Zephyr™ Power Management

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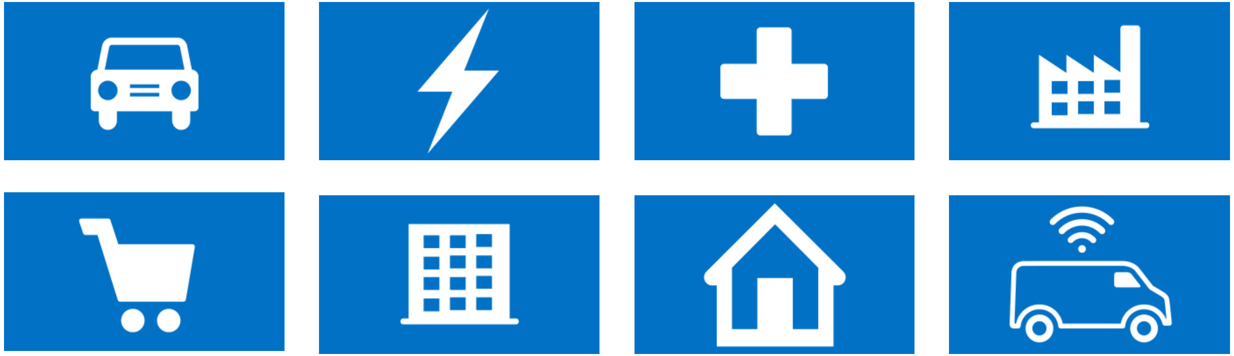
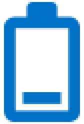
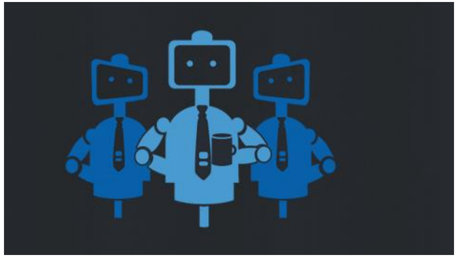
Agenda

- Why Power Management?
- The core concepts behind Zephyr RTOS PM
- Power Management Infrastructures
- Future direction

Think Possible…

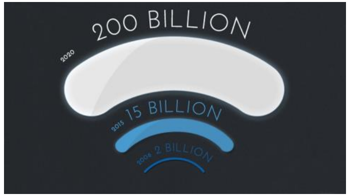


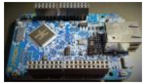


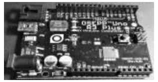


Zephyr RTOS PM – Core Concepts

- Multi architecture/board/SOC
- Designed for IoT/embedded
- Customizable for different needs
- Flexibility and variety of options
- Scalable design
- Follow open source process

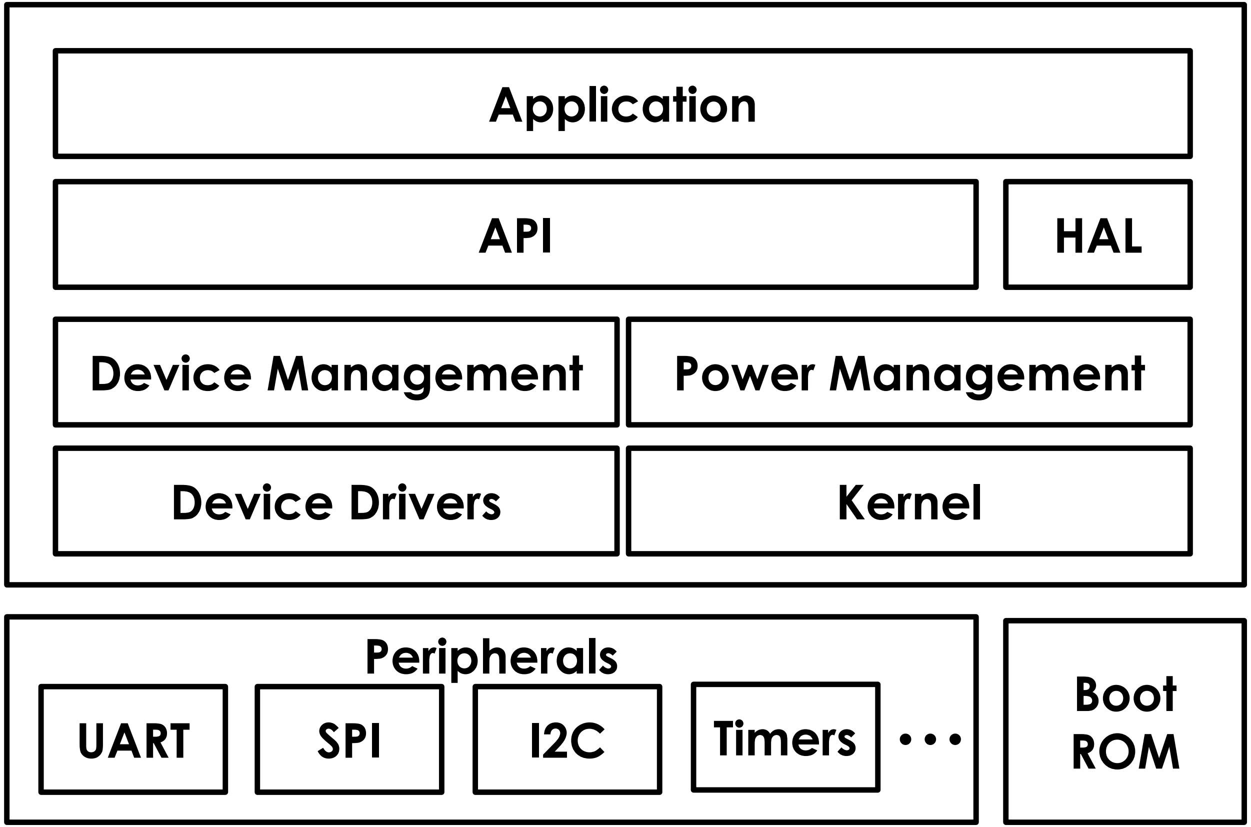




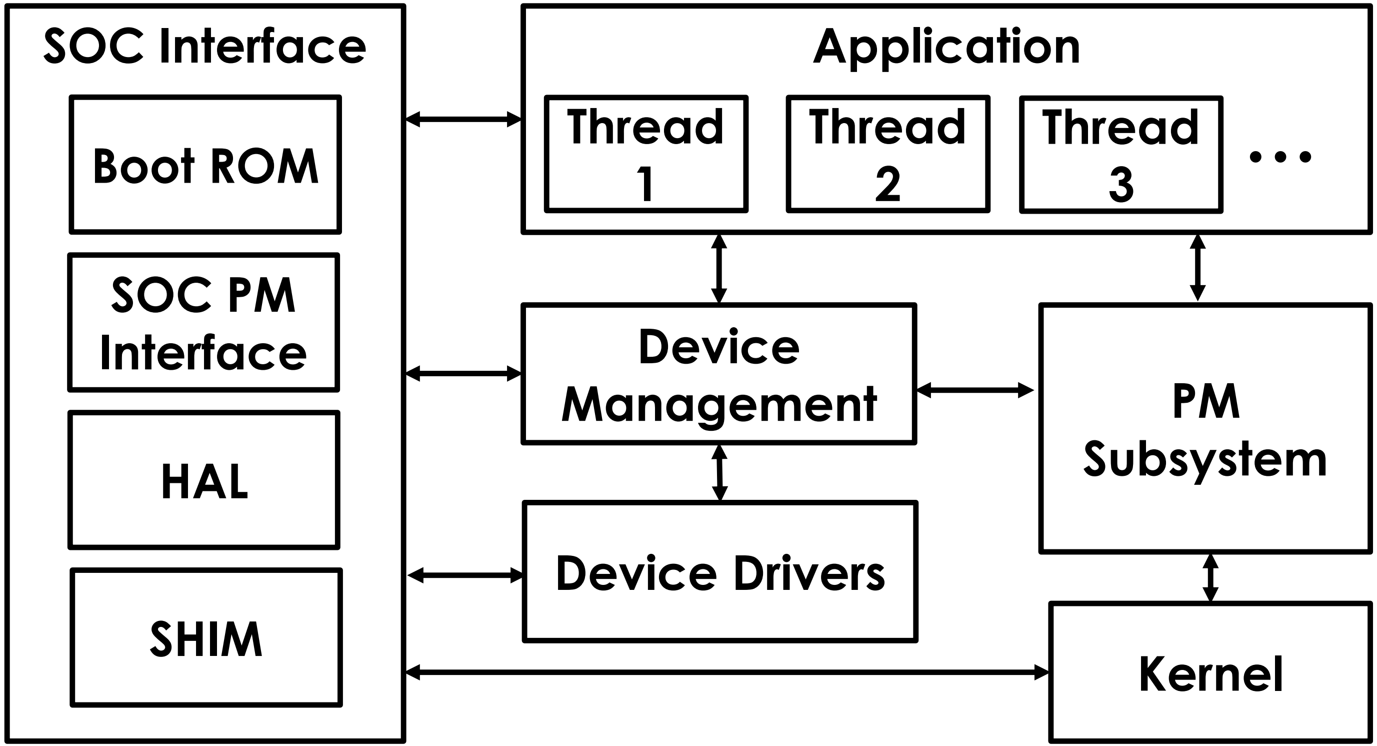


Zephyr RTOS components

(partial)



PM high level layout



Zephyr RTOS PM Deep Dive

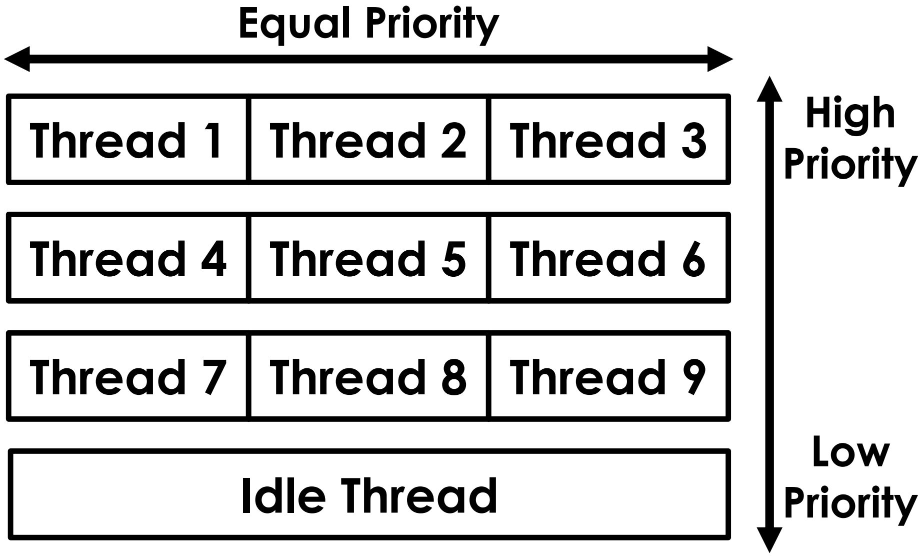
Zephyr RTOS PM features

- Event based kernel idling
- System power management
- Device power management

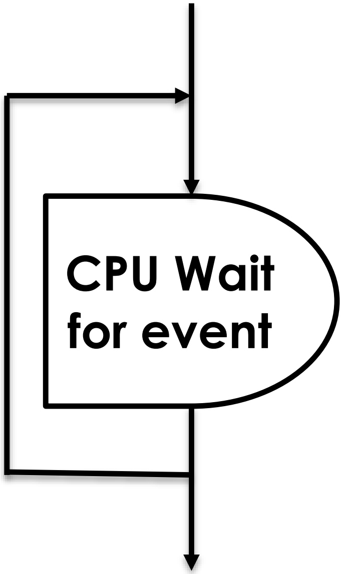
First a quick intro to the scheduler…

Kernel scheduling and idling

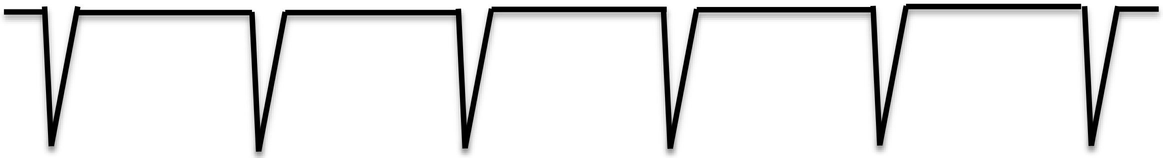
- Priority based scheduling
- Threads wait on semaphore or yield
- Idle Thread scheduled when no other thread can run
- Idle Thread is lowest priority thread
- System Power Management happens in Idle Thread



Inside the Idle Thread

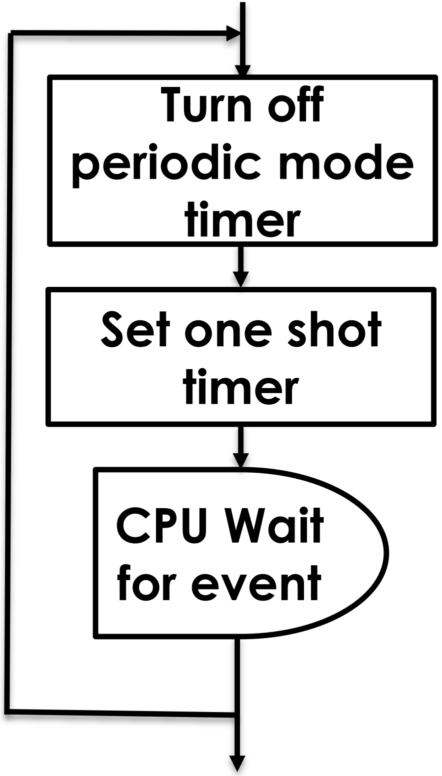


Periodic mode timer ticks

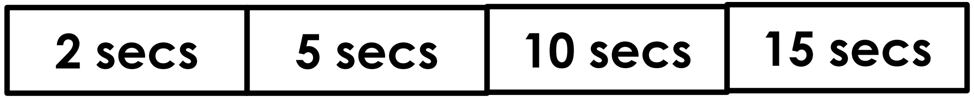


- Kernel scheduler gets invoked from ISR of timer or other event
- If no thread is ready to run, schedules Idle Thread again

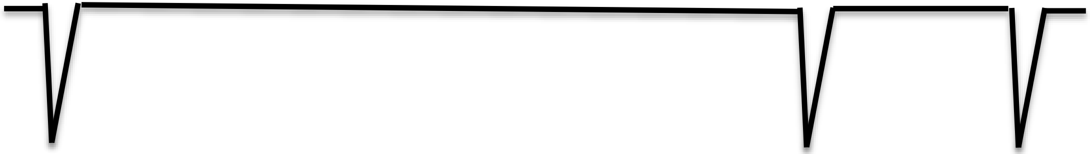
Event Based Idling



Ordered list of thread wait/timeout periods



No ticks until a thread is ready to run



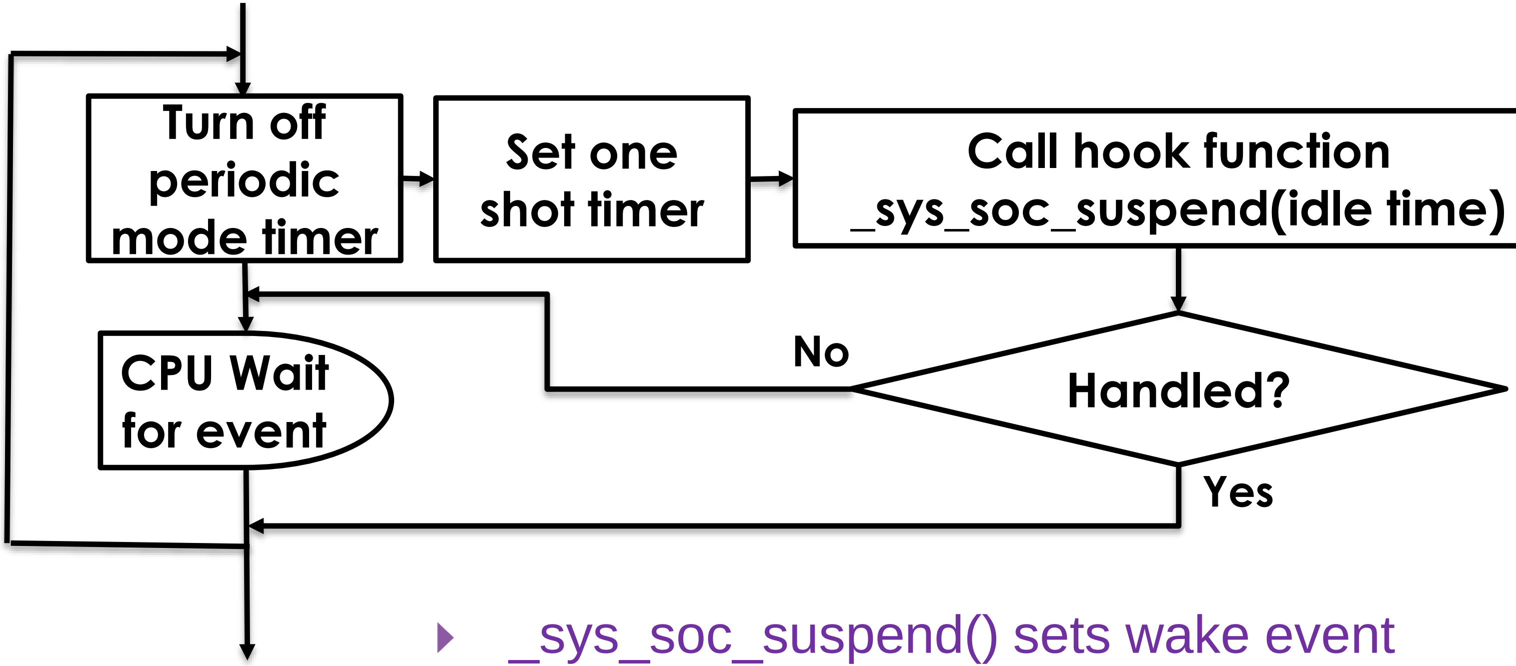
- Power saved by avoiding unnecessary wake events
- <u>ISR turns periodic mode timer on again</u>

System Power Management

Hooks into the Kernel Idle Thread

- _sys_soc_suspend(idle time)
  - Going to idle
- _sys_soc_resume()
  - Notify low power state exit or wake event
  - SOC implementation dependent
- Simple and intuitive
  - When idle - save power
  - When active - real-time performance

Triggered from Idle Thread



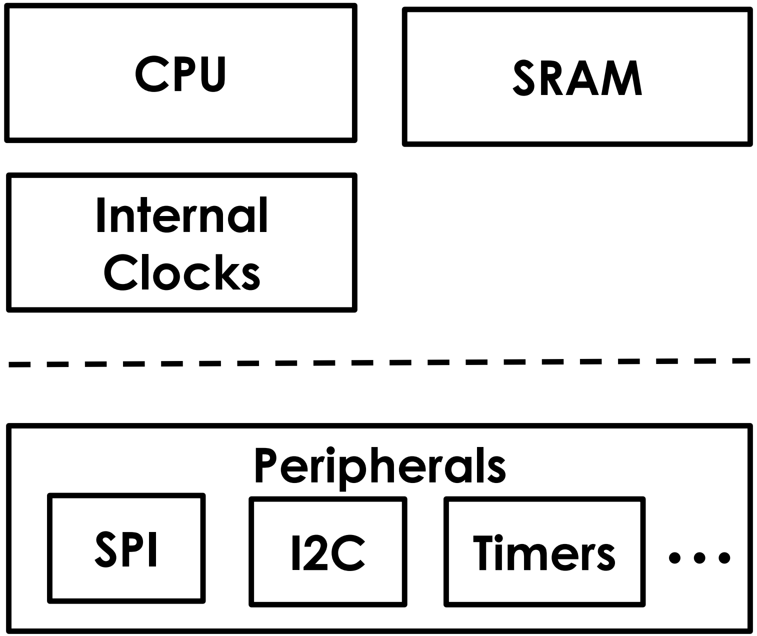
- _sys_soc_suspend() sets wake event
- Wake -> ISR -> Periodic Mode On -> Scheduler

Inside _sys_soc_suspend

Quick look into HW PM features…

Categories based on HW PM features

- CPU Low Power State
  - CPU clock gated
  - Peripherals active
- SOC Deep Sleep
  - CPU power gated
  - Selective RAM retention
  - Most peripherals lose power
- Different power savings
- Different wake latencies
- Different resume paths



_sys_soc_suspend(<idle time>)

- Setup wake event
- If short idle time
  - Any PM operation that takes less time
  - Enter a CPU low power state
- If long idle time
  - Save states of devices that will lose power
  - Any PM operation that saves more power
  - Enter SOC Deep Sleep

_sys_soc_resume()

- Deep Sleep wake notification
  - Depends on SOC specific implementation
- Wake event notification
  - Optionally called from ISR of wake events
  - Before Kernel schedules other tasks or process nested interrupts
  - Call _sys_soc_disable_wake_event_notification() if not required

Device Power Management

Device Power States

- Classified based on device state retention
  - DEVICE_PM_ACTIVE_STATE
  - DEVICE_PM_LOW_POWER_STATE
  - DEVICE_PM_SUSPEND_STATE
  - DEVICE_PM_OFF_STATE

Device Power Management Overview

- Integrated with Device Management
- Drivers maintain per device power states
- Device APIs to set and get state
- Application, Driver or SOC interface can set states
- Multiple design options to manage device PM
    - Central – Only in _sys_soc_suspend()
    - Distributed – By Applications, Drivers, SOC Interface.

Device PM APIs

```
device_list_get(struct device **device_list, int *device_count)

device_get_power_state(struct device *device,
                       uint32_t *device_power_state)

device_set_power_state(struct device *device,
                       uint32_t device_power_state)

device_busy_set(), device_busy_clear(),

device_any_busy_check(), device_busy_check()
```

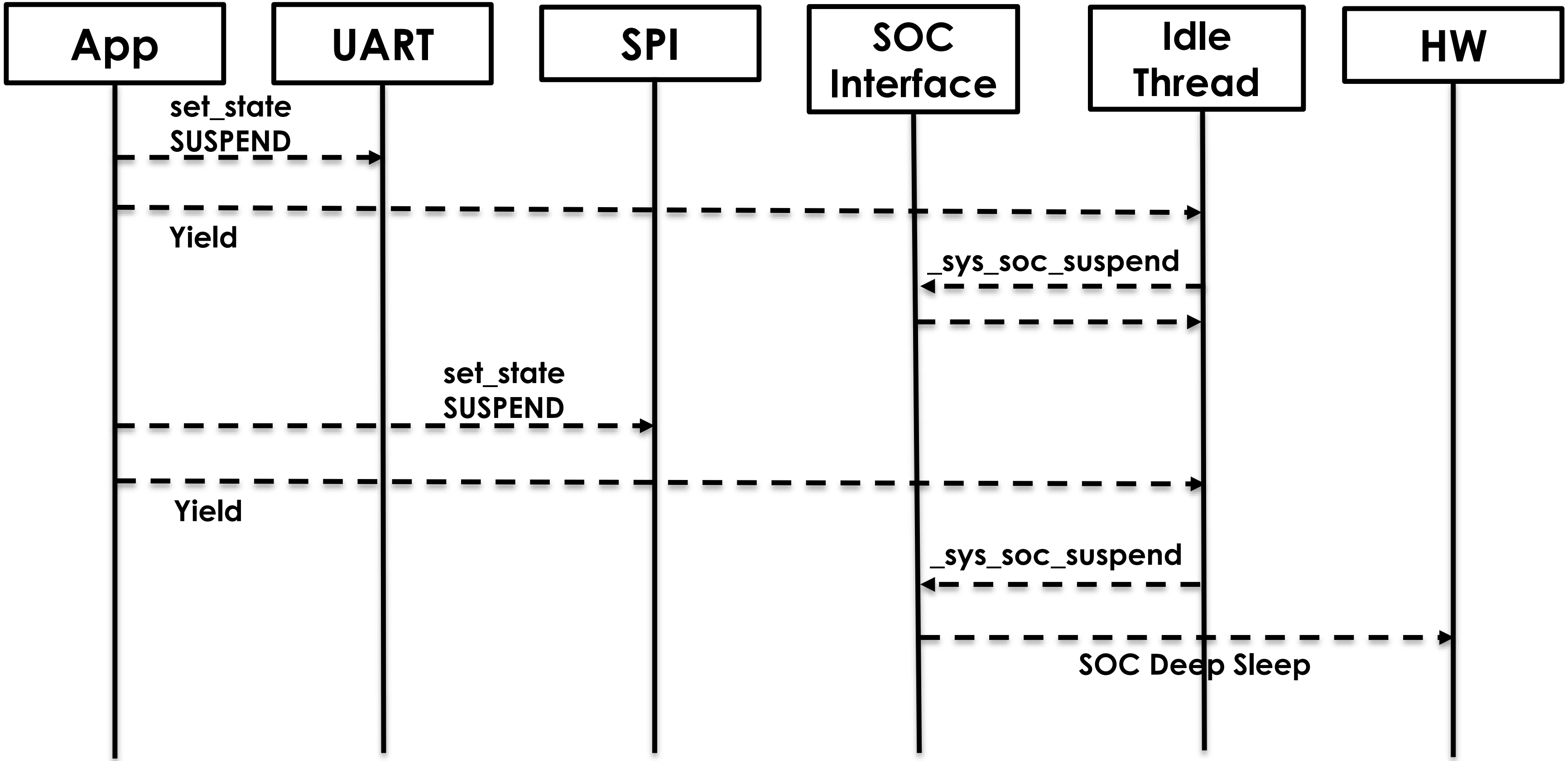
Device Driver PM Interface

- PM Control Function
- Control codes
  - DEVICE_PM_SET_POWER_STATE
  - DEVICE_PM_GET_POWER_STATE
- Part of Device Interface
- Access only through Device APIs

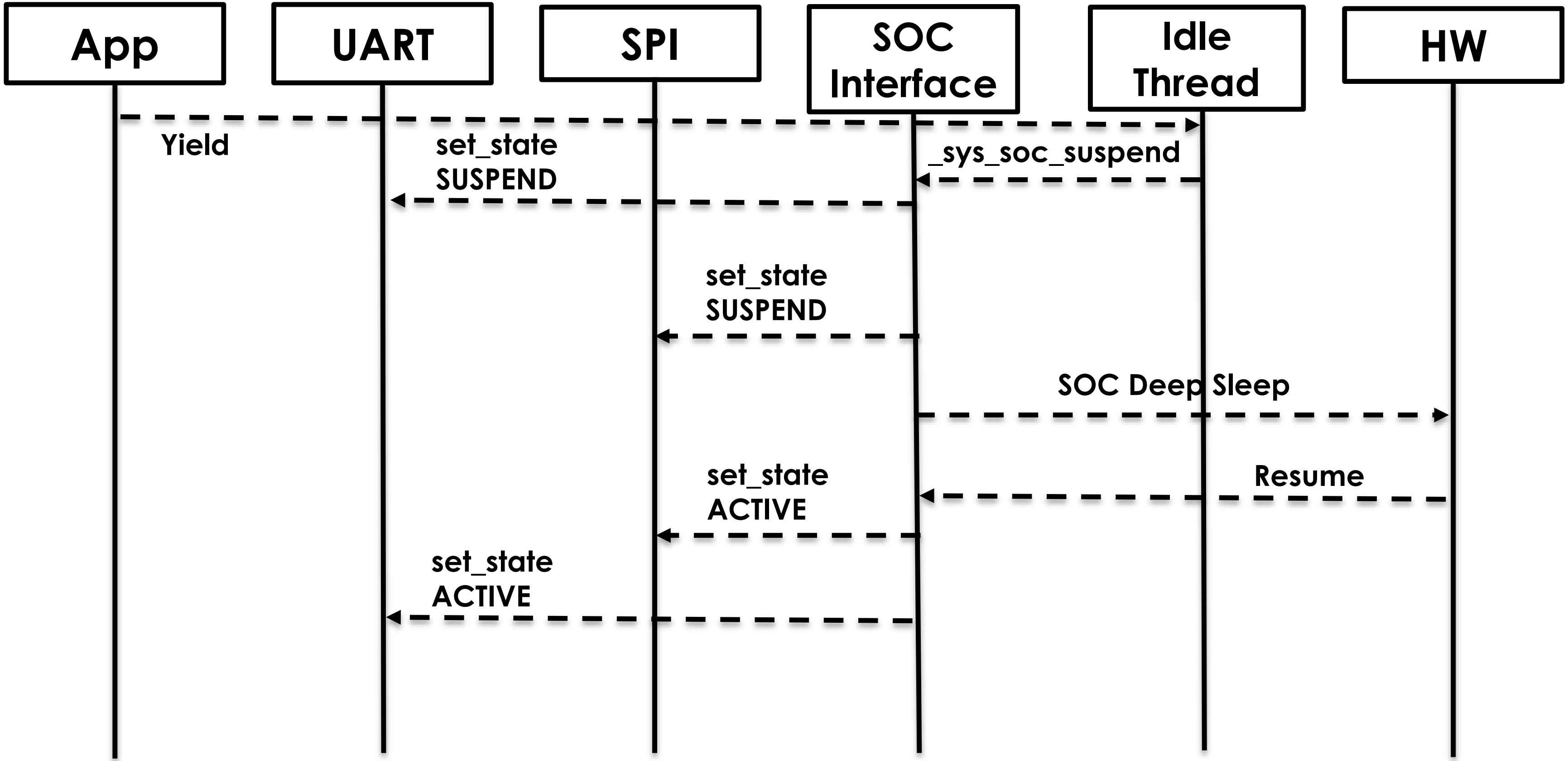
```
int (*device_pm_control)(
        struct device *device,
        uint32_t command, void *context);

static int example_control_fn(...)
{
        switch (ctrl_command) {
        case DEVICE_PM_SET_POWER_STATE:
                set state code
        case DEVICE_PM_GET_POWER_STATE:
                get state code
        }
        return 0;
}
```

Power Management Examples

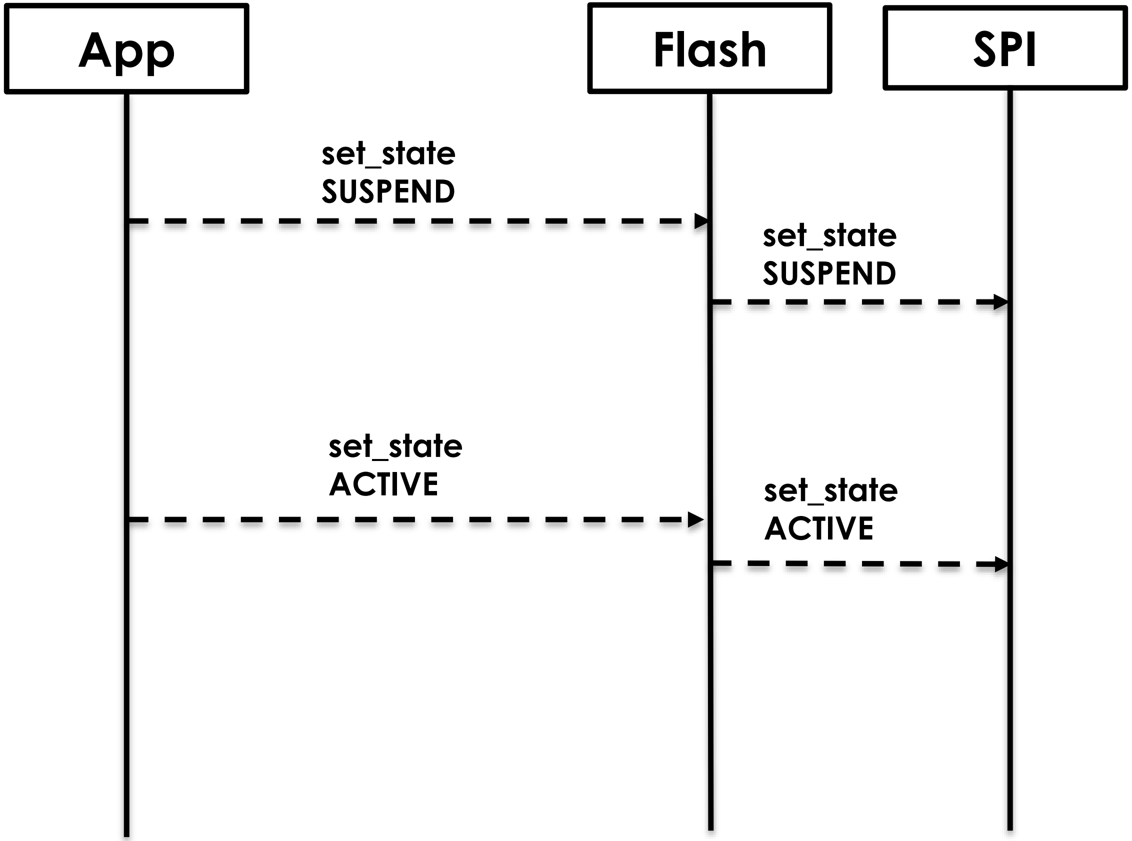
PM Example 1 (Distributed Device PM)



PM Example 2 (Central Device PM)



PM Example 3 (Flash on SPI)



Adding PM Support

- Configure Board, SOC, CPU, Arch
  - (If not done already…)
- Enable/Disable PM feature configs
- _sys_soc_suspend / _sys_soc_resume
- PM support in device drivers
- PM support in application

Summary

Future direction

- New PM features derived from kernel updates
  - Tick-less kernel
  - Different time unit options
- Add ARC* and ARM* examples
- Distributed Device PM examples

Summary

- Multi Arch, CPU, SOC, Board support
- Simple and Intuitive hook interface
- Versatile Device PM options
- Configurable, Scalable, Portable
- Open Source

Questions