Arm® System Control Processor (SCP) Firmware-101

Firmware Architecture Overview

Souvik Chakravarty

Agenda

- What is SCP Firmware
- Basic Building Blocks
- SCP Firmware execution stages
- Inter Module Communication
- Threading
- Guidelines for new Module Design
- Status & Next Steps

What is SCP Firmware

Introduction

- To abstract power and system management tasks away from Application Processors (APs).
- Compliant to Arm System Control & Management Interface (SCMI) specification.
- Code is opensource: https://github.com/ARM-software/SCP-firmware.
  - Contributions are welcome!
- Execution Environment agnostic. Can be run on RTOS or bare-metal environments.

A software reference implementation for the System Control Processor (SCP) and Manageability Control Processor (MCP) components found in several Arm Compute Sub-Systems.

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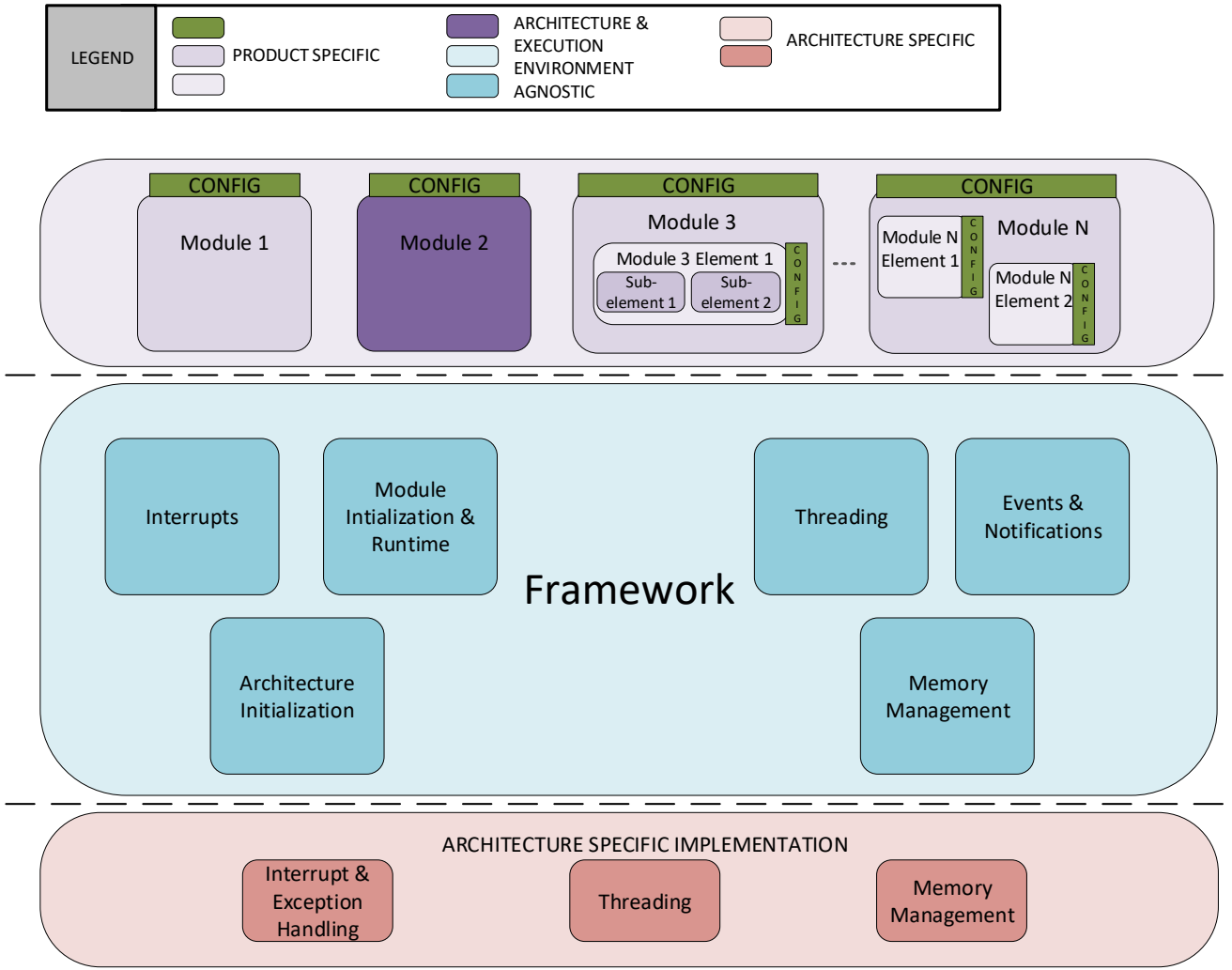
Basic Building Blocks

Overall Layout

- 3 layers:
  - Architecture:
    - Provides execution environment dependent functionality like threading, interrupts, memory management etc.
  - Framework:
    - Provides common services to all modules like Initialization, Event, Notification & Interrupt handling.
      - Depends on architecture layer for execution environment dependent services
    - Architecture and execution environment agnostic
    - Drives the initialization, orchestration of, and interactions between modules
  - Modules:
    - Architecture agnostic
    - A module performs a well-defined set of operations.



Basic Building Blocks

Modules (struct fwk_module)

- Types of Modules
  - **Hardware Abstraction Layer:**
    - Generic interface to a class of drivers, e.g. sensor.
    - Other modules use platform drivers through HAL APIs
  - **Driver**:
    - Controls a specific device.
    - May implement APIs defined by a HAL module.
    - Driver can opt to not use HAL.
  - **Protocol**:
    - Provide protocol specific interfaces, e.g. arbitration of messaging channels, to other modules
  - **Service**
    - Work or functionality that is not related to hardware devices.
    - May be self contained and not expose any APIs to other modules
- Binding
  - Binding enables modules to use another module's set of APIs.
  - Each set of APIs provided by a module is uniquely identified.
    - Module elements may provide different implementations of the same set of APIs

Combining Modules into a Product

- Product consists of a product.mk file that defines one or more firmware targets.
- Each Firmware target is a binary image built when building the product.
- A firmware target is fully defined by its set of modules and their configuration data through struct fwk_module_config.

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Basic Building Blocks

Elements & Sub-Elements

- Elements
  - A resource that is owned and governed by a module.
  - An abstraction to refer to a device, a protocol or a service instance.
  - E.g., elements of a driver type module may represent each hardware device instance it controls.
  - Elements are optional.
  - Element description.
    - One per element.
    - Contains element configuration data.
  - Elements are defined by:
    - a structure containing a pointer to a name string
    - the number of sub-elements associated with the element
    - a void pointer to data that is in a module-defined format
- Sub-Elements
  - Resource owned and governed by an element.
  - Don’t have descriptors.

EXAMPLE

- SENSOR HAL is a Module.
- PVT and Thermal Sensor Drivers are Modules that use Sensor HAL.
- PVT and Thermal Sensors are arranged in several groups. Each group is an element having its own configuration.
- Each sensor within a group is a sub-element.

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SCP Firmware Execution Stages

Pre-Runtime & Runtime

- Pre-Runtime Stages: 5 Stages in fixed order

- Runtime Stage

SCP Firmware Execution Stages

Pre-Runtime & Runtime

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  - **Module Initialization**: *.init*() function of module called by framework with module configuration data.
- Runtime Stage

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SCP Firmware Execution Stages

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  - **Bind**: *.bind*() function of module called by framework. Modules & elements bind to other modules & elements. Optional Stage.
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  - **Start**: *.start*() function of module called by framework. Modules can use resources of other modules to complete initialization. Optional Stage.
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- Runtime Stage
  - Normal execution flow directed primarily by interaction between modules.
  - Event, notifications and responses generated and processed.

Inter-Module communication

Events & Notifications

- Events: Abstraction for communicating requests/responses.
  - Mechanism for implementing a logical task in callee context.
  - Module provides .process_event() handler which gets called by Framework when event targeting module is found.
  - When the task associated to a request is completed, a response event may be sent. A response may be sent as part of the processing of an event or later.
    - Delayed Response: Response is sent later and not immediately after processing the Event
    - Standard Response: Framework generates response as soon as .process_event() returns.
    - Response is an Event with response flag set. Processed by Firmware in same manner as Events.

- Notifications: Events with notification field set.
  - Modules can subscribe to notifications from other modules.
  - Notifications are broadcast to all subscribed modules by the framework.
  - Can be used to implement dependency chain.
    - e.g., if before a System Power Transition, we may need to change a clock or setup some wakeup handling. The modules can use notifications from System Power Module.

- Responsiveness
- Scalability (Implicit queueing)
- Execution Environment Independence
- Lockless

- Events (fwk_event)
  - Response Required
    - Delayed Response
    - Standard Response
  - No response Required

- Notifications (fwk_event)
  - Response Required
    - Delayed Response
    - Standard Response
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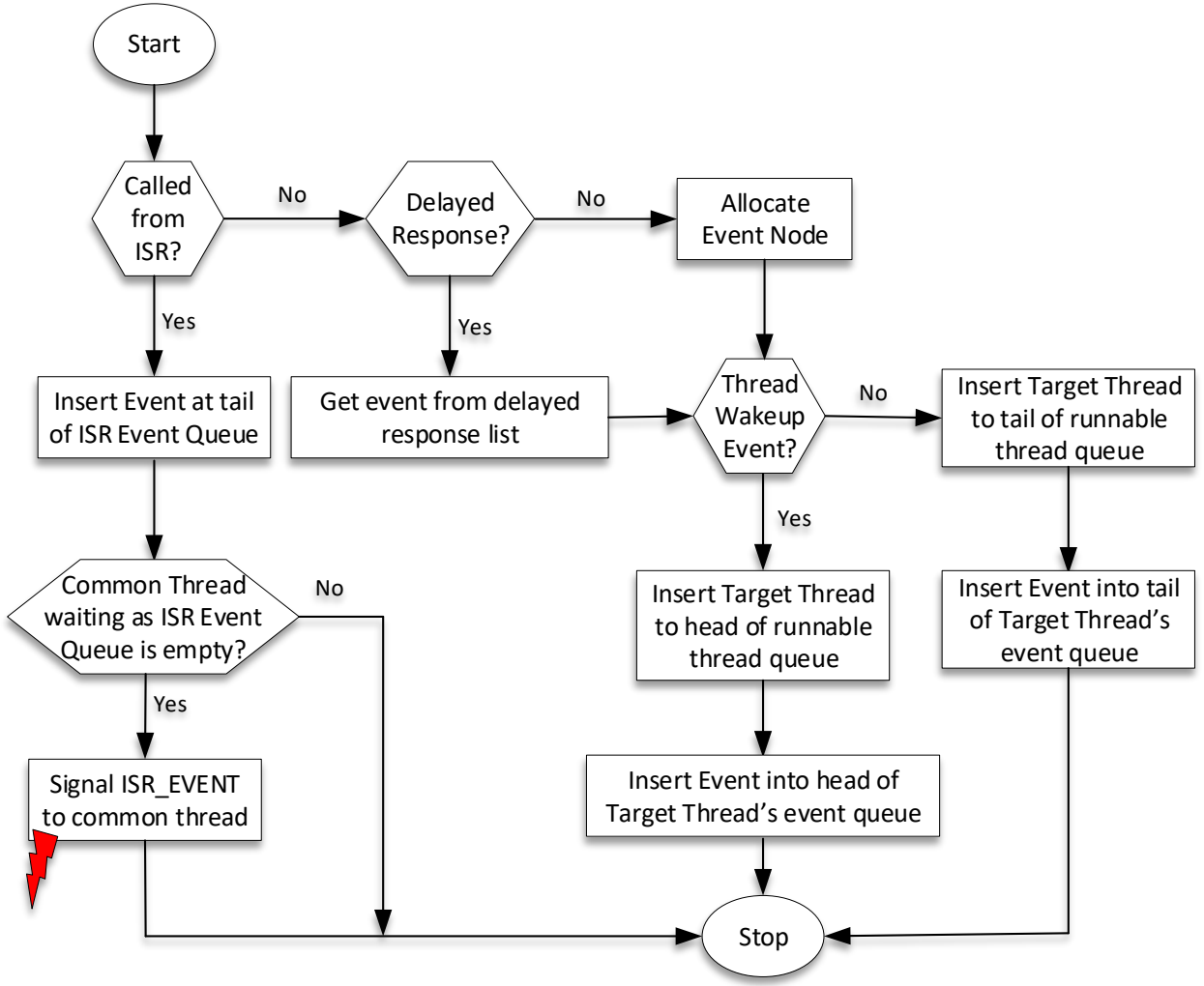
Event Handling

Creating an Event



put_event()

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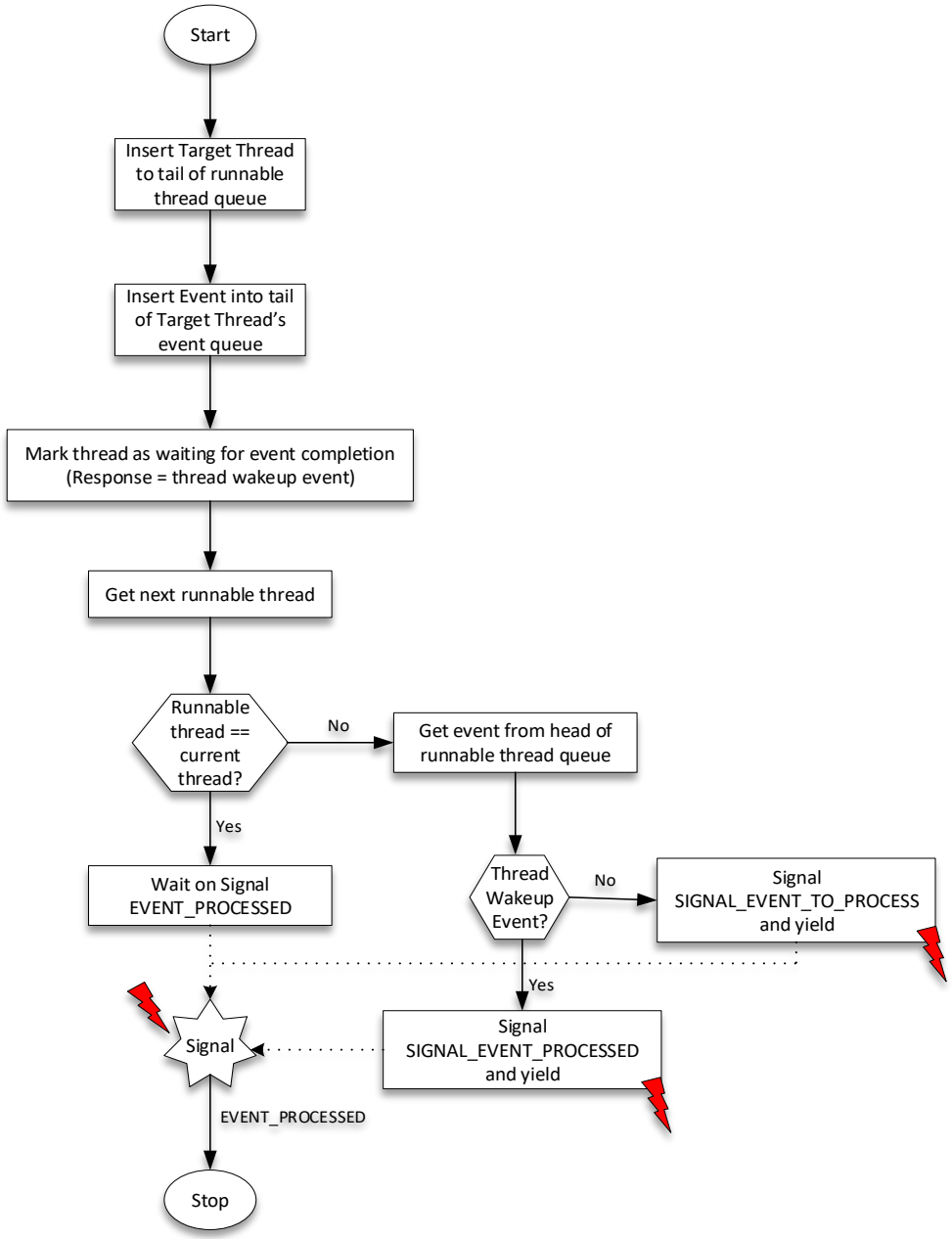
Event Handling

Creating an Event

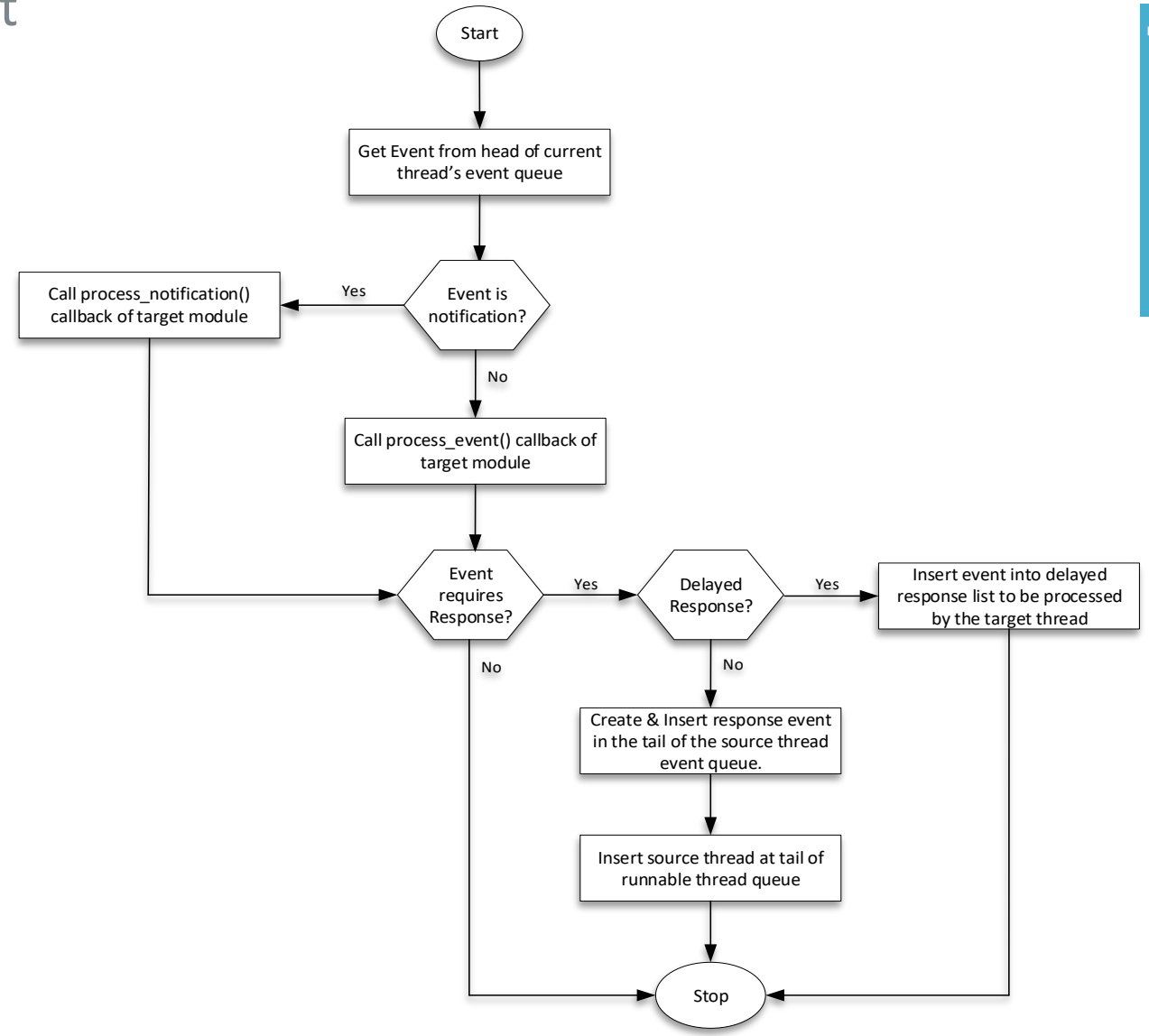
put_event_and_wait()

- Module does not use the common/framework thread.
- The thread blocks till event is processed and response is generated.



Event Handling

Processing an Event



Events Processed in Framework/Common Thread or Module Thread Context

Threading

Features of SCP Threading Model

- Soft-realtime scheduling.
- Support both single and multi-threaded environments with equi-priority threads (no-preemption).
- Support for co-operative scheduling like in CMSIS compliant RTX RTOS.
- No Multi-processor support.
- Independence from direct RTOS calls through threading APIs defined by the framework.
  - These APIs are mapped to CMSIS for now.

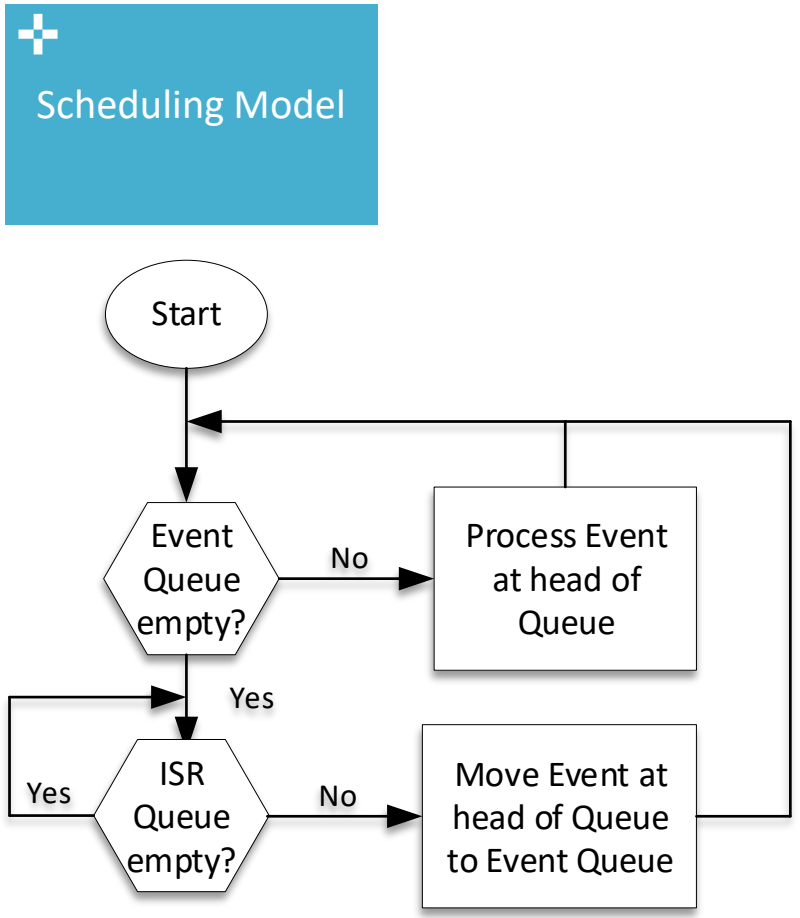
Hybrid co-operative scheduling model

- The scheduling is co-operative among threads at same priority level.
- Eliminates the need for locks
- Makes the code simpler and avoids cases of deadlock.
- It removes execution-context/RTOS dependency and prevents overheads.
- Events are processed sequentially within a thread context.

Threading

Single Threaded Mode

- Simplest mode of operation and suits almost all non-RTOS-based execution environments.
- No Threading Overheads.
- BUILD_HAS_MULTITHREADING not defined.
- Framework thread is the only thread and services all events.
- Modules do not have own threads.
- Single event queue for all events, responses and notifications.
- When an interrupt occurs, it gets serviced.
  - If part of the interrupt processing needs to be postponed (bottom half) an event gets inserted in the ISR Event Queue.
- When the Event Queue is empty, a single event in fetched from the ISR Event Queue and pushed into the tail of the Event Queue.



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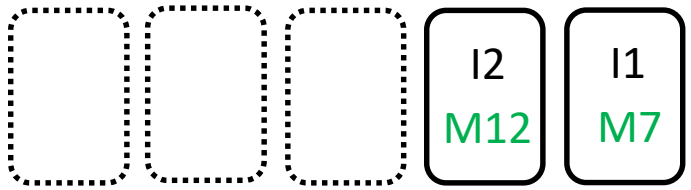
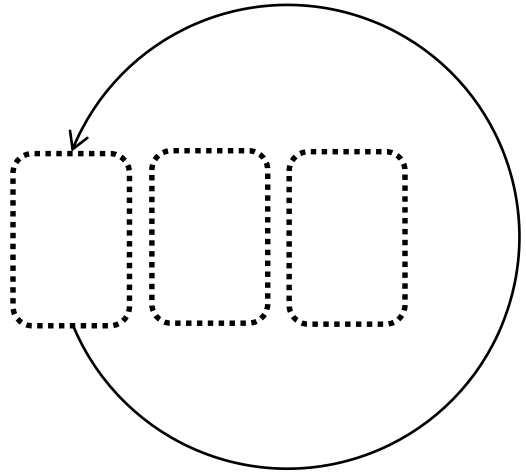
Single Threaded Mode

Execution Flow

Event Driven –
No Priority



Queue of interrupt events



Queue of framework events

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Single Threaded Mode

Execution Flow

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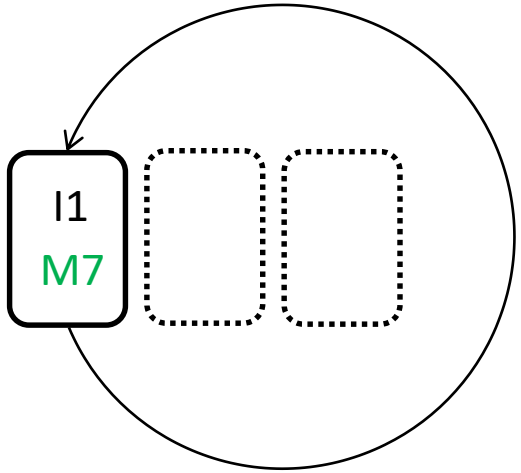

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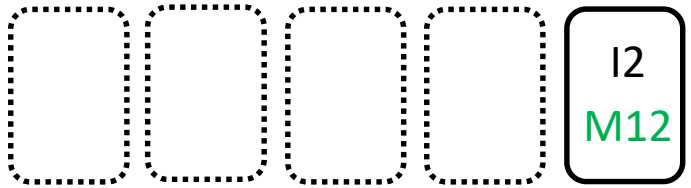

Queue of interrupt events

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Single Threaded Mode

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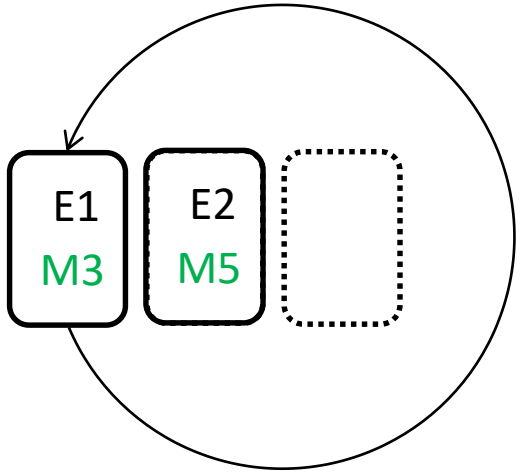

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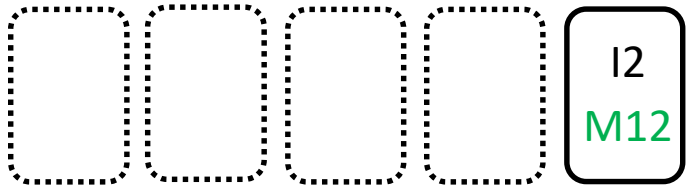

Queue of interrupt events

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Single Threaded Mode

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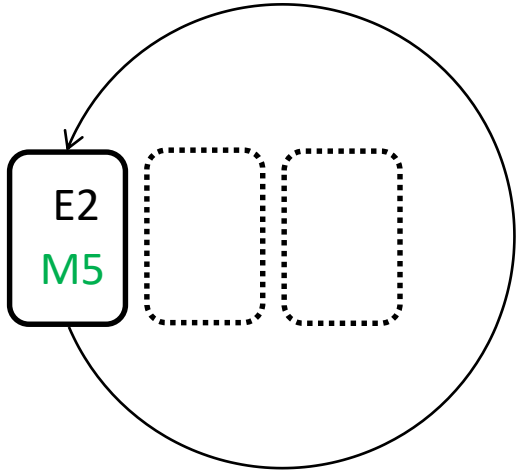

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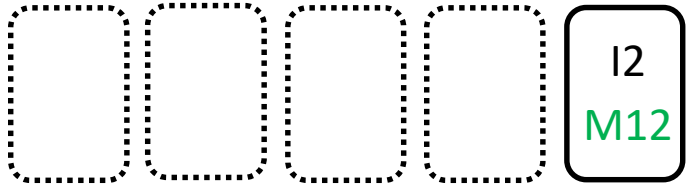

Queue of interrupt events

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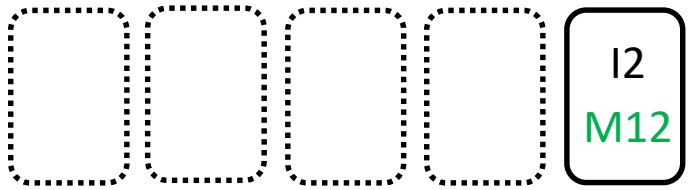

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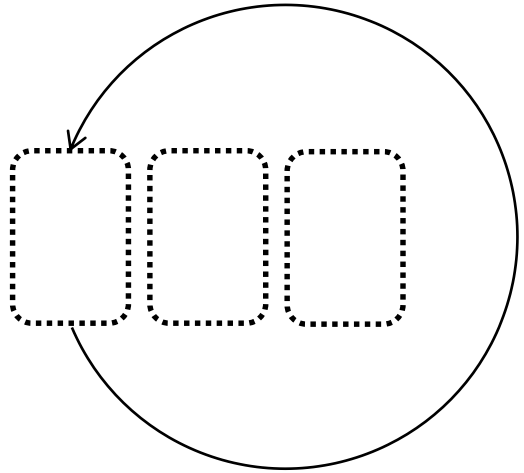

Queue of framework events

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Single Threaded Mode

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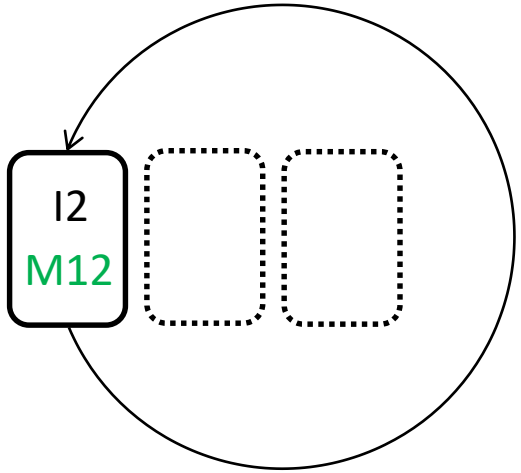

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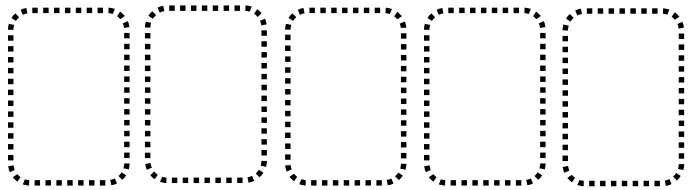

Queue of interrupt events

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Single Threaded Mode

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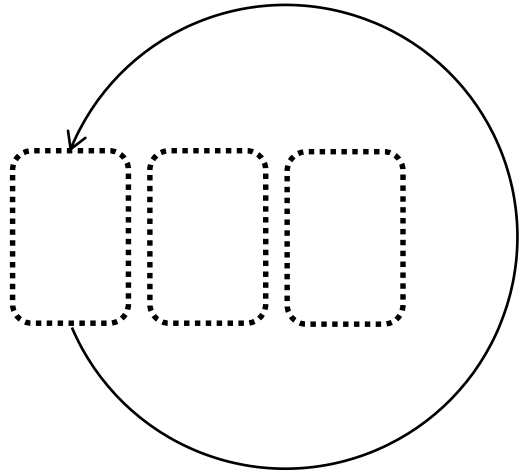

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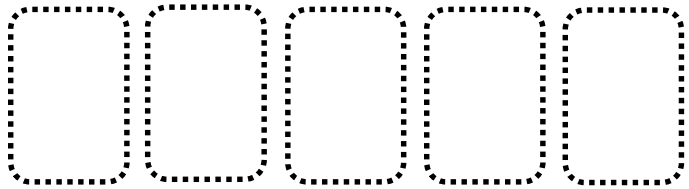

Queue of interrupt events

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Threading

Multi-Threaded Mode

- Suitable for RTOS based environments.
- BUILD_HAS_MULTITHREADING defined.
- One primary thread called the ‘common thread’.
  - In addition, each module can create its own thread.
- Common thread processes all events targeted to the modules which do not have their own thread.
- Each thread has its dedicated event queue.
- Threads are used to provide separate Module context for Event Processing.
  - Running arbitrary thread functions is disallowed.
- There is only one thread which is signaled to run at any point of time.

Scheduling Model

- All threads of same priority.
- All threads have same thread function – provided by the framework.
- Threads wait for a signal from another thread to wakeup and handle an event targeting it.

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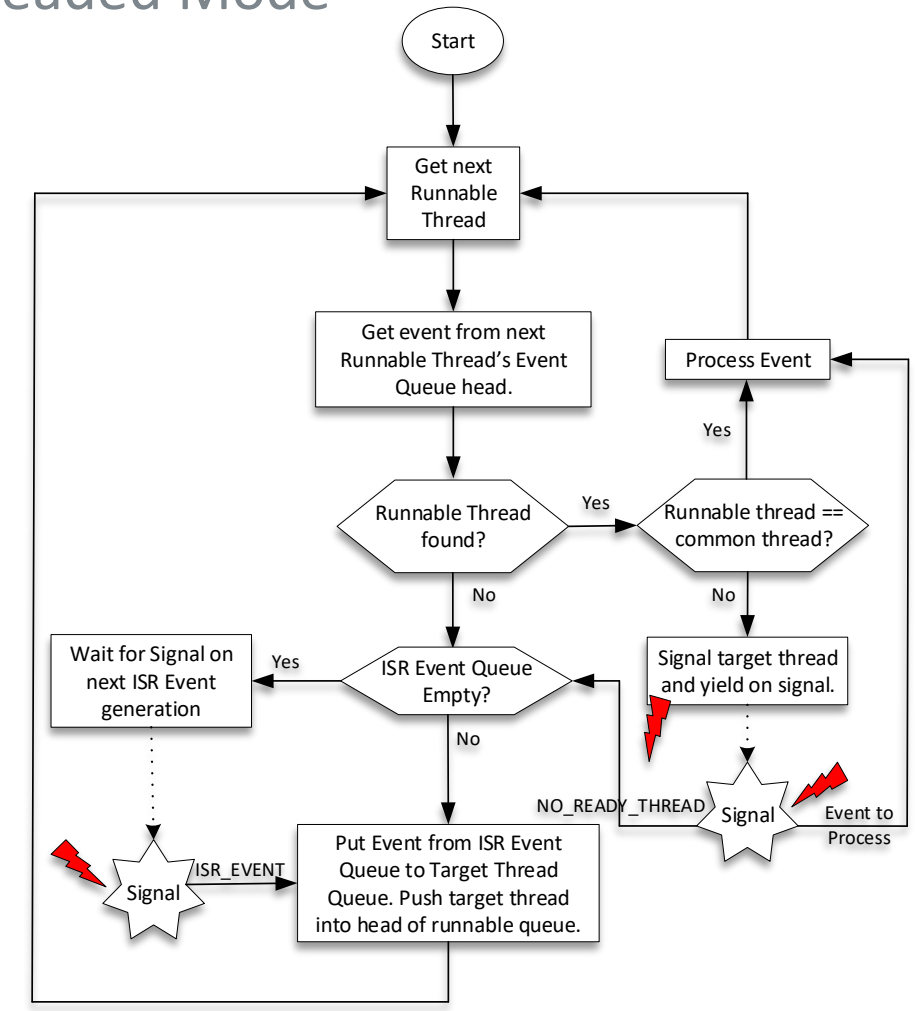
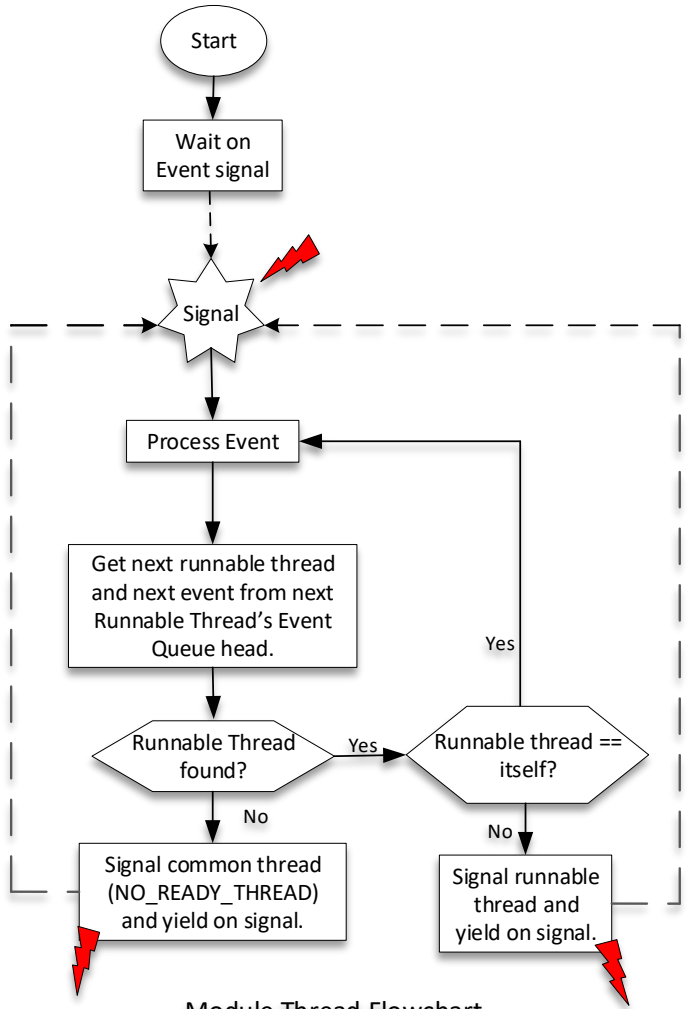
Threading

Multi-Threaded Mode



Common Thread Flowchart

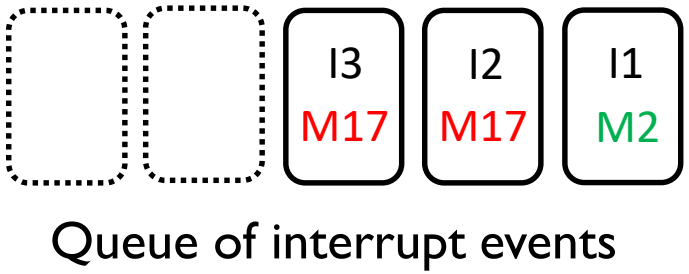


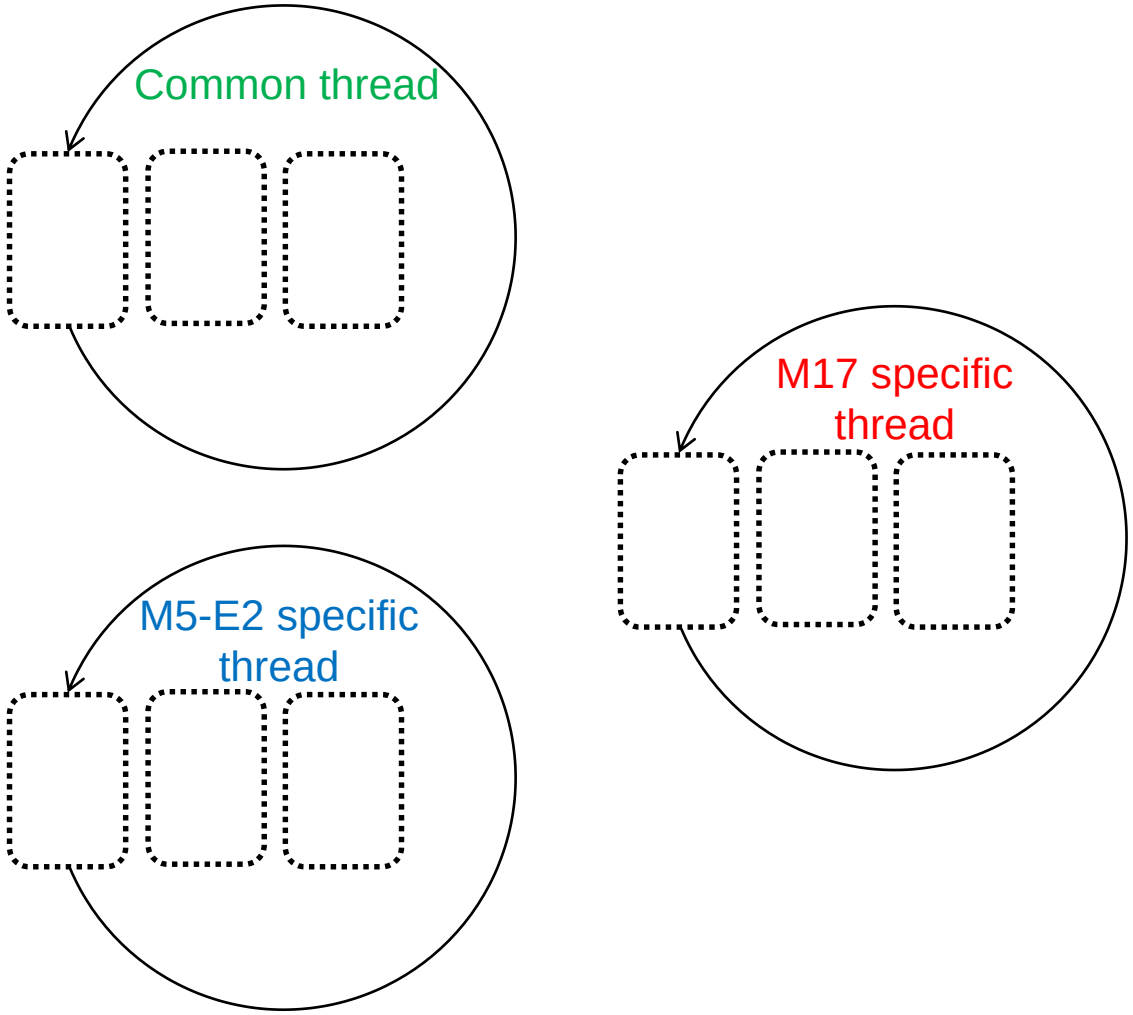
Module Thread Flowchart

Multi Threaded Mode

Execution Flow

- Event Driven – No Priority
- Soft real time constraints (no thread priority)





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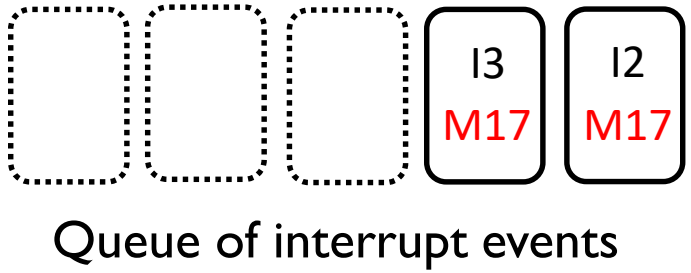

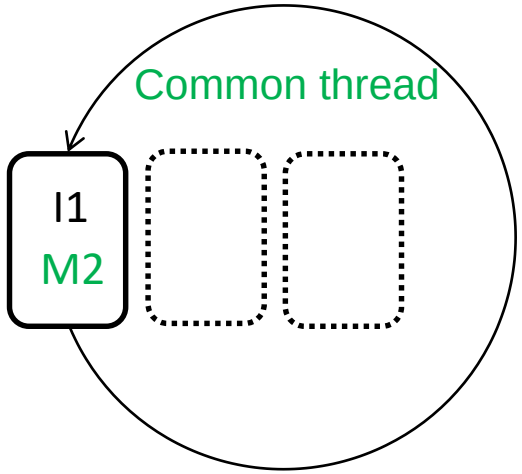

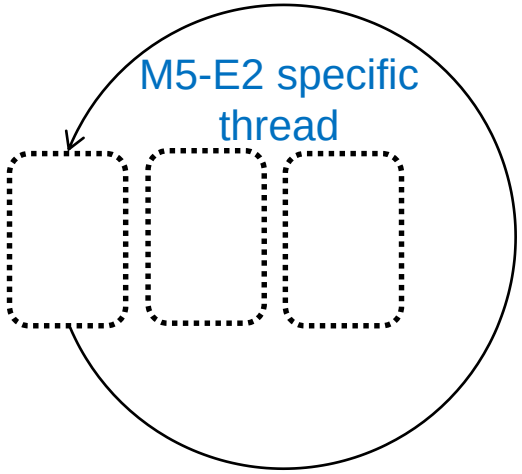

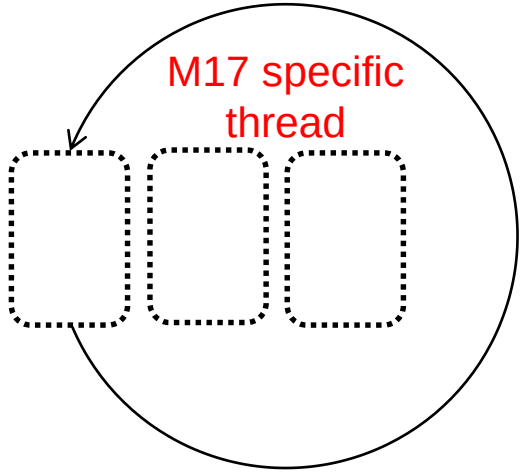

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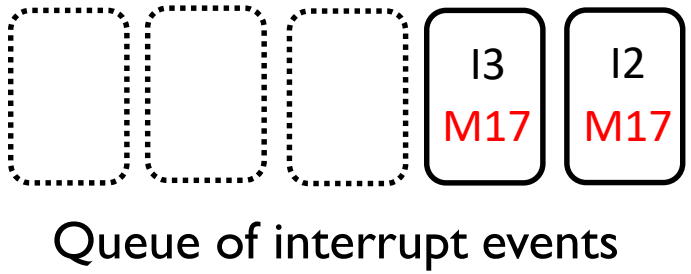

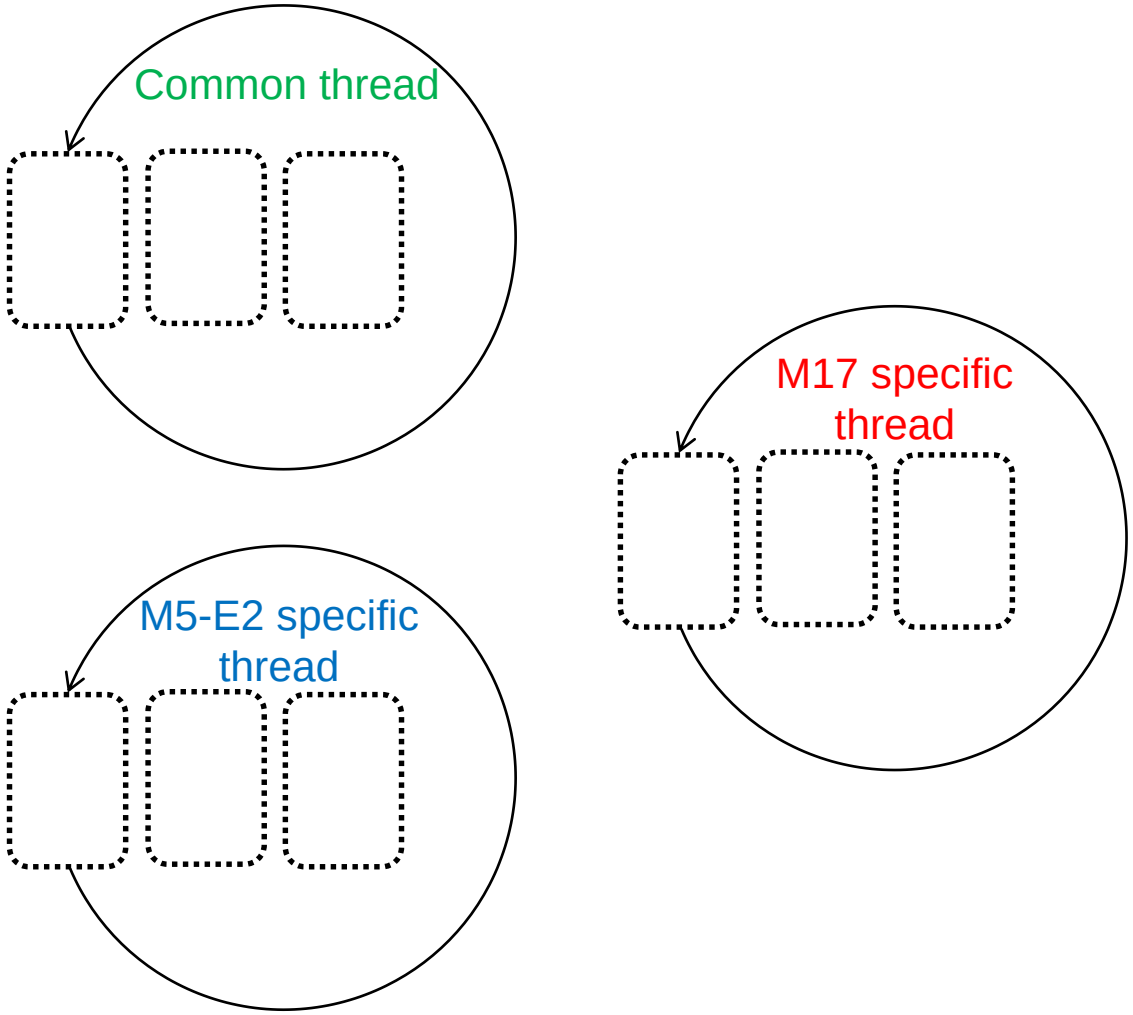

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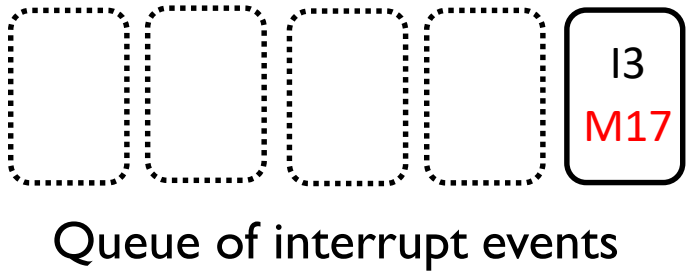

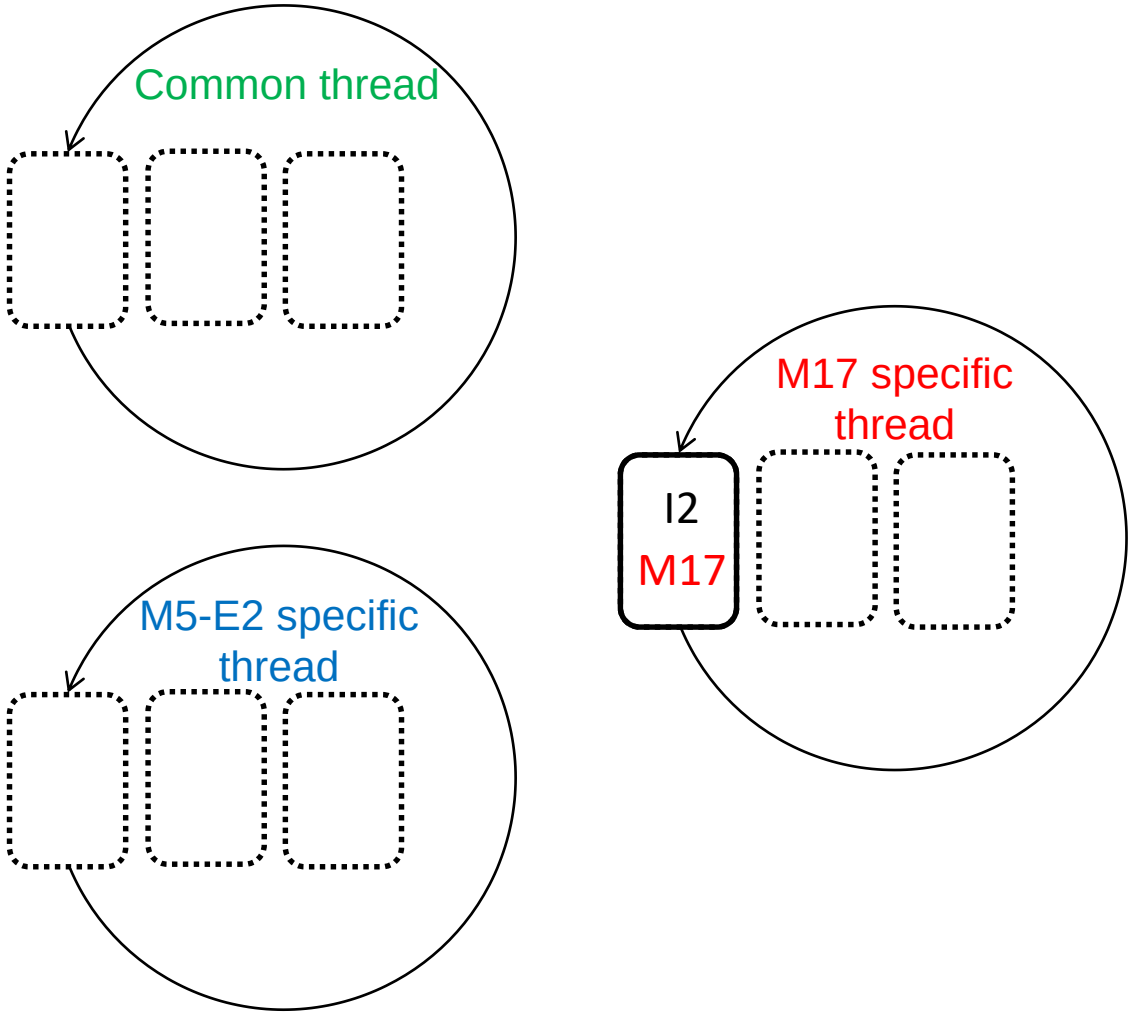

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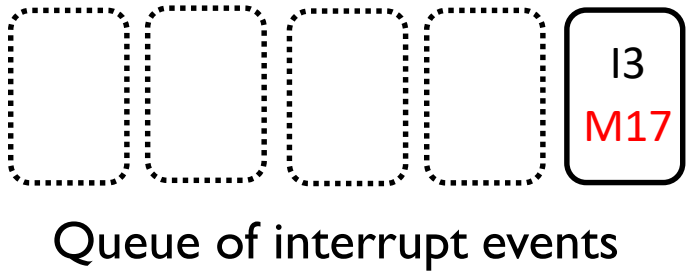

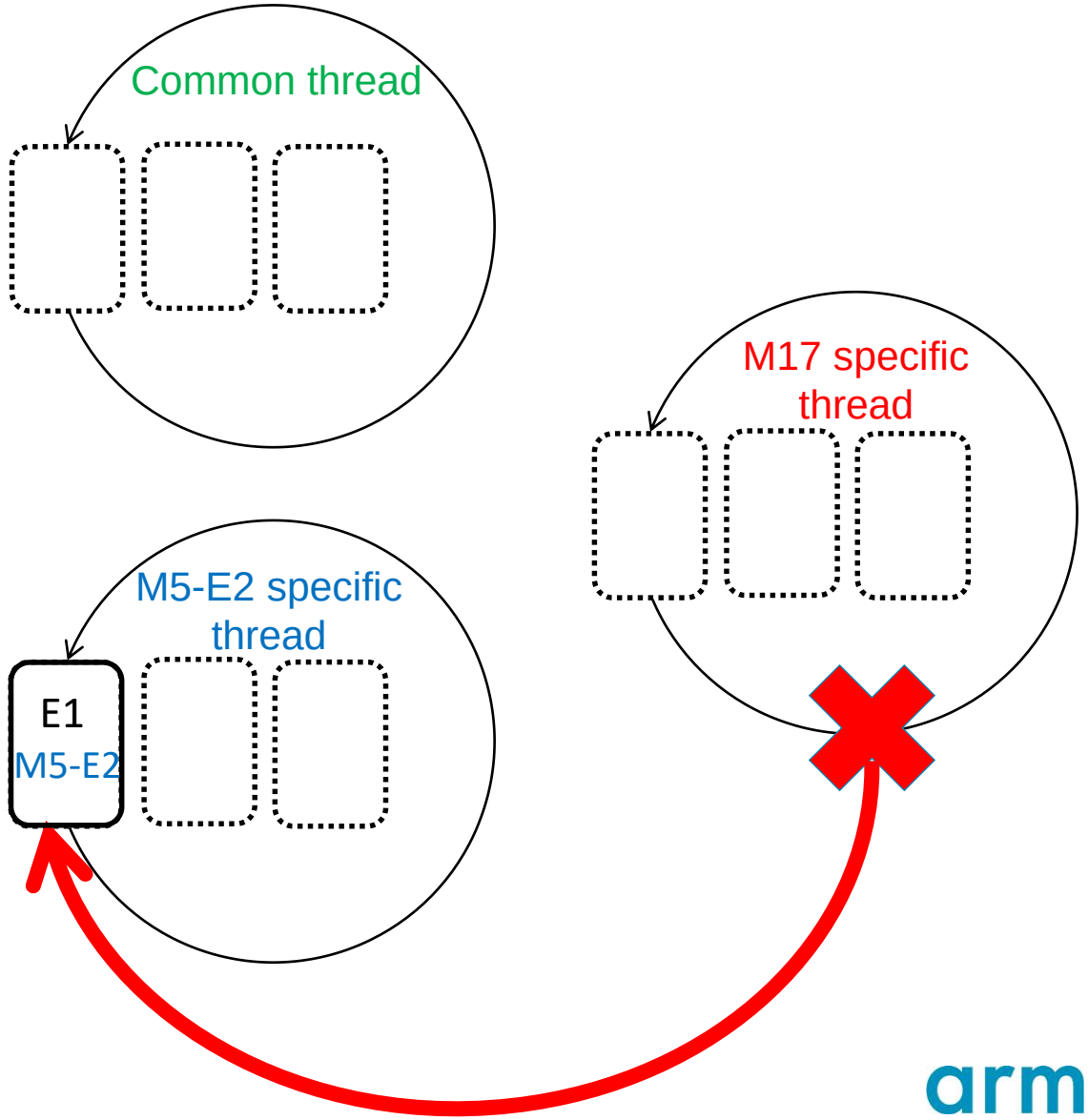

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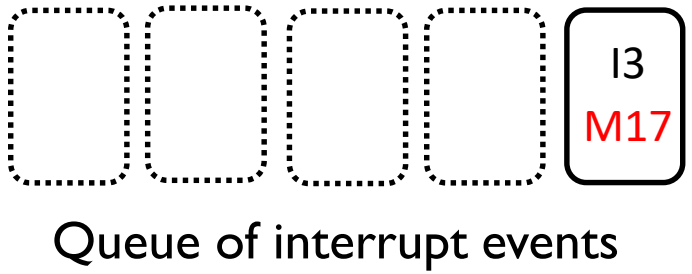

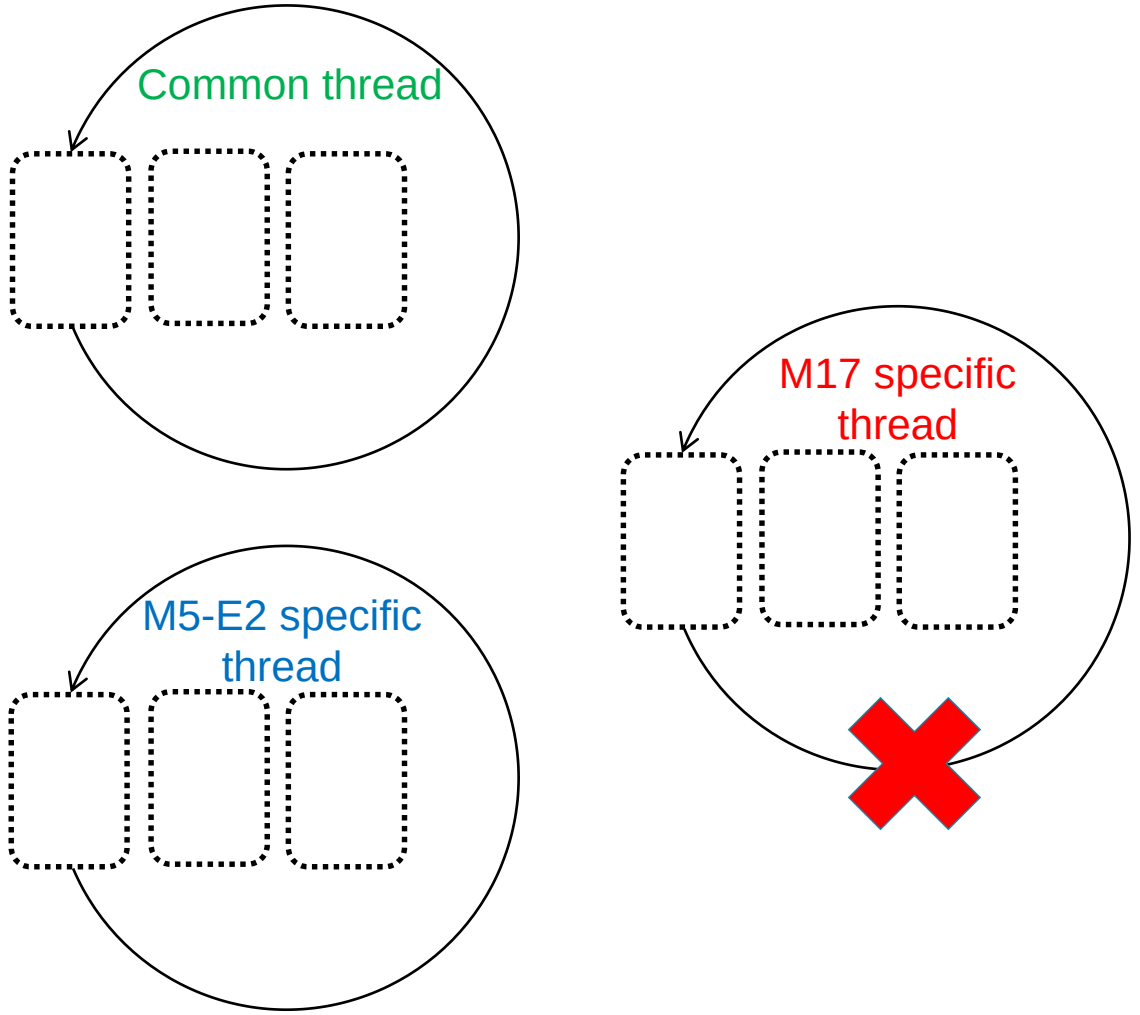

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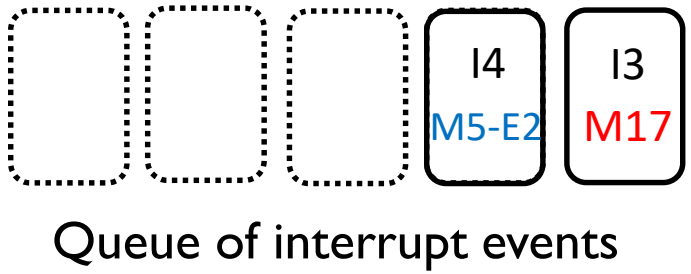
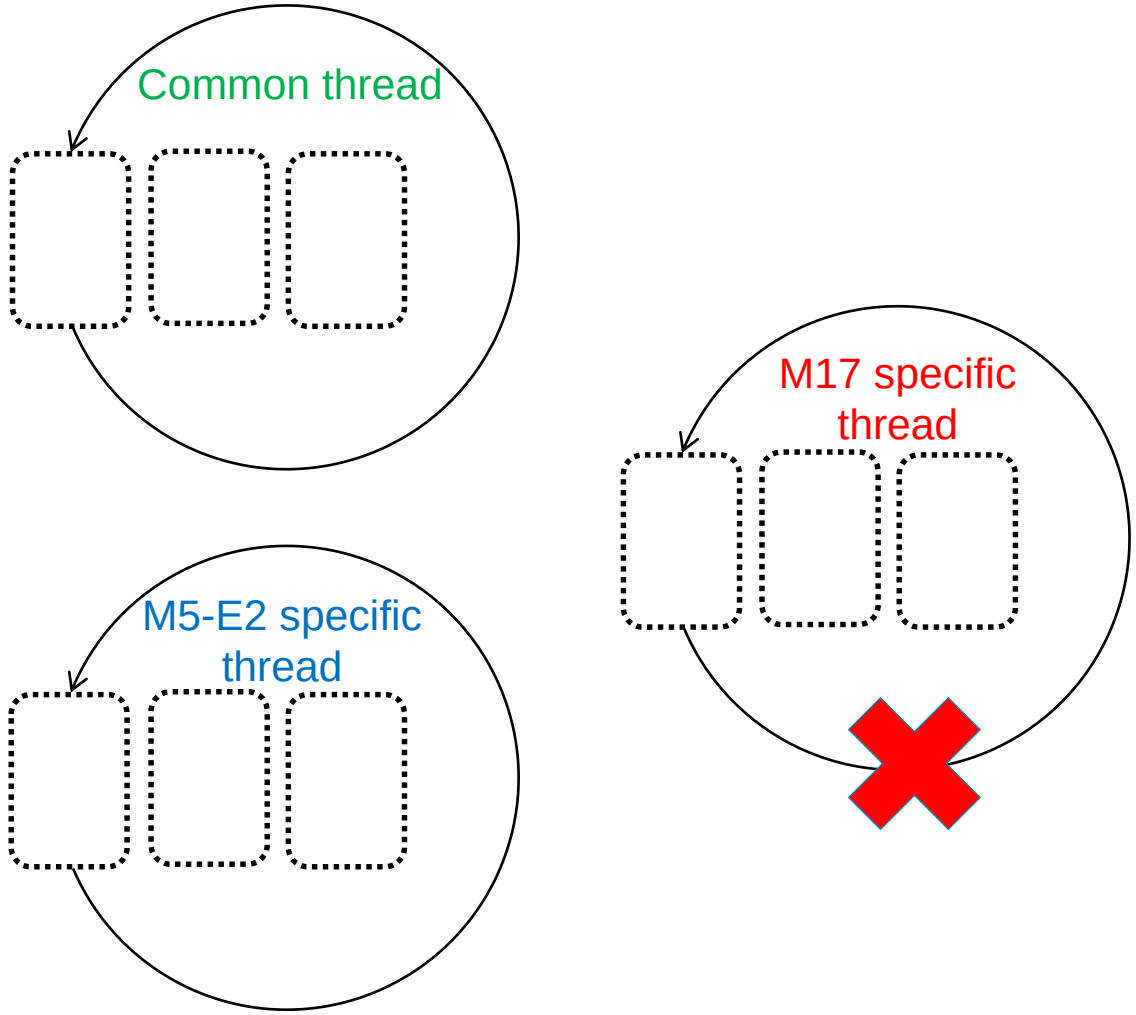


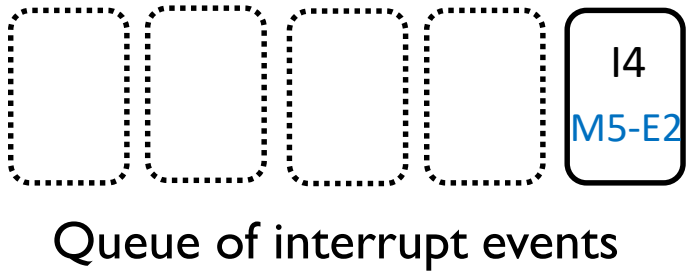


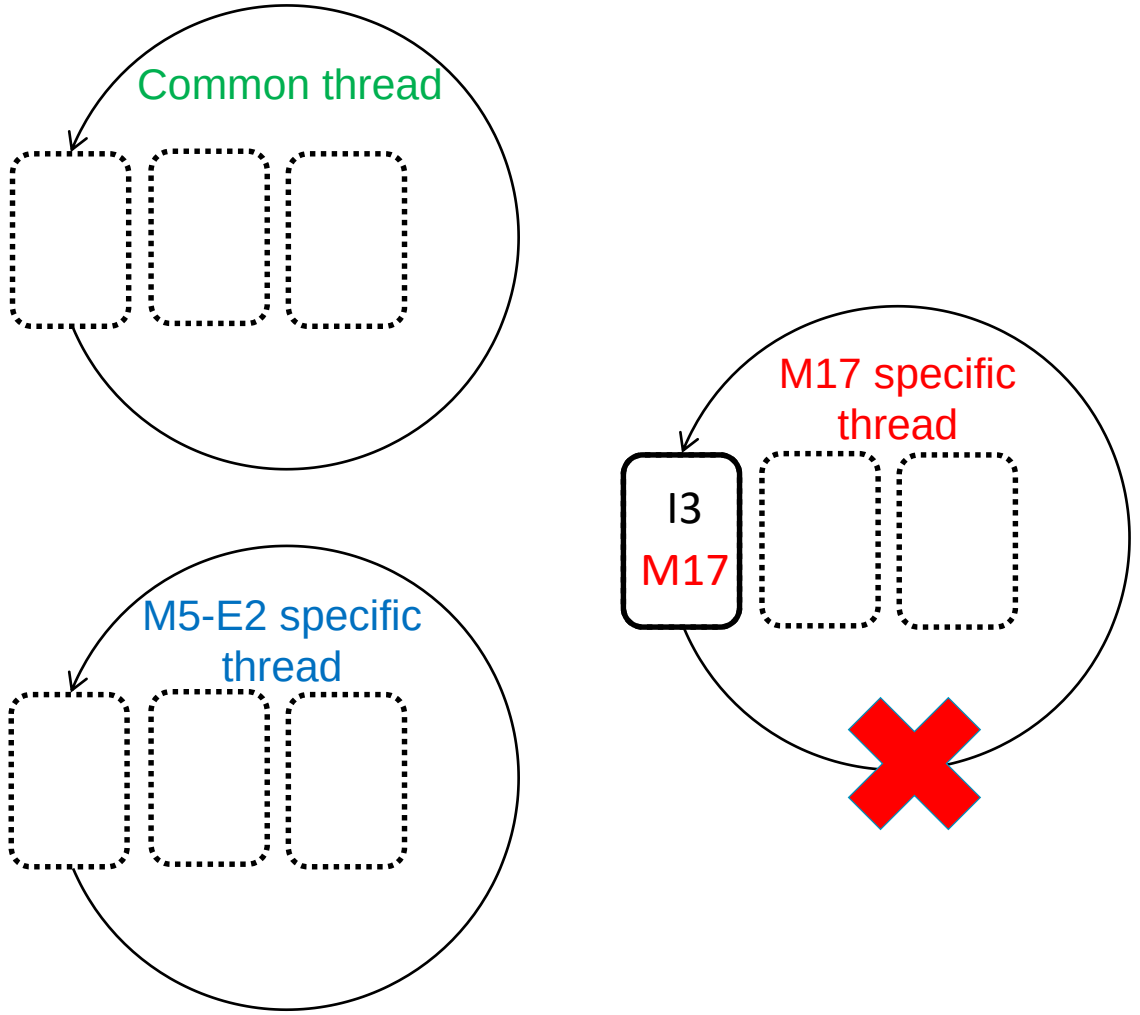
arm

Multi Threaded Mode

Execution Flow

- Event Driven – No Priority
- Soft real time constraints (no thread priority)





arm

Multi Threaded Mode

Execution Flow

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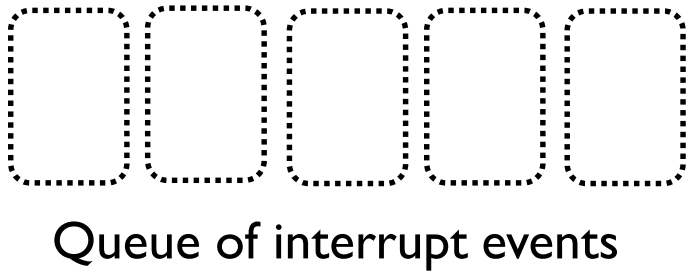
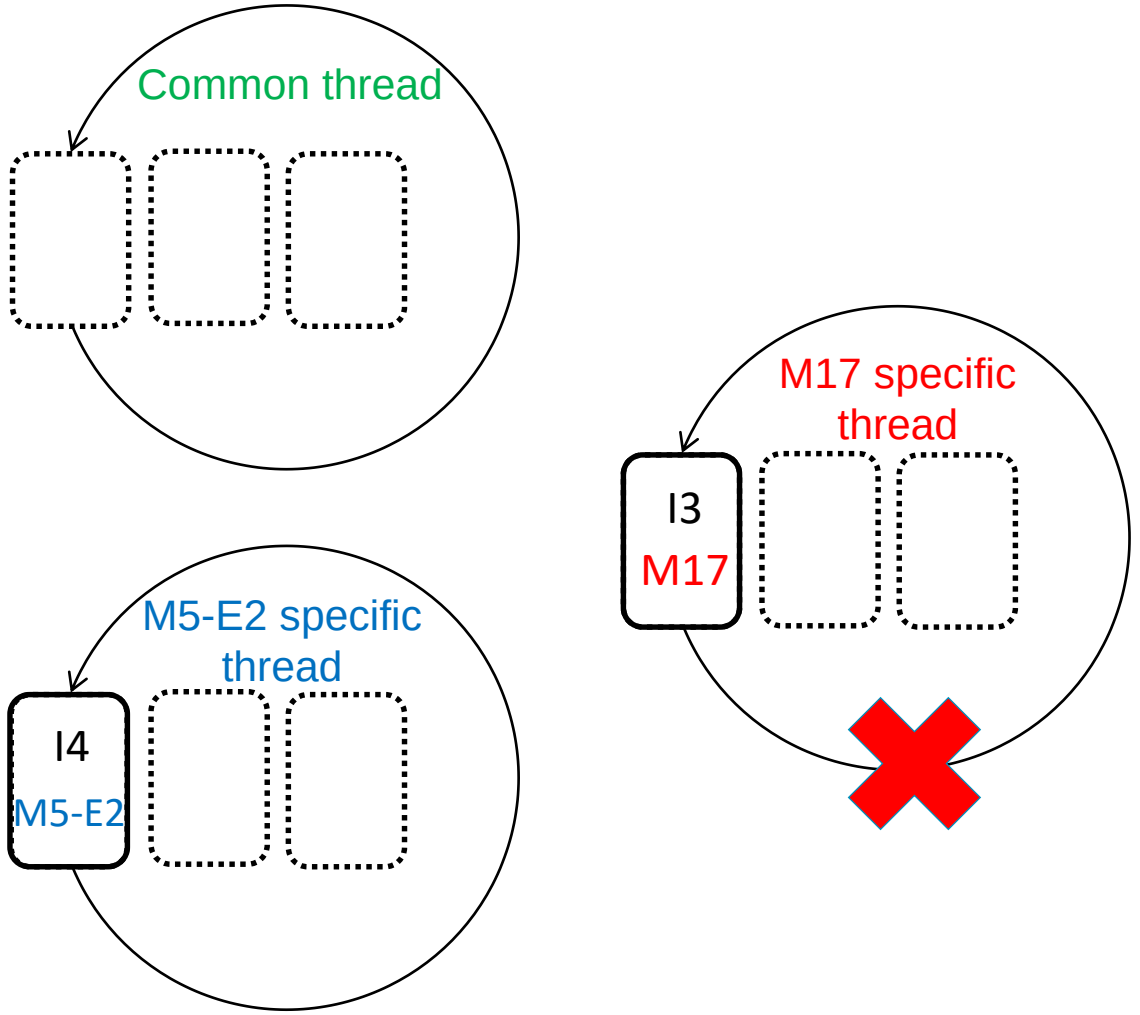
- Soft real time constraints (no thread priority)



Queue of interrupt events

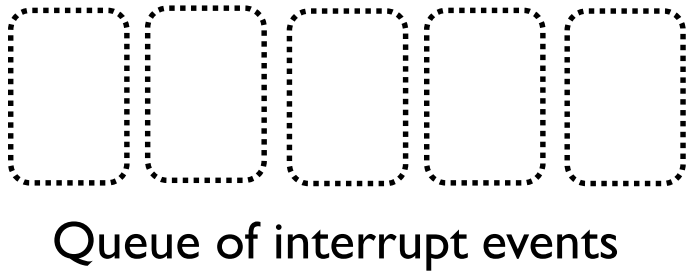


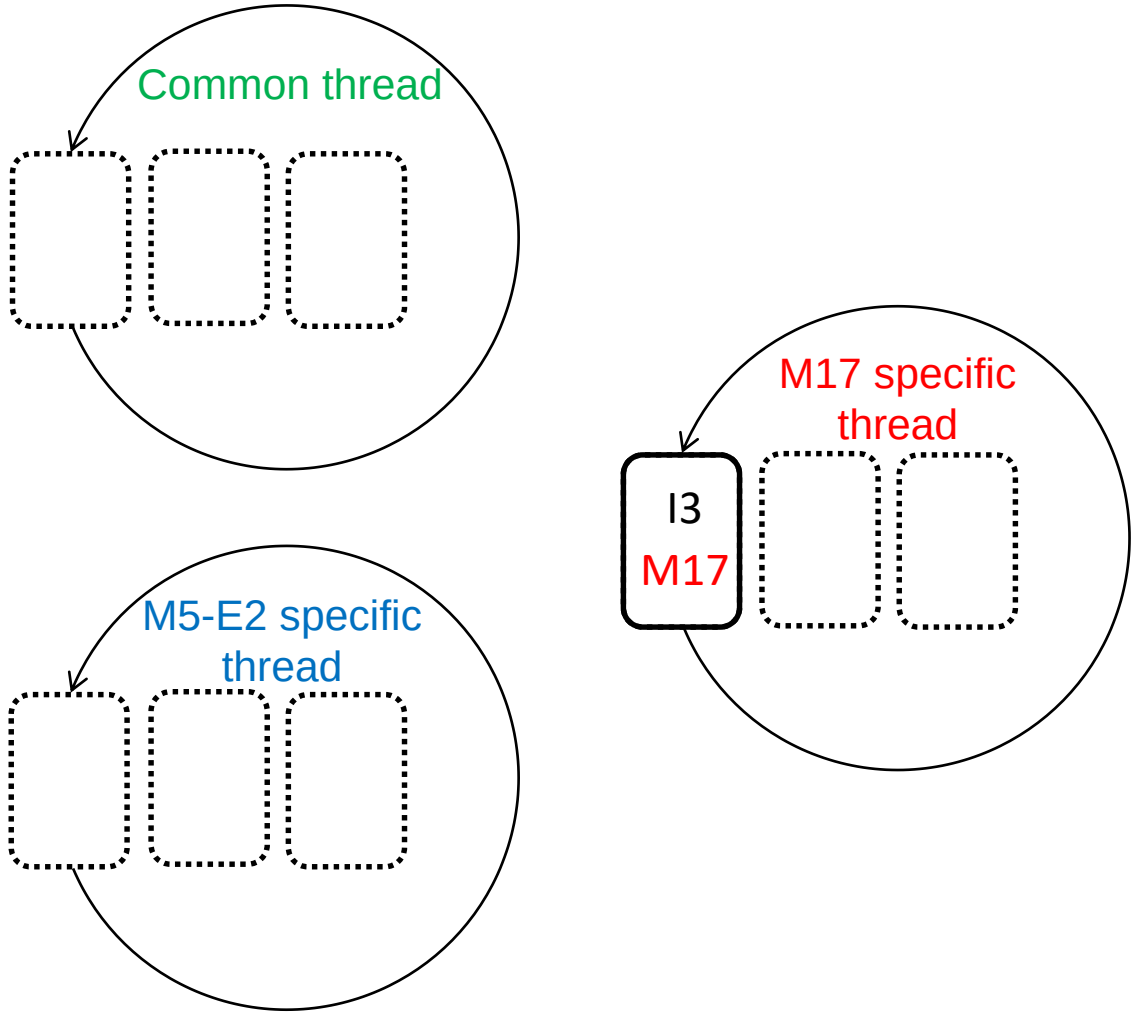
arm

Multi Threaded Mode

Execution Flow

- Event Driven – No Priority
- Soft real time constraints (no thread priority)





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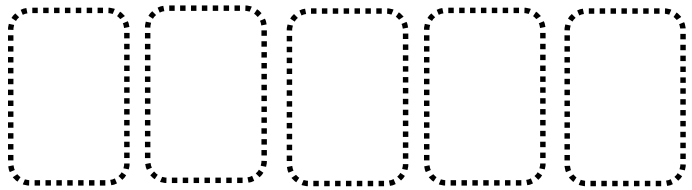
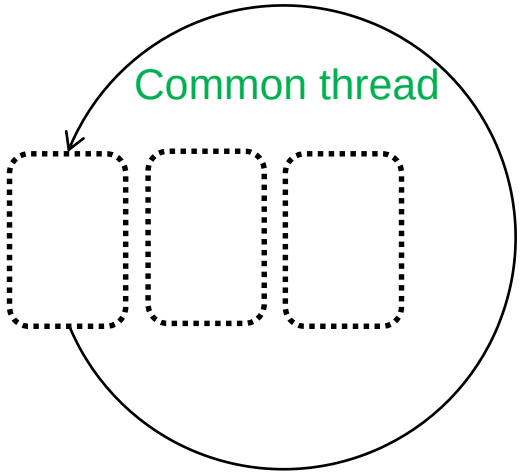
Multi Threaded Mode

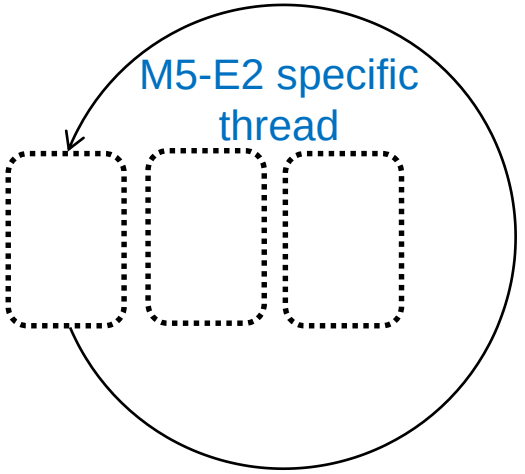
Execution Flow

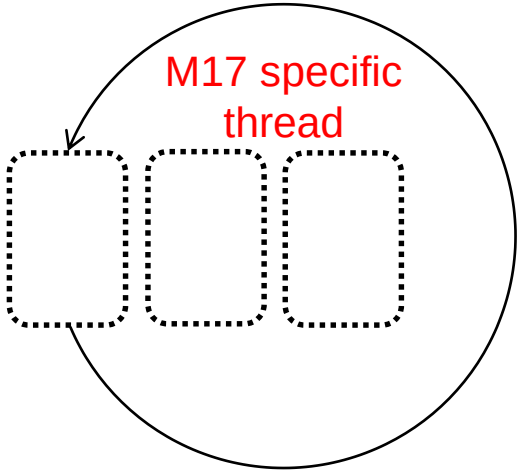
- Event Driven – No Priority
- Soft real time constraints (no thread priority)



Queue of interrupt events







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Guidelines for New Module Design

- Generic Modules must support both single threaded and multi-threaded mode.
  - Product specific modules can choose to support any threading mode.

- Modules should not :
  - block in single threaded mode without a timeout.
  - perform long-running tasks in caller context. It should generate an event and split long-running tasks into smaller tasks via events.
  - have shared contexts with other modules which require locking.
  - allocate memory which will not be used later. The firmware does not have a memory “free” API. Dynamic memory management is not implemented to keep the firmware simple and efficient.

Status & Next Steps

- Neoverse N1 reference design, SGM-775, SGI-575 are supported – SCP Release v2.5.0
- SCP Idle (Turn OFF SCP when Idle): Under Design
- SCMI Protocols support in Single Threaded Mode: Under Design
- Full PM Support on reference Hardware (Arm Juno Board): Target Q4 2019
  - Power Domains, DVFS, Clocks, Sensors, PMIC over I2C, Thermal, etc.
- Work ongoing to enable SCP Firmware as Secure World resident firmware for Power and Performance Management – Linaro/STMicroelectronics/Arm.

Useful Links

- SCMI Specification: http://infocenter.arm.com/help/topic/com.arm.doc.den0056b/DEN0056B_System_Control_and_Management_Interface_v2_0.pdf
- SCP Firmware: https://github.com/ARM-software/SCP-firmware

Thank You
Danke
Merci
谢谢
ありがとう
Gracias
Kiitos
감사합니다
धन्यवाद
شكرًا
תודה