

Android Bootloader and Verified Boot Lecture 8

Security of Mobile Devices

2018

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Bootloader

Recovery

Verified Boot

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- Software that runs when device is powered up
- Proprietary and specific to the SoC
- Initialize hardware
- Find and start the OS
- Separate bootloader for each booting stage

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- Supported by most bootloaders
- Special hardware key combination while booting
- adb reboot bootloader
- Flashing raw partition images
- Booting transient system images



- Default on customer devices
- Cannot flash or boot images
- Flash only images signed by device manufacturer
- Unlocking bootloader:
 - Removes fastboot restrictions
 - Removes signature check
 - Format userdata partition

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- Minimal Linux-based OS
- RAM disk with low-level tools
- Minimal UI
- Stored on the recovery partition
- Apply updates OTA packages
 - Patch of the system files and updater script
 - Code-signed using device manufacturer's private key
 - Recovery includes public key and verifies OTA
 - OTA from trusted source

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- Flashed in fastboot/download mode
- No OTA verification
- Completely replace main OS
- Root access through ADB
- Obtain raw partition data

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Encrypted data partition:

- Install rootkit on system partition
- Access to decrypted user data when in main OS
- Remote access
- Verified boot
 - Verify boot partition with key stored in hardware
 - Can prevent rootkit attack
 - Limit damage done by malicious system partition





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- Linux kernel framework
- Generic way to implement virtual block devices
 - Linux's Logical Volume Manager
 - Full disk encryption
 - RAID arrays
 - Distributed replicated storage
- Mapping a virtual block device to one or more physical ones
- May modify the data in transfer (dm-crypt)

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- Android verified boot based on dm-verity
 - Device-mapper block integrity checking target
- Verifies the integrity of each device block when read
 - Success -> Block is read
 - ► Fail -> IO error

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Uses a Merkle tree:

- Hashes of all device blocks
- Leaf nodes hashes of physical device blocks
- Intemediate nodes hashes of child nodes
- Root node based on all hashes of lower levels
- ► A change in a single device block -> change root hash
- To verify all device blocks -> verify root hash

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- When a block is read:
 - Verify hash by traversing the precalcuated hash tree
 - After that, the block is cached
 - Subsequent reads to the block no verification
- Device needs to be mounted read-only
- Mounting read-write -> integrity check fail



Recommended for partitions with system files

- Modified only by OS update
- Integrity check failure -> OS or disk corruption
- Malware modified a system file
- Well integrated with Android
 - Only the user partition is mounted read-write
 - OS files on system partition

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- From Android 4.4
- Implemented differently from one from the Linux kernel
- RSA public key
 - On boot partition verity_key
 - Verify dm-verity mapping table
 - Location of target device
 - Offset of the hash table
 - Root hash
 - Salt

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- Verity metadata block:
 - On disk after last filesystem block
 - Includes mapping table and signature
- Verifiable partition:
 - verify flag in fstab file

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- Filesystem manager encounters verify flag
- Loads verity metadata from device
- Verifies signature with verity key
- Success -> Parses dm-verity mapping table
- Passes table to Linux device-mapper
- Creates virtual dm-verity block device

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- Virtual block device mounted instead of physical device
- All block reads are verified using the hash tree
- Integrity verification and I/O error:
 - When modifying a file
 - When adding a file
 - When remounting partition as read-write

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- ▶ Boot partition: kernel (dm-verity), RAM disk, verity key
- Needs to be trusted
- Verification is device-specific
- Implemented in the bootloader
- Using signature verification key stored in hardware



- 1. Generate hash tree
- 2. Create dm-verity mapping table
- 3. Sign the table
- 4. Generate and write verity metadata block on device



Using veritysetup

- Included in cryptsetup
- Cryptographic volume management tools package
- Works directy with block devices or system images
- Writes hash table in a file
- Hash tree stored on the same target device
- Offset location after the verity metadata block
- Specify offset when running veritysetup





- Root hash used to create mapping table
- Table includes:
 - dm-verity version
 - Undelying data and hash device
 - Data and hash block sizes
 - Data and hash disk offsets
 - Hash algorithm
 - Root hash
 - Salt

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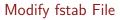


Using 2048 bit RSA key

- In mincrypt format
- Serialization of RSAPublickey structure
- In the boot partition verity_key file
- PKCS#1 v1.5 signature
- ► Table + signature -> 32 KB verity metadata block

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To enable integrity verification

Add verify flag for system partition

```
marlin:/ $ cat /vendor/etc/fstab.marlin
# Android fstab file.
#<src> <mnt_point> <type> <mnt_flags and options> <fs_mgr_flags>
/dev/block/platform/soc/624000.ufshc/by-name/system /system ext4 ro,barrier=1
wait,slotselect,verify
```

- When booting, virtual dm-verity device is created
- Mounted at /system instead of the physical device

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- Any modification to the system partiton
- Any OTA without verity metadata update
- Compatible OTA -> Update hash tree and metadata

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- Android Hacker's Handbook, Joshua J. Drake, 2014

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- Bootloader
- Fastboot mode
- Locked bootloader
- Signed images
- Recovery OS
- OTA packages

- Custom recovery
- Device mapper
- Verified boot
- dm-verity
- Hash tree
- Mapping table

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