NuttX 2019 International workshop

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NUTTX AND PAYMENT CARD INDUSTRY SECURITY STANDARDS

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SESSION OBJECTIVES

- Discuss Approaches and Get Community Feedback for
- Enhancing NuttX Security w.r.t.
  - Cryptographic Key Storage and Access Control
  - Code Signing and NuttX SDKs
- To Empower NuttX as a Platform for
  - Payment Devices
  - Secure IoT Devices

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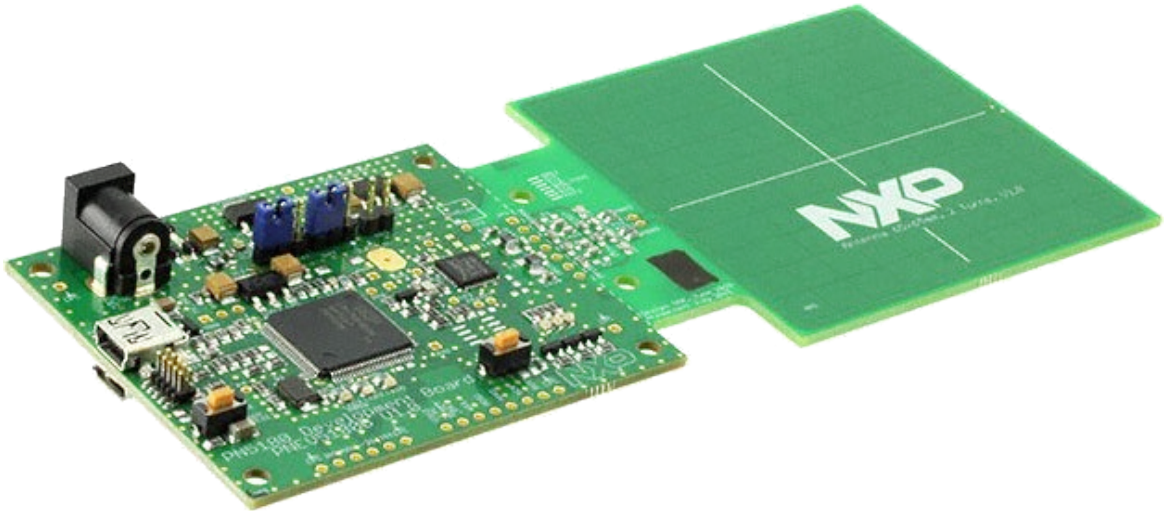
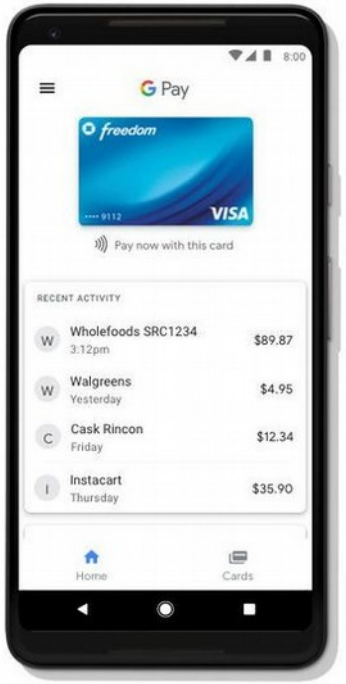
PAYMENT

- Linux® based Contactless (NFC) Secure Card Reader (SCR)
- EMV® Contactless Kernels for all major Credit Card Brands
- Tamper Responsive Cryptographic Tokens with PKCS#11 API
- Secure Boot, Secure Firmware Update, Signed Application Code
- Payment Applications developed by Third Partys with FEIG cVEND SDK: GNU Toolchain, FEIG Libraries and Tools
- Payment Card Industry - PIN Transaction Security - Point of Interaction (PCI PTS POI) Version 4.0 Compliant
- Card Data Protection only (No PIN Processing)
- “The Raspberry Pi® of Payment Terminals” - Good Market Reception

COULD THIS BE DONE WITH NUTTX ON AN MCU? DEMO!



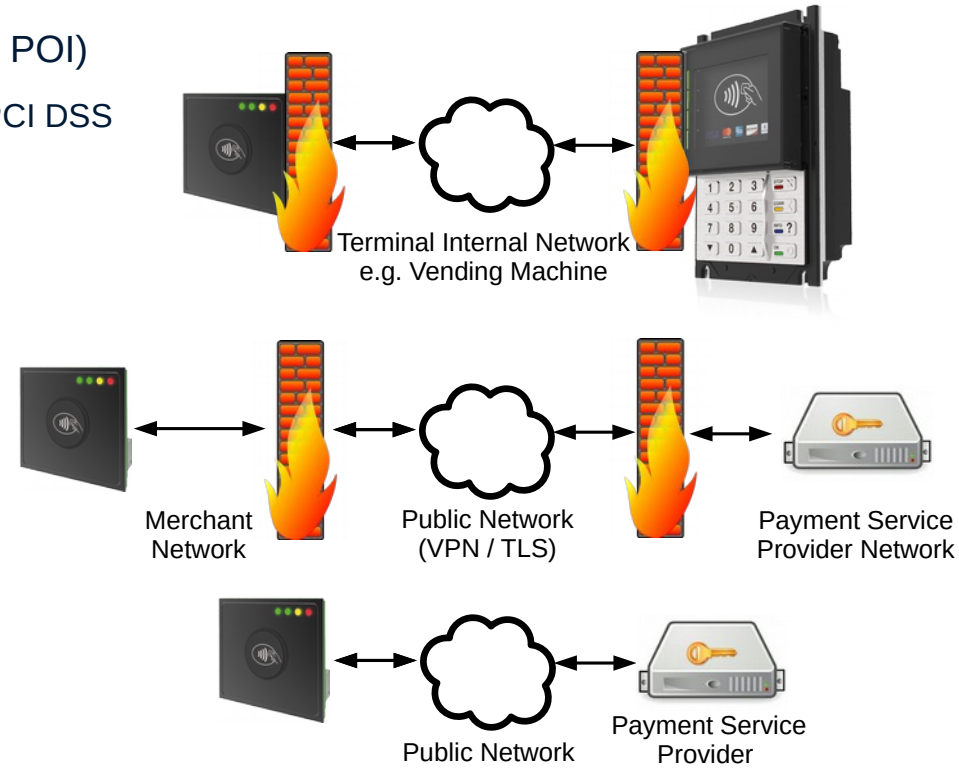


MINIMAL POINT-OF-SALE DEMO

PAYMENT CARD INDUSTRY SECURITY STANDARDS

PCI Security Standards Council

- PIN Transaction Security - Point of Interaction (PCI PTS POI)
  - Not strictly required if no PINs are handled, but helps for PCI DSS
  - SCR Requirements: Keystore / No Application
- PCI Data Security Standard (PCI DSS)
  - Assessing the complete Card Data Environment (CDE)
  - No Secure Card Reader required
- PCI Point-to-Point-Encryption (PCI P2PE)
  - Terminal-to-Host-Encryption
  - Merchant Network no longer in scope of PCI DSS
  - Requires Host specific Protocol Encryption on Terminal
  - SCR Requirements: Keystore and Application



CRYPTOGRAPHIC KEY STORAGE AND ACCESS CONTROL

How to guarantee that applications

- never have access to clear text cryptographic keys, and
- can use cryptographic keys only for their intended purpose

PROTECTING KEYS WITH AN APPLICATION INTERPRETER

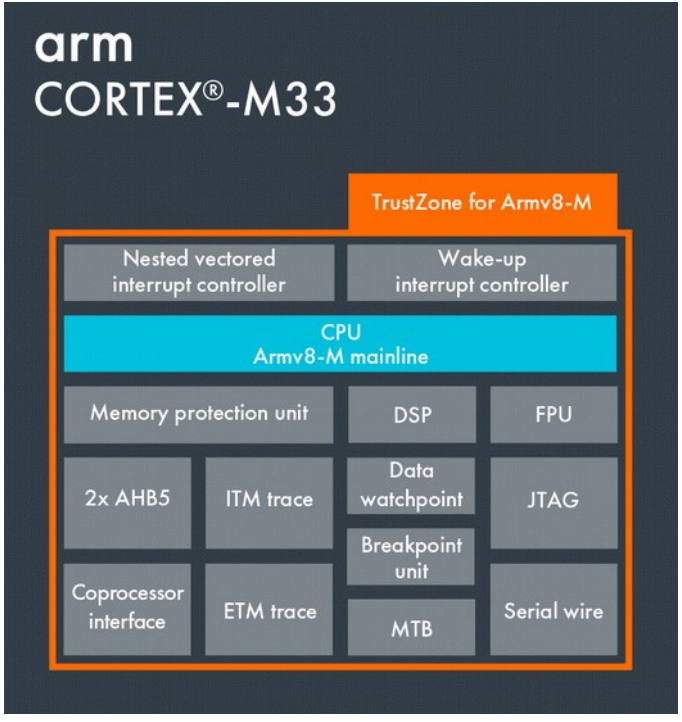
- Use MicroPython, QuickJS, or other interpreters
- Controlled Access to Keystore via C function wrappers
  - MicroPython user C module, or
  - QuickJS C API, or
  - ...
- NuttX Flat Build sufficient (e.g. no Memory Protection required)
- Cons:
  - Considerable Resource Load
  - Embedded Developers love C

PROTECTING KEYS WITH THE MEMORY PROTECTION UNIT

- NuttX Protected Build
  - Keystore “Device Driver” to provide Crypto Services and enforce Access Control
  - Keys stored in MPU protected privileged RAM / Flash / Battery-Backed SRAM
  - PKCS#11 API (or conceptually similar) via `ioctl()`
  - Might be Sebastien Lorquet’s Crypto Mangager
- Just how secure is the NuttX Protected Build? From the NuttX TODO file:
  - “In the current design, the kernel code calls into the user-space allocators to allocate user-space memory.”
    - At least to allocate space for a new tasks stack. Others? “That could be fixed by dropping to user mode”. Hard?
  - “Another place where the system calls into the user code in kernel mode is work_usrstart() to start the user work queue.”
    - Plugged by de-configuring LIB_USRWORK?
  - “When a C++ ELF module is loaded, its C++ constructors are called via sched/task_starthook.c logic. This logic runs in protected mode.”
    - Plugged by BINFMT_DISABLE?
  - Are there more known holes to be plugged?

PROTECTING KEYS WITH ARM TRUSTZONE

arm TRUSTZONE



- Upcoming Cortex-M23 / -M33 MCUs include TrustZone technology
  - E.g. STM32L5 or LPC5500
    - Focus on IoT Security
    - Sampling now
    - ARMv8-M
- NuttX as a Trusted Execution Environment?
  - “SMP and TrustZone on the i.MX6 quad was part of a research project with a University [...]”

    ”I have heard of people using NuttX as TrustZone masters on high end products [...]”

    (Greg’s comment on NuttX Issue #92)
  - There are some references to TRUSTZONE in `arch/arm/src/armv7-a/arm_gicv2.c`

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NUTTX BASED SOFTWARE DEVELOPMENT KIT

How to ship an embedded device with

- vendor controlled firmware (including the NuttX kernel)
- on which system integrators can install their own application

BOARD SPECIFIC NUTTX SOFTWARE DEVELOPMENT KIT

- Configure **`nuttx`** for Protected Mode Kernel and SDK build for a certain board (e.g. **`pnev5180b/sdk`**)
- Create GNU toolchain with Buildroot (e.g. **`cortexm3-eabi-defconfig-7.3.0`**)
- **`make pass2`** generates the ***kernel blob*** (to be flashed via e.g. DFU as *firmware*)
- **`make pass1 export`** creates **`nuttx-export.zip`**
  - copy header files and **`libnuttx.a`** into toolchain
  - copy linker script (**`nuttx.ld`**) and **`userspace.c`** into toolchain
- Example: Compile hello world example into a ***userspace blob*** (to be flashed via e.g. DFU as *application):*
  - **`arm-nuttx-eabi-gcc -o hello hello.c ~/nuttx-sdk/share/nuttx/userspace.c -nostdlib -lnuttx -Tldscripts/nuttx.ld`**
- Streamlining: Compile **`userspace.c`** into **`libnuttx.a`**, make **`nuttx.ld`** default linker script, make **`-nostdlib`** implicit. Ideas?
- With a **`config.site`** file in the **`sysroot`** static libraries can be compiled for NuttX from autotools packages.
- Buildroot with NuttX kernel? http://lists.busybox.net/pipermail/buildroot/2015-July/131978.html

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SECURE BOOT AND CODE SIGNING

How to guarantee that access to the system integrator‘s cryptographic keys is granted only to his application

SECURE BOOT / SIGNED APPLICATIONS

- Integrity Check of Kernel Blob Out-of-Scope
  - Boot ROM's or 1st Level Boot Loader's job
- Integrity Check of Application Code (Only Authorized Applications get Keystore Access)
  - Extend the User-Mode Blob Header (`struct userspace_s`) with meta-data:
    - A digital signature (e.g. RSASSA-PKCS1-v1_5) of `us_entrypoint` value and `text`, `data`, `rodata`, and ~~`bss`~~ section contents.
    - A version field to protect against downgrades.
- `nx_start_application()` verify that
  - no downgrade was performed (by comparing version field agains value stored in Flash / EEPROM of highest ever installed application code version), and
  - the digital signature is correct with a Public Key stored as part of the NuttX Kernel Blob or in the Keystore
- If checks fail stay in Device Firmware Upgrade (DFU) mode

- There Probably are Questions
- But they are not on this Bulleted List
- Because of Causality

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