BUS
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Measured boot: How to link the operating system to the platform integrity

Capitole du libre – 17/11/2018

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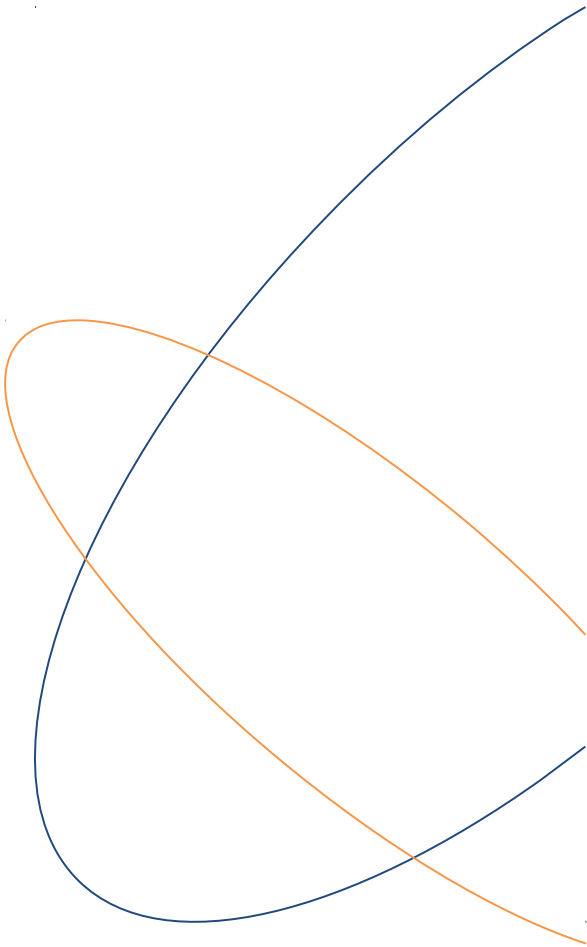
Plan

1) Measure boot overview
2) Trusted Platform Module overview
3) Measured boot in practice
4) Open source tools for implementation
5) Questions?



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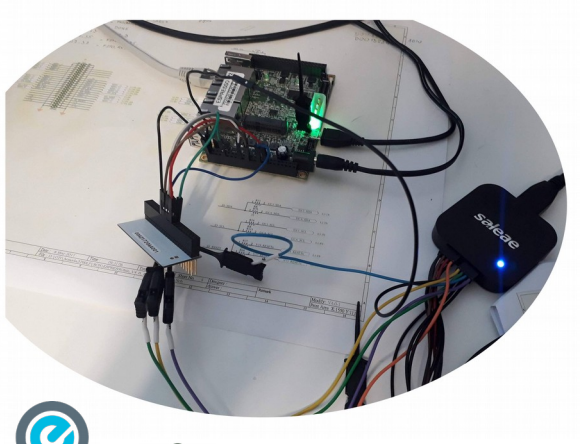
Speaker presentation

- A Sigfox employee for more than three years
- My main activities:
  - New platform integration
  - Build system
  - Board support packages
  - Core system features
- Free software enthusiast
- Contributor in my free time



openembedded

yocto PROJECT

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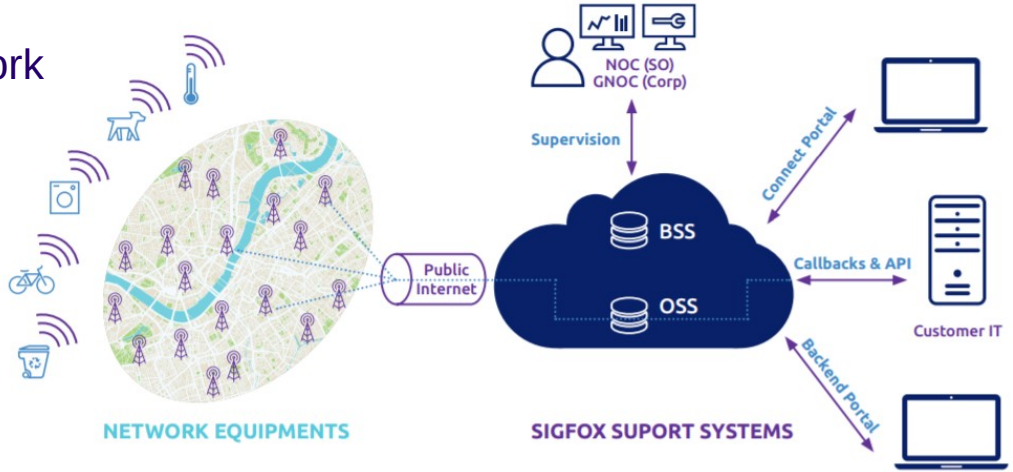
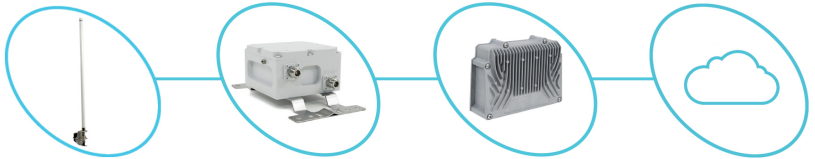
Sigfox presentation

- A global Low Power Wide Area network
  - Low cost
  - Low power
  - Several thousand of base stations
  - +50 countries
- Offer data and cloud services
  - Geo-location
  - Etc.
- Contribute to open sources





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What is a Sigfox base station ?

Access point which receive messages from devices to send them to our cloud.

- Hardware
  - CPU X86-64 / ARMv7 / ARMv8
  - RAM >= 1GBytes
  - Watchdog
  - SSD / eMMC / NAND >= 1GBytes
  - RADIO USB / SPI
  - Ethernet
  - 4G
  - TPM
- Software
  - Connectivity management
  - Data management
  - Hardware management
  - Identity management
  - Monitoring
  - Software Defined Radio
  - Time management

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Measured boot overview

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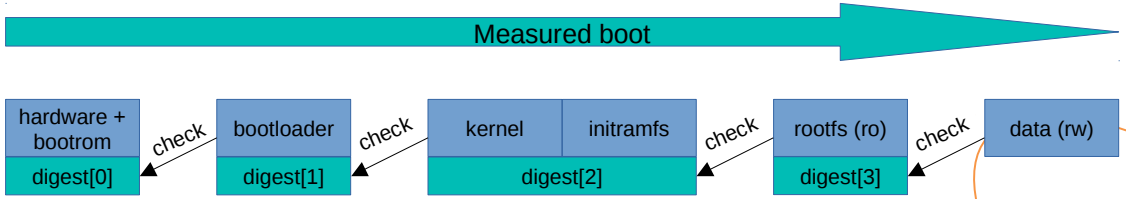
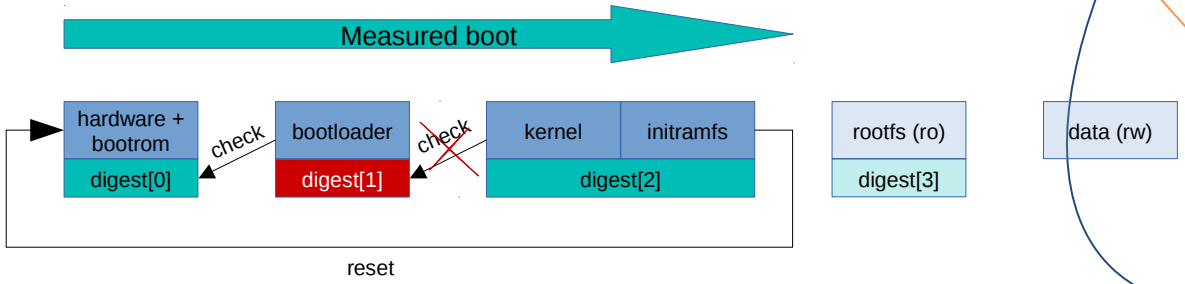
Measured boot: definition



Measured boot chain of trust which prevents the boot stage execution when the system state (from previous stage) is not expected.



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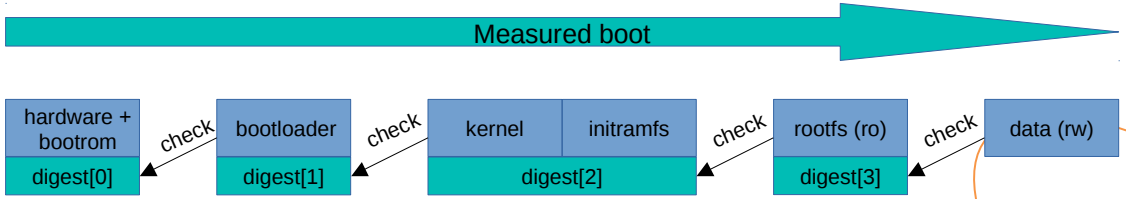
Measured boot: difference with secure boot



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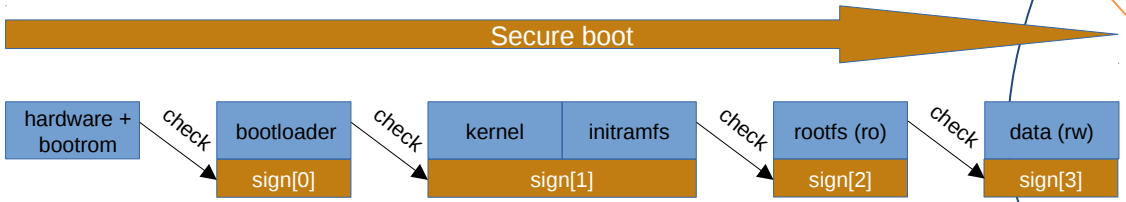

Secure boot chain of trust which prevent the next boot stage execution when the signature is invalid.

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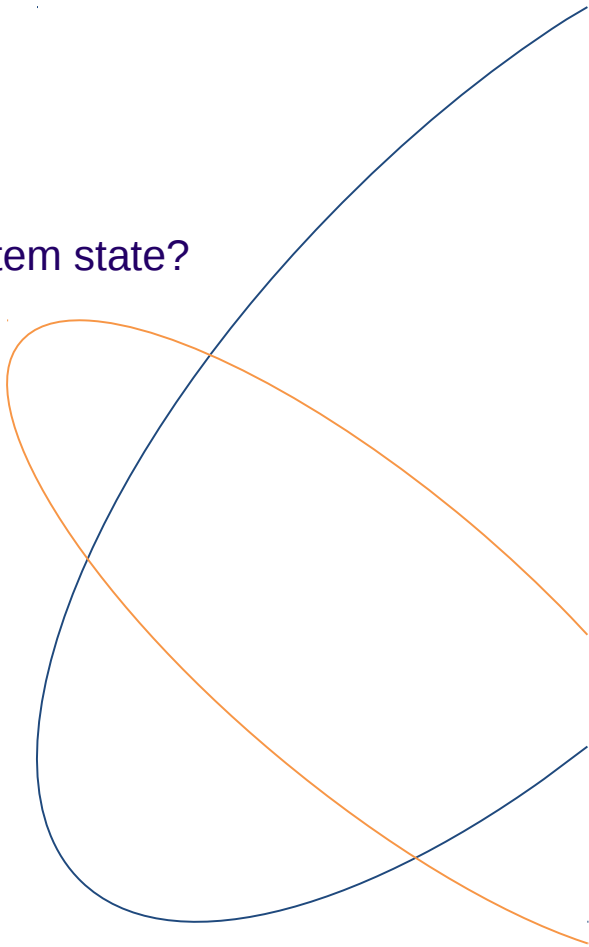
Measured boot: how to

How to guarantee the integrity of the representation of the system state?

This requires to use a trusted environment:

- to execute cryptography operations
- to store data representing the current stage integrity
- to read data representing previous stages integrity

=> The solution use a Trusted Platform Module (TPM)



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Trusted Platform Module overview

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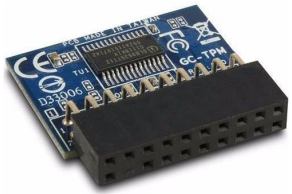
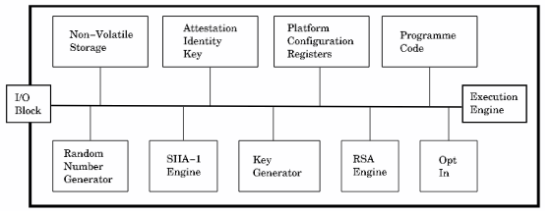
Trusted Platform Module

Trusted Platform Module (TPM, also known as ISO/IEC 11889) is an international standard for a secure cryptoprocessor, a dedicated microcontroller designed to secure hardware through integrated cryptographic keys.

Each TPM chip contains two unique RSA keys from a persistent memory which cannot be accessed by software, cannot be cannot changed or extracted from the chip:

- The Endorsement Key (EK)
- The Storage Root Key (SRK)





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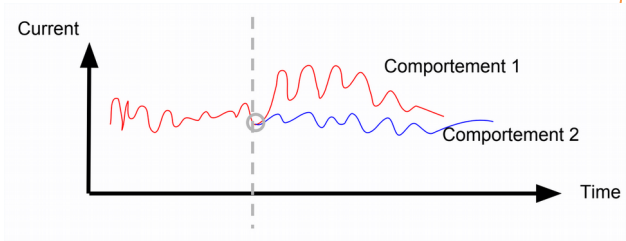
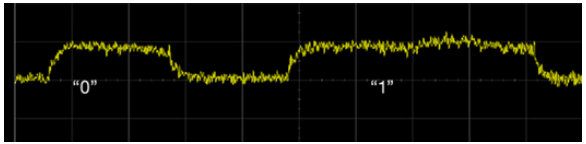
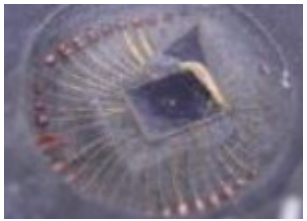
TPM hardware protections

It is protected against physical attacks:

- Brute force
- Side-channel
- Fault injection
- Imaging techniques
- Etc.







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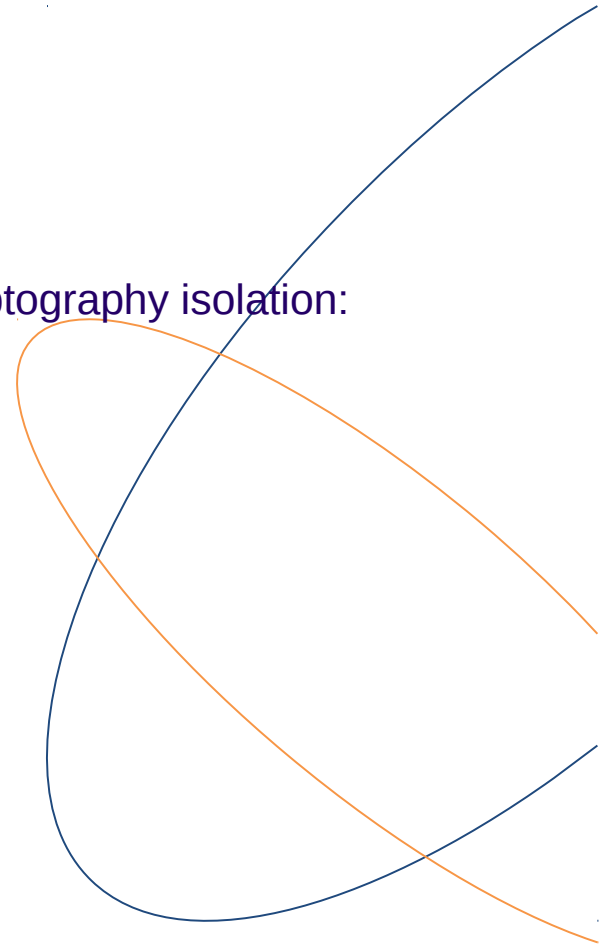
TPM Cryptography features

Warning! TPM is not a cryptography accelerator but offer cryptography isolation:

- To add/remove keys (keys can not extracted)
- To generate random number
- To generate RSA key
- To hash
- To encrypt/decrypt signature



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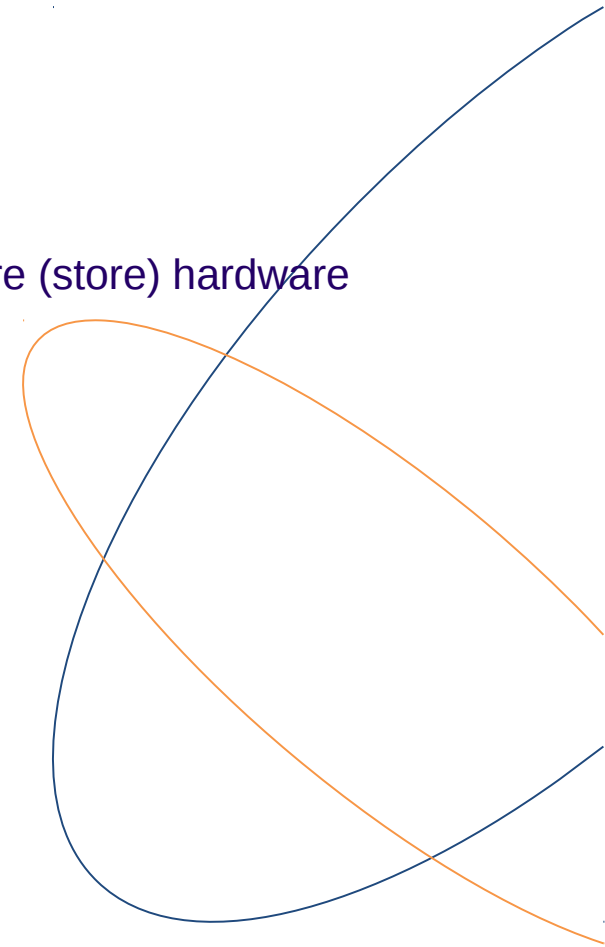
TPM Platform Configuration Registers

- Platform Configuration Registers (PCR) used to measure (store) hardware and software states representing the system integrity.
- 24 banks containing SHA256 (or SHA1) hashes

```
PCR_00: 3d 45 8c fe 55 cc 03 ea 1f 42 3f 15 62 be ec
PCR_01: c6 91 c0 ef b4 b4 0e f8 f9 5b 3b 95 a8 2f f4
…
PCR_23: 64 7c 9a 36 3b 5c 94 38 81 de 68 78 9c 00
```



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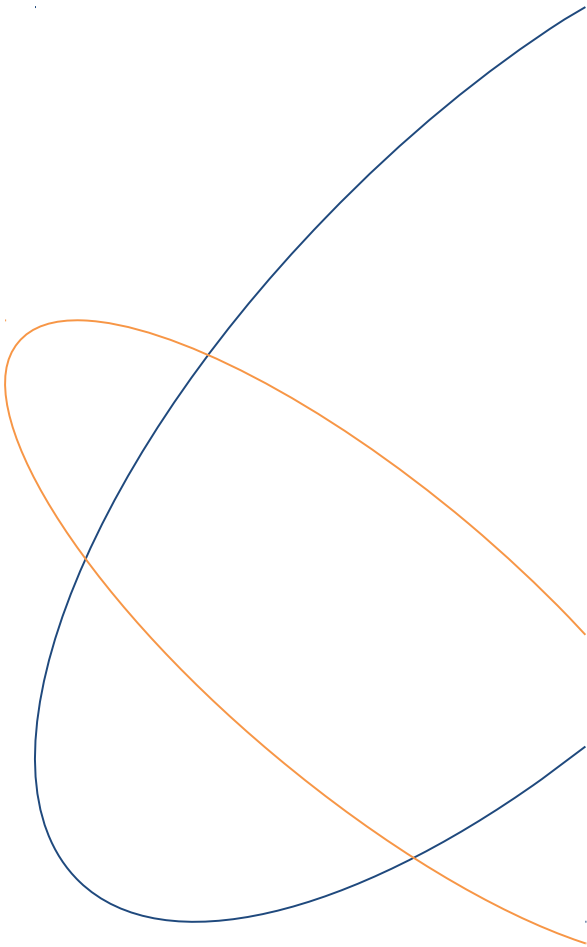
TPM PCR UEFI conventions

PCR Number	Convention
0	BIOS
1	BIOS Configuration
2	Option ROMs
3	Option ROMs Configuration
4	MBR (master boot record)
5	MBR Configuration
6	State transitions and wake events
7	Platform manufacturer specific measurements
8-15	Static operating system
16	Debug
23	Application support



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TPM PCR Operations

- These PCRs can then be read to report their state.
- PCRs can also be used in an extended authorization policy to restrict the use of other objects by:
  - hmac
  - password
  - Policy
- Can be accessed through a resource manager (kernel or userspace)

TPM PCR extend

The PCR update calculation, called an “extend”, is a one-way hash so that measurements can’t be removed.

Formula to measure the platform integrity:

PCR[N] = HASHalg(PCR[N] || ArgumentOfExtend)

Example:

PCR_10: 64 7c 9a 36 3b 5c 94 38 81 de 68 78 9c 00

tpm_extend 10 5fd4be8028d48249a594d18d8e6e

PCR_10: 21 31 10 06 a2 b7 dc 68 f4 7f 04 db fd e2 8f

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Measured boot in practice

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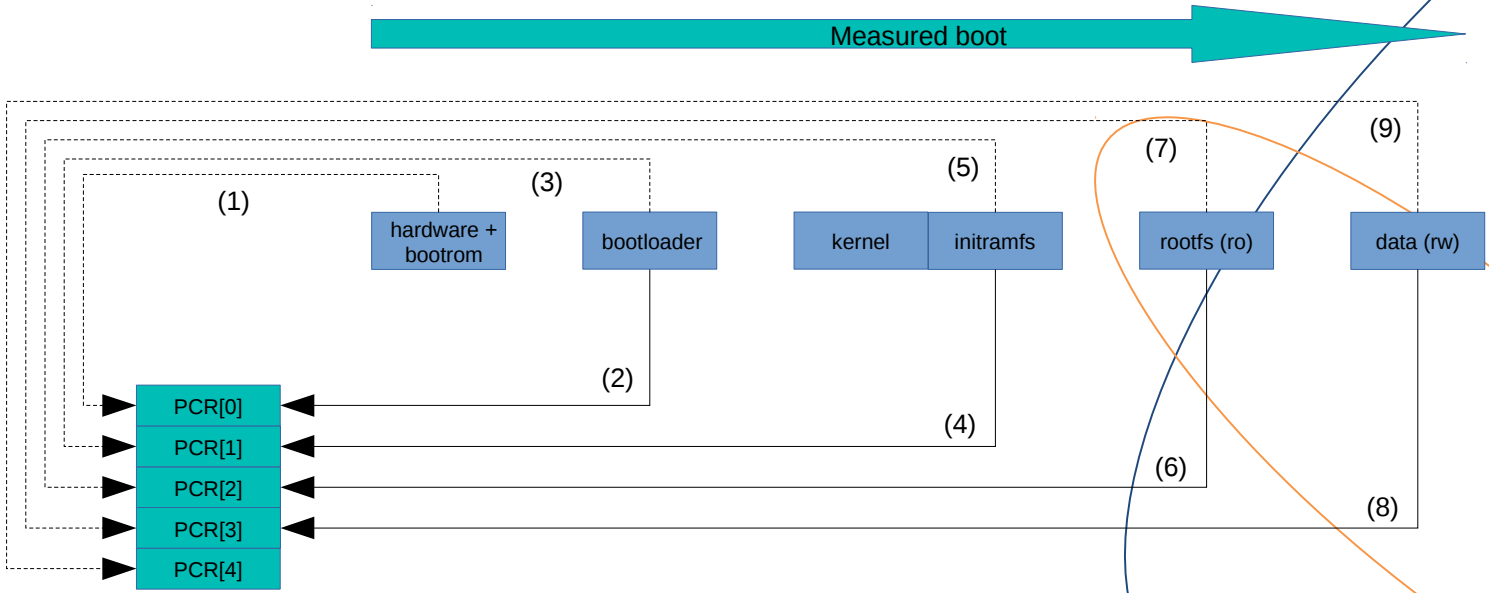
Measured boot using TPM



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Measured boot variants

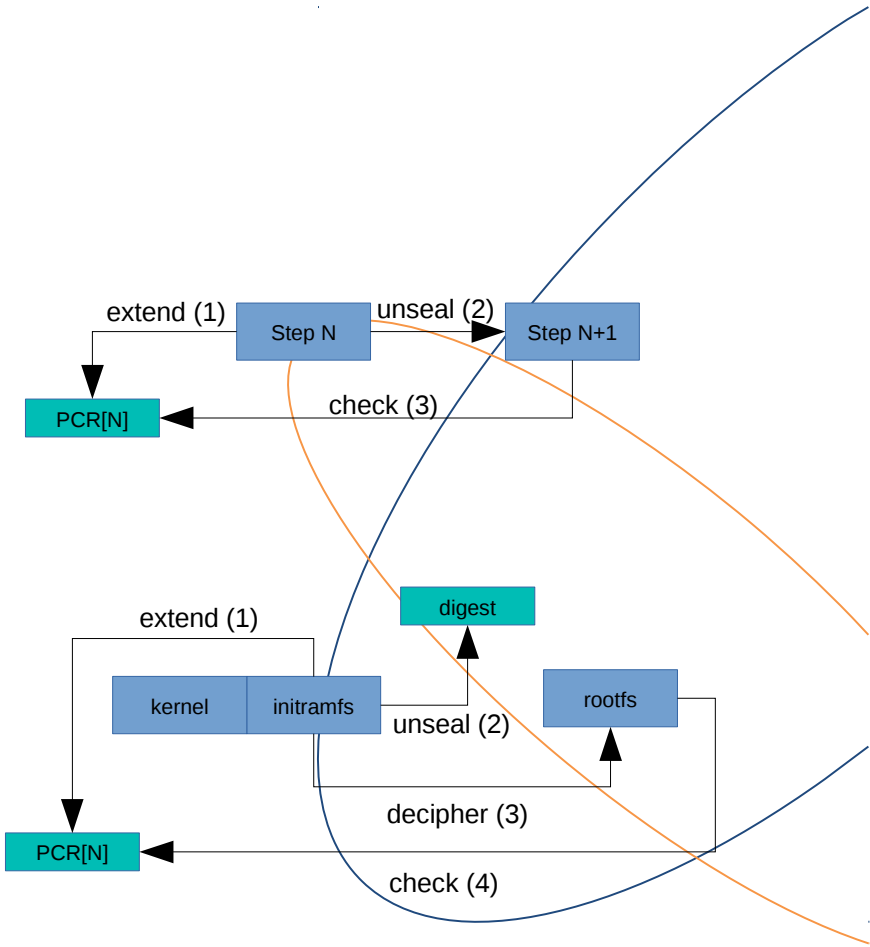
There are some variants:

- to unseal all boot stages

  (unseal = decipher data using the TPM bind key and platform integrity)

- to unseal the cryptsetup key file and to use this deciphered key file to decipher the rootfs

- Etc.



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Measured boot issue

Is it possible to build a complete chain of trust using only the measured boot?

Currently, it is very difficult because all boot stages must be capable to extend and read PCRs (or can be patched):

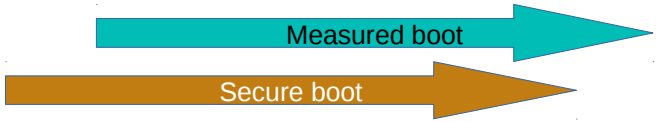
- bootROM: have rarely this support and can not be patched. So it is necessary to use another method to build a chain of trust.
- bootloader: some have the support or can be patches.
- kernel: have the support but require to use an initramfs to bootstrap the real rootfs.
- rootfs: have the support

Measured boot issue

There are two available solutions:

1- Use the secure boot solution provided by the manufacturer in order to have a root of trust for the measurement, that means the last stage from secure boot measure all hardware parts, the previous boot steps and the next step.

2 - Use the measured boot to harden the a full secure boot trust of chain, to prevent secure boot limitation, against bootkit (and filesystems).



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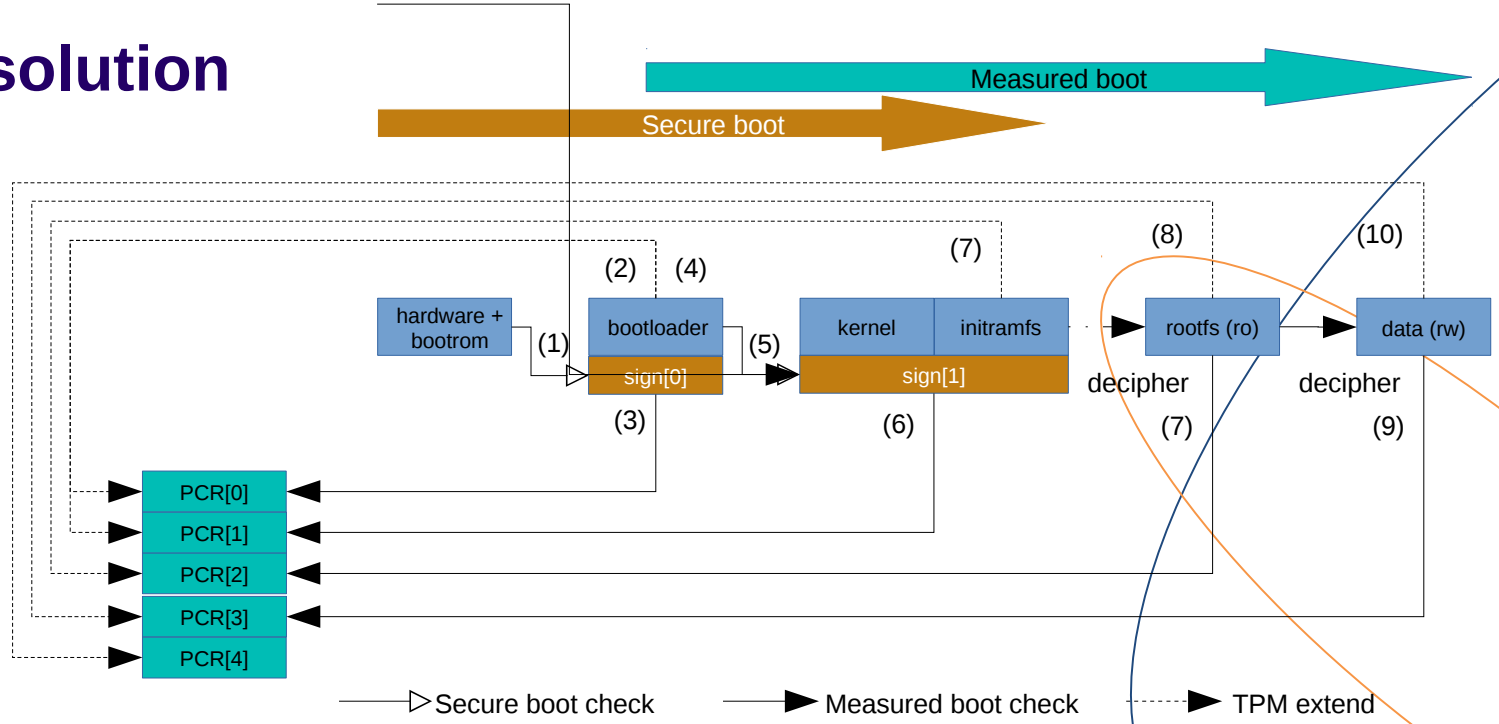
A solution



Here, in first, the bootloader extends the PCR[0] with the digest of hardware integrity, checks the value and extends the PCR[1]...

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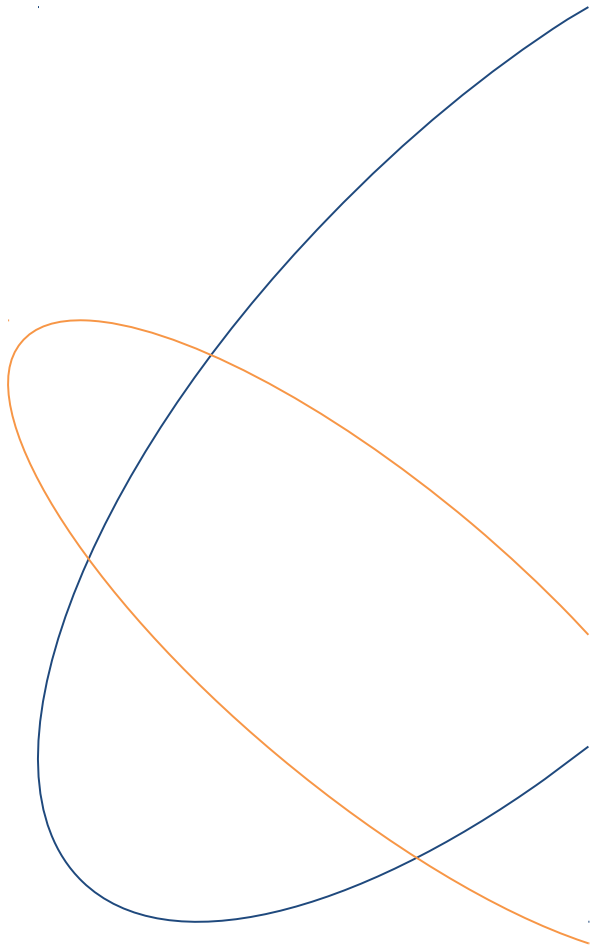
Open sources tools for implementation

Available tools

- UEFI Bios
  - Core Root of trust for measurement (CRTM)
- Bootloader
  - TrustedGrub
  - U-boot
- Kernel: TPM_TIS, IMA/EVB
- Userspace
  - TPM2-tools
  - Trousers
- Etc.



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References

- TCG TPM2 Software Stack and Embedded Linux : https://elinux.org/images/6/6e/ELC2017_TPM2-and-TSS_Tricca.pdf
- TPM2 Software Stack (TSS2) : https://events.linuxfoundation.org/wp-content/uploads/2017/11/Getting-Started-with-the-TPM2-Software-Stack-TSS2-Philip-Tricca-Intel-1.pdf

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Questions?

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Thank you!

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