Device Power Management for Idle

Ulf Hansson, Linaro, Power Management
ulf.hansson@linaro.org

Linaro connect
San Diego 2019

Goal: Don’t waste energy when idle!

- System wide PM
- Runtime PM
- PM topologies and firmware interfaces
- Deployment and good practices
- Wakeup management

Feel free to ask questions!

System wide sleep - overview

System wide sleep for all devices/resources.

- Triggered from userspace.
  - Closing the lid on your laptop.
- Triggered internally by the kernel.
  - Autosleep - used by Android.
- Sleep may be prevented by wakeup sources (wake locks).
  - Kernel: pm_stay_awake(), pm_wakeup_event(timeout).
  - Userspace: /sys/power/wake_lock|unlock.

System wide sleep - low power states

- Suspend-to-idle - always supported.
- Suspend-to-standby.
- Suspend-to-RAM.
- Suspend-to-disk (aka hibernation).

System wide sleep - sysfs

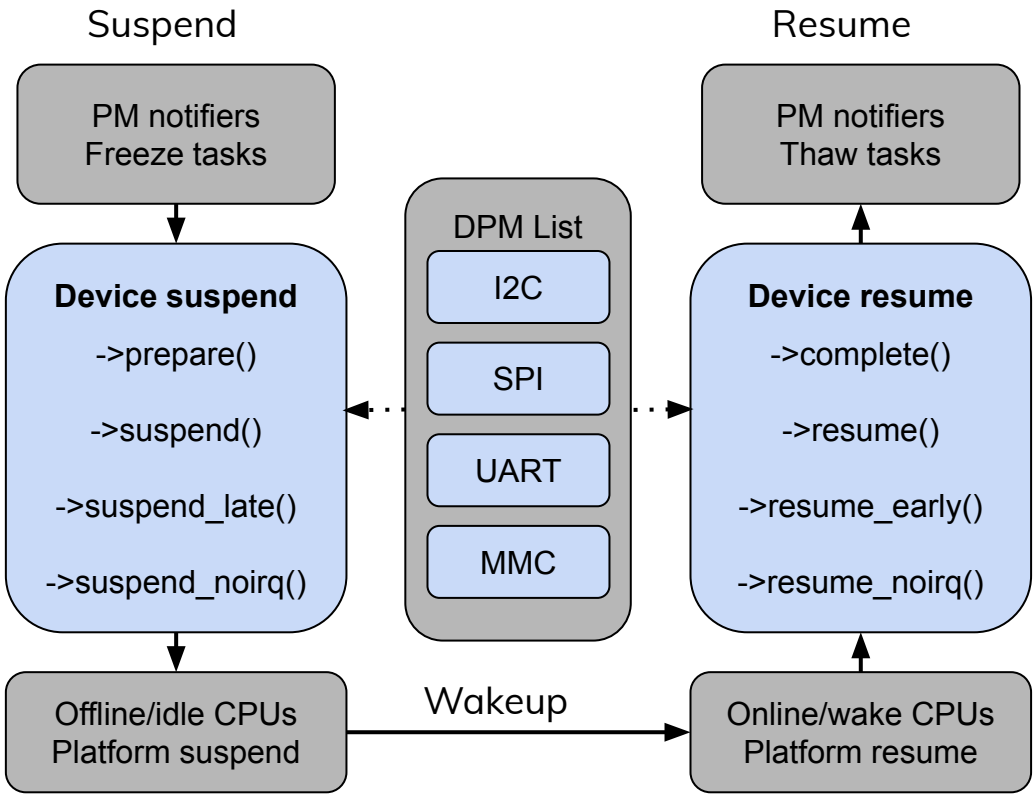
- echo [state] > /sys/power/state
  - “**freeze**” == suspend-to-idle == ACPI S0 (always supported)
  - “**standby**” == ACPI S1 (platform specific)
  - “**mem**” == depends on /sys/power/mem_sleep (platform specific)
  - “**disk**” == hibernation

- echo [state] > /sys/power/mem_sleep
  - “**s2idle**” == suspend-to-idle
  - “**shallow**” == “standby”
  - “**deep**” == suspend-to-RAM

- echo [state] /sys/power/autosleep
  - State available in /sys/power/state
  - “**off**” == disable autosleep

Documentation/admin-guide/pm/sleep-states.rst

System suspend/resume



Runtime PM - overview

At request inactivity and for unused devices on a running system.

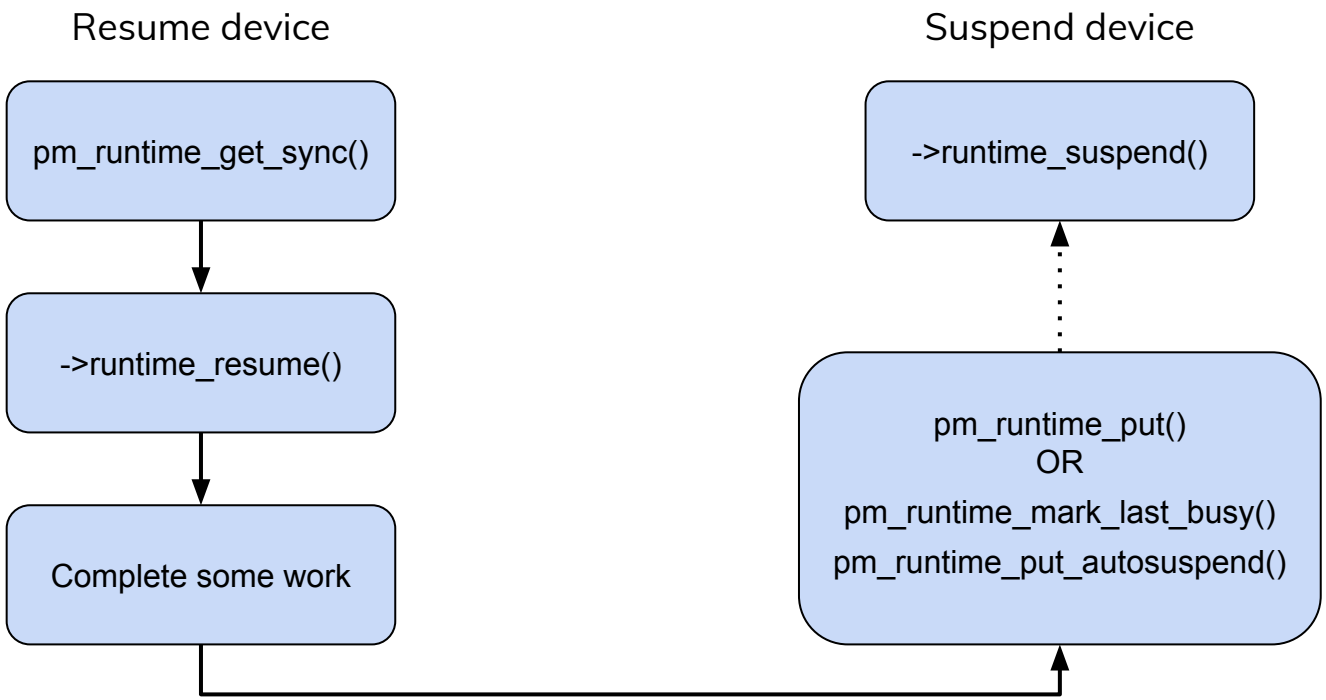
- Deployment needed by the subsystem/driver - per device.
  - **pm_runtime_enable()**.
- Suspend and resumed state.
  - **pm_runtime_resume()**.
  - **pm_runtime_suspend()**.
- Allows reference counting.
  - **pm_runtime_get_sync()** - synchronous.
  - **pm_runtime_put()** - asynchronous.
- Defer suspend to after a period of idle.
  - **pm_runtime_set_autosuspend_delay()**.
  - **pm_runtime_use_autosuspend()**.
  - **pm_runtime_mark_last_busy()**.

Runtime PM - sysfs

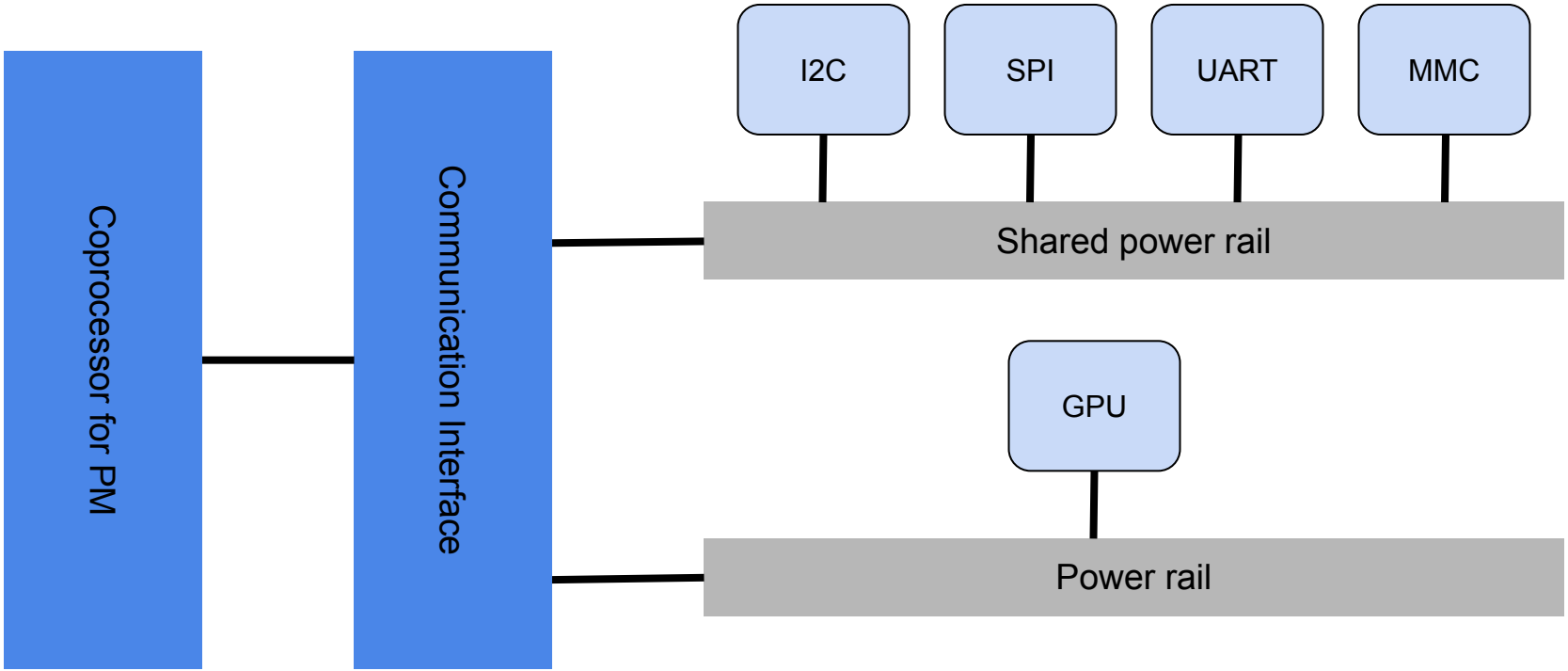
- echo [on|auto] > /sys/devices/*/*/power/control
  - Force a device to become and stay resumed.

- cat /sys/devices/*/*/power/runtime_*
  - State and stats.
  - CONFIG_PM_ADVANCED_DEBUG.

Runtime PM suspend/resume



SoC PM Topology - PM domains



The device PM callbacks

```
struct dev_pm_ops {
        int (*prepare)(struct device *dev);
        void (*complete)(struct device *dev);
        int (*suspend)(struct device *dev);
        int (*resume)(struct device *dev);
        int (*suspend_late)(struct device *dev);
        int (*resume_early)(struct device *dev);
        int (*suspend_noirq)(struct device *dev);
        int (*resume_noirq)(struct device *dev);
        ...
        int (*runtime_suspend)(struct device *dev);
        int (*runtime_resume)(struct device *dev);
        int (*runtime_idle)(struct device *dev);
};
```

System wide suspend/resume

Runtime PM suspend/resume

Hierarchy of device PM callbacks

```
struct device {
…
struct device                   *parent;
…
struct dev_pm_domain            *pm_domain;
struct bus_type                 *bus;
struct device_driver            *driver;
…
};
```

The ACPI PM domain

- Used on x86 and ARM servers.
  - drivers/acpi/device_pm.c (etc) - Rafael J. Wysocki

- Centralized power management - based on firmware.
  - Devices, PM topology, clocks, power-rails, wakeups, etc - all in FW.

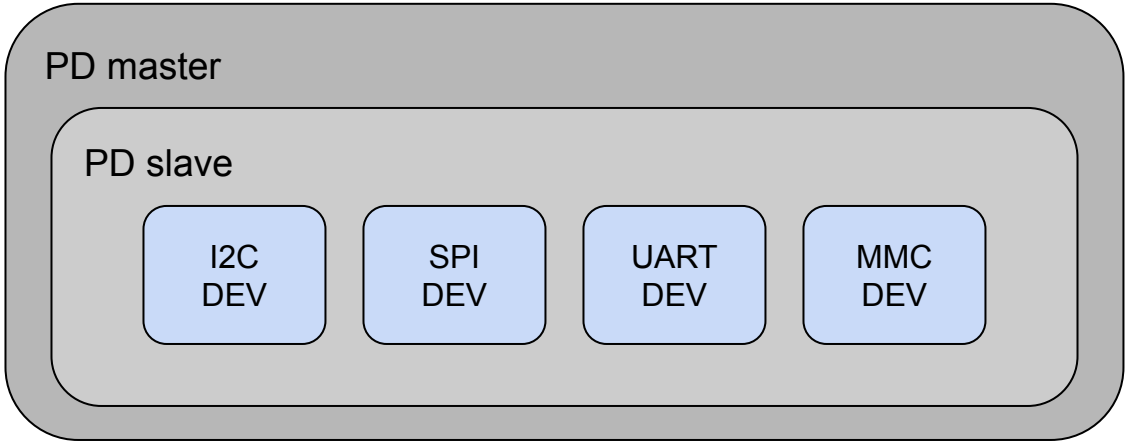
More details another time...

The generic PM domain (genpd) - overview

A generic/flexible solution for idle management of PM domains and devices.

- Widely used on ARM SoCs.
  - drivers/base/power/domain*, include/linux/pm_domain.h - Ulf Hansson, etc
- PM topology described in DT.
  - Documentation/devicetree/bindings/power/*
- Interface to register a genpd provider.
  - Callbacks to power on/off the PM domain (support for multiple idle states).
  - Callbacks to power on/off the devices.
- Attach/detach a device to a genpd, even multiple genpds per device.
- Deals with CPU devices - in another separate session.
- Deals with performance states - that’s another topic.

Genpd - topology in DT



Documentation/devicetree/bindings/power/power_domain.txt

```
pm_domains {
        compatible = "foo,power-controller";
        pd_master: pd_master {
                #power-domain-cells = <0>;
        };
        pd_slave: pd_slave {
                power-domains = <&pd_master>;
                #power-domain-cells = <0>;
        };
};

i2c@12350000 {
        compatible = "foo,i-leak-current";
        reg = <0x12350000 0x1000>;
        power-domains = <&pd_slave>;
};
spi@12356000 {
        compatible = "bar,i-leak-current";
        reg = <0x12356000 0x1000>;
        power-domains = <&pd_slave>;
};
```

The genpd governor

Problem: When is low latency more important than wasting energy?

Option 1:

- Use runtime PM autosuspend.

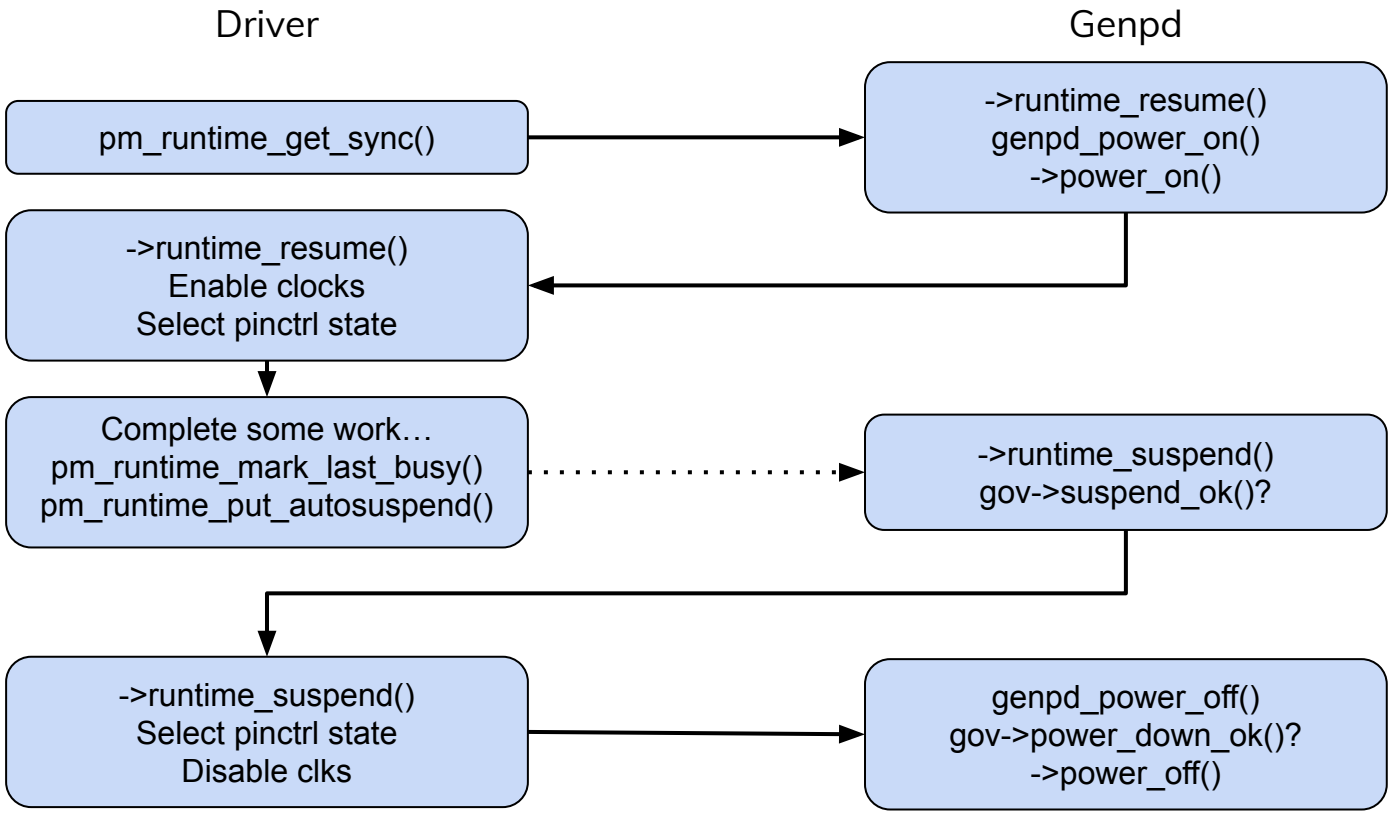
Option 2:

- Keep the device resumed.

Option 3:

- Use the genpd governor to obey to dev PM QoS constraints.

Genpd and runtime PM



Deploy PM support - what methods?

A rather common method:

- Deploy system wide PM support.
- Deploy runtime PM support.
- Add support for wakeup settings.
- Deploy genpd support.

A smother method:

- Deploy genpd support.
- Deploy runtime PM support.
- Use the *runtime PM centric approach* - get system wide PM support for “free”.
- Deal with wake-up settings.

Deploy genpd support

1. DT documentation about your PM domain(s).
2. Update DTB and add device nodes.
3. Implement the SoC specific parts for the PM domain(s).
4. Initialize a genpd via pm_genpd_init().
5. Register an genpd OF provider via of_genpd_add_provider_simple|onecell().
6. Build the PM domain topology via of_genpd_add_subdomain().

There are plenty of good examples: 36 callers of pm_genpd_init().

Combine runtime PM and system wide PM

Observation 1:

Operations to put a device into low power state, may be very similar during system suspend as runtime PM suspend and vice versa for resume.

- Goal 1: Minimize open coding.

Observation 2:

Don’t runtime resume the device during system suspend and system resume, unless it’s really going to be used.

- Goal 2: Avoid wasting energy.
- Goal 3: Decrease system suspend time and system resume time.

The runtime PM centric approach

- Runtime PM callbacks used for system suspend/resume - it's flexible!
  - Call **pm_runtime_force_suspend()** from the ->suspend|_late|_noirq() callback.
  - Call **pm_runtime_force_resume()** from the ->resume|_early|_noirq() callback.

The simplest scenario:

mydrv.c:

```
static const struct dev_pm_ops mydrv_dev_pm_ops = {
        SET_SYSTEM_SLEEP_PM_OPS(pm_runtime_force_suspend, pm_runtime_force_resume)
        SET_RUNTIME_PM_OPS(mydrv_ runtime_suspend, mydrv_runtime_resume, NULL)
};
```

There are plenty of good examples: ~140 users.

Remote wakeups - for runtime PM

- Enable if supported.
  - UART - wake on console. SDIO IRQs - WiFi.
- At ->runtime_suspend():
  - Enable wakeup IRQ and configure the logic.
  - Disable device IRQ.
- At ->runtime_resume():
  - Disable wakeup IRQ and reconfigure the logic.
  - Re-enable device IRQs.

If not supported - keep device runtime resumed!

Simplified by helpers:

- **dev_pm_set_dedicated_wake_irq()** - setup the IRQ.
- The runtime PM core enables/disables the IRQ!

System wakeups - for system suspend/resume

- Enable if supported and wanted by userspace.
  - GPIO power button. UART - wake on console. SDIO IRQs - WakeOnLan.
- At ->probe():
  - **device_init_wakeup()** - to announce wakeup support:
- At ->suspend():
  - **device_may_wakeup() -** enable wakeup IRQ and configure the logic - **enable_irq_wake()**.
  - Disable device IRQ.
- At ->resume():
  - **device_may_wakeup()** - disable wakeup IRQ and reconfigure the logic - **disable_irq_wake()**.
  - Re-enable device IRQs.

Simplified by helpers:

- **dev_pm_set_dedicated_wake_irq()** - setup the IRQ.
- The PM core enables/disables wakeup IRQs at the “noirq” phase.

Thank you

Join Linaro to accelerate deployment of your Arm-based solutions through collaboration

contactus@linaro.org

Linaro connect
San Diego 2019