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;
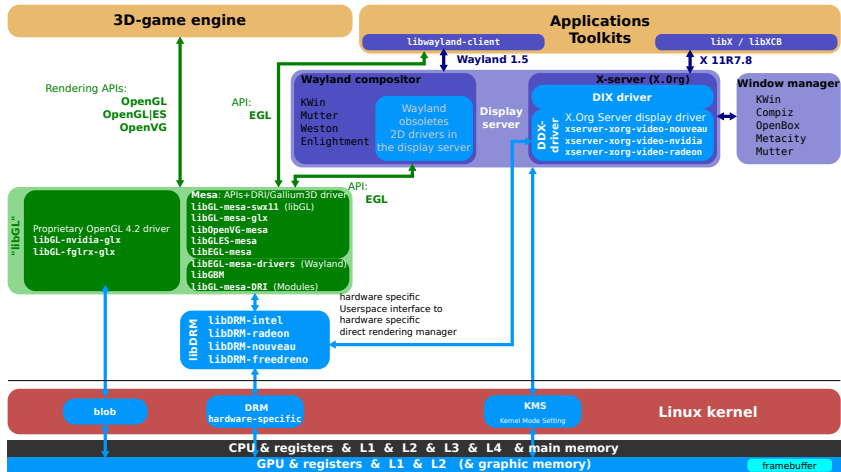 - The list is too long (and boring) ;)

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, ...).
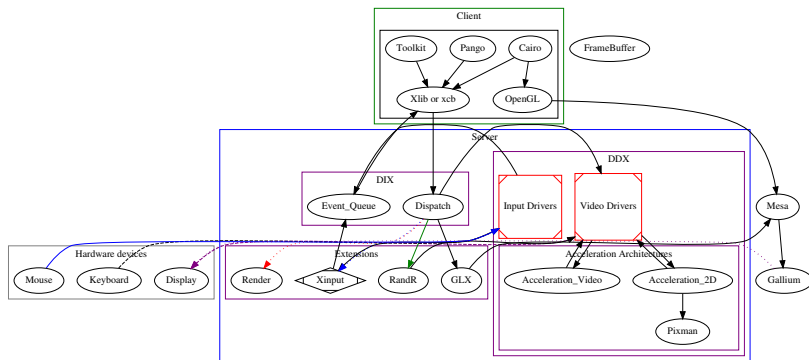
Architecture of the X-Server

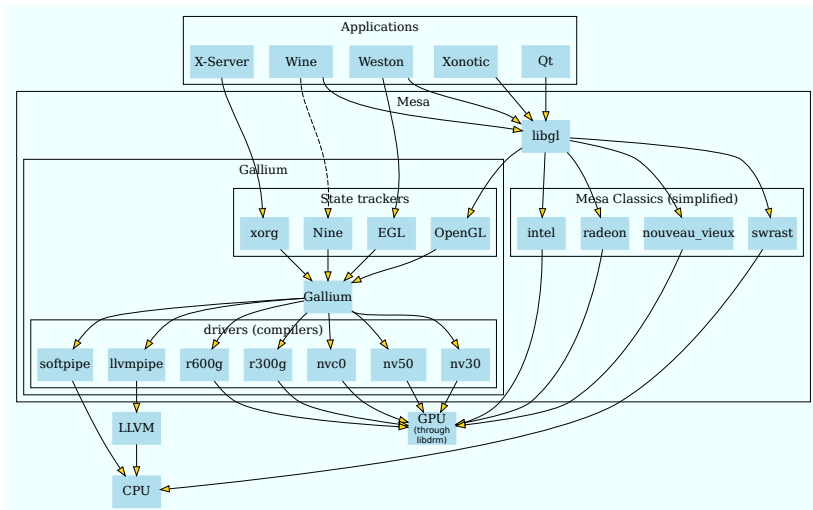Figure: General overview of the X-Server's internal architecture

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 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
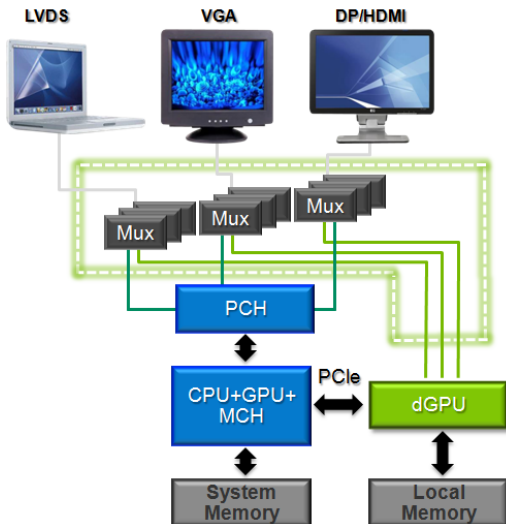

Figure: Switchable graphics

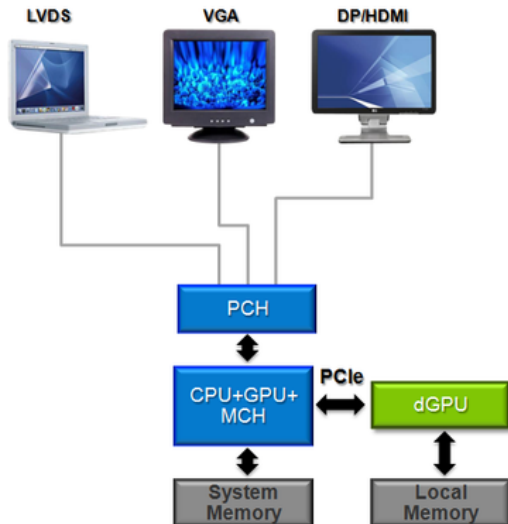## Handling the outputs : Software multiplexer

Figure: The "real" Optimus architecture

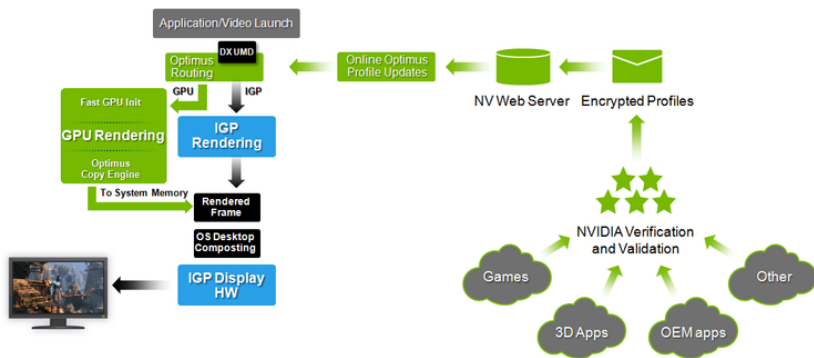# Switching from one GPU to another : How windows does it

Figure: The global hardware/software infrastructure

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.

Summary

1 Introduction to the Linux graphics stack

2 Optimus

3 Prime
- Introduction
- How to
- Demos

4 Nouveau

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Prime

Prime

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

- vgaswitcheroo: switching graphics (Linux 2.6.34);
- DMA-Buf: sharing buffers across drivers (Linux 3.XX);
- 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;
- 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 (April 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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