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Static & Dynamic Analysis

Mobile Security 2021

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Outline

- Why app analysis?
- Approaches / Techniques
  - Reverse Engineering
  - Static & Dynamic Program Inspection
- Tools

Introduction

Problem

- Software that is cheap, correct, secure, efficient, … is a myth!
- Users have to trust (unknown) developers
- Source code usually not published publicly
  - How many % of app users could verify it anyway?

What now?

- Minimize number of security threats
  - Developers will always make mistakes
  - Need for automated security checks
- Software reverse-engineering

CHALLENGE 1: Broader mobile attack surface

THE DEVICE

BROWSER
- Phishing
- Framing
- Clickjacking
- Man-in-the-Middle
- Buffer overflow
- Data caching

PHONE/SMS
- Baseband attacks
- SMS phishing

SYSTEM
- No/Weak passcode
- Android rooting/iOS jailbreak
- OS data caching
- Passwords & data accessible
- Carrier-loaded software
- No/Weak encryption
- User-initiated code
- Confused deputy attack
- TEE/Secure Enclave Processor
- Side channel leak
- Multimedia/file format parsers
- Kernel driver vulnerabilities
- Resource DoS
- GPS spoofing
- Device lockout

APPS
- Sensitive data storage
- No/Weak encryption
- Improper SSL validation
- Configuration manipulation
- Dynamic runtime injection
- Unintended permissions
- Escalated privileges
- UI overlay/pin stealing
- Third-party code
- Intent hijacking
- Zip directory traversal
- Clipboard data
- URL schemes
- GPS spoofing
- Weak/No Local authentication
- Integrity/tampering/repacking
- Side channel attacks
- App signing key unprotected
- App transport security
- XML serialization
- JSON-RPC
- SQLite database

MALWARE

THE NETWORK
- Wi-Fi (no/weak encryption)
- Rogue access point
- Packet sniffing
- Man-in-the-middle
- Session hijacking
- DNS poisoning
- SSL Strip
- Fake SSL certificate
- Baseband
- Wifi (chip/firmware attack)
- BGP hijacking
- IMSI-catcher
- LTE
- HTTP Proxies
- VPNs

CLOUD / DATA CENTER

WEB SERVER
- Platform vulnerabilities
- Server misconfiguration
- Cross-site scripting
- Cross-site request forgery
- Weak input validation
- Cross origin resource sharing
- Brute force attacks
- Side channel attacks
- Hypervisor attack
- VPN

DATABASE
- SQL injection
- Privilege escalation
- Data dumping
- OS command execution

Introduction

Technical objectives

- Fight complexity
  - More code = more bugs = more attack vectors
- Secure platform
  - Smaller attack surface for apps
  - Tighter boundaries for data misuse
- Find out what apps are doing
  - Reverse engineering
  - How do know what they are doing?
  - What is malware?

Reverse Engineering

> discovering the technological principles of a device, object or system through analysis of its structure, function and operation

Source: https://goo.gl/UZqNm

Why?

- Curiosity :-)
- Protocol interoperability
  - Windows file share support in Linux (Samba)
- API compatibility
  - Windows emulation on Linux (Wine)
- Unlocking hardware
  - Jailbreaking iPhone, PS4

State of Mobile Application Security

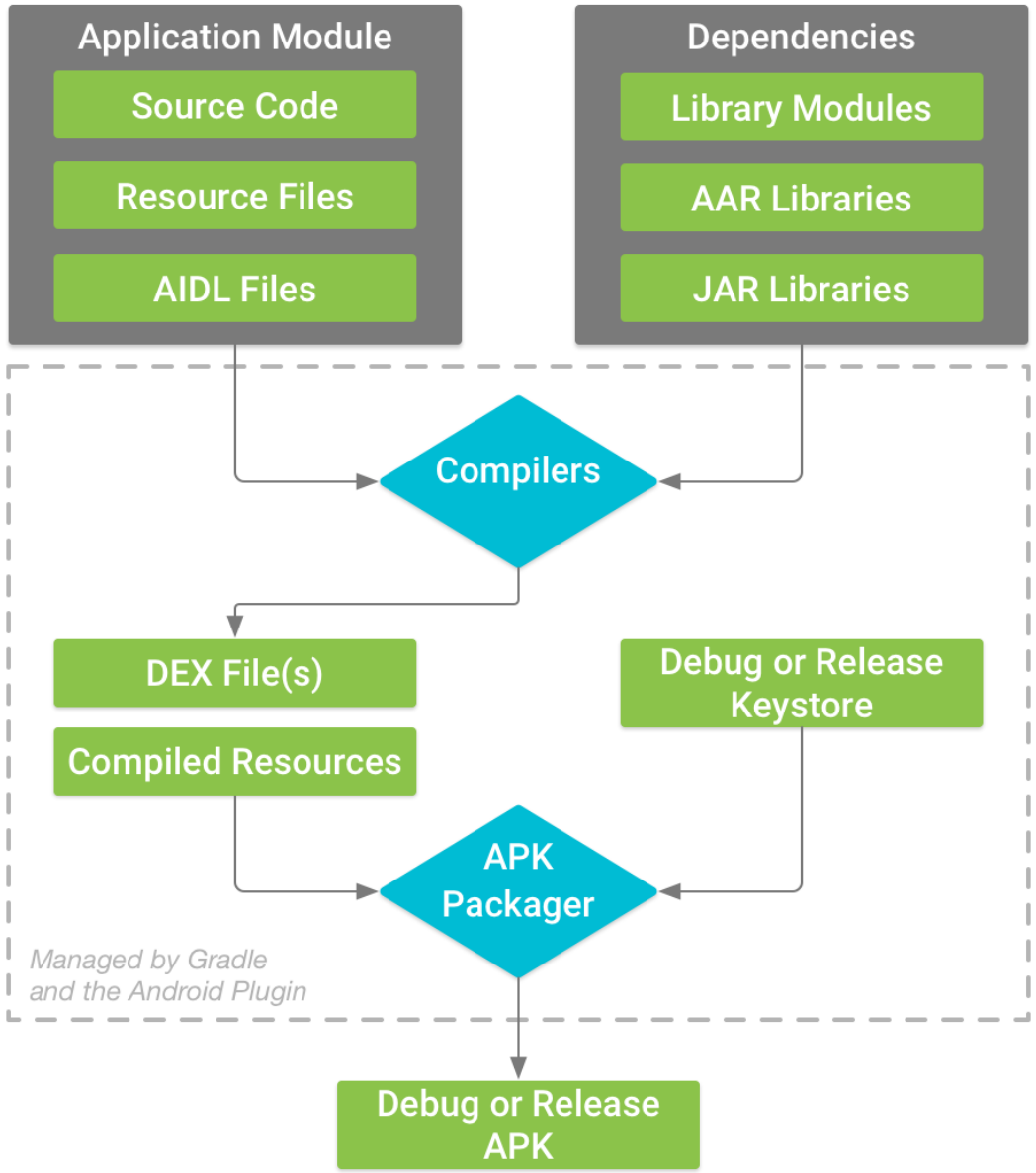
Different Types

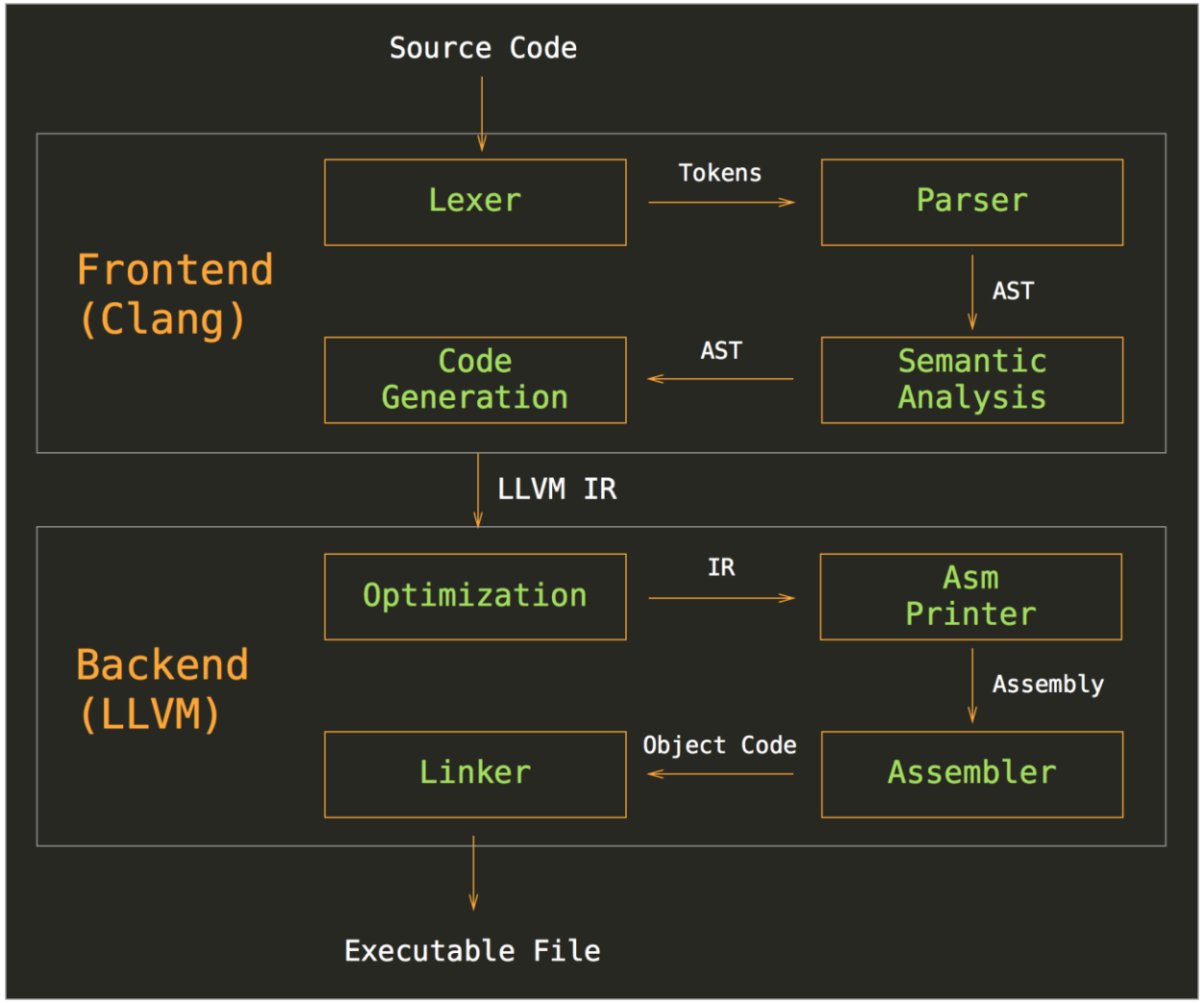
- Static Analysis
  - Analyze code without running
  - Inspecting disassembled or decompiled code

- Dynamic Analysis
  - Analyze app behaviour while running
    - Network traffic, file system access, user input, sensor usage, …
  - Mostly done in emulators

- Hybrid Analysis
  - Combines both types and often multiple tools

Build Processes





Static Analysis

Control Flow Graph

What?

- All possible execution paths in a program
- Directed graph consisting of
  - Nodes = Basic Blocks
  - Edges = Possible flow between nodes

Steps to obtain CFG

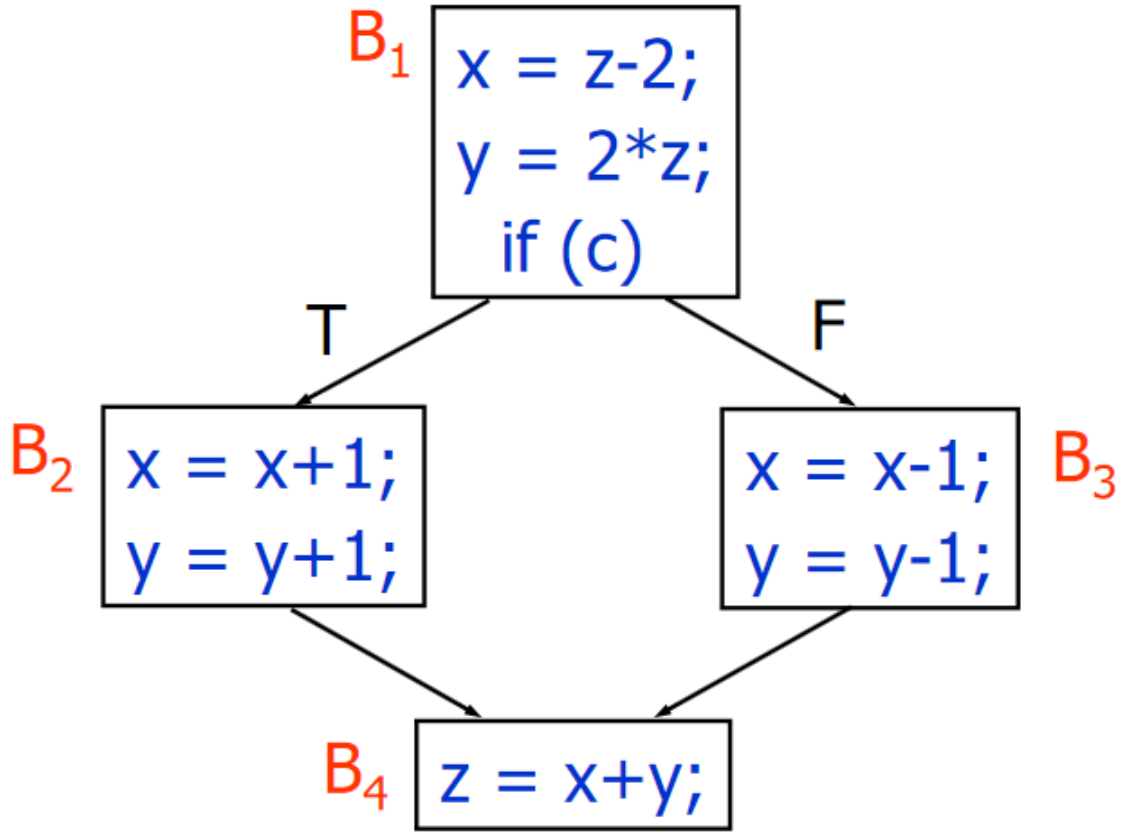
1. Identify all basic blocks
   - Instructions that cannot halt oder branch out
2. Add all edges
   - Hard with indirect calls / self-modifying code

Control Flow Graph

Program

```
x = z-2 ;
y = 2*z;
if (c)  {
    x = x+1;
    y = y+1;
}
else {
    x = x-1;
    y = y-1;
}
z = x+y;
```

Control Flow Graph



Source: https://goo.gl/PWPZJo

Data Flow Graph

What?

- Get all variable changes at some execution point
- Shows show data changes through a Basic Block
  - What input/output is sent to/from a function?

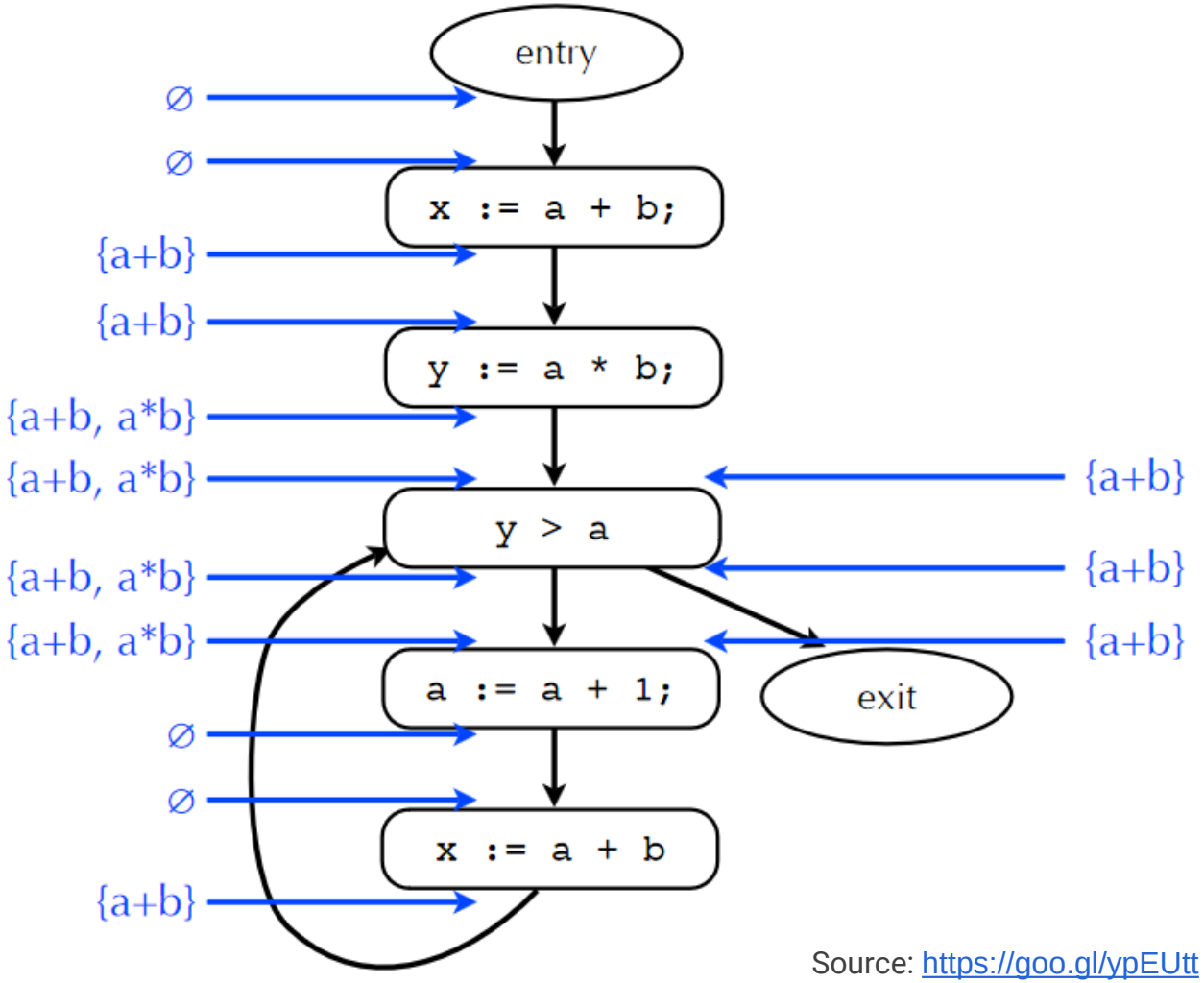
Two types

- Forward Analysis
  - „Find all statements that are **influenced** by some starting point (slicing criterion)“

- Backward Analysis
  - „Find all statements that are **influencing** some target (slicing criterion)“

Forward Analysis

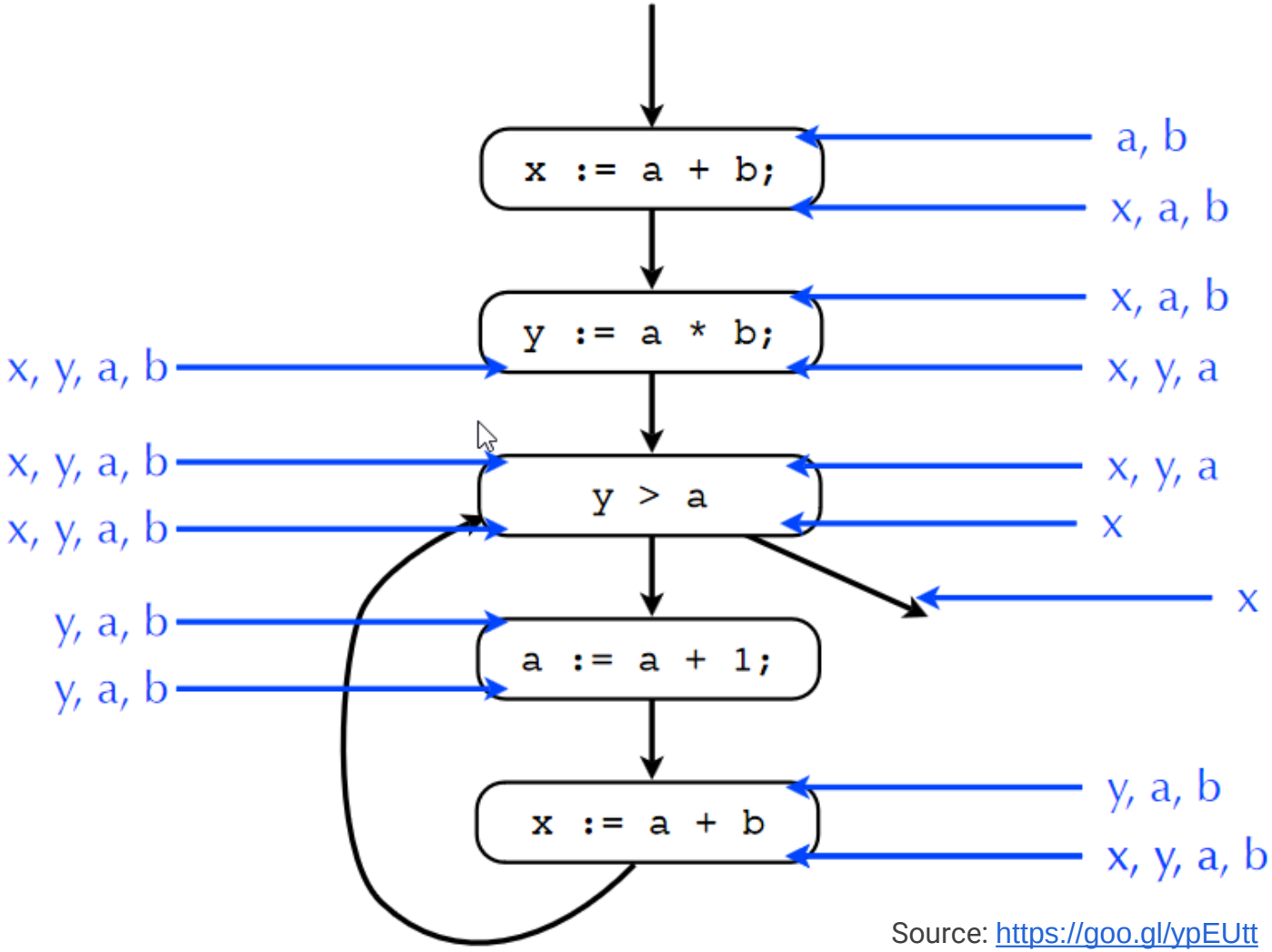
Computing available expressions



Source: https://goo.gl/ypEUtt

Backward Analysis

Computing live variables



Source: https://goo.gl/ypEUtt

Source & Sink Analysis

What?

- **Source** = User's location, address book, camera
- **Sink** = Internet, SMS, Bluetooth, …

→ Check if there is potential data flow between source & sink

On Android / iOS

- Sensitive sources reachable via API methods, e.g. cell location
- Hundreds of possible sources and sinks

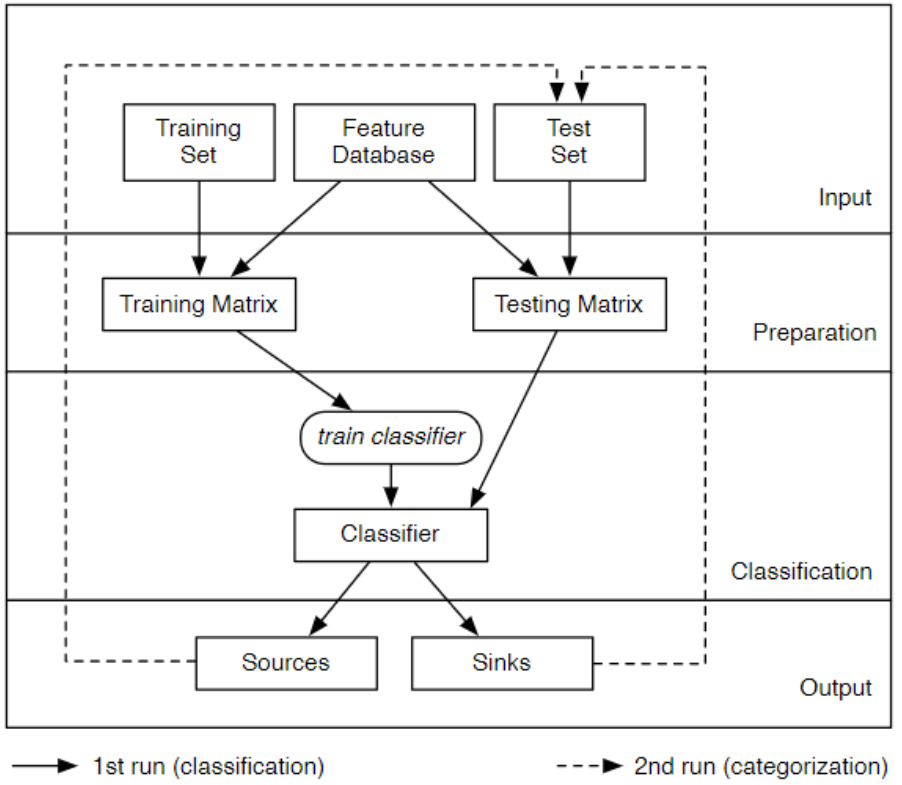
```
1  void onCreate() {
2  TelephonyManager tm; GsmCellLocation loc;
3  // Get the location
4  tm = (TelephonyManager) getContext().
5      getSystemService
           (Context.TELEPHONY_SERVICE);
6  loc = (GsmCellLocation)
       tm.getCellLocation();
7
8  //source: cell-ID
9  int cellID = loc.getCid();
10 //source: location area code
11 int lac = location.getLac();
12 boolean berlin = (lac == 20228 && cellID
       == 62253);
13
14 String taint = "Berlin: " + berlin + " ("
       + cellID + " | " + lac + ")";
15 String f = this.getFilesDir() +
       "/mytaintedFile.txt";
16 //sink
17 FileUtils.stringToFile(f, taint);
18 //make file readable to everyone
19 Runtime.getRuntime().exec("chmod 666 "+f);
20 }
```

Source: https://goo.gl/6o2VU2

Android - SUSI

- Supervised Machine Learning
  - Train classifier with small set of manually defined APIs as sources
  - Apply on whole Android source code code to find other sources and sinks

- Outputs lists of possible sources and sinks
  - Does not find leaks by itself
  - Can be used as basis for taint tracking



Source: https://goo.gl/6o2VU2

Android – Soot

What?

- Started as Java optimization framework
  - Now used to analyse Java / Android, optimize, visualize

Features

- Call-graph reconstruction
  - Calling relationships between subroutines
- Points-to analysis
  - Which pointers or heap references can point to which variables / storage locations
- Def-use chains
  - Forward Analysis
- Data flow analysis

Dynamic Analysis

Workflow

What?

- Analysis of properties of running program
- Only parts of programs that are actually executed
  - No code snippets
  - Usually run in sandbox / emulator
- Black-box testing

Purpose

- Run-time error detection
- Test program behaviour with user interactions
- Check for malicious / strange actions

Workflow

On Android / iOS

Network traffic, IPC, Permission usage, Accessed resources, Sensor data

Definable

- Environment
  - Virtual Machine / Emulator: Easier to monitor and reset
  - Physical device: Real sensor data, WiFi networks, etc.
- Logging
  - Create protocol while running
- Interaction
  - Simulate user input
- Execution time

Android - Droidbox

- Dynamic Taint Analysis and Method hooking
- Needs modified Android version
  - Patches Dalvik and core system

Analyzes

- Incoming / outgoing traffic
- File read, write operations
- Listing broadcast receivers
- Sent SMS and phone calls
- Performed cryptographic operations

```
23    [Read operations]
24    ------------------
25       [22.9400451183]     Path: /data/data/droidbox.tests/files/myfilename.txt^A
26              Data: Write a line
27       [24.2107310295]     Path: /data/data/droidbox.tests/files/myfilename.txt
28              Data:
29       [25.997330904]    Path: /data/data/droidbox.tests/files/output.txt
30              Data: null
31       [26.781430006]    Path: /data/data/droidbox.tests/files/output.txt
32              Data:
33    [Write operations]
34    ------------------
35       [21.3330090046]     Path: /data/data/droidbox.tests/files/myfilename.txt^A
36              Data: Write a line
37       [21.3614990711]     Path: /data/data/droidbox.tests/files/output.txt
38              Data: null
39 [Crypto API activities]
40 ----------------------
41       [26.8029410839]     Key:{0, 42, 2, 54, 4, 45, 6, 7, 65, 9, 54, 11, 12, 13, 60, 15} Algorithm: AE
42       [26.811686039]    Operation:{encryption} Algorithm: AES
43              Data:{357242043237517}
44       [26.818600893]    Key:{0, 42, 2, 54, 4, 45, 6, 7, 65, 9, 54, 11, 12, 13, 60, 15} Algorithm: AES
45       [26.8250999451]     Operation:{decryption} Algorithm: AES
46              Data:{357242043237517}
47       [26.8305909634]     Key:{0, 42, 2, 54, 4, 45, 6, 8} Algorithm: DES
48       [26.8399989605]     Operation:{encryption} Algorithm: DES
49              Data:{357242043237517}
50       [26.8453080654]     Key:{0, 42, 2, 54, 4, 45, 6, 8} Algorithm: DES
51       [26.853967905]    Operation:{decryption} Algorithm: DES
52              Data:{357242043237517}
```

Android / iOS - Frida

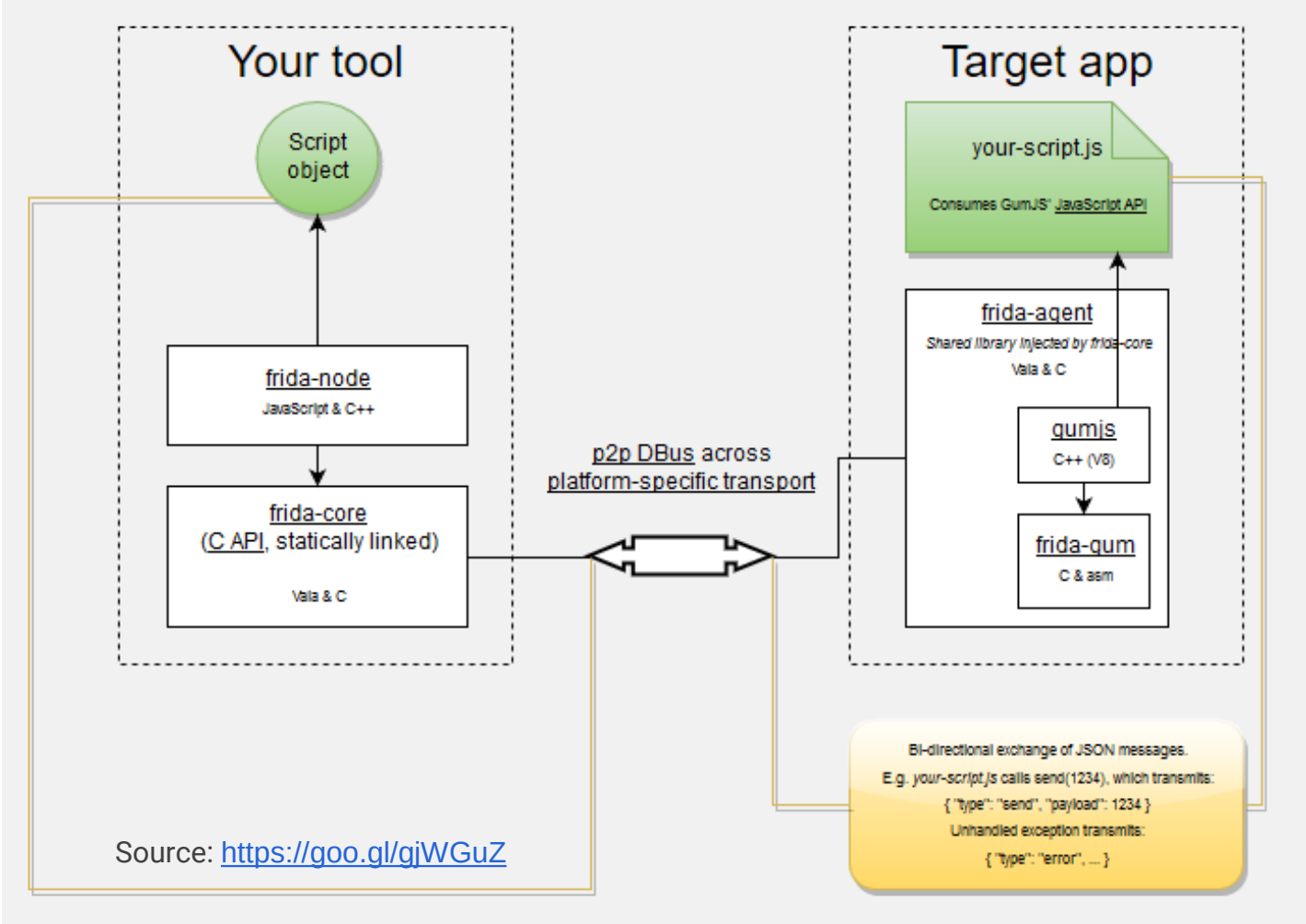
FRIDA

Principle

1. Inject custom logic into process
2. Intercept function calls
3. Stalk process
   - Code tracing
   - Avoid anti-debugger products

Features

- Attaching to process
- Hooking & calling functions
- Modifying function arguments
- Inspecting & modifying memory



Outlook

- 20.05.2021
  - Mobile Network Security

- 10.06.2021
  - Presentation of your results of task 2