OS Security

Mobile Sandboxing & Linux Containers

Radboud University, Nijmegen, The Netherlands

Winter 2016/2017

Announcement + Short recap

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    1. OS-level virtualization (OS allows multiple secure virtual servers to be run)
    2. Application-level virtualization (Application behaves at runtime in a similar way when directly interfacing with the original OS)
    3. Full/native virtualization (VM simulates “enough" hardware to allow an unmodified guest OS to be run in isolation)
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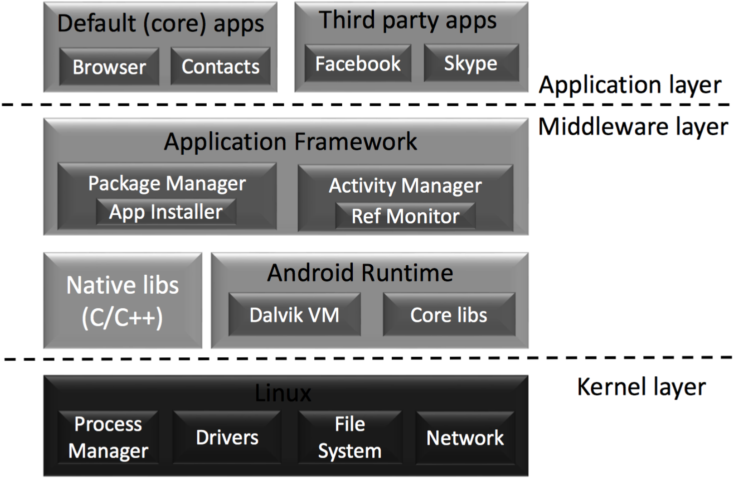
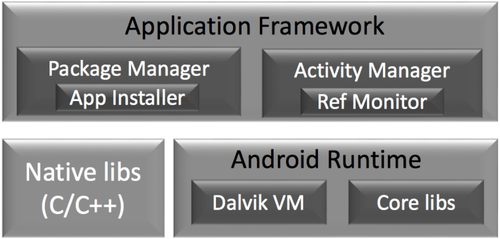
  - Comparmentalization on Qubes OS & demo of TUDOS
  - VM vulnerabilities (hardware-oriented attacks, management interface exploits, break out jail attacks, VM-based rootkits, application privilege escalation (to be revisited today!!), etc)

Android software stack



Middleware Layer - Native libraries

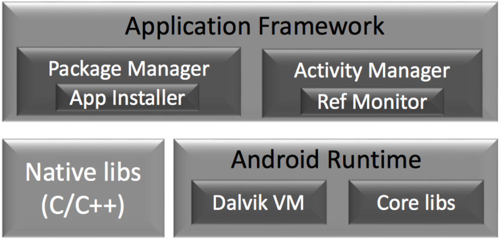
- C/C++ system libraries
- Exposed to developers via Android application framework
- Core libraries include: Libc (Bionic), media libraries, Surface manager, 3D libraries, SQLite, SSL



Middleware Layer - Android Runtime

- Dalvik Virtual Machine (DVM)

- Core Libraries



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- Dalvik Virtual Machine (DVM)
  - Virtual machine optimized for embedded environments
  - Runs optimized file format ".dex" and Dalvik bytecode generated from Java .class/.jar files at build time
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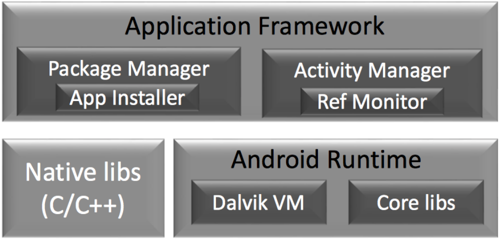

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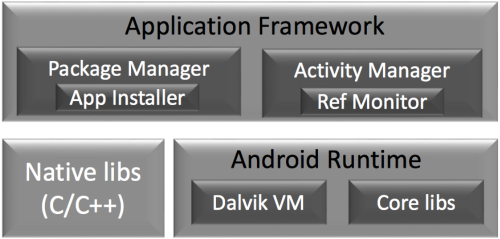
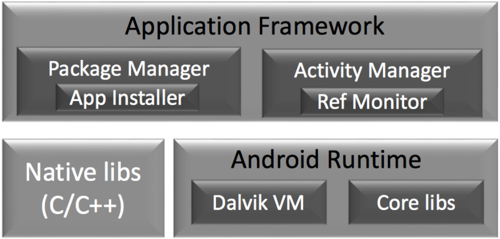
  - Provide most of the functionality available in the core libraries of Java
  - Provides core APIs of Java



Middleware Layer - Application Framework

- Provides developers API to basic functionalities and services, for e.g. set alarms, access location information, set up a phone call, etc.



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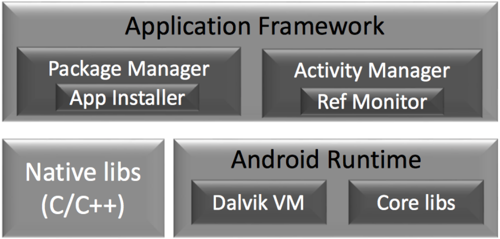

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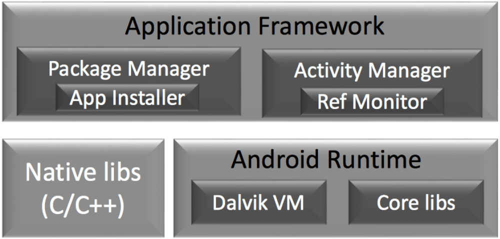

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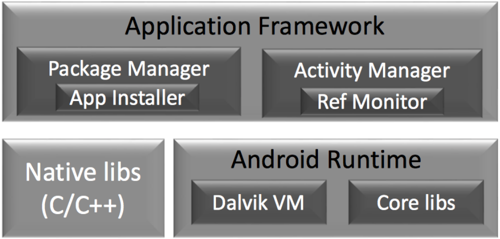
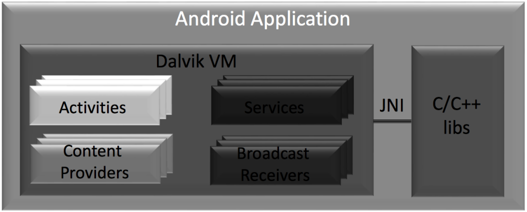
  - Installation of new applications
  - Management of permissions and applications



Application Layer

- Applications are written in Java
- Each app is executed within its own Dalvik VM instance
- Applications also include native code via Java Native Interface (JNI)



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- Android applications consist of the following components:
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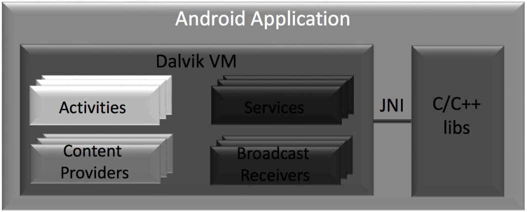
  2. Services (background processes)
  3. Broadcast receivers (application mailboxes)
  4. Content providers (SQL-like databases)



Android Security Framework

- Application Isolation
- Application Access Control
- Code Integrity
- Application Distribution

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- Application Distribution
  - Apps go through a vetting process before they are uploaded to the official app market

Application Isolation via Sandboxing

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- Sandboxing is enforced by Linux
  - Each app is assigned a unique UserID and runs in a separate process (more on that later)
  - Each app has a private data folder

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  - **At filesystem level:**
  - Each app has its private data directory
  - Only the app can access its own data directory

App Sandboxing: Process Level

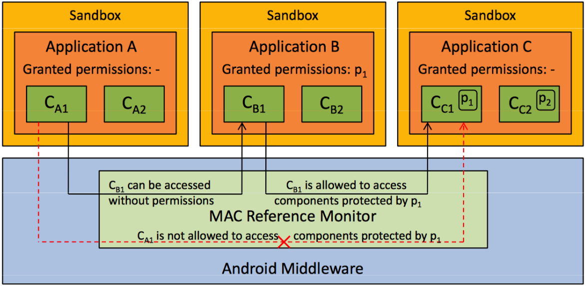
- Android system assigns a unique User ID (UID) to each Android app
- A UID is generated at install-time
- A UID is often called an AppID
- It runs each app as a separate process with its own UID
- Apps run within the sandboxing environment in the kernel

App Sandboxing: Filesystem Level

- Each application is assigned a dedicated data directory
- Only application has permission to read and write to its own directory (in theory!!)
- Sandboxing applies to all applications, including native ones

When can things go wrong?

- Permission escalation attack (see full paper[1])
- An application with less permissions (a non-privileged caller) is not restricted to access components of a more privileged application (a privileged callee)

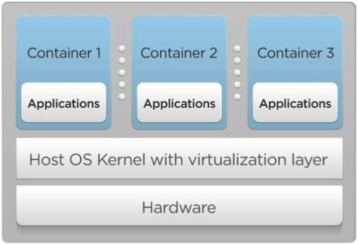


[1] https://www.trust.cased.de/fileadmin/user_upload/Group_TRUST/PubsPDF/DDSW2010_Privilege_Escalation_Attacks_on_Android.pdf

Linux Containers
(Part II of this lecture)

What are Linux Containers (LXC)?

- LXC is an OS-level virtualization method for running multiple isolated Linux systems (containers) on a single control host (LXC host)



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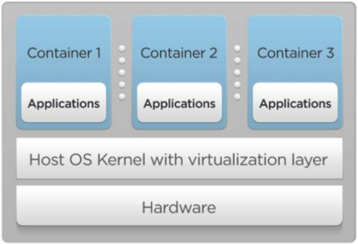
- It does not provide a virtual machine, but rather provides a virtual environment that has its own CPU, memory, block I/O, network, etc. space and the resource control mechanism.



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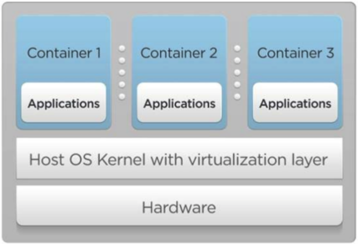
- It does not provide a virtual machine, but rather provides a virtual environment that has its own CPU, memory, block I/O, network, etc. space and the resource control mechanism.
- This is provided by **namespaces** and **cgroups** features in Linux kernel on LXC host. It is similar to a chroot, but offers much more isolation.
- Benefits: fast provisioning, bare-metal like performance, lightweight



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- There are currently 6 namespaces:
  1. mnt (mount points, filesystems)
  2. pid (processes)
  3. net (network stack, NICs, routing)
  4. ipc (System V IPC)
  5. uts (hostname)
  6. user (UIDs, what uid and gid are visible?)

Mount

- Short name: mnt
- Purpose: different processes have different views of the mount points ("next-gen chroots")

```
# propagation between host & namespaces
mount --make-(r)shared  / (2-way sharing)
mount --make-(r)private / (no sharing)
mount --make-(r)slave   / (1-way sharing)
```

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  - Each container (*) can have its own init (pid 1)
  - Multiple namespaces create multiple nested process trees
  - Migrate containers (*) across hosts keeping the same internal pids

Network

- Short name: net
- Purpose: different network devices, IP addresses, routing tables etc. per namespace

IPC

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- Isolating a process by the IPC namespace gives it its own interprocess communication resources, for e.g. System V IPC and POSIX messages
- Objects created in an IPC namespace are visible to all other processes that are members of that namespace, but are not visible to processes in other IPC namespaces
- When an IPC namespace is destroyed (i.e., when the last process that is a member of the namespace terminates), all IPC objects in the namespace are automatically destroyed

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- Purpose: each namespace can have different hostname + domainname
- UTS namespaces provide isolation of two system identifiers: the hostname and the NIS domain name.
- These identifiers are set using `sethostname` and `setdomainname`, and can be retrieved using `uname`, `gethostname`, and `getdomainname`

User

- Purpose: User namespaces isolate security-related identifiers and attributes, in particular, user IDs and group IDs, the root directory, keys, and capabilities
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- A process's user and group IDs can be different inside and outside a user namespace
- In addition, a process can have a normal unprivileged user ID outside a user namespace while at the same time having a user ID of 0 inside the namespace; in other words, the process has full privileges for operations inside the user namespace, but is unprivileged for operations outside the namespace

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- Examples of cgroup modules:
  - cpu: weighted proportional share of CPU for a group (`mm/memcontrol.c`)
  - cpuset: cores that a group can access (`kernel/cpuset.c`)
  - block io: weighted proportional block IO access (`net/core/netprio_cgroup.c`)
  - memory: max memory limit for a group (`security/device_cgroup.c`)

Docker

- An open-source project that automates the deployment of applications inside software containers by providing an additional layer of abstraction and automation of OS-level virtualization on Linux
- Docker uses resource isolation features of the Linux kernel such as cgroups and kernel namespaces to allow independent"containers" to run within a single Linux instance, avoiding the overhead of starting and maintaining virtual machines

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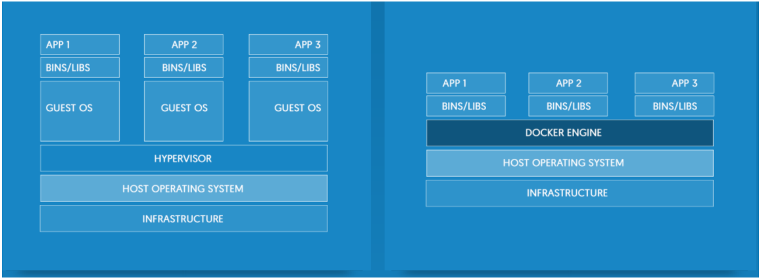
- Docker implements a high-level API to provide lightweight containers that run processes in isolation.
- A Docker container, as opposed to a traditional virtual machine, does not require or include a separate OS (comparison on next slide).
- It relies on the kernel’s functionality and uses resource isolation (CPU, memory, block I/O, network, etc.) and separate namespaces to isolate the application’s view of the operating system.

Traditional virtualization vs Docker



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