Execute This!

Analyzing unsafe and malicious dynamic code loading in Android applications

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Code loading in Android

- Apps can load code dynamically at runtime
  - E.g., download code from the Internet
  - Various ways (DexClassLoader, CreatePackageContext, etc.)
- Good news: Permissions enforced on external code
- Bad news: No additional checks

```java
// Create cache directory if necessary
String dexDir = "LoaderOptimized";
File optimized = context.getDir(dexDir, 0);
try {
    optimized.createNewFile();
} catch (IOException e) {
    logView.append("Error: execution failed\n");
    Log.e(TAG, "Dex dir creation failed", e);
}

// Create the class loader
DexClassLoader loader = new DexClassLoader(
        mExecutableFile.getAbsolutePath(),
        optimized.getAbsolutePath(),
        null, context.getClassLoader());
try {
    // Find class and method
    Class<?> remote = loader.loadClass("MyRemoteClass");
    Method run = remote.getMethod("doSomething",
            Context.class);

    // Instantiate the class
    Object code = remote.newInstance();

    // Invoke the method on the instance
    run.invoke(code, context);
} catch (ClassNotFoundException e) {
    logView.append("Error: execution failed\n");
    Log.e(TAG, "Unable to load the class", e);
} catch (InstantiationException e) {
    logView.append("Error: execution failed\n");
    Log.e(TAG, "Unable to instantiate the class", e);
} catch (IllegalAccessException e) {
    logView.append("Error: execution failed\n");
    Log.e(TAG, "Access to the class forbidden", e);
} catch (NoSuchMethodException e) {
```

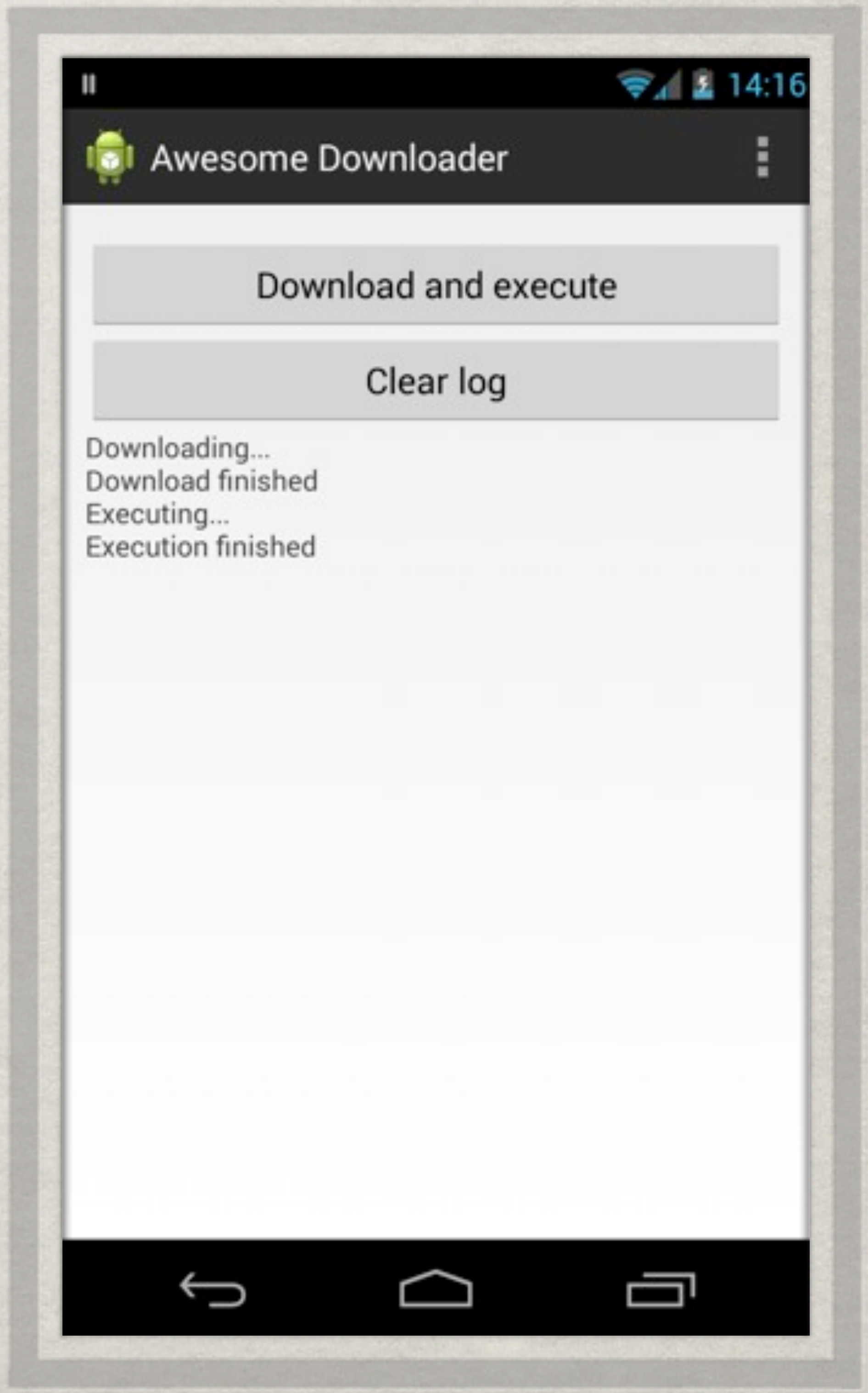
Implications

1. Malicious apps
   - Download arbitrary additional code to circumvent offline analysis
   - Reminder: Checks run at the store
   - Conceptual flaw in the stores' vetting process
2. Benign apps
   - ...use code-loading techniques as well (details later)
   - Must implement custom security mechanisms
   - Dangerous vulnerabilities

Proof-of-concept exploits

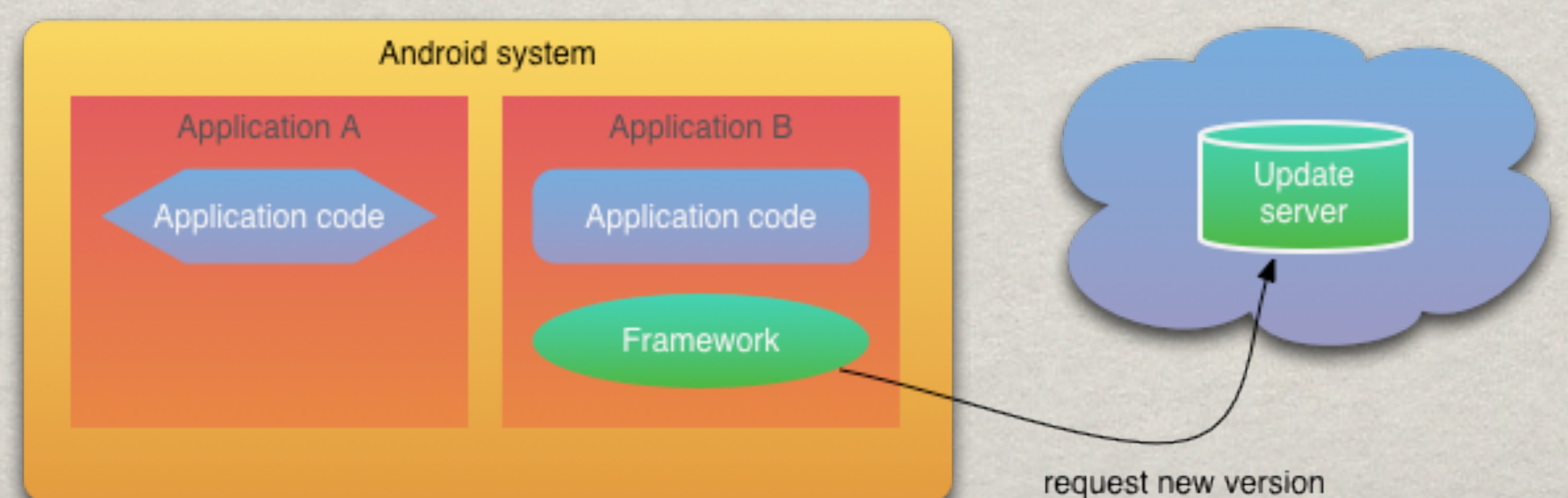
Bypassing Google Bouncer

- Simple downloader app
  - Connects to our server
  - Downloads a payload
  - Executes the payload
- Submitted to Google Play in April 2013, accepted within 90 minutes
- Allows to run arbitrary code on users‘ devices
  - Even targeted payloads possible
  - Remark: we refrained from using it on other people‘s devices...



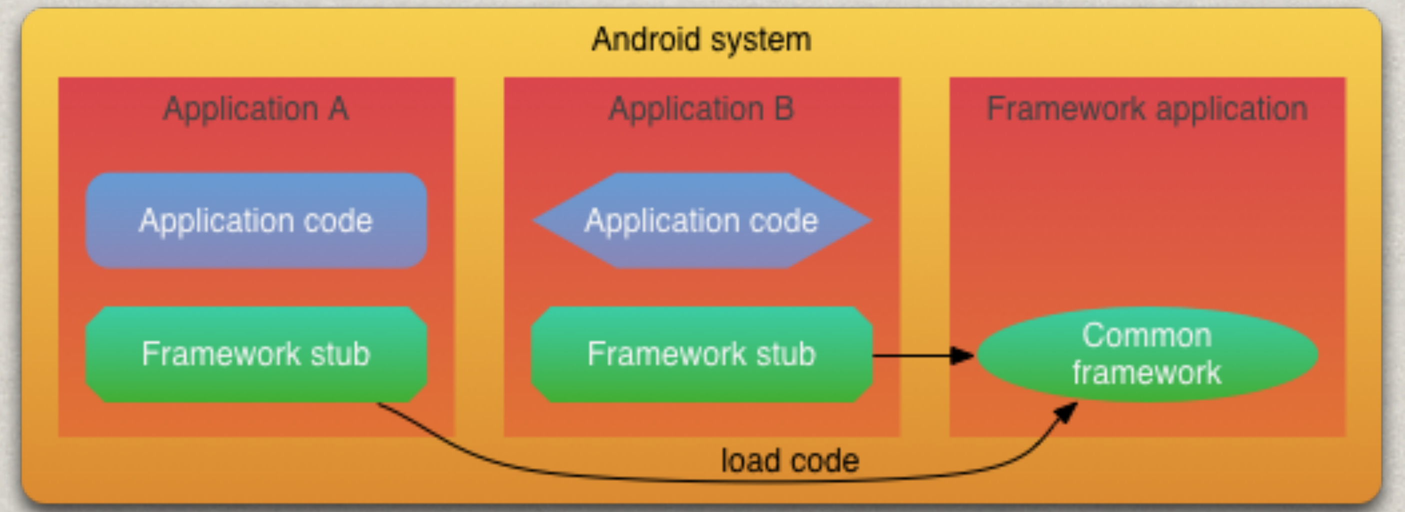
Gunzombie exploit

- Benign app, among top 50 in November 2012, millions of users
- Includes advertisement framework AppLovin
  - Framework tries to download updates…
  - …on every app launch…
  - …via HTTP!
  - No real integrity/authenticity checks
- App is vulnerable to code injection (by hijacking the HTTP connection)



Attacking a shared framework

- Popular framework for app development (not named here)
  - Installed as a stand-alone app
  - Loaded via app identifier
  - App identifiers are not globally unique!
- We inject code by installing an app with the same identifier first



Large-scale study

How prevalent is the problem?

- Goal: assess percentage of apps vulnerable to code injection due to dynamic loading

- Test set: 1,632 apps from Google Play, each with 1,000,000+ installations

- Secondary test sets: top 50 free apps as of November 2012 and August 2013, respectively

- Technique: static analysis, heuristics to detect code-loading techniques (more later)

Loading techniques

- Various ways to load external code
  - Load JARs, APKs, DEX files (compiled Java code)
  - Linux shared objects (native code)
  - Load code from other apps
  - Install APKs (requires user approval)
- Various pitfalls...
  - Insecure downloads using HTTP
  - Download to world-writable storage locations
  - Assumption of package name uniqueness

Detection approach

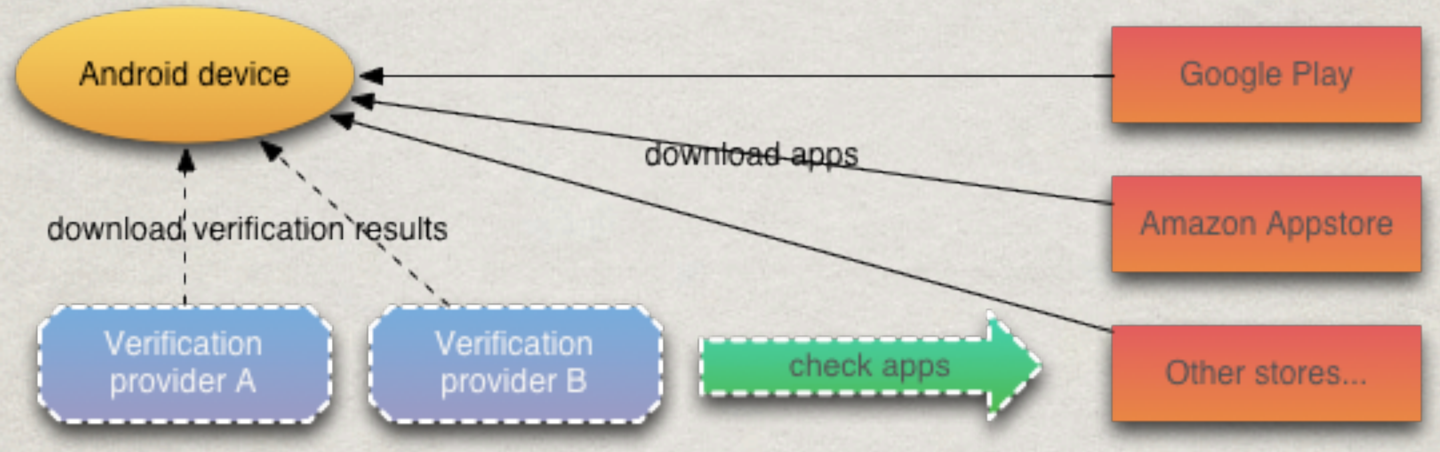
- Goal: find code loading and detect vulnerable implementations
- Construct CFG with the help of Androguard
- Transformation into SSA
- Context-insensitive call graph construction based on class hierarchy analysis
- Heuristics based on backward slicing
  - Determine value of sensitive API parameters
    - Example *createPackageContext(name, flags)*: check that flags cause runtime environment to load code
  - Classification step based on heuristics
  - Heuristics for all previously mentioned loading techniques

Analysis results

- 9.25% out of 1,632 apps vulnerable
- Similar situation among top apps
- Alarming tendency: more vulnerable apps in top 50 in August 2013 than November 2012
- Different motivations for use of code loading
  - Updates (e.g., AppLovin)
  - Shared components
  - A/B and beta testing
  - Loading add-ons

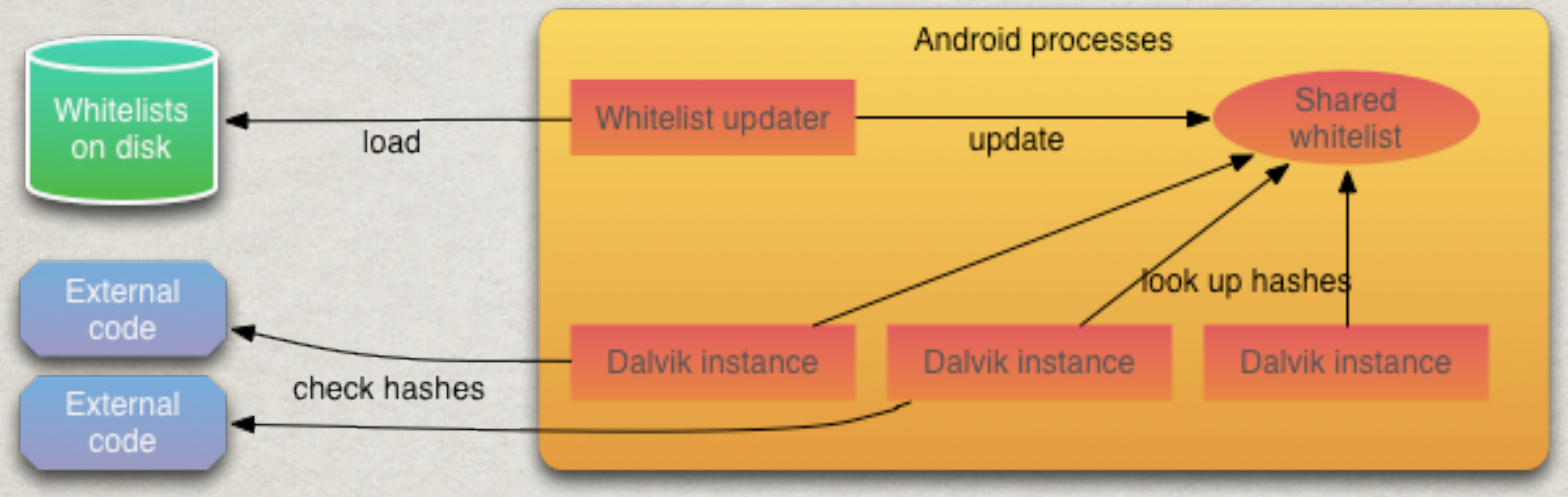
Our Protection Mechanism

Whitelisting scheme



- Trusted entities (e.g. app stores) publish whitelists
  - Comparable to code signatures
  - Users can choose from different whitelist providers
- Code is checked against whitelist before execution
- Prevents all exploits mentioned before

Implementation



- Based on standard Android 4.3
- Modification of DVM
  - Reminder: DVM executes Java code for apps
  - Apps have to ask DVM to load external code
  - DVM processes keep shared whitelist in memory
  - Negligible performance penalty
- Problem: native code (more later)

Limitations and Future Work

Native code

- Cannot control loading in native code
- Prohibiting native code entirely is not an option
- Idea: adapt Google Native Client
  - Sandbox for running native code in browsers
  - Available for ARM architecture
  - Restrict native code, so that malicious external native code is not a problem
  - Subject to ongoing research...

Practicality

- Modification of the Android system
  - Requires update or reinstallation
  - Realistically only deployable to new devices
  - For ideal distribution Google has to approve
- Verification providers
  - Stores already check every single app
  - Adding checks of external code is feasible

Conclusion

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- Large-scale study on external code-loading in benign and malicious Android apps
- 9.25% of popular benign apps are vulnerable, millions of users at risk
- Malicious apps can evade detection
- Proposed a flexible protection scheme

Thank You!
Questions?