Lecture 7

L4Android: A Generic Operating System Framework for Secure Smartphones

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Context

- Ubiquity of smartphones
- Need for secure apps
  - Near Field Communication
  - SIM cards
- Inherent lack of security in smartphone software

Security issues: delayed updates

- Mainline Android development done by Google
- Phone vendors deploy customized Android versions
- "Maintenance nightmare":
  - Provide periodic updates that fix vulnerabilities
  - Or no updates at all because of high costs

Security issues: Linux kernel

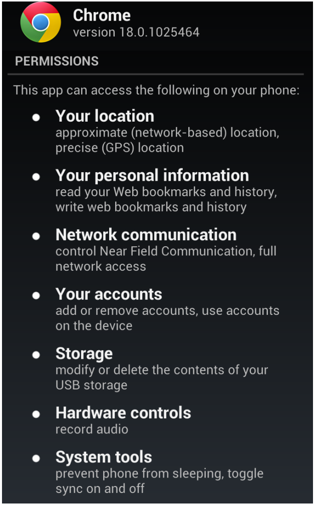
- Monolithic kernels are difficult to certify/verify
- Device drivers run with full privileges
- Kernel components aren't isolated
- Device manufacturers develop custom (often proprietary) drivers

Security issues: rooted phones

- Root privileges allow full access to:
  - All the user data
  - Manufacturer settings
  - The kernel
- "Rooted" phones are more vulnerable
  - Android phones don't allow root access by default
- Root access can be obtained
  - Manually by the user
  - By malicious software (via exploits)

Security issues: Android permission system

- Permissions in Android
  - Based on Mandatory Access Control (MAC)
  - “All or nothing” paradigm
  - Too coarse-grained
    - E.g.: grant access to Internet and Address Book
    - → Software can send user Address Book to any remote location



Chrome
version 18.0.1025464

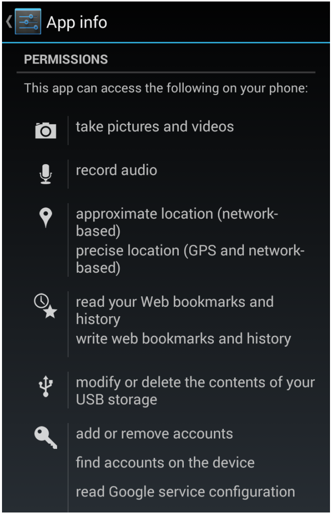
PERMISSIONS

This app can access the following on your phone:

- **Your location**
  approximate (network-based) location, precise (GPS) location
- **Your personal information**
  read your Web bookmarks and history, write web bookmarks and history
- **Network communication**
  control Near Field Communication, full network access
- **Your accounts**
  add or remove accounts, use accounts on the device
- **Storage**
  modify or delete the contents of your USB storage
- **Hardware controls**
  record audio
- **System tools**
  prevent phone from sleeping, toggle sync on and off

Security issues: Android permission system

- Permissions in Android
- Chrome 39



App info

PERMISSIONS

This app can access the following on your phone:

- take pictures and videos
- record audio
- approximate location (network-based)
  precise location (GPS and network-based)
- read your Web bookmarks and history
  write web bookmarks and history
- modify or delete the contents of your USB storage
- add or remove accounts
  find accounts on the device
  read Google service configuration

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A solution

- Isolate OS inside a **virtual machine**
- Run secure apps outside the OS
- Use a **microkernel**-based framework
  - ”Extended hardware”
  - Small Trusted Computing Base (TCB)
  - Drivers as user space services

A solution: L^4Android

- Framework for developing secure smartphone apps
- Components:
  - Microkernel: Fiasco.OC μkernel
  - Services: L4Re runtime environment
  - Paravirtualized kernel: L^4Android
  - User space: Android libraries, apps, . . .

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Fiasco.OC: Overview

- Based on Jochen Liedtke's L4 microkernel
- Implements basic OS abstractions
  - Address Spaces
  - Threads
  - Scheduling
  - Inter-Process Communication (IPC)
  - Interrupt Delivery (via Asynchronous IPC)

Fiasco.OC: Protection Domains

- Protection Domains:
  - Equivalent to Linux namespaces/containers
  - Host tasks on top of the microkernel
  - Provide isolation
    - Among virtual machines
    - Between VMs and the TCB

Fiasco.OC: Capabilities

- Capabilities provide access control to:
  - Kernel objects
    - Address spaces
    - Threads
    - Communication channels
  - Interrupts
- Fine-grained control over resources

Fiasco.OC: Verification

- Microkernel exposes minimal interface
  - Small number of system calls
- Code base is small (∼20,000 lines of code)
- Kernel is formally verifiable

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L4 Runtime Environment

- Software layer on top of the microkernel
- Simplifies development in microkernel user space
- Consists of:
  - Basic functionality: allocators, data structures, etc.
  - User libraries: C, C++, pthread etc.
  - Servers providing access to I/O devices

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L^4Android

- L^4Linux: Linux kernel modified to run paravirtualized
  - On top of Fiasco.OC + L4Re
  - With fine-grained access to devices via I/O servers
    - An L^4Linux instance can run without any access to peripherals
    - Or it can be used as a driver provider
- L^4Android Kernel
  - Based on L^4Linux
  - Contains Android patches (wakelocks, binder etc.)
  - Therefore it is able to run the Android user stack

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Evaluation: Overview

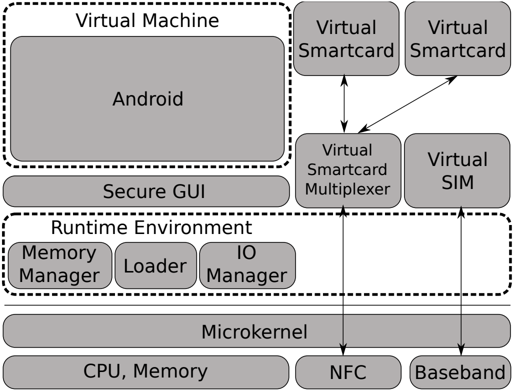
- Four proposed scenarios
  - Software Smartcard
  - Mobile Rootkit Detection
  - Hardware Abstraction Layer
  - Unified Corporate and Private Phone
- Last scenario implemented as a demo
- Runnable on ARM and x86 architectures
  - Freescale iMX.51 (Cortex-A8)
  - Aava Mobile developer phone (Moorestown)

Evaluation: Software Smartcard

- Smartcard:
  - Processor and memory integrated on a plastic card
  - Cryptographic coprocessor smarcards for:
    - Mobile phones (SIM, NFC)
    - Credit cards
    - USB tokens
- "Software smartcard":
  - Performing the same computations on a general-purpose processor
  - Cheaper and more flexible than a physical smartcard
  - Usually unfeasible due to high security demands

Evaluation: Software Smartcard

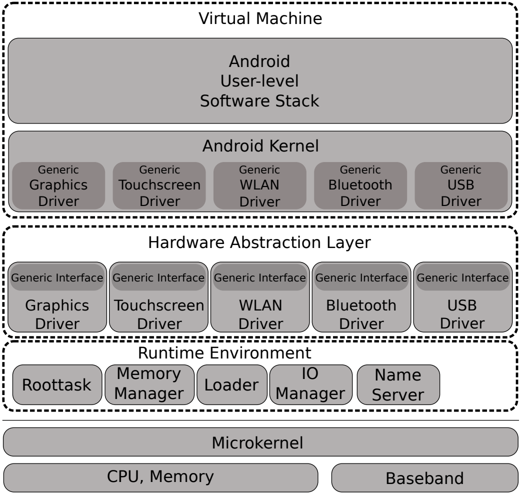
Possible Smartcard setup:



Evaluation: Software Smartcard

- Fiasco.OC provides a secure computing base
  - The smartcard operations run on top of the microkernel
  - L4Re and microkernel syscalls offer a trusted interface
  - Isolation from the L^4Android domain is achieved
- Timing attacks are deflected by secure scheduling
- Vendors can implement various virtual smartcard configurations

Evaluation: Hardware Abstraction Layer



Evaluation: Hardware Abstraction Layer

- HAL: proposed L4-based development model for Linux drivers
- Move driver logic to a layer between L4Re and the guest kernel
- Develop generic driver stub in the guest OS
  - Easier to port drivers to new kernel versions
    - By updating the Linux-HAL interface
  - Driver faults are isolated from the rest of the system

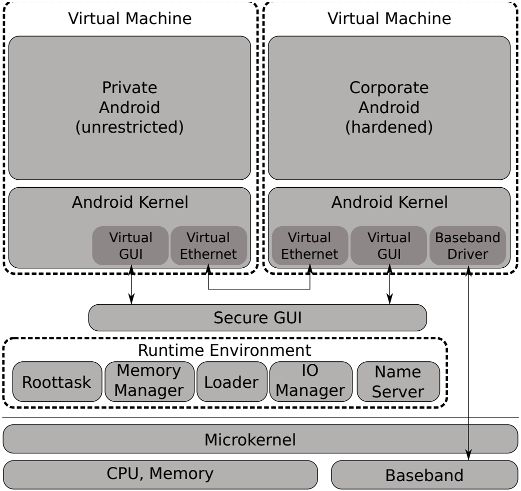
Evaluation: Dual Android Phone

- Corporate smartphones contain sensitive information
- Employees routinely carry two smartphones:
  - A company-provided smartphone configured according to the company's security policy
  - A personal, unrestricted phone
- Alternative: Bring Your Own Device (BYOD)

Evaluation: Dual Android Phone

- Solution: a single phone running two Android virtual machines
  - Private Android: can even be rooted
  - Secure Android: implements corporate security policies
- User can easily switch between instances at runtime

Evaluation: Dual Android Phone



Evaluation: Dual Android Phone

- Access to devices is multiplexed between instances
  - Stub drivers in the guest kernels
  - Driver servers in the L4 Runtime Environment
- Virtualization requirements:
  - Secure GUI server
  - Virtual Ethernet interfaces
  - Mobile telephony, hardware graphics/sound acceleration
    - Drivers are binaries in the Linux kernel or Android user space
    - Difficult to virtualize

Evaluation: Dual Android Phone

- Demo: `http://l4android.org`

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- smartphones
- operating system security
- Mandatory Access Control
- protection domain
- capability
- Trusted Computing Base
- paravirtualization
- microkernel
- L4
- I/O server

Resources

- http://l4android.org
- http://l4linux.org
- http://os.inf.tu-dresden.de/L4/
- http://users.sec.t-labs.tu-berlin.de/~steffen/papers/spsm03-lange.pdf
- Jochen Lietdke: On μ-Kernel Construction

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