RGBDroid: A Novel Response-based Approach to Android Privilege Escalation Attacks

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What I will talk about..

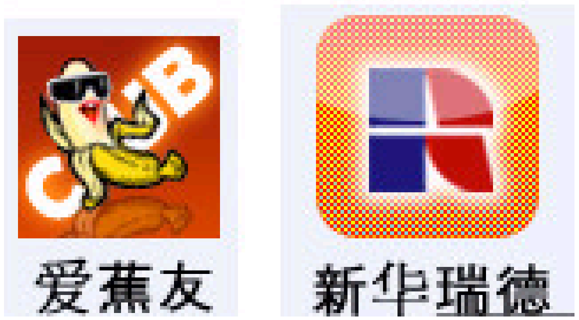
- Privilege escalation attack is dangerous especially on Android

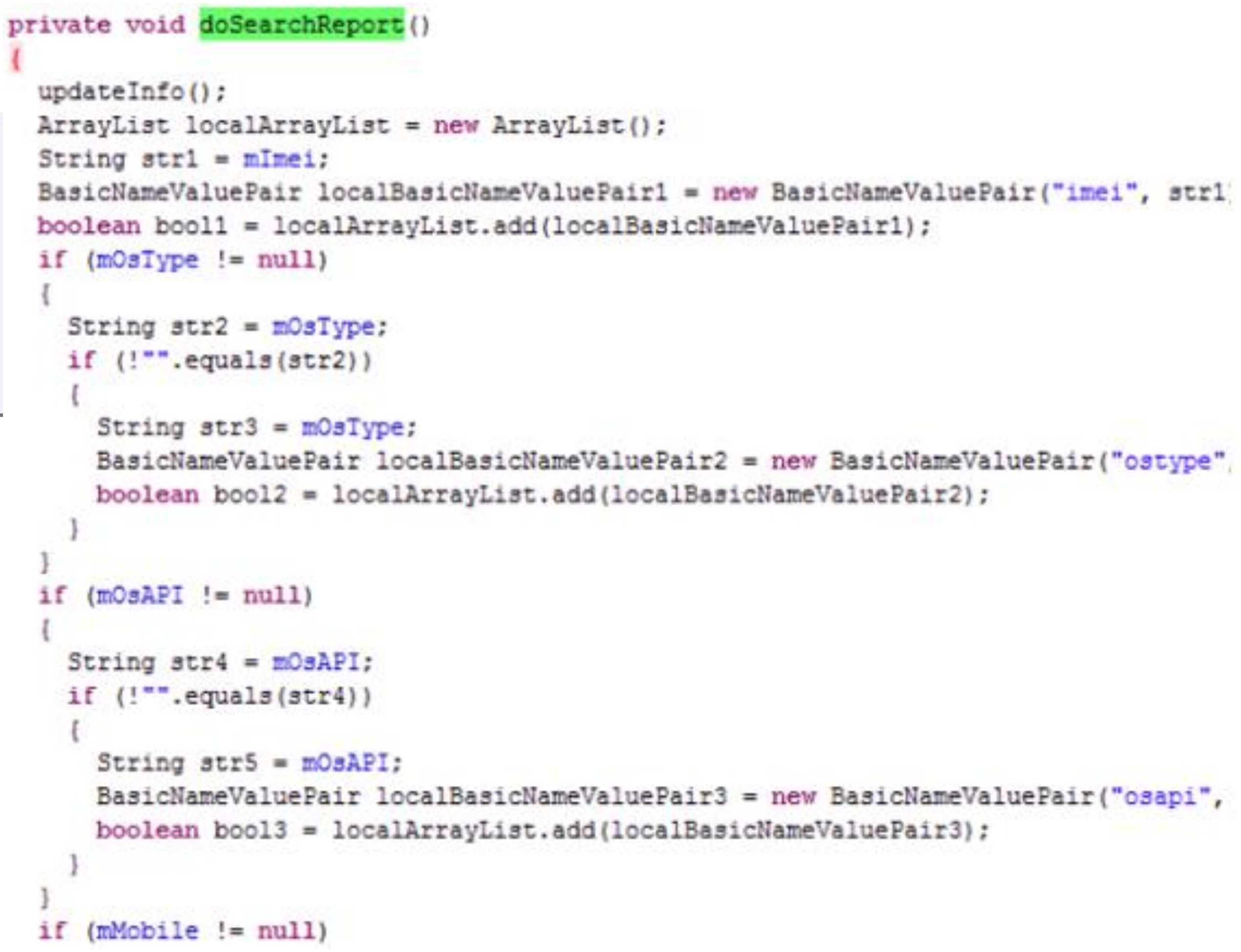
- Difference between prevention-oriented security and response-oriented security

- Since Android is a single user system and its native mechanism is static, we are able to predict its operations

Danger of privilege escalation attacks

- **DroidKungFu**





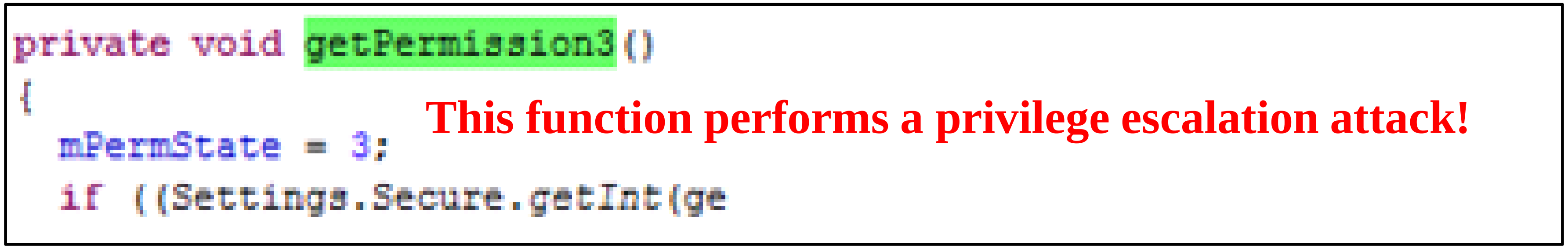
```
private void doSearchReport()
{
  updateInfo();
  ArrayList localArrayList = new ArrayList();
  String str1 = mImei;
  BasicNameValuePair localBasicNameValuePair1 = new BasicNameValuePair("imei", str1
  boolean bool1 = localArrayList.add(localBasicNameValuePair1);
  if (mOsType != null)
  {
    String str2 = mOsType;
    if (!"".equals(str2))
    {
      String str3 = mOsType;
      BasicNameValuePair localBasicNameValuePair2 = new BasicNameValuePair("ostype",
      boolean bool2 = localArrayList.add(localBasicNameValuePair2);
    }
  }
  if (mOsAPI != null)
  {
    String str4 = mOsAPI;
    if (!"".equals(str4))
    {
      String str5 = mOsAPI;
      BasicNameValuePair localBasicNameValuePair3 = new BasicNameValuePair("osapi",
      boolean bool3 = localArrayList.add(localBasicNameValuePair3);
    }
  }
  if (mMobile != null)
```

imei
ostype
osapi
model
SDKVersion
SDcard info
internal Memory Size
Net operator
phone number
running service

http://www.xinh*****.com:8111/GetCert/DevInfo?
http://search.go**********id.com:8511/search/getty.php
http://search.go**********id.com:8511/search/rpty.php

Danger of privilege escalation attacks

- **DroidKungFu**



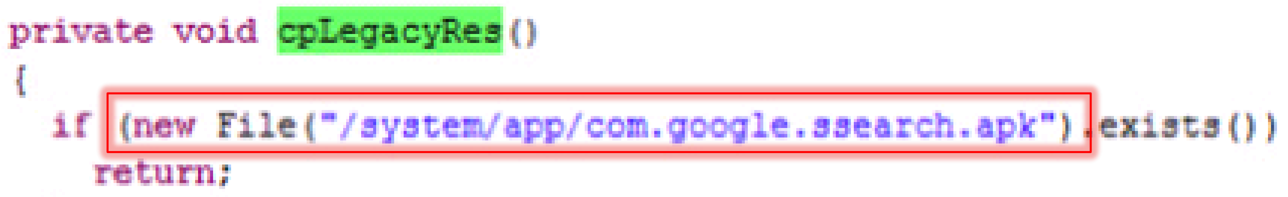
```
private void getPermission3()
{
  mPermState = 3;
  if ((Settings.Secure.getInt(ge
```

This function performs a privilege escalation attack!

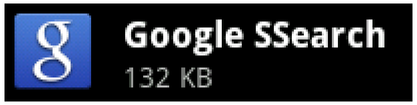
DroidKungFu is an embedded exploit code, which
is called ***"RageAgainstTheCage"*** and developed by C-SKILLS

After the privilege escalation attack!

DroidKungFu installs additional malicious app in ***'asset'*** directory

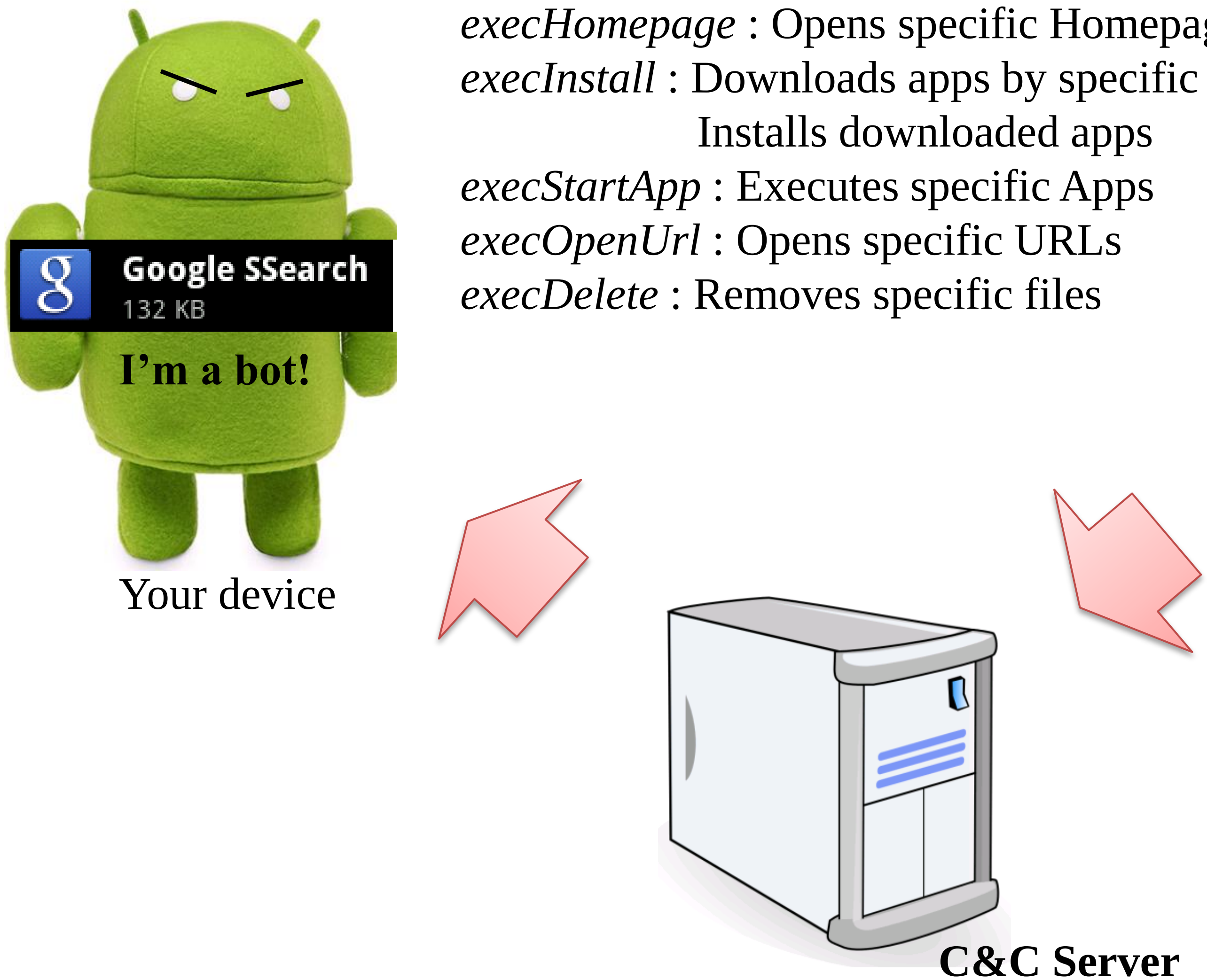


```
private void cpLegacyRes()
{
  if (new File("/system/app/com.google.ssearch.apk").exists())
    return;
```



Danger of privilege escalation attacks

- DroidKungFu

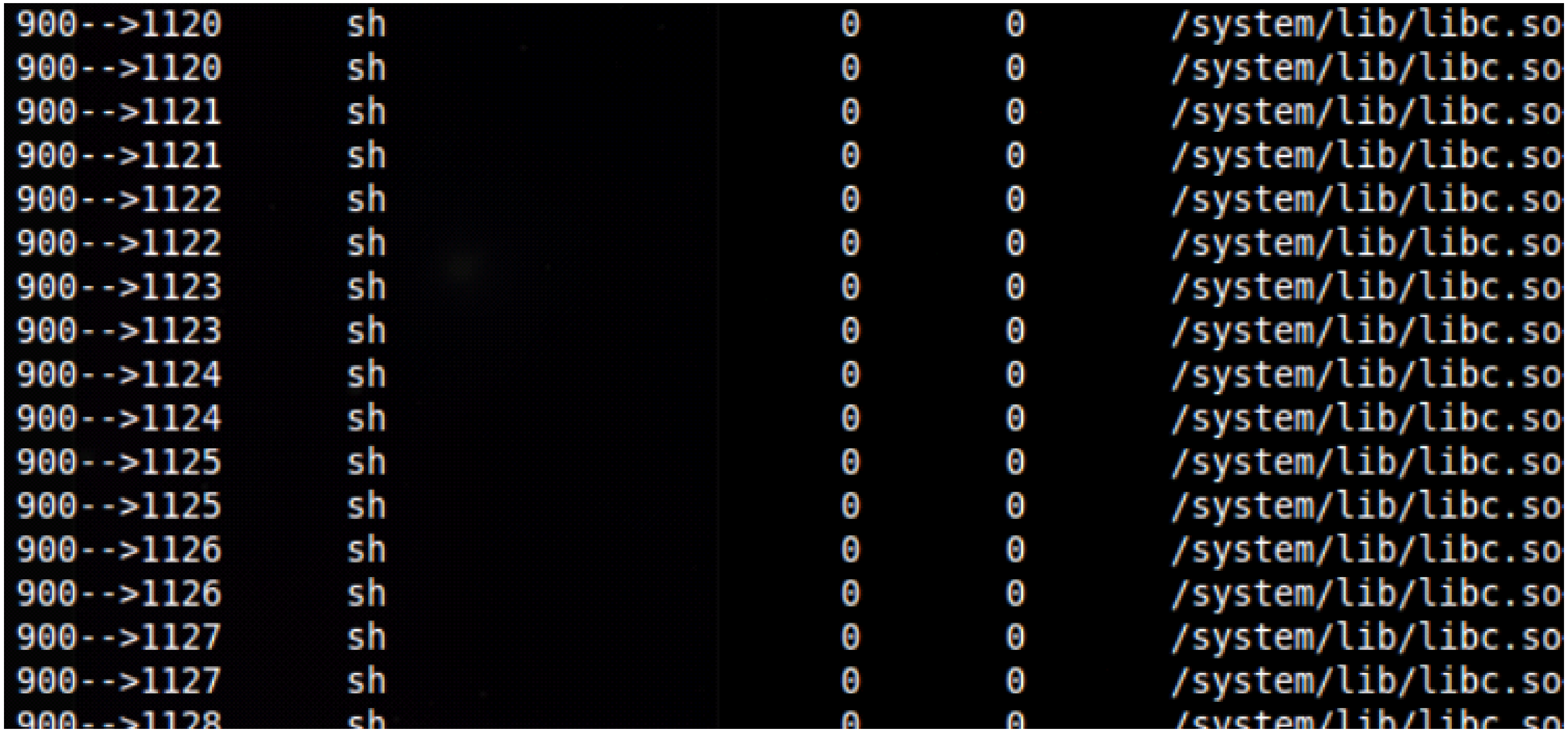


execHomepage : Opens specific Homepages
execInstall : Downloads apps by specific URLs, Installs downloaded apps
execStartApp : Executes specific Apps
execOpenUrl : Opens specific URLs
execDelete : Removes specific files

Android works statically and predictably

- Analyzed file access patterns hooking system calls in Android
- Also identified processes which run with root privileges

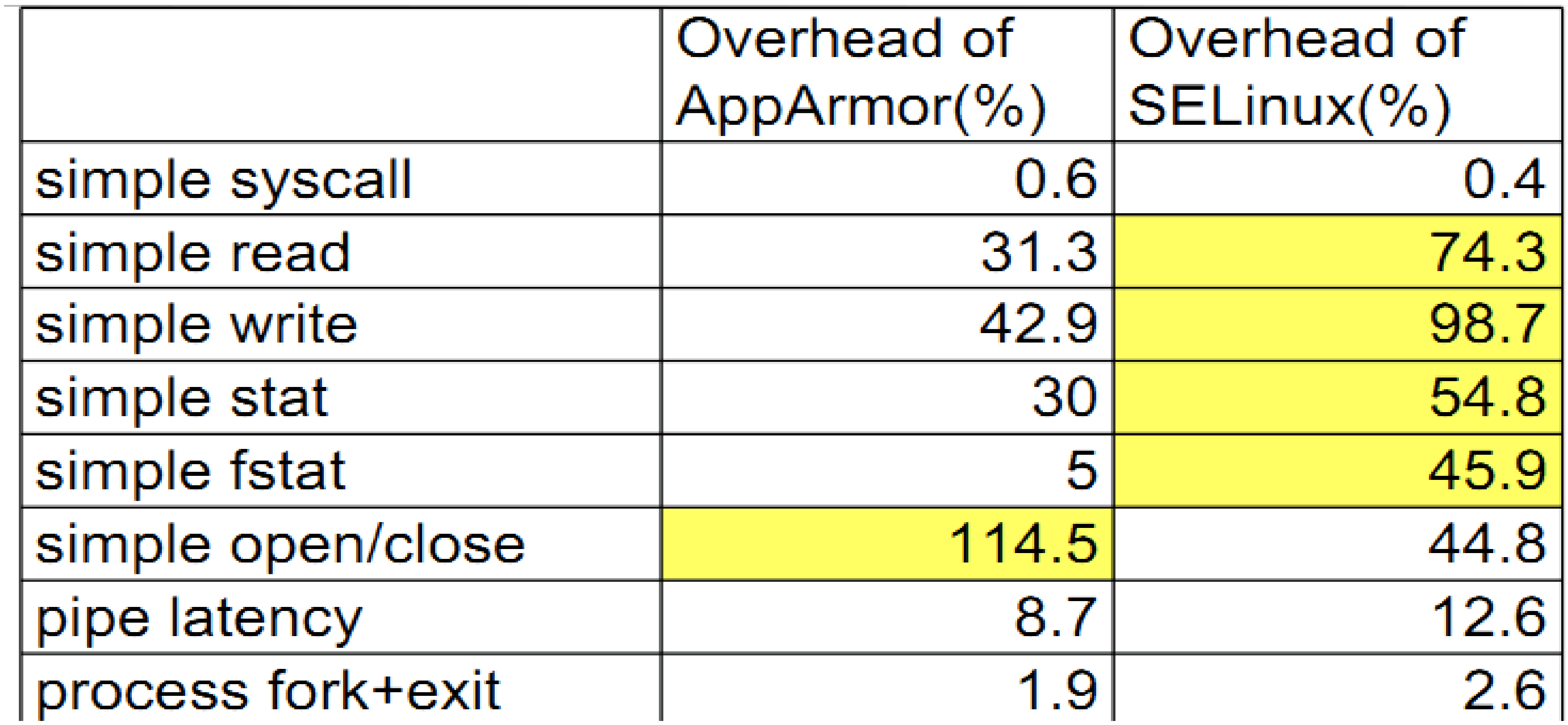
ppid→pid process name uid euid file to access



```
900-->1120      sh          0       0       /system/lib/libc.so
900-->1120      sh          0       0       /system/lib/libc.so
900-->1121      sh          0       0       /system/lib/libc.so
900-->1121      sh          0       0       /system/lib/libc.so
900-->1122      sh          0       0       /system/lib/libc.so
900-->1122      sh          0       0       /system/lib/libc.so
900-->1123      sh          0       0       /system/lib/libc.so
900-->1123      sh          0       0       /system/lib/libc.so
900-->1124      sh          0       0       /system/lib/libc.so
900-->1124      sh          0       0       /system/lib/libc.so
900-->1125      sh          0       0       /system/lib/libc.so
900-->1125      sh          0       0       /system/lib/libc.so
900-->1126      sh          0       0       /system/lib/libc.so
900-->1126      sh          0       0       /system/lib/libc.so
900-->1127      sh          0       0       /system/lib/libc.so
900-->1127      sh          0       0       /system/lib/libc.so
900-->1128      sh          0       0       /system/lib/libc.so
```

Prevention vs. Response

- **Prevention-oriented security may cause high overhead**



	Overhead of AppArmor(%)	Overhead of SELinux(%)
simple syscall	0.6	0.4
simple read	31.3	74.3
simple write	42.9	98.7
simple stat	30	54.8
simple fstat	5	45.9
simple open/close	114.5	44.8
pipe latency	8.7	12.6
process fork+exit	1.9	2.6

Prevention vs. Response

- Prevention-oriented security solutions must predict all potential attacks and vulnerabilities
  - To do so, the overall threat and risk analysis is required
  - This can cause high overhead → It is almost impossible
  - Moreover, these solutions may not explicitly describe what they prevent.
  - Therefore, these solutions are not perfect

Prevention vs. Response

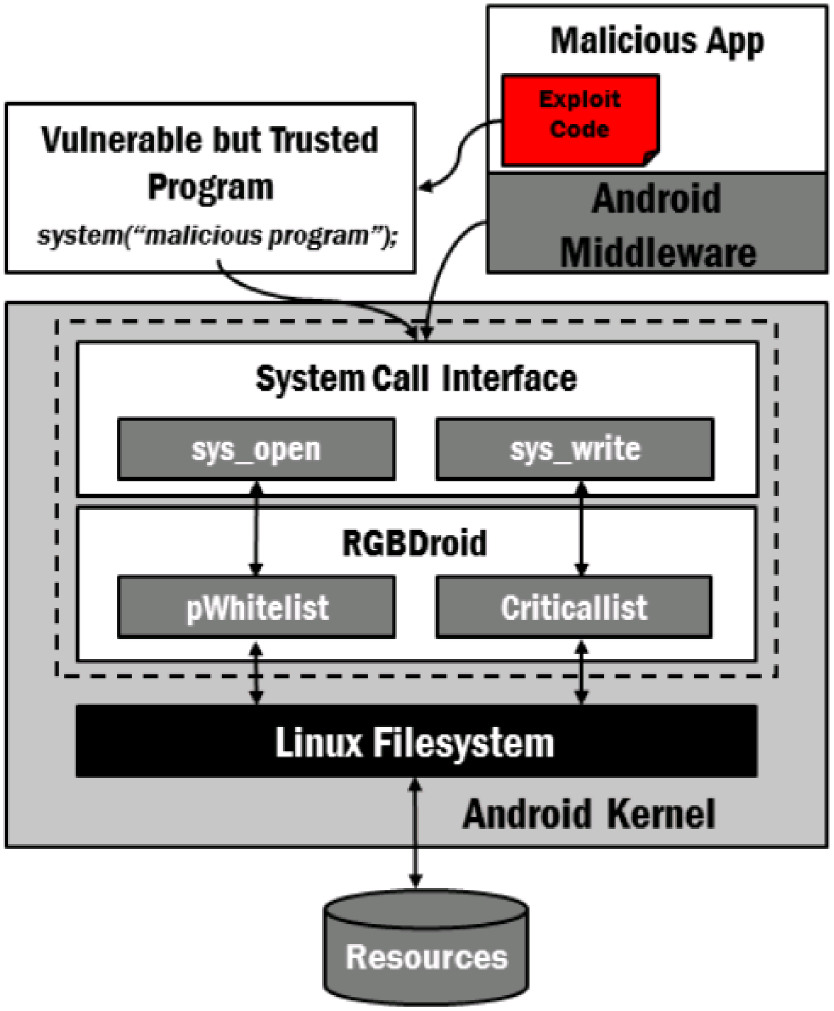
- Our response-oriented security first defines critical malicious behaviors to be potential dangers under the assumption that Android system was compromised by attacker

- We then make a response policy for each defined malicious behavior considering features of the Android system
  - We apply this response policy to our security approach

- We have designed and implemented *RGBDroid* system for the response-oriented security approach

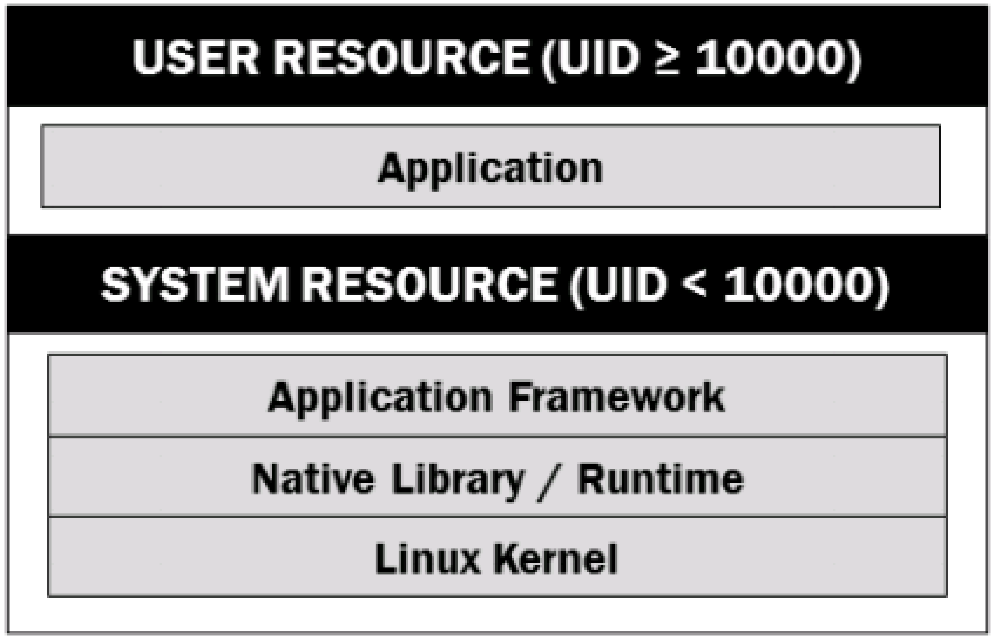
RGBDroid overview

- Android statically works with following the standard policy
  - The root privileges are used only by specific processes
  - There are critical system resources which can be modified by a designated process



RGBDroid overview

- User layer resources are owned by the accounts whose UID is greater than or equal to 10000
- System layer resources are owned by the accounts whose UID is less than 10000



pWhitelist in RGBDroid

- pWhitelist is the list of programs that can run with root privileges

- Root privilege in Android is only used by specific processes (ex. daemons)

- RGBDroid denies any resources access request made by a program which is not a member of pWhitelist

```
unsigned short uid;
unsigned short euid;

if uid == 0 OR euid == 0
    if !(procname == procname_in_whiltelist)
        return deny;
call sys_open();
```

Criticallist in RGBDroid

- **Criticallist is a list of system layer resources that even a process with root privilege cannot modify.**

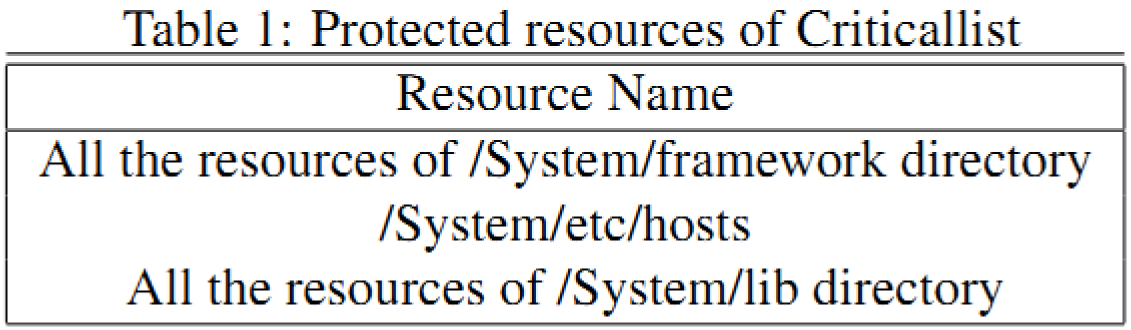
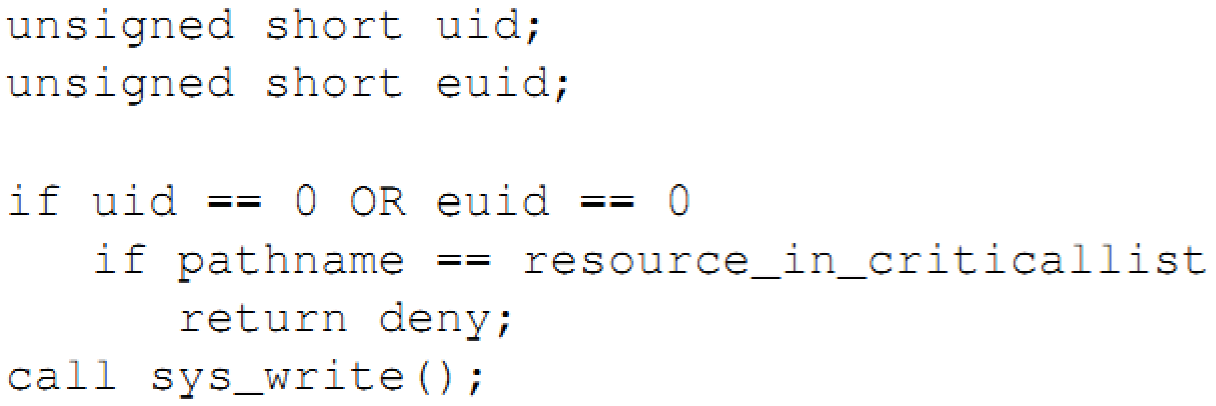


Table 1: Protected resources of Criticallist

Resource Name
All the resources of /System/framework directory
/System/etc/hosts
All the resources of /System/lib directory

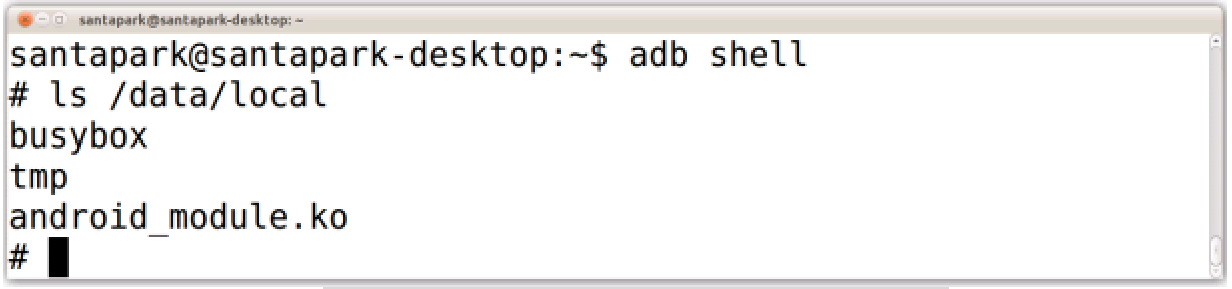


```
unsigned short uid;
unsigned short euid;

if uid == 0 OR euid == 0
    if pathname == resource_in_criticallist
        return deny;
call sys_write();
```

What we can response..

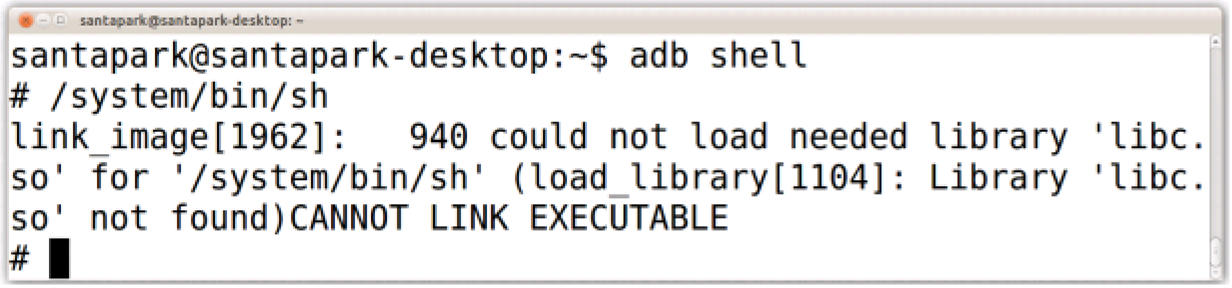
- Shell acquisition: Many attacks try to get a root shell
- pWhitelist in RGBDroid prevents illegal access to the root shell and disallows the attempt



santapark@santapark-desktop: ~

```
santapark@santapark-desktop:~$ adb shell
# ls /data/local
busybox
tmp
android_module.ko
# 
```

After apply RGBDroid



santapark@santapark-desktop: ~

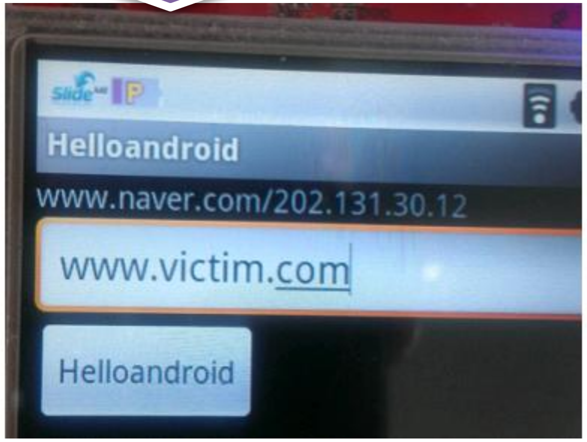
```
santapark@santapark-desktop:~$ adb shell
# /system/bin/sh
link_image[1962]:   940 could not load needed library 'libc.
so' for '/system/bin/sh' (load_library[1104]: Library 'libc.
so' not found)CANNOT LINK EXECUTABLE
# 
```

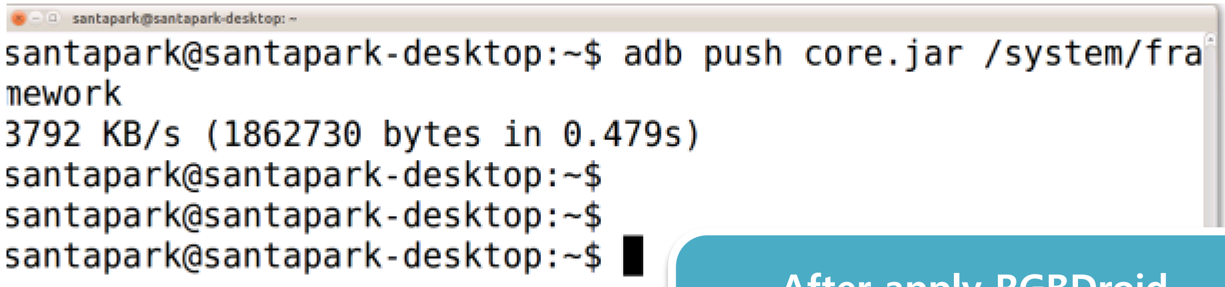
What we can response..

- Restrict illegal modification of critical system resources
- Attacker can do various malicious things by manipulating the resources

  (ex. /system/framework/core.jar, framework.jar, hosts, etc.)

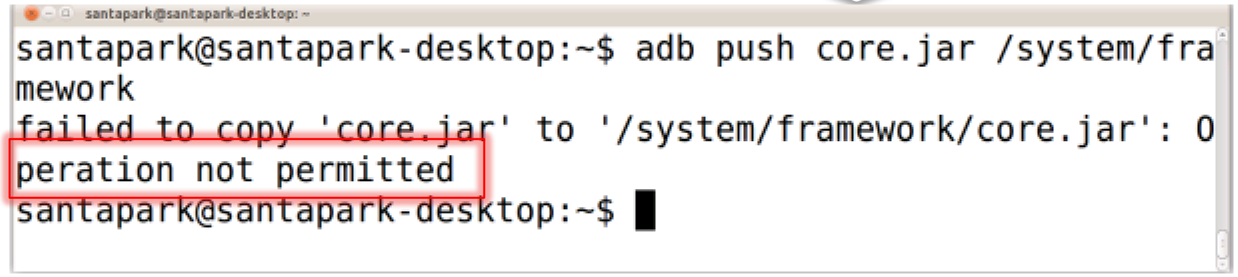
DNS Spoofing:
Request: www.victim.com
Redirection : www.naver.com





```
santapark@santapark-desktop:~$ adb push core.jar /system/fra
mework
3792 KB/s (1862730 bytes in 0.479s)
santapark@santapark-desktop:~$
santapark@santapark-desktop:~$
santapark@santapark-desktop:~$
```

After apply RGBDroid
Manipulation of critical system resource will fail ☺



```
santapark@santapark-desktop:~$ adb push core.jar /system/fra
mework
failed to copy 'core.jar' to '/system/framework/core.jar': O
peration not permitted
santapark@santapark-desktop:~$
```

Performance Evaluation

- After applying RGBDroid, I/O throughput diminishes by 6.2%, 6.7%, 8.1% for insertion, update, and deletion operation respectively
- The overall average I/O throughput decreases by 7%

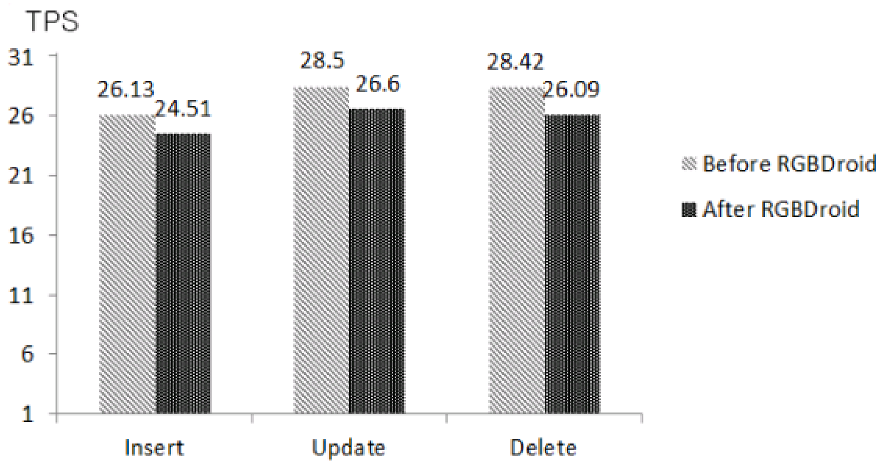


Table 2: I/O Performance Measurement Table (Unit: TPS (Transactions Per Second))

Count	Before RGBDroid			After RGBDroid		
	Insert	Update	Delete	Insert	Update	Delete
1	25.77	28.17	28.28	24.83	26.56	26.71
2	26.02	28.69	28.1	25.22	26.83	26.67
3	26.14	28.95	28.58	24.84	27.17	23.95
4	26.8	28.72	28.76	23.95	26.36	26.69
5	25.94	28.81	28.3	22.98	26.23	25.36
6	27.4	28.4	28.79	24.78	25.52	26.44
7	24.51	28.67	28.66	23.25	26.69	26.03
8	27.23	27.37	28.5	25.09	27.23	26.89
9	24.49	28.53	27.55	25.03	26.1	26.5
10	26.99	28.73	28.67	25.12	27.33	25.64
Ave.	26.13	28.50	28.42	24.51	26.60	26.09

Performance Evaluation

- Processing time increases by 6.2%, 6.7%, and 8.4% for each operation after RGBDroid is applied.
- Average processing time for all three operations increases by 7% overall, which can be considered small processing overhead

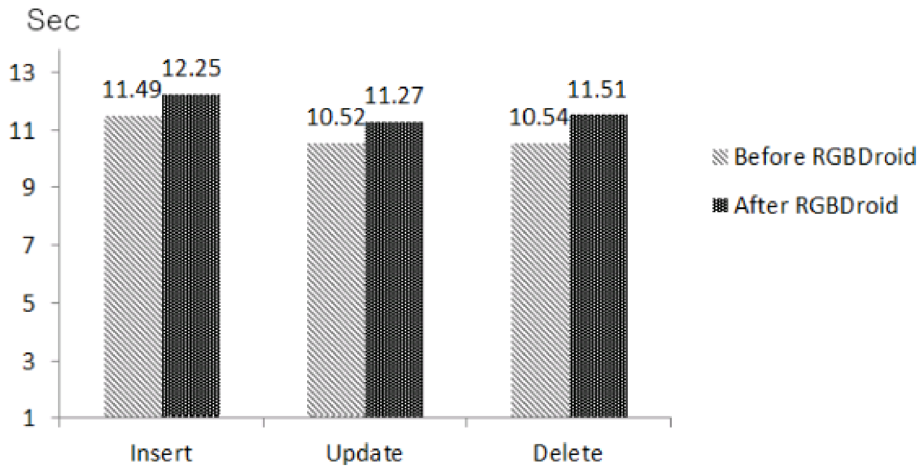


Table 3: User processing time measurement table (Unit: second)

Count	Before RGBDroid			After RGBDroid		
	Insert	Update	Delete	Insert	Update	Delete
1	11.64	10.64	10.6	12.07	11.29	11.23
2	11.52	10.45	10.67	11.89	11.17	11.24
3	11.47	10.36	10.36	12.07	11.04	12.52
4	11.19	10.44	10.42	12.52	11.37	11.23
5	11.56	10.41	10.59	13.05	11.43	11.82
6	10.94	10.56	10.42	12.1	11.75	11.34
7	12.23	10.46	10.46	12.9	11.23	11.52
8	11.01	10.95	10.52	11.95	11.01	11.16
9	12.24	10.51	10.88	11.98	11.49	11.31
10	11.11	10.44	10.46	11.94	10.97	11.7
Ave.	11.49	10.52	10.54	12.25	11.27	11.51

Analysis of Our Approach

- Predicting all possible vulnerabilities is unrealistic both in principle as well as in practice.
- Response-based approach does not have to consider how vulnerabilities can be exploited
- Response-based approach also explicitly specify what the security system responses
  - It does not need to monitor and trace all accesses to critical resources.
  - It does not require monitoring numerous parts of the system *(does need a few additional operations*)
  - It causes only a small performance overhead unlike the prevention approach.

Conclusion

- In the Android, recent malware illegally manipulates system resources or turns the system into a bot by privilege escalation attacks
- This paper presented RGBDroid system for response-based security approach
  - It does not require monitoring or predicting all the potential vulnerabilities but just requires blocking possible malicious acts after attacks
  - It is very suitable for Android environment
- We have plan to evolve our response-based security approach into malicious behavior-oriented security one

Any questions?

THANK YOU FOR YOUR ATTENTION!