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Systems Security

COMSM1500

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Hardware Root of Trust

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Plan

- Goal of trusted computing
- Rootkit
- Remote Attestation
- Return Oriented Programming
- Secure boot
- TPM

Trusted computing goal

- We need to trust computing devices
  - Laptop, phone, smart meter etc…
- You cannot know a computer is compromised by looking at it
  - Even harder remotely
- Malware/backdoor try to hide themselves
  - We are far from the Morris Worm ;-)

Arms race

- It is possible to detect malware from a higher privilege level
  - Malware wants to get there
  - Arms race to prevent this to happen
- Difficult to deal with rootkits
- What's a rootkit?

Arms race

- It is possible to detect malware from a higher privilege level
  - Malware wants to get there
  - Arms race to prevent this to happen
- Difficult to deal with rootkits
  - Set of software to maintain persistent present on a computer
  - Conceal their own presence or generally the presence of another software
  - Variant at different level (userspace -> kernel -> hypervisor -> firmware)
  - Can infect your boot sector… (formatting does not help!)

Rootkit

- Imagine malware X
- Rootkit will be a kernel module (i.e. think of something like a driver)
  - May filter ls results to exclude malware X files
  - May filter ps results to exclude malware X
  - May prevent deleting the files
  - May prevent killing the process
  - etc…
- You cannot kill (or notice) the rootkit from above!

Rootkit

Homework/exam question:
Explain the role of a rootkit
and how it works.

- Imagine malware X
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  - May filter ls results to exclude malware X files
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  - etc…
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Software approach

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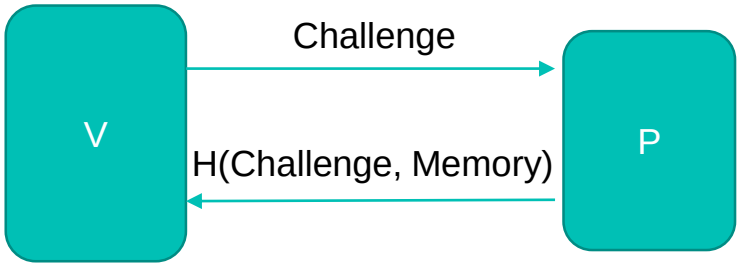
Remote attestation (software)

- Can we detect a compromised computer?
- We want to verify remotely the integrity of a system:
  - We know the hardware
  - We know the software that should be running
  - We want to verify the device is not compromised
- Problem: what is the sign of compromise
  - Code integrity

Remote attestation (software)

- Untrusted prover “P” and trusted verifier V
- V knows P memory content
- V send challenge with a nonce to P
- P compute a “checksum”
- V verify the checksum



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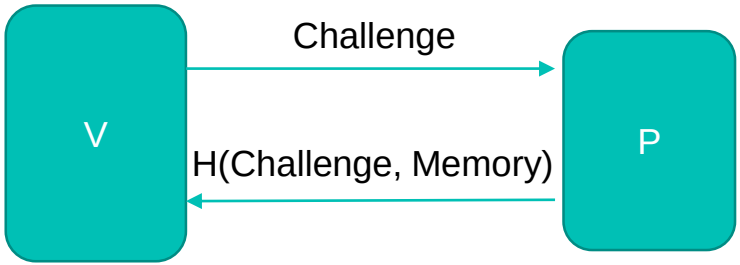

Homework/exam question:
Explain succinctly remote attestation

What remote attestation tells you

- Positive result
  - Correct memory content
  - Good device
- Negative result
  - Malfunctioning device
  - Malicious device
- No response
  - Malfunctioning device
  - Malicious device

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Problem?

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Problem?

One example

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Return oriented programming

- Return to libc (but better!)
- Gain control of return pointer via buffer overflow
- Do not insert any code
- Jump to pieces of code that do something you want
- Chains those pieces of code (can easily get up to 1000 instructions)
- Check paper on github for details (docs/rop folder)

Return oriented programming

Homework/exam question:
Explain ROP
(i.e. read the paper)

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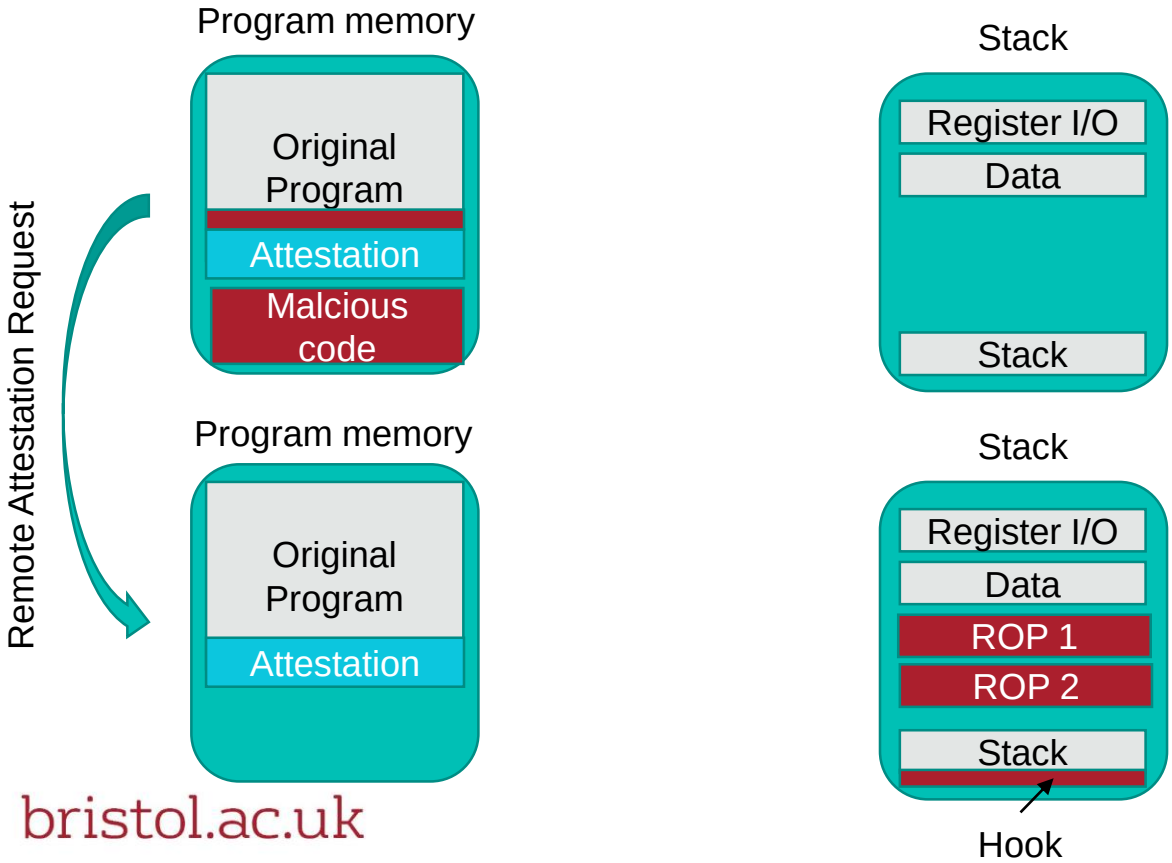
ROP rootkit


Program memory
Original Program
Attestation
Malcious code


Stack
Register I/O
Data
Stack

ROP rootkit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ROP 1
ROP 2
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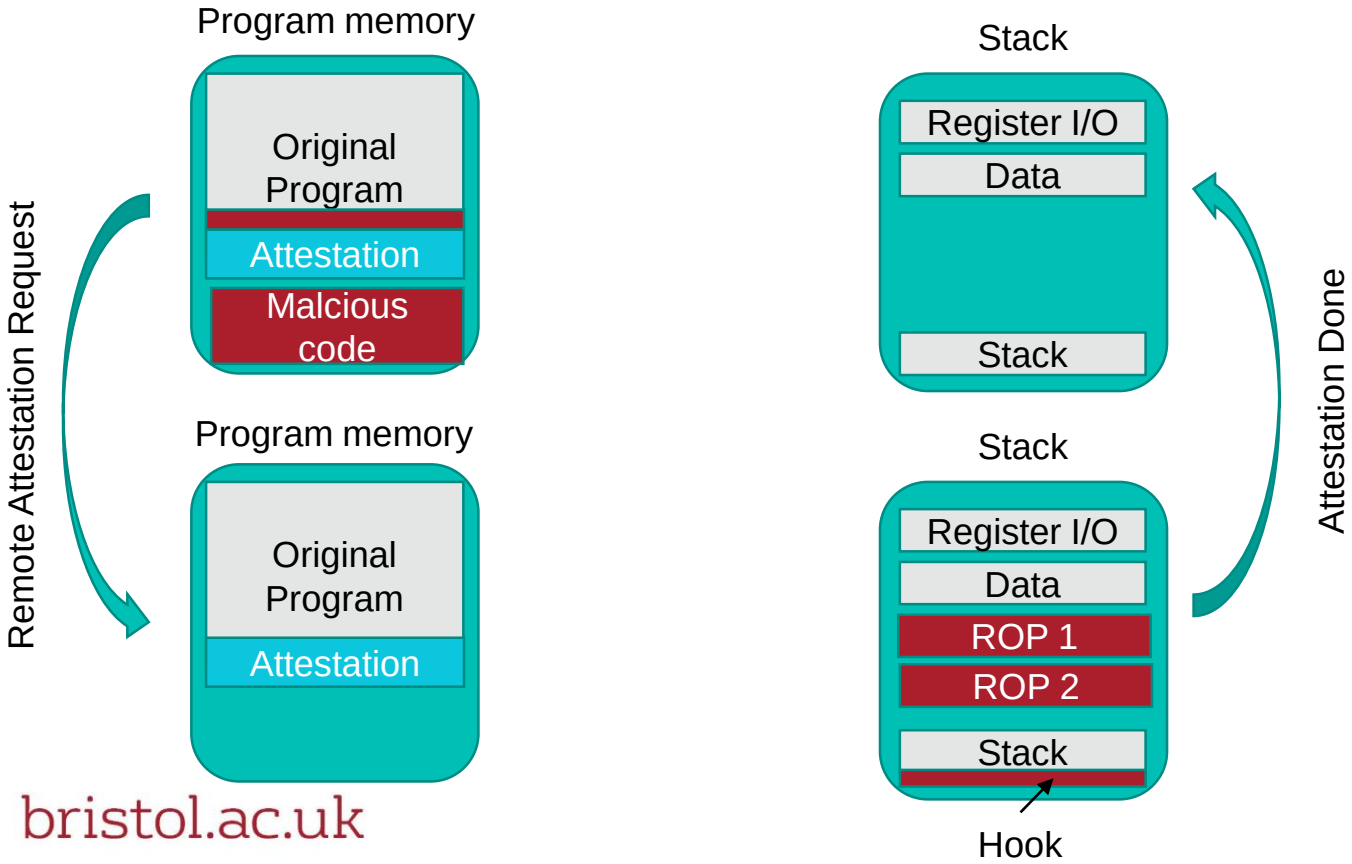
Hook

ROP rootkit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ROP 1
ROP 2
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Hook
Attestation Done

ROP rootkit

Homework/exam question:
Explain how an ROP rootkit works.

- Powerful attack
  - Standard and well understood techniques
  - Difficult to prevent (arms race)
- Existing example
  - See github (docs/rop) for example of ROP rootkit on windows
- Hard to detect
  - Smart attacker trap code that check integrity…
  - … so when it is checked program memory is correct

Software-based Attestation

- Software-based attestation is difficult
  - impossible?
- We need hardware-based attestation

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Hardware approach

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Hardware-based trusted computing

- Rely on hardware to provide some strong guarantee:
  - Prevent booting modified image (secure boot)
  - Proving integrity of running software (attestation)
  - Protecting secret from a modified OS (sealing)
  - Proving identity (authentication)

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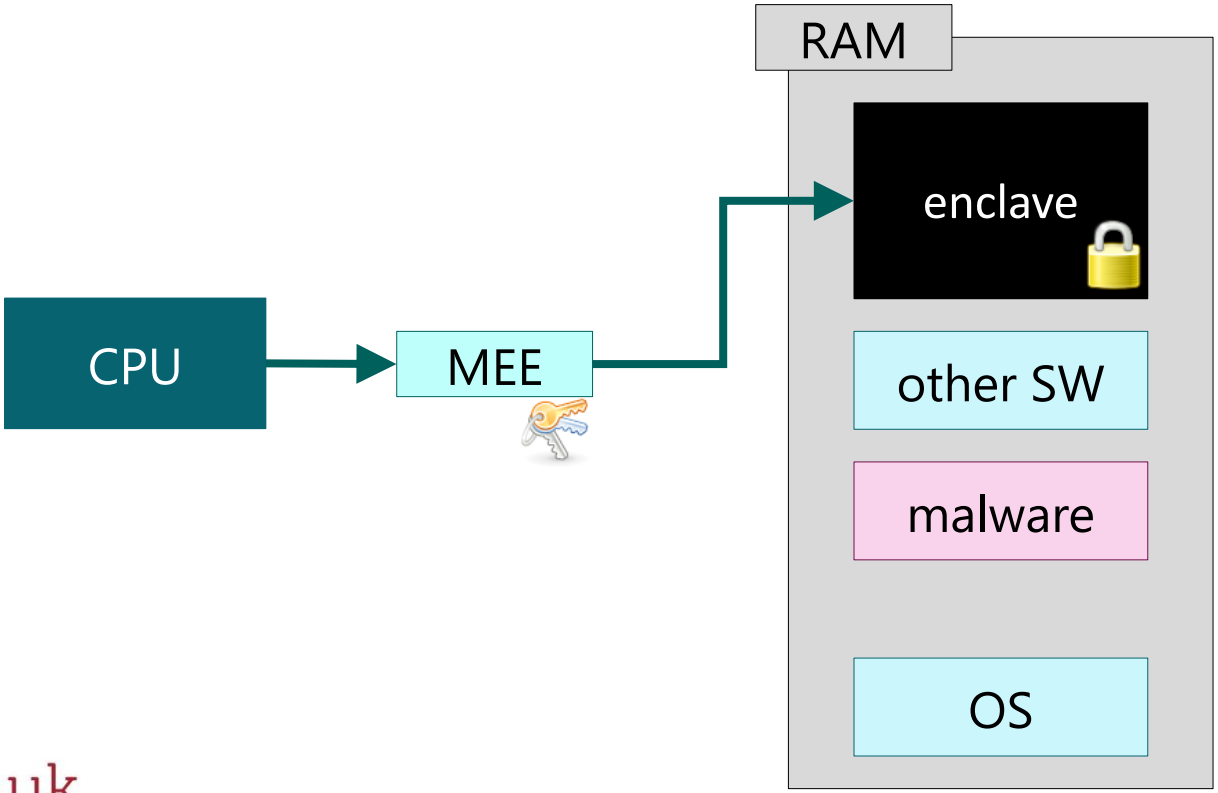
- Where is Intel SGX?
  - Sealed execution

Memory protection



Static Root of Trust

- Provide measurement of code at loading time
- Example TPM v1.1
  - Hashes code before loading
  - Store the hash in a TPM register
  - Value can be used as proof of the status of the system

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- Example: Secure Boot
  - Fixed boot loader in ROM
  - Contain a public key
  - Loads code
  - Verify the signature with the public key
  - if valid execute, otherwise halt

Static Root of Trust

Homework/exam question: Give examples of static roots of trust

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Problem?

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Static Root of Trust problem

- Verifies only static information
  - Code at loading time
- Long running application
  - Do we reboot the system to do a sensitive operation?
- Runtime status of a device is not known
  - Attacker can compromise a system during execution
- Reboot not sufficient
  - iPhone has secure boot
  - … so only safe code is executed
  - yet permanent jailbreak
  - Configuration file loaded during boot exploit a vulnerability…
  - … solution verify configuration? Then it is not really a configuration…

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- Solution SGX/ARM trust zone (context dependents etc…)

Secure boot

- Good to prevent booting untrusted image
- In control of the owner of the key
  - In general the device manufacturer
- Does not tell much about the runtime status of the device
  - Can be defeated after every reboot

Secure boot

Homework/exam question:
Discuss the limitation of
Secure boot.

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- In control of the owner of the key
  - In general the device manufacturer
- Does not tell much about the runtime status of the device
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TPM-based Trusted Computing

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TPM (Trusted Platform Module)

- Trusted Computing Group
  - Microsoft, Intel, IBM etc…
- Promoting standard for more trusted computing
  - Additional chip on the motherboard
  - … called TPM
- Used for
  - Disk encryption
  - System Integrity
  - Password protection
  - … and more

Trusted Computing vs Secure Boot

- Secure boot allows signed software to execute
- Authenticated boot
  - Make measurement of the software being executed
  - e.g. can be verified by third parties

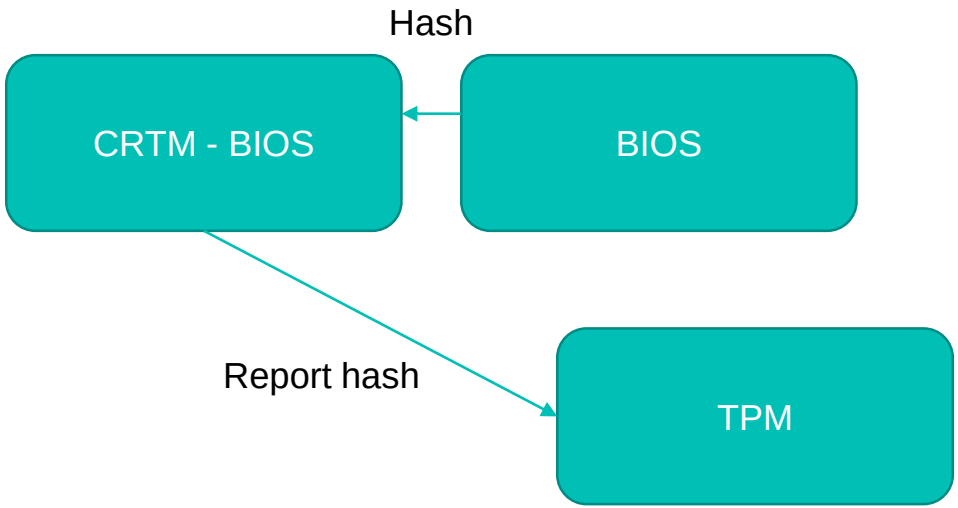
- You could combine both

Requirements

- We can achieve trust if we can verify the system has booted correctly
- We assume the pc hardware has not been modified
  - Key function is in the hardware TPM
- We need to monitor the boot process
  - Initial boot measure by the “Core Root of Trust” (ROM)
  - Hash the BIOS, store results in TPM, start the BIOS
  - BIOS do its job, load the next stage, hash it store in TPM etc…

Authenticated Boot

Authenticated Boot



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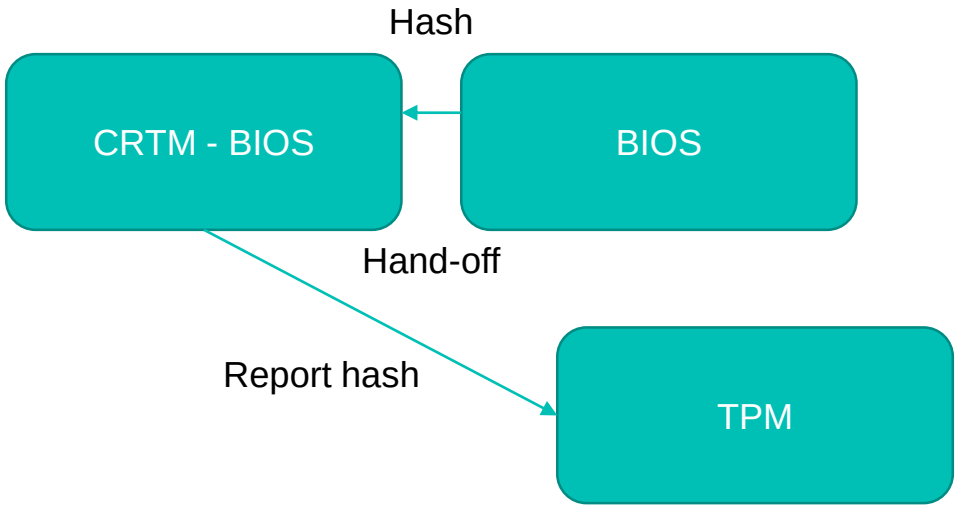

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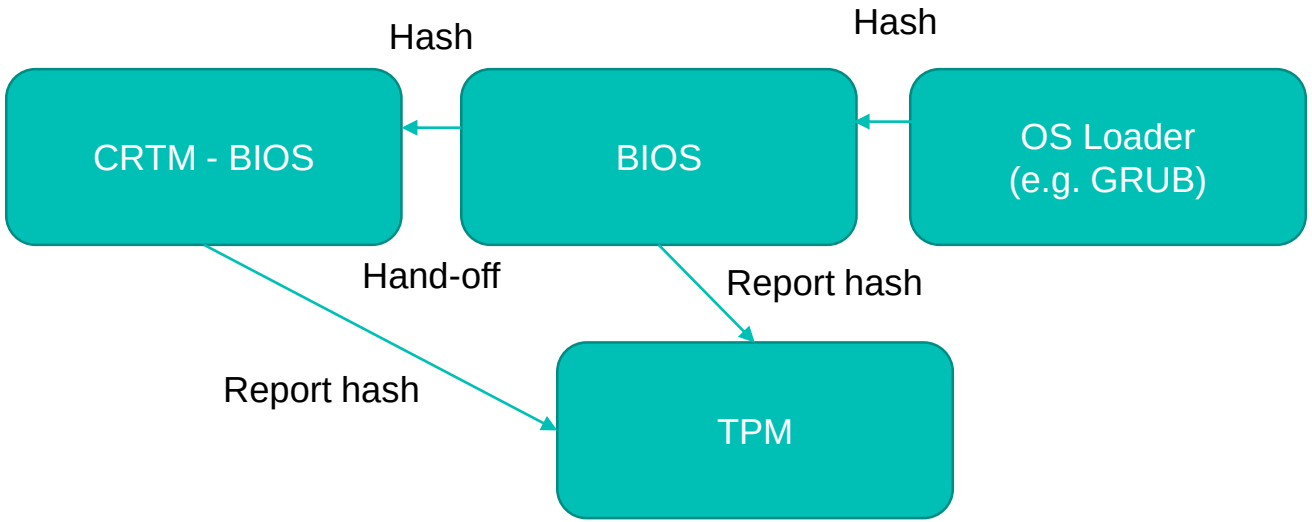

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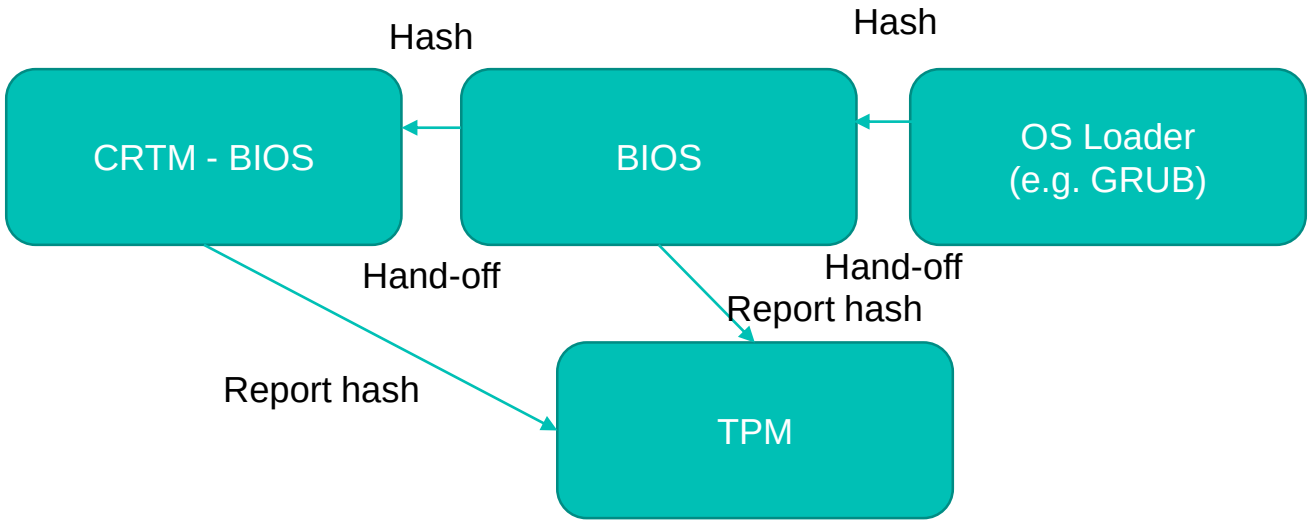

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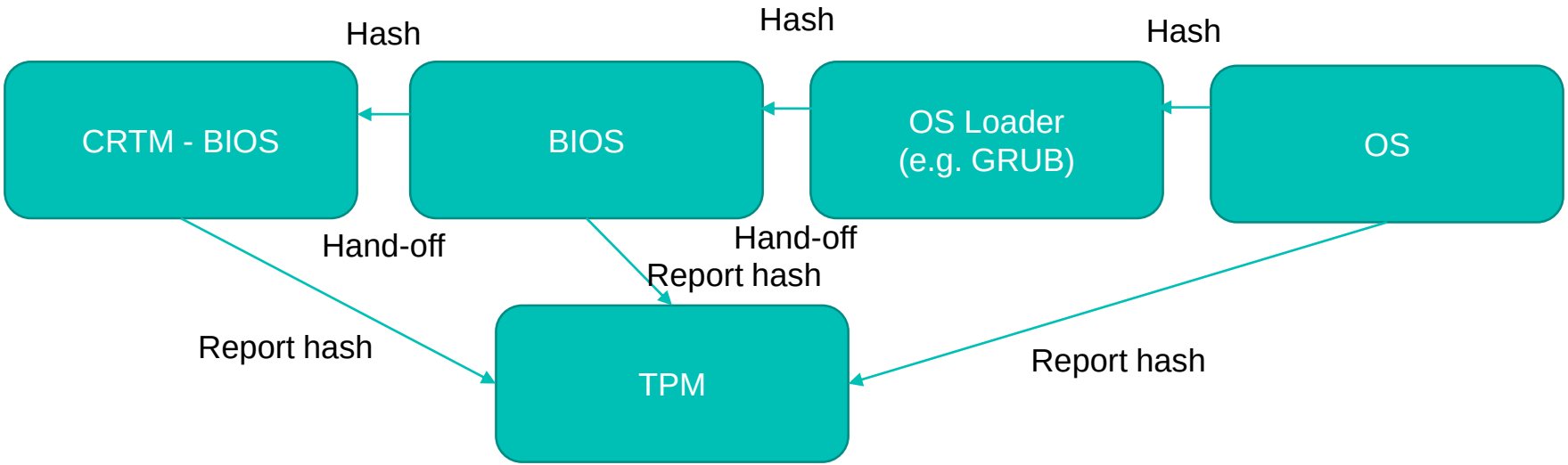
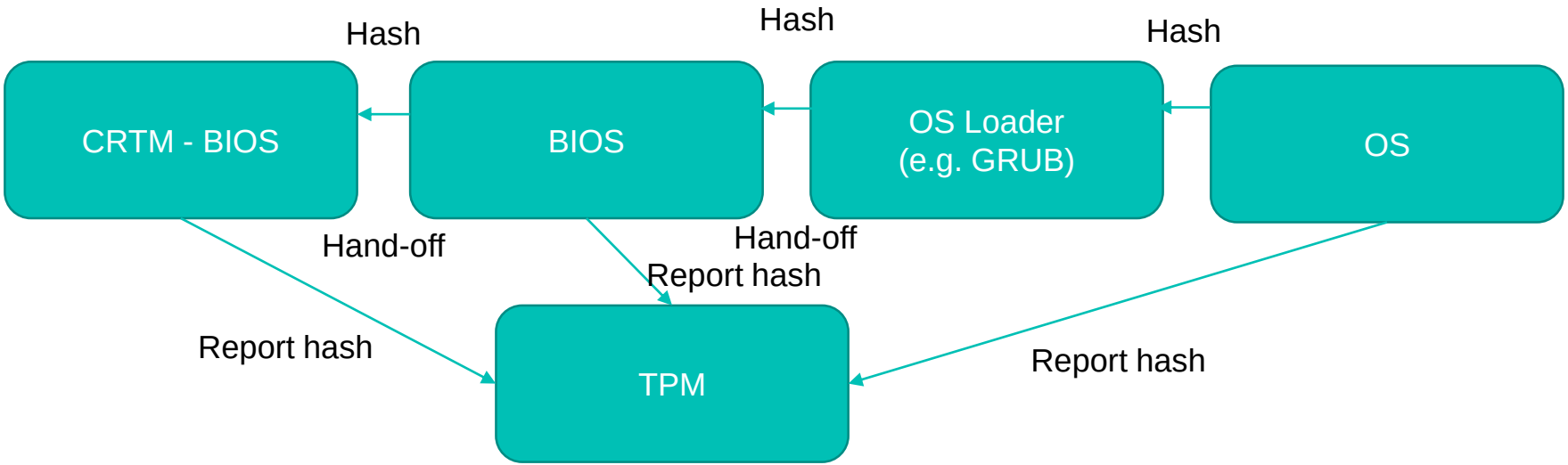


Authenticated Boot (simplified)



TPM registers

- Platform configuration registers (PCRs)
  - Used to store platform integrity metrics
- A PCR hold a summary of a series of value
  - Not the entire chain of hash
  - The chain can be infinite
- A PCR register is extended
  - PCR = HASH(PCR | new measurement)
  - Shielded TPM location (i.e. cannot be modified from outside)
  - Measurement are provided by software

TPM and Remote Attestation

- PCR cannot be modified
  - Only reset at reboot
- TPM contains a key used to sign the attestation
- Verifier
  - Verify the TPM certificate/key
  - Verify the PCRs
- Attestation
  - PCRs value
  - sign(PCRs, challenge[nonce])

Remote attestation

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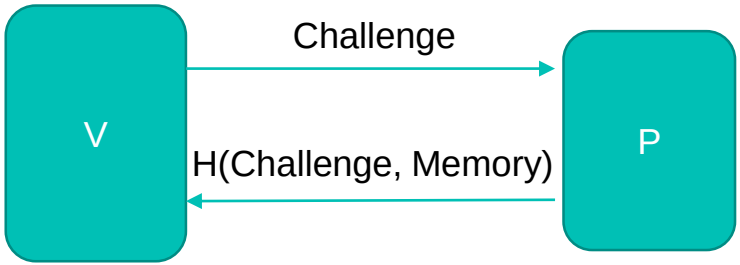

TPM and Remote Attestation

- You need not to stop at the OS
  - Can attest kernel modules (e.g. drivers)
  - Applications…
  - Configurations…
  - Scripts…
  - Where to stop?
  - Problem with load order? (remember it is a chain)
- Check IMA paper on github (docs/ima)
  - Linux implementation by IBM

TPM and Remote Attestation

Homework/exam question:
Explain how to perform
RA with TPM.

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TPM and Remote Attestation

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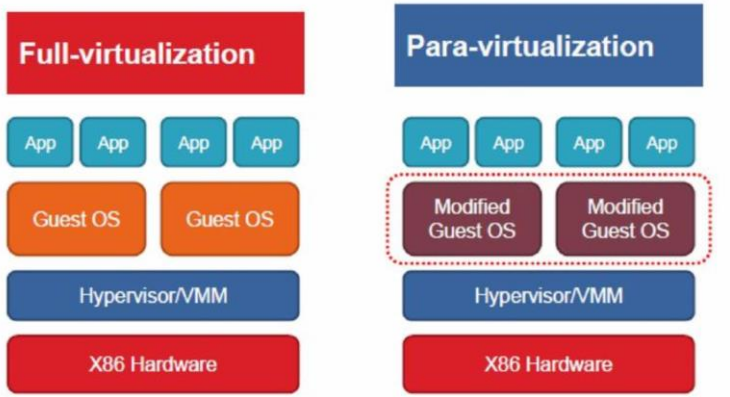
- Can also work for VM (check vTPM by IBM)



Plan

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Thank you, questions?

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