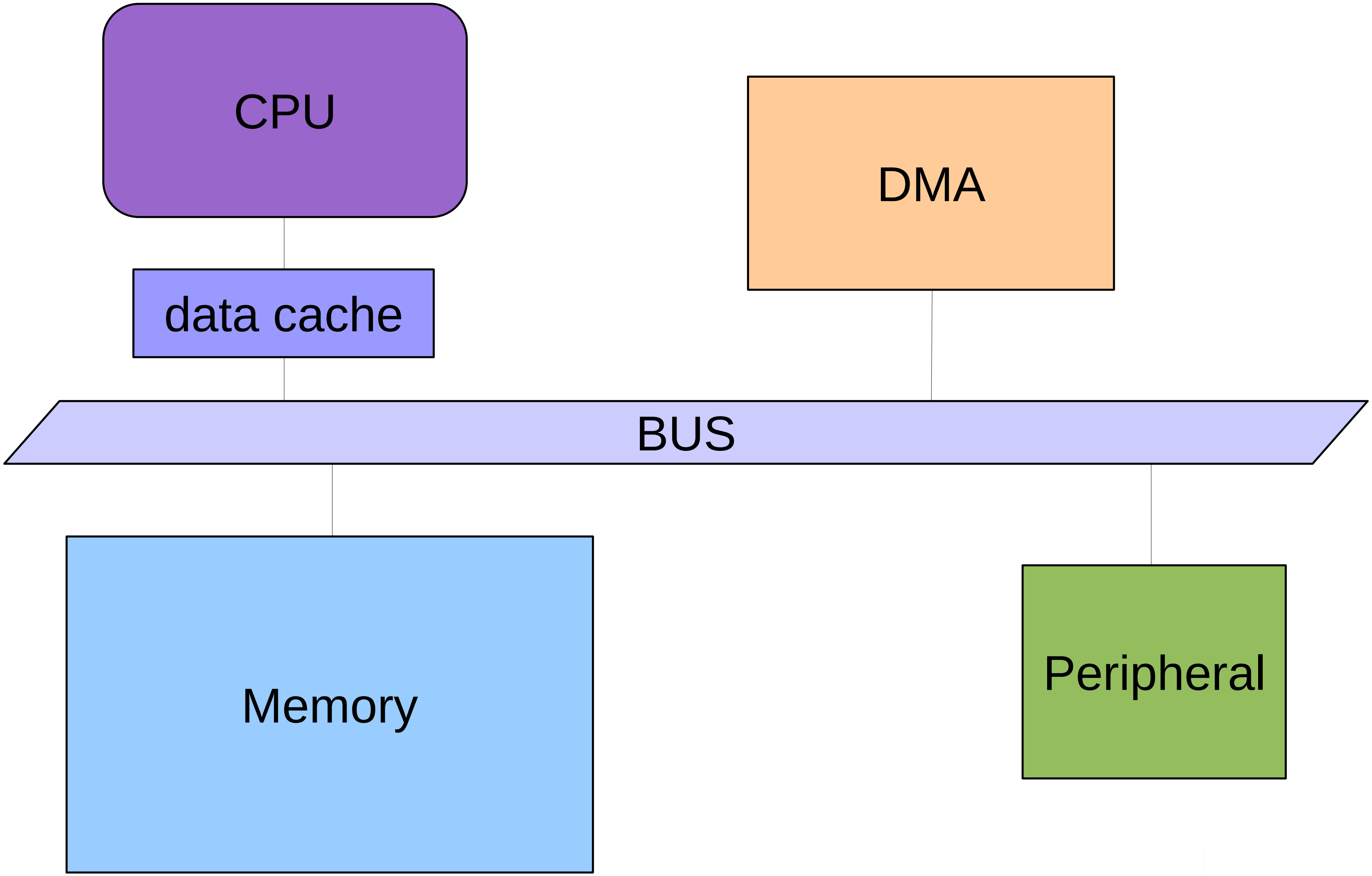
Linux DMA

DMA integration



Constraints with a DMA

- A DMA deals with physical addresses, so:
  - Programming a DMA requires retrieving a physical address at some point (virtual addresses are usually used)
  - The memory accessed by the DMA shall be physically contiguous

- The CPU can access memory through a data cache
  - Using the cache can be more efficient (faster accesses to the cache than the bus)
  - But the DMA does not access to the CPU cache, so one need to take care of cache coherency (cache content vs memory content)
  - Either flush or invalidate the cache lines corresponding to the buffer accessed by DMA and processor at strategic times

DMA memory constraints

- Need to use contiguous memory in physical space.
- Can use any memory allocated by kmalloc (up to 128 KB) or __get_free_pages (up to 8MB).
- Can use block I/O and networking buffers, designed to support DMA.
- Can not use vmalloc memory (would have to setup DMA on each individual physical page).

Reserving memory for DMA

To make sure you've got enough RAM for big DMA transfers...
Example assuming you have 32 MB of RAM, and need 2 MB for DMA:

- Boot your kernel with mem=30

The kernel will just use the first 30 MB of RAM.

- Driver code can now reclaim the 2 MB left:

```
dmabuf = ioremap (
                0x1e00000,        /* Start: 30 MB */
                0x200000);        /* Size: 2 MB */
```

Memory synchronization issues

Memory caching could interfere with DMA

- Before DMA to device:

Need to make sure that all writes to DMA buffer are committed.

- After DMA from device:

Before drivers read from DMA buffer, need to make sure that memory caches are flushed.

- Bidirectional DMA

Need to flush caches before and after the DMA transfer.

Linux DMA API

The kernel DMA utilities can take care of:

- Either allocating a buffer in a cache coherent area,
- Or making sure caches are flushed when required,
- Managing the DMA mappings and IOMMU (if any).
- See Documentation/DMA-API.txt
for details about the Linux DMA generic API.
- Most subsystems (such as PCI or USB) supply their own DMA API, derived from the generic one. May be sufficient for most needs.

Coherent or streaming DMA mappings

Coherent mappings

The kernel allocates a suitable buffer and sets the mapping for the driver.

- Can simultaneously be accessed by the CPU and device.
- So, has to be in a cache coherent memory area.
- Usually allocated for the whole time the module is loaded.
- Can be expensive to setup and use on some platforms.

Streaming mappings

The kernel just sets the mapping for a buffer provided by the driver.

- Use a buffer already allocated by the driver.
- Mapping set up for each transfer. Keeps DMA registers free on the hardware.
- Some optimizations also available.
- The recommended solution.

Allocating coherent mappings

The kernel takes care of both buffer allocation and mapping:

```
include <asm/dma-mapping.h>
void *                              /* Output: buffer address */
   dma_alloc_coherent(
        struct device *dev,         /* device structure */
        size_t size,                /* Needed buffer size in bytes */
        dma_addr_t *handle, /* Output: DMA bus address */
        gfp_t gfp                   /* Standard GFP flags */
   );
void dma_free_coherent(struct device *dev,
   size_t size, void *cpu_addr, dma_addr_t handle);
```

Setting up streaming mappings

Works on buffers already allocated by the driver

<include linux/dmapool.h>

```
dma_addr_t dma_map_single(
    struct device *,                  /* device structure */
    void *,                           /* input: buffer to use */
    size_t,                           /* buffer size */
    enum dma_data_direction    /* Either DMA_BIDIRECTIONAL,
                                  DMA_TO_DEVICE or
                                  DMA_FROM_DEVICE */
    );
```

```
void dma_unmap_single(struct device *dev, dma_addr_t handle, size_t
    size, enum dma_data_direction dir);
```

DMA streaming mapping notes

- When the mapping is active: only the device should access the buffer (potential cache issues otherwise).
- The CPU can access the buffer only after unmapping! Use locking to prevent CPU access to the buffer.
- Another reason: if required, this API can create an intermediate *bounce buffer* (used if the given buffer is not usable for DMA).
- The Linux API also supports scatter / gather DMA streaming mappings.

DMA summary

Most drivers can use the specific API provided by their subsystem: USB, PCI, SCSI... Otherwise they can use the Linux generic API:

Coherent mappings

- DMA buffer allocated by the kernel
- Set up for the whole module life
- Can be expensive. Not recommended.
- Let both the CPU and device access the buffer at the same time.
- Main functions:
dma_alloc_coherent
dma_free_coherent

Streaming mappings

- DMA buffer allocated by the driver
- Set up for each transfer
- Cheaper. Saves DMA registers.
- Only the device can access the buffer when the mapping is active.
- Main functions:
dma_map_single
dma_unmap_single