The Arm laptop project

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- Windows on Arm (WoA)
- Laptops built on (Qualcomm) 64-bit Arm SoCs
- Quiet and power efficient
- Non-standard boot chain
- Customised OS

Introduction

- Windows on Arm (WoA)
- Laptops built on (Qualcomm) 64-bit Arm SoCs
- Quiet and power efficient
- Non-standard boot chain
- Customised OS
- What would it take to run Linux on them?

- Linaro project
- Funded by Arm and Qualcomm
- Hardware from Qualcomm and Lenovo
- Proof-of-concept: Mainline Linux on Arm laptop (built for Windows)
- How far could we get?

- Johan Hovold
- Björn Andersson
- Linaro's Qualcomm landing team
- Building on work done by Qualcomm, Linaro and many others

Talk outline

- Background
- Status
- Work in progress
- Open issues
- Setup instructions
- Distro support

- Linaro and Arm collaboration
- Try to get Linux to boot on WoA laptops
  - ASUS NovaGo TP370QL
  - HP Envy x2
  - Lenovo Mixx 630
  - Lenovo Yoga C630
- Enable basic features
- Investigate options for distro support (e.g. ACPI vs DT)
- https://github.com/aarch64-laptops/
- #aarch64-laptops on OFTC

Lenovo ThinkPad X13s

- Snapdragon 8xc Gen3 Compute (sc8280xp)
- 13.3" FHD (1920x1200) display
- 32 GB LPDDR4 (up to)
- 1 TB NVMe SSD (up to)
- Adreno 690 GPU
- 2 speakers, 2 microphones, headphone jack
- 5 MP camera
- Wi-Fi 6E (802.11ax)
- Bluetooth 5.1
- 5G modem (optional)
- 2 × USB-C 3.2 Gen 2
- 49.5 Wh battery

Boot firmware

- Qualcomm and Windows on Arm
- UEFI
  - Runtime services not available after boot (e.g. EFI variables)
- ACPI vs DT
  - Supporting Qualcomm's non-standard ACPI not feasible
- DtbLoader.efi
  - Ship devicetree blob with UEFI firmware
  - Allows for generic distro installers
- Hypervisor
  - UEFI and Linux starts in EL1
  - No virtualisation

- Feature implementation and mainlining
  - Reverse engineering
  - Refactoring (technical debt)
  - Firmware requests
- Bug fixing
- Patch review
- Patch tracking
- Work-in-progress (WIP) branches
- Support (#aarch64-laptops)

- Important fixes and features under development
- Minimal `johan_defconfig`
- Rebased on RC kernels
- Several regressions found and fixed early
    - Example: IRQ software resend in 6.5-rc1
- 41 branches so far, latest:
    - `https://github.com/jhovold/linux/tree/wip/sc8280xp-v6.6-rc2`
- Announced on `#aarch64-laptops`
    - Testing by early adopters
    - Repackaged with distro config (e.g. by steev)
    - Base for distro images (e.g. Ubuntu)

- Use Windows firmware files for bringup
- Work with Lenovo and Qualcomm to get firmware released
- Wi-Fi board file not compatible with ath11k firmware
  - Took one year to get calibration data released
- Everything but video acceleration now in linux-firmware.git

Mainline feature support

- 6.0
  - Backlight
  - CPUfreq
  - Keyboard
  - Remoteproc
  - Touchpad
  - Touchscreen
  - USB
  - Watchdog
- 6.1
  - System suspend
- 6.2
  - Modem
  - NVMe SSD
  - PCIe (x4)
  - Thermal sensors

- 6.3
  - Battery
  - External display
  - Internal display (*)
- 6.4
  - Bluetooth
  - IOMMU (**)
  - RTC
  - Touchpad (alternate)
  - Wi-Fi
- 6.5
  - Audio
  - GPU
  - USB-C orientation switching

Work in progress

- Camera
  - Raw sensor data
  - Software processing (e.g. debayering)
- EFI variables[1] (merged for 6.7)
  - Maximilian Luz
- Fingerprint reader[1]
- Video acceleration[1]
- USB-C muxing (4-lane DisplayPort)
- Performance optimisation (e.g. better memory bus scaling)
- Power consumption

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[1]Supported in WIP branches

- Idle: 3.2 W (15 h)[2]
- Suspend: 1.7 W (29 h)
    - Suspend to idle
    - Not yet hitting deepest low-power state

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[2]Backlight at 66%, PCIe ASPM, Xorg, Wi-Fi

Audio

- Speakers, microphones, headphone jack and DisplayPort working in 6.5
- Late fix for speaker and headphone distortion
- Kernel, topology and UCM files need to be updated in lock step
- Known issues
    - Pops and clicks (partial fix in WIP branch)
    - Microphone distortion

GPU

- Adreno 690 support in Linux 6.5 and Mesa 23.1
  - Rob Clark
  - Important fix in Mesa 23.1.4 (Firefox crash)
- Extracted a690 GMU firmware not (yet) in linux-firmware
  - Driver will use a660 GMU firmware in 6.6 (and 6.5.3)
  - Use symlink before 6.5.3

```
# ln -s a660_gmu.bin a690_gmu.bin
```

Bluetooth

- Unique device address (BD_ADDR) stored externally
- Need details from Qualcomm (or reverse engineer)
- No support in bluetoothd for setting custom or random address
  - https://github.com/bluez/bluez/issues/107
- Must be set manually (or using systemd service) for now
- Similar problem with Wi-Fi MAC address
  - Falls back to random address

```
# btmgmt --index 0 public-addr 00:11:22:33:44:55
```

Remote processors

- Qualcomm protection-domain mapper daemon (`pd-mapper`)
  - https://github.com/andersson/pd-mapper
- Reads configuration shipped with remoteproc firmware
- Tells remote processors which services to start
- Tells kernel where to find services
  - Audio
  - Battery
  - USB-C Alternate Mode
- Battery may not charge if `pd-mapper` not running
- Depends on Qualcomm IPC Router name service (`qrtr-ns`)
  - https://github.com/andersson/qrtr
- Functionality should be moved to kernel and devicetree

- X13s comes with one of two touchpad controllers
- Boot firmware should determine which one is populated
- Update the devicetree accordingly

Touchpad devicetree

```
&i2c21 {
    touchpad@15 {
        compatible = "hid-over-i2c";
        reg = <0x15>;
        interrupts = <182 IRQ_TYPE_LEVEL_LOW>;
        vdd-supply = <&vreg_3p3>;
        status = "disabled";
    };
    touchpad@2c {
        compatible = "hid-over-i2c";
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        status = "okay";
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};
```

- X13s firmware does not support this
- Linux needs to probe both touchpads
- HID driver already checks if a device is present
- Used for optionally populated devices (e.g. the X13s touchscreen)

HID driver probe

```
int i2c_hid_core_probe(struct i2c_client *client, ...)
{
    ...
    i2c_hid_core_power_up();

    /* Make sure there is something at this address */
    ret = i2c_smbus_read_byte(client);
    if (ret < 0) {
        i2c_hid_core_power_down();
        return -ENODEV;
    }
    hid = hid_allocate_device();
    ...
    hid_add_device(hid);
    return 0;
}
```

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Asynchronous probe woes

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- Interrupt mapping race in IRQ core
  - Affects all shared interrupts
  - Two mappings for the same interrupt line
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  - Or allow sharing?
- Extend devicetree specification?
  - Mark devices as mutually exclusive
  - Force sequential probe

- Resources may have been (left) enabled by boot firmware
    - Clocks
    - Regulators
    - Power domains
    - Interconnects
- Handover should be seamless (e.g. EFI framebuffer)
- Disable any resources not needed to save power

- Unused clocks and power domains disabled at late init
  - Breaks display handover when display driver built as module
  - Workaround: clk_ignore_unused and pd_ignore_unused
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- Interconnect state synced when all consumers' drivers are bound
  - Power state left at maximum if driver fails to probe
  - Example: Firmware missing (video acceleration)
  - Example: Driver disabled

Disabling unused resources

- Need common mechanism for disabling unused resources
- Could be built on device links and sync-state mechanism, which triggers when all consumers' drivers are bound
- Also need timer for consumers that fail to probe?
- Timer extended when a driver is bound (cf. deferred probe)
- Trigger state sync on expiry
- Problem: Need to pause timer in rescue shell
- Alternative: User space triggers sync when booted
  - Use existing state_synced sysfs interface?

Future work

- Camera ISP
- Bluetooth `BD_ADDR` and Wi-Fi MAC address
- Hibernation
- Keyboard special keys (e.g. mic mute)
- Thermal throttling, non-CPU (e.g. GPU, DSP, charger, radio)
- Trusted Platform Module (TPM)
- USB Power Delivery (USB-PD)
- Virtualisation

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Getting started with X13s

- Linux 6.5 (mainline or WIP)
  - `https://github.com/jhovold/linux/tree/wip/sc8280xp-v6.5`
  - `make johan_defconfig`
- `linux-firmware-20230919`
  - `ln -s a660_gmu.bin a690_gmu.bin`
  - `qcvss8280.mbn` (with WIP branch)
- alsa-ucm-conf 1.2.10 + volume fixes
  - `https://github.com/alsa-project/alsa-ucm-conf/pull/335`
- Mesa 23.1.4
- Qualcomm pd-mapper and qrtr-ns daemons
  - `https://github.com/andersson/pd-mapper`
  - `https://github.com/andersson/qrtr`

- `clk_ignore_unused` (generic issue)
- `pd_ignore_unused` (generic issue)
- `arm64.nopauth` (firmware bug)
- `efi=noruntime` (firmware bug)
- `iommu.passthrough=0 iommu.strict=0` (USB throughput)
- `pcie_aspm.policy=powersupersave` (PCIe ASPM)

Initramfs

- Modules needed to boot
  - `nvme`, `phy_qcom_qmp_pcie`, `pcie_qcom`
- Modules needed for early console (optional)
  - `i2c_hid_of`, `i2c_qcom_geni`
  - `leds_qcom_lpg`, `pwm_bl`
  - `qrtr`, `pmic_glink_altmode`, `gpio_sbu_mux`, `phy_qcom_qmp_combo`
  - `panel_edp`, `msm`, `phy_qcom_edp`
- Depends on config
- Documented in commit message for `johan_defconfig`
- Missing display dependency can break EFI framebuffer

Distro support

- https://launchpad.net/~ubuntu-concept/+archive/ubuntu/x13s
- https://fedoraproject.org/wiki/Thinkpad_X13s
- https://wiki.debian.org/InstallingDebianOn/Thinkpad/X13s

Summary

- Lenovo ThinkPad X13s well supported by mainline Linux 6.5
- More features under way (e.g. camera)
- Working on improving suspend power consumption

- For updated status, known issues and other resources, see:
  - `https://github.com/jhovold/linux/wiki/X13s`

Thanks!

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