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Introducing the Power Sequencing Subsystem

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About me

- Linux kernel developer for the Qualcomm Landing Team at Linaro
- 15 years of embedded linux experience
- Maintainer of the GPIO subsystem
- Author and maintainer of libgpiod
- Open-source contributor to many other projects
- Interested in complex software architecture

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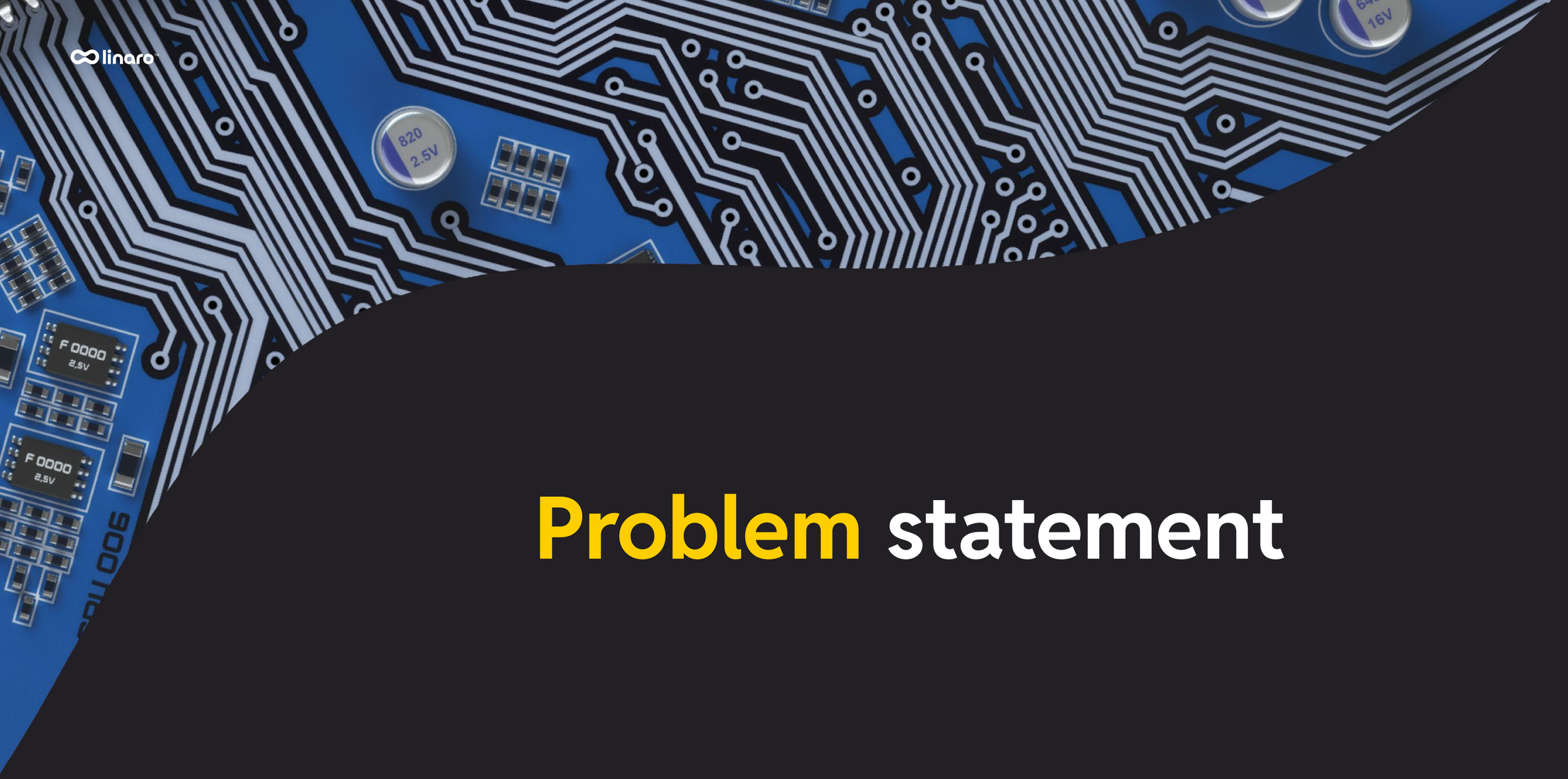

Problem statement

Dynamic bus chicken-and-egg problem

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- The drivers will not power up these devices unless they are detected
  - Typically the drivers binding to these devices handle the resources
- IOW We must power up the device to detect it but we must detect it to power it up

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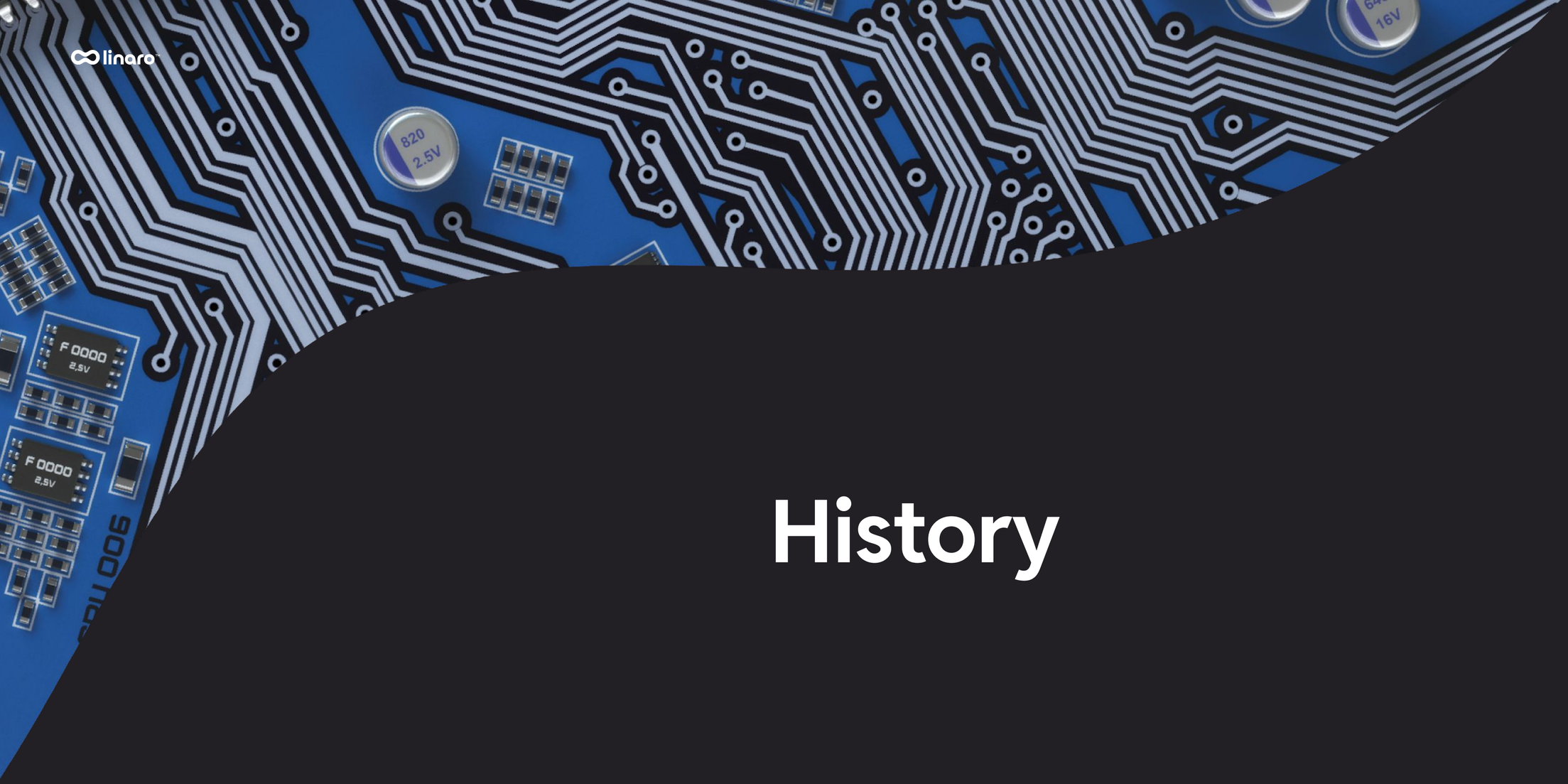
- Code reuse for complex power-up sequences shared by multiple drivers



History

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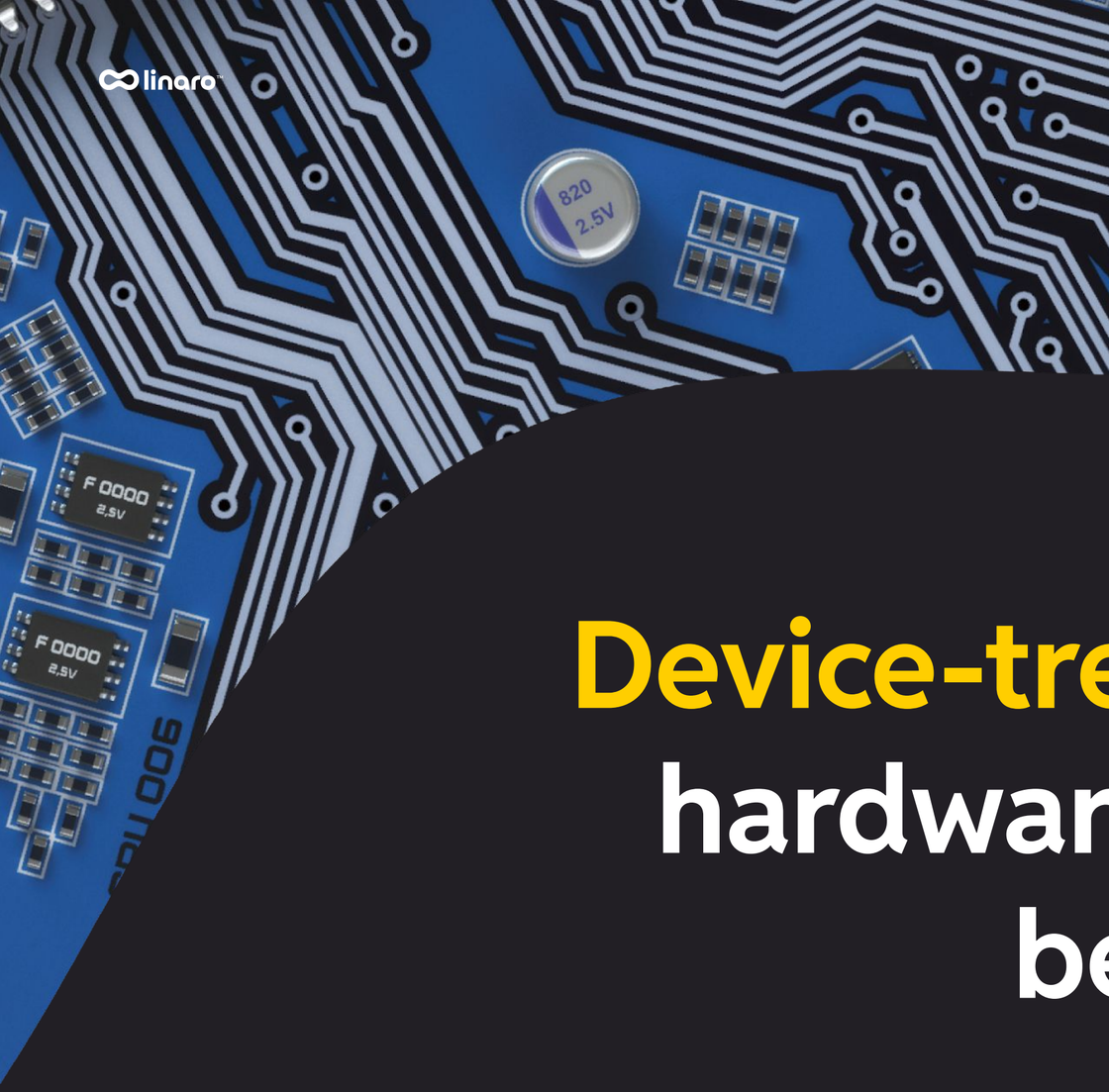
- PCI slot/M.2 driver proposition at LPC 2023



Device-tree describes the hardware itself, not its behavior!

Example

```
// This is OK

foo {
   compatible = "foobar";
   enable-gpios = <&gpio0 0>;
   vdd-supply = <&host_pmic_out0>;
   resets = <&some_rst FOOBAR>;
};
```

```
// This is *NOT* OK

foo {
   compatible = "foobar";
   pwrseq = <&pwrseq_provider>;
};
```

Device-tree and driver code don’t have to correspond to each other 1:1

DT vs C

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DT vs C

- Typically driver subsystems have common code handling device-tree nodes
  - For instance `gpiochip_add_data()` will parse the DT node looking for common GPIO chip properties
- This is just an implementation detail, there's no rule that states that a DT node called `pmic@0` must become a regulator provider and that its driver must call `regulator_register()`
- We can actually do whatever makes sense with a DT node as long as it keeps on correctly describing the underlying hardware

High-level abstraction: Power Sequencing subsystem (pwrseq)

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  - get()/put()
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- Simple interface for consumers:
  - get()/put()
  - power_on/off()
- Powerful for providers:
  - Concept of targets, units and dependencies
  - Run-time consumer <-> provider matching
  - Flexible interpretation of device nodes
    - May bind to nodes that would otherwise looks like they “belong” to a different subsystem

Power Sequencing consumers

```
struct pwrseq_desc *desc;
int ret;

desc = pwrseq_get(dev, "foo");
if (IS_ERR(desc))
   return PTR_ERR(desc);

ret = pwrseq_power_on(desc);
if (ret)
   return ret;

ret = pwrseq_power_off(desc);
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pwrseq_put(desc);
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`struct pwrseq_desc` is a proxy protecting the internal reference counting

`devm_pwrseq_get()` is also available

Power Sequencing providers

- Unit
  - Discrete part of the power on/off sequence
  - Binary state: enabled/disabled
    - Enable state is counted
  - May have a list of dependencies
    - They must be enabled before this unit
    - This unit must be disabled before any of its dependencies
  - Examples:
    - Enable clock
    - Enable a GPIO
    - Deassert a reset

Power Sequencing providers

- Target
  - Named unit that can be selected by consumers
  - Consists of the “target” unit and its dependencies
  - Multiple targets may share parts of the power sequence: for instance the `“bluetooth”` and `“wlan”` targets may share the `“regulator-enable”` unit
  - Examples:
    - `“bluetooth”` target
      - `“bluetooth-enable”` is the target unit
      - `“bluetooth-enable”` depends on `“clock-enable”`, `“regulators-enable”` and `“gpio-enable”`

Power Sequencing providers

- Descriptor
  - Opaque handle provided to consumers that want to use the power sequencer
  - References a single target
  - Assigned by `pwrseq_get()`
  - Can only ever increase and decrease the enable count of a target by 1

Power Sequencing providers

```
# cat /sys/kernel/debug/pwrseq
pwrseq.0:
  targets:
    target: [bluetooth] (target unit: [bluetooth-enable])
    target: [wlan] (target unit: [wlan-enable])
  units:
    unit: [regulators-enable] - enable count: 2
    unit: [clock-enable] - enable count: 2
    unit: [bluetooth-enable] - enable count: 1
      dependencies:
        [regulators-enable]
        [clock-enable]
    unit: [wlan-enable] - enable count: 1
      dependencies:
        [regulators-enable]
        [clock-enable]
```

Power Sequencing providers

- Run-time matching
  - Each provider driver provides a .match() callback
    - The functionality of this callback is entirely driver-specific
  - Consumer calls pwrseq_get()
  - The pwrseq core goes through the list of registered providers and calls the .match() callback passing it the (potential) consumer device
  - If the function returns non-zero, we assume it's a match
- Example matching mechanism:
  - We expect that the consumer takes the `vdd-supply` from the provider's node
  - We parse the `vdd-supply` phandle and see if it exists and leads us to the provider node

Low-level abstraction: PCI power control

PCI Power Control concept

```
&pcieport0 {
   wifi@0 {
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      ...
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Idea: Let’s create platform devices for child nodes of the host bridge and use their platform drivers to power-up the device

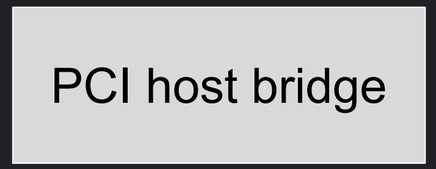
PCI Power Control concept

- Reuse DT nodes for known PCI devices
- Create platform devices that bind to these nodes
- Enable relevant resources
- Let PCI core know that it can now rescan the bus
- Let the platform device become the parent of the PCI device binding to the same node so that the suspend/resume callbacks of the former are always called after/before those of the latter respectively

PCI Power Control implementation

- Minimal API
  - `pci_pwrctl_device_set/unset_ready()` + single configuration structure
- Populate platform devices for PCI of nodes when the host bridge is probed
- Mark the relevant OF node as reused to avoid pinctrl issues

PCI Power Control implementation



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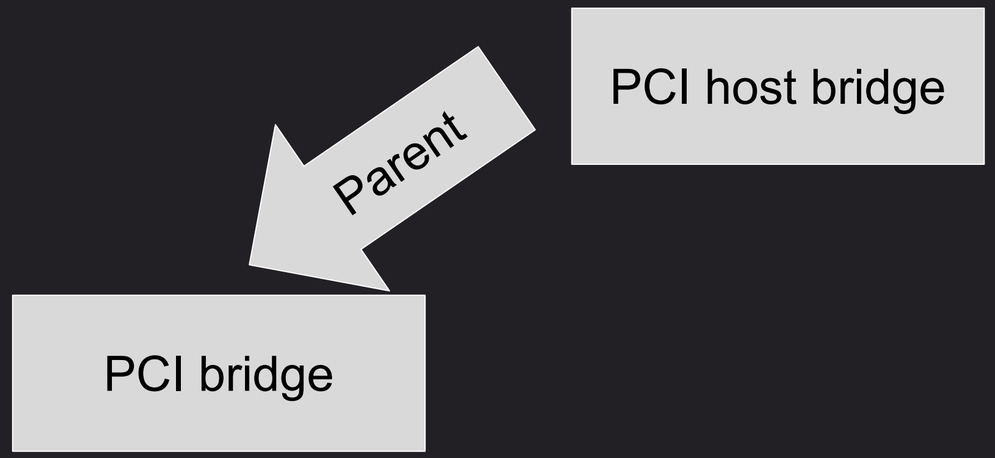

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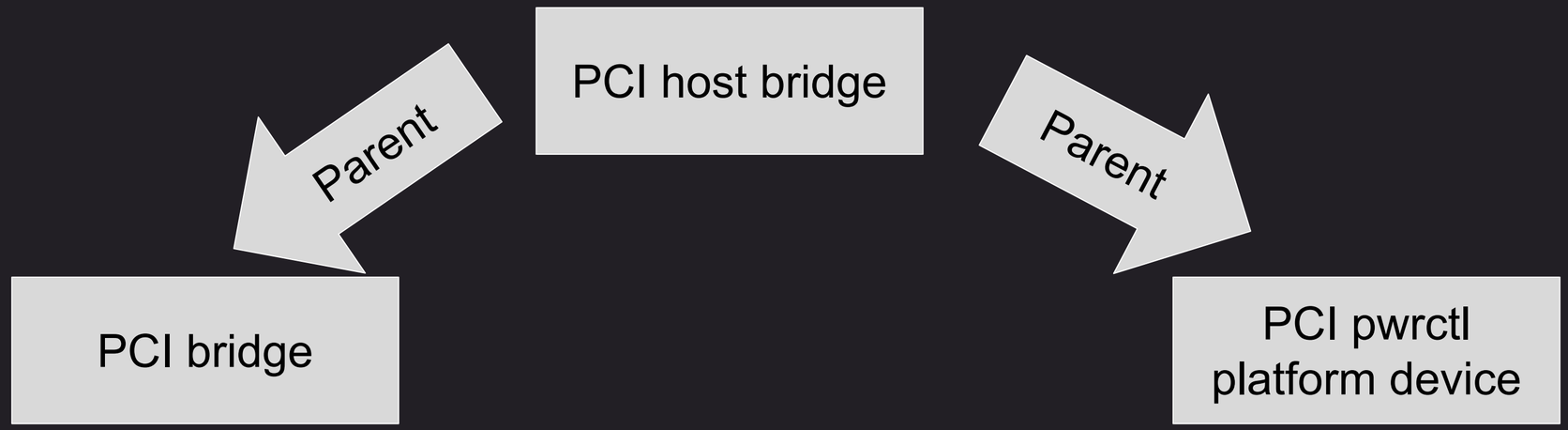

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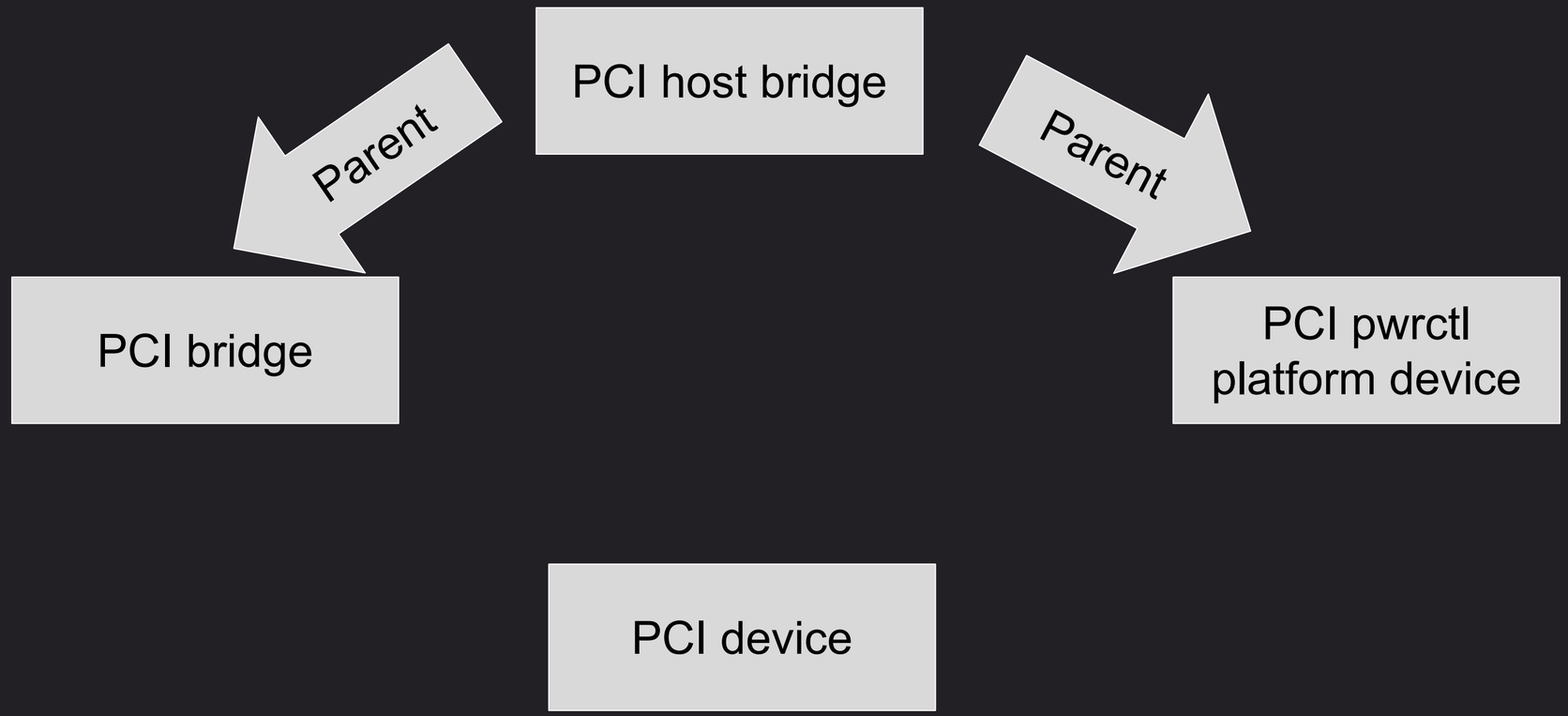

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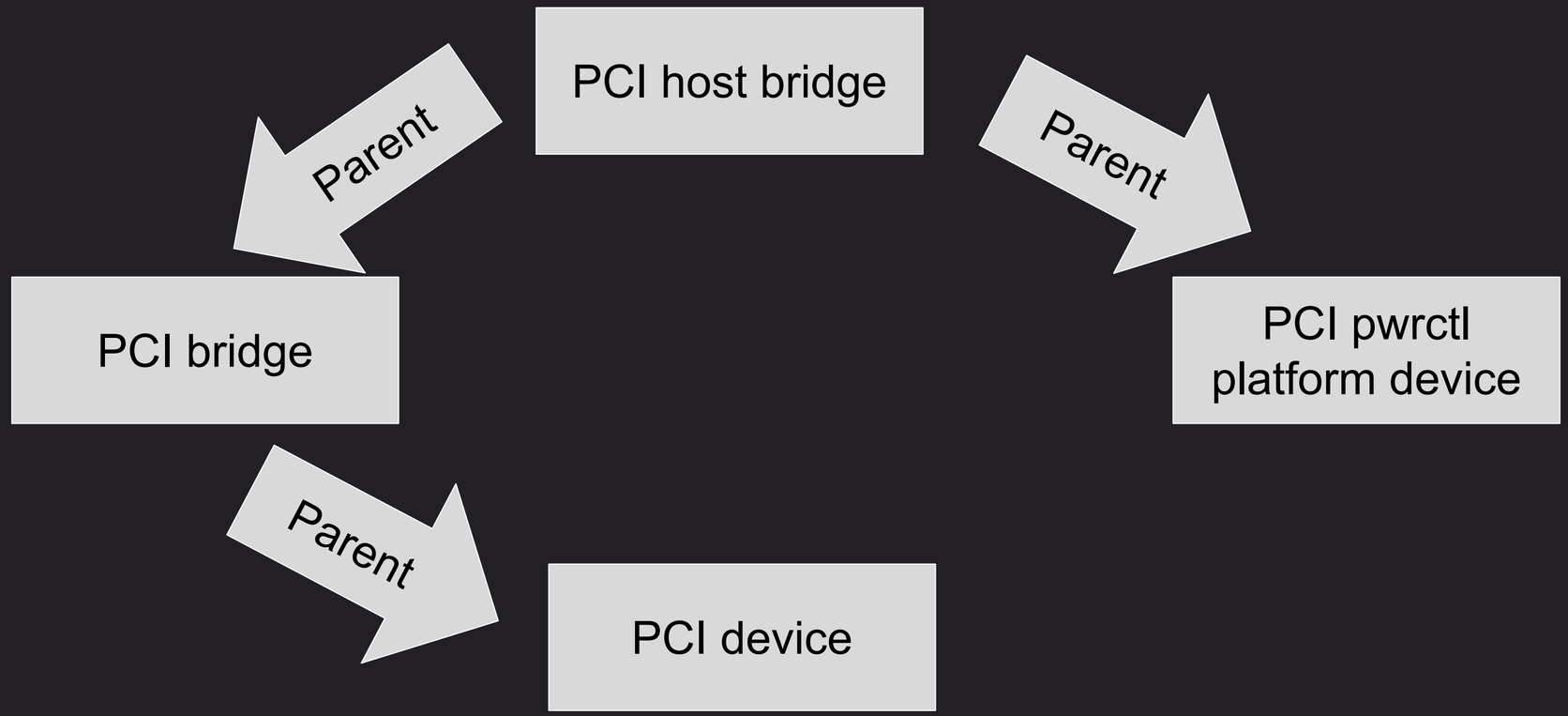

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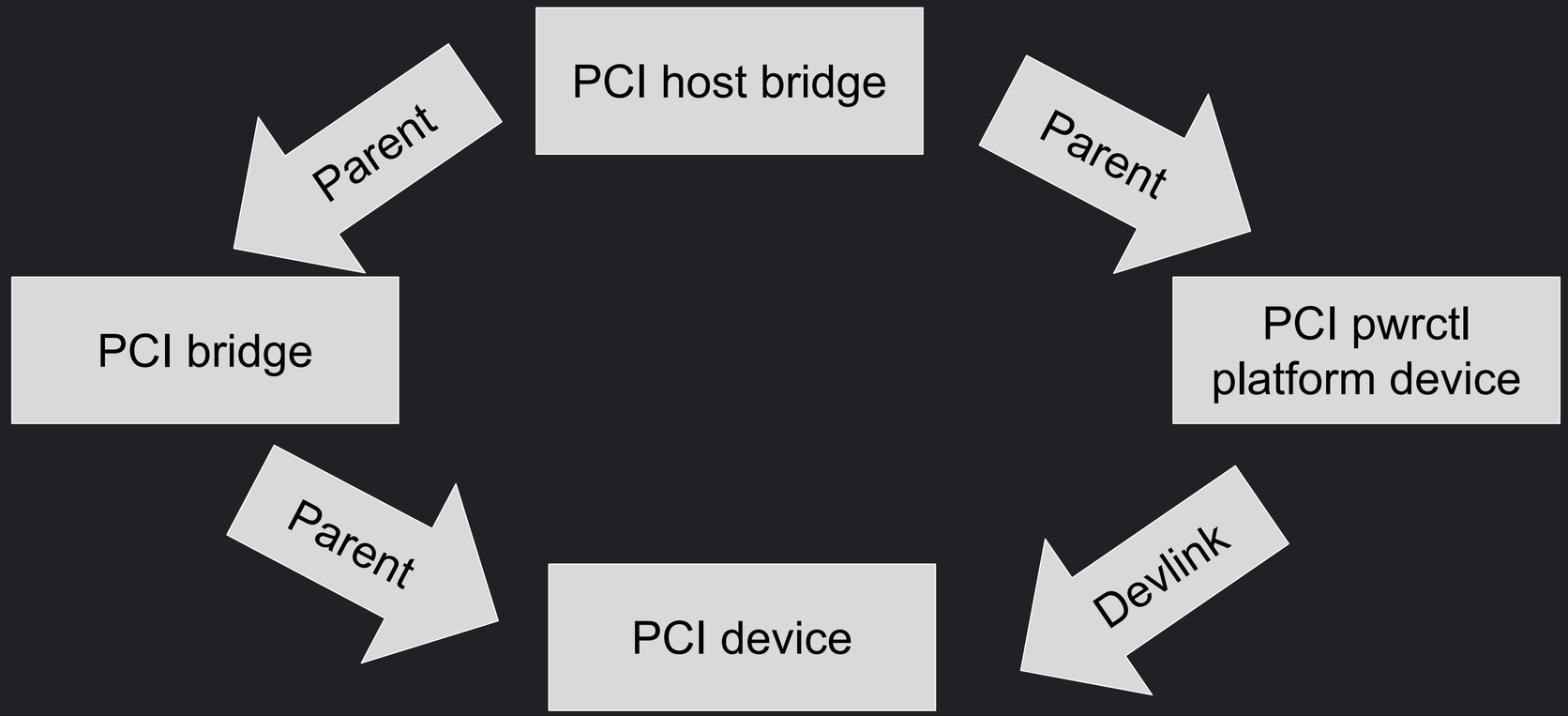

By your powers combined:
pwrseq + PCI pwrctl

Where are we at?

- All core pwrseq and PCI pwrctl code is in mainline as of v6.11-rc1
- Some bug-fixes followed
- RB5, sm8650-qrd, sm8650-hdk, sm8550-qrd, sc8280xp-crd and X13s use pwrseq for Bluetooth and WLAN
- Already got the first submission (although bad...) for a new pwrseq driver from Amlogic which further proves that this is something that was needed for a long time

Q & A

Thank You!

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