-;
- Video decoding accel on NV40-NV117 (non-free).

Nouveau: Current developments

Current work

- Maxwell support:
  - Released in two times (March then September);
  - Modesetting: DONE;
  - 2D/3D support: MOSTLY DONE;
  - Video decoding: TODO
  - Open source firmware: WIP
- Manual reclocking support:
  - nv40-a3: crude support, disabled by default;
  - nva3-ac: good chances of working;
  - Fermi: crude support, disabled by default;
  - Kepler: WIP, good chances of partial support;
  - Maxwell: TODO
- Adding new OpenGL extensions:
  - Everything is done up to Fermi;
  - OpenGL 4 for the other GPUs.

Involvement from NVIDIA

NV

- 1998(?): NVIDIA releases "nv", a Linux OSS 2D driver;
- 1998: Obfuscation commit, release only pre-processed source.

Little hope of NVIDIA ever working again on an OSS driver

"It's so hard to write a graphics driver that open-sourcing it would not help [...] In addition, customers aren't asking for opensource drivers."
Andrew Fear, NVIDIA software product manager, April 2006

Short history of Nouveau

Nouveau

- 2005: Stephane Marchesin improves nv and works on 3D
- 2008: Open Arena runs on nv40
- 2009: KMS driver based on TTM for memory management
- 2010: Merged in Linux 2.6.33
- 2010: Nv is deprecated by NVIDIA, “use VESA”.

A new hope from NVIDIA

- September 2013: NVIDIA releases some vbios documentation;
- January 2014: NVIDIA starts adding support for their Tegra K1 in Nouveau, as requested by its clients;
- Full support for the Tegra K1 expected by the end of 2014.

Summary

Questions?

Thank you for listening! Questions?

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