Allocation Constraint Sets

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Problem Statement

- Hardware places “constraints” on memory allocations because memory access logic contains limitations
- The limitations may depend on how the hardware is used
- Historically, these are accounted for by the hardware’s driver
- Problems arise when sharing memory between two devices or engines
    - No single driver aware of all limitations anymore
- How does one allocate memory compatible with a given set of devices?
    - iGPU/dGPU “PRIME” sharing, video encode/decode/capture + GPU processing, etc.

Definitions: Constraint

- An atom defining a single limitation of the memory access capabilities exposed by a device or engine
- Examples: address or pitch alignment, maximum buffer size or pitch, locality, contiguity, bank placement or interleaving
- Atomic: each constraint expresses a non-decomposable fully defined, limitation
- Can be mergeable
    - (min pitch alignment 4) + (min pitch alignment 6) = (min pitch alignment 12)

Definitions: Usage

- Description of data stored in and operations to be performed on memory
- Examples: Pixel/Texel format, texturing, rendering, video encode/decode/capture, display at particular resolution and rotation
- May vary in detail depending on API or driver

Definitions: Constraint Set

- A list of individual constraints imposed on memory by a given usage
- Can be merged
- Merging multiple constraint sets results in a constraint set expressing the constraints imposed by the superset of the usage associated with each input constraint set
- Merging two constraint sets results in a set containing at most the sum of the number of elements in each input set
    - i.e., merging must not in itself generate new constraints

(surf align >= 64)
(pitch align >= 64, surf align >= 128)

(surf align >= 128, pitch align >= 64)

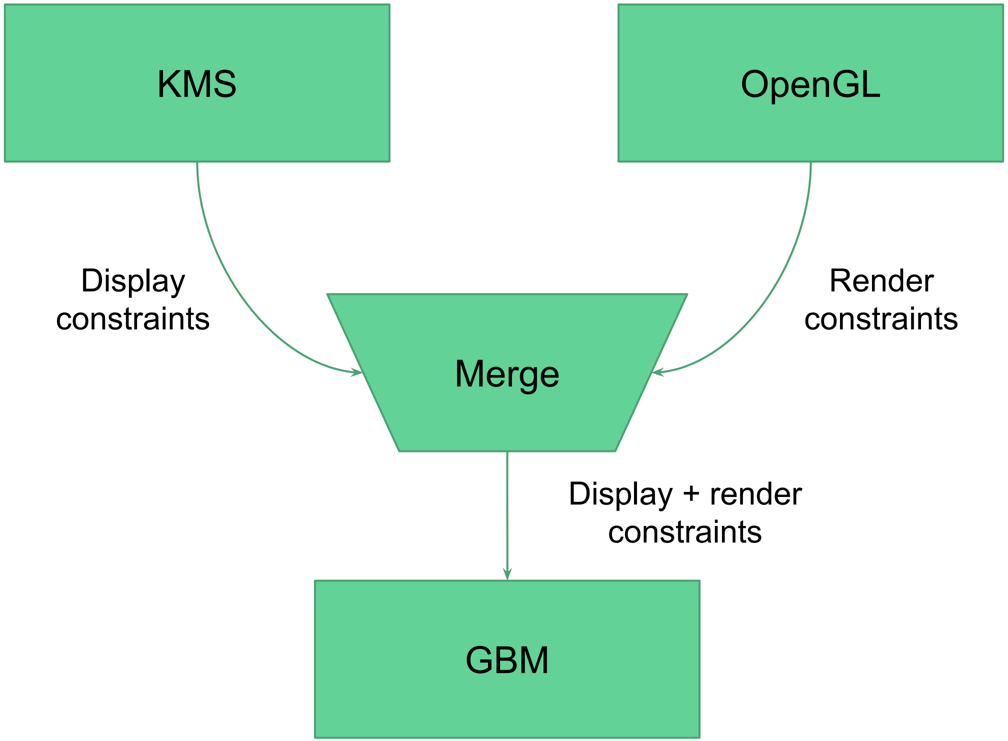
Design Goals

- Integrate with existing ecosystem
  - OpenGL, Vulkan, DRM-KMS, GBM, V4L, etc.
- Extensible
- Focus on constraint resolution alone
  - Not trying to solve allocator choice, IOMMU discovery/programming, etc.

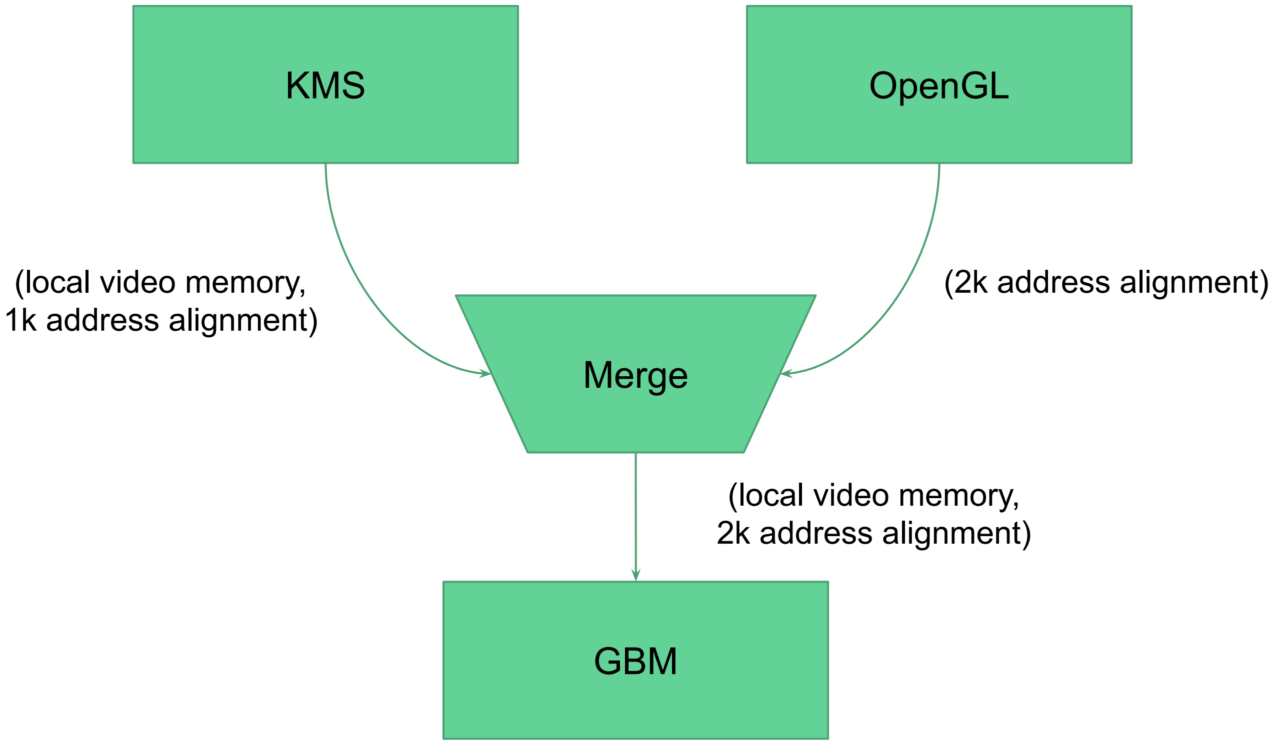
High-Level Design Proposal

- Leverage existing API mechanisms to describe usage
  - Vulkan image properties, OpenGL formats/texture parameters, DRM-KMS planes, etc.
- Query constraints from existing APIs for a given usage in that API
  - Very similar to existing format modifier reporting and query APIs
- Constraints are reported separately for each modifier supported by a usage
  - E.g., set of constraints generated for ***each*** format+modifier[+external_only] tuple in OpenGL
- Provide logic to merge constraint sets
- Pass resulting constraint set to allocation API of choice at allocation time

Example Usage: Rendering and Displaying



Example Usage: Rendering and Displaying



Case Study 1: Pitch Alignment Requirements

- Min pitch alignment: NV = 32 or 256, AMD* = 256, Intel* = 1, Bpp, or 64
- Want a surface that can be displayed, textured, and rendered to on all GPUs
- Query list of modifiers for each device, specifying this usage
  - Pointless here, given the layout is going to be linear
- Intersect modifiers
- Query and merge constraints for each usable modifier, specifying usage again
  - Merge operation for this type of constraint: Find least common multiple of all values

Case Study 1: Lessons

- Applicable to all minimum alignment: offset, pitch, width, height, etc.
- Generalizes to maximums and minimums by using other merge operators
- Relatively simple to code up and visualize

Case Study 2: Local (Video) Memory

- Discrete NVIDIA display engines can only scan out from video memory
- Naive solution is simple: a value-less constraint of type “local”
- Problem 1: Local to what? Could be many devices with local memory
- Problem 2: How local? Some devices have multiple local heaps of memory
- Proposed Solution: Constraint contains a list of heap supported IDs
- Each device can expose multiple heap IDs
- Heap IDs could be namespaced by subsystem (dma-buf heaps, DRM, etc.)
- Merge two locality constraints by intersecting heap list

Case Study 2: Lessons

- Constraint merging can fail: The intersected list may be empty!
- Likely need a “regular memory” heap or heaps that are universally recognized
    - Not necessarily universally supported
    - Should lack of a heap constraint imply compatibility only with the “regular memory” heap?
- The development of a good Heap ID mechanism is a large task by itself

Case Study 3: Unknown Constraints

- Design disperses constraint knowledge throughout system components
- The system components cannot realistically be version locked
  - E.g., old kernel, new userspace, or vice-versa
- At some point, a component will encounter a constraint it is not aware of
- How is this handled?
- Ignore it: Resulting allocation may not be compatible with usage
- Fail the merge or allocation: Fails when “implicit” constraints become explicit
  - E.g., all allocations go in video memory in existing code, new code relies on “local” constraint

Case Study 3: Unknown Constraints (Continued)

- Implicit constraint example: local/video memory
- Prior to constraints, GPU driver assumes allocations go in video memory
  - The local memory constraint is hence made implicit by this allocator
- After introduction of local memory constraint, allocator drops assumption
  - Only allocates memory in video memory when it sees the constraint
- Old driver component unaware of constraint allocates, expecting video memory
  - Bug: No constraint, so it gets non-video memory. Lack of forward/backward compatibility

Case Study 3: Unknown Constraints (Continued)

- Proposal: Version all components of the system
- Each constraint has an associated version it was introduced at
- Version of each constraint set included as a special-case, required constraint
  - Merge op is min()
- Allocators merge their version into the constraint set at allocation time
- Allocators preserve prior implicit constraints if constraint set version < explicit constraint version
- Ignore constraints > (resulting constraint set version)

Case Study 3: Lessons

- Both backwards and forwards compatibility are important
- Ignoring unknown constraints should produce behavior no worse than using an older version of the component that expressed the constraint

Low-Level Design Proposal

- Constraint sets are variable-length lists of `uint64_t` items
- First list item is a header with a “type” field and size
  - Explicit length necessary for parsing/skipping unknown constraint types
- Most constraints will be vendor-agnostic
  - Are any vendor-specific constraints required? Fully opaque constraints? Complicates merging.
- Implement merging logic and helper functions/macros in “shared library”
  - Small, but needs a home. Current proposal: header-only library in kernel uapi headers.
- Recommend guess-and-check logic for choosing an allocator
  - DRM devices and userspace APIs that use them will likely be good guesses

Low-Level Design Proposal: EGL/OpenGL

```
int eglQueryDmaBufConstraintsEXT(EGLDisplay dpy,
                                 EGLint format,
                                 EGLuint64KHR modifier,
                                 EGLBoolean external_only,
                                 EGLint max_set_size,
                                 void *constraints,
                                 EGLint *set_size);
```

Low-Level Design Proposal: Vulkan

```
struct VkImageDrmConstraintSetFormatProperties { // Extends VkImageFormatProperties2
    VkStructureType    sType;
    void*              pNext;
    uint32_t           drmConstraintSetMaxSize;
    uint32_t           drmConstraintSetSize;
    void*              pDrmConstraintSet;
};
struct VkMemoryDrmConstraintSetAllocateInfo {    // Extends VkMemoryAllocateInfo
    VkStructureType    sType;
    const void*        pNext;
    uint32_t           drmConstraintSetSize;
    void*              pDrmConstraintSet;
};
```

Low-Level Design Proposal: Vulkan (continued)

```
struct VkImageDrmConstraintSetCreateInfo { // Extends VkImageCreateInfo
    VkStructureType    sType;
    const void*        pNext;
    uint32_t           drmConstraintSetSize;
    const void*        pDrmConstraintSet;
};
```

Low-Level Design Proposal: DRM-KMS

- Usage described by test-only atomic commits
    - e.g. “rotation” may change constraints
- Inputs: framebuffer width, height, format, modifier
- Output: set of constraints

- `drmModeAddFB2WithModifiers` with zero `bo_handles` gives a test-only FB
- New `OUT_FB_CONSTRAINTS_PTR` blob property used to collect constraints

- Maybe need to pass a list of modifiers as input?

Low-Level Design Proposal: GBM

```
struct gbm_bo *
gbm_bo_create_with_constraints(struct gbm_device *gbm,
                               uint32_t width, uint32_t height,
                               uint32_t format,
                               const uint64_t *modifiers,
                               unsigned int modifier_count,
                               const void **constraint_sets,
                               const unsigned int *set_sizes);
```

Low-Level Design Proposal: Constraint Merge Library

```
static __u64
drm_constraint_merge(void *set_out, __u64 out_size,
                     const void *set_a, __u64 a_size,
                     const void *set_b, __u64 b_size);
```

WIP code here: https://gitlab.freedesktop.org/emersion/drm-constraints

Workshop

Tomorrow, 15:35 UTC

https://xdc2020.x.org/event/9/contributions/634/

Questions?

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- Notes for this talk: https://paste.sr.ht/~emersion/e10214caff180f1d8f85f560a3c2beac6a96bc0c