Embedded Linux Conference

arm

Will it Boot?

Standards for embedded Linux

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THE LINUX FOUNDATION

Exactly what problem are you trying to solve?

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- Typically, embedded Linux is vertically integrated
  - Firmware, OS, and apps bound together in a single build
  - Every platform has slightly different behaviour
- Scale Problems
  - Distro must be customized to boot (change Devicetree, vendor kernel tree, special configuration)
  - Platform owner must maintain everything – problem for security updates
  - Distros cannot handle per-platform customization
- Ecosystem Problems
  - Extra engineering cost to get suitable OS booted – problem for ODM/OEM market
  - Embedded using different tools from other parts of Linux ecosystem

Standards are designed to reduce engineering effort, while increasing the flexibility of products

Tension between standardization and flexibility

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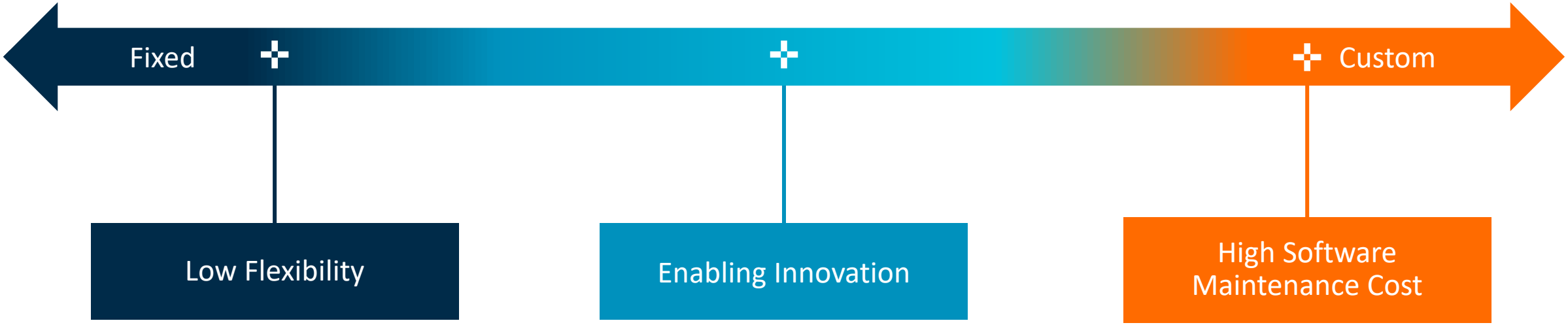

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Major changes to embedded Linux aren't realistic

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- Embedded Linux has well established, mature technology and tools
  - Projects: U-Boot, TF-A, OPTEE
  - Meta-distros: Yocto, OpenWRT
  - Devicetree
- Rearchitecting from ground up is not an option
  - Need migration path
  - Cannot be disruptive
  - Minimal engineering effort
- To be relevant, standards must work with existing tools and techniques

Distros need consistency

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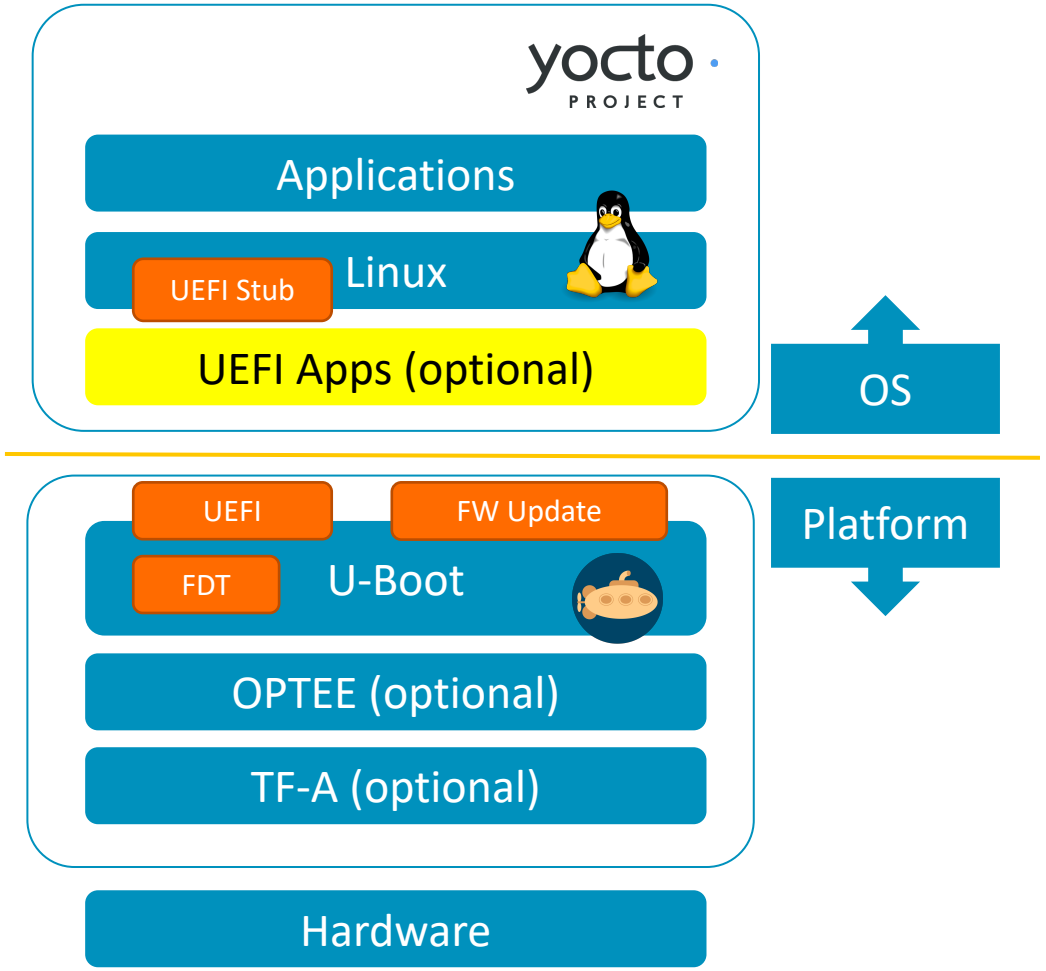
- Embedded Linux doesn’t mean custom OS
  - Distros can provide better support options
- Custom board enablement is not supported
  - Generic image must boot
  - Platform drivers must not cause conflicts
  - Ideally use same technologies as non-embedded platforms
- Mainline first policy
- Need standards for:
  - Boot order and control
  - Pre-boot execution environment (e.g., for Shim, Grub, systemd-boot, etc)
  - Platform description
  - Firmware Update
  - Verified boot


yocto PROJECT
Applications
Linux
UEFI Stub
UEFI Apps (optional)
OS
UEFI
FW Update
FDT
U-Boot
Platform
OPTEE (optional)
TF-A (optional)
Hardware

UEFI is specification, not implementation

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- Multiple implementations
- Tianocore EDK2 is the reference open source implementation
  - https://github.com/tianocore/edk2
- U-Boot also implements UEFI
  - CONFIG_EFI_LOADER

Very little in UEFI is required

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- The subset of what OSes require is nicely contained
- EBBR project defines a UEFI subset suitable for embedded Linux
  - Required features to support Linux Distros
  - Implemented in U-Boot
  - Works with embedded hardware
  - Uses Devicetree
- Problematic runtime features are optional
  - SetVariable()
    - not easy to implement if OS owns the storage device
  - SetTime()
    - OS owns the RTC device
  - UpdateCapsule()
    - Again, OS owns flash device

UEFI defines the ABI

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OS uses firmware services during early boot, before device drivers get loaded

BootServices

Callable before EBS()

- Boot Services Table
  - Events and Notifications
  - Memory Management
  - Image Loading
  - Watchdog Timer
  - ExitBootServices()
- Protocols (ABI extensions)
  - Network
  - Console
  - Storage
  - Graphics

RuntimeServices

Callable before and after EBS()

- Runtime Services Table
  - Variables
  - Timers, Wakeup and RTC
  - System Reset
  - Firmware update

SystemTable

- Pointers to data about the system
- System Descriptions
  - Devicetree
  - SMBIOS
  - ACPI
- UEFI details
  - ESRT
  - RuntimeServicesSupported

UEFI defines the behaviour

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- Boot device selection
- BootOrder and BootXXXX
- Removable device booting
- Handoff to OS

UEFI defines *limited* functions at runtime

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- Set/Get RTC settings
- Set/Get Variables
- UpdateCapsule()

UEFI Secure Boot

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- Authentication scheme for delegating authority
- Hierarchical key database
  - Platform Key (PK) – Root of trust for UEFI
  - Key Exchange Key (KEK) – signing authorities
  - DB & DBX – key & hash databases, allow and revoke respectively

Firmware Update

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- U-Boot implements UpdateCapsule() ABI and ESRT
- Device Firmware Update (DFU) backend
- UEFI Capsule as wrapper around FIT image
  - Capsules can be managed by fwupd & LVFS
  - tools/mkimage -f capsule.its capsule.itb
  - tools/mkeficapsule capsule.itb capsule.bin
- CapsuleApp.efi for applying capsules
  - Use either self-built SCT, or Arm SystemReady ACS image
  - FS1:\> boot/efi/apps/capsuleapp.efi /path/to/capsule.bin

Devicetree tied to Linux kernel doesn’t scale

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- Historically considered tied to the Linux kernel build
- Doesn’t work for the distros
- Isn’t great for Yocto either
- Firmware needs to provide copy of Devicetree by default
  - Enables OS portability

Mainline Linux

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- Distros have a mainline-first policy
  - If board support isn’t in mainline, the distros will not support
- Mainline support helps Yocto too
  - Less reliance on custom vendor trees
  - Uprev kernel or apply security patches
- Requiring mainline solves many support problems

Testing

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- UEFI Self Certification Test (SCT)
  - UEFI ABI test utility
  - https://github.com/tianocore/edk2-test
  - https://gitlab.arm.com/systemready/edk2-test-manifest
- U-Boot UEFI Self Tests
  - CONFIG_CMD_EFI_SELFTEST=y
  - => bootefi selftest
- FWTS
- Arm's SystemReady ACS-IR
  - Prebuild disk images – work on SD and USB
  - https://github.com/arm-software/arm-systemready
  - Includes: SCT, Arm BSA & BBR tests, FWTS

Formal Compliance Testing

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- Arm launched SystemReady program in October 2020
- First certifications in June 2021
- Requirements
  - Conform to EBBR
  - Pass SystemReady ACS-IR test suite
  - Boot 2 unmodified Linux distros
  - Support UpdateCapsule()
- Using 3rd party testing labs
- More information
  - https://developer.arm.com/systemready
  - Contact email: systemready@arm.com

Work to be done

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- Boot Device Selection (BDS) improvements
  - BDS currently implemented as hush scripts
  - Boot list or menu
- Console device selection
  - console= kernel argument still needed too frequently
  - Enabling framebuffer should not break console
- Measured Boot
- Devicetree validation and stability

Certification program is running now

See www.arm.com/systemready-certification-program for list of certified platforms and expect more announcements this year

Join us on the EBBR community project at https://github.com/arm-software/ebbr

Contact us about getting your platform certified systemready@arm.com