Android and Anonymity

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Goals for Today

- Lab 3 discussion
- Android
- Anonymity

- HW 3 now out (due Friday)
- Lab 3 out just now
Mobile Device Security (Android)

Android

- Based on Linux
- Layers:
  - Android Application Runtime (generally written in Java, run in the Dalvik virtual machine; sometimes native applications or native libraries)
  - Android OS
  - Device Hardware
- Applications
  - Pre-installed
  - User-installed
    - Via app stores
    - Via over the air (OTA) updates.
Android Software Stack

Application Sandboxes

- Based on Linux: Has clear notion of users and permissions
- Each application
  - Assigns unique user ID (UID)
  - Runs as that user in a separate process
- Different than traditional operating systems where multiple applications run with the same user permissions
Application Sandboxes (II)

- Desktop browser sandbox: language specific
- Android sandbox: baked into the OS, via the kernel
  - No restriction on how applications are written
  - Native code
  - Java code
- Conventional systems: memory corruption errors lead to complete compromise
- Android: memory corruption errors only lead to arbitrary code execution in the context of the particular compromised application
- (Can still escape sandbox -- but must compromise Linux kernel to do so)
File permissions

◆ Files written by one application cannot be read by other applications
  • Not true for files stored on the SD card

◆ It is possible to do full filesystem encryption
  • Key = Password combined with salt, hashed with SHA1 using PBKDF2.
Memory Management

- Address Space Layout Randomization to randomize addresses on stack
- Hardware-based No eXecute (NX) to prevent code execution on stack/heap
- Stack guard derivative
- Some defenses against double free bugs (based on OpenBSD’s dmalloc() function)
- ...

(See http://source.android.com/tech/security/index.html)
Applications

- **Activity**: Code for single, user-focused task
- **Services**: Code that runs in the background
- **Broadcast Receiver**: Receive Intents (messages from other applications)

**AndroidManifest.xml**
- Overall information about application (activities, services, ...)
- Also specifies which permissions are required by applications
Permissions / Manifests

- **Services that cost you money**
  - directly call phone numbers

- **Your location**
  - coarse (network-based) location, fine (GPS) location

- **Network communication**
  - full Internet access

- **Your accounts**
  - Google Maps, manage the accounts list, use the authentication credentials of an account

- **Storage**
  - modify/delete USB storage contents

This application can access the following on your phone:

- **Your personal information**
  - read contact data, write contact data

- **Network communication**
  - full Internet access

- **Your accounts**
  - Google mail, manage the accounts list, use the authentication credentials of an account

- **Storage**
  - modify/delete USB storage contents

- **System tools**
  - prevent phone from sleeping, write subscribed feeds, write sync settings

Permissions

- Example permissions
  - Camera
  - Location (GPS)
  - Bluetooth
  - SMS functions
  - Network capabilities

- Cannot grant / deny individual permissions
- Once accepted, users not notified of permissions again
- Security exception thrown if attempt to access resource not declared in manifest
Obtaining User Consent for Permissions

 General options:
  • At install time (manifests)
  • At time of use (prompts)

 Why manifests
  • Users are evaluating the application, the developers, etc, to see if they want the app
  • Prompts slow down user; hinder user experience
  • Users may just say “OK” to all dialogs without reading them

 Why prompts
  • At time of resource access
  • Opportunity for user to be more in control of actual resource use (app with GPS permissions should only actually access the GPS when the user wishes -- but can’t tell with manifest model)

 (Alternative: User-driven access control, Roesner et al (2012))
Application Signing

- Apps are signed
  - Often with self-signed certificates
- Signed application certificate defines which user ID is associated with which applications
  - Different apps run under different UIDs
- Shared UID feature
  - Shared Application Sandbox possible, where two or more apps signed with same developer key can declare a shared UID in their manifest
Shared UIDs

- App 1: Requests GPS / camera access
- App 2: Requests Network capabilities

Generally:
- First app can’t exfiltrate information
- Second app can’t exfiltrate anything interesting

With Shared UIDs (signed with same private key)
- Permissions are a superset of permissions for each app
- App 1 can now exfiltrate; App 2 can now access GPS / camera
Questions

٠ Q1: How might malware authors get malware onto phones?

٠ Q2: What are some goals that mobile device malware authors might have?

٠ Q3: What technical things might malware authors do?
Malware

◆ Legitimacy of apps
  - Self-signing means that signers can claim to be whoever they wish

◆ Installation vector
  - (Seems to be) “drive-by-downloads” and exploits for infection, and more social engineering (tricking users to install)
  - E.g., “sideloading” sites: distribute pirated versions of popular applications, which can be decompiled and modified to include malicious behavior
  - Utilities, games, adult-oriented apps [Lookout Mobile Threat Report, August 2011]
Malware techniques

- Add background Service
- Modify existing application source code
- Component library replacement

- To avoid basic signature detection:
  - Dynamically download new Dalvik bytecode
  - Use DexClassLoader API to run the downloaded code

- Use exploit to obtain root access
- Many other techniques
Malware Functions

- Make a profit
  - Premium number dialers
  - Aggressive adware
  - Data collection (obtain personally-identifiable information that can be sold)
  - Banking trojans (e.g., FakeToken.A to bypass two-factor authentication)
- Bot clients (phone have limited resources, so more useful as a mechanisms to support other goals, e.g., later targeted data collection)
  - Internet C&C
  - SMS C&C
- Privileged Operations Trojans (obtain root)
- Disruptive Trojans (denial of service, destroy data)
  - Not stealthy; no profit
Privacy on Public Networks

- Internet is designed as a public network
  - Machines on your LAN may see your traffic, network routers see all traffic that passes through them

- Routing information is public
  - IP packet headers identify source and destination
  - Even a passive observer can easily figure out who is talking to whom

- Encryption does not hide identities
  - Encryption hides payload, but not routing information
  - Even IP-level encryption (tunnel-mode IPSec/ESP) reveals IP addresses of IPSec gateways
Questions

Q1: Why might people want anonymity on the Internet?

Q2: Why might people not want anonymity on the Internet?
Questions

Q1: How might one go about trying to obtain anonymity? What technical approaches might we use?

Q2: How might one go about trying to violate someone else’s anonymity?
Applications of Anonymity

- **Privacy**
  - Hide online transactions, Web browsing, etc. from intrusive governments, marketers and archivists

- **Untraceable electronic mail**
  - Corporate whistle-blowers
  - Political dissidents
  - Socially sensitive communications (online AA meeting)
  - Confidential business negotiations

- **Law enforcement and intelligence**
  - Sting operations and honeypots
  - Secret communications on a public network
Applications of Anonymity (II)

- Digital cash
  - Electronic currency with properties of paper money (online purchases unlinkable to buyer’s identity)
- Anonymous electronic voting
- Censorship-resistant publishing
What is Anonymity?

- Anonymity is the state of being not identifiable within a set of subjects
  - You cannot be anonymous by yourself!
    - Big difference between anonymity and confidentiality
  - Hide your activities among others’ similar activities

- Unlinkability of action and identity
  - For example, sender and the email he or she sends are no more related after observing communication than they were before

- Unobservability (hard to achieve)
Chaum’s Mix

- Early proposal for anonymous email

- Public key crypto + trusted re-mailer (Mix)
  - Untrusted communication medium
  - Public keys used as persistent pseudonyms

- Modern anonymity systems use Mix as the basic building block
Basic Mix Design

Adversary knows all senders and all receivers, but cannot link a sent message with a received message.
Anonymous Return Addresses

M includes $\{K_1, A\}_{pk(mix)}$, $K_2$ where $K_2$ is a fresh public key

$\{r_1, \{r_0, M\}_{pk(B)}, B\}_{pk(mix)}$
Mix Cascade

- Messages are sent through a sequence of mixes
  - Can also form an arbitrary network of mixes ("mixnet")
- Some of the mixes may be controlled by attacker, but even a single good mix guarantees anonymity
- Pad and buffer traffic to foil correlation attacks
Disadvantages of Basic Mixnets

- Public-key encryption and decryption at each mix are computationally expensive
- Basic mixnets have high latency
  - Ok for email, not Ok for anonymous Web browsing
- Challenge: low-latency anonymity network
  - Use public-key cryptography to establish a “circuit” with pairwise symmetric keys between hops on the circuit
  - Then use symmetric decryption and re-encryption to move data messages along the established circuits
  - Each node behaves like a mix; anonymity is preserved even if some nodes are compromised
Another Idea: Randomized Routing

- Hide message source by routing it randomly
  - Popular technique: Crowds, Freenet, Onion routing
- Routers don’t know for sure if the apparent source of a message is the true sender or another router
Onion Routing

Sender chooses a random sequence of routers

- Some routers are honest, some controlled by attacker
- Sender controls the length of the path

[Reed, Syverson, Goldschlag '97]
Routing info for each link encrypted with router’s public key
Each router learns only the identity of the next router
Tor

- Second-generation onion routing network
  - http://tor.eff.org
  - Developed by Roger Dingledine, Nick Mathewson and Paul Syverson
  - Specifically designed for low-latency anonymous Internet communications

- Running since October 2003
- “Easy-to-use” client proxy
  - Freely available, can use it for anonymous browsing
Tor Circuit Setup (1)

- Client proxy establish a symmetric session key and circuit with Onion Router #1
Client proxy extends the circuit by establishing a symmetric session key with Onion Router #2
- Tunnel through Onion Router #1 (don’t need)
Client proxy extends the circuit by establishing a symmetric session key with Onion Router #3

- Tunnel through Onion Routers #1 and #2
Using a Tor Circuit

- Client applications connect and communicate over the established Tor circuit.
Tor Management Issues

- Many applications can share one circuit
  - Multiple TCP streams over one anonymous connection
- Tor router doesn’t need root privileges
  - Encourages people to set up their own routers
  - More participants = better anonymity for everyone
- Directory servers
  - Maintain lists of active onion routers, their locations, current public keys, etc.
  - Control how new routers join the network
    - “Sybil attack”: attacker creates a large number of routers
  - Directory servers’ keys ship with Tor code
Attacks on Anonymity

- **Passive traffic analysis**
  - Infer from network traffic who is talking to whom
  - To hide your traffic, must carry other people’s traffic!

- **Active traffic analysis**
  - Inject packets or put a timing signature on packet flow

- **Compromise of network nodes**
  - Attacker may compromise some routers
  - It is not obvious which nodes have been compromised
    - Attacker may be passively logging traffic
  - Better not to trust any individual router
    - Assume that some fraction of routers is good, don’t know which
Deployed Anonymity Systems

- Tor (http://tor.eff.org)
  - Overlay circuit-based anonymity network
  - Best for low-latency applications such as anonymous Web browsing

- Mixminion (http://www.mixminion.net)
  - Network of mixes
  - Best for high-latency applications such as anonymous email
Some caution

- Tor isn’t completely effective by itself
  - Challenges if you have cookies turned on in your browser, are using JavaScript, etc.
  - Exit nodes can see everything!