UDI Advanced Topics

DMA and Interrupts

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Robert Lipe
UDI Development Team Lead
E-mail: robertl@sco.com

Agenda

- **Background**
- Direct Memory Access (DMA)
- Interrupt Handling
- Q & A

Prerequisites

This presentation assumes knowledge of:

- UDI Architecture (F8)
- UDI Fundamental Types (F8)
- UDI Buffer Management (F9, F10)
- UDI Programmed I/O (F9, F10)

References

- **DMA and Interrupts are defined in the *UDI Physical I/O Specification***
- **Also covered in Physical I/O are:**
  - Programmed I/O (PIO)
  - Bus Bridge Metalanguage

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- Background
- **Direct Memory Access (DMA)**
- Interrupt Handling
- Q & A

DMA Overview

- What is DMA?
- DMA constraints and DMA handles
- Mapping a buffer for DMA
- Scatter/gather lists
- Unmapping a buffer
- Allocating DMA-able memory

What is DMA?

- DMA is used by physical I/O devices to access mainstore memory directly w/o software intervention
- OS and driver must set up DMA mappings and tell device the addresses to use
- DMA is more efficient than PIO

DMA Constraints
Overview

- **DMA constraints indicate addressing restrictions of a device's DMA engine**
  - e.g. 24-bit vs 32-bit vs 64-bit
  - Uses general constraints mechanism
    - **`udi_constraints_t`** opaque handle
    - **`udi_constraints_attr_t`** attribute code
- **Constraints are propagated at bind time**

DMA Constraints

Attribute Codes (udi_constraints_attr_t)

- **DMA constraints attributes include:**
  - UDI_DMA_ADDRESSABLE_BITS
  - UDI_DMA_ALIGNMENT_BITS
  - UDI_DMA_SCGTH_MAX_ELEMENTS
  - UDI_DMA_ELEMENT_LENGTH_BITS
  - many others…
- **Many specified as number of bits**

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DMA Constraints
Attribute Values

- **Each attribute has:**
  - Least restrictive value
  - Most restrictive value
  - Default value (usually same as least restrictive)
- **Driver can set, reset or combine attributes**

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DMA Constraints
Setting Attributes

- **`udi_constraints_attr_set` sets one or more attributes to most restrictive of current and new values**
- **If attribute has no sense of more/less restrictive, new value is used**
- **`udi_constraints_attr_reset` resets one attribute to its default value**

DMA Constraints
Combining Constraints

- **Sometimes drivers must combine two sets of constraints from other drivers**
  - Typically done in multiplexors such as IP
- **`udi_constraints_attr_combine` combines two constraints objects using selected combine method:**
  - UDI_ATTR_MOST_RESTRICTIVE
  - UDI_ATTR_LEAST_RESTRICTIVE

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Constraints Propagation

- **Parent driver calls `udi_constraints_propagate`**
- **Environment copies constraints and sends child a `udi_channel_event_ind`**
- **Child driver adds its constraints using `udi_constraints_attr_set`**

DMA Handles

- **Opaque handle used for DMA services**
  - Refers to a set of DMA mapping resources
  - Type is: **`udi_dma_handle_t`**
  - Constraints associated with each DMA handle
- **DMA handle typically re-used for multiple DMA mappings**

Preparing for DMA
udi_dma_prepare

- **Allocate DMA handle for buffer mapping**

```
void udi_dma_prepare (
     udi_dma_prepare_call_t *callback,
     udi_cb_t *gcb,
     udi_constraints_t constraints,
     udi_ubit8_t flags );

typedef void udi_dma_prepare_call_t (
     udi_cb_t *gcb,
     udi_dma_handle_t new_dma_handle );
```

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Mapping a Buffer for DMA

udi_dma_buf_map

- **Map a buffer into device's DMA space**
  - Uses previously-allocated DMA handle

```
void udi_dma_buf_map (
     udi_dma_buf_map_call_t *callback,
     udi_cb_t *gcb,
     udi_dma_handle_t dma_handle,
     udi_buf_t *buf,
     udi_size_t offset,
     udi_size_t len,
     udi_ubit8_t flags );
```

- **One mapping per handle at any one time**
  - Same handle may be re-used after unmapping

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Mapping a Buffer for DMA
Callback Function

- **Callback from `udi_dma_buf_map`:**

```
typedef void udi_dma_buf_map_call_t (
     udi_cb_t *gcb,
     udi_scgth_t *scgth,
     udi_buf_t *new_buf,
     udi_boolean_t complete,
     udi_status_t status );
```

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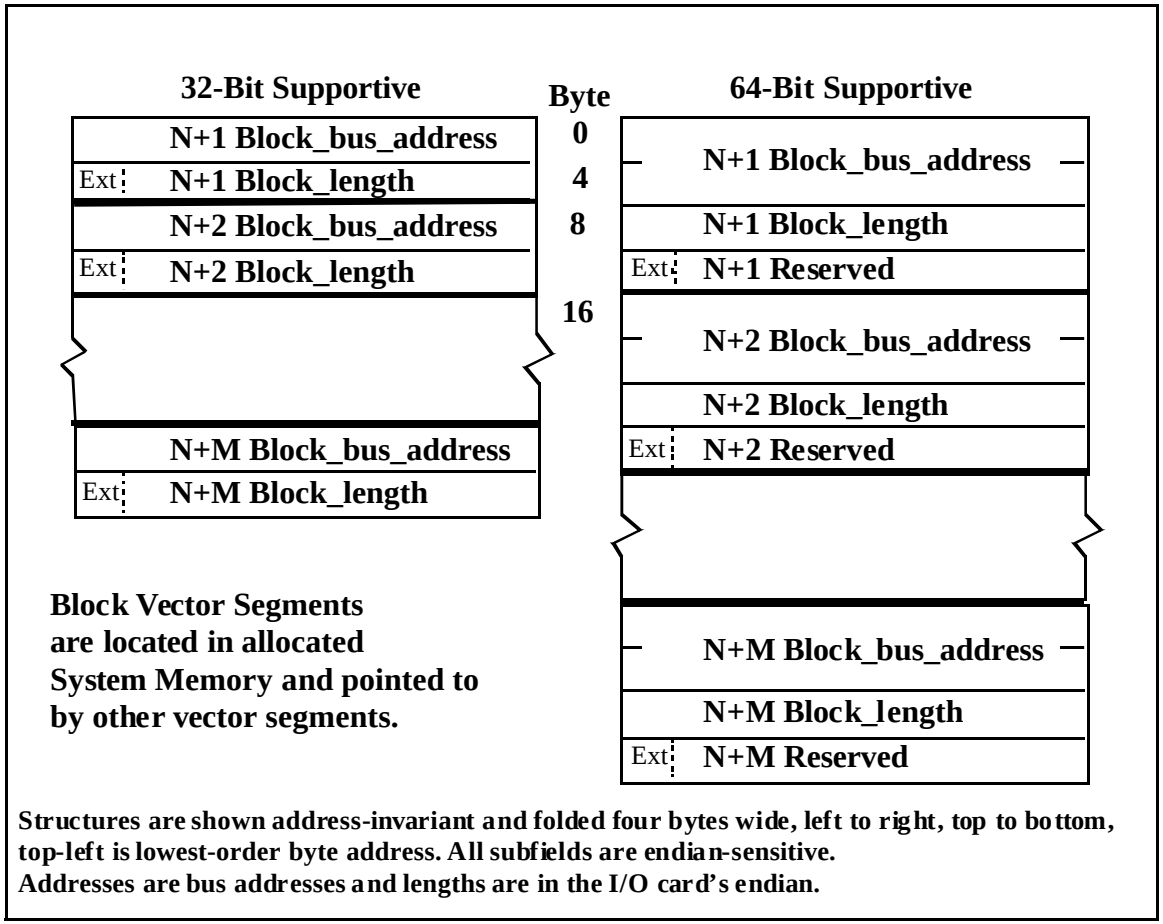
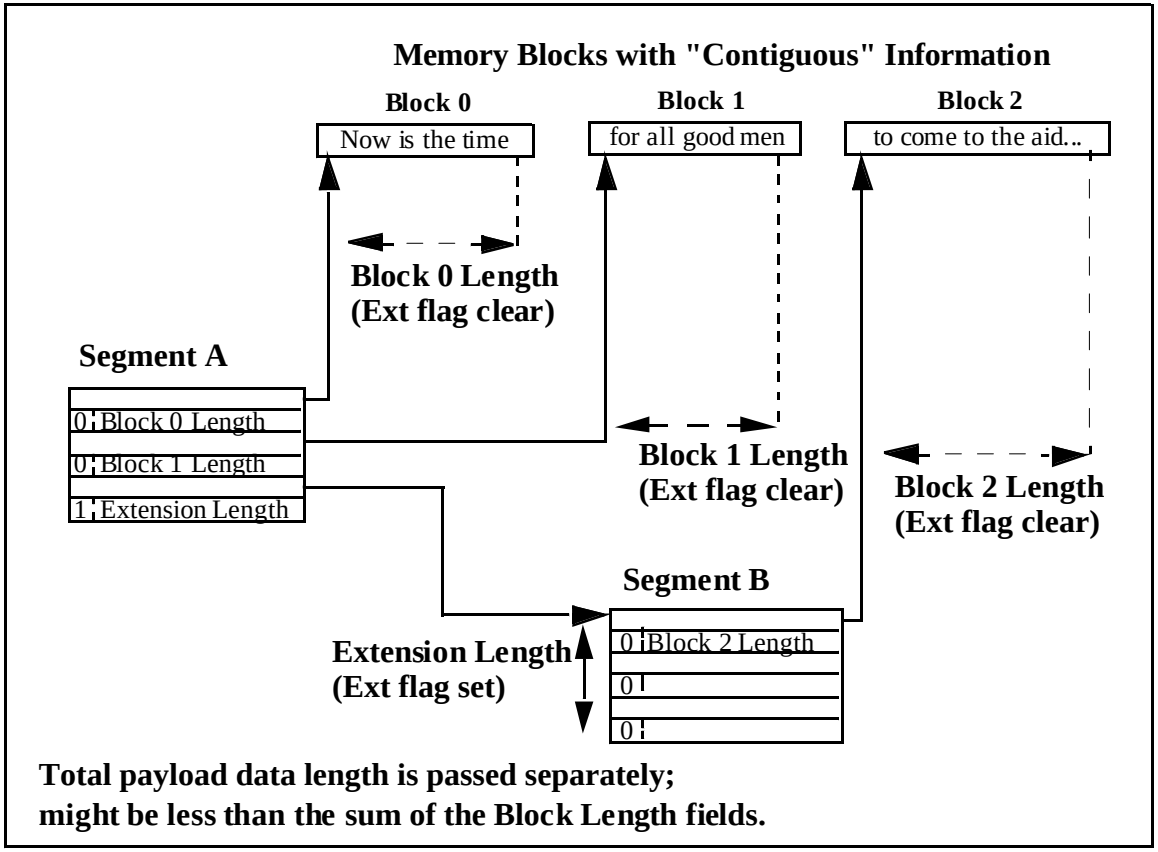
Scatter/Gather Lists

- **Lists (address, length) pairs**
  - Addresses from device viewpoint (card-relative)
  - IEEE 1212.1 compatible
- **Scatter/gather list itself visible from:**
  - Driver if UDI_SCGTH_DRIVER_MAPPED
  - Device if UDI_SCGTH_DMA_MAPPED
  - Or both...

Scatter/Gather Segments



Scatter/Gather Example



Scatter/Gather Endianness

- **Device-endian if DMA-mapped**
  - Driver sets UDI_DMA_SCGTH_ENDIANNESS
- **Driver-endian if only driver-mapped**
- **If mapped for both, driver must do endianness conversions**
  - If **`scgth_must_swap`** is set
  - Helped by endianness utility functions/macros

Unmapping a Buffer

- **Unmap a buffer when I/O complete**

```
void udi_dma_buf_unmap (
     udi_dma_handle_t dma_handle );
```

- **Flushes caches if needed**
  - If needed during I/O use **udi_dma_sync**
- **DMA handle may be re-used for another mapping**

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Allocating DMA-able Memory

- **DMA-able memory for “long-term” shared control structures**

```
void udi_dma_mem_alloc (
     udi_dma_mem_alloc_call_t *callback,
     udi_cb_t *gcb,
     udi_constraints_t constraints,
     udi_ubit8_t flags,
     udi_size_t len );
```

- **Allocates memory and DMA handle, and maps the memory, all in one call**

Allocating DMA-able Memory
Callback Function

- **Callback from `udi_dma_mem_alloc`:**

```
typedef void udi_dma_mem_alloc_call_t (
     udi_cb_t *gcb,
     udi_dma_handle_t new_dma_handle,
     void *mem_ptr,
     udi_scgth_t *scgth,
     udi_boolean_t must_swap );
```

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- Background
- Direct Memory Access (DMA)
- **Interrupt Handling**
- Q & A

Interrupt Handling Overview

- **Two phases to interrupt handling**
  - Interrupt attachment (and detachment)
  - Interrupt event handling
- **Two types of interrupt handling**
  - Interrupt preprocessing
  - Interrupt regions

Attaching Interrupt Handlers

- **Interrupt attachment channel operation:**

```
typedef struct {
     udi_cb_t gcb;
     udi_index_t interrupt_idx;
     udi_ubit8_t max_event_pend;
     udi_ubit16_t event_buf_size;
     udi_pio_handle_t preprocessing_handle;
} udi_intr_attach_cb_t;

void udi_intr_attach_req (
     udi_intr_attach_cb_t *cb );
```

- **Interrupt detachment channel operation:**

```
void udi_intr_detach_req (
     udi_intr_attach_cb_t *cb );
```

Interrupt Preprocessing

- **Preferred method for interrupt handling**
- **Driver passes PIO handle to bridge mapper during intr_attach**
  - Contains a PIO transaction list
- **When interrupts occur, bridge executes transaction list without having to call driver**

Interrupt Preprocessing
(continued)

- **PIO trans list dismisses interrupt**
- **Partial or complete results sent via udi_intr_event_ind channel op to driver**
  - If trans list determines (shared) interrupt not generated by device, no op sent to driver
- **Drivers do *not* execute with interrupts disabled**

Interrupt Regions

- **If interrupt can't be dismissed with PIO trans list, driver can't use preprocessing**
- **Interrupt regions disable device interrupt while executing**
  - Specified by region attribute in static properties
  - Must be a secondary region
  - udi_intr_event_ind called with no preprocessing

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