Linux Matchmaking

Helping devices and drivers find each other

FOSDEM 2024 - Kernel Devroom

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About Me

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- Kernel and Bootloader Porting
- Driver and Graphics Development
- System Integration
- Embedded Linux Consulting

Tale of a kernel update

- `git rebase --onto` (or `umpf build`)
- `make oldconfig`
- `make`
- Deploy the updated kernel artifacts

Tale of a kernel update

- `git rebase --onto` (or `umpf build`)
- `make oldconfig`
- `make`
- Deploy the updated kernel artifacts
- …
- System hangs at boot
  - If you have a known good → `git bisect`
  - If you don't → need to debug

Example Breakage

- After updating and running `make olddefconfig` (or `menuconfig`), system no longer boots
  - Culprit commit: `c20e8c5b1203 ("mfd: rk808: Split into core and i2c")`

```
-config MFD_RK808
+config MFD_RK8XX
+       bool
+       select MFD_CORE
+
+config MFD_RK8XX_I2C
        tristate "Rockchip RK805/RK808/RK809/RK817/RK818 Power Management Chip"
+       select MFD_RK8XX
```

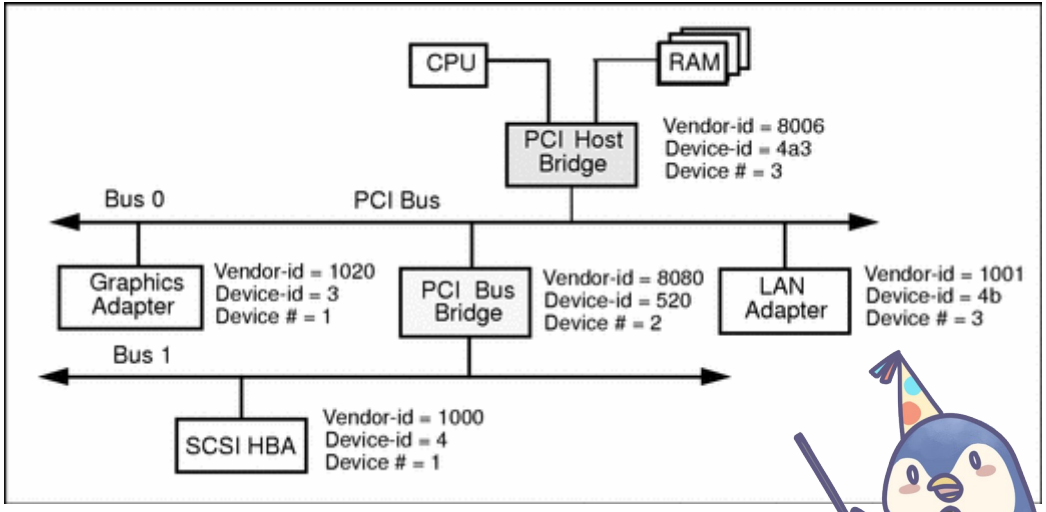
- RK8xx is the system's power management IC
  - Not much the kernel drivers are willing to do without it being available...

Resolving missing dependencies

- Resolution is trivial once you find the issue, but how do we get there without comparing to a known good and no errors?
  - → Need to retrace driver attempts at initializing the devices

Device/Driver Model

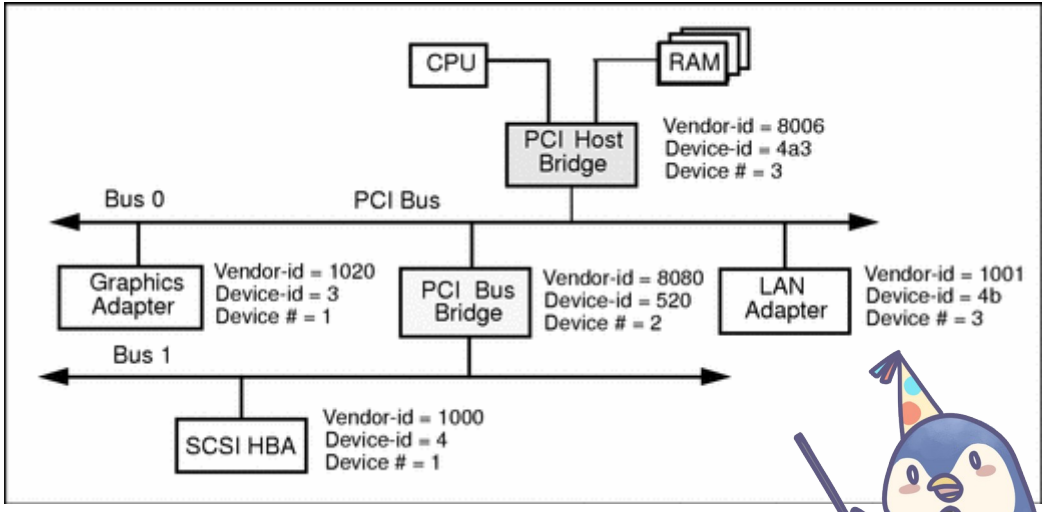
- `struct bus_type`
- `struct device_driver`
- `struct device`



[PCI-BUS]

Device/Driver Model

- struct **bus_type**
  - int (*match)(struct **device** *, struct **device_driver** *)
- struct **device_driver**
  - int (*probe)(struct **device** *)
  - ~~int~~void (*remove)(struct **device** *);
- struct **device**



[PCI-BUS]

Device/Driver Model: Matching

```
struct pci_dev {
     unsigned short  vendor;
     unsigned short  device;
     struct device   dev;
     struct resource resource[DEVICE_COUNT_RESOURCE];
};


struct pci_driver {
     const struct pci_device_id *id_table;
     int  (*probe)(struct pci_dev *dev, const struct pci_device_id *id);
     void (*remove)(struct pci_dev *dev);
     int  (*sriov_configure)(struct pci_dev *dev, int num_vfs);
     struct device_driver  driver;
};

struct pci_device_id {
     __u32 vendor, device;           /* Vendor and device ID or PCI_ANY_ID*/
     kernel_ulong_t driver_data;     /* Data private to the driver */
};
```

catch-all-and-a-bag-of-chips platform bus

```
static int platform_match(struct device *dev, struct device_driver *drv)
{
      struct platform_device *pdev = to_platform_device(dev);
      struct platform_driver *pdrv = to_platform_driver(drv);

      /* When driver_override is set, only bind to the matching driver */
1     if (pdev->driver_override)
            return !strcmp(pdev->driver_override, drv->name);

      /* Attempt an OF style match first */
2     if (of_driver_match_device(dev, drv))
            return 1;

      /* Then try ACPI style match */
3     if (acpi_driver_match_device(dev, drv))
            return 1;

      /* Then try to match against the id table */
4     if (pdrv->id_table)
            return platform_match_id(pdrv->id_table, pdev) != NULL;

      /* fall-back to driver name match */
5     return (strcmp(pdev->name, drv->name) == 0);
}
```

```
&{/soc} {
      compatible = "simple-bus";

      timer@fffec600 {
            compatible =
              "arm,cortex-a9-twd-timer";
            reg = <0xfffec600 0x100>;
            interrupts = <1 13 0xf01>;
            clocks = <&mpu_periph_clk>;

      };
};
```

Device/Driver Model: Probing

- Once a match is found, a device will be *probed:*
  The driver checks device existence, requests resources and registers with relevant kernel API (e.g. `register_netdev`)
  - Driver is happy
    → `return 0` and device is bound
  - Driver doesn't recognize the device
    → `return -ENODEV` or `-ENXIO` to silently skip match
  - Driver encounters an error and needs to cleanup
    → return any other (negative) error code

Device Dependencies

- Devices often need resources exported by other devices:
  - Generic
    - pinctrl (`"init"`, `"default"` states)
    - DMA configuration
  - Bus-specific. For platform devices:
    - Clock assignment: Initial assignment of parents and rates
    - Single Power domain power-up
  - Device-specific
    - Clocks, Multiple Powerdomains, GPIOs, Resets, PHYs, … and a whole lot more

Device Dependencies

- What if device exporting resource is unavailable?
  - Avoidance:
    - initcalls
    - Makefile ordering

Reordering Driver Registration

```
#define core_initcall(fn)               __define_initcall(fn, 1)
#define core_initcall_sync(fn)          __define_initcall(fn, 1s)
#define postcore_initcall(fn)           __define_initcall(fn, 2)
#define postcore_initcall_sync(fn)      __define_initcall(fn, 2s)
#define arch_initcall(fn)               __define_initcall(fn, 3)
#define arch_initcall_sync(fn)          __define_initcall(fn, 3s)
#define subsys_initcall(fn)             __define_initcall(fn, 4)
#define subsys_initcall_sync(fn)        __define_initcall(fn, 4s)
#define fs_initcall(fn)                 __define_initcall(fn, 5)
#define fs_initcall_sync(fn)            __define_initcall(fn, 5s)
#define rootfs_initcall(fn)             __define_initcall(fn, rootfs)
#define device_initcall(fn)             __define_initcall(fn, 6)
#define device_initcall_sync(fn)        __define_initcall(fn, 6s)
#define late_initcall(fn)               __define_initcall(fn, 7)
#define late_initcall_sync(fn)          __define_initcall(fn, 7s)
```

```
# Many drivers will want to use DMA so this has to be made available
# really early.
obj-$(CONFIG_DMADEVICES)  += dma/

# SOC specific infrastructure drivers.
obj-y                     += soc/
obj-$(CONFIG_PM_GENERIC_DOMAINS) += pmdomain/

# regulators early, since some subsystems rely on them to initialize
obj-$(CONFIG_REGULATOR)         += regulator/
```

Reordering Driver Registration

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#define device_initcall_sync(fn)        __define_initcall(fn, 6s)
#define late_initcall(fn)               __define_initcall(fn, 7)
#define late_initcall_sync(fn)          __define_initcall(fn, 7s)
```

```
mfg: power-domain@MT8183_POWER_DOMAIN_MFG {
     domain-supply = <&mt6358_vgpu_reg>;
     #power-domain-cells = <1>;
};
```

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Device Dependencies

- What if device exporting resource is unavailable?
  - Avoidance:
    - initcalls
    - Makefile ordering
  - Detection
    - `-EPROBE_DEFER`

Probe Deferral

- Driver signals missing dependency by returning `-EPROBE_DEFER (== -517)`
- Device probe will be cleaned up as if probe had failed
- Probe is retried at a later time after other devices have been probed

```
icc_path = devm_of_icc_get(&pdev->dev, "usb1");
if (IS_ERR(icc_path)) {
     if (PTR_ERR(icc_path) != -EPROBE_DEFER)
          dev_err(dev, "couldn't get interconnect: %pe\n", icc_path);
     return PTR_ERR(icc_path);
}
```

Probe Deferral

- Probe deferrals are listed in sysfs

```
root@DistroKit:~ cat /sys/kernel/debug/devices_deferred
32f10100.usb
32f10108.usb
381f0040.usb-phy
382f0040.usb-phy
32ec0000.blk-ctrl
38330000.blk-ctrl
32f10000.blk-ctrl
```

- ... and also printed after deferred_probe_timeout (10 if CONFIG_MODULES=y)

```
[   16.611797] platform 32f10100.usb: deferred probe pending
[   16.621405] platform 32f10108.usb: deferred probe pending
[   16.631022] platform 381f0040.usb-phy: deferred probe pending
[   16.640967] platform 382f0040.usb-phy: deferred probe pending
[   16.650899] platform 32ec0000.blk-ctrl: deferred probe pending
[   16.660483] platform 38330000.blk-ctrl: deferred probe pending
[   16.670102] platform 32f10000.blk-ctrl: deferred probe pending
```

- If only there was a reason for why the probe was deferred...

dev_err_probe

```
if (IS_ERR(icc_path)) {
       if (PTR_ERR(icc_path) != -EPROBE_DEFER)
              dev_err(dev, "couldn't get interconnect: %pe\n", icc_path);
       return PTR_ERR(icc_path);
}
```

```
if (IS_ERR(icc_path))
       return dev_err_probe(dev, PTR_ERR(icc_path), "failed to get interconnect\n");
```

Benefits:

- compact
- Includes error code
- Stores probe error reason message into `struct device`

Probe Deferral

- SysFS also lists probe deferal reasons if provided

```
root@DistroKit:~ cat /sys/kernel/debug/devices_deferred
32f10100.usb            platform: supplier 32f10000.blk-ctrl not ready
32f10108.usb            platform: supplier 32f10000.blk-ctrl not ready
381f0040.usb-phy        platform: supplier 32f10000.blk-ctrl not ready
382f0040.usb-phy        platform: supplier 32f10000.blk-ctrl not ready
32ec0000.blk-ctrl       imx8m-blk-ctrl: failed to get noc entries
38330000.blk-ctrl       imx8m-blk-ctrl: failed to get noc entries
32f10000.blk-ctrl       imx8mp-blk-ctrl: failed to get noc entries
```

... and since v6.8-rc1, on probe deferall timeout too:

```
[   16.611797] platform 32f10100.usb: deferred probe pending: platform: supplier 32f10000.blk-ctrl not ready
[   16.621405] platform 32f10108.usb: deferred probe pending: platform: supplier 32f10000.blk-ctrl not ready
[   16.631022] platform 381f0040.usb-phy: deferred probe pending: platform: supplier 32f10000.blk-ctrl not ready
[   16.640967] platform 382f0040.usb-phy: deferred probe pending: platform: supplier 32f10000.blk-ctrl not ready
[   16.650899] platform 32ec0000.blk-ctrl: deferred probe pending: imx8m-blk-ctrl: failed to get noc entries
[   16.660483] platform 38330000.blk-ctrl: deferred probe pending: imx8m-blk-ctrl: failed to get noc entries
[   16.670102] platform 32f10000.blk-ctrl: deferred probe pending: imx8mp-blk-ctrl: failed to get noc entries
```

Tracing

- `earlycon`
- `ignore_loglevel initcall_debug dyndbg="file dd.c +p"`
- `clk_ignore_unused pd_ignore_unused`

- `ftrace=function_graph ftrace_graph_max_depth=3 ftrace_graph_filter=probe_func`

Then in userspace: `cat /sys/kernel/tracing/trace`

→ *Wishlist:* Dump ftrace buffer during on `probe_func` return without patching the kernel.
Maybe already possible with bootconfig? Ongoing discussion

Device Dependencies

- What if device exporting resource is unavailable?
  - Avoidance:
    - initcalls
    - Makefile ordering
    - Firmware device links (`fw_devlink`)
  - Detection
    - `-EPROBE_DEFER`

fw_devlink

- Parse firmware-provided description for dependencies
  - currently supports 25 device tree bindings
  - Follows device properties and manually created links
- Reflect these dependencies in software
- Walk the dependency graph to minimize probe deferral
- Probe deferral can stil happen
  - Waiting for module to be inserted
  - Cyclic dependencies
- Device links inspectable in `/sys/class/devlink`

Image Resources

- Kernel Recipes Mascot by Emma Tizzoni: https://www.flickr.com/photos/hupstream/53273034553/in/album-72177720312084838

- [PCI-BUS]: https://docs.oracle.com/cd/E19455-01/805-7378/6j6un038j/index.html

Summary

- There's a lot of ways to match devices to drivers
- There's a lot of resources that devices need for proper operations
- There's a lot of ways device driver probes may never succeed
  → When you find a new one, stick in a `dev_err_probe()` to makes the world a tiny bit better

Questions?