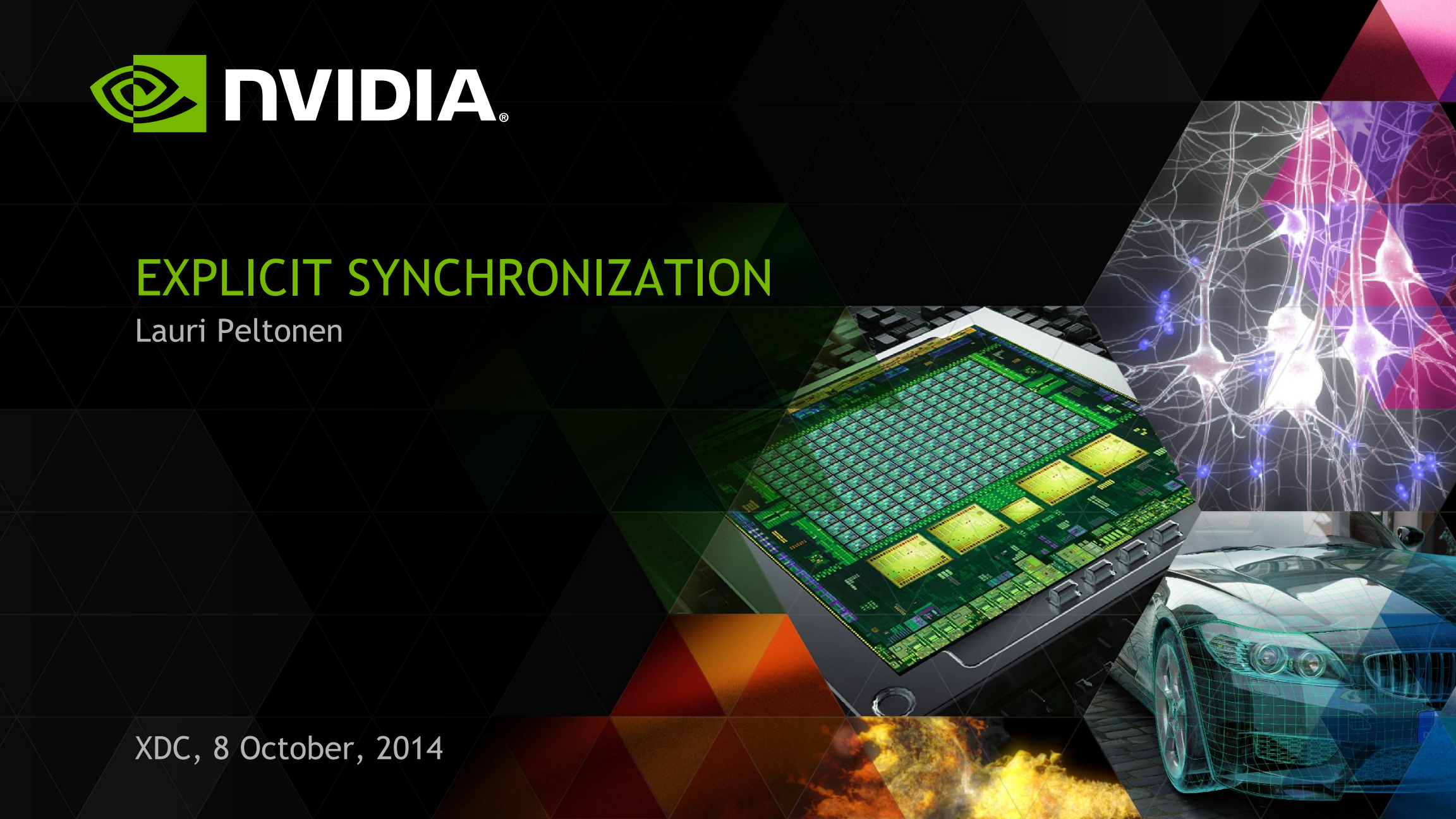

EXPLICIT SYNCHRONIZATION

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WHAT IS EXPLICIT SYNCHRONIZATION?

- Fence is an abstract primitive that marks completion of an operation
- Implicit synchronization
  - Fences are attached to buffers
  - Kernel manages fences automatically based on buffer read/write access
  - Currently used by DRM (dma-buf fences)
- Explicit synchronization
  - Fences are passed around independently
  - Kernel takes and emits fences to/from user space when submitting work
  - Currently used on Android (sync fence fd's)

ADVANTAGES

- Improved performance of bindless graphics APIs
- Better alignment with user space graphics APIs
- Allow parallel processing of user space suballocations
- Fits in nicely with explicit buffer handoffs

BINDLESS GRAPHICS PERF IMPROVEMENTS

- Bindless graphics and Compute APIs allow building very large working sets that any given command buffer can reference
  - References can be by runtime-generated virtual address rather than slots or enums
- These working sets can be shared across multiple contexts or command queues
  - Implicit sync may force serialization in these cases
- Locking and updating fences for every active buffer is costly
  - Working set sizes can be thousands of buffers

ALIGNS WITH USERSPACE GRAPHICS APIS

- Developers are demanding explicit control of the driver behavior and hardware whenever possible
- Current Generation OpenGL is defined in terms of explicit synchronization
  - EGLSync, GLSync
- “Hidden” ordering dependencies and stalls because of implicit sync are at odds with these design philosophies

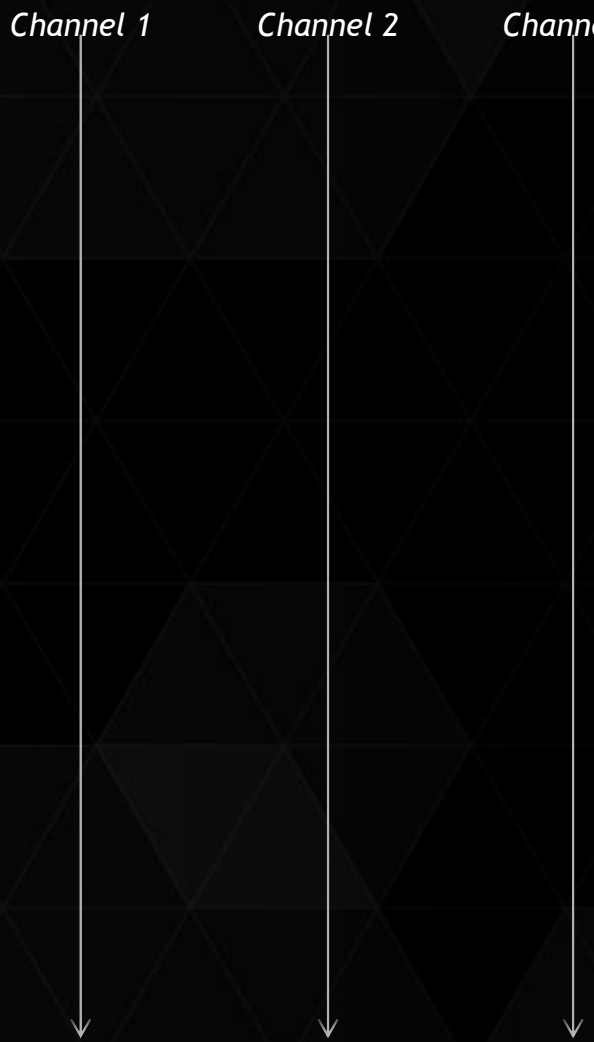
USER SPACE SUBALLOCATION

- User space drivers and applications use suballocation for performance reasons
  - By definition, kernel has no visibility into this process
- Operations on separate portions of a buffer should be allowed to proceed in parallel
  - Even if they reside in one kernel-visible buffer

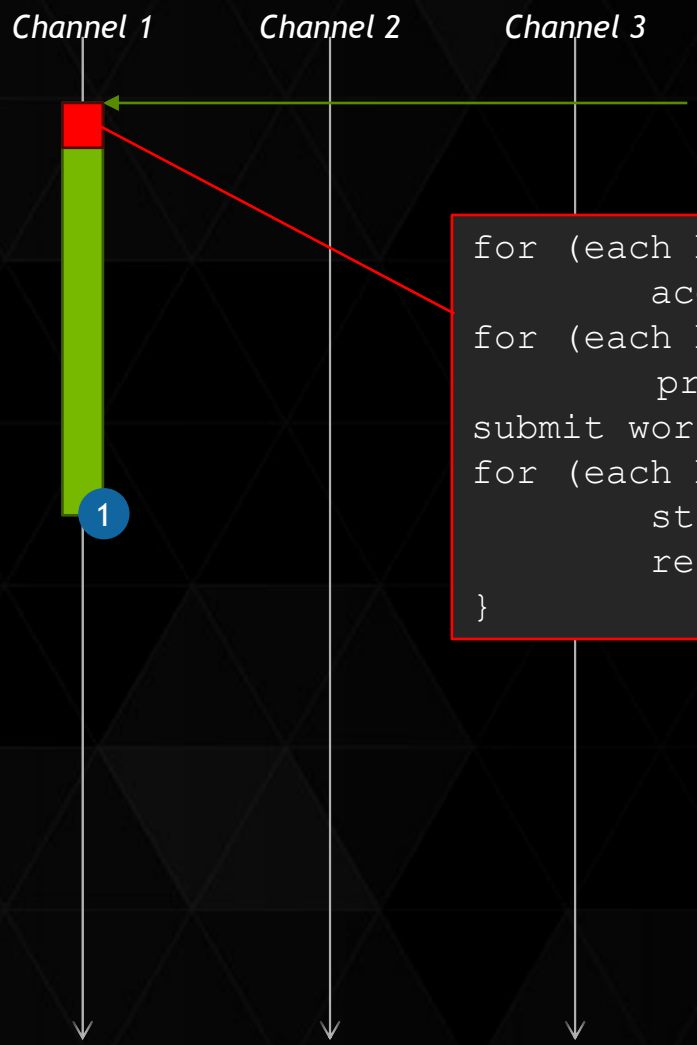
EXPLICIT INTEROP HANDOFFS

- Modern processors have many specialized engines
  - Video processing
  - 3D/2D graphics
  - CPU cores
- Each of these may have its own caches, memory compression engines, or other specialized memory access quirks
- When buffers are shared between them, engine-specific state transitions may be needed
  - May be costly operations. May be difficult to perform just-in-time.
  - Simplest solution is for user space to request them explicitly
  - Might as well do explicit synchronization in the same code path

IMPLICIT SYNC EXAMPLE



IMPLICIT SYNC EXAMPLE




```
nouveau_pushbuf_kick(push1, chan1);
```

```
for (each buffer in working set)
        acquire ww mutex
for (each buffer in working set)
        program wait fence cmd
submit work
for (each buffer in working set) {
        store fence
        release ww mutex
}
```

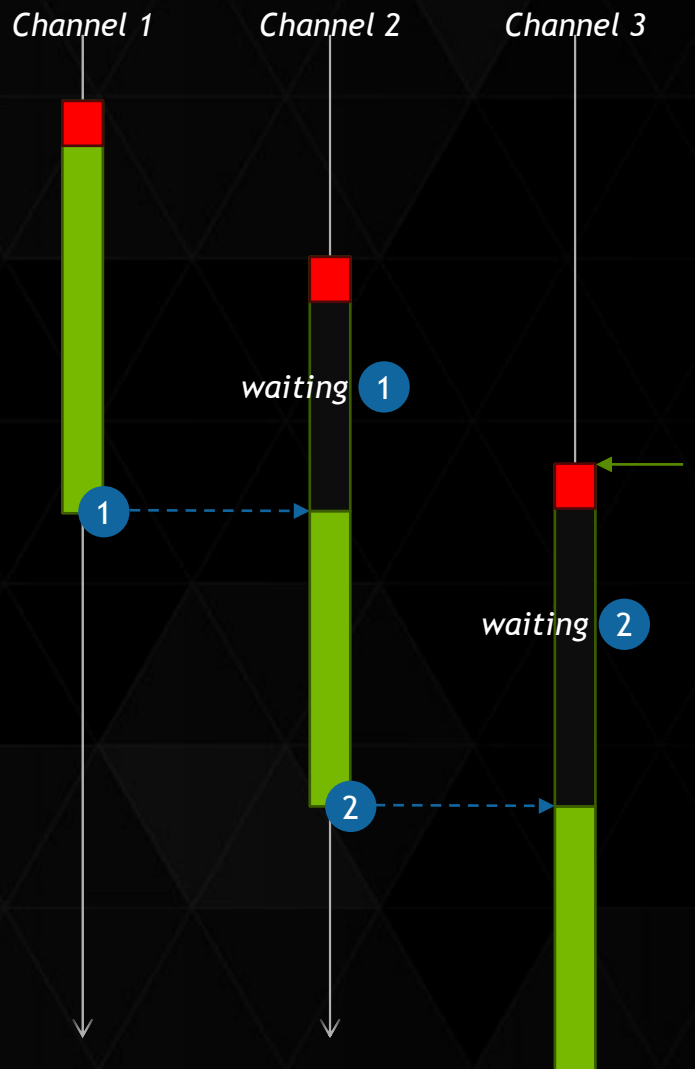
```
nouveau_pushbuf_kick(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan)
```

IMPLICIT SYNC EXAMPLE


```
nouveau_pushbuf_kick(push1, chan1);

// push2 has no dependencies, but kernel enforces a wait
nouveau_pushbuf_kick(push2, chan2);
```

```
nouveau_pushbuf_kick(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan)
```

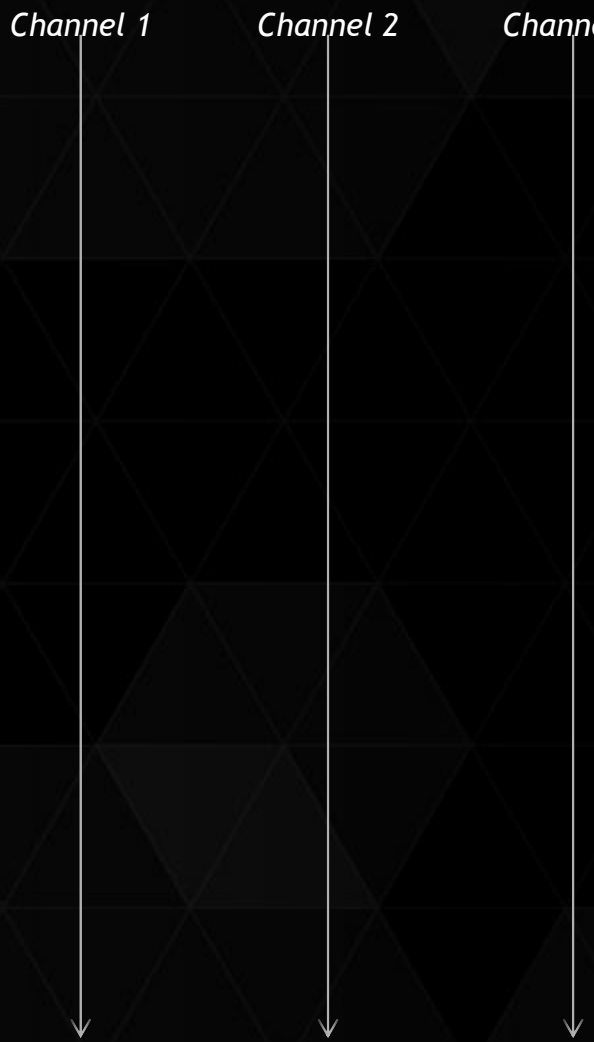
IMPLICIT SYNC EXAMPLE



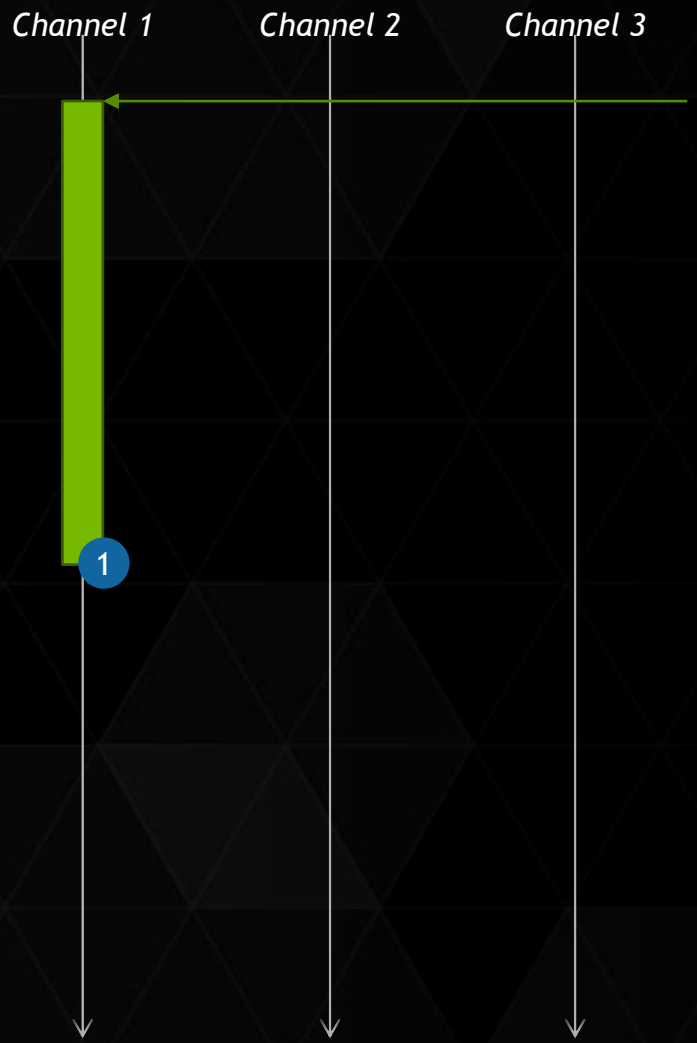

```
nouveau_pushbuf_kick(push1, chan1);


// push2 has no dependencies, but kernel enforces a wait
nouveau_pushbuf_kick(push2, chan2);


// push2 depends on push1 only, but user space cannot
// express that to kernel
nouveau_pushbuf_kick(push3, chan3);
```

```
nouveau_pushbuf_kick(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan)
```

EXPLICIT SYNC EXAMPLE



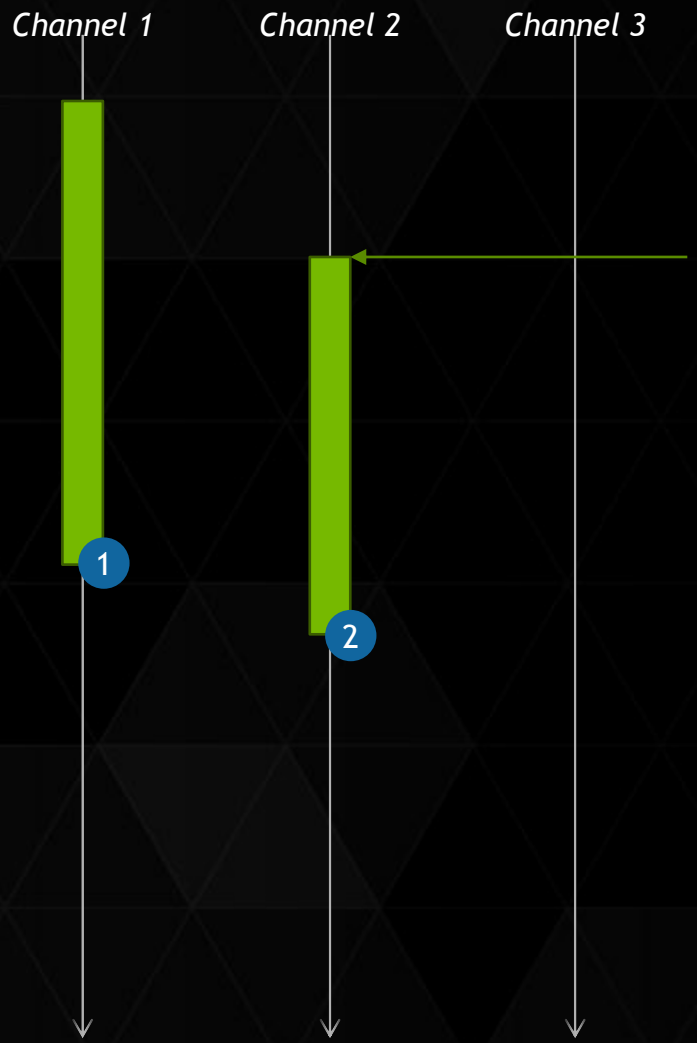
EXPLICIT SYNC EXAMPLE




```
int fence1 = -1;
nouveau_pushbuf_kick_fence(push1, chan1, -1, &fence1);
// now fence1 == 1
```

```
nouveau_pushbuf_kick_fence(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan,
        int waitFenceFd,
        int *emitFenceFd)
```

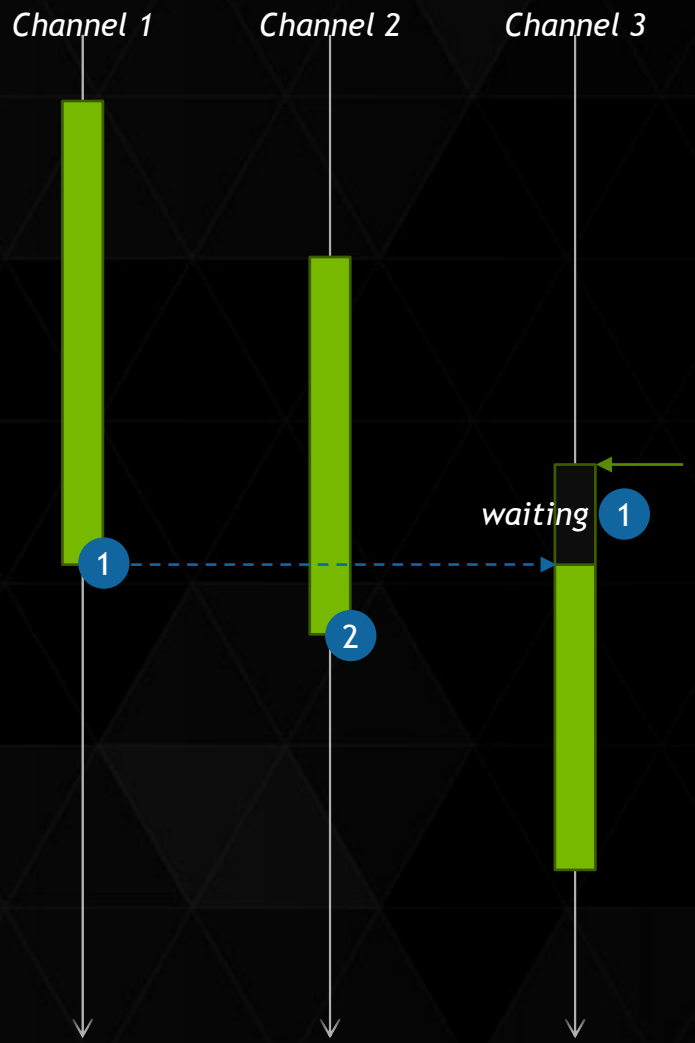
EXPLICIT SYNC EXAMPLE




```
int fence1 = -1;
nouveau_pushbuf_kick_fence(push1, chan1, -1, &fence1);
// now fence1 == 1

int fence2 = -1;
nouveau_pushbuf_kick_fence(push2, chan2, -1, &fence2);
// now fence2 == 2
```

```
nouveau_pushbuf_kick_fence(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan,
        int waitFenceFd,
        int *emitFenceFd)
```

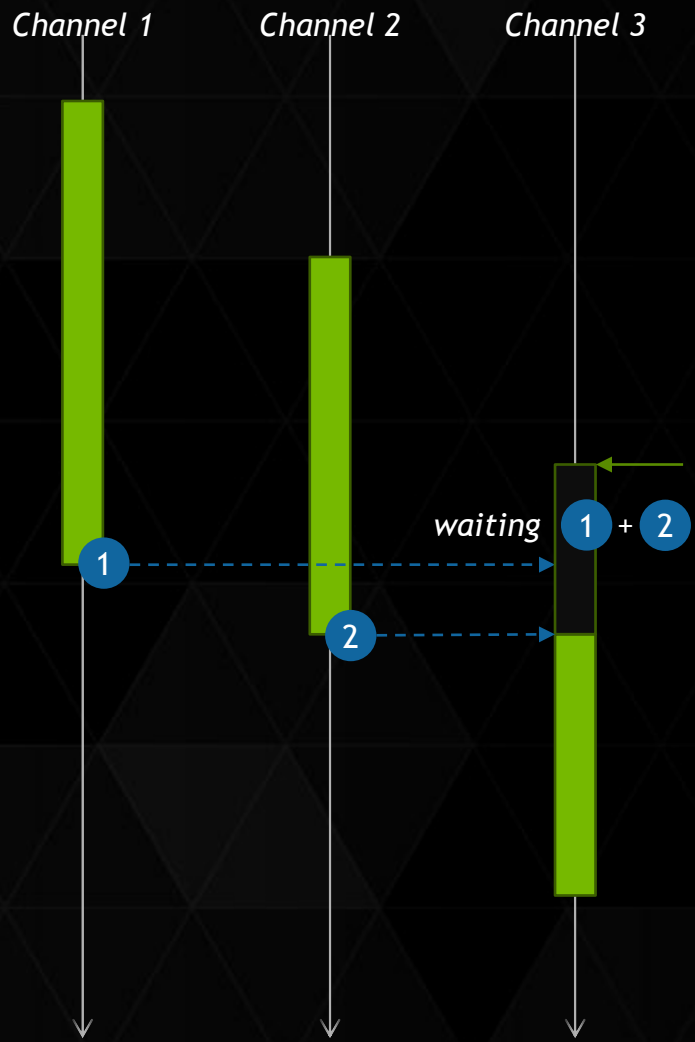
EXPLICIT SYNC EXAMPLE




```
int fence1 = -1;
nouveau_pushbuf_kick_fence(push1, chan1, -1, &fence1);
// now fence1 == 1

int fence2 = -1;
nouveau_pushbuf_kick_fence(push2, chan2, -1, &fence2);
// now fence2 == 2


// the last operation depends on 1 only
nouveau_pushbuf_kick_fence(push3, chan3, fence1, NULL);
```

```
nouveau_pushbuf_kick_fence(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan,
        int waitFenceFd,
        int *emitFenceFd)
```

EXPLICIT SYNC EXAMPLE




```
int fence1 = -1;
nouveau_pushbuf_kick_fence(push1, chan1, -1, &fence1);
// now fence1 == 1

int fence2 = -1;
nouveau_pushbuf_kick_fence(push2, chan2, -1, &fence2);
// now fence2 == 2

// the last operation depends on 1 and 2
int merged = sync_merge(fence1, fence2);
nouveau_pushbuf_kick_fence(push3, chan3, merged, NULL);
```

```
nouveau_pushbuf_kick_fence(
        struct nouveau_pushbuf *push,
        struct nouveau_object *chan,
        int waitFenceFd,
        int *emitFenceFd)
```

RESIDENCY AND PINNING

- When we need to swap out or unmap a buffer, we need to wait until it is no longer accessed by hw
- This is not the perf-critical case, so we can be conservative in order to optimize the critical path. For example, on Nouveau:
  - Store one fence to channel vm at each submit
  - Use that fence when evicting or unmapping buffers
  - No need to lock / update fences to every buffer individually at submit?
- All this is driver specific logic, not common DRM

PATH FROM IMPLICIT SYNC -> EXPLICIT SYNC

- No need to disrupt existing model
  - If a particular device is happy with implicit sync, it can keep using it
- Allow kernel and user space drivers that prefer explicit to opt-in:
  - Allow user space to handle intra-driver synchronization explicitly
  - Allow user space to associate synchronization primitives with buffers for backwards compatibility with current APIs and drivers
  - Move towards tracking working sets rather than individual buffers for object lifetime/work completion/paging purposes

THANKS!

- drivers/staging/android/sync.c
- [RFC] Explicit synchronization for Nouveau (+ RFC patches)
  - dri-devel@lists.freedesktop.org, nouveau@lists.freedesktop.org
- Let’s discuss more over lunch/dinner!

BACKUP

DEADLOCKS?

- Circular dependencies can be avoided, if fences are only generated in kernel when work is submitted
  - This guarantees that user space cannot ask kernel to wait for a fence whose work will be submitted later
- Deadlocks can be avoided, if additionally all submitted work completes in finite time
  - This assumption might fail for implicit fences also
  - Timeout mechanisms

EXPLICIT SYNC VS. ANDROID SYNC FD'S

- Could also be a process local handle?
  - But should support conversion to and from Android sync fd's