Embedded Graphics Drivers in Mesa

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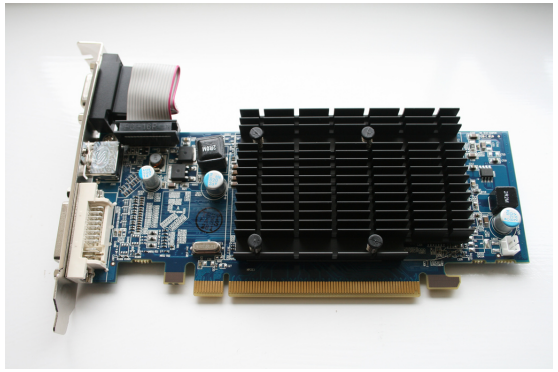
Overview

About GPUs

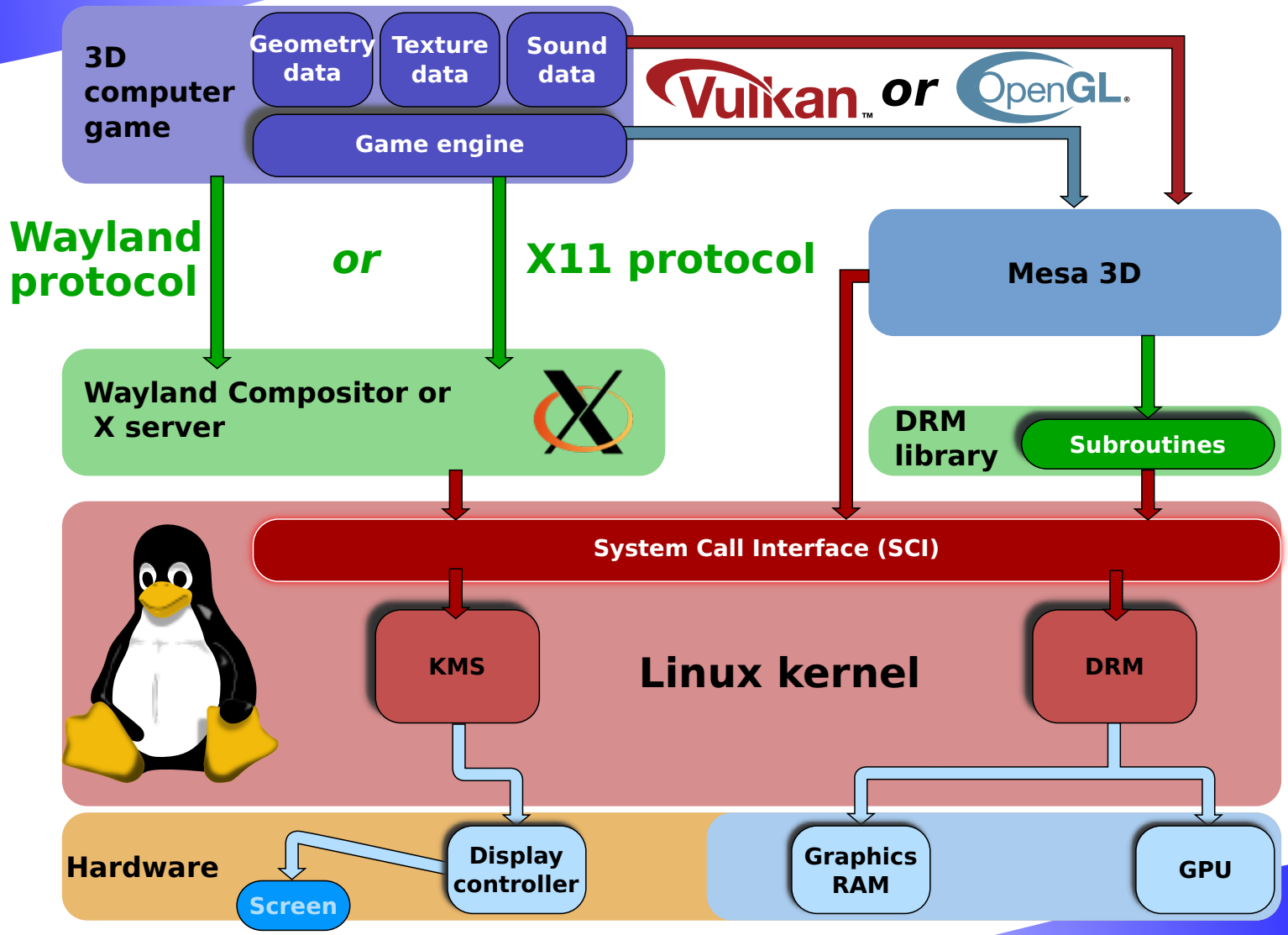
- It is a specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display device. Wikipedia.



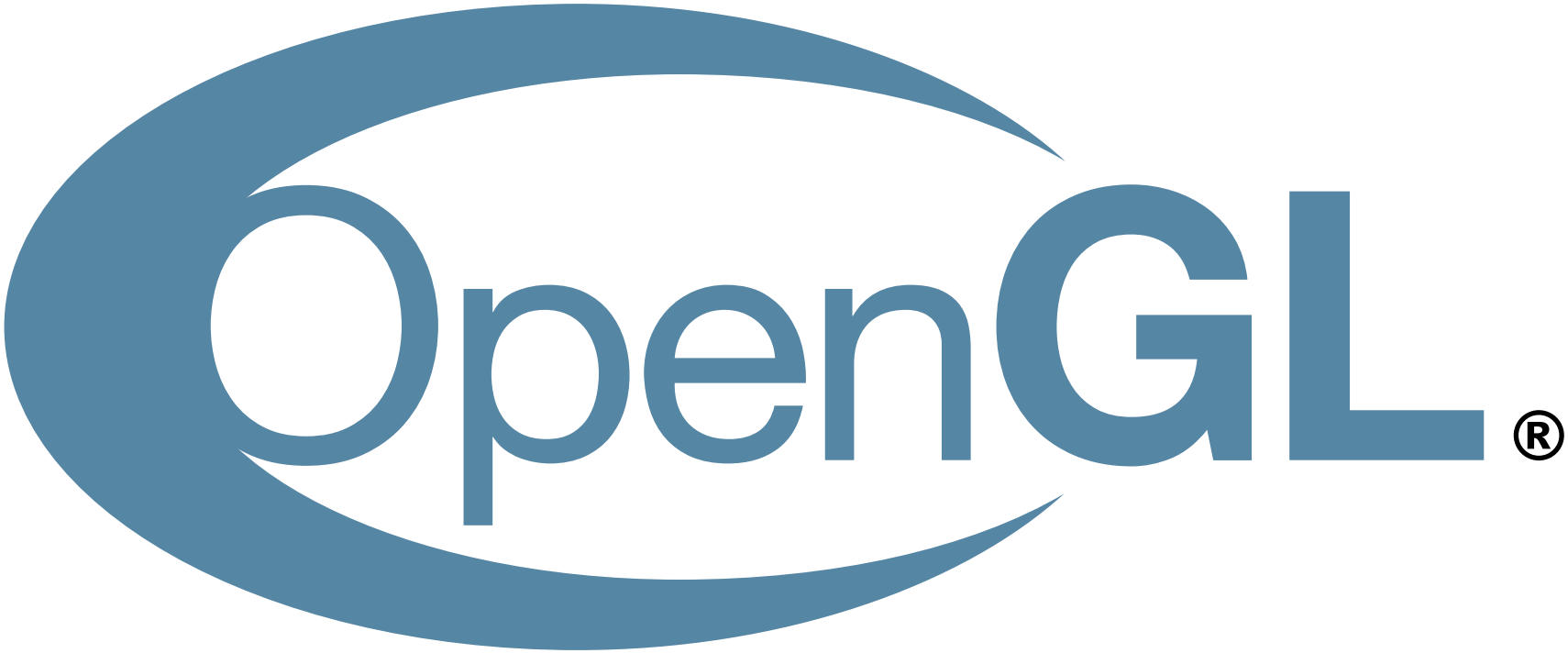
- They are becoming increasingly general purpose processors that can run programs (shaders).
- They are highly threaded and typically use SIMD to operate on multiple inputs at the same time.
- Still contain fixed function pieces for graphics-specific functions:
  - Texture sampling
  - Primitive assembly
  - etc

Linux graphics stack

based on diagram by Shmuel Csaba Otto Traian; GNU FDL 1.3+ and CC-BY-SA 3.0+; created 2014-03-02, last updated 2015-05-30



Graphics APIs


OpenGL®

- OpenGL 1.0 was released in January 1992 by Silicon Graphics (SGI).
- Based around SGI hardware of the time which had very fixed functionality.
- Eg, explicit API to draw a triangle with a colour:

```
/* Set a blue colour */
glColor3f(0.0f, 0.0f, 1.0f);
/* Draw a triangle, describing its points */
glBegin(GL_TRIANGLES);
 glVertex3f(0.0f,1.0f,0.0f);
 glVertex3f(-1.0f,-1.0f,0.0f);
 glVertex3f(1.0f,-1.0f,0.0f);
glEnd();
```

- In 2004 OpenGL 2.0 was released.
- Introduced the concept of shaders.
- Can now influence the rendering with programs called shaders.
- Eg, choose a colour programatically:

```
void main()
{
        /* Choose the colour based on the X-position of the pixel */
        gl_FragColor = vec4(gl_FragCoord.x * 0.008 - 1.0, 0.0, 0.0, 1.0);
}
```

- In later versions of GL more and more functionality is moved into the programmable shaders.
- Much more programmable, much less fixed-function.
- Inputs are more often given in buffers rather than via API calls.
- Eg, vertex data now in a buffer:

Buffer containing vertices

```
# Position      Colour
-1 -1           0xff0000ff
0  -1           0xff0000ff
-1 0            0xff0000ff
0  -1           0xff0000ff
-1 0            0xff0000ff
0  0            0xff0000ff
```

Commands describing buffer layout

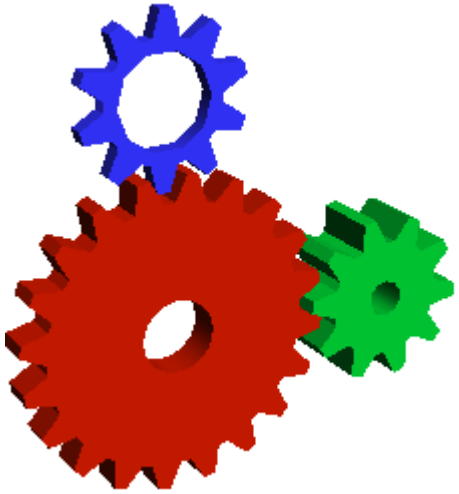
```
glVertexAttribPointer(0, 2, GL_FLOAT,
                      GL_FALSE, 12, 0);
glVertexAttribPointer(1, 4, GL_UNSIGNED_BYTE,
                      GL_TRUE, 12, 8);
```

OpenGL ES

- Simplified version of OpenGL targetting embedded devices.
- Removes most of the legacy cruft and things that are hard to implement in hardware.
- Is increasingly similar to modern versions of OpenGL which also try to deprecate old functionality.


Vulkan
TM

- Vulkan 1.0 released in 2016
- Clean break from legacy OpenGL
- Much less driver overhead
- Everything is specified in buffers
- The application has the responsibility to manage buffers and synchronisation.
- Harder to use but allows applications to exploit the hardware better
- Suitable for both embedded and desktop hardware



Mesa

- Open-source implementation of the OpenGL and Vulkan specifications for a variety of hardware on user-space as a library.
- The Mesa project was originally started by Brian Paul.
  - Version 1.0 released in February 1995.
  - Originally used only software rendering
  - Now has support for many different hardware devices
  - Current version is 18.0.

- There are drivers for:
  - Intel (i965, i915, anv)
  - AMD (radv, radeonsi, r600)
  - NVIDIA (nouveau)
  - Imagination Technologies (imx)
  - Broadcom (vc4, vc5)
  - Qualcomm (freedreno)
  - Software renderers (classic swrast, softpipe, llvmpipe, OpenSWR)
  - VMware virtual GPU
  - Etc

- Supports:
  - OpenGL 4.6
  - OpenGL ES 3.2
  - Vulkan 1.1
- All are the latest versions
- Caveat: not all drivers support the latest version

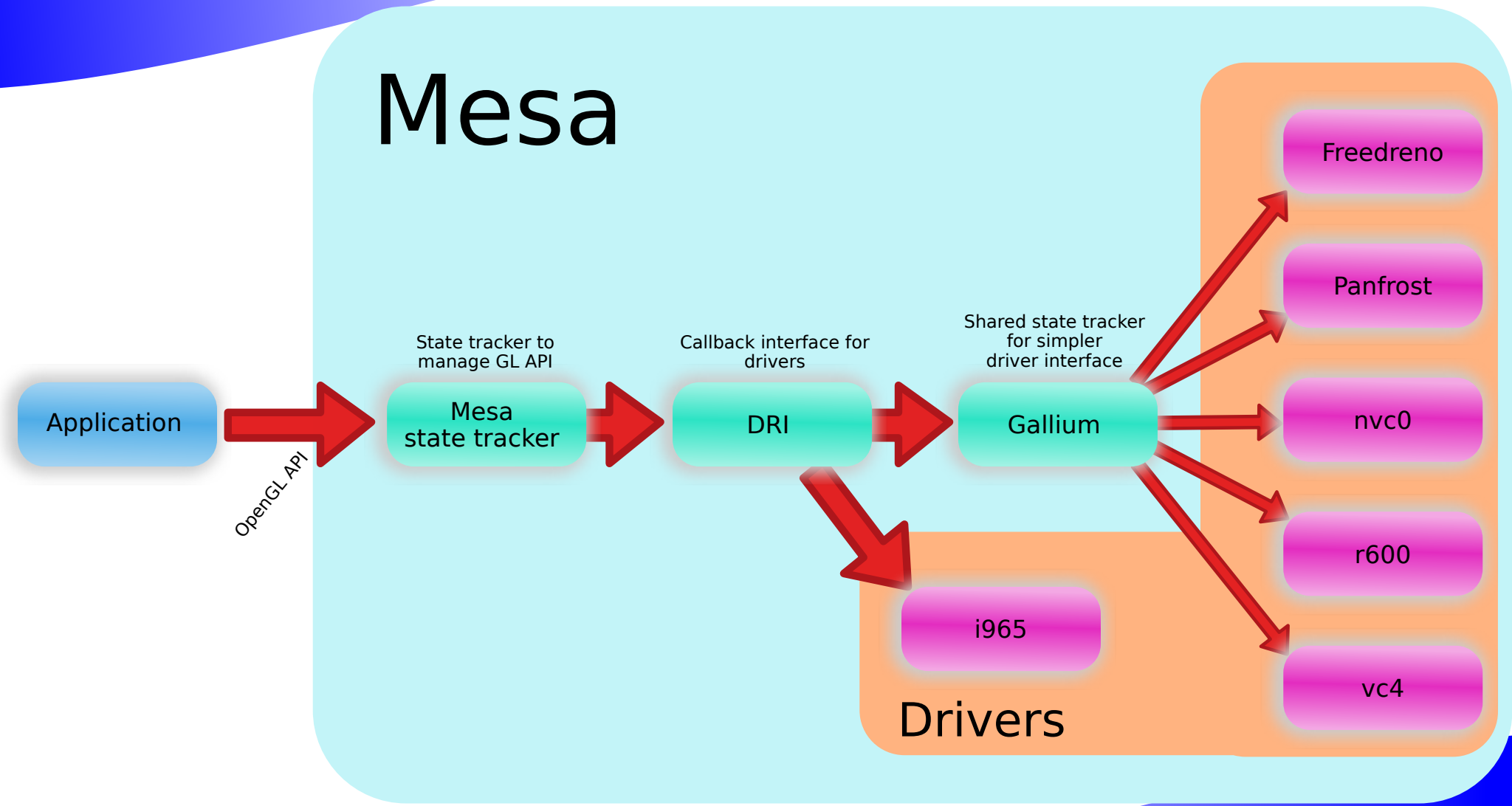
Mesamatrix

Leaderboard

There is a total of **249** extensions to implement. The ranking is based on the number of extensions done by driver.

#	Driver	Extensions	OpenGL	OpenGL ES
1	mesa	(95.6%) 238	4.6	3.2
2	radeonsi	(92.0%) 229	4.5	3.2
3	i965	(91.2%) 227	4.6	3.2
4	nvc0	(88.4%) 220	4.5	3.1
5	r600	(81.5%) 203	4.5	3.1
6	virgl	(80.7%) 201	4.3	3.2
7	softpipe	(74.7%) 186	3.3	N/A
8	freedreno	(70.3%) 175	3.1	3.1
9	llvmpipe	(69.5%) 173	3.3	N/A
10	nv50	(61.0%) 152	3.3	N/A
11	swr	(60.2%) 150	3.3	N/A
12	etnaviv	(25.7%) 64	N/A	N/A

Architecture of Mesa


Mesa
Application
OpenGL API
State tracker to manage GL API
Mesa state tracker
Callback interface for drivers
DRI
Shared state tracker for simpler driver interface
Gallium
Freedreno
Panfrost
nvc0
r600
vc4
i965
Drivers

Embedded drivers

Freedreno

Panfrost

Broadcom

Thanks.

Questions?